The Galileo of Palomar

Essays in memory of Halton Arp

edited by Christopher C. Fulton
and Martin Kokus

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Back cover: Halton Arp with Toivo Jaakkola at a workshop honouring Jean-Pierre Vigier in Paris in 1990. Photo: Publisher

Readers wishing to consult a version of the book with figures in color may download the PDF file from HaltonArp.com.

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About the Editors

Christopher C. Fulton received a Bachelor of Science degree in Biochemistry from the University of California at Los Angeles (UCLA) in 1970, a Master's degree in Public Health (UCLA) in 1973, certification in computer systems programming (UCLA) in 1980, and a Doctorate in physics from the University of Western Australia (UWA) in 2010 based on his astrophysical work with Halton Arp. From 2002 to 2013 he collaborated in the study of quasar and galaxy redshifts with Arp, and is co-author with him on a number of published and unpublished papers dealing with the nature of quasar and galaxy redshifts and their cosmological implications.

Martin Kokus received a Bachelor of Science in Physics from the University of Pittsburgh in 1971 and an Master of Science in Engineering Physics from the University of Virginia in 1975, where he studied the Urban Heat Island Effect. He subsequently worked for NASA's Technology Utilization Office and later modeled turbulence at Redstone Arsenal. He taught physics at a variety of institutions, including Bloomsburg University and Alice Lloyd College. He has published papers on technology transfer, atmospheric science, seismic periods, cosmological redshift quantization, fractal models of the universe, and non-standard approaches to unification.
He collaborated with Halton Arp on several occasions, beginning in 1993.

Chip Arp (1927-2013)

Jayant V. Narlikar

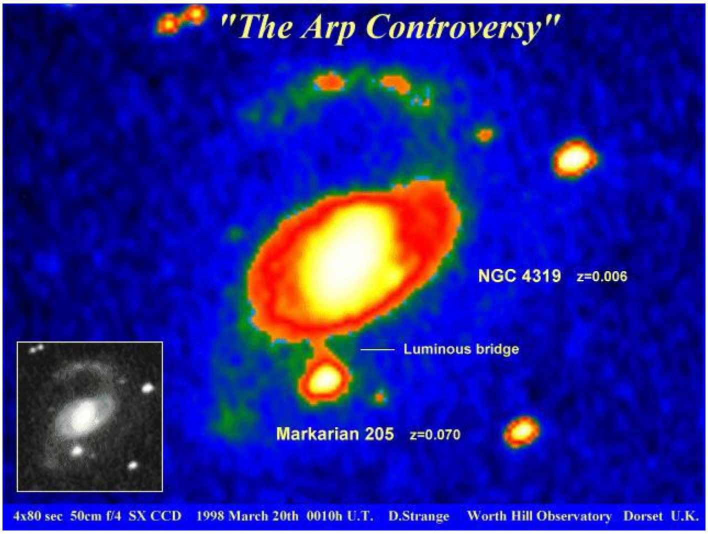
Halton C. Arp, more commonly known as Chip Arp, passed away in Munich on December 28, 2013. His death marks the departure from the astronomical stage of one more of the classic astronomers who revived astronomy with modern tools, observational or theoretical, in the post-World War II decade: like Jan Oort, Allan Sandage, Geoffrey Burbidge, Fred Hoyle, *etc*.

Born on March 21, 1927 Chip graduated from Harvard in 1949, followed by a Ph.D. at Caltech in 1953. He was a contemporary of another great astronomer at Caltech, Allan Sandage and, as students, both were inspired by Edwin Hubble in his last years. Chip became a staff member at the Palomar Observatory and worked there from 1957 to 1986. His final years from the mid-1980s were spent at the Max Planck Institute for Astrophysics in Munich.

An excellent observer in optical astronomy, Chip was known to be very meticulous, and one of his compilations the *Atlas of Peculiar Galaxies* is a Bible for observers studying the morphology, evolution and any unusual aspects of galaxies. Indeed, his early work, gave the promise that he would emerge as a leading worker in the astronomical establishment.

Instead, by the mid-1960s Chip began to find evidence that went against the views of the Establishment. After four decades, the Hubble law was getting firmly established and extended to distances of a hundred to a thousand times those covered in Hubble's pioneering survey. Chip's contemporary, Allan Sandage was playing a leading role in one of the two teams of optical astronomers engaged in this major cosmological investigation.

Against this background, Chip's studies of the unusual objects led him to discover apparent anomalies in Hubble's law. A typical anomalous case would be a pair of extragalactic sources *A* and *B* lying very close to each other with redshifts z_A and z_B such that $z_B \gg z_A$. If we take Hubble's law as correct, we have to conclude that *B* is much farther away from us than *A*. This means that *B* happens to be projected so close to *A* by chance. If we know the population density on the sky of *B* type sources we can estimate this probability of this event. Suppose it turns out to be much less than 1%...often as low as 0.01%. If, following the usual statistical practice,



The anomalous pair NGC 4319 and M 205

we reject the hypothesis of Hubble's law, we have to conclude that these two sources are real neighbors and B posseses an extra component of redshift. Chip called this intrinsic redshift z_i and defined it by the relation

$$(1 + z_i)\,(1 + z_A) = (1 + z_B)$$

This intrinsic redshift is often referred to as 'anomalous' redshift. It implies that Hubble's law does not account for all the redshift of the extragalactic object.

Such an assertion amounts to killing the holy cow of cosmology. The modern theory of cosmology (the so-called *big bang* theory) depends on Hubble's law being right. Not surprisingly Chip had to face tremendous opposition or skepticism from most quarters. More so when he produced evidence that quasars are objects with large intrinsic redshifts.

The case of the pair of neighbouring objects NGC 4319 (a galaxy) and Marakarian 205 (a quasar like object with significantly larger redshift than the neighbouring galaxy) is of interest in illustrating how the anomalous cases are treated. In 1971, Arp found a filamentary connection between these two neighbours, and if it were real, it became hard to understand this pair in conventional terms. However, other observers repeated the observations and claimed that there was no filament, thus casting doubt on Chip's claim and credibility as observer. Chip then repeated the observation showing the filament and arguing that if the film is not exposed long enough no filament would be seen. The last word in this controversy was said in 1983 by Jack Sulentic who used the newly available CCD technology to demonstrate the reality of the filament.

At first, in the late sixties Chip was asked to produce more evidence of this kind with the expectation that what he had found was a flash in the pan with no further cases of that kind turning up. He did and found such cases not only in optical astronomy but also in radio and x-ray astronomy. Also his cases included: (1) unusual concentration of high redshift quasars near NGC galaxies with redshifts less than 0.1, (2) alignments of quasars near a central galaxy suggesting that the quasars were ejected by the galaxy, (3) matching redshifts of quasars across the galaxy again suggesting ejection, (4) two galaxies connected by filaments or bridges but having different redshifts, and (5) periodicity in the intrinsic redshifts.

Chip had an explanation of cases (1) to (4) in terms of a variable mass theory emerging from the Machian theory of gravity of Hoyle and Narlikar. But the apparent periodicity was hard to explain. At the time of writing this account there is conflicting evidence about this effect originally found by Karlsson in 1971 with some observers claiming that the effect goes away with large populations like those in Sloan Digital Sky Survey while others showing that it persists when correct statistical analysis is done. This effect was occupying Chip in recent times.

Naturally, in his lifetime Chip had to face violent opposition when publishing papers. His work was unofficially banned from conferences. A crisis came when his own institution (The Palomar Observatory) banned his usage of its telescopes. One of the stated reasons for denying him observing time was reportedly that what he observed did not seem to make sense! He resigned and settled in Germany where he initially was Humboldt Fellow at the Max Planck Institute for Astrophysics. There too he did not have smooth sailing but he could use archival data to demonstrate more anomalous cases. There were, inevitably, difficulties and delays with publication but he patiently persisted.

Chip was awarded the Helen B. Warner Prize by the American Astronomical Society, in 1960, followed by the Newcomb Cleveland Prize for his address at the AAAS Section D. In 1981-83 he was the President of the Astronomical Society of the Pacific.

Chip wrote two very readable books on his experiences and findings of anomalous cases: *Quasars, Redshifts and Controversies* and *Seeing Red*. These books, especially the latter one, reflect his frustration at his failure to make the Establishment take the anomalies seriously.

It would not be improper to call Chip Arp the Galileo of modern times.

The Redshift Rift

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A personal view of the collaboration of Halton Arp and Chris Fulton during the last decade of Dr. Arp's life.

Key words: Galaxy : redshifts, Quasar: redshifts, (cosmology:) cosmic microwave background, cosmology : observations

1. Introduction

In memorializing Halton Christian (Chip) Arp, we are facing a descriptive conundrum. On the one hand we are celebrating the life of an individual of great intellect with a matching set of accomplishments in scientific research stretching over six decades. On the other hand, when we report on or reminisce about the last five of those decades, or speculate on future endeavors, we must include in our presentation the occurrence of deep controversy with an eventual disassociation from the very community in and for which he produced results. We are consequently moved to begin with an exposition of how and why this situation came to exist and subsequently persist.

In April 1996 I attended the International Conference on Mathematical Models of Time (Tifft & Cocke 1996). Though not yet a professional astronomer, I was well read in the subject. I had read Chip's *Quasars, Redshifts and Controversies* (Arp 1987) and deemed it to be a confirmation of my previously held contention that the standard model of cosmology (a.k.a the Big Bang) was long overdue for an extreme revision, or more perspicuously, that astronomy and cosmology required a paradigm shift if each was to remain classified as a science. I spoke directly but only briefly with Chip during the conference. Our paths next crossed in 2002 when Ross Cutts — one of my subject lecturers at the University of Western Sydney in Australia — encouraged me to engage with Chip based on a paper that I had written to satisfy a history of astronomy course requirement. Randall Meyers — a composer, film producer, alternative cosmology advocate, and fellow student — put me in touch with Chip via e-mail.

Chip was one of a select group of people who had worked directly with Edwin Hubble. He spent his first decade as an astronomer accomplishing seminal work on galaxies. That work continued while he still had time on the 200-inch telescope on Mount Palomar in California, but the next five decades were dedicated to the elucidation of the nature of quasars (quasi-stellar objects, or QSOs) and their relationship with galaxies, as manifested by the positions, redshifts, magnitudes, and morphologies of these objects. Our close collaboration took place in the last of those decades.

In the science of the universe, there is a rift between the proponents of the standard model and anyone who dares to question that marvelously entrenched edifice. The schisim has existed in some form since the discovery in the early 20th century by Edwin Hubble, supported by his observations and those of others, of an apparent correspondence between the measured redshift of objects external to our galaxy and the measured distances of those objects. Originally, the distances were measured independently of the redshifts, but as the telescopes became more powerful and the distances consequently increased, it became either more difficult or impossible to devise independent distance measures. The result is that it has long been and still is common practice to assume that each measured extragalactic redshift, without exception, is due to the expansion of space-time and therefore the distance is simultaneously derivable from the measured redshift. The highest redshifts discovered as of 2014 exceed 7 (a galaxy by Finkelstein *et al.*, 2013; a quasar by Momjian *et al.*, 2014), but for the vast majority of extragalactic objects with a redshift exceeding ~ 1, no distances have been measured independently of the presumed redshift distance. The unverified redshift-distance assumption is actually being used as an axiom, because it has always been and still is nothing more than an article of faith. If the axiom is false, the standard model falls apart completely and irrevocably; but use of the axiom is by no means the only standard model flaw, as outlined in detail by Van Flandern (2002).

Four of the additional flaws can also be regarded as axioms, because if even one of them is not verified, again the standard model cannot survive: the standard model interpretation of the Cosmic Microwave Background (CMB); the presumptive occurrence of an epoch in the very early Universe called Inflation; the presumptive existence of Dark Matter; and the presumptive existence of Dark Energy. The CMB can be and has been measured, though not without issues concerning the interpretation of the data and with the availability of non-standard model explanations for the existence of the CMB. The standard model requires the CMB, but the CMB does not require the standard model. Inflation is a mathematical concept devised to have the standard model arrive at the CMB black body temperature of ~ 2.7 degrees Kelvin, which the standard model cannot otherwise manage. Dark Matter and Dark Energy are both conceptual entities devised to arrange for observations of the Universe to fit the standard model; neither entity has been observed or is known to be observable, as implied by the adjective prefixed to its name.

Mindful of the above, Chip and I began our collaboration by considering how best to take advantage of the very large redshift survey data that was coming on line. Initially, circa 2003, this meant working with the 2dF Galaxy Redshift Survey (2dFGRS) galaxies (Sadler *et al.* 2002) and the 2dF Quasar Redshift Survey (2QZ) quasars (Croom *et al.* 2001). Subsequently, we would tackle the Sloan Digital Sky Survey (SDSS) galaxies and quasars (York *et al.* 2000). More recently, we also folded in the 2MASS (Two Micron All Sky Survey; Skrutskie *et al.* 2006) Redshift Survey (2MRS) galaxies from the 2MRS Ks = 11.75 mag (2MRS11.75) sampling of nearby galaxies (Huchra *et al.* 2012). I took on the overall task of performing statistical analyses of the galaxy/quasar relationships using the positions, redshifts, and magnitudes of tens or hundreds of thousands of objects from the respective surveys. Chip took on the overall task of performing careful human analysis of individual galaxy/quasar systems selected from lists of tens or hundreds of associations identified by a computer algorithm that we designed and implemented to detect quasar families around parent galaxies. What follows is a synopsis of our effort, which continues unabated at present.

2. A Seminal Paper

Our first collaborative paper, entitled "Periodicities of Quasar Redshifts in Large Area Surveys" (Arp *et al.* 2005), was first-authored by Chip and co-authored by Dr. David Roscoe, of Sheffield University in the United Kingdom, and myself. The paper is only a glimpse of what was to follow, but it is instructive to relate how the paper was received, or not, by the astronomical community and to consider what the paper represented in terms of examining the nature of redshifts. Arp *et al.* (2005) was originally submitted to the *Monthly Notices of the Royal Astronomical Society* (*MNRAS*) in early 2004. Surprisingly, it was not immediately rejected and ultimately was the subject of three referee reports, the last of which was accompanied by rejection. We next submitted it to the *Astronomical Journal* (*AJ*) with the same review pattern and results. In order to expose the paper to the astronomical/cosmological community, we eventually placed the paper on Astro-ph as a preprint. In spite of the paper never having been published in any standard journal, the preprint is still being downloaded to this day, and, more importantly, the paper has been cited by Bell & McDiarmid (2006) and Godlowski et al. (2006) and challenged by Tang & Zhang (2005) and Ryabinkov et al. (2007). These events are notable because although the paper was found to be unworthy of publication by two of the most read and cited mainstream refereed astronomical journals, it was nevertheless worth being challenged in those very same journals, namely in *MNRAS* and in the sister journal of *AJ*, the *Astrophysical Journal* (*ApJ*).

Arp *et al.* (2005) treats the periodicity of quasar redshifts in the 2dF and SDSS surveys by means of several different analytical methods:

- Plotting magnitude versus measured redshift density contours of the quasars in the initial and final releases of the 2QZ quasars to crudely reveal periodicity structure in the data.
- Close examination of individual galaxy/quasar systems in sample areas to determine whether the redshifts follow the Karlsson formula (Karlsson 1971, 1973, 1977, 1990).
- Application of a new minimum residuals method, devised by Chip, to detect specific galaxies as parents of ejected quasars.

The density contours method was fruitful at least for the 2dF data set, but it was a crude approach that could not track the detailed behavior of individual quasars. The individual systems examination method was very fruitful and was in fact the primary method that Chip had been using for decades to reveal a very long list of quasar-galaxy associations, including, but not limited to, the collection of discordant redshift systems cataloged in Chip's *Catalog of Discordant Redshift Associations* (Arp 2003). The minimum residuals method, which was performed by hand for the two examples presented in Arp *et al.* (2005), was in fact the method of choice, because a modification of the method ultimately became the basis for a full blown statistical analysis of any then or future available large redshift survey. The only way to sort out the intricacies of the quasar/galaxy relationships was to examine entire data sets and to analyze the positions, redshifts, and magnitudes in the context of a statistical framework. Another strong motivation for invoking statistics was to counter the often stated contention by standard model proponents that discordant redshift occurrences needed to be established in great numbers if they were to be regarded as anything more than mere anomalies awaiting some future simple explanation that fits into the standard model.

3. The Statistical Work

We started with a computer program I had already written that could download astronomical objects from disparate data sources, store the data in multiple databases, and manipulate the data in various ways. It took about a year to build into the program a knowledge of the quasar ejection hypothesis based on quasar Karlsson redshifts and a statistical framework that could perform Monte Carlo simulations and other statistical analyses on the growing body of available object data. These capabilities evolved as we worked on each data set, produced and revised papers for submission, devised and performed tests to verify the quasar family detection algorithm, and formulated the attendant documents to respond to the journal referee reports. This process continues today. Our first resulting statistical paper, entitled "The 2dF Redshift Survey I: Physical Association and Periodicity in Quasar Families" (Fulton & Arp 2012), first-authored by myself and co-authored by Chip, used the 2dF galaxy and quasar data sets to perform quasar family detections. It was submitted to *ApJ* in May 2006, and after eight referee reports by two consecutive referees, it was finally published by *ApJ* in July 2012. This outcome is due at least in part to the *ApJ* Editor-in-Chief, Professor Ethan T. Vishniac, who gave us extra time when we requested it on more than one occasion, and who agreed to and was instrumental in locating a second referee. The latter development was generally important, but more so because the ensuing five objective, incisive, and suggestion-laden reports and our lengthy and detailed responses effectively and thoroughly vetted the algorithms and procedures on which the paper is based.

The object of the current discussion is not to recapitulate the contents of Fulton & Arp (2012), as it best communicates that information. In the chasm left by Chip's absence, I choose to lay out the paper in less technical terms and relate its significance to readers.

4. Which Trees in the Dense Forest?

Imagine peering at a dense forest that is very far away, so far in fact that, even with a very powerful and excellent pair of binoculars, it is difficult to discern which branches belong to which trees in the forest. If we now substitute quasars for the branches and galaxies for the trees, we have an exposition of the problem we face in making definitive assessments of whether any two extragalactic objects are physically associated with one another or that instead one of the two objects is far away in the background of the other. This is a general problem in astronomy that is all too germane to the ejection hypothesis case, as diagrammed in Figure 1 for two putative parent galaxies. The distances involved and the potential overlaps of any true physical associations can combine to make it diffcult to distinguish which galaxy is the true parent. It turns out, however, that Karlsson periodicity can in many cases be used in conjunction with the ejection hypothesis to determine the true physical associations and simultaneously also verify the existence of Karlsson periodicity. That is what Fulton & Arp (2012) accomplishes for the 2dF data set.

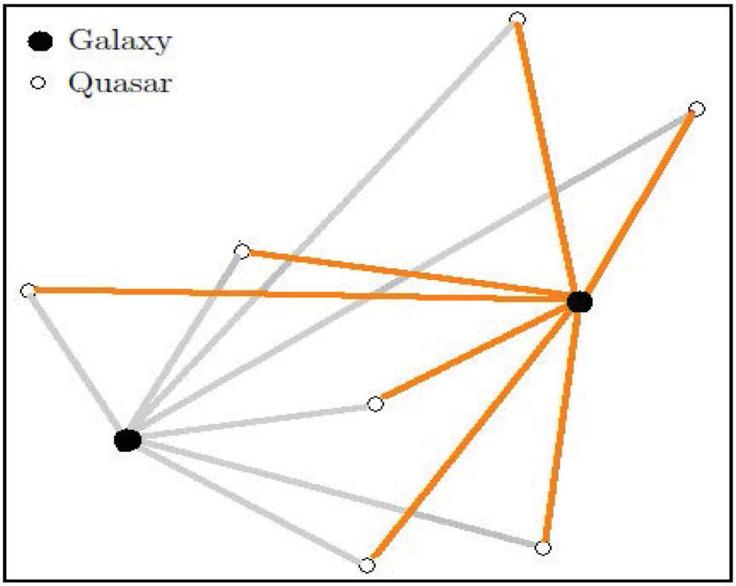

Fig. 1.— Diagram of two galaxies (filled circles) vying for parentage of seven quasars (open circles) that are within some predetermined reach of both galaxies. The Karlsson periodicity and ejection hypothesis can in many cases sort out which branch (quasar companion) in the dense forest belongs to (is associated with) which tree (parent galaxy).

The detection algorithm throws out any multiply associated quasars, increasing the likelihood of detecting only true families but also causing some true families to be discarded, simply because there is no way to correctly choose between the multiples.

5. Significance of the Detection Signal

Fulton & Arp (2012) uses Monte Carlo simulations as a control to measure the statistical significance of the results produced by the quasar family detection algorithm based on constraints designed to measure the presence of Karlsson periodicity in quasar redshifts, and therefore also the physical association of a given quasar with a specific galaxy. In Figure 2 we plot the significance that is the primary result of Fulton & Arp (2012), except that we use the extremities of the blue curves in Figure 5 therein to form a single envelope, and we plot on the abscissa in the opposite direction and label the axis as increasing periodicity. The figure caption describes the results in terms of certain well defined portions of the envelope. The upshot of the figure is that not only does the periodicity signal exist, but it also has characteristics that are not likely to accompany a

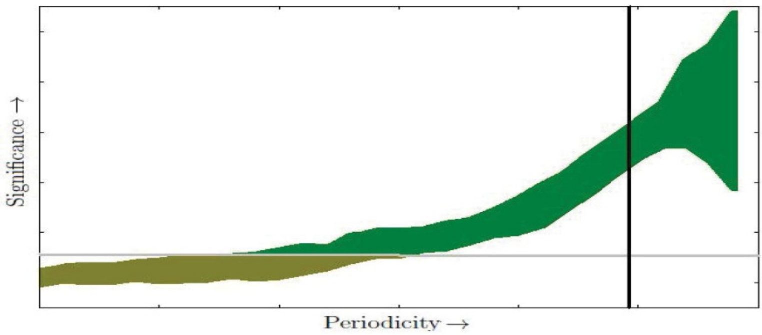

Fig. 2.— Signal significance envelope based on the same data used to plot the blue curves shown in Figure 5 of Fulton & Arp (2012). The significance of the signal rises with increased adherence to the Karlsson formula, referred to also as the periodicity. The grey horizontal line separates the strong significance (green) portion of the envelope from the present but weak significance (olive) portion. The vertical thickness of the envelope measures the tendency of each detected quasar family member to be close in redshift to at least one other candidate quasar. This envelope is fairly tight for most of the periodicity range, which lies to the left of the black vertical line. The envelope widens, i.e. the signal is more sensitive to differences in quasar redshift closeness, for the highest periodicity range, which lies to the right of the black vertical line. It is also in this latter range that the greatest significance is achieved.

fictitious signal, such as one caused by a procedural error or a design flaw in the model under investigation.

During the development of our quasar family detection algorithm, I would periodically generate lists of these families so that Chip could scan them looking for individual systems that could be written up as papers. The result was a collection of systems with some very interesting characteristics and for which Chip was able to track down existing observations at a number of electromagnetic wavelengths. We had difficulty in getting papers on these systems published, so a few of these papers again ended up on Astro-ph as preprints. The Arp-Madore galaxy AM 2230-284 is a notable example that was masterfully researched and revealed by Chip (Arp & Fulton 2009).

Fulton & Arp (2012) having established a solid statistical basis for both Karlsson periodicity and the ejection hypothesis, whether or not it was challenged in the literature, the next step was to repeat the experiment with other data sets, both to confirm the 2dF results and to move on to much larger and statistically and otherwise improved data sets. In our case, that meant that the next step was to apply the detection algorithm to the SDSS galaxies and quasars, and ultimately also to the nearby 2MRS galaxies.

6. On-going Work with the SDSS and 2MRS Data Sets

During the months just prior to the publication of Fulton & Arp (2012), we started work in earnest on a follow-on study to examine the SDSS galaxies and quasars using the detection algorithm and attendant techniques developed during the 2dF work. This work culminated in a supplementary paper to Fulton & Arp (2012), entitled "Physical Association and Periodicity in Quasar Families with SDSS and 2MRS" (Fulton *et al.* 2016; still under submission to *ApJ*), first-authored by myself and co-authored by Chip and Professor John G. Hartnett, of the University of Adelaide in Australia. We had earlier become aware of some work by John that showed the presence of a previously unidentified selection effect in the SDSS quasar redshift data (Hartnett 2009), and this paper became an important consideration when we were constructing a statistical sample of the SDSS quasars. Fulton *et al.* (2016) uses the SDSS quasars and galaxies to verify the results produced in Fulton & Arp (2012) for the 2dF quasars and galaxies. Depending on how it is sampled, the SDSS data set has at least an order of magnitude larger populations of both galaxies and quasars; but additionally important is the research that has been done by others (Richards *et al.* 2002; Schneider *et al.* 2010; Shen *et al.* 2011) on the SDSS data release 7 (DR7), the release we are using, to enable construction of a proper quasar statistical sample.

As we were processing the SDSS results and starting to write the Fulton *et al.* (2016) manuscript, we were also considering another project to analyze another galaxy data set that became available in early 2012. Huchra *et al.* (2012) had painstakingly and efficaciously assembled a catalog of nearby galaxies, the 2MRS galaxies, based on the 2MASS survey of galaxies, numerous other data sources, and direct human examination of spectra to accurately determine the morphologies and redshifts for as many of the galaxies as possible. Having this information specifically for nearby galaxies would enable us to test the behavior of the detection algorithm when applied to mainly far away (SDSS) versus nearby (2MRS) galaxies. Consequently, we expended the time and effort to carefully and exhaustively test the 2MRS galaxies in combination with the SDSS quasars. The 2MRS results were not only important on their own, they were actually intimitely related to the SDSS results, so much so that in hindsight it would have been a serious mistake to have omitted the 2MRS analyses from Fulton *et al.* (2016).

As Fulton *et al.* (2016) is currently under submission, we cannot expound its content or make reference to its sections, but we can state that

Fulton *et al.* (2016) brings to the table a considerable body of new and striking information. Hopefully Fulton *et al.* (2016) will be published by *ApJ* and the astronomical/cosmological community not only will become aware of but will also respond to its content.

7. Summary

No one disputes the existence of quasar clusters, and these assemblages can be as large as a few degrees on the sky. However, conflict arises when we further ascertain that the cluster members are not necessarily all at the same redshift and that the small or large quasar assemblages often found in close proximity to or even surrounding a galaxy are strong indications of physical association. In Fulton & Arp (2012) we go out of our way to present and cite both sides of the standard model *versus* ejection hypothesis issue; but, unlike the case of Arp *et al.* (2005), to date no one in the astronomical/cosmological community has responded to Fulton & Arp (2012), even though the latter has been published in a mainstream journal. Now there is a contradiction.

The paper that I wrote for the history of astronomy course was not unlike the story outlined in this essay, the subject matter being a hard look at the gross disconnect between the current cosmological paradigm and the existence of an extensive body of observations that flatly contradict it. The disconnect is inextricably linked, both historically and technically, to the interpretation of extragalactic redshifts, and the epoch over which the disconnect extends is framed by the careers of two extremely accomplished and exceptional observational astronomers, Edwin Hubble and Halton Arp. Consequently, I entitled the history paper "The Redshift Rift: From Hubble to Arp" and left it behind as the finished product of just another student assignment. The article "From Hubble to Arp" in this volume is an updated version of that paper. What I have recorded above is the same story, but it has the advantage of following more than a decade of technical advances, increasingly abundant redshift and other data from very large surveys, and the ability and wherewithal to data mine the resulting plethora of observations. There is still a very large redshift rift. Chip was unable to bridge enough of that rift during his lifetime to see a positive result in the academic and professional communities, but on many occasions he expressed the desire that I carry on his quest. I consider that expression an honor and I accept the responsibility. To that end, the effort continues.

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Scientific and Political Elites in Western Democracies

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Examples are examined where science conduct falls far short of the ideal. Similar failings in political processes are considered. The question is asked whether there are common roots to these failures, and if so, how they can be corrected.

Evolution of an Elite into an Oligarchy

In the 1940's the largest telescope of its time, the 200-inch at Palomar, was conceived and built. Since Rockefeller and Carnegie were rival capitalists, the Rockefeller Foundation could only give the money to California Institute of Technology, rather than the Carnegie Institution of Washington where the world's leading astronomers were. Cal Tech, however had no Astronomy Department so an agreement was signed between the two Institutions that they would jointly operate the Observatory. The noted Carnegie astronomers such as Hubble, Baade, and R. Minkowski then initially used most of the telescope time. Younger staff members were gradually included.

Quasars were discovered in 1963 and astronomers rushed to observe them because they assumed their high redshifts meant they were at great distances and that the nature of the universe would thereby be revealed. The Cal Tech radio astronomer who isolated the positions of the first quasars asked for telescope time to observe their spectra and obtain their redshifts. He was told only certain of the faculty could observe with the 200-inch telescope. Those select few went on to measure the spectra and reap the headlines and the original discoverer left the field in disgust.

As a Carnegie astronomer I was observing on the telescope but the radio positions of the quasars were kept secret and so I did the next best thing—photograph peculiar and disrupted galaxies to see how they were formed and evolved. Ironically, in the end, they turned out to be surrounded by quasars which were obviously not out at the edge of the universe. That news was not welcomed by the observers who had inflated their reputations with discoveries of a new "most luminous object in the universe" every few weeks.

There followed an interregnum of about 17 years in which the Cal Tech astronomy Department pressed for a larger and larger share of the telescope time. One must know that in the operating agreement for the Observatory the Carnegie astronomers were appointed full faculty members at Cal Tech. Then in 1980 Cal Tech broke the agreement, taking over the 200-inch and severing the faculty appointments of the Carnegie astronomers. There were bitter protests by the suddenly discharged faculty (Appeals to the American Association of University Professors were not heeded). In the subsequent allocation committees Cal Tech included only a few of the less senior Carnegie staff who then received small amounts of time, but more time than the senior Carnegie members whose time was cut to nil. Telescope time was, and is, the currency of the realm, and in the competition for scientific pre-eminence the senior Cal Tech Faculty had just helped themselves to a large bonus from the company assets.

But it is not just a question of territorial expansion and control, there is also the question of eminence and prestige and the impossibility of being wrong. This becomes clearer to me now when I look back at the events of 1982-83. At that time I received a letter from the joint Carnegie Institution of Washington-California Institute of Technology telescope time allocation committee. It was unsigned but it said that if I did not give up my present line of research they would not allocate me any further telescope time. I responded with data showing my publications and citations far exceeded those of the committee members as well as other senior Cal Tech astronomers. But the following year Cal Tech had taken over 75 percent of the 200-inch time. Next year my time was reduced to zero. I resigned my supposedly tenured position.

This is how the elite body of astronomers, which is now the reigning authority in Astronomy, was formed. By now, of course, the students of Cal Tech have gone on to many other elite faculties, and astronomers from Harvard, Princeton, Cambridge, *etc.* have arrived in Pasadena. So as with many self selected elites, their power has grown to be almost monolithic.

But why were they so intent on suppressing the small amount of observation time which tested the current paradigms? I must describe at this point a few of the observations which are so threatening. I think some specific cases can make it clear that the current paradigm is fundamentally incorrect. It will also become clear that the longer the contradictory information is suppressed the greater the catastrophe modern science will suffer.

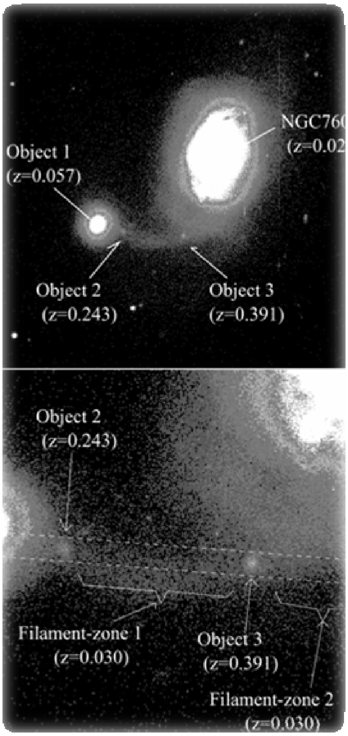

Figure 1. NGC 7603 is a Seyfert galaxy of redshift 8,700 km/sec. The companion attached to the arm has a red shift of 17,100 km/sec. Two quasar-like objects of 72,900 and 117,300 km/sec have been discovered in this arm by Lopez-Corredoira and Gutierrez.

Examples of Intrinsic Redshifts and non Big Bang cosmology

There are many crucial pieces of evidence I could cite but I will single out only three here as examples of the many similar kinds of results which by now, with great difficulty, have managed to be published.

a) NGC 7603

Number 92 in my *Atlas of Peculiar Galaxies* has a large companion on the end of a luminous arm. In 1971 a spectrum revealed that this companion was 8,000 km/sec higher redshift than the central, active Seyfert galaxy. This amount of excess redshift cannot be accommodated in the conventional picture where redshifts mean velocities in an expanding universe. They could not be at such different distances and be physically interacting. When Fred Hoyle heard about this he came up from the Cal Tech campus to my Carnegie office and asked to see the original picture. In 1972 he gave the prestigious Russell Lecture at the Seattle meeting of the American Astronomical Society and outlined a theory whereby younger galaxies radiated intrinsically redshifted photons. His theory of growing particle masses was a more general solution to the conventional field equations but was physically a Machian (not Einsteinian) theory. At the end of the lecture he said the NGC 7603 observation created a crisis in physics and we needed to cross over the bridge to a radically more general physics.

Over the years the evidence for non-velocity redshifts has grown enormously, both for quasars and galaxies. A number of researchers have tried to make the establishment admit the consequences of this evidence. But it has been suppressed and ignored. *However, in an event of great irony, 30 years after Hoyle's talk featuring NGC 7603, two young Spanish astronomers have announced the finding of two quasar-like, much higher redshift objects imbedded in the arm which connects the low redshift galaxy to the higher redshift companion of NGC 7603, as shown in Figure 1. As in many past cases, this result alone should have settled instantly and finally the existence of intrinsic redshifts.* Instead the paper was turned down by *Nature* Magazine, rejected by the *Astrophysical Journal* and only finally accepted by the European journal, *Astronomy and Astrophysics*.

b) The Virgo Cluster

In another case, the brightest quasar in the sky (3C273) was found in 1966 to be paired with one of the brightest radio galaxies in the sky (3C274) across the brightest galaxy in our Local Supercluster. The chances were a million to one that they belonged to the Local Supercluster and that the quasars were not at their redshift distances. Then this region was measured in high energy X-rays and the connection from the central low red shift galaxy to the quasar 3C273 was explicitly visible. The influential journal *Nature* refused to publish it although they had just published the top half of the X-ray map of the cluster. Then the gamma ray satellite came along and showed the cluster in the highest possible energy range, greater than 100 MeV, as shown in Figure 2. Not only was the 3C273 quasar at redshift $z = .158$ attached to the central galaxy at $z = .003$ but the famous quasar 3C279 at $z = .538$ was also part of this high energy filament. The data was interpreted by Arp, Narlikar and Radecke as showing birth of new matter and new galaxies and the evolution of redshift from high values to low. It was published finally in *Astroparticle Physics*, Vol. 6, 1997. The clear pictorial connection has been suppressed ever since and the original author of this extraordinarily important result is no longer a professional researcher.

The above is another kind of failure of the scientific system, unfortunately more common today. The orbiting observatory had been built at great expense, reduction procedures financed, and analytical personnel salaried. When a great discovery was made it was hidden, not shown in

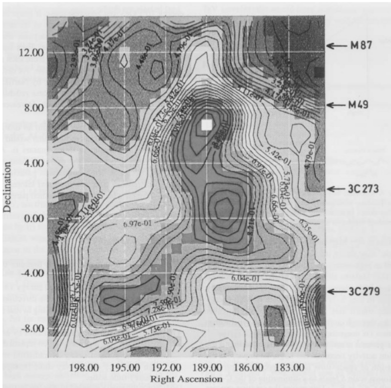

Figure 2. Gamma rays, greater than 100 MeV showing connection from M49 (z = .003) to the quasars 3C273 (z= .158) and 3C279 (z = .538).

conferences or published; because for one reason, I believe, the team feared that they would be attacked as incompetent observers.

Some of the orbiting instruments that made epochal breakthroughs had their results published, but their significance was ignored. I visited one director regularly pointing out the obvious discoveries. He politely nodded and then went about ignoring the crowning achievement of his project.

c) The radio quasar 3C343.1

Science is based on repeatable observations of real objects and the relationships between them. In order to avoid generalizations, however, we show here another specific object which demonstrates that the foundation of current extragalactic astronomy and cosmology is fundamentally, inescapably, incorrect. Figure 3 shows a radio map of a strong radio source. Two redshifts are measured for this object with one much larger than the other. According to conventional cosmology they are in different parts of the universe. But we see they are, in fact, joined by a bridge of radio material. The chance of this observed configuration being an accident is one part in one hundred thousand billion! Other examples like this have been observed where the chance of accidental occurrence is only one in a billion. But this would seem to be the ultimate *experimentum crucis*.

The ejection in opposite directions of material from active galaxies, including very high redshift material like quasars, has been building up now for over 37 years. Yet the radio map shown here and the notation that this object had "two redshifts," one a "background object," lay unnoticed and unchallenged in the voluminous literature for 4 years! When it was finally submitted to the Astronomical Society of the Pacific it was rejected. In spite of my being a past President of this organization they refused other observational results and communications and I had to resign. It is particularly vexing that the A.S.P. has as a primary goal educating the public about as-

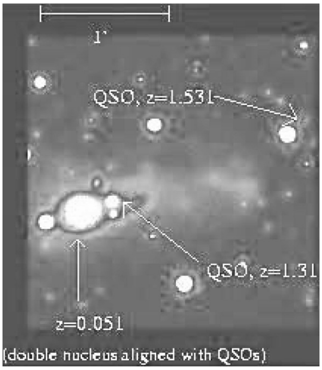

Figure 3. Radio map at 1.6Ghz of 3C343.1 by Fanti *et al*. *A&A* 143, 292, 1985. (Separation of sources about 0.25 arcsec.)

tronomy. But since it was hijacked by fanatical Big Bang adherents, it has been exactly misinforming the public.

We might also mention in passing that if the quasar redshift is transformed to the rest frame of the galaxy, it becomes $z = .31$, very close to the redshift $z = .34$ of the galaxy and to the quantized redshift peak of $z = .30$. Evidence has also been piling up for redshift periodicity for 36 years—a result which is an instant refutation of conventional expanding universe theories. From time to time incorrect papers claiming to refute quantization of redshifts are published and papers demonstrating it are rejected.

Can Academia Reform?

Since this enormous amount of contradictory empirical evidence has not been accepted over the last generation I personally believe that it will not be accepted until there is a fundamental change in the structure of academia. To start with routine operations, electronic communication today makes it not sensible to pay for wasteful transportation of observers to remote sites in the world. Buttons can be pushed as easily in the home office. Observations could be performed by email request with small key observations having priority over larger, more critically reviewed programs. Countless conferences in exotic places of the world between mutually agreeing researchers tend to be vacation treats for the elite and their helpers.

Certainly Academic Science is overfunded in terms of the usefulness of its current end product. If more of this money were channelled instead to non-academic researchers there would ensue a pressure for the academics to consider seriously some of the more innovative and realistic work of people who were primarily interested in understanding their subject. Of course a more democratic science would introduce a lot of wild ideas, but then research only by the elite seems to produce only bandwagon ideas which are sure to be wrong.

The only alternative to censorship (a.k.a. refereeing) in professional journals is personal communication between individuals and groups. Recently that has taken a great step forward with the Internet. In any case, the professional academic journals will soon be expanding their shelf space faster than the speed of light. That will not break any physical limit because there will be no information involved (like cosmic inflation theory). But for the life blood of science, which is communication, there appears to be no hope in the public media, which at present appears sound asleep.

The Media

When a newspaper like the *N.Y. Times* hears about an event of international interest they call up the Whitehouse and ask the President what it means. That is featured on the front pages, and perhaps a few Republican and Democratic Senators, and "think tanks" are quoted on following pages. Letters to editors and columnists with "respectable" views are reported further inside. Deep inside the *Sunday Times*, which hits the apartment door with a sound like thunder, can be found scraps of opinions by foreigners, artists and miscellaneous people. Very democratic, you say, with opinions being represented roughly in proportion to their numbers in the society.

Not so. The Bush Republicans stole the 2000 election by stopping recounts in Florida, disfranchising thousands upon thousands of democratic voters, and finalizing it all with a right wing coup in the Supreme Court. The *Times* together with a few other "respectable newspapers" thought it over for a long while and finally issued a lame opinion that "Bush would have won anyway"—hail the chief! Aside from the loser being awarded the winner, no one mentioned that if the U.S. had the more representative democratic structure of many European nations, it would today be governed by a democrat (plurality)—green, coalition of Gore and Nader.

The bad news is that the *Times* is the very best. The rest of the newspapers, the entirety of the TV and huge amounts of radio programming is given over to the most shallow repetition of what is believed to be patriotic slants of the news. Is it any wonder that most of the rest of the world was against pre-emptive war while the U.S. was reported to be 70 percent in favor? (Actually in Bay Area San Francisco, and other more enlightened communities, the sentiment was clearly reversed).

But now what happens when a scientific event occurs? The *N.Y. Times* calls up Princeton and asks their opinion. The professor tells them, "That report of a new observation has been shown to have been false. Everyone agrees that my theory is the correct one." If the Science reporter really gets serious he calls up Harvard, Cal Tech or Univ. of Chicago. He gets the same story that "Contradictory observations are incorrect and that the real controversy is over whether the undetectable "dark" matter in the universe is 90 percent like I say, or 95 percent like some other prestigious scientists claim." The rest of the national media, understandably, do not mention it. Occasionally they run a story "Einstein invented dark matter and space is curved!"

Real investigative reporting is truly a lost art. In science it is horrific, with reporters never lifting their feet off their desk or their hand off the telephone. In politics, which people believe is more important, however, there are a few brilliant exceptions which show what can be accomplished with hard work. Two I would mention are Michael Moore and Greg Palast. (See Internet for biographies and books published.) They actually get the original records and confront the "experts" with what they have said and enumerate the statistics and facts which contradict the establishment consensus. And of course, there is Noam Chomsky, who is the leading founder of linguistics and speaks brutal truths for anyone who cares to consult his political writings.

How does reporting of astronomy and cosmology to the public compare with political reporting? What are the factors which control this science and does the kind of democracy which exists in western nations today control scientific knowledge?

Democracy and the Media

The inescapable fact about western democracy is that it is heavily controlled by money. We all know that money buys political influence for the people who invest in public relations and lobbying. This influence in turn leads to more monetary return which can be used to gain more influence. In Science it is rather direct, with Institutions and researchers applying to the government for grants and support. In politics one must influence legislation. But a public relations department is crucial for the image and most academic institutions have one. This activity is usually conflated with "educating the public." One can try to limit funding contributions to politicians, but it will be difficult to limit the euphemistic term "public education." Perhaps we could try under the motto of "separation of church and state."

The countervailing force of investigative journalism is difficult to encourage because it is so easy to just accept predigested handouts from respectable sources. One must fall back on old fashioned democratic populism: the wide and wild opinion forum of the internet; the *Meta Research Bulletin* by Tom Van Flandern; books published by small publishers like *Apeiron*. Two books have now been written compiling all the discordant evidence; *Quasars, Redshifts and Controversies* (in Italian, *La Contesse Sulle Distanze Cosmiche e le Quasar*, Jaca Book) and *Seeing Red: Redshifts, Cosmol-*

ogy and Academic Science (in press in Italian by Coelum). Presently a *Catalogue of Discordant Redshift Associations* is in press at Apeiron, Montreal. *A Different Approach to Cosmology* by Burbidge, Hoyle and Narlikar and all the references therein is available.

It is possible that long-lasting changes must grow from the grass roots upward and that independent decisions by enough citizens will force the media to discharge its responsibilities and ultimately help redirect money into more productive channels.

Problems With Directors, Chairpersons and CEO's

Aside from Engineering and Medical Faculties which generally have to produce something that works, Academic Directors tend to be crippled with problems of power, prestige, cronyism and issuing degrees only to students who demonstrate that they know the correct answers in the subjects they have studied. The best results I have seen is in Departments that rotate the then onerous job of chairperson every one to two years. Diversity of independent faculty—while faculty still remains a working concept—seems best suited to achieve balance of power and interests.

Business is no less ruthlessly competitive and ethically challenged. Excessive executive compensation just welds seamlessly the connection between money and prestige. One overpaid entrepreneur was known to remark "Money is just a way of keeping score." In a capitalist economy stockholders seem to be the only hope. They are beginning to realize executives most interested in money for themselves are not usually most interested in the health of the company or the world. In the very long run it may be that unregulated capitalism produces an exploitative evolution for humanity that is self limiting in that it destroys its own environment. A more adaptive type evolution may be slower but safer.

I might make a few summary remarks: Why has all the observational evidence been disregarded when it falsifies almost everything that is supposedly known about extragalactic astronomy? Perhaps the informal saying, "To make extraordinary changes one requires extraordinary evidence" really means, "To make personally disadvantageous changes no evidence is extraordinary enough." I felt it was necessary to resign because freedom of research was the most important issue, and here was a rare factual issue that should have had a strong reformative effect when it turned out to have been improperly suppressed. As a relief from the disastrously competitive climate in the U. S., I found more tolerance in Europe. And the opportunity to change to X-rays, a different observational wavelength furnished new kinds of data and stimulation.

The Beliefs of Society

But finally, in the long view, is improvement in the moral basis of society necessary to bring about beneficial changes in both Science and Democracy? By moral I mean an operational definition of "that which will promote long term survival." One of the problems is that we have a culture that rewards conformity more than innovation. Children are generally taught that there is always one correct answer. Not to get that answer means failure. That produces fear. One can see the effects in classes where the students do not ask questions (as in the graduate classes I taught at Cal Tech). One can see the effect persisting in mature scientists.

Education tends toward social indoctrination. The most important task of a school is not to teach *what* to think but *how* to think. Grades should also depend on questions asked as well as answered. The value of experiments, empirical versus theoretical analysis and testing fundamental assumptions should be emphasized. For many people this would mean liberal schools and elements of home education.

On the psychological and philosophical front one can ask questions like: "Why do people seek power? What can be done to make society and media less exploitative. How best to promote tolerance for divergent views and respect for nature. In the media, can we combat the unbearable hypocrisy surrounding military aggression?"

In a democracy scientific truth should not be voted on by a self selected elite. I remember Linus Pauling, a double Nobel Prize winner, who nevertheless had trouble defending his professorship at Cal Tech, enunciating his Golden Rule: "Do unto others 10 percent better than they do unto you (10 percent to allow for subjective judgement)." Perhaps then we may permit the race to evolve in the direction of what we call intelligence.

The Local Interpretation of the Microwave Background Radiation

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For more than half a century, the linear expansion of the universe, an assumed big bang, has been the only basis of the commonly accepted cosmological concepts. Observations have been located in the reference-frame of General Relativity. But that later adequation is far from convincing. Hence some authors, Zwicky being the first, have greatly doubted the big bang cosmologies, and even the reality of expansion. For years, Vigier, I, and coauthors, have proposed alternatives to the Doppler interpretation of the observed redshifts, based on Arp's observations on one side, and on solar system observations on the other side. More recently, together with Narlikar, Ochsenbein, and Wickramasinghe, we have advocated the local origin of the background microwave radiation, traditionally considered as born from the very early Universe. A consequence of our finding is to slow down considerably the expansion rate of the Universe, even to a non-expansion, and to increase the "age" of the Universe even to infinity. The possibility is open for cosmological constructions strongly different from the classical standard, or "convergence," models, the recent avatars of the big bang.

Introduction

The evolution of the observable and close-by universe was not contemplated until recently — not until the times of Tycho and Kepler ... The earlier civilizations considered the celestial world, "above" the Earth, to be essentially immutable (unlike the terrestrial world of life and death), a world created *ab nihilo* by a δεμιουργοσ, by some god, by Jahveh, by Allah, by God...

During the last two centuries, astronomers have discovered stellar evolution, the existence of independent galaxies, the very large distance of these galaxies, as well as important phenomena such as the redshift of the spectrum of galaxies, the rotational velocity of stars within galaxies, the existence of active galaxies and quasars, the microwave background radiation from the whole sky, *etc*. Here we describe some of these discoveries and discuss their interpretation.

During the years 1920-1930, Hubble made the decisive observation that there was a correlation between the redshift and the distance of galaxies (Hubble, 1929). From that discovery, the idea of an expanding universe appeared. The only interpretation of the redshift was that of the Doppler-Fizeau effect, implying that all galaxies were receding from one another. Not only was the velocity, V, deduced from the redshift linked with the distance, D, of the galaxy, but it was a linear relation, characterized by the so-called Hubble constant, $H = V/D$, expressed usually in kilometres per second per megaparsec.

At about the same time, to account for the expanding Universe newly advocated by Hubble (and later by his pupils and followers, Humason, Sandage, and others), the theoreticians tried to construct "model universes." The theoretical basis for these theories was Einstein's General Relativity (GR), which was described by two equations, too well known to be reproduced here. Before Hubble's discovery, the first solution of the GR equations was Einstein's stationary Universe. That solution was made possible by the arbitrary introduction of a repulsive term, the "cosmological constant Λ," as an integration constant of the equations. After Hubble's discovery, the cosmological constant was no longer necessary. Friedmann (1922, 1924) and Lemaître (1933), independently proposed models without Λ — models which were relativistic and compatible with any expanding universe.

In the years 1940-50, from that set of contributions the idea of a "big bang" emerged, as the cause of the linear expansion extrapolated backwards. Yet a big bang from what? Nobody dared to say what! Only the pope, Pius the XIIth, (1951) had the audacious idea to assimilate the big bang with the "fiat lux" of the Scriptures.

But an obvious question arose. What were the physical conditions at the time of the big bang? Another more subtle question was: what is the meaning of "time" in the early life of the Universe at a very high density? Also, the expansion may be linear around us, but there is no reason why it had to be so, either in the distant past or in the distant future.

The mathematical models were not developed for thermodynamics. It was there that Gamow (1948) on one side, and Alpher and Herman (1948) on the other, published their contribution in the early forties. In their well-known publications, they advocated a "hot big bang," from which they predicted that we should now observe a relic isotropic black body radiation at about 5 K surrounding us. It would most likely be observed in the microwave frequencies, *i.e.*, the millimeter wavelengths. At about the time of that prediction, Fred Hoyle (who did not believe in the reality of the models with a singular point of infinite density at the origin of "time") coined the phrase "big bang," as a form of mockery in a radio broadcast!

However, the ~5 K radiation, predicted (more or less precisely) by Gamow and his colleagues, was observed only somewhat later, as ~3 K, by Leroux (1956), who did not identify it as cosmological in origin. Still later, it was observed in 1964 by Penzias and Wilson (1965), who (with the help of theoretical guidance from Dicke (1965) and his co-workers) identified their observation with Gamow's prediction.

From 1965 on, the doubts were forgotten; the big bang models soon became the only plausible view of universal evolution (see Bernardeau, 2006); it was (and still is!) almost a dogma, accepted by everyone nowadays; papers that cast its validity in doubt are systematically rejected by most of the journals. Some of their authors have even been severely hindered in their professional lives, such as the excellent observer Halton Arp, who wrote a book, *Seeing Red*, about his difficulties with the establishment (1998).

Since that period, many brilliant observations have been performed, from Earth or from space, such as COBE, WMAP, and Planck. They fully confirmed the Penzias and Wilson observations, and they have succeeded in mapping the 3K radiation over the whole sky with a remarkable accuracy, confirming its black body character of isotropy, and fixing its temperature at 2.74 K. The Hubble observations were also followed by colleagues or pupils, refining up and down the rate of expansion, to $H = 74.3 \pm 2$ km s^{-1} Mpc^{-1}, which corresponds to an "age of the Universe" of 13.8 billion years.

The present paper reviews the papers that predict a background radiation of 3 K (or thereabouts) from purely local causes, in a not necessarily expanding universe, the better known of these attempts being Eddington's, in the thirties, and ours, more recently. But earlier attempts to determine that temperature do exist, with an accuracy that is quite impressive if we take into account the paucity of observations at the time!

From Guillaume (1896) to Eddington (1938)

We shall follow here, more or less, the analysis by Assis & Neves (1995) of the papers published before the discovery of Hubble's law of linear expansion.

As early as 1896, the Swiss (Nobel prize winner) Charles Edouard Guillaume (1896) estimated the radiation of the stars as follows:

> We conclude that the radiation of the stars alone would maintain the test particle we suppose might have been placed at different points in the sky, at a temperature of 5.6 K.

Much later, Arthur Stanley Eddington (1926), modelled the Milky Way radiation as a set of 2000 stars of apparent bolometric magnitude 1.0, and predicted a temperature of 3.18 K as the "temperature of interstellar space." With a completely different approach Regener (1933), using data on cosmic rays, obtained an interstellar temperature of 2.8 K. Walther Nernst developed a static model of the Universe in 1937, and derived an interstellar temperature of 0.75 K. From measurements of molecular spectra (CN essentially) McKellar and Herzberg derived a rotational temperature of 2.3 K in 1941.

It was about at that time, just after the second world war, that Gamow, and Alpher & Herman, in 1947 and 1948, predicted temperatures of the interstellar medium from the theory of the expanding universe. They found $T > 5$ K in 1948. But in 1961, Gamow, working on the same theoretical basis, gave as a predicted temperature of interstellar space the high value of 50 K!

The prediction by Alpher & Herman was published in widely read journals, such as the *Physical Review* and *Nature*; hence it gained considerable credence. As a result, later on, the predictions of interstellar temperatures from other hypotheses, similar to those used by Eddington and Guillaume, found difficulty being published and accepted.

Finlay-Freundlich and Max Born (1954)

In 1954, Finlay-Freundlich, with the explicit approval of Max Born, proposed a "tired-light mechanism," assuming a redshift proportional to the length of the path of photons coming from distant galaxies and to the fourth power of the temperature of the medium. He found a value of T such as $1.9 < T < 6.0$ K; and Born, from these data, predicted the observation of the microwave cosmic radiation, such as was found later by Penzias and Wilson (1964). These papers, published in lesser-known journals, were completely overlooked.

But, obviously, even after the discovery by Penzias and Wilson, the question would still appear to be quite open. As a result, we have revisited the question.

Our Papers (2006 and 2015)

We were lucky enough to have easy access to the data gathered by the astrometric space telescope Hipparcos, and to the star catalogues produced from these data, Tycho I and Tycho II. In our first publication, Narlikar and I (Pecker & Narlikar, 2006) made a preliminary estimation of the flux F radiated by the Milky Way and of the corresponding temperature. We used actual measures of stellar brightness in the visible spectral band, and corrected them using a bolometric correction deduced from the spectral type of the stars; moreover, we treated the less bright stars in a very schematic way.

Here we should note an important item (completely overlooked by our critics, as well as by some referees!): the radiation from galactic stars is obviously not isotropic; its temperature is therefore not an indication of the temperature induced in the ISM (interstellar matter, circumsolar) by this radiation. How is that interstellar dust distributed? There are certainly different clouds to be considered. One is more or less distributed like the Solar planetary system; at larger distances, another one may roughly follow the distribution of stars in the Galaxy; a third (perhaps "dark matter"), originating from a still larger volume, might even be more or less spherical. Therefore the dust around us can be considered as more or less isotropically distributed at large distances. These dust particles, heated by an anisotropic radiation, radiate an isotropic radiation — that of a blackbody.

In our second paper (Pecker *et al.* 2015), we did a more elaborate analysis of the same data, using not a bolometric correction, but the multicolour photometry available on Hipparcos.

The results of the analyses of the Tycho 2 catalogue are $F = 1.782 \times 10^{-2}$ erg cm^{-2} s^{-1}, using bolometric correction, or $F = 1.71 \times 10^{-2}$ erg cm^{-2} s^{-1}, using multicolor data.

The equilibrium temperature of the stellar radiation would then be (a quantity similar, in a way, to the "effective temperature" of a star): $T_{eff} = [F/\sigma]^{1/4} = 4.21$ K, or $T_{eff} = 4.17$ K.

In such a situation, a dust grain is not heated by the stellar flux on all its surface, but only on the fraction $\Omega/4\pi < 1$, Ω being the solid angle under which one sees, from the solar environment, the whole of the Milky Way. The whole of the grain is heated, so the grain radiates isotropically a blackbody radiation at the temperature $T_0 < T_{eff}$, and the isotropic radiated flux is $F_0 = \sigma T_0^{\,4} = (\Omega/4\pi)F$, where $T_0 = (F_0/\sigma)^{1/4} = (F\Omega/4\pi\sigma)^{1/4}$, (a quantity somewhat similar to the "surface temperature" of a star).

But what is the value of Ω? As determined by us from the COBE images, we can consider the Milky Way as a band of 5° to 15°, both sides of the celestial Equator. It is about 1/9 to 1/3 of the whole sky. This means that the local average flux transferred into thermal energy is only a fraction $q = \Omega/4\pi = 1/9$ to 1/3 of the flux F, when considered per centimeter square of the grain surface. This results in a reduction of the local thermal temperature of the grain, with respect to the temperature equivalent to the incident energy, by the factor $q^{1/4} \approx 0.58$ to 0.76, thus bringing it down to $T_{eff}q^{1/4} = T_0 = 2.42$ K to 3.20 K. An "average value," corresponding to a Milky Way of 10° each side of the galactic plane, would thus be $T_0 > \approx 2.81$ K, with an uncertainty of about 15%, remarkably close to the observed value. We consider this not to be pure chance.

But the relation between the value of the temperature of the radiated flux and the corresponding observed value really depends on the opacity of the circumsolar medium, whatever its extent. The question of opacity is indeed a key problem that we have to seriously consider.

If we denote by τ the value of the optical depth of the medium "around us," then the value of the observed background flux would be only $F_{obs} = k, F = F(1 - \exp(-\tau))$, or $F_{obs} = F\tau$ for small values of τ.

Can we reasonably estimate τ? To be able to well identify our data with the observed microwave radiation, we would need typically $\tau > 0.1$. But observations of nearby galaxies, by the Planck satellite (Bouchet 2006) seem to lead to the opposite conclusion (F. Combes, private communication). Is that indeed conclusive? It should be borne in mind the fact that the structure of the Universe is hierarchized in a fractal way, as demonstrated years ago by de Vaucouleurs (1970). The observation of nearby galaxies, embedded in the Local Cluster of galaxies, or even in the Local Supercluster, would not rule out the fact that the solar system, the Galaxy, the Local Cluster of galaxies, are minor structures indeed, all embedded in the Universe — but minor structures which may contain a lot of absorbing matter. We are indeed embedded in a medium of possibly high global opacity in the microwave domain. The pervasive radiation in that relatively small part of the Universe is therefore "local" at the scale of the Universe.

Therefore, we see that, even if the opacity is low at the scale of the Local Cluster of galaxies, there is no reason for this to be so at the scale of the much larger Local Supercluster. The temperature of the radiation coming from the galaxies around would probably be lower than the 4 K in our celestial location, but possibly not much, as the density in galaxies (and of dust particles) may be rather high in clusters.

At the present time, we therefore see no strong reason not to identify the results of our determination , using only the flux from stars, with the observed cosmic microwave backround, to which we refuse to apply the qualitative term "cosmological." What, then, is the nature of the absorbing material which absorbs the microwave radiation, much less the visible or UV radiation? Hoyle *et al.* (1968) and Wickramasinghe (2006) made the detailed proposal of metallic whiskers. Computing their opacity from a Mie-type theory, they obtain a sharp opacity peak in the microwave domain; moreover, for some cases of distant galaxies, they show that such absorption is really very strong. This would limit the generality of the statement above, namely that we observe some galaxies well in the observed microwave background radiation. It must not be forgotten that these galaxies are members of the Local group, and hence rather close-by objects. It seems therefore to us that there is no real contradistinction between the observation of these very few close-by galaxies and the non-observation of most of the galaxies.

The Sunyaev–Zel'dovitch effect (S-Z effect)

The S-Z effect has often been used as a decisive argument in favor of the standard views of the 3 K radiation. We remind the reader that the effect is in essence due to an inverse Compton effect, where electrons of high (galactic) energy interact with photons of low energy (MBR). It can explain the spatial distribution on the sky of the MBR. We cannot do better than to rewrite our previous statement. Our interpretation may be objected to on the grounds that it does not correctly take into account the S-Z effect as applied to photons from the MBR. This objection, as already explained in Pecker *et al.* (2015), is, however, not correct. The S-Z effect demonstrates that the MBR existed as far back in time as the typical redshifts ≥ 2 for clusters of galaxies. How does the apparently local origin of MBR account for this effect? To answer this question, we first note that a typical cluster containing several hundred galaxies will have starlight generated in similar amounts as in the nearby Virgo cluster of galaxies. There is nothing special about the thermalizing mechanism described here as it relates to our cluster, and it will be expected to operate in every cluster. In the standard picture, the background radiation present in a typical cluster of redshift z would have a thermal spectrum with temperature $T = 2.7(1+z)$ K. Accordingly one could make a calculation of how much of this radiation is depleted in the millimeter region and enhanced in the high energy (typically X-ray) region by Compton scattering. The definitive ambient temperature makes this calculation relatively simple. In our model, we can likewise proceed so far as the calculation of Compton depletion and enhancement are concerned. However, the assumed thermal spectrum will have a temperature depending on the stellar background in the cluster. In short, we do not and cannot have a unique epoch dependent temperature on which to carry out such a calculation. Recent studies by PLANCK (Planck Collaboration *et al.* 2011a,b) have considerably enhanced the database of objects that exhibit the S-Z effect so as to enable us to propose a test to distinguish between the standard model and our model. First, we expect a larger variation in the magnitude of the effect, because the temperature of the background radiation varies from cluster to cluster even at the same epoch. Secondly, if we have optical details about the cluster, it may be possible to include that information to work out the X-ray enhancement. Then one may tabulate and plot the X-ray enhancement against the optical luminosity of the cluster. Provided such data are available in an unambiguous form, the S-Z effect holds out the possibility of distinguishing between this model and the standard model.

Conclusions

We are led, by the considerations above, to refuse to apply to the background radiation the qualitative term of "cosmological." It is indeed a "local" radiation, meaning that it comes from a limited part of space — limited, but nevertheless very large, probably including the local Supercluster. What are the cosmological consequences of this finding upon the cosmological constructions?

First of all, we could choose to continue to describe the Universe as expanding at the Hubble rate, — but only around us, *i.e.*, inside the Local Supercluster. This would resemble the classical homogeneous Einstein-de Sitter model. It also resembles the more sophisticated QSSC (Quasi Steady State Cosmology) model, oscillating between two states, one of very high density, the other one of very low density (Burbidge *et al.*, 2000).

One could also, in a more drastic move, consider as a possibility the non-expanding model — a solution preferred by the author of the present paper. In that case, the redshift of distant galaxies must be explained by some other mechanism than the classical Doppler-Fizeau effect. More than half a century ago, Fritz Zwicky (1957) proposed a "tired-light" mechanism. The idea was proposed again later on by Finlay-Freundlich (1953, 1954) and by Max Born (1953, 1954). In 1976 this author proposed (Pecker, 1976) a detailed mechanism of interaction between light bosons and photons, presenting the Feynman diagrams associated with such an interaction. These bosons were however not identified with a known particle. But the assumption of the existence of such particles is indeed of the same nature as the assumption of "dark matter," and it is still more difficult to invent "dark energy," as both are, like "inflation," in essence *ad hoc* components of the Universe!

Other, more mathematical types of models have been proposed; we shall not consider them in this paper but shall instead refer the reader to the Collège de France Colloquium (Pecker & Narlikar, 2006).

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The Emerging Abnormal Redshifts

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One long-lived dogma in the early thirties was that the spectral shifts were all due to the Doppler-Fizeau effect, *i.e.*, to the velocity of the light source, in the direction of (blue shifts) or away from (redshifts) the observer. However, a massive particle, when travelling, may lose energy by interaction with the medium it crosses; hence it may lose velocity or mass. But what to say about the photon, of which the velocity is, according to everyone, a natural constant, and whose mass is, according the largest number of physicists, strictly zero? So another dogma was, that for reasons of symmetry, the photon rest-mass, if such a notion has a sense, has to be strictly zero, and its velocity strictly c, a well-measured constant of nature.

So, let me introduce here some personal remembrances. During the early seventies, Jean-Pierre Vigier, an old friend, came to my office. He was, like his mentor, Louis de Broglie, convinced that the photon should have a non-zero rest-mass. In order to demonstrate it, Vigier had planned a few interferometric experiments, more sophisticated than the simple Young holes, introducing polarization. But he could not find any spectroscopist willing to, or able to, carry out these experiments, in spite of their great ability in such a field. One was Alain Aspect, whose interferometric measures were excellent, but did not fit the very exacting requirements of Vigier. Faced with this situation, Vigier suggested to me that the proof of the non-zero rest-mass of the photon could be found in "abnormal" redshifts in the astrophysical data. He was also convinced that the famous expansion of the Universe was not necessarily true; hence that the so-called "cosmological" redshifts, discovered by Slipher and confirmed by Hubble, Humason, Sandage, Tammann, and many others, where not due to the Doppler effect, but to the loss of energy of massive photons travelling into space. That was the hypothesis called the "tired-light" mechanism, earlier already proposed by Zwicky, Born, Finlay-Freundlich and others. Vigier and I then became firm heroes in favour of the tired-light mechanism. .

At that time, although I was allergic to the very idea of a big bang, for philosophical reasons, having heard Pope Pius XII saying officially, and writing, that the Big bang was nothing else but the *fiat lux* of the Scriptures. I was not so strongly opposed to the present expansion of the Universe, not incompatible with an infinite duration of the Universe. But the idea of Vigier was interesting, and we started to look at local possible abnormal redshifts close to the Sun. It was at about that time that Roddier and Jorand insisted on the fact that the Einstein gravitational effect was not sufficient to account for the spectral redshift at the solar limb. Investigating the information on the deviation of light rays by the Sun during a solar total eclipse we found (following Mikhaïlov) that the observations were in excess of the Einsteinian prediction. Finally, the 3cm, 18cm, 21cm eclipses of radio-sources seemed to show an excess of redshift when the source was located very near the solar limb, either after or before the eclipse[1]. Needless to say, Vigier and I had several younger scientists who contributed to the necessary studies: Depaquit, LeDenmat, Mérat, Moles, Maric, Karoji, Jaakola, Tait, Roberts.

Therefore, Vigier and I prepared an extensive paper, in which we announced the existence of abnormal redshifts, and the possibility therefore for a non zero-mass of the photon, implying a strong revision of the expansion paradigm.

In 1971, we proposed our paper to *Astrophysical Letters*, of which the chief editor was my friend, colleague, and mentor Evry Schatzman. Schatzman asked four different non-anonymous referees. They rejected the paper, after many discussions with them, splitting hair whenever possible. That was in 1972. We had to accept the verdict.

In the meanwhile, Halton (Chip) Arp had published (1972[2]) his wealth of new data on abnormal redshifts in groups of two or more galaxies and quasars. This was published in the *Astrophysical Journal*, and duly received a rather large audience; some were critical, some enthusiastic. We had lost our hope of priority, but we were glad to see our ideas shared by Arp, the best observer of the Palomar Observatory, the bright follower of Fritz Zwicky. Our first extensive paper finally appeared in 1976, under my name only[3], though it was the result of our collective effort.

The opponents of Chip Arp's results were active and destructive; they soon opposed Arp in a very strong way, forbidding him to observe at

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[1] Abstracted in J.-C.Pecker, Décalage vers le rouge et expansion de l'univers, Paris: Editions de CNRS, p. 619, 1977

[2] H. Arp, *Astrophysical Journal (Letters)*, **174**, L111, 1972.

[3] J.-C. Pecker and J-P. Vigier, *Astrofizika*, **12**, 315, 1976.

Palomar, forcing him to publish in various non-refereed journals. In particular Sandage was aggressively determined to eliminate Arp's abnormal redshifts from the scientific scene. According to his detractors, they were only artefacts, due in part to the refractive amplification due to the gravitational fields of galaxies. And artefacts are not allowed to cross the editorial offices of journals. Therefore Chip decided to go away from the USA, to München, in Germany, where he died in 2013, quite recently. Arp himself tells that sad story in his book *Seeing Red* (a *double entendre*), published by *Apeiron*, and gave a compendium of his observations in another book published also by *Apeiron*, a catalogue of abnormal redshifts[4]. Both books had very little impact, being even unknown to the majority of astronomers. Looking however at his results made me still more convinced that they could not be spurious, in spite of the spurious character of one or two of his cases. I claim that had Arp found only one case of non-velocity redshift, it would be a great discovery; I am convinced that he actually discovered dozens of them. And therefore, I do believe that the "abnormal" redshifts are indeed… abnormal redshifts, and that the very expansion of the Universe should be questioned.

We shall miss Chip, his talent, his ideas, his warm personality. He was indeed the exemplary victim of the stubborn conservatism of a large part of the astronomical community.

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[4] H. Arp, *Seeing Red* (Montreal: Apeiron, 1997); H. Arp, *Catalogue of Discordant Redshift Associations* (Montreal: Apeiron, 2003)

The Local Contribution to the Microwave Background Radiation*

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The observed microwave background radiation (MBR) is commonly interpreted as the relic of an early hot universe, and its observed features (spectrum and anisotropy) are explained in terms of properties of the early universe. Here we describe a complementary, even possibly alternative, interpretation of MBR, first proposed in the early 20th Century, and adapt it to modern observations. For example, the stellar Hipparcos data show that the starlight energy density from the Milky Way, if suitably thermalised, yields a temperature of ~2.81K. This and other arguments given here strongly suggest that the origin of MBR may lie, at least in a very large part, in re-radiation of thermalised galactic starlight. The strengths and weaknesses of this alternative radical explanation are discussed.

Key words: Galaxy : stellar content, (cosmology:) cosmic microwave background, cosmology : observations

1 Introduction

In 1926, Eddington made an order of magnitude calculation in which he estimated the total radiation background from stars in the Galaxy by assuming a population of only 2000 stars of apparent bolometric magnitude $m = 1.0$. He arrived at an energy density of starlight of around 7.67×10^{13} erg cm^{-3}. If equated to a black body equilibrium distribution, this worked out to a temperature of ~3K. Eddington (1926) identified this as the "temperature of interstellar space." An earlier calculation of Guillaume (1896)

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had led to a similar order of temperature ($\sim 5-6$K). Both he and Eddington had felt that the actual temperature might be somewhat higher than estimated this way.

First we note that the observed microwave background radiation (MBR) is a very close approximation to a black body of temperature of $T_0 = 2.726$K. This radiation, *a priori*, could have three possible sources, without excluding other possible interpretations:

1. Cosmological radiation (CR in brief) as the fossil radiation from an early hot universe, cooled adiabatically by expansion, as first proposed by Alpher and Herman (1948), and later as definitely accepted in the reference frames of the "standard" cosmological models;
2. Direct radiation (DR) from galaxies and stars, eventually scattered by dust, and
3. Reradiated radiation (RR), *i.e.*, stellar radiation in the Galaxy or galaxies which is absorbed and reradiated by dust (*i.e.*, non scattered). A systematic historical account of various attempts to estimate the temperature of cosmic radiation background along those lines was given by Assis and Neves (1995).

It is interesting to note that although George Gamow was not a co-author of the paper (Alpher and Herman 1948) predicting the existence of a relic background, he later was an enthusiastic proponent of the interpretation. His own estimate of the thermal temperature of the background increased progressively through a sequence of values from 7K to 50K. *As is now realized, the standard model with its given dynamical parameters is not able to predict the present temperature of this background. The observed value of 2.726K is taken as an additional parameter of the theory.*

The CR, as is well known, is not related to starlight or to any population of discrete sources. The MBR according to CR would have existed even in a universe without any star formation. The CR ignores completely any possible influence of starlight, be it scattered or reradiated. The second alternative (DR) seems unworkable as its radiation background is quite small both in the microwaves and IR, compared to the observed MBR, and clearly anisotropic and different in its spectrum from a blackbody radiation. However, as we shall soon see, a plausible case can be made for the third alternative, that of RR. This alternative does not call for any cosmological relic radiation and was indeed suggested by several authors without reference to cosmology. We have already mentioned Guillaume (1896) and Eddington (1926), but Regener (1933), Nernst (1938), Born (1953, 1954), made similar estimations, as described by Assis and Neves (1995).

The discovery of small scale inhomogeneities of the MBR by COBE and the subsequent fine measurements of their power spectrum by WMAP has provided momentum to the CR with detailed explanations of the observed features. However, as mentioned above, the actual temperature of the MBR cannot be predicted: it is taken as a free parameter arbitrarily set at its present value. An alternative way of stating this is to say that as yet, the photon to baryon number ratio cannot be deduced from any calculations pertaining to the "early universe."

By contrast, in the RR contribution to the MBR, the temperature of the background can be derived from the given data on the stellar background, without any recourse to a cosmological model. It is known for example: that if all the observed helium were produced in stars, the resulting starlight would have an energy density equalling that of a black body of 2.7K (see for example, Hoyle, Wickramasinghe and Reddish, 1968; Hoyle, Burbidge and Narlikar, 2000). This, of course suggests an astrophysical character for the MBR rather than a cosmological one. In this paper we will elaborate on this idea further.

2 The RR Version

2.1 The "source-function"

In an earlier paper referred to henceforth as Paper I, Pecker and Narlikar (2006) had calculated (see the Appendix) the flux F of starlight received at the Earth, based on the extensive Hipparcos data stored in the CDS archives at Strasbourg.

That flux is obviously highly anisotropic. From it, and to derive the local temperature of the medium, we need to treat a transfer problem, quite similar to that ruling the stellar atmospheres. We shall therefore use the classical context of radiative equilibrium, as described in several standard textbooks on stellar structure. In the radiation transfer equation, we shall neglect the so-called "scattering term," as it does not concern the "reradiation," being important at the short wavelengths, whereas the reradiation is important only at the long wavelengths (microwaves). We can write, in a plane-parallel geometry:

$$\mathrm{d}I_\nu \big/ \mathrm{d}h = -\kappa_\nu I_\nu + B_\nu , \tag{1}$$

where we relate the optical depth τ_ν to the vertical height h by $\kappa_\nu \mathrm{d}h = -\mathrm{d}\tau_\nu$, κ_ν being the opacity of matter to radiation of frequency ν. The "source-function" B_ν can be taken to be the Planck function. B_ν is function of the local black body temperature at height h, which we denote by $T(h)$. Note that although the source function B_ν in the interstellar medium (ISM), is by definition isotropic, the intensity I_ν of the radiation coming from the Galaxy is indeed obviously anisotropic. In that particular case, if, at a given location in the medium, we denote the mean intensity of radiation averaged over all directions by $\langle I_\nu \rangle$, then the conservation of radiative flux gives the result:

$$\langle I_\nu \rangle = \int_0^\infty \langle I_\nu \rangle \kappa_\nu \, \mathrm{d}\nu = \int_0^\infty B_\nu(T) \, \mathrm{d}\nu = B(T) \tag{2}$$

The dominant part of the left-hand side integral is the one contributed by the short wave lengths and visible parts of the spectrum; there the opacity of ISM is very weak, and we can consider that the intensity of the radiation coming from the Galaxy is identical with what we observe at the Earth, with the radiation flux resulting from observations reported in the preceding paragraph.

The relation of the flux *F* as observed with the intensity $\langle I_\nu \rangle$ is simple and derives from an integration over the whole sky, as follows:

$$F_0 = \left(\tfrac{1}{4\pi}\right)\left(\int_0^{2\pi} \int_0^{\pi} \langle I(\theta) \rangle \cos\theta \sin\theta \, \mathrm{d}\theta \, \mathrm{d}\phi\right) \tag{3}$$

Within this framework, the real value of the flux F_0, which is an average value of the intensity, is smaller than the value of the flux *F* of galactic radiation, which is the average value of the intensity of only a small fraction of the sky, namely the Milky Way, the rest of the sky being almost dark.

The results of the analyses of the Tycho 2 catalogue are (see Appendix):

$$\begin{aligned} &F = 1.782\times10^{-2}\ \mathrm{erg.cm^{-2}\,s^{-1}} > F_0, \text{ using bolometric corrections} \\ &or\ F = 1.71\,\mathrm{erg.cm^{-2}\,s^{-1}}, \text{ using multicolour data} \end{aligned} \tag{4}$$

Assuming that the radiation was coming isotropically from all directions, the equilibrium temperature of the dust medium would be

$$T_{eff} = \left[{F}/{\sigma}\right]^{\frac{1}{4}} = 4.21\ \mathrm{K}, \text{ or } T_{eff} = 4.17\ \mathrm{K} \tag{5}$$

where σ is the Stefan constant. This is the "effective temperature," as in stellar atmospheres, *i.e.,* not the local temperature, but the temperature of radiation, both being equal to each other only if the radiation field is isotropic.

However, *the distinctive property of the stellar radiation flux is that it is not isotropic*. The bulk of it comes from the plane of the Milky Way. The solid angle Ω subtended by the star distribution in the Milky Way is not 4π. A dust grain does not receive radiation from all directions, hence a large part of the dust grain does not receive radiation. The flux F_0 actually received by each cm^2 of a grain (be that squared centimetre in light or in shadow) is, on the average,

$$F_0 = \left({\Omega}/{4\pi}\right) F, \tag{6}$$

In such a situation, a dust grain is not heated by the stellar flux on all its surface but only on the fraction $\Omega/4\pi < 1$, but it reaches an equilibrium temperature. The rest of the grain is not heated, but radiates. Thus it radiates isotropically the blackbody radiation at the temperature $T_0 < T_{eff}$, and the isotropic radiated flux is

$$F_0 = \sigma T_0^4 = \left(\Omega/_{4\pi}\right) F,, \tag{7}$$

hence

$$T_0 = \left(F_{\sigma}/_{\sigma}\right)^{\frac{1}{4}} = \left(F\Omega/_{4\pi\sigma}\right)^{\frac{1}{4}} \tag{8}$$

What is the value of Ω? As determined by us from the COBE images (Mather *et al.*, 1994), we can consider the Milky Way as a band of 50 to 150, both sides of the celestial equator. It is about 1/9th to 1/3rd of the whole sky. This means that the local average flux transferred into thermal energy is only a fraction $q = \Omega/4\pi = 1/9 \text{ to } 1/3$ of the flux *F*, when considered per centimeter square of the grain surface. This results in a reduction of the local thermal temperature of the grain, with respect to the temperature equivalent to the incident energy, by the factor

$$q^{\frac{1}{4}} \approx 0.58 \text{ to } 0.76 \tag{9}$$

thus bringing it down, from equation (8), to

$$T_0 q_{eff}^{\frac{1}{4}} = 2.42 \text{ K to } 3.20 \text{ K} \tag{10}$$

An "average value" corresponding to a Milky Way of 100 each side of the galactic plane would be:

$$\langle T_0 \rangle \approx 2.81 \text{ K} \tag{11}$$

An analogy with the local radiation field in the solar photosphere can help: there the effective temperature is of the order of ≈ 5770 K and the local "surface" temperature of the order of ≈ 4670 K.

2.2 The opacity term

In the RR case we assume that, given an effective thermalisation of dust, a similar situation will occur for the reradiated radiation, *i.e.*, a local isotropy. As the re-radiation by the interstellar dust occurs predominantly in the microwave band, given the above value of T_0, it can produce a completely isotropic black body radiation of temperature T_0 in the vicinity of the Earth. Therefore the "source-function" of the equation of the radiation transfer is $B_{\nu\nu}(T_0)$, $B_\nu(T)$ Bv (T) being the Planck-function. For this blackbody radiation to be as intense as that within an opaque furnace, *i.e.*, that of an undiluted blackbody, it requires the re-emitting medium to be sufficiently opaque in that band. If the medium is not opaque, but has an optical depth

τ, then the temperature of the microwave radiation field at the Earth will be reduced by the factor $\left(1-e^{-\tau}\right)^{1/4}$. For τ of the order of 10, it would be reduced by a factor of the order of 10^5. Clearly for the above explanation to be viable, the optical depth must largely exceed unity in the microwave spectral domain. As the late Fred Hoyle once put it: the situation is that of a mountaineer lost in heavy fog which produces a very short visibility. The anisotropic landmarks that would have helped him to find the right track are obscured by this low visibility

Also, in a local explanation, the absorbing dust must be very close, perhaps not far from the galactic centre. In any case it has to be located within the Local Group.

What type of absorbing matter can be viable? What are the dust particles in the galactic environment that produce such a "microwave fog"?

These dust particles will be such that for them the grey approximation would be valid. We have computed here above the equilibrium temperature arising from the radiation energy flux of all stars in the Galaxy at a point in the solar system (where we happen to be). We know more or less the absorption coefficient of dust in the visible and UV parts of the spectrum and its density distribution in the galactic surroundings. For the purposes of our discussion let us assume that it is non zero, and so the starlight will therefore be absorbed (partially) and reradiated. If the process is allowed to go on many times in the lifetime of the Galaxy, then an equilibrium temperature T_0 such as determined above will be reached. The actual time scale for this to occur is estimated as follows.

The interstellar matter would reach this temperature only if the lifetime of the region where the interaction takes place is sufficiently long. Since the galactic age is of the order of 10 Gyr, the time taken for thermalisation can be as high as 1 Gyr. Taking the galactic dimension to be ~ 30 kpc, light takes $\sim 10^5$ years to traverse it once. Thus in a period of 10^7 years the starlight will get absorbed and reemitted ~ 100 times. And so the galactic time scale of 10^{10} years is more than adequate to assure thermalisation.

2.3 The dust absorbing in the microwave domain

The conventional candidates for interstellar absorption, *e.g.*, atoms or molecules of various kinds, and dust, *e.g.*, of carbonaceous grains, have been well discussed in the context of galactic environment. None of these serve our purpose of providing opacity peaking in the microwave region. However, the dust made of metallic whiskers discussed by Hoyle and Wickramasinghe (1988) will serve the purpose adequately.

The metallic whiskers form when the metals synthesised in supernovae are ejected as vapours which cool down to condense in solid form. Laboratory experiments (Sears, 1957, Nabarro & Jackson, 1958, Dittmar, 1958, Lefèvre, 1967) show that these condensates are not spherical but are shaped like whiskers. Typically a whisker may be 0.5 – 1.0 mm long and around 10^{-6} cm in cross-sectional diameter. Absorption of light by such whiskers peaks at mm-wavelengths, being moderate in the optical band and much less in the radio wavelengths. For details see Hoyle and Wickramasinghe (1988), Wickramasinghe & Hoyle (1994), Wickramasinghe (2006). Whiskers are swept away by the shock wave generated by the supernova and propelled by radiation pressure can reach even beyond the parent galaxy.

Whiskers have earlier been invoked by Narlikar *et al.* (2007) to explain the origin of the microwave background in the Quasi-Steady State Cosmology (QSSC) (see also: Burbidge *et al.*, 2000). According to the QSSC, the universe has no beginning; it expands in a long term exponential way together with short term oscillations as exemplified by the following scale factor:

$$S(t) = \exp(t/P) \times \left[1 + \eta \cos(2\pi t/Q)\right], \tag{12}$$

where $P = 20\,Q$, and η has magnitude less than unity. Thus this model is non-singular. It is argued that new matter is produced at the beginning of each cycle when the scale factor is minimum; that this matter forms into stars which evolve and eventually get extinguished. With typically $Q = 50$ Gyr, this is possible in each cycle for all but the very low mass stars. The relic starlight from all the previous cycles can be calculated and it is shown that the thermalisation of this relic radiation leads to the observed MBR with a Planckian spectrum and power spectrum as observed by WMAP (2003, 2006). The thermalisation is done by metallic, *i.e.*, mainly by carbon and iron whiskers. The same whiskers in the intergalactic medium help reproduce the observed redshift-magnitude relation for Type 1A supernovae (Wickramasinghe & Wickramasinghe, 2008, Narlikar *et al.*, 2002). Other astrophysical evidence for whisker-dust has been discussed by Narlikar *et al.* (1996).

3 Thermalization

While iron at cryogenic temperatures and in the form of long thread-like particles (whiskers) is likely to be the dominant source of opacity in the microwave region, carbon particles also in the form of whiskers considerably exceed the effect of iron at shorter wavelengths. This is both because carbon is produced by stars more abundantly than iron, and because the efficiency of carbon is greater at shorter wavelengths.

The value of mass absorption coefficient Q_{abs} for graphite whiskers is essentially constant for all wavelengths longer than ~1mm, extending even to long radio wavelengths, and is ~0.33 for whiskers of diameter

$0.01\mu m$ and length ~ 1 mm, equivalent to an absorption coefficient of $10^5 cm^2 g^{-1}$.

The great bulk of the optical radiation that becomes subject to thermalization has been travelling for $10^6 - 10^7$ years, and even more in the case of microwaves. The radiation incident on a carbon whisker has mostly been in propagation at least for this long and includes all the microwave radiation existing before. So all such radiation is exceedingly uniform in its energy density. For the moment we assume that radiation to be entirely uniform, returning to the slight deviations from uniformity shortly. What we do not assume, however, is that the carbon whiskers responsible for absorbing the starlight and re-emitting it into microwaves are uniformly distributed. The carbon whiskers can be lumpy on the scale of clusters of stars. This means that the conversion of starlight to microwaves will start lumpily but each carbon whisker, wherever it is situated, finds itself in a radiation bath of uniform energy density, a radiation bath of which the major fraction already consists of microwaves from previous scatterings and the rest is mostly starlight still to be converted to microwaves. If the whole were microwaves, then having regard to the total flatness of Q_{ab} with respect to wavelength through the range longward of $\sim 1\mu m$, the temperature attained by the particles would be simply the standard microwave temperature, ~ 2.73 K as we know it to be. But because a fraction, say ten percent of the radiation is at shorter wavelengths, the stellar component has a higher value of Q_{abs}. This forces up the temperature of the grains, to a value or order

$$\sim (0.9 + 3^{1/4} \times 0.1)2.73 \leq 2.82\text{K},$$

the second term in the brackets being contributed by the absorption of the starlight. Here we have assumed a factor 3 by which Q_{abs} is higher at shorter wavelengths. As the starlight is progressively absorbed with optical depth τ, the factor 0.1 in this equation is replaced by $0.1\, exp -\tau$ and the factor 0.9 is replaced by $(1 - 0.1\, exp -\tau)$, so that the grain temperature varies according to

$$[1 + 0.1e^{-\tau}(3^{1/4} - 1)]2.73\text{K}.$$

Thus as the starlight begins to be absorbed the whisker temperature goes about 0.1 K higher and lapses back to 2.73 K as the starlight is progressively absorbed.

The effect of τ being lumpily distributed on the scale of clusters of stars causes this process of a slight temperature rise followed by a fall back to 2.73 K to be correspondingly lumpy. *But what it does not do is to make the total radiation energy density lumpy at all.* Once the radiation energy density is uniform in total, this essential property is not changed by absorption and re-emission due to particles. Because of course each particle emits just as much energy as it absorbs the total assembly of particles has itself only a negligible heat content the particles do not store heat except in a very small amount. Thus, objections to this theory, based on lumpiness of the particles, are not correct.

Since the emissivity of the particles has no wavelength dependence they simply emit a Planck distribution $1/[exp(hv/kT)-1]$ at whatever value of T they may happen to have, according to the above temperatures which may range up to about 2.82 K. But in general they do not produce the Planck intensity $v^3[(exp)hv/kT)-1]$. When T is raised slightly to 2.82 K the intensity distribution is slightly diluted. So what is the outcome from this first absorption of the starlight? It is a uniform energy density of microwaves with a distribution approximately that of a black body at 2.73 K, but with some fluctuations in the details of the intensity curve with those details having initially a somewhat uneven distribution to the extent that the carbon whiskers are distributed unevenly.

But now, with the starlight absorbed, and with the temperature of the particles everywhere the same, further absorption and re-emission inevitably generates the strict Planck distribution for 2.73 K. Only a few further absorptions are sufficient for this last step. It can be done with carbon whiskers, as Narlikar, Edmunds and Wickramasinghe (1976) suggested nearly four decades ago. However, the addition of even a small quantity of iron whiskers, with very high opacity at the center of the microwave distribution, would make this final step even more decisive. We need to clarify that the MBR is produced in the QSSC by the astrophysical process of thermalising starlight, but it is supposed to exist all over the universe. Thus according to the QSSC, the MBR temperature at the present epoch is 2.7 K all over the universe. Although in the present model of RR we are using the same thermalising agent as the QSSC, the MBR produced in this model is purely local. Taking metallic density to be $\sim 10^{-28}$g cm^{-3} in the Galaxy we get an optical depth of ~ 10 across our local region extending upto just beyond the Milky Way. Light takes ~ 106 yrs to cross this region. Thus over $\sim 10^{10}$ yrs, the presumed age of the Galaxy, light makes $\sim 10^4$ trips. Each trip giving $\tau = 10$, clearly there is ample opportunity for a very strict Planckian distribution to be reached.

We see maser emission from some extragalactic sources, but how weakened are they in the microwave band, we do not know. The resolving power of the microwave satellites like COBE, WMAP and even PLANCK is grossly insufficient to enable seeing microwave emitting galaxies. But one could observe clusters of galaxies; and it has been claimed to be actually the case. Finding such sources would be a key observation in apparent contradiction with the present model. We come back to that important point in the final discussion.

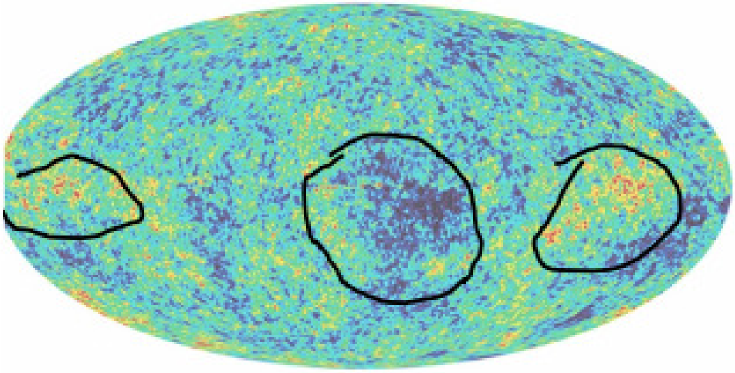

Fig. 1 – Could the microwave features have originated in our own Galaxy? From WMAP. On the original skymap issued by the NASA/WMAP group (see references), the authors have indicated three remarkable regions dominated, unlike the rest of the map, by dark blue or red colours, indicating a peculiar behaviour. They are located in the Milky Way. They do escape any power-type analysis, in view of their large size and small number.

4 Observational Constraints

Indirect observations like those by Swings and Rosenfeld (1937), McKellar (1941), Douglas and Herzberg (1958) *etc.*, are strictly local and do not allow us to constrain this model or to make a distinction between CR and RR. Some authors have claimed to find by the same method temperatures higher than 3K in the vicinity of some quasars of high redshift located near their mother galaxy. This argument is interesting but not decisive; the "local" contribution in those conditions might be quite different than in the case of our own Galaxy. But direct and detailed studies of the MBR by COBE (1990, 1994, 1996) or WMAP (2003, 2006) do indeed allow us to make a distinction between RR and CR. The CR performs well in explaining these observations, but at the expense of assumptions of non-baryonic dark matter and dark energy, for which no independent direct evidence exists so far.

At the same time, we wish to draw attention to the features in the COBE and WMAP data which seem to have been generally ignored. In the domain relative to the galactic plane there exist (Figure 1) two well-known conspicuous reddish-yellow regions and one conspicuous blue region, both of which are by essence not included in the power spectrum analysis as published, both of which are located in the galactic plane. The images of the whole sky are corrected for the galactic non-black body (stellar) radiation. But if there is a galactic black body component, the correction procedure will not get rid of it. Therefore what we observe may well have a black body component of galactic origin. In which case one may wonder if the observed small scale fluctuations are indicative of turbulent patterns in our Galaxy rather than being a signature of galaxy formation in some early epoch.

The picture we have proposed for our Galaxy and its neighbourhood, could very well apply to other galaxies and thus we may see local microwave radiation fields around them. This may explain why we may still see Sunyaev-Zeldovich effects at large redshifts. We will return to this issue in the final discussion.

We end with a piece of evidence that may prove potentially hard to explain. This relates to solar motion measured relative to the rest frame of the MBR. The numerical values obtained by various sources may be summarized as follows:

- COBE data (1996): Solar apex: $l = 264^0$ & $b = 48^0$ with velocity towards the apex (estimated by us from the quoted data $\Delta T = 3.35$ mK and Wien's law) = 364 km s^{-1}.
- Landolt-Bornstein compilation (1965): Solar apex with respect to galactic stars (the standard solar motion): $l = 56^0$ & $b = 22.8^0$ with velocity towards apex = 20 km s^{-1}.
- Velocity relative to close-by extragalactic universe, as derived from galactic rotation: Velocity at the Sun's location = 225 km s^{-1}.
- Apex of Galaxy's motion relative to the extragalactic universe: This has been difficult to estimate but order of magnitude value of the motion is expected to be around 100-200 km s^{-1} as measured relative to the Local Group of galaxies.

From these figures it is difficult to reconcile in an unambiguous way the COBE measurements with all that we know about the solar motion as summarized above. However, the existence of any solar motion relative to the MBR is disturbing for the RR-framework.

5 Discussion

Our interpretation may be objected to on the grounds that it does not take into account correctly the SunyaevZeldovich effect (hereafter S-Z effect), as applied to the photons of the MBR. This objection is not correct. The S-Z effect is in essence an inverse Compton effect linked with the interaction between incident photons and local electrons. The S-Z effect demonstrates that the MBR existed as far back in time as the typical redshifts ≥ 2 of clusters of galaxies. How does the apparently local origin of MBR account for this effect? To answer this question, we first note that a typical cluster containing several hundred galaxies will have starlight generated in similar amounts as in our own (Virgo) cluster of galaxies. The thermalizing mechanism described here has nothing special about our cluster and it will be expected to operate in every cluster. In the standard picture the background radiation present in a typical cluster of redshift z would have a thermal spectrum of temperature $T = 2.7(1+z)$. Accordingly one could make a calculation of how much of this radiation is depleted in the millimetre region and enhanced in the high energy (typically X-ray) region by Compton scattering. The definitive ambient temperature makes this calculation relatively simple. In our model, we can likewise proceed so far as the calculation of Compton depletion and enhancement are concerned. However, the thermal spectrum assumed will have a temperature depending on the stellar background in the cluster. In short we do not and cannot have a unique epoch dependent temperature on which to carry out such a calculation. Recent studies by PLANCK (2012) have considerably enhanced the database of S-Z effect so as to enable us to propose a test to distinguish between the standard model and our model. First, we expect a larger variation in the magnitude of the effect, because the temperature of the background radiation varies from cluster to cluster even at the same epoch. Secondly, if we have optical details of the cluster, it may be possible to fold in that information to work out the X-ray enhancement. Then one may tabulate and plot the X-ray enhancement against the optical luminosity of the cluster. Provided such data are available in an unambiguous form, the S-Z effect holds out the possibility of distinguishing between this model and the standard model.

6 Conclusion

We would like to point out that the estimate of stellar contribution to the MBR made here is based on the extensive database of HIPPARCOS, used in their totality. Thus it goes to a considerably greater accuracy than Eddington's 1926 *rough* estimate, which used 2000 stars of magnitude 1 located at 10 pc to approximate the desired stellar contribution. Actually Eddington computed only the temperature of the incoming galactic radiation; he did not estimate or even consider the temperature of the dust, which can be computed only by taking into account, as we do, the distribution on the sky of the light sources. Moreover, we also have the advantage of the COBE spectrum of MBR for a comparison with the thermalised stellar background. Thus our work is based on direct observational evidence. For this reason the excellent agreement ($\approx 3\%$ difference) found between the MBR temperature and that of the thermalised stellar background needs to be taken very seriously. Another suggestive argument that favours thermalisation is that the solar system seems to be entering a dense spiral arm of the Galaxy (McCrea 1975).

To summarize, we feel that the RR interpretation deserves further consideration since *prima facie* it is able to provide a very accurate estimate of the observed MBR temperature, *viz.*, 2.81 K in place of 2.726 K. The accuracy of these data is however not good enough to rule out a very small cosmological contribution to the MBR. The acceptance of the RR paradigm, however, would imply revising considerably the standard model with profound cosmological implications.

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WMAP, see Bennett *et al.*, 2003; Bouchet, 2006.

Appendix

Detailed Computation of the Radiative Flux Received at Earth

1 Introduction

The flux F received at the Earth is defined by

$$F = \sum_i F_i, \quad F_i = \int_\lambda F_{i,\lambda}(\lambda)\, d\lambda \tag{1}$$

where the summation is made over all the sources of radiation, each producing a bolometric flux F_i;. Each bolometric flux is the integral of the flux density $F_{i,\lambda}$ over all frequencies (or wavelengths).

The computation of F was made with 2 different methods: a first method using the standard bolometric correction (section 2), and a second one using direct flux computations (section 3). Both methods rely on the usage of all-sky photometric surveys. We use here the Tycho-2 catalog in the optical, and the 2MASS in the near-infrared.

1.1 The Tycho-2 catalog

The Tycho-2 catalog (Høg *et al.*) resulting from the *Hipparcos* mission contains positions, proper motions and two-color photometric data for the 2.5 million brightest stars in the visible band. The satellite scanned the whole sky, and the result is a bias-free catalog containing all the sources detected. The result is therefore especially appropriate for statistical applications.

The passbands used by the Tycho mission, V_T and B_T, differ slightly from the Johnson BV standard colors (see Fig. 1, adapted from Maiz-Apellaniz): the central wavelengths (in Angstroms) of the Tycho system are 4192 and 5232 for Tycho, compared to 4380 and 5470 for Johnson (Fiorucci & Munari). As a consequence, the color index $V_T - B_T$ differs slightly from the Johnson index B – V, the average relation being $(B-V) = 0.850(V_T - B_T)$ (Hipparcos)

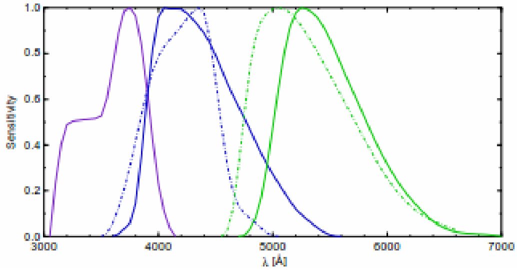

Fig. 1 – Sensitivity curves for the Johnson *U BV* (full lines) and the Tycho $B_T V_T$ filters (dotted lines) (from Maiz-Apellaniz)

1.2 Infra-red surveys

The fraction of the light received in the red and infra-red part of the spectrum can be computed from the 2MASS point source catalog (Cutri *et al.*), which contains about 500 million point sources detected in the near-IR bands J (1.24μm) H (1.65μm) and K_s (2.17μm).

1.3 The ASCC-2.5 catalog

Kharchenko (2007) combined the Tycho-2 catalog with other ground-based astrometric catalogs, and also the 2MASS catalog. The result is a catalog of 2501313 stars, with accurate astrometry (positions, proper motions) photometry in B and V (reduced to Johnson system) plus the near-IR photometry from the 2MASS. However it should be noticed that only a small fraction of the infra-red flux is received from optically bright stars – the ASCC-2.5 catalog is therefore not adapted for the estimation of the flux received in the infra-red part of the spectrum.

1.4 Other all-sky surveys

The deepest all-sky surveys in the optical are still represented by the photographic surveys like POSS—but the photographic calibrations are generally not reliable, the brighter part being absent. However the UCAC3 all-sky survey (Zacharias *et al.*), reports a relatively accurate photometry in a band covering the wavelengths 579-642nm, *i.e.*, the orange-yellow part of the optical spectrum. The brighter stars (≤ 4) are absent from this survey; these were manually added.

2 Estimation with Bolometric Corrections

In a first step, we have used the VT magnitudes of the Tycho-2 catalogue, and corrected them using a standard bolometric correction, given as a function of the spectral type. The stars from the brightest down to magnitude 2.5 (*i.e.*, from Sirius (VT = −1.088) and Canopus (VT = −0.608) etc to z Centauri (VT = 2.497), *i.e.*, 142 stars altogether) were individually considered. For less bright stars, we have used bins of VT magnitudes covering intervals of 0.25 magnitude down to $V_T = 15$; to correct for the bolometric correction, we have used the average value of the B_T magnitude for each bin. We have also considered the 15 brightest galaxies, from LMC ($m = 0.86$) down to NGC 4736 ($m = 8.91$), and applied to the data a solar-like bolometric correction. The examination of the data has demonstrated that stars less bright than $V_T = 15$ do not contribute to the total flux received at the Earth. Our result is

$$F = 1.782\ 10^{-2} \text{erg cm}^{-2}\ \text{s}^{-1} \tag{2}$$

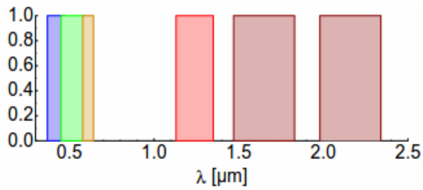

Fig. 2 – Illustration of the coverage of the electromagnetic spectrum by the all-sky survey used (bands $B_T V_T rJHK_s$)

3 Direct Estimation of the Flux

Table 1 Characteristics of the filters and their zero-magnitude fluxes

$\lambda_0(\mu m)$	FWHM(μm)	Band	F_0(Jy)	Remarks
0.419	0.067	B_T	3943	Tycho
0.438	0.093	B	4063	Johnson
0.523	0.095	V_T	3761	Tycho
0.547	0.084	V	3636	Johnson
0.610	0.063	r	3300	UCAC3
1.24	0.15	J	1594	2MASS
1.65	0.24	H	1024	2MASS
2.16	0.25	K_s	667	2MASS

Here we try to estimate directly the flux of Eq.(1) from large all-sky surveys. The total flux of Eq.(1) can be derived directly from the observations in various filters, if the observations can be converted into actual fluxes. For this computation, we need to know, for each filter:

- its coverage along the electromagnetic spectrum. Here we assume this coverage can be reduced to a central wavelength λ_0 and a bandwidth W
- the relation flux-magnitude, to convert the observed magnitudes (conventionally expressed in the Vega system) into actual fluxes. This relation follows the definition of the monochromatic magnitude $m\lambda = -2.5 \log(F_\lambda/F_{0\lambda})$, where $F_{0\lambda}$ represents the flux density of a zero-magnitude star.

The parameters adopted here are summarized in Table 1 where the central wavelengths and their FWHMs are from the ADPS database (Fiorucci & Munari), and the zero-magnitude factors from the NStED[*] database, except for the UCAC3 where the value of 3300 was assumed from the comparison with similar filters. The relation between the bandwidth W and the FWHM is assumed to be $W = \sqrt{3/2 \ln 2} \simeq 1.47$ FWHM, which

[*] NASA/IPAC/NExScI Star and Exoplanet Database, see
http://nsted.ipac.caltech.edu/NStED/docs/parhelp/Photometry.html

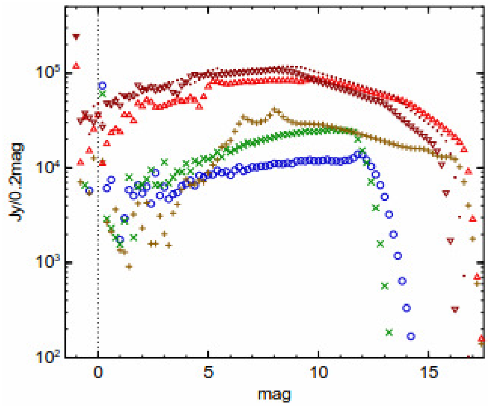

Fig. 3 – All-sky flux densities from all-sky surveys as a function of magnitude in bands *B* (circles) *V* (crosses) *r* (pluses) *J* (triangles), *H* (dots) and *K* (inverted triangles)

stands for a Gaussian filter. The resulting coverage of the electromagnetic spectrum by the 6 bands is furthermore illustrated in Fig.2.

Table 2 Resulting figures for the total flux (in $\mu W\ m^{-2}$) received in the bands summarized in Table 1; values in italics are interpolations or extrapolations

Band		Observed ($\mu W\ m^{-2}$)	completeness	faint end ($\mu W\ m^{-2}$)		Total ($\mu W\ m^{-2}$)
F(B)	=	1.016	($m_B \leq 12$)	*+0.479*	=	1.495
F(V)	=	1.481	($m_V \leq 12$)	*+0.654*	=	2.135
F(r)	=	1.015	($m_r \leq 15$)	*+0.275*	=	1.390
F(J)	=	2.011	($m_J \leq 15$)	*+0.412*	=	2.510
F(H)	=	1.444	($m_H \leq 14$)	*+0.275*	=	1.719
F(K)	=	1.299	($m_K \leq 13$)	*+0.259*	=	1.558
gap	=	*4.412*	($m \leq 15$)	*+0.688*	=	5.010

The observed fluxes in the *BVrJHK* bands are illustrated in Fig. 3, which shows the variation of the flux density in each of the 6 bands as a function of the magnitude. The behaviour of the UCAC3 flux density in the range 7–9mag is likely due to a difficulty of the calibration of the brighter stars.

Using the filter characteristics of Table 1, the observed fluxes can be computed in each of the 6 bands. The results are listed in the "Observed" column of Table 2 (non-italicized values), where the limits of completeness in each band are also specified.

The limits in the completeness of the Tycho optical bands may be estimated with the photographic surveys, at least in the range 13–18mag. Figure 4 shows the trends of the photographic blue and red magnitudes from USNO-A2.0 catalogue (Monet) beyond the limits of the Tycho-2 catalog, where the decline can be estimated to be $d\ln N/dm \simeq -0.18$, *i.e.*, an addi-

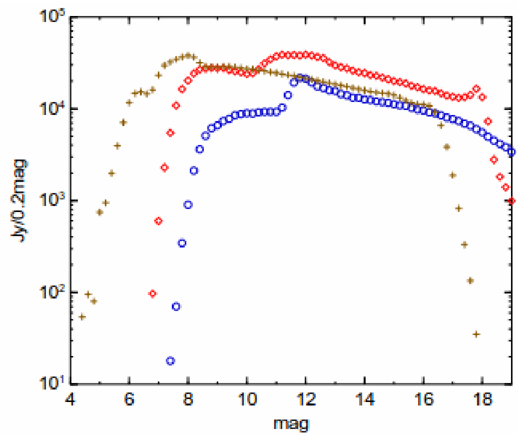

Fig. 4 – All-sky flux densities from all-sky photographic survey USNO-A2 in B (circles) and R (diamonds); the pluses represent the UCAC3 magnitudes, as in Fig. 3

tional flux of the order of 5.5 of the flux corresponding to the higher 1-mag bin. The final estimation of the fluxes in each filter is given in the right-hand column of Table 2.

The gap between r and J bands was estimated from an interpolation between the V and J bands for the bright part ($m \le 12$), and from an interpolation between the r and J bands for the fainter objects; the results of this estimation are given in the bottom line of Table 2.

The remaining overlaps and small gaps in the coverage of the wavelength range 364nm (Balmer jump) to 2.5μm can finally be estimated with the linear approximation

$$\begin{aligned} F(0.364-2.5\mu m) = F(B_T) + 0.908F(V_T) + 0.782F(r) \\ +1.216F(J) + 1.477F(H) \\ +1.287F(K) + F(gap) \end{aligned} \qquad (3)$$

which gives the final value $F = 17.1\mu W\,m^{-2}$

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Apparent Discordant Redshift QSO-Galaxy Associations

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An "exotic" idea proposed by Viktor Ambartsumian was that new galaxies are formed through the ejection from older active galaxies. Galaxies beget galaxies, instead of the standard scenario in which galaxies stem from the evolution of the seeds derived from fluctuations in the initial density field. This idea is in some way contained in the speculative proposal that some or all QSOs might be objects ejected by nearby galaxies, and that their redshift is not cosmological (Arp, G./M. Burbidge and others).

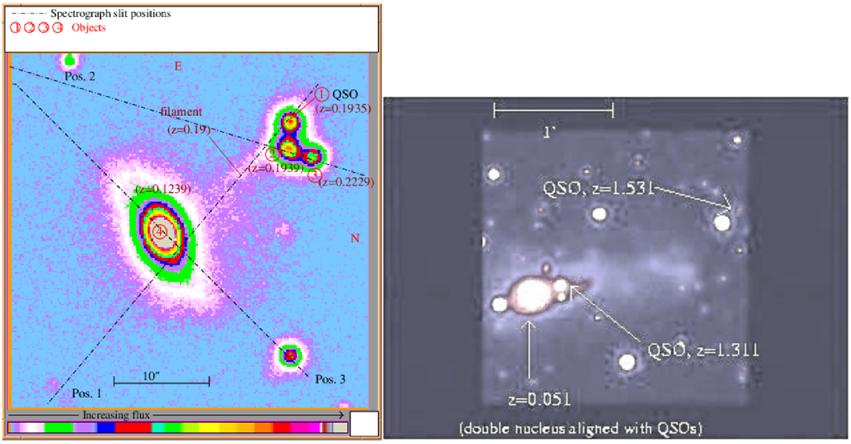
I will discuss some of the arguments for and against this scenario; in particular, I shall talk about the existence of real physical connections in apparently discordant QSO-galaxy redshift associations. On the one hand, there are many statistical correlations of high-redshift QSOs and nearby galaxies that cannot yet be explained in terms of gravitational lensing, biases, or selection effects; and some particular configurations have very low probabilities of being a projection of background objects. Our understanding of QSOs in general is also far from complete. On the other hand, some cases which were claimed to be anomalous in the past have found an explanation in standard terms. As an example, I will show some cases of our own research into this type: statistics of ULXs around nearby galaxies, and the Flesch & Hardcastle candidate QSOs catalog analysis. My own conclusion is neutral.

1. The problem and the observations that give rise to it

Viktor A. Ambartsumian suggested the idea that new galaxies are formed through ejection from older active galaxies (Ambartsumian 1958). This idea has had a certain continuity in the research carried out over the last 40 years based on the hypothesis that some extragalactic objects, and in particular high redshift QSOs, might be associated with low redshift galaxies, thus providing a non-cosmological explanation for the redshift in QSOs (*e.g.*, Arp 1987, 2003; Narlikar 1989; Burbidge 2001; Bell 2002a,b, 2006, 2007; López-Corredoira & Gutiérrez 2006a); that is, a redshift produced by a mechanism different from the expansion of the Universe or the Doppler effect. Ambartsumian never accepted the idea of non-cosmological redshifts; however, the scenario of QSOs ejected by galaxies is a common theme of the Armenian astrophysicist and in proposals of discordant QSO-galaxy redshift associations.

There are plenty of statistical analyses (*e.g.*, Chu *et al.* 1984; Zhu & Chu 1995; Burbidge *et al.* 1985; Burbidge 1996, 2001; Harutyunian & Nikogossian 2000; Benítez *et al.* 2001; Gaztañaga 2003; Nollenberg & Williams 2005; Bukhmastova 2007) showing an excess of high redshift sources near low redshift galaxies, positive and very significant cross-correlations between surveys of galaxies and QSOs, an excess of pairs of QSOs with very different redshifts, *etc.* An excess of QSOs near the minor axes of nearby parent galaxies has also been observed (López-Corredoira & Gutiérrez 2007); however, the discovered excess for position angles lower than 45 degrees is significant only at the 3.5-σ level (3.9-σ for $z_{QSO} > 0.5$) with the QSOs of the SDSS-3rd release (López-Corredoira & Gutiérrez 2007) and somewhat lower [2.2-σ (2.5-σ for $z_{QSO} > 0.5$)] with the SDSS-5th release.

There are plenty of individual cases of galaxies with an excess of QSOs with high redshifts near the center of nearby galaxies, mostly AGN. In some cases, the QSOs are only a few arcseconds away from the center of the galaxies. Examples are NGC 613, NGC 1068, NGC 1097, NGC 3079, NGC 3842, NGC 6212, NGC 7319 (separation galaxy/QSO: 8″), 2237+0305 (separation galaxy/QSO 0.3″), 3C 343.1 (separation galaxy/QSO: 0.25″), NEQ3 (see Fig. 1/left; a QSO-″narrow emission line galaxy″ pair separated 2.8″ from another emission line galaxy with a second redshift, and all of them lying along the minor axis of an apparently distorted lenticular galaxy at 17″ with a third redshift), *etc.* In some cases there are even filaments/bridges/arms apparently connecting objects with different redshift: in NGC 4319+Mrk 205, Mrk273, QSO1327-206, NGC 3067+3C232 (in the radio), NGC 622, NGC 3628 (in X-ray and radio), NEQ3 (Fig. 1/left), *etc.* The probability of chance projections of background/foreground objects within a short distance of a galaxy or onto the filament is as low as 10^{-8}, or even lower. The alignment of sources with different redshifts also suggests that they may have a common origin, and that the direction of alignment is the direction of ejection. This happens with some configurations of QSOs around 1130+106, 3C212, NGC 4258, NGC 2639, NGC 4235, NGC 5985, GC 0248+430 (Fig. 1/right), *etc.* Other proofs presented in favor of the QSO/galaxies association with different redshift is that no absorption lines were found in QSOs corresponding to foreground galaxies (*e.g.* PKS 0454+036, PHL 1226), or distortions in the morphology of isolated galaxies.



Left: NEQ3; Sloan r' band, taken on the 2.6 m NOT (La Palma, Spain); reproduction of Fig. 1 of Gutiérrez & López-Corredoira (2004). Right: GC 0248+430, a galaxy with two nuclei, and two QSOs, all of them aligned (+/- 5 degress); Sloan r' band, taken on the 2.6 m NOT; reproduction of Fig. 6 of López-Corredoira & Gutiérrez (2006a).

The non-cosmological redshift hypothesis also affects galaxies differently from QSOs. Cases such as NGC 7603, AM 2004-295, AM 2052-221, NGC 1232, VV172, NEQ3, NGC 450/UGC 807, *etc.* present statistical anomalies also suggesting that the redshift of some galaxies might have non-cosmological redshifts different from QSOs. Not all supporters of the non-cosmological redshift agree with this idea; for instance, Arp claims that galaxies might have non-cosmological redshift because they derive from an evolution of ejected QSOs, while G. Burbidge only defends the non-cosmological redshifts in QSOs. In this paper, except for this paragraph, I shall talk only about anomalies in QSOs.

2. Probabilities of being background QSOs

There are two possible interpretations of these data: either QSOs with different redshifts are objects with different distances and the configurations are due to chance, or there are non-cosmological redshifts, and QSOs with different redshifts are at the same distance. The first position, the standard one, defends the hypothesis that in all cases the main galaxy is surrounded by background QSOs. The idea is quite straightforward. The position of anomalous redshifts is not naive enough to deny this possibility, and this might be the case in some examples. However, the question is not whether such a fortuitous projection is "possible" but whether it is "probable."

For the calculation of this probability *P*, it is normally assumed that the background/foreground objects in a small area are distributed according to a Poissonian distribution with the average density in any line of sight. There may be some clustering of QSOs, but this does not essentially affect the numbers. A conspiracy in which a given line of sight crosses several clusters of QSOs at different redshifts is not justified because the increase in probability due to the increase in density along lines of sight with clusters is compensated for by the additional factor to be multiplied by the present amount P to take into account the probability of finding clusters in the line of sight. On average, in any arbitrary line of sight in the sky, the probability will be given anyway by the Poissonian calculation of P with the average density of QSOs in the sky (see further details in subsection 5.3.1 of López-Corredoira & Gutiérrez 2004).

A much more important matter concerns the consideration of the number of events in the whole sky. Of course, there may be many objects that are quite peculiar but we must consider the global probability in the whole sky multiplying by the number of galaxies or QSOs as in the anomalous case. For instance, if we found an NGC galaxy of magnitude m_g with a very low probability P_0 of being surrounded by N QSOs up to some magnitude and angular distance, we must calculate the global probability P, multiplying it by the number of NGC galaxies (around eight thousand; or somewhat larger if we considered the southern hemisphere), or at least the galaxies in the whole sky up to magnitude m_g.

It is said that one should not carry out a calculation of the probability for a configuration of objects known *a priori* (for instance, that they form a certain geometrical figure) because, in some way, all possible configurations are peculiar and unique. That is right so long as we speak about random configurations that do not indicate anything special. For example, if the Orion constellation is observed and we want to calculate the chance of its stars being projected in that exact configuration, we will get a null probability (tending towards zero as the allowed error in the position of the stars with respect to the given configuration goes to zero), but the calculation of this probability is worthless because we have selected a particular configuration observed *a priori*. Therefore, the statistics to be carried out should not be about the geometrical figure drawn by the sources, unless that geometrical configuration is representative of a physical process in an alternative theory (for instance, aligned sources might be representative of the ejection of sources by a parent source).

In this last sense, I think that much of the statistics already published is valid and indicates the reality of some kind of statistical anomaly. It would be useful to look out for physical representations indicating peculiarities beyond mere uniqueness. I disagree with the claim that all attempts to calculate probabilities of unexpected anomalies are *a posteriori* and whose validity may therefore be rejected. Some astrophysicists, when looking at the images of the controversial objects, argue along the lines that the anomalous distributions of QSOs are curious, but that since they were observed their probability is 1 and there is therefore nothing special about them. According to this argument, everything is possible in a Poissonian distribution and nothing should surprise us. But I believe that statistics is something more serious than the postmodern rebuff that anything is possible.

We think that this anti-statistical position, this way of rejecting the validity of the calculated probabilities, is equivalent to the scepticism that those unfamiliar with mathematics express when we discuss the low probability of winning the lottery. They continue to bet regardless with hope that, however low the probability, somebody is sure to win so why not me. Typically they are unaware of how low some probabilities are and make no distinction between a case such as $P \sim 10^{-2}$, which is a low but certainly makes a win possible from time to time, and the case $P \sim 10^{-7}$, which virtually ensures no wins during seven lifetimes of daily betting. Small numbers, like the huge numbers prevalent in astronomy, are not easily assimilated. Of course, somebody wins the lottery but this is because the number of players multiplied by the probability of winning of each player is a number not much lower than one; otherwise, nobody would ever be likely to win.

Even worse, imagine that a person wins the lottery four consecutive times with only one bet each time. If we did not believe in miracles, we might think that this person had cheated. We might carry out some statistical calculations and show how improbable it was that he/she could have won by chance. Somebody might say about these calculations that they are not valid because they were carried out *a posteriori* (after the person won the lottery four consecutive times). We would not agree because there is an alternative explanation (he/she is cheating; and this explanation could be thought of before the facts) and the event of winning the lottery four consecutive times, apart from being very peculiar among the random possibilities, would be an indication to support this hypothesis.

For our cases, we have facts (higher concentration of QSOs, alignments, QSOs projected onto filaments) which suggest that an alternative (a priori) theory claiming that galaxies/QSOs may be ejected by galaxies better represents the observations. The measured probabilities are not to form triangles or any shape observed a priori only because it was observed. The peculiarity that is analysed is not comparable with the previous example of Orion because we have in mind a physical representation rather than a given distribution of sources. The difference from the Orion problem is that the peculiarity of Orion is not associated with any peculiar physical representation to be explained by an alternative theory. The question is as follows: what is the probability, *P*, that the apparent fact be the fruit of a random projection of sources at different distances? In other words, what is the probability, P, that the standard theory can explain the observed facts without aiming at alternative scenarios?

There is some *a posteriori* information used normally in the calculations: for instance the maximum magnitude or distance of the QSOs according to what we have observed in our particular case. It is in this sense an *a posteriori* calculation, we are calculating the most pessimistic case (the lowest probability). Because of this, the values of P might be slightly underestimated (by a factor not higher than 10-100) with respect to an a priori calculation without any information on magnitudes or radii, but values of P lower than $\sim 10^{-4}$ should in any case be considered as statistically anomalous. In order to make a fairer estimate of the probability, we could calculate $P^* = 2^n P$, where n is the number of parameters on which P depends. For instance, when we observe a source with magnitude 19 and we calculate $P(m<19)$ we are putting the limiting magnitude exactly at the observed number; a fairer calculation would be $P^*(m < (19+x))$ such that a source with magnitude 19 is a typical average source in the range $m<(19+x)$, *i.e.* roughly that half of the sources with $m < (19+x)$ have $m < 19$ and the other half have $19 < m < (19+x)$. This is equivalent to calculating $P^*(m<(19+x)) = 2P\ (m<19)$ and for the correction we can multiply by a factor two for any independent parameter. Values of P^* lower than around 10^{-3} should be considered as statistically anomalous.

3. Gravitational lensing

An explanation for anomalous redshift systems might be found in principle if we considered some kind of gravitational lensing by the foreground object. However, the effect on the enhancement of the probability produced by an individual galaxy is small. In order to increase by at least an order of magnitude in P per object, *i.e.*, an average enhancement of ~ 10 in density for each of the QSOs, we would need an average magnification of around 20,000 (López-Corredoira & Gutiérrez 2004, sect. 5.3.2). This is so because the enhancement in the source counts increases because of the flux increase of each source but decreases owing to the area distortion, which reduces the number counts by losing the sources within a given area (Wu 1996). A magnification of 2×10^4 is extremely high and impossible to achieve by a galaxy lens. The highest known values are up to a factor ~ 30 (Ellis *et al.* 2001) for background objects apparently close to the central parts of massive clusters. Moreover, a single galaxy would only produce a significant magnification at very close distances (a few arcseconds) from the center. The possibility of multiple gravitational microlenses within the galaxy (Paczynski 1986) does not work either (Burbidge *et al.* 2005, sect. 5; López-Corredoira & Gutiérrez 2006, sect. 8).

Weak gravitational lensing by dark matter has also been proposed as the cause of the statistical correlations between low and high redshift objects, but this seems to be insufficient to explain them (Kovner 1989; Zhu *et al.* 1997; Burbidge *et al.* 1997; Burbidge 2001; Benítez *et al.* 2001; Gaztañaga 2003; Jain *et al.* 2003; Nollenberg & Williams 2005; Tang & Zhang 2005) and cannot work at all for the correlations with the brightest and nearest galaxies; López-Corredoira & Gutiérrez (2007) have shown that gravitational lensing is not the solution for the possible minor axis excess of QSOs. Scranton *et al.* (2005) have claimed that the small amplitude correlation between QSOs and galaxies from the SDSS survey is due to weak gravitational lensing but this does not explain the most general case with bright nearby galaxies. Komberg & Pilipenko (2008) suggested the existence of a large number of globular or proto-globular clusters in the intergalactic medium of clusters of galaxies as an explanation of the correlations, a hypothesis which is awaiting testing. In principle, it seems there are many field galaxies with an excess of surrounding QSOs. Further research is in any case necessary in some of these aspects.

4. Are all QSOs with anomalies really QSOs?

Even more important than thinking about gravitational lensing or discussing the probabilities of background projections is being sure that the identification of QSOs and their redshifts is correct. For instance, in a case like 3C 343.1 (Arp *et al.* 2004a), if we believe that it is indeed a radio galaxy at $z=0.34$ and a radio QSO at $z=0.75$ separated by 0.25″, the coincidence is really spectacular, but are we sure of the correct identification of the sources?

An example: Burbidge *et al.* (2003) suggested that many of the ultraluminous compact X-ray sources (ULXs) found in the main bodies of galaxies are "local" QSOs, or BL Lac objects, with high intrinsic redshifts in the process of being ejected from those galaxies. Certainly, there is an overdensity of these X-ray sources near galaxies but, before claiming a case of anomalous redshift, we have to be sure that they are indeed QSOs with different redshifts. Arp *et al.* (2004b) took some spectra of ULXs and saw that some of them are QSOs but others were not. López-Corredoira & Gutiérrez (2006b) have shown that $>50\%$ of ULXs are effectively QSOs but, except for a few cases which are anomalous for other reasons (*e.g.*, NGC 3628, NGC 4319), the probability of these QSOs being background objects is significant, while the cases with ULXs over the expected background were not QSOs. Therefore, there are not enough statistical anomalies to claim that some ULXs are non-cosmological redshift QSOs.

Another example: Flesch & Hardcastle (2004) published a catalog of candidate QSOs (with a probability > 40% of being QSOs) derived from the correlation of radio and X-ray sources with blue point-like optical objects. In this catalog, there is an overdensity of QSO candidates in fields near galaxies and for bright sources. However, López-Corredoira *et al.* (2008) showed that the probabilites of being QSOs were overestimated for bright objects and near galaxies. Therefore, again, there are in principle no reasons to think about statistical anomalies in this catalog.

5. Discussion

Some of the examples of apparent associations of QSOs and galaxies with different redshifts may be just fortuitous cases in which background objects are close to the main galaxy, although the statistical mean correlations remain to be explained, and some lone objects have a very low probability of being a projection of background objects. Nevertheless, these very low probabilities (down to 10^{-8} or even lower, assuming correct calculations) are not extremely low and, if the anomaly is real, one wonders why we do not find very clear anomalous cases with probabilities as low as 10^{-20}. Gravitational lensing seems not to be a solution yet, although further research is required, and the aim that the probabilities be calculated *a posteriori* is not in general an appropriate answer for avoiding or forgetting the problem.

There are also other aspects of QSOs that are not well understood within the cosmological redshift assumption, and which could find an explanation within a non-cosmological redshift hypothesis (López-Corredoira & Gutiérrez 2006a, sect. 9): the extremely high luminosity of QSOs at high redshift and the absence of bright QSOs at low redshift, periodicity of redshifts, their age and metallicity and the lack of evolution signs, superluminal motions, spectral features in the emission and absorption lines that are not well understood, the mechanism of triggering activity, the fact that Faraday rotation does not increase with redshift, *etc.*

There are two possibilities: either all cases of associations are lucky coincidences with a higher probability than expected for some still unknown reason, or there are at least some few cases of non-cosmological redshifts. If we accepted that some objects (maybe not all of them) with different redshifts had the distance of the main galaxy, there might be some truth in those models (Burbidge 1999; Arp 1999a,b, 2001; Bell 2002a,b) in which QSOs and other types of galaxies are ejected by a parent galaxy, as proposed by Ambartsumian (1958). In these models, galaxies beget galaxies, so not all the galaxies would be made from initial density fluctuations in a Big Bang Universe. For the explanation of the intrinsic redshift, there are several alternative hypotheses (reviews at Narlikar 1989; López-Corredoira 2003, sect. 2.1; 2006).

In my opinion, we must consider the question as an open problem to be solved. I maintain a neutral position, neither in favor of nor against non-cosmological redshifts. The debate has lasted a very long time, around 40 years, and it would be time to consider making a last effort to finish with the problem. However, the scientific community does not seem very interested in solving the problem because most researchers consider it already solved. Supporters of the standard dogma of all redshifts being cosmological do not want to discuss the problem. Every time it is mentioned they just smile or talk about "*a posteriori*" calculations, manipulations of data, crackpot ideas, without even reading any paper on the theme. The Arp-Burbidge hypothesis has become a topic in which everybody has an opinion without having read the papers or knowing the details of the problem, because some leading cosmologists have said it is bogus. This means that it is very difficult to make any progress in this field, as is usual when a researcher is away from the mainstream (López-Corredoira & Castro-Perelman, eds., 2008). On the other hand, the main supporters of the hypothesis of non-cosmological redshifts continue to produce tens of analyses of cases in favor of their ideas without too much care, pictures without rigorous statistical calculations in many cases, or with wrong identifications, underestimated probabilities, biases, use of incomplete surveys for statistics, *etc.*, in many other cases. There are, however, many papers in which no objections are found in the arguments and they present quite controversial objects, but due to the bad reputation of the topic, the community simply ignores them. In this panorama, it would be difficult for the problem to be solved soon. Mainstream cosmologists are waiting for the death of the main leaders of the heterodox idea (mainly Arp and the Burbidges) to declare the idea as definitively dead. However, as in the case of Ambartsumian, some challenging ideas could survive or even be revived after some time if we leave open problems without a clear solution. Therefore, I would recommend that the community either finds good arguments against the Arp-Burbidge hypothesis, or that it allows their ideas to cohabit within the possible speculative hypotheses in cosmological scenarios.

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Via Aristotle, Leibniz, Berkeley & Mach to Necessarily Fractal Large-scale Structure in the Universe

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An Essay in honour of Halton (Chip) Arp.

The claim that the large scale structure of the Universe is hierarchical has a very long history going back at least to Charlier's papers of the early 20th century. In recent years, the debate has largely focussed on the works of Sylos Labini, Joyce, Pietronero and others, who have made the quantitative claim that the large scale structure of the Universe is quasi-fractal with fractal dimension $D \approx 2$. There is now a consensus that this is the case on medium scales, with the main debate revolving around what happens on the scales of the largest available modern surveys.

Apart from the (essentially sociological) problem that their thesis is in absolute conflict with any concept of a Universe with an age of ≈ 14 billion years or, indeed, of any finite age, the major generic difficulty faced by the proponents of the hierarchical hypothesis is that, beyond hypothesizing the case (*e.g.*, Nottale's *Scale Gravity*), there is no obvious mechanism which would lead to large scale structure being non-trivially fractal. This paper, which is a realization of a worldview that has its origins in the ideas of Aristotle, Leibniz, Berkeley and Mach, provides a surprising resolution to this problem: in its essence, the paper begins with a statement of the primitive self-evident relationship which holds that, in the universe of our experience, the amount of material, *m*, in a sphere of redshift radius R_z is a monotonic increasing function of R_z. However, because the precise relationship between any Earth-bound calibration of radial distance and R_z is unknowable, then fundamental theories cannot be constructed in terms of R_z, but only in terms of a radial measure, *R* say, calibrated against known physics. The only certainty is that, for any realistic calibration, there will exist a monotonic increasing relationship between R_z and *R* so that we have $m = M(R)$ for *m* and *R* inceasing monotonically together. But the monotonicity implies $R = G(m)$ which, *in the absence of any prior calibration of R*, can be interpreted as the *definition* of the radius of an astrophysical sphere in terms of the amount of mass it contains—which is the point of contact with the ideas of Aristotle, Leibniz, Berkeley and Mach. The development of this idea leads necessarily to the final result, which is that a definitive signature of a Leibnizian universe is the *perception* that large scale structure in the Universe of our experience is quasi-fractal of dimension $D = 2$.

Chip Arp

There is nothing I can add to the memory of Chip Arp as a brave, committed and outstanding astronomer for whom the telescope is not an instrument designed to validate our preconceived earth-bound ideas, but rather is an instrument of *exploration* the primary function of which is to *explore unknown realms* ... but I can add my personal recollections of his being one of the most gracious men it has ever been my honour and pleasure to meet.

Having been asked to write something to honour Chip's memory in this volume, my immediate question to myself was *Well what could I write that could possibly match the man?* I thought along the following lines: arguably the single most prominent phrase that one could associate with Chip's memory is *discordant redshifts* by which is meant the existence of significant redshifting in astronomical objects which is *definitely* not attributable to distance. If, as many believe (including myself), discordant redshifts are a common reality, then we are forced to question the ordinary interpretation of *all* redshifts as a property of (so-called) universal expansion, and hence to question the paradigm of the expanding universe itself. We are then in an unknown country where the entire world-view which has dominated the 20th Century must be considered with very suspicious eyes: so, it seemed to me that an essay which sets out to explore an alternative way of thinking about our universe which, arguably, has its origins in Greek thought, might just fit the bill. What I write sheds no light at all on those mysteries which Chip put before us, but rather it proceeds from the idea that those mysteries remind us that we know so very very little and that, perhaps, one day if we can just release our imagination a little bit more ... the stars may be within reach of our children's children's children ...

1. Introduction:

We can summarize the major results of this paper as follows:

- The conflict between the idea that matter in the universe is, on large enough scales, distributed homogeneously and the idea that it is distributed in a quasi-fractal fashion with $D \approx 2$ is, at source, the conflict between two opposing views of the nature of space, the one having its origins in the ideas of Democritus and traceable through Newton to Einstein and the other having its origins in the ideas of Aristotle and traceable through Leibniz & Berkeley to Mach. The perception that matter in the universe of our experience is distributed as $D \approx 2$ on large scales can be interpreted directly as a signature that this universe is structured according to the Leibniz-Berkeley ideal.

- The foregoing considerations lead naturally into a discussion concerning the nature of time, and equally naturally, to its quantitative definition which can be qualitatively described as "ordered process." When this quantitative definition is considered in the idealized case of an exactly $D = 2$ universe, we find that classical lightcone geometry emerges naturally, together with the Lorentz transformations as those transformations which keep invariant the foregoing definition of physical time.

The arguments of this paper serve to emphasize that we will never be able to say how the universe *is*—being forever constrained merely to say how it *looks*.

We begin with a brief review of the phenomenological arguments which led to the basic hypothesis that large-scale structure in the Universe is non-trivially quasi-fractal, and comment briefly on the ramifications to canonical cosmology *if* this hypothesis proves to be correct. We then give a brief account comparing and contrasting the two major world-views which have dominated thinking about the nature of the cosmos for over two thousand years before, finally, providing the quantitative development which leads to the main results of this paper.

1.1. Brief technical note on "fractals"

Throughout this analysis, we constantly refer to large scale structure as being fractal $D \approx 2$. Strictly speaking, this is loose language, since the term "fractal" refers to scale-invariant behaviour on all scales whereas, in astrophysical parlance, only astrophysical scales are implied. Additionally, in this paper we use the term "fractal" to describe *classical distributions* which behave as $M \sim R^2$ when, strictly speaking, the power-law behaviour of fractal distributions refers to an average behaviour when averaged over all points of the distribution. For this reason, and from time to time, we use the phrase "quasi-fractal" as a reminder of that fact.

1.2. The hierarchical Universe

Prior to the 1920s, the Universe was generally conceived to be of infinite extent—in time, space and mass content—and to be regulated by Newton's Laws. This, combined with the apparently reasonable cosmological assumption of a uniform distribution of matter gave rise to two problems—Olber's paradox (1825) and its gravitational version, Seeliger's paradox (1895), according to which every massive body experiences an indefinite gravitational acceleration. Charlier [1,2,3] showed that if the assumption of a uniform matter distribution was replaced by that of an hierarchical distribution of matter (with, in modern terms, a fractal dimension of $D \leq 2$), then Olber's paradox became resolved. It is also the case—as Charlier similarly argued—that such an hierarchical distribution of matter also resolves Seeliger's gravitional paradox.

However, Charlier's work was overtaken by Eddington's recognition that Le Maitre's dust-cosmology solution of Einstein's equations provided a natural explanation for the redshift discoveries of Slipher & Hubble. Le Maitre's rudimentary cosmology has evolved, over the years, into the *Standard Model*, a basic assumption of which is that, on some scale, the universe is homogeneous; however, in early responses to suspicions that the accruing data was more consistent with Charlier's conceptions of an hierarchical universe than with the requirements of the *Standard Model*, de Vaucouleurs [4] showed that, within wide limits, the available data satisfied a mass distribution law $M \approx r^{1.3}$, whilst Peebles [5] found $M \approx r^{1.23}$. The situation, from the point of view of the *Standard Model*, continued to deteriorate with the growth of the data-base to the point that, Baryshev *et al.* [6] state

> ...the scale of the largest inhomogeneities (discovered to date) is comparable with the extent of the surveys, so that the largest known structures are limited by the boundaries of the survey in which they are detected.

For example, several redshift surveys of the late 20th century, such as those performed by Huchra *et al.* [7], Giovanelli and Haynes [8], De Lapparent *et al.* [9], Broadhurst *et al.* [10], Da Costa *et al.* [11] and Vettolani *et al.* [12] *etc.*, discovered massive structures such as sheets, filaments, superclusters and voids, and showed that large structures are common features of the observable universe; the most significant conclusion drawn from all of these surveys was that the scale of the largest inhomogeneities observed in the samples was comparable with the spatial extent of those surveys themselves.

In the closing years of the century, several quantitative analyses of both pencil-beam and wide-angle surveys of galaxy distributions were performed: three examples are given by Joyce, Montuori & Labini [13] who analysed the CfA2-South catalogue to find fractal behaviour with $D = 1.9 \pm 0.1$; Labini & Montuori [14] analysed the APM-Stromlo survey to find fractal behaviour with $D = 2.1 \pm 0.1$, whilst Labini, Montuori & Pietronero [15] analysed the Perseus-Pisces survey to find fractal behaviour with $D = 2.0 \pm 0.1$. There are many other papers of this nature, and of the same period, in the literature all supporting the view that, out to $30 - 40h^{-1}\,Mpc$ at least, galaxy distributions appeared to be fractal with $D \approx 2$.

This latter view became widely accepted (for example, see Wu, Lahav & Rees [16]), and the open question became whether or not there was transition to homogeneity on some sufficiently large scale. For example, Scaramella *et al.* [17] analyse the ESO Slice Project redshift survey, whilst Martinez *et al.* [18] analyse the Perseus-Pisces, the APM-Stromlo and the

1.2-Jy IRAS redshift surveys, with both groups claiming to find evidence for a cross-over to homogeneity at large scales.

At around about this time, the argument reduced to a question of statistics (Sylos Labini & Gabrielli [19], Gabrielli & Sylos Labini [20], Pietronero & Sylos Labini [21]): basically, the proponents of the fractal view began to argue that the statistical tools (*e.g.*, correlation function methods) widely used to analyse galaxy distributions by the proponents of the opposite view are deeply rooted in classical ideas of statistics and implicitly assume that the distributions from which samples are drawn are homogeneous in the first place. Recently, Hogg *et al.* [22], having accepted these arguments, applied the techniques argued for by the pro-fractal community (which use the *conditional density* as an appropriate statistic) to a sample drawn from Release Four of the Sloan Digital Sky Survey. They claim that the application of these methods does show a turnover to homogeneity at the largest scales, thereby closing, as they see it, the argument. In response, Labini *et al.* [23] have criticized their paper on the basis that the strength of the conclusions drawn is unwarranted given the deficiencies of the sample—in effect, that it is not big enough.

To summarize, the proponents of non-trivially fractal large-scale structure have won the argument out to medium distances and the controversy now revolves around the largest scales encompassed by the SDSS.

1.3. Theoretical implications

The notion of non-trivially quasi-fractal large-scale structure in the Universe is problematic for proponents of any form of big-bang cosmology for the following reason: if there is non-trivially fractal structure in the Universe then, ideally, the mechanism for the formation of such structure should be open to a theoretical understanding. But the equations of General Relativity are hyperbolic, so that global structure at any epoch is always going to be determined primarily by initial conditions—in other words, large-scale fractal structure (should it exist) in the Universe cannot be explained within the confines of General Relativity, but only in terms of *initial* conditions which are external to it. Whilst this *might* actually be the case, the primary function of science must always be to attempt the understanding of that which is observed. Thus, any attempt to explain away vast and spectacular structures observed today in terms of "conditions before the universe came into being" would be to evade the most significant of all questions—in other words, big-bang cosmology would fail to meet the most basic requirement of a scientific theory.

It follows that the hypothesis that large-scale structure in the Universe is non-trivially fractal and the hypothesis that General Relativity is the fundamentally correct theory by which the Universe and its properties can be understood, are in direct opposition to each other. This implies that, if we are to take the fractal hypothesis seriously (as the phenomenology suggests we should), then only a radical review of our ideas of space and time can hope to provide any understanding how such structure can occur.

2. A brief history of ideas of space and time

The conception of space as the container of material objects is generally considered to have originated with Democritus and, for him, it provided the stage upon which material things play out their existence—*emptiness* exists and is that which is devoid of the attribute of *extendedness* (although, interestingly, this latter conception seems to contain elements of the opposite view upon which we shall comment later). For Newton [24], an extension of the Democritian conception was basic to his mechanics and, for him:

> ... absolute space, by its own nature and irrespective of anything external, always remains immovable and similar to itself.

Thus, the absolute space of Newton was, like that of Democritus, the stage upon which material things play out their existence—it had an *objective existence* for Newton and was primary to the order of things. In a similar way, time—*universal time,* an absolute time which is the same everywhere—was also considered to possess an objective existence, independently of space and independently of all the things contained within space. The fusion of these two conceptions provided Newton with the reference system—*spatial coordinates* defined at a *particular time*—by means of which, as Newton saw it, all motions could be quantified in a way which was completely independent of the objects concerned. It is in this latter sense that the Newtonian conception seems to depart fundamentally from that of Democritus—if *emptiness* exists and is devoid of the attribute of *extendedness* then, in modern terms, the *emptiness* of Democritus can have no *metric* associated with it. But it is precisely Newton's belief in *absolute space & time* (with the implied virtual clocks and rods) that makes the Newtonian conception a direct antecedent of Minkowski spacetime—that is, of an empty space and time within which it is possible to have an internally consistent discussion of the notion of *metric.*

The contrary view is generally considered to have originated with Aristotle [25,26] for whom there was no such thing as a *void*—there was only the *plenum* within which the concept of the *empty place* was meaningless and, in this, Aristotle and Leibniz [27] were at one. It fell to Leibniz, however, to take a crucial step beyond the Aristotelian conception: in the debate of Clarke-Leibniz (1715 ~ 1716) [28] in which Clarke argued for Newton's conception, Leibniz made three arguments of which the second was:

> Motion and position are real and detectable only in relation to other objects ... therefore empty space, a void, and so space itself is an unnecessary hypothesis.

That is, Leibniz introduced a *relational* concept into the Aristotelian world view—what we call *space* is a projection of *perceived relationships* between material bodies into an inferred world, whilst what we call *time* is the projection of ordered *change* into an inferred world. Of the three arguments, this latter was the only one to which Clarke had a good objection—essentially that *accelerated motion*, unlike uniform motion, can be perceived *without* reference to external bodies and is therefore, he argued, necessarily perceived with respect to the *absolute space* of Newton. It is of interest to note, however, that in rebutting this particular argument of Leibniz, Clarke, in the last letter of the correspondence, put his finger directly upon one of the crucial consequences of a relational theory which Leibniz had apparently not realized (but which Mach much later would) stating as absurd that:

> ... the parts of a circulating body (suppose the sun) would lose the *vis centrifuga* arising from their circular motion if all the extrinsic matter around them were annihilated.

This letter was sent on October 29th 1716 and Leibniz died on November 14th 1716, so that we were never to know what Leibniz's response might have been.

Notwithstanding Leibniz's arguments against the Newtonian conception, nor Berkeley's contemporary criticisms [29], which were very similar to those of Leibniz and are the direct antecedents of Mach's, the practical success of the Newtonian prescription subdued any serious interest in the matter for the next 150 years or so until Mach himself picked up the torch. In effect, he answered Clarke's response to Leibniz's second argument by suggesting that the *inertia* of bodies is somehow induced within them by the large-scale distribution of material in the universe:

> ... I have remained to the present day the only one who insists upon referring the law of inertia to the earth and, in the case of motions of great spatial and temporal extent, to the fixed stars ... [30]

thereby generalizing Leibniz's conception of a relational universe. Mach was equally clear in expressing his views about the nature of time: in effect, he viewed *time* (specifically Newton's *absolute time*) as a meaningless abstraction. All that we can ever do, he argued in [30], is to measure *change* within one system against *change* in a second system which has been defined as the standard (*e.g.*, it takes half of one complete rotation of the earth about its own axis to walk thirty miles).

Whilst Mach was clear about the origins of inertia (in the fixed stars), he did not hypothesize any mechanism by which this conviction might be realized, and it fell to others to make the attempt—a typical (although incomplete) list might include the names of Einstein [31], Sciama [32], Hoyle & Narlikar and Sachs [33,34] for approaches based on canonical ideas of spacetime, and the names of Ghosh [35] and Assis [36] for approaches based on quasi-Newtonian ideas.

It is perhaps one of the great ironies of 20thC science that Einstein, having coined the name *Mach's Principle* for Mach's original suggestion and setting out to find a theory which satisfied the newly named Principle, should end up with a theory which, whilst albeit enormously successful, is more an heir to the ideas of Democritus and Newton than to the ideas of Aristotle and Leibniz. One has only to consider the special case solution of Minkowski spacetime, which is empty but metrical, to appreciate this fact.

3. From Leibniz to inertia as a relational property

In this paper we take the general position of Leibniz about the relational nature of space to be self-evident and consider the question of *spatial metric* within this general conceptualization—that is, how is the notion of invariant *spatial* distance to be defined in the Leibnizian particle universe? To answer this question, we begin by considering the universe of our actual experience and show how it is possible to define an invariant measure for the radius of a statistically defined astrophysical sphere purely in terms of the amount of matter it contains (to within a calibration exercise); we then show how the arguments deployed can be extended to define an invariant measure for an *arbitrary* spatial displacement within the statistically defined astrophysical sphere. In this way, we arrive at a theory within which a metrical three-space is projected as a secondary construct out of the primary distribution of universal material. This has the subtle consequence that it becomes misleading to talk about "the distribution of matter in space"—rather, the talk is about "the distribution of space around matter." In practice, as we shall see, this gives rise to a worldview in which the most simple model universe is Euclidean and in which it is *axiomatic* that material appears to be distributed quasi-fractally, $D = 2$.

The question of how *time* arises within this worldview is particularly interesting: the simple requirement that *time* should be defined in such a way that Newton's Third Law is automatically satisfied has the direct consequence that *time* becomes an explicit measure of change within the system, very much as anticipated by Mach. In the most simple model, the overall result is a quasi-classical (one-clock) theory of relational space & time which is:

- a Euclidean universe within which it is axiomatic that material appears to be distributed quasi-fractally, $D = 2$ and within which there is a condition of global dynamical equilibrium;

- point-source perturbations of this Euclidean universe recover the usual Newtonian prescriptions for gravitational effects.

The first of these two points refers to the universe that Leibniz was effectively considering in his debate with Clarke of 1715 ~ 1716—one within which inertial effects play no part. The second refers to the universe that Clarke used to refute Leibniz's second argument, and the one that Mach had in mind—the universe of rotations and accelerations. Thus, given our Leibnizian worldview, we see that inertial effects themselves have their fundamental source in changed material relationships—they, too, are *relational* in nature.

3.1. The general argument

Following in the tradition of Aristotle, Leibniz, Berkeley and Mach we argue that no consistent cosmology should admit the possibility of an internally consistent discussion of *empty* metrical space & time—unlike, for example, General Relativity which has the empty spacetime of Minkowski as a particular solution. Recognizing that the most simple space & time to visualize is one which is everywhere inertial, then our worldview is distilled into:

> **The elemental question:** is it possible to conceive a globally inertial space & time which is irreducibly associated with a non-trivial global mass content and, if so, what is the inferred distribution of this matter content for any observer?

In pursuit of this question, we shall assume an idealized universe:

- which consists of an infinity of identical, but labelled, discrete 'galaxies' which possess an ordering property which allows us to say that galaxy $\mathcal{G}_0$ is nearer/further than galaxy $\mathcal{G}_1$. Notwithstanding the strong likelihood of discordant redshifts being a part of physical reality, it remains the case that, in a broad sense, galaxy redshifts are correlated with distance and are thus an example of such an ordering property;
- within which 'time' is to be understood, in a qualitative way, as a measure of process or ordered change in the model universe;
- within which there is at least one origin about which the distribution of material particles is statistically isotropic—meaning that the results of sampling along arbitrary lines of sight over sufficiently long characteristic 'times' are independent of the directions of lines of sight.

3.2. Astrophysical spheres and a galaxy-count calibrated metric for radial displacements

It is useful to discuss, briefly, the notion of spherical volumes defined on large astrophysical scales in the universe of our experience: whilst we can certainly give various precise operational definitions of spherical volumes on small scales, the process of giving such definitions on large scales is decidedly ambiguous. In effect, we have to suppose that redshift measurements are (statistically) isotropic when taken from an arbitrary point within the universe and that they vary monotonically with distance on the large scales we are concerned with. With these assumptions, spherical volumes can be defined (statistically) in terms of redshift measurements—however, their radial calibration in terms of ordinary units (such as metres) becomes increasingly uncertain (and even unknown) on very large redshift scales.

With these ideas in mind, the primary step taken in answer to the elemental question above is the recognition that, on large enough scales in the universe of our experience (say >30 Mpc), we can identify a redshift-defined astrophysical sphere and, having identified it, we can estimate the amount of matter, m say, contained within this sphere by, for example, simply *counting* the galaxies it contains. Once this is done, we can, if we wish, *define* a radial scale for the sphere at any given time (whatever we might mean by *time*) purely in terms of the mass it contains; that is, we can say

$$R = G(m,t) \rightarrow \delta R = G(m+\delta m,t) - G(m,t) \tag{1}$$

where R is the mass-calibrated radius, m is the mass concerned and G is an arbitrarily chosen monotonic increasing function of m.

Thus, for any given G, we have immediately defined an invariant radial measurement such that it becomes undefined in the absence of matter—in effect, we have, in principle, a metric which follows Leibniz in the required sense for any displacement which is purely radial.

3.3. The time-independent *versus* the time-dependent development

If we continue the development from (1) then the result is a two-clock theory of the *frame-time/particle proper time* type. By contrast, a much-simplified one-clock quasi-classical theory results if we make the (cosmological) assumption that all epochs are identical so that t in (1) can be dropped. It transpires that, from the point of view of statements about large-scale structure, the differences between the simple one-clock theory and the more complicated two-clock theory are differences of detail only: for example, suppose that S is a statement concerning large scale-structure in the one-clock theory then, in the two-clock theory, this statement would be qualified as follows: *when observed over time scales that are small compared to the characteristic time scales of the volumes concerned, then* S.

Thus, for the sake of simplicity—so that the basic ideas are most easily revealed—we make the assumption that all epochs *are identical* so that the t-dependence in (1) can be dropped with the consequence that it becomes

$$R = G(m) \tag{2}$$

It is important to emphasize that this latter equation is not an *hypothesis* about reality; it is a non-trivially true statement about the real universe which recognizes that we can, if we so choose, *define* a measure of physical length on a cosmological scale purely in terms of a quantity of matter. It is this which is the non-trivial point of contact with the ideas of Leibniz, Berkeley *et al.* and which allows the development (below) of a quantitative—if rudimentary—cosmology in the mode of Leibniz & Berkeley.

3.4. A mass-calibrated metric for arbitrary spatial displacements

The foregoing provides a way of giving an invariant measure in the real universe, defined in terms of mass, for displacements which are purely *radial* from the chosen origin. However, if, for example, a displacement is *transverse* to a radial vector, then the methodology fails. Thus, we must look for ways of generalizing the above ideas so that we can assign a mass-calibrated metric to *arbitrary* spatial displacements within the real universe—that is, we must look for a way of assigning a *metric* to this universe. To this end, we invert (2) to give a mass model

$$Mass \equiv m = M(R) \equiv M(x^1, x^2, x^3),$$

for our rudimentary universe. Note that we make no assumptions about the relation of the spatial coordinates, (x^1, x^2, x^3), to the redshift-defined radial displacement, R.

Now consider the normal gradient vector $n_a = \nabla_a M$ (which does not require any metric stucture for its definition): the change in this arising from a displacement dx^k can be *formally* expressed as

$$dn_a = \nabla_i (\nabla_a M) dx^i, \tag{3}$$

where we shall later argue (*cf.* §7) that the affinity required to give this latter expression an unambiguous meaning is the usual metric affinity—*except of course, the metric tensor g_{ab} of our curvilinear three-space required to define this latter object is not, itself, yet defined.*

Now, since g_{ab} is not yet defined, then the covariant counterpart of dx^a, given by $dx_a = g_{ai} dx^i$, is also not yet defined. However, we note that, assuming $\nabla_a \nabla_b M$ to be nonsingular, then (3) provides a 1:1 mapping between the contravariant vector dx^a and the covariant vector dn_a so that, in the absence of any other definition, we can *define* dn_a to be the covariant form of dx^a. In this latter case the metric tensor of our curvilinear three-space automatically becomes

$$g_{ab} = \nabla_a \nabla_b M \tag{4}$$

which, through the implied metric affinity, is a highly non-linear partial differential equation defining g_{ab} to within the specification of *M*. The scalar product

$$dS^2 \equiv dn_i dx^i \equiv g_{ij} dx^i dx^j \tag{5}$$

then provides an invariant measure for the magnitude of the infinitesimal three-space displacement, dx^a, given purely in terms of the mass model, *M*.

To briefly summarize: equation (4) encapsulates the reality that, *in the universe of our experience,* it is possible to give a real quantitative meaning to the ideas of Leibnitz and Berkeley; in other words, that within this universe, the notion of metrical physical space can be considered as a projection from the relationships that exist between material 'objects'—whatever these might be.

3.5. This definition of g_{ab} as a model of daily human experience

In order to emphasize how the foregoing is more than merely an "interesting hypothesis," it is useful to show how it relates directly to the primitive human being's intuitive assessments of "distance traversed" in everyday life without recourse to formal instruments.

In effect, as we travel through a physical environment, we use our changing perspective of the observed scene in a given elapsed time to provide a qualitative assessment of "distance traversed" in that elapsed time. So, briefly, when walking across a tree-dotted landscape, the changing *angular* relationships between ourselves and the trees provide the information required to assess "distance traversed," measured in units of human-to-tree displacements, within that landscape. If we remove the perspective information—by, for example, obliterating the scene with dense fog—then all sense of "distance traversed" is destroyed.

In the above definition of g_{ab}, the part of the tree-dotted landscape is played by the mass-function, *M*, whilst the instantaneous perspective on this "landscape" is quantified by the normal vector n_a and the change in perspective arising from a coordinate displacement, dx^a,is quantified by the change in this normal vector, dn_a. The invariant measure defined at (5) can then be considered to be based on a comparison between dx^a (for which an invariant magnitude is required) and dn_a.

In other words, g_{ab} as defined acts as a descriptive model for our intuitive sense of physical metric space—the same intuitive sense of space that probably led Aristotle, Leibniz and Berkeley *et al.* to formulate their quantitative ideas on the nature of physical space in the first place.

3.6. Units

The units of dS^2 at (5) are easily seen to be those of mass only and so, in order to make them those of *length*²—as dimensional consistency requires—we define the working invariant as $ds^2 \equiv \left(2r_0^2/m_0\right)dS^2$, where r_0 and m_0 are scaling constants for the distance and mass scales respectively and the numerical factor has been introduced for later convenience.

Finally, if we want

$$s^2 \equiv \left(\frac{r_0^2}{2m_0}\right)dn_i dx^i \equiv \left(\frac{r_0^2}{2m_0}\right)g_{ij}dx^i dx^j \tag{6}$$

to behave sensibly in the sense that $ds^2 > 0$ whenever $|d\mathbf{r}| > 0$ and $ds^2 = 0$ only when $|d\mathbf{r}| = 0$, then we must replace the condition of non-singularity of g_{ab} by the condition that it is strictly positive definite; in the physical context of the present problem, this will be considered to be a self-evident requirement.

3.7. The affine connection

We have assumed that the affinity required to give unambiguous meaning to (3) can be defined in some sensible way. To do this, we simply note that, in order to define conservation laws (*i.e.*, to do physics) in a Riemannian space, it is necessary to have a generalized form of the Gauss divergence theorem in that space. This is certainly possible when the affinity is defined to be the metric affinity, but it is by no means clear that it is ever possible otherwise. Consequently, the affinity is defined to be metrical so that g_{ab}, given at (4), can be written explicitly as

$$g_{ab} \equiv \nabla_a \nabla_b M \equiv \frac{\partial^2 M}{\partial x^a \partial x^b} - \Gamma^k_{ab}\frac{\partial M}{\partial x^k}, \tag{7}$$

Where Γ^k_{ab} are the Christoffel symbols, and given by

$$\Gamma^k_{ab} = \frac{1}{2}g^{kj}\left(\frac{\partial g_{bj}}{\partial x^a} + \frac{\partial g_{ja}}{\partial x^b} - \frac{\partial g_{ab}}{\partial x^j}\right).$$

4. The metric tensor given in terms of the mass model

We have so far made no assumptions about the nature of the coordinate system $\left(x^1, x^2, x^3\right)$. However, we now recall our elemental question, originally formulated in §1, and note that within the context of the quasi-classical one-clock model now being considered, it can be more explicitly stated as

> **The elemental question:** is it possible to conceive a globally Euclidean space with a universal time which is irreducibly associated with a non-

> trivial global mass distribution which is in a state of dynamical equilibrium and, if so, what are the properties of this distribution as inferred from within the Euclidean space?

This question is most directly answered by *assuming* the existence of the globally Euclidean space in the first place for the analysis of (7) and seeing where the assumption leads us. Thus, we define $\left(x^1, x^2, x^3\right)$ as Cartesian coordinates in a globally defined rectangular frame and suppose the usual Pythagorean relationship, $R^2 = \left(x^1\right)^2 + \left(x^2\right)^2 + \left(x^3\right)^2$.

With this understanding, it can be shown how (7) can be exactly resolved to give an explicit form for g_{ab} in terms of $m \equiv M(R)$: defining the notation

$$\boldsymbol{R} \equiv \left(x^1, x^2, x^3\right), \quad \Phi \equiv \frac{1}{2}\left(\boldsymbol{R}\cdot\boldsymbol{R}\right) = \frac{1}{2}R^2 \quad \text{and} \quad M' \equiv \frac{dM}{d\Phi},$$

this explicit form of g_{ab} is given as

$$g_{ab} = A\delta_{ab} + Bx^i x^j \delta_{ia}\delta_{jb}, \tag{8}$$

where

$$A \equiv \frac{d_0 M + m_1}{\Phi}, \quad B \equiv -\frac{A}{2\Phi} + \frac{d_0 M'M'}{2A\Phi},$$

for arbitrary constants d_0 and m_1 where, as inspection of the structure of these expressions for *A* and *B* shows, d_0 is a dimensionless scaling factor and m_1 has dimensions of mass. Noting now that *M* always occurs in the form $d_0 M + m_1$, it is convenient to write $\mathcal{M} \equiv d_0 M + m_1$, and to write *A* and *B* as

$$A \equiv \frac{\mathcal{M}}{\Phi}, \quad B \equiv -\left(\frac{\mathcal{M}}{2\Phi^2} - \frac{\mathcal{M}'\mathcal{M}'}{2d_0\mathcal{M}}\right), \tag{9}$$

4.1. A unique calibration for the radial scale

We began by assuming only the Leibnizian definition of an astrophysically defined sphere's radius in terms of the sphere's mass content, $R = G(m)$ (*cf.* equation (2)), where *G* is an unknown monotonic increasing function. Note that, since galaxy-counts can be used as a proxy for *m*, then $R = G(m)$ is necessarily an *invariant*. We subsequently generalized the discussion using, as a model, a human being's intuitive notion of "distance traversed" and requiring, as a crucial detail, that we ended up with a formal structure within which we can define conservation laws—*cf.* §7. In the following, we show that, as a direct consequence of this modelling approach, the functional form, *G*, and hence the Leibnizian definition of *R* in terms of *m*, become uniquely determined.

Using (8) and (9) in (6), and using the Pythagorean identity $x^i dx^j \delta_{ij} \equiv R dR$ then, with the notation $\Phi \equiv R^2/2$, we find, for an arbitrary displacement dx, the invariant measure:

$$ds^2 \equiv g_{ij} dx^i dx^j = \left(\frac{R_0^2}{2m_0}\right)\left\{\frac{\mathcal{M}}{\Phi} dx^i dx^j \delta_{ij} - \Phi\left(\frac{\mathcal{M}}{\Phi^2} - \frac{\mathcal{M}'\mathcal{M}'}{d_0 \mathcal{M}}\right) dR^2\right\}$$

which is valid for the unknown calibration $R = G(m) \leftrightarrow m = M(R)$. If the displacement dx is now constrained to be purely *radial*, then we find

$$ds^2 = \left(\frac{R_0^2}{2m_0}\right)\left\{\Phi\left(\frac{\mathcal{M}'\mathcal{M}'}{d_0 \mathcal{M}}\right) dR^2\right\},$$

Use of $\mathcal{M}' \equiv d\mathcal{M}/d\Phi$ and $\Phi \equiv R^2/2$ reduces this latter relationship to

$$ds^2 = \frac{R_0^2}{d_0 m_0}\left(d\sqrt{\mathcal{M}}\right)^2 \rightarrow ds = \frac{R_0}{\sqrt{d_0 m_0}} d\sqrt{\mathcal{M}} \rightarrow s$$

$$= \frac{R_0}{\sqrt{d_0 m_0}}\left(\sqrt{\mathcal{M}} - \sqrt{\mathcal{M}_0}\right), \quad \text{where} \quad \mathcal{M}_0 \equiv \mathcal{M}(s=0)$$

which defines the invariant magnitude of a purely *radial* displacement from the origin solely in terms of the mass-model representation $\mathcal{M} \equiv d_0 M + m_1$. But the invariant magnitude of a purely radial displacement has, until this point, been represented as $R = G(m)$. It follows that $s \equiv R = G(m)$ so that, finally, we have

$$s \equiv R = G(m) \equiv \frac{R_0}{\sqrt{d_0 m_0}}\left(\sqrt{\mathcal{M}} - \sqrt{\mathcal{M}_0}\right), \tag{10}$$

where $\mathcal{M}_0$ is the value of $\mathcal{M}$ at $R = 0$.

Since we are engaged in a discussion about astrophysical distance scales, it is pertinent to ask, at this point, what relation the radial measure *R* here has to the ordinary distance measures of astrophysics? This question is largely answered at the beginning of §4, where *R* is defined *via* the Pythagorean relationship, and completely answered in §2 where we show how Euclidean space is an exact special case of the forgoing considerations so that *R* can be identified definitively as the first rung of the standard cosmic distance ladder.

4.2. The special case of Euclidean space

To summarize general points, *m* is the amount of mass contained within an astrophysical sphere of redshift radius R_z, and $R = G(m)$ is the Leibnizian statement which defines the sphere's radius in ordinary units of length in terms of its mass content.

Remembering $\mathcal{M} \equiv d_0 m + m_1$ (see §4) and noting that $M(R=0)=0$ necessarily, then $\mathcal{M}_0 = m_1$ and so (10) can be expressed as

$$R = \frac{R_0}{\sqrt{d_0 m_0}}\left(\sqrt{d_0 m + m_1} - \sqrt{m_1}\right),$$

for the Leibnizian *definition* of the radius *R* in ordinary units of length of the astrophysical sphere which has mass content *m*. For the idealized case $m_1 = 0$ this definition becomes

$$R = R_0 \sqrt{\frac{m}{m_0}}. \tag{11}$$

Reference to (8) shows that, with this latter definition and $d_0 = 1$, then $A = 2m_0 / R_0^2$ and $B = 0$ so that $g_{ab} \sim \delta_{ab}$ with the consequence that the associated three-space becomes ordinary Euclidean space.

Furthermore, since all points are equivalent in a Euclidean universe, then the choice of origin for *R* in (11) is arbitrary. In other words, (11) can be understood to describe—in the same statistical sense that we assume the universe to be isotropic from arbitrarily chosen origins—the relationship between the Leibnizian definition of *R* in terms of *m* as observed from an arbitrarily chosen origin.

4.3. Fractality $D \approx 2$ as a signature of the Leibniz-Berkeley ideal

The relationship (11) can be equivalently stated as

$$4\pi R^2 = 4\pi R_0^2 \frac{m}{m_0}$$

which can be directly interpreted to mean that

> the area, measured in ordinary Euclidean units, of the astrophysically defined sphere of redshift radius R_z is equal to its mass content to within a scale factor.

This result has the *axiomatic* consequence that, if an observer in this Euclidean universe chooses to investigate the "spatial distribution of matter" using a Euclidean yardstick then he will necessarily find a quasi-fractal $D = 2$ distribution of matter. Thus, from this point of view, the observation of $D \approx 2$ in the universe of our experience is actually a *signature* that the space of our real experience really is projected as a secondary construct out of its matter content, in the manner of the Leibnitz-Berkeley ideal.

5. The temporal dimension

So far, the concept of "time" has only entered the discussion in a qualitative way in §2—it has not entered in any quantitative way and, until it does, there can be no discussion of dynamical processes.

Since, in its most general definition, time is a parameter which orders change within a system, then a necessary pre-requisite for its quantitative definition is a notion of change within the universe. The most simple notion of change which can be defined in the universe is that of changing relative spatial displacements of the objects within it. Since our model universe is populated solely by primitive galaxies which possess only the property of enumerability (and hence quantification in terms of the *amount* of material present) then, in effect, all change is gravitational change. Thus, the question of how we define "time" is tightly bound up with the question of how we quantify gravitation in the present schema.

At this point we need to be careful: if we were dealing with the two-clock model (where one of the clocks—ordinary frame-time—is built into the theory from the beginning) then we would be working within a Riemannian *spacetime* and could then incorporate the fact that "all change is gravitational change" by invoking the Weak Equivalence Principle and requiring that all trajectories are geodesic in the spacetime manifold. However, we are actually working with the one-clock model (where this clock has yet to be defined at all) and the manifold is a purely spatial one; consequently gravitation here *cannot* be modelled simply by requiring that all trajectories are geodesic. Notwithstanding this point, we note that within a defined Newtonian gravitating system (say, the solar system) the overall *shape* of a body's trajectory is determined purely by the body's instantaneous velocity at any particular defined point on the trajectory—specifically, it is independent of the body's mass. This suggests that the *shapes* of gravitational trajectories *can* be identified as geodesics within our spatial manifold. This leads directly to a perfectly conventional Lagrangian description of particle trajectories in terms of an arbitrarily defined temporal ordering parameter in which the Lagrange density is degree zero in that temporal-ordering parameter. From this, it follows, as a standard theorem, that the corresponding Euler-Lagrange equations form an *incomplete* set.

The origin of this incompleteness property traces back to the fact that, because the Lagrangian density is degree zero in the temporal ordering parameter, it is then invariant with respect to any transformation of this parameter which preserves the ordering. This implies that, in general, such temporal ordering parameters cannot be identified directly with physical time—they merely share one essential characteristic.

So, there exists a symmetry—the invariance of the equations of motion under transformations of the temporal ordering parameter—which must be broken if any notion of physical time is to enter the discussion. Remembering that we are working within a quasi-classical regime, it is then interesting (and gratifying) to find that the Newtonian condition "the action between two particles is along the line connecting them" is exactly what is required to break the symmetry, thereby introducing a notion of "physical time" into the present schema. The net result, in effect, is that orbital periods within gravitating systems become the basis by which systems of physical time are defined within our model universe.

5.1. The equations of 'motion' on the spatial manifold

The geodesic equations in the space with the metric tensor (8) can be obtained, in the usual way, by defining the Lagrangian density

$$\mathcal{L} \equiv \left(\frac{1}{\sqrt{2g_0}} \right) \sqrt{g_{ij}\dot{x}^i\dot{x}^j} = \left(\frac{1}{\sqrt{2g_0}} \right) \left(A\left(\dot{\mathbf{R}} \cdot \dot{\mathbf{R}}\right) + B\dot{\Phi}^2 \right)^{1/2}, \tag{12}$$

Where $g_0 \equiv m_0 / R_0^2$, and $\dot{x}^i \equiv dx^i/dt$, *etc.*, and forming the associated variational principle

$$\mathcal{I} = \left(\frac{1}{\sqrt{2g_0}} \right) \int \sqrt{g_{ij}\dot{x}^i\dot{x}^j}\, dt \tag{13}$$

where t is the temporal ordering parameter. The first thing to note here is that this variational principle is of order zero in t so that it is invariant with respect to arbitrary transformations of this parameter. This has the consequences referred to above:

- firstly that the temporal ordering parameter cannot be identified with physical time;
- secondly that the resulting Euler-Lagrange equations for a single particle, given by

$$\begin{aligned} &2A\ddot{\mathbf{R}} + \left(2A'\dot{\Phi} - 2\frac{\dot{\mathcal{L}}}{\mathcal{L}} A \right) \dot{\boldsymbol{R}} + \\ &+ \left(B'\dot{\Phi}^2 + 2B\ddot{\Phi} - A'\left(\dot{\mathbf{R}} \cdot \dot{\mathbf{R}}\right) - 2\frac{\dot{\mathcal{L}}}{\mathcal{L}} B\dot{\Phi} \right) \boldsymbol{R} = 0 \end{aligned} \tag{14}$$

- where $\dot{\mathbf{R}} \equiv d\boldsymbol{R}/dt$, $A' \equiv dA/d\Phi$ and $\Phi \equiv \left(\boldsymbol{R} \cdot \boldsymbol{R}\right)/2 = R^2/2$ *etc.*, cannot form a complete set so that some additional constraint must be applied to close the system.

A similar circumstance arises in General Relativity when the equations of motion are derived from an action integral which is formally identical to (13). In that case, the system is closed by specifying the arbitrary time parameter to be the "particle proper time," so that

$$d\tau = \mathcal{L}(x^j, dx^j) \;\rightarrow\; \mathcal{L}(x^j, \frac{dx^j}{d\tau}) = 1 \tag{15}$$

which is then considered as the necessary extra condition required to close the system.

5.2. Newtonian action as the closing constraint

Given the isotropy conditions imposed on the model universe from the chosen origin, symmetry arguments lead to the conclusion that the net action of the whole universe of particles acting on any given single particle is such that any net acceleration of the particle must always appear to be directed through the coordinate origin. Note that this conclusion is *independent* of any notions of retarded or instantaneous action. This constraint can then be stated as the Newtonian condition that:

> Any acceleration of any given material particle must necessarily be along the line connecting the particular particle to the coordinate origin.

This latter condition simply means that the equations of motion must have the general structure

$$\ddot{\mathbf{R}} = G\left(t, \boldsymbol{R}, \ddot{\mathbf{R}}\right)\boldsymbol{R},$$

for scalar function $G\left(t, \boldsymbol{R}, \ddot{\mathbf{R}}\right)$. Equation (14) has this structure if the coefficient of $\ddot{\mathbf{R}}$ in that equation is zero; that is, if

$$\left(2A'\dot{\Phi} - 2\frac{\dot{\mathcal{L}}}{\mathcal{L}}A\right) = 0 \quad \rightarrow \frac{A'}{A}\dot{\Phi} = \frac{\dot{\mathcal{L}}}{\mathcal{L}} \quad \rightarrow \quad \mathcal{L} = k_0 A \tag{16}$$

for arbitrary constant k_0 which is necessarily positive since $A > 0$ and $\mathcal{L} > 0$. The condition (16) can be considered as the condition required to close the incomplete set (14) and is directly analogous to (15), the condition which defines 'proper time' in General Relativity.

Thus, from (14) the equations of motion can be finally written as

$$2A\ddot{\mathbf{R}} + \left(B'\dot{\Phi}^2 + 2B\ddot{\Phi} - A'\left(\dot{\mathbf{R}}\cdot\dot{\mathbf{R}}\right) - 2\frac{A'}{A}B\dot{\Phi}^2\right)\boldsymbol{R} = 0 \tag{17}$$

5.3. Physical time defined as process

Equation (16) can be considered as that equation which removes the pre-existing arbitrariness in the 'time' parameter by *defining* physical time:- from (16) and (12) we have

$$\begin{gathered} \mathcal{L}^2 = k_0^2 A^2 \\ A\left(\dot{\mathbf{R}}\cdot\dot{\mathbf{R}}\right) + B\dot{\Phi}^2 = 2g_0 k_0^2 A^2 \\ g_{ij}\dot{x}^i\dot{x}^j = 2g_0 k_0^2 A^2 \end{gathered} \tag{18}$$

so that, in explicit terms, physical time is *defined* by the relation

$$dt^2 = \left(\frac{1}{2g_0 k_0^2 A^2} \right) g_{ij} dx^i dx^j, \quad \text{where } A \equiv \frac{\mathcal{M}}{\Phi} \tag{19}$$

In short, the elapsing of time is given a direct physical interpretation in terms of the process of *displacement* in the model universe.

Finally, noting that, by (19), the dimensions of k_0^2 are those of $L^6 / \left[T^2 \times M^2 \right]$, then the fact that $g_0 \equiv m_0 / R_0^2$ (*cf.* §1) suggests the change of notation $k_0^2 \propto v_0^2 / g_0^2$, where v_0 is a constant having the dimensions (but not the interpretation) of 'velocity'. So, as a means of making the dimensions which appear in the development more transparent, it is found convenient to use the particular replacement $k_0^2 \equiv v_0^2 / \left(4d_0^2 g_0^2 \right)$. With this replacement, the *definition* of physical time, given at (19), becomes

$$dt^2 = \left(\frac{4d_0^2 g_0}{v_0^2 A^2} \right) g_{ij} dx^i dx^j .$$

5.4. Physical time, the light cone and a "photon" background

We show that, in the idealized limiting case of $\left(d_0, m_1\right) = \left(1, 0\right)$ which gives rise to *exactly* Euclidean space, the foregoing definition of "physical time" implies that the material distribution associated with this idealized physical space has properties which suggest that it can be properly interpreted as a "sea of photons." In particular, there is a natural emergence of light cone geometry together with Bondi's interpretation of light velocity, *c*. It then becomes natural to tentatively associate with "sea of photons" with the Microwave Background Radiation.

For this case, the definition of *R* at (11) together with the definitions of *A* and *B* in §4 give

$$A = \frac{2m_0}{R_0^2}, \quad B = 0$$

so that, by (18) (remembering that $g_0 \equiv m_0 / R_0^2$ and $k_0^2 \equiv v_0^2 / \left(4d_0^2 g_0^2 \right)$), and writing $\boldsymbol{R} \equiv \left(x, y, z\right)$ for convenience, we have

$$\left(\frac{dx}{dt} \right)^2 + \left(\frac{dy}{dt} \right)^2 + \left(\frac{dz}{dt} \right)^2 = v_0^2 \tag{20}$$

for all displacements in the model universe. It is (almost) natural to assume that the constant v_0^2 in (20) simply refers to the constant velocity of any given particle, and likewise to assume that this can differ between particles. However, each of these assumptions would be wrong since—as we now show— v_0^2 is, firstly, more properly interpreted as a conversion factor from spatial to temporal units and, secondly, is a *global* constant which applies equally to all particles.

To understand these points, we begin by noting that (20) is a special case of (18) and so, by (19), is more accurately written as

$$dt^2 = \frac{1}{v_0^2}\left(dx^2 + dy^2 + dz^2\right) \tag{21}$$

which, by the considerations of §3, we recognize as the *definition* of the elapsed time experienced by any particle undergoing a spatial displacement (dx, dy, dz) in the model inertial universe. Since this universe is isotropic about all points, then there is nothing which can distinguish between two separated particles (other than their separateness) undergoing displacements of equal magnitudes; consequently, each must be considered to have experienced equal elapsed times. It follows from this that v_0 is not to be considered as a locally defined particle speed, but is a *globally* defined constant which has the effect of converting between spatial and temporal units of measurement; that is, it is more accurately thought of as being a conversion factor from length scales to time scales—which is identical to Bondi's interpretation of *c*, the light speed.

Since, in the Universe of our experience, the only global constant with dimensions of velocity is *c*, then it is natural to make the identification $v_0 \equiv c$ in (21) so that the light-cone arises in an entirely natural manner. The Lorentz transformations, which now follow automatically, then have the natural interpretation as those transformations which keep invariant the definition of physical time. The inferred "matter distribution" is then naturally interpreted as a composition of *photon-like particles* with the Bondian complexity that these particles arbitrate between length scales and time scales—within the context of the theory, this is a direct consequence of the fact that *time* arises automatically as a measure of *change* within the particle distribution very much as Mach conceived it.

6. The axiomatically $D \approx 2$ inertial universe

By the considerations of §2, the limiting case of the axiomatically $D = 2$ Euclidean universe is recovered by the parameter choice $(d_0, m_1) = (1, 0)$ and, as is also shown in §2, this implies A=const>0 and $B = 0$ in (17). In other words, in this limiting case

$$\ddot{\mathbf{R}} = 0 .$$

Thus, this universe is necessarily also a globally inertial equilibrium universe, and the questions originally posed in §1 are finally answered.

6.1. Seeliger's gravitational paradox

This paradox boils down to the statement that, within a Euclidean universe with a uniform distribution of matter and within which Newton's Universal Law is assumed, it is possible to assign an *arbitrary* gravitational acceleration to *any* particle depending on how one evaluates the (non-uniformly convergent) integrals which arise. Charlier showed that, within his proposed hierarchical universe, the paradox disappears.

However, Charlier's argument is not relevant here since Newton's Universal Law is not assumed. The relevant point here is simply that, as shown above, the axiomatically $D=2$ material universe is necessarily a globally inertial equilibrium universe, so that Seeliger's gravitational paradox does not arise within the Leibnizian cosmology developed here.

6.2. Olber's paradox

It has already been pointed out in §2 that Charlier argued in 1908 how Olber's Paradox disappeared if matter in the universe was assumed distributed hierarchically (fractally in modern parlence) such that $M \sim R^a$ for $a \leq 2$. Thus, by Charlier's arguments, Olber's Paradox—like Seeliger's paradox—cannot exist within the Leibnizian cosmology developed here.

6.3. Implications for theories of gravitation

Given that gravitational phenomena are usually considered to arise as mass-driven perturbations of flat inertial backgrounds, then the foregoing result—to the effect that the inertial background is axiomatically associated with the *appearance* of a $D=2$ "distribution of matter in space"—must necessarily give rise to completely new perspectives about the nature and properties of gravitational phenomena. However, as we showed in §4, the structure of the idealized "inertial background" suggests that it can be properly interpreted as a "photon sea"—reminiscent of the microwave background—out of which (presumably) ordinary material can be considered to condense in some fashion.

7. Summary

7.1. The significance of "Large Scale Structure"

The main result of this paper amounts to the statement that the conflict between the idea that material in the Universe "should be" distributed homogeneously and the claim that it appears (on large scales) to be quasi-fractal $D \approx 2$ is, at source, the conflict between two opposing notions of "space":

- one as an objective reality which functions as a container of material—a notion which can be traced from Democritus, through Newton to Einstein (in practice);
- the other as a secondary construct projected out of relationships between material objects—a notion which can be traced from Aristotle, Leibniz & Berkeley to, most recently, Mach.

The problem for those subscribing to the Leibniz-Berkeley ideal has always been how to provide it with quantitative expression—the problem which this paper set out to address. We began by noting the empirical fact that in the universe of our experience, and on large enough scales, we can use the distance-ordering property of galactic redshifts to define astrophysical spheres and can subsequently estimate the amount of matter, m say, contained within any given such sphere simply by *counting* the galaxies it contains. We then noted that we could *define* a calibration for the radius of such a sphere purely in terms of the estimated contained mass, so that $R = G(m)$ where G is an arbitrarily defined monotonic increasing function of m. It is this latter step which is the non-trivial point of quantitative contact with the Leibniz-Berkeley ideal. Such a definition of R implies a simple definition of a radial displacement, dR, in terms of the matter contained between two shells, radius R and $R + dR$.

There then followed a technical discussion about how this idea of *an invariant radial displacement being defined in terms of an amount of matter* could be generalized for arbitrary non-radial displacements. This discussion took its cue primarily from the human being's sense of how relative displacement is perceived (such "sense" being at the root of the Leibniz-Berkeley ideal), and led to a worldview within which quantitative questions can be formulated and answered. Thus, given that the most simple conception of space that we have is one which is everywhere Euclidean, the fundamental quantitative question formulated, in effect, was:

> What is the quantitative form of the definition $R = G(m)$ in a Euclidean universe?

The worldview replied $R \sim \sqrt{m}$. It is then axiomatic that if an observer asks the Newtonian question "what is the distribution of matter in space?" and sets out to answer this question using a predetermined Euclidean ruler, he will then find that it appears to be fractal, $D \approx 2$. In fact, according to the arguments presented here, this result should be interpreted as a signature that the universe is "constructed" according to the ideals of Leibniz & Berkeley.

7.2. The nature of "time"

The discussion which led to the foregoing conclusion also unavoidably entailed a corresponding discussion concerning the nature of "time"—as Mach himself pointed out, so far as "time" is concerned, the most we can ever do is to define the "time required for process A to occur" in terms of the "time required for process B to occur." For example, "I can walk 50 miles between one sunrise and the next." From this viewpoint, it is arguable, for example, that the individual proton—never observed to decay, and therefore a stranger to change—exists *out of time*. But the internal distribution of an assembly of (labelled) protons, on the other hand, does change and a sequence of snapshots of such a changing assembly could be considered as an evolutionary sequence *defining of itself the passage of time.* In effect, "time" is defined as a metaphor for "ordered change within a physical system" and it is this definition of "time" which arises automatically from the considerations which lead to the $R \sim \sqrt{m}$ Euclidean Universe above—there is a set of particles which possess only the property of *enumerability* from which the concept of "time" arises as a metaphor for "ordered change."

It was then extremely interesting to find that, in the limiting case of an exactly Euclidean universe, our considerations about the nature of time *and the necessary role of Newton's Third Law (cf. §2) in defining what is meant by physical time* led automatically to lightcone geometry and hence to the Lorentz transformations as those transformations which keep invariant the definition of temporal process within the Euclidean universe.

7.3. Implications for gravitation theory

The foregoing development amounts to that of providing the essential framework for a theory of gravitation in a universe conforming to the Leibniz-Berkeley ideal and so obvious questions to be answered are:

- can the classical theory of Newton for a point source (like the Sun) be recovered?
- does the relativistic form of the theory (the two-clock model) for a point source pass the standard tests, up to and including those associated with the binary pulsar?

For the Newtonian case, it is sufficient to consider point-source perturbations of the $(d_0, m_1) = (1,0)$ limiting case of the $D = 2$ Euclidean universe. All Newtonian structure can then be recovered in a straightforward way whilst the strong field, or relativistic cases, can be recovered with a fine tuning of the arguments presented here.

7.4. Implications for the observations

Probably the major difficulty for both sides of the structure debate is that the measuring rods used on large scales cannot be reliably nor independently calibrated—a problem that becomes increasingly severe with increasing scale. For that reason alone then, as things stand, there is probably no reasonable prospect that the debate can ever be unambiguously concluded. However, *even if* the debate could be concluded to the satisfaction of the pro-homogeniety proponents, an open question would remain: *how are the quasi-fractal structures, which are agreed to exist on medium scales, to be* *explained?* Since recourse to "initial conditions" cannot constitute an illuminating explanation, then there is no answer even to this limited question within standard big-bang cosmology.

A universe "constructed" according to the Leibniz-Berkeley ideal provides a rational escape route: according to this ideal, it is axiomatic that when reliably calibrated Euclidean measuring rods are used to determine the "distribution of material in space," then a fractal $D = 2$ matter distribution will be inferred. In practice, the measuring rods we use are reliably defined to be Euclidean on small scales and become progressively less reliably calibrated as the scales increase. The actually inferred $D \approx 2$ structure out to medium scales is readily understood on these terms. Accepting this as circumstantial evidence favouring the Leibniz-Berkeley ideal, it then becomes natural to progress by calibrating the measuring rods in such a way that the inferred "structure" is $D = 2$ on all scales, by definition. The gain is a new way to calibrate distance scales and therefore, for example, a new way to investigate the redshift phenomenon itself.

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Experimental Verification of Velocity Dependent Inertial Induction

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A theory of Velocity Dependent Inertial Induction based upon an extension of Mach's Principle has been proposed by the last author. The application of the theory has produced very interesting results explaining many phenomena which remained unexplained through conventional physics.

All the results of the previous publications were encapsulated in Ref [1] published in 2000. Even then it is desirable to verify the theory directly through experiments conducted in a laboratory. This article describes the proposed experiment that can detect the effect of Velocity Dependent Inertial Induction on photons causing excess red-shift.

Introduction

The model of inertial induction combining the acceleration dependent part proposed by Sciama[2] and the velocity dependent part by Ghosh [3–5] has been able to solve many problems of celestial mechanics, astrophysics and cosmology. In spite of the fact that the proposed model of inertial induction does not contain any free adjustable parameters, quantitatively correct results are obtained in many unrelated phenomena [6–10] providing enough credibility to the proposed theory. As the extra effects due to the proposed extension of Mach's Principle are extremely small, so far any terrestrial laboratory experiments have not been attempted. In this article a feasible experiment has been suggested in which the red-shifts suffered by photons travelling in the horizontal and vertical directions are to be compared. As the red-shifts are to be different due to the velocity dependent inertial induction term, the changes in the frequencies of the two laser beams can be detected through interferometry.

Velocity Dependent Inertial Induction

It is desirable to present the proposed theory briefly. The model of inertial induction was first proposed in 1984 [3,4] which suggests, that the total interactive force between the two particles depends not only on their relative distance but also on their relative velocity and acceleration. Therefore, force $\mathbf{F}$ on m_1 due to velocity dependent inertial induction from m_2 can be expressed as follows (Figure 1):

$$\mathbf{F} = \frac{Gm_1m_2}{c^2r^3}v_{rel}^2\ \mathbf{r}\cos\alpha\left|\cos\alpha\right| \tag{1}$$

where G is the universal gravitational constant, c is the speed of light in vacuum, $\mathbf{r}$ is the position vector of m_2 with respect to m_1 and α is the angle made by $\mathbf{v}_{rel}$ with $\mathbf{r}$ as shown. When the force of velocity and acceleration dependent inertial induction terms between two gravitational masses m_1 and m_2 are combined with the Newtonian static gravitational term the total

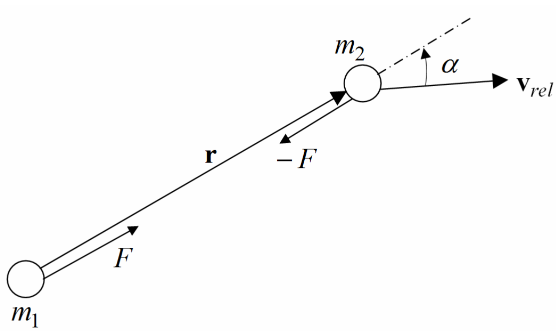

Figure 1 – Force due to velocity dependent inertial induction

force due to static and dynamic gravitational interaction between the two particles can be expressed as follows [1]:

$$F = \frac{Gm_1m_2}{r^3} r\hat{u}_r + \frac{Gm_1m_2}{c^2r^2} v^2 f(\alpha)\hat{u}_r + \frac{Gm_1m_2}{c^2r} af(\beta)\hat{u}_r$$

The angles α and β are those made by the velocity and acceleration vectors with the vector **r**. The relative velocity between the two bodies is **v** and the acceleration is **a.** The application of the model has not only been able to generate the correct cosmological red-shift but, when applied to local interactions, the inertial induction mechanism has been able to explain the secular acceleration of Phobos[7] whose value is found to be, $1.5 \times 10^{-3} \deg yr^{-2}$ and also certain other unexplained phenomena in celestial mechanics, worth mentioning among those are the secular retardation of the Earth's rotation due to velocity dependent inertial induction [4], transfer of solar angular momentum [6], excess red shifts and flat rotation curves of spiral galaxies [5,7].

The present article describes a possible terrestrial experiment to detect the extremely small velocity dependent inertial induction effect by comparing the wave lengths of two laser beams moving in the horizontal and vertical directions. In the next section the magnitude of the red-shift of photons moving vertically and horizontally are determined.

Effect of Velocity Dependent Inertial Induction on Photons Moving in the Horizontal and Vertical Directions near the Earth Surface

Figure 2 shows the earth and a photon of mass m_p at a location B at a given instant. The photon is moving on the earth's surface with a speed c in the horizontal direction as indicated. Now an elemental mass δm_E of the earth

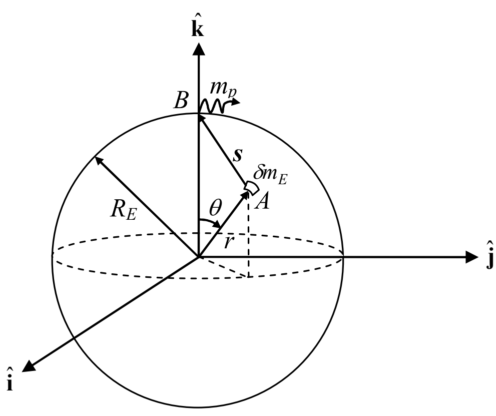

Figure 2 – Force on a photon moving horizontally on the earth's surface

at a location A is considered. So the force on the photon due to the velocity dependent inertial induction of the elemental mass δm_E,

$$\mathbf{dF} = -\frac{G(\delta m_E)m_p}{c^2 s^2} c^2 \cos\alpha . \left|\cos\alpha\right| \hat{\mathbf{s}}$$

where $\hat{\mathbf{s}}$ is the unit vector along $\mathbf{s}$, representing the relative position of the photon with respect to the elemental mass δm_E, which is equal to $\rho(r)\left(r^2 \sin\theta\right) d\varphi d\theta dr$ and $\rho(r)$ is the density of the earth at that location. The angle between the direction of motion and the vector $\mathbf{s}$ is α. Therefore, $\cos\alpha = \hat{\mathbf{s}}.\hat{\mathbf{j}}$.

The relative distance between A and B is, $\mathbf{s} = \mathbf{B}$**-**$\mathbf{A}$, where $\mathbf{B}$ is the position vector of the photon and $\mathbf{A}$ is the position vector of the elemental mass at A.

$$\mathbf{A} = \hat{\mathbf{i}}\, r\sin\theta\cos\varphi + \hat{\mathbf{j}}\, r\sin\theta\sin\varphi + \hat{\mathbf{k}}\, r\cos\theta$$

$$\mathbf{s} = -\hat{\mathbf{i}}\left(r\sin\theta\cos\phi\right) - \hat{\mathbf{j}}\left(r\sin\theta\sin\phi\right) + \hat{\mathbf{k}}\left(R - r\cos\theta\right)$$

$$\cos\alpha = -\frac{r\sin\theta\sin\phi}{s}$$

Therefore, $\mathbf{dF} = \dfrac{Gm_p}{s^4}\left\{\rho(r)\, r^4 \sin^2\theta\sin\phi\left|\sin\theta\sin\phi\right|\right\} d\phi\, d\theta\, dr$

The component of the elemental force along in the y direction

$$\mathbf{dF}_y = -\frac{Gm_p}{s^5}\left\{\rho(r)\, r^4 \sin^3\theta\sin^2\phi\left|\sin\theta\sin\phi\right|\right\} d\phi\, d\theta\, dr$$

$$s^2 = R^2 + r^2 - 2rR\cos\theta$$

The y component of the total force on the photon can be estimated by integrating over the whole earth with respective limits. So,

$$F_y = -Gm_p \int_0^{R_E}\int_0^{\pi}\int_0^{2\pi}\left[\left\{\rho(r)\, r^4 \sin^3\theta\sin^2\phi\left|\sin\theta\sin\phi\right|\right\}\Big/ s^5\right] d\phi\, d\theta\, dr$$

Now the amount of energy lost by the photon while travelling 1 m on the earth's surface from point B is given by

$$\Delta E = F_y\, dy$$

The loss of energy of the photon will finally result in an increase of the wavelength. If $\Delta\lambda$ be the change in its wavelength, then its fractional shift can be expressed as

$$z = \frac{\Delta\lambda}{\lambda} = -\frac{\Delta E\lambda}{hc}$$

The density variation of the earth can be expressed as follows;

$$\rho(r) = (18 - 10\zeta) \times 10^3 \qquad \text{for } 0 \le \zeta \le 0.2$$

$$\rho(r) = (13.143 - 5.714\zeta) \times 10^3 \qquad \text{for } 0.2 \le \zeta \le 0.55$$

$$\rho(r) = (9.667 - 6.667\zeta) \times 10^3 \qquad \text{for } 0.55 \le \zeta \le 1$$

where $\zeta = r/R_E$

$$R_E = 6.378 \times 10^6$$

Using the above density variation and taking dy equal to 1 m, the value of z comes out to be 1.89×10^{-17}

This is the fractional red-shift of a photon during its travel of 1 meter horizontally.

A similar analysis is done to find out the effect of velocity dependent inertial induction from earth when the photon moves vertically from the earth's surface. Figure 3 shows the schematic diagram of this case.

The drag force can be expressed as

$$F_z = -Gm_p \int_0^{R_E}\int_0^{\pi}\int_0^{2\pi} \left[\frac{\left\{ \rho(r)\, r^2 \sin\theta (R - r\cos\theta)^2 \left|(R - r\cos\theta)\right| \right\}}{s^5} \right] d\phi\, d\theta\, dr$$

Therefore, a fractional shift in wavelength of the photon when it is moving a distance of 1 meter vertically on the earth's surface, comes out to be 6.5×10^{-17}.

Scheme of the Experiment

The basic scheme of the suggested experiment is somewhat similar to that conducted by Michelson and Morley. The difference being that in the present case a laser beam is split into two beams — one moving in the vertical direction and the other moving in the horizontal direction. The beams are

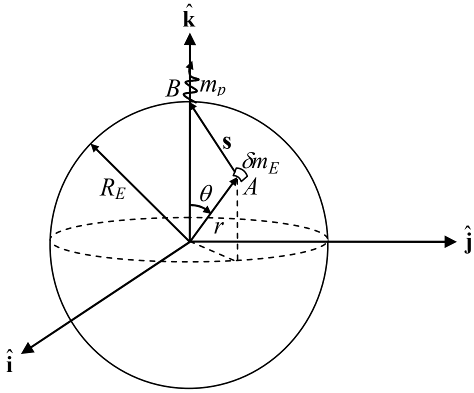

Figure 3 – Force on a photon moving vertically on the earth's surface

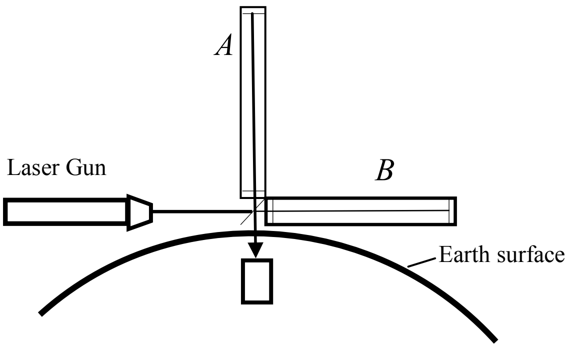

Figure 4 – Basic scheme of the experiment

reflected by sets of parallel mirrors many times. The photon moving in the vertical direction is subjected to an inertial drag that keeps on adding with each trip; whereas the effect of the gravitational red-shift gets cancelled as the red-shift during the trip in the upward direction gets cancelled by an equal amount of blue shift during the downward movement. There is no red-shift due to gravitational pull when a photon moves horizontally but the inertial drag produces a red-shift in each trip that keeps on adding. So, if the red-shift during a vertical trip of distance L be Δz_1 and the red-shift during a horizontal trip of the same distance be Δz_2, after n number of reflected trips the red-shifts of the two beams will be $n\Delta z_1$ and $n\Delta z_2$. It is possible to detect the difference by interference of the two beams.

The beam from the laser gun is split by the mirror; one of the two components gets reflected repeatedly between mirrors in the tube A vertically and the other one gets reflected between the mirrors in tube B horizontally. If the distance between the pairs of the mirrors be L, then in a period of time T the number of travels will be

$$N = cT/L$$

So far as the vertical arm is concerned the red-shift during the upward travel will be that due to the gravitational pull by the earth and that due to the velocity dependent inertial induction whose magnitude during each step generates a fractional red-shift of $6.5 \times 10^{-17}L$ where L is in meters. During the next downward travel of the photon the earlier gravitational red-shift gets cancelled by an equal amount of blue shift but that due to the inertial induction effect again produces a fractional red-shift equal to $6.5 \times 10^{-17}L$. So in time T the total fractional red-shift suffered by the beam in arm A will be $6.5 \times 10^{-17}cT$. At the same time the beam in tube B does not suffer any red shift due to gravitation as it is moving horizontally. However, during each step it suffers a fractional red shift of $1.89 \times 10^{-17}L$ due to inertial induction effect. Therefore after a period of time T the total fractional red-shift of the beam in B will be $1.89 \times 10^{-17}cT$. At the end when the

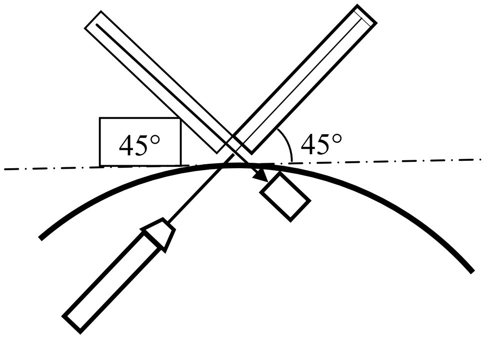

Figure 5 – Calibration of the set up

two beams are combined the difference in wave lengths can be detected by interferometry.

To take care of the extraneous effects the set up should be calibrated to a null result by keeping both the tubes A and B at 45° to the horizontal as shown in Figure 5.

Experiments using geostationary satellites: It may be possible to use signals from the geosynchronous satellites for detecting frequency shift due to the inertial induction of the earth. The signals can be in a vertical direction or tangential to the earth's surface. The expected fractional frequency shifts have been estimated as shown below.

Vertical Movement

Figure 6 shows the earth and a photon of mass m_p at a location B at a given instant. The photon is moving from the earth's surface with a speed c in the vertical direction as indicated. Now an elemental mass δm_E of the earth at a location A is considered. So the force on the photon due to the velocity dependent inertial induction of the elemental mass δm_E, is

$$\mathbf{dF} = -\frac{G(\delta m_E)m_p}{c^2 s^2} c^2 \cos\alpha . \left|\cos\alpha\right| \hat{\mathbf{s}}$$

where $\hat{\mathbf{s}}$ is the unit vector along s, representing the relative position of the photon with respect to the elemental mass δm_E, which is equal to $\rho(r)\left(r^2 \sin\theta\right) d\phi d\theta dr$ and $\rho(r)$ is the density at that location. The angle between the direction of motion and the vector s is α . Therefore,

$$\cos\alpha = \hat{\mathbf{s}}.\hat{\mathbf{k}}$$

The relative distance between A and B is, $\mathbf{S} = \mathbf{B} - \mathbf{A}$, where $\mathbf{B}$ is the position vector of the photon and $\mathbf{A}$ is the position vector of the elemental mass at A.

$$\mathbf{A} = \hat{\mathbf{i}}\, r\sin\theta\cos\phi + \hat{\mathbf{j}}\, r\sin\theta\sin\phi + \hat{\mathbf{k}}\, r\cos\theta$$

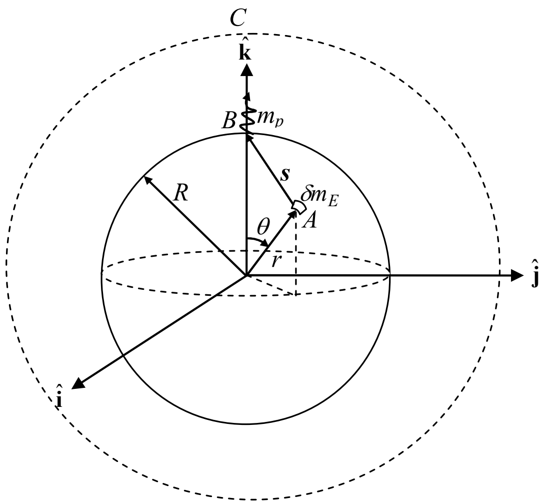

Figure 6 – Force on a photon moving vertically from the earth's surface

$$\mathbf{s} = -\hat{\mathbf{i}}(r\sin\theta\cos\varphi) - \hat{\mathbf{j}}\,(r\sin\theta\sin\varphi) + \hat{\mathbf{k}}\,(z - r\cos\theta)$$

$$\cos\alpha = \frac{(z - r\cos\theta)}{s}$$

The drag force can be expressed as

$$F_z = -Gm_p \int_0^{R_E}\int_0^{\pi}\int_0^{2\pi} \left[\left\{ \rho(r)\, r^2 \sin\theta (z - r\cos\theta)^2 \left|(z - r\cos\theta)\right| \right\} / s^5 \right] d\varphi\, d\theta\, dr$$

$$s^2 = z^2 + r^2 - 2rz\cos\theta$$

Now the amount of energy lost by the photon while travelling towards *C* from point *B* is given by

$$\Delta E = F_z\ dz$$

The loss of energy of the photon will finally result in an increase of the wavelength. If Δλ be the change in its wavelength, then its fractional shift can be expressed as[8]

$$z = \frac{\Delta\lambda}{\lambda} = -\frac{\Delta E \lambda}{hc}$$

The density variation of the earth used for calculation has been presented before.

[8] As per common practice *z* is varying between limits from the surface of the Earth to the point C, so one more integral will place it at that point and thus represent the total energy drop.

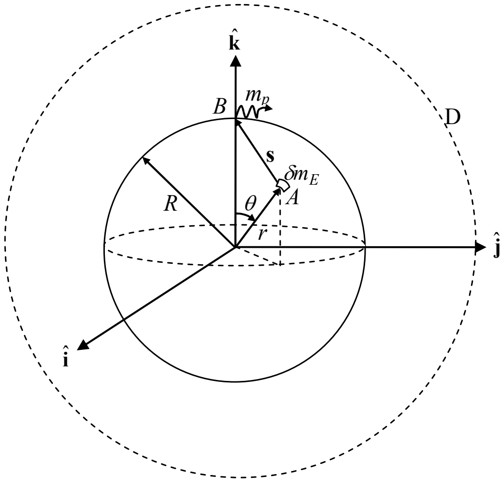

Figure 7 – Photon moving to a geosynchronous satellite horizontally

The fractional shift in wavelength of the photon when it is moving vertically from the earth's surface to a geosynchronous satellite comes out to be $\mathbf{4.7977 \times 10^{-10}}$. (Note: position of the satellite, means its value is not indicated, which was taken as 35,000 km).

Horizontal Movement

Using the above density variation and taking the limit from B to D, the value of z comes out to be $\mathbf{6.66 \times 10^{-10}}$

Experiment with photons grazing the earth

Figure 8 shows the earth and a photon of mass m_p at a location B at a given instant. The photon is moving above the earth's surface with a speed c in the horizontal direction as indicated. Now an elemental mass δm_E of the earth at a location A is considered. So the force on the photon due to the velocity dependent inertial induction of the elemental mass δm_E, is

$$\mathbf{dF} = -\frac{G(\delta m_E)m_p}{c^2 s^2} c^2 \cos\alpha . \left|\cos\alpha\right| \hat{\mathbf{s}}$$

where $\hat{\mathbf{s}}$ is the unit vector along s, representing the relative position of the photon with respect to the elemental mass δm_E, which is equal to $\rho\left(r\right)\left(r^2 \sin\theta\right) d\varphi d\theta dr$ and $\rho\left(r\right)$ is the density at that location. The angle between the direction of motion and the vector $\mathbf{s}$ is α .

The relative distance between A and B is, S = B – A, where B is the position vector of the photon and A is the position vector of the elemental mass at A.

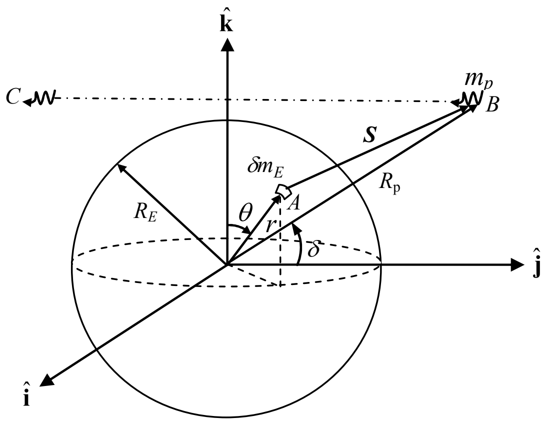

Figure 8 – Force on a photon moving horizontally above the earth's surface

$$\mathbf{A} = \hat{\mathbf{i}}\, r\sin\theta\cos\varphi + \hat{\mathbf{j}}\, r\sin\theta\sin\varphi + \hat{\mathbf{k}}\, r\cos\theta$$

$$\mathbf{B} = \hat{\mathbf{j}}\, R_p\cos\delta + \hat{\mathbf{k}}\, R_p\sin\delta$$

$$\mathbf{s} = -\hat{\mathbf{i}}\left(r\sin\theta\cos\phi\right) + \hat{\mathbf{j}}\left(R_p\cos\delta - r\sin\theta\sin\phi\right) + \hat{\mathbf{k}}\left(R_p\sin\delta - r\cos\theta\right)$$

$$F_y = Gm_p \int_0^R \int_0^\pi \int_0^{2\pi} \left[\frac{\left\{ \rho(r)\left(r^2\sin\theta\right)\begin{pmatrix} R_p\cos\delta - \\ r\sin\theta\sin\phi \end{pmatrix}^2 \begin{vmatrix} R_p\cos\delta - \\ r\sin\theta\sin\phi \end{vmatrix} \right\}}{s^5} \right] d\phi\, d\theta\, dr$$

$$\Delta E = F_y\, dy$$

$$y = R_p\cos\alpha$$

$$z = \frac{\Delta\lambda}{\lambda} = -\frac{\Delta E\lambda}{hc}$$

Fractional frequency shift for different grazing distances

$\delta = 30°$	$z = 3.5148 \times 10^{-11}$
$= 60°$	$z = 4.2385 \times 10^{-12}$
$= 65°$	$z = 2.2662 \times 10^{-12}$
$= 70°$	$z = 1.0543 \times 10^{-12}$
$= 75°$	$z = 4.0521 \times 10^{-13}$
$= 80°$	$z = 1.1831 \times 10^{-13}$

These magnitudes of red-shifts are measurable using the present day available technology

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A Review of Anomalous Redshift Data

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One of the greatest challenges facing astrophysics is derivation of remoteness in cosmological objects. At large scales, it is almost entirely dependent upon the well-established Hubble relationship in spectral redshift. The comparison of galactic redshifts with distances arrived at by other means has yielded a useable curve to an acceptable confidence level, and the assumption of scale invariance allows the adoption of redshift as a standard calibration of cosmological distance. However, there have been several fields of study in observational astronomy that consistently give apparently anomalous results from ever-larger statistical samples, and would thus seem to require further careful investigation. This paper presents a review summary of recent independent work, primarily (for galaxies and proto-galaxies) by teams led by, respectively, D. G. Russell†, M. Lopez-Corredoira‡, and H. C. Arp§, and for galaxy clusters and large-scale structures, those of N. A. Bahcall**, and J.C. Jackson. Included also are several other important contributions that will be fully cited in the text. The observational evidence is presented here *per se* without attempting theoretical conclusions or extrapolating the data to cosmology.

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Key words: redshift, quasars, galaxies, expansion, cosmology, anomalous, peculiar.

1. Introduction

The first question that needs to be answered in a review of anomalous redshift data is, *"What is the statistical significance of the samples being cited?"* Put another way; are anomalous redshift associations not in fact just extremely rare events that can be written off to chance alignments and optical illusion? This was for decades the criticism leveled particularly at the observa-

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tional work of Halton Arp, so I will let him answer it (from his paper with Chris Fulton, 2008):

> Fulton & Arp have analyzed the positions, redshifts, and magnitudes of *~118,000 galaxies* and *~25,000 quasars* in the 2dF deep field. The examination of individual samples revealed concentrations of high *z* galaxies and quasars near galaxies. A natural extension of the analysis was to determine the average densities of objects over the survey area as a whole.[1]

Redshift is an extremely important quantity in astrophysics, and supports a large body of theory. In cosmology, it gives us the radial calibration along line-of-sight that determines almost exclusively the depth in 3-D representation of structure. In 1929, Edwin Hubble discovered that for galaxies in his field of view, that is, fairly local, the fainter they are, the higher the redshift. From the outset, data patterns were indistinct and tenuous. Hubble's original redshift data were described by Weinberg [2] as leaving him

> ...perplexed how he (Hubble) could reach such a conclusion—galactic velocities seem almost uncorrelated with their distance, with only a mild tendency for velocity to increase with distance.

Hubble himself remained unconvinced that the Doppler effect correctly explained his observations. In Hoyle, Burbidge, and Narlikar, in *A Different Approach to Cosmology* [3], (pages 32—33), we learn that

> ...In the case of the redshifts it had been accepted that they must be corrected for solar motion with respect to the centroid of the Local Group, since it had been realised since 1936 that the systematic redshift does not operate within the Local Group.

The crucial implication of this was that it was impossible to test redshift-expansion against parallax distance measures, the most reliable method for quantifying celestial remoteness, albeit within the limits of achievable baseline scale. Given that uncertainty increases dramatically with remoteness on all axes, it would appear that *the Hubble relationship fits best where it is tested least*.

Historically, galaxy counts compiled by Abell (*Catalogue of Rich Clusters*, 1958), Zwicky *et al.* (*Catalogue of Galaxies and Clusters of Galaxies*, 1961-1968), and Arp (*Atlas of Peculiar Galaxies*, 1966) made no attempt to reconcile redshift values with other properties in space, but the data were invaluable to later analysts constructing 3-D interpretations. The *Sloan Digital Sky Survey* (SDSS) and the *Centre for Astrophysics* (CfA) survey, as two examples of modern works, have given us 3 dimensional interpretations of pie slices of the universe that rest, or fall, with redshift distance. All these mentioned surveys produced peculiar patterns when arranged spatially according to redshift, and even more obvious anomalies where resolution permitted detection of material connections between bright objects.

M.B. Bell, of Herzberg Institute of Astrophysics in Canada, sums it up:

> Because the belief that the redshift of quasars is cosmological has become so entrenched, and the consequences now of it being wrong are so enormous, astronomers are very reluctant to consider other possibilities. However, there is increasing evidence that some galaxies may form around compact, seed objects ejected with a large intrinsic redshift component from the nuclei of mature active galaxies. [4]

2. Phenomenology

Anomalous redshifts are defined as quantities significantly at variance with the Hubble Law. To assess whether the arrangement in an apparent system is or is not anomalous, we would look for *"properties of nearness, alignment, disturbances, connections"* (Arp, Burbidge, Burbidge [15]).

Thus, we may assume that there is something anomalous about the redshift of an astrophysical object if:

1. There is a prevalence of high redshift objects near the nucleus of nearby galaxies, or high redshift galaxy-like systems associated with low redshift clusters;
2. Physical connections are seen between objects with significantly varying redshifts;
3. Apparent proximity of high redshift objects is given by non-redshift distance indicators;
4. Radial alignment suggests ejection and common origin of objects with excessively varying redshifts;
5. Absorption lines (or lack thereof) of higher redshift objects places them in the foreground of lower redshift background systems;
6. Morphological associations, for example asymmetries in rotation curves or overall shapes, in contradiction of redshift distance.
7. The redshift is systematically quantised in discrete values (the Karlsson Effect).

3. Overview

3.1. Galaxies

Our descriptive knowledge of galaxies increased exponentially from the time of Hubble's first foray into extra-galactic astronomy in the late 1920s. However, our definitive *understanding* of these systems seems to have simultaneously gone backwards. Edwin Hubble designed his Tuning Fork classification system around his belief that galaxies were stable and symmetrical, reducible to a linear hierarchy of just a handful of distinct species. By the 1950s, it was obvious that Hubble's galaxy classes were woefully inadequate, and that galaxies were indeed behaving mysteriously. In 1956, Fritz Zwicky was the first astronomer to describe large-scale tidal effects characterising galaxies, in the form of *"clouds, filaments, and jets of stars"* [6]. He attributed these phenomena to *ejection*, caused by *galaxy collisions*. Viktor Ambartsumian tendered a very important alternative view, theorising the *fissioning* of celestial objects. This raised the possibility that galaxy-galaxy interactions and consequent tidal disturbances described by Zwicky, could well be caused primarily by the ejection of one object by another without their prior *merging* necessarily. Either way, they were definitely peculiar.

In the paper "Large Scale Structure in the Universe Indicated by Galaxy Clusters," [7] Neta Bahcall, widow of the late John Bahcall and professor of astronomy at Princeton, summarises it thus:

> Still, despite the great effort and many ingenious ideas, no single theory for the formation of galaxies and large-scale structure can yet satisfactorily match all observations.

It would therefore appear, at super-galactic scales at least, redshift-distance correlations are always in some or other respect anomalous when tested against the body of theory.

3.2. Quasars

Alan Sandage and Thomas Matthews, in a landmark fusion of optical and radio astronomy, identified Quasi-Stellar Objects (QSOs, hereafter *quasars*) in 1963. They were properly described in terms of their spectral signature, and presented an unusual defining characteristic: Redshifts significantly higher than other objects seen on the sky. This created difficulties for physical theory because at their redshift-implied remoteness, they would by known physics be impossibly bright. Quasars are very compact objects, typically only ~1 LY across. If they really are at their redshift distance, they would be so energetic that their luminosity requires extraordinary physics (for example, the invocation of Black Holes and Dark Matter halos).

If one plots quasars' redshift against apparent brightness, as Hubble did for galaxies, one gets a wide scatter, as compared with a smooth curve for the same plot done for galaxies. This seems to indicate that quasars do not follow the Hubble law, and there is no direct indication that they are at their proposed redshift distance. In fact, it is argued if Hubble had been given the plot for quasars first, he and other astronomers would not have concluded the Universe was expanding.

Furthermore, the calculated charge density of quasars is in some cases so high that it would appear that photons could not likely escape the interior, meaning that quasars should be radio- and X-ray-quiet. They obviously were not. Even more onerous was the precision measurement of radial expansion rate by very long baseline radio interferometry. Quasars appeared to be expanding at up to ten times the speed of light, with obviously serious implications for underlying theory and Einsteinian physics.

All of these quandaries about quasars were real only at their redshift-implied remoteness, and would tend to disappear if the objects were in fact closer to our point of observation. It was clear that quasars were peculiar enough to warrant further investigation to establish observationally *what* they actually were in the scheme of things, and *where* they might be located in space.

3.3. Observations and Catalogues

It would be fair to say that the controversy surrounding quasars and the implied phenomenon of intrinsic redshift may be attributed mainly to the early observational work of Dr Halton C. Arp, then a professional astronomer working at the major West Coast observatories of the USA. His interest in the astronomical distance ladder, stemming from his doctoral work with Edwin Hubble and subsequent 2-year stint observing Cepheids in South Africa, brought redshift into focus. In 1965, two oddities caught his interest: Galaxies appeared to be in turmoil, showing signs of great internal stress and presenting themselves in ways that could not neatly be accommodated on Hubble's Tuning Fork; and an unusual prevalence of quasars, in pairs or more, aligned closely across active (Seyfert-like) galaxies. In 1966, Arp published a collection of these images in his classic *Atlas of Peculiar Galaxies*.

The furore that followed split the astrophysical community, with most astronomers declaring that close alignment of quasars with AGN was just chance, line-of-sight coincidence with no statistical or physical significance. A small minority took an alternative view, however, amongst them (besides Arp) Margaret and Geoff Burbidge, Fred Hoyle, Jayant Narlikar, and Jack Sulentic. Arp's subsequent publications continued to display observational evidence of these associations, now improved by advanced instrumentation to include more detail than just tight angular spread, and led ultimately to his *Catalogue of Discordant Redshift Associations*, [8] published in 2003.

Up to then, the samples available to Dr Arp had been limited in scope, but contemporary large-scale cosmic surveys, prominently the Sloan Digital Sky Survey (SDSS), immediately introduced millions of objects to the field of study. Amongst them were more than 40 000 positively identified quasars. The two deep field surveys are also invaluable sources of redshift data. The 2dF Galaxy Redshift Survey (2dFGRS) lists ~250 000 galaxies, and the 2dF Quasar Redshift Survey (2QZ) examines ~25 000 quasars. In the words of Arp and Fulton,

> The resulting collection of objects can be analyzed to obtain the average numbers of galaxies and quasars per square degree as shown in Table 1. The subject count records the occurrence of galaxies and quasars inside a circle of radius 30′ around each galaxy and the background count records

> the occurrence of galaxies and quasars in a concentric annulus of equal area enclosing the subject circle. [1]

4. Fields of study

4.1. Statistical Distribution

Halton Arp and colleagues found that three aspects of quasar distribution were anomalous: Their distribution amongst other objects, that is, the 2-D density of quasars on the sky, showed an inordinate prevalence of quasars paired in close (angular) proximity across Active Galactic Nuclei; objects apparently physically associated in space had significantly varying redshifts; and the asymmetrical concentrations of isophotes on AGN/quasar maps indicated that the quasars were moving away from the AGN, suggesting ejection. It is not practicable to present here an analysis of each case, so I have selectively chosen three examples to illustrate the principles being put forward. It is interesting to note Arp's use of the collective noun "family" in his recent work; it emphasises the important increase in power and resolution of modern surveys. From the first tentative observed alignments of pairs of quasars in the 1960s, we are now introduced to groups of ten or more closely gathered around active galaxies.

4.1.1. NGC 3516: The Rosetta Stone

In 1997, Halton Arp, together with a team of Chinese astronomers, published a landmark paper: "Quasars around the Seyfert Galaxy NGC3516." [9] Arp has described this system as the "Rosetta Stone" of Intrinsic Redshift. He says:

> We report redshift measurements of 5 X-ray emitting blue stellar objects (BSOs) located less than 12 arc min from the X-ray Seyfert galaxy, NGC 3516. We find these quasars to be distributed along the minor axis of the galaxy and to show a very good correlation between their redshift and their angular distance from NGC 3516. All of the properties of the high redshift X-ray objects in the NGC 3516 field confirm the body of earlier results on quasars associated with active galaxies. We conclude that because of the number of objects in this one group, the evidence has been greatly strengthened that quasars are ejected from nearby active galaxies and exhibit intrinsic redshifts.

4.1.2. AM 2230-284 large quasar family

This striking example of a family of 14 quasars (reduced to 7 by magnitude constraints) gathered around the central galaxy AM 2230-284 is examined in one of Arp's most recent studies (Arp and Fulton 2008) [1]. Arp:

> In order to work with a manageable number of cases…I was asked to excerpt from the most constrained test a list of the families with the largest number of detected companions. The list supplied 44 galaxies with 7-9 such companions. Glancing through these associations revealed the sur-

> prising appearance of families in which many of the quasar companions were strikingly similar in redshift. In one case the redshifts of all 7 quasars within a radius of $d = 30$ were closely the same…The fact that there are so many quasars all of nearly the same redshift around this galaxy marks them as being associated with a high degree of probability.(…)

The peculiarity of this system typically extends also to the rate at which it expands intrinsically. Radial expansion at 3600 km s^{-1} is measured, which includes a significant ejection component. Conservatively, we may say that $V_{exp} \ll 3600$ km s^{-1}. We may then check to see if it matches the expansion rate expected if it really were at its redshift-supposed distance. Arp says:

> It is interesting to calculate what the rate of expansion would be if the cluster were at its conventional redshift distance…Hence the cluster should be expanding with 9, 955 km/s. But only 3, 600 km/s is measured and most, if not all, of that is deemed ejection velocity. At the conventional redshift distance, however, just the expansion of space should imprint nearly 3 times as much front to back expansion velocity than actually measured for this quasar cluster.

4.1.3. The Quasars around NGC5985

Halton Arp "Redshifts of New Galaxies": [10]

> (It) shows one of the most exact alignments of quasars and galaxies known. Attention was drawn to this region when it was discovered that a very blue galaxy in the second Byurakan Survey had a quasar of redshift $z = 0.81$ only 2.4 arcsecs from its nucleus. Even multiplying by 3×10^4 galaxies of this apparent magnitude or brighter in their survey they estimated only a chance proximity of 10^{-3}. A combined numerical probability of the configuration gives a chance of around 10^{-9} to 10^{-10} of being accidental. Nevertheless several peer reviewers recommended against publication on the grounds that the accidental probability was 'greater' than this. But, of course, several dozens of cases of anomalous associations had been reported since 1966 with chance probabilities running from 10^{-4} to 10^{-5}. What is the combined probability of all these previous cases? And what is the motivation to claim each new case is '*a posteriori*'?

4.2. Physical association in specific systems

Meanwhile, the original observations catalogued by Dr Arp had prompted open enquiry by a number of astronomers in various fields of study. At the *Instituto de Astrofisica de Canarias*, Martin Lopez-Corredoira and Carlos Gutierrez (hereafter L-C & G), both professional astronomers, studied individual systems to try to establish the presence of evidence supporting or refuting physical associations and material connections between objects in apparent proximity incompatible with their respective redshifts.

In their classic 2005 paper, "Research on Candidates for Non-Cosmological Redshifts," [11], L-C & G hint at their uphill battle for telescope time:

> A surprising fact regarding our observations is that we have observed only about a dozen systems. The reason is mainly because we obtained only a few nights of observation time on 2 to 4 metre telescopes. In subsequent applications, no time was obtained despite our having published several papers in major astronomical journals on the topic.

It is worth adding that of the 12 they were permitted to observe, fully half were found to contain definite anomalies, clearly justifying their research.

L-C & G had set themselves the target of trying to investigate, by close observation, the discordant redshift associations listed in Arp's Atlas—a daunting task given the sheer numbers involved. They say:

> The sample of discordant redshift associations given in Arp's atlas is indeed quite large, and most of the objects remain to be analysed thoroughly. For about 5 years, we have been running a project to observe some of these cases in detail, and some new anomalies have been added to those already known. For instance, in some exotic configurations such as NGC 7603 or NEQ3, which can even show bridges connecting four objects with very different redshifts, and the probability for this to be a projection of background sources is very low.

4.2.1. Markarian 205

The classic case, featured on the covers of all Arp's books, is the famous "invisible" bridge linking NGC 4319 and the quasar Mrk 205. Arp published the original images in 1972. In the early 1980s, Dr Jack Sulentic soundly debunked two much-cited papers that claimed the observed bridge simply did not exist, and in 2007, he reacted again to similar claims, this time in a press release from Hubble Heritage. "The papers H. Arp and I wrote have never been refuted in the literature. Did we make a mistake no one told us about?" In the HST image, Sulentic says:

> You can see the narrow core in the connection, which HST is able to detect because of its excellent resolution. It is seen exactly where we found it in the earlier studies…Hubble Space Telescope has in fact, confirmed our earlier work.

4.2.2. NGC 7603

In 2002, these two astronomers applied for telescope time to study the field surrounding NGC 7603 [12]. It is particularly interesting because it is one of the cases where filamentary connections appear between objects of different redshift. In 2004, they revisited the study, and published a comprehensive summary paper in *Astronomy & Astrophysics*, entitled "Research on candidates for non-cosmological redshifts." [11] The authors presented in this review new evidence from this specific set of observations, particularly concerning two knots in the filament connecting NGC 7603 ($z = 0.029$) and NGC 7603B ($z = 0.057$).

> The angular proximity of both galaxies and the apparently luminous connection between them makes the system an important example of a possi-

> ble anomalous redshift association. Arp has claimed that the compact member, NGC 7603B, was somehow ejected from the bigger object. Moreover, there are also two objects overimposed on the filament apparently connecting both galaxies. We identified several emission lines in the spectra of the two knots, and…we determined their redshifts to be 0.394±0.002 and 0.245±0.002 for the objects closest to and farthest from NGC 7603 respectively…According to the line ratios, these objects are HII-galaxies but are quite peculiar…However, if we consider an anomalous intrinsic redshift case…they would be on the faint tail of the HII-galaxies; they would be dwarf galaxies, 'tidal dwarfs', and this would explain the observed strong star formation ratio...Of course, this would imply that we have non-cosmological redshifts.

L-C & G conclude [11]:

> Therefore, some facts, although not conclusive, seem to suggest that there is an interaction between the four galaxies of different redshift: the existence of the filament itself, the strong Hα emission apparently observed in the HII galaxies typical of dwarf galaxies, and the low probability of having three background sources projected on to the filament. As a speculative hypothesis, we might think that the three galaxies were ejected by NGC 7603…it seems extremely unlikely that objects 1–4 at different distances can, by chance, give a projection in the way these figures show up.

4.2.3. MGC 7-25-46, NGC 7319, and Stephan's Quintet

In 2004, Margaret Burbidge presented to the annual meeting of the American Astronomical Society a paper that created alarm in the world of cosmology. It was called "The Discovery of a High Redshift X-Ray Emitting QSO Very Close to the Nucleus of NGC 7319." [13] In it, the authors presented observational evidence that a strong X-ray source (an *Ultraluminous X-ray Source* or ULX) with relatively high redshift ($z = 2.114$) lay in the *foreground* of NGC 7319, an active galaxy with relatively low redshift ($z = 0.022$). Several tests were conducted to determine whether or not it lay in the foreground, for if it were, beyond reasonable doubt, the case would be conclusive.

Is the QSO behind the galaxy?

> It is not surprising that interstellar sodium D1 and D2 absorption are seen in the spectrum of the QSO. If the ejected gas and the QSO lie near the plane of the disk, however disrupted that may be, we would still expect about half the possible optical depth of gas between the QSO and the observer. But we have no way of knowing whether the amount of gas observed here represents the total column of gas through the system, half, or even less. One obvious question suggests itself, namely: Does the color of the QSO indicate that it is inordinately reddened and therefore obscured as if it were a background object? […] We find that it is about 0.1 to 0.2 mag. bluer than average.

They conclude:

> We have clearly demonstrated that the ULX lying 8 arc sec from the nucleus of NGC 7319 is a high redshift QSO. This is to be added to the list of

> more than 20 ULX candidates which have all turned out to be genuine QSOs. Since all of these objects lie within a few arc minutes or less of the centres of these galaxies, the probability that any of them are QSOs at cosmological distance, observed through the disk of the galaxy, is negligibly small." [13]

4.2.4. Double radio source 3C343.1

Dr Arp and the Doctors Burbidge published the results of their study in 2004: "The Double Radio Source 3C343.1: A galaxy-QSO pair with very different redshifts." [5] They summarise the case as follows:

> The strong radio source 3C343.1 consists of a galaxy and a QSO separated by no more than about 0.25″. The chance of this being an accidental superposition is conservatively ~1×10^{-8}. The $z = 0.344$ galaxy is connected to the $z = 0.750$ QSO by a radio bridge. The numerical relation between the two redshifts is that predicted from previous associations. This pair is an extreme example of many similar physical associations of QSOs and galaxies with very different redshifts... We have discussed this pair of objects from the standpoint of whether there could be any 'a posteriori quality' to their extraordinarily small probability of being an accidental configuration. In fact we have found that this pair has properties very similar, but more extreme than most of the other associations of QSOs and galaxies which have been discovered earlier—properties of nearness, alignment, disturbances, connections. Since there are very few cases that have been examined this closely, the possibility is raised that there are more such associations to be discovered.

4.2.5. NEQ 3

This is a system of 3 compact objects with angular spread < 6 arcsecs, aligned with the minor axis of a lenticular galaxy at ~ 17 arcsecs. Although it is an intriguing astronomical system, the only prior study of NEQ3 had been by Arp, some 27 years previously. He had noted a filament connecting the galaxy and the 3 outriggers, and L-C & G studied the system in some detail. In "QSO + Galaxy association & discrepant redshifts in NEQ3," [15] L-C & G state:

> A filament is situated along the optical line connecting the main galaxy and the three compact objects. We have obtained a better image of the filament (previously noted by Arp) along the line of the minor axis of object 4…again, as in NGC 7603, we have seen that the system is even more anomalous than previously thought: we now have three different redshifts instead of two. Also as in NGC 7603, the origin of the filament is a mystery; it is supposed to be due to the interaction of the pair 1,2 with some other galaxy to the south-west. Where is this object? It seems that object 4 is the galaxy concerned, and this would imply anomalous redshift.

4.3. Redshift survey of local galaxies

David G Russell (as distinct from David M Russell of the University of Southampton, who publishes also in astrophysics) is engaged in an ongoing, novel study of spiral galaxies in the Virgo Cluster, using the Tully-

Fisher Relationship (TFR) to identify those galaxies that were physically bound in the cluster, and then comparing their mean redshift values. TFR describes an empirically derived correlation between the spin rate and luminosity of certain classes of spiral galaxy. It is an extremely robust ratio, remaining tight over at least 7 magnitudes, which represents a factor of 600 in luminosity. In 60 years of use, the TFR principle has entrenched itself as a major component in the extragalactic distance scale, and is widely regarded as the second most reliable measure of remoteness at that scale, or, to put it another way, it the most important secondary measure of cosmological distance.

In his 2003 paper "Intrinsic Redshifts in Normal Spiral Galaxies," [16] Russell states:

> The Tully-Fisher (TF) relation calibrated in both the B-band and the I-band indicates that
>
> 1) The redshift distribution of Virgo Cluster spirals has a morphological dependence that is inconsistent with a peculiar velocity interpretation.
> 2) Galaxies of morphology similar to ScI galaxies have a systematic excess redshift component relative to the redshift expected from a Hubble Constant of 72 km s^{-1} Mpc^{-1}.
> 3) Pairs and groups of galaxies exist for which the TF relation provides excellent agreement among individual members, but for which the group redshift deviates strongly from the predictions of the Hubble Relation.
>
> It is again found that morphology plays a role as these galaxies are all of Hubble types Sbc and Sc. The overall results of this study indicate that normal Sbc and Sc galaxies have a systematic excess redshift component relative to the predictions of the standard Hubble relation assuming a Hubble Constant of 72 km s^{-1} Mpc^{-1}. The excess redshifts identified in this analysis are consistent with the expectations of previous claims for non-cosmological (intrinsic) redshifts.
>
> The most dramatic result in Table IV is the extreme excess redshifts of the ScI/Seyfert group. Since three of these galaxies (NGC 4321, NGC 4535, NGC 4536) have Cepheid distances it is unlikely that this phenomenon results from inaccurate distances (see also Arp 2002). The result cannot be attributed to the morphological density relation (Dressler 1980) because the redshift excess is systematically positive and the galaxies in question are on both the front and backside of the mean cluster distance. Adopting a strict velocity interpretation of galaxy redshifts requires that as a group the giant Sb galaxies are approaching the Milky Way with a mean velocity of –898 km s^{-1} while the giant ScI galaxies are receding from the Milky Way with a mean velocity of +824 km s^{-1}.

The implication of Russell's last sentence is crucial—the standard redshift interpretation of velocity would have us believe that galaxies migrate peculiarly by *type!* The notion of species-dependent universal expansion is an exceptionally strong argument against the Hubble Law.

4.4. Large-scale structure: The "Finger of God" and Kaiser Effect anomalies in galaxy clusters.

J.C. Jackson [17] in 1972 found an observational effect in galaxy distribution data that caused clusters of galaxies to appear elongated when expressed in redshift space, taking on the appearance of "fingers" pointing towards Earth. The virial association of high velocities in clusters with their gravitation distorts the Hubble redshift relationship, and consequently, distance measurements are inaccurate, that is, anomalous according to the model. N. Kaiser [18] in 1987 revealed a related but smaller effect occurring in even larger structures. These *"Pancakes of God"* are attributed to line-of-sight distortion unrelated to distributions predicted by the virial theorem.

Furthermore, redshift-mapped large structures give anomalous results in terms of the Cosmological Principle, a fundamental requirement of the Standard Model of Cosmology, and the mathematical bedrock of universal expansion theory. In the paper "Large Scale Structure in the Universe Indicated by Galaxy Clusters," [7] Neta Bahcall states:

> The results imply the existence of very large-scale structures with scales of ~ 100-150h^{-1} Mpc…[]…The cosmological principle states that the Universe is homogeneous and isotropic. Observations of galaxies and clusters, however, show inhomogeneities and structure on all scales studied so far…When does the Universe become homogeneous? How does the clumpy distribution of luminous matter fit with the highly isotropic distribution of the microwave background radiation on the largest scales? The answers are not known yet.

Either the redshift data are anomalous, or the implied spatial properties do not fit, or both.

They are anomalous also for the λ-CDM model. Bahcall:

> The large scale structure results discussed in this review, however, constitute a difficulty for CDM. Considerable evidence for structure on scales ≥ 30h^{-1} Mpc has now been accumulated by a number of investigators; this large-scale structure (and velocity) cannot be matched by unadorned CDM models… If these largest scale results are confirmed by new and deeper observations, it will be damaging to the simplest CDM models. [7].

5. Periodicity

In 1967, Burbidge and Burbidge detected what appeared to be a quirky statistic in the redshifts of quasars: A preferred value of $z = 1.95$. In 1971, by which time the quasar database had expanded significantly, J. G. Karlsson established that quasar redshifts do indeed have preferred peaks, given by the formula $(1 + z_2)/(1 + z_1) = 1.23$, and tend to fall into the series $z = 0.061$, 0.30, 0.60, 0.91, 1.41, and 1.96. This phenomenon was verified by W.G. Tifft in a series of studies from 1976 to 1997, referenced in the supporting paper "Discrete Components in the Radial Velocities of ScI galaxies" by Bell, Comeau, and Russell [19]. Burbidge and Napier found in 2000 in their paper "The Distribution of Redshifts in New Samples of Quasi-Stellar Objects" [20] that

> The redshift distributions of the samples are found to exhibit distinct peaks…identical to that claimed in earlier samples but now extended out to higher redshift peaks…predicted by the formula but never seen before.

In March 2006, M. B. Bell and D. McDiarmid of the National Research Council of Canada published a paper entitled "Six Peaks Visible in Redshift Distribution of 46,400 Quasars…" [21] They find that

> The peak found corresponds to a redshift period of $\Delta z = \sim 0.70$. Not only is a distinct power peak observed, the locations of the peaks in the redshift distributions are in agreement with the preferred redshifts predicted by the intrinsic redshift equation.

Most recently (2008), Arp and Fulton published their findings "The 2dF Redshift Survey II: UGC 8584 – Redshift Periodicity and Rings" [22]:

> UGC 8584 was selected by a computer program as having a number of quasars around it that obeyed the Karlsson periodicity in its reference frame…9 of the nearest 10 quasars turned out to be extremely close to the predicted values.

6. Gravitational lensing

M. Lopez-Corredoira and C. M. Gutierrez, "Research on candidates to non-cosmological redshifts" [11] (in E. J. Lerner and J. B. Almeida, Eds., *1st Crisis in Cosmology Conference, CCC-1*, AIP Conference Proceedings, Vol 822, 2006):

> Weak gravitational lensing by dark matter has also been proposed as the cause of the statistical correlations between low and high redshift objects, but this seems to be insufficient to explain them, and cannot work at all for the correlations with the brightest and nearest galaxies. More recently, Scranton *et al.* have contradicted these results and have claimed that the correlation between QSOs and galaxies from the SDSS-survey is due to weak gravitational lensing. Indeed, what they have found was an ad hoc fit of the halo distribution function to an angular cross-correlation with very small amplitude of faint galaxies with QSO candidates selected photometrically (5% of this sample are not QSOs). Who knows what the origin is of this very small cross correlation? In any case, as said, no explanation of gravitational lensing for correlations with the brightest and nearest galaxies is possible in terms of gravitational lensing, for instance for the high amplitude angular correlation found by Chu *et al.* (and) Scranton *et al.*, even if they were right, have not solved the question of the correlation of galaxies and QSOs, because cross-correlations with bright and nearby galaxies, which are the most significant, are still without explanation in standard cosmological terms.

7. Discussion & Conclusion

The physical association between objects with different redshifts has been made abundantly clear in observation. In the documentary programme *Universe–the Cosmology Quest* [23], Geoff Burbidge puts it most succinctly:

> If you see two objects close together with very different redshifts, you only have one of two explanations. One is that a large part of the redshift has nothing to do with distance. The other is that it's an accident. So the real issue…is how frequently do you expect to see accidents?

High-resolution galaxy images acquired by powerful telescopes, and statistically significant samples from contemporary deep space surveys tell us clearly that we have a challenging situation. Galaxies are troubled, displaying morphological dynamics that defy convenient, simple classification into distinct species. We have seen images of galaxies giving vent to their inner turmoil by spewing matter into the close environment, in the form of clouds, filaments, jets, and compact objects, probably including quasars.

Whichever way we treat quasars in cosmological modelling, they are peculiar. If they are distant, they are too bright to be true, and if they are nearby, they call for extraordinary physics to explain ejection. The holographic map of galaxy clusters in redshift space produces fingers and pancakes that point towards us in a way that exaggerates our significance in the scheme of things, and in any event are unlikely to exist in real space. Additionally, the possibility of super-galactic-scale structure weighs against the Cosmological Principle.

Several arguments have been raised in discussion and in the literature against those made in this review, including that the measured masses of quasars allow the implied intrinsic brightness at redshift distance; that the observed matter bridges are merely spectroscopic artefacts; that clustering of QSOs around AGN is statistically trivial; that the Virgo Cluster is in fact two clusters consisting of exclusive galaxy types migrating in opposite directions; that emission and absorption ratios indicate cosmological remoteness. None of these arguments has been brought to a definite conclusion, and face well supported opposition by the authors cited in this review. There are at the time of writing no grounds to assume from the evidence before us that intrinsic redshift is positively excluded as a factor in the anomalous observations. The anomalies have not been resolved.

This paper asks the question, without implicitly stating an answer, "Do quasars present a compelling case that some additional cause of cosmological redshift, other than velocity, is prevalent in the Universe?" How we react to anomalous results is going to be crucial to the future of cosmology, the empirical foundation of astrophysics, and indeed, possibly the importance of scientists to the progress of society generally. How we incorporate discordant results into our knowledge base and theoretical structures will in my view define the relationship between astronomy and cosmology, and may well determine whether such a link can exist at all.

8. Acknowledgements

None of those mentioned here necessarily agrees or disagrees with any argument or inference made in this paper. I do not wish to imply that those who graciously offered me help are thereby indelibly stamped with the same philosophical and scientific persuasion as I am.

As always, Martin Lopez-Corredoira has taken time to share his experience with me, and review my work with a friendly, critical eye. Dave Russell is ever courteous, never too busy to swap data and ideas. Chip Arp has been magnanimous as usual, giving me free rein with his published work. Geoffrey Burbidge offered some incisive advice of a more general nature, which was gratefully received.

This paper is dedicated to my late mentor and teacher, South African solar astronomer Robert Bennett Blore, to whom my debt is incalculable.

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Coherent Spectroscopy in Astrophysics

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1. Introduction: Concerning light theory

At the beginning of 20th century, Planck and Einstein disagreed about the cause of the quantization of exchanges of energy between light and matter. Planck finally admitted the existence of what was to become the "photon" when Einstein proposed an interpretation of photoelectric emission of metals based on the assumption that the atoms are free in a metal. (Nowadays, we say that the "free" electrons make "plasmons."). In 1917, Einstein wrote the paper [Einstein*] which led to the discovery of lasers, in which he implicitly rejected the photon.

Quantum electrodynamics rigorously introduces the photon *via* a quantization of the energy of "normal modes" of the electromagnetic field. But the textbooks either do not give any definition of these "normal modes," or refer to a vague definition in acoustics. The best definition is: "a set of modes is *normal* if it is unable to exchange energy with other modes." W.E. Lamb, Jr., W.P. Schleich, M.O. Scully, & C.H. Townes criticized the use of these normal modes because absolute isolation of an optical system is impossible [Lambw*]. Thus they write that the photon is a "pseudo particle," not a small elementary particle. For example, a photon detected on a pixel of a photocell placed at the focus of a telescope has propagated in a volume defined by the mirror of the telescope, the image of a distant star on the photocell, and the length of the light pulses which make up ordinary time-incoherent light. A long time before its observation, the distant photon had a very large transverse dimension: it was a "flat photon," not an elementary particle.

Unfortunately, for a long time, Einstein's theory of optical coherence was ignored, and Townes was mocked when he tried to build the first laser. Now, most astrophysicists continue to cite Menzel [Menzel*], who, after confusing radiance and irradiance (http://en.wikipedia.org/wiki/Radiance) asserts that "it is easily proved that so-called coherent interactions are negligible in nebulae."

As a result, astrophysicists do not avail themselves of the magnificent tools developed in laboratories that work on or with lasers, in particular:

Impulsive Stimulated Raman Scattering (ISRS), super-radiance, multi-photon interactions. For example, when the propagation of light at the Lyman alpha frequency in atomic hydrogen is studied, the photons are assumed to be absorbed "on the spot" and re-emitted incoherently. A Monte-Carlo computation shows a scattering of light as in a cloud; here the addition of a strange hypothesis is needed. On the other hand, when Einstein's theory is used, a light beam propagates in an absorbing or amplifying homogeneous medium as in a transparent medium, except that its absolute spectral radiance at frequency ν, I_ν is changed along a path dx as $dI_\nu = B_\nu I_\nu dx$, where B_ν is Einstein's coefficient.

The previous formula seems absurd because it makes it appear that a dark beam $I_\nu = 0$ cannot be amplified. In 1911, Planck demonstrated that the minimal, mean value of absolute radiance of a monochromatic polarized light beam of frequency ν is the "zero point radiance" $I_{v,0} = h\nu / 2c^2$ [Planck*]. In place of absolute radiance, we often use a relative radiance which neglects the zero point radiance, but this is dangerous because energy is proportional to the square of the absolute field. By squaring a relative field, some physicists make a mistake in measurements by "photon counting" at low relative radiance, for instance in fourth-order interference experiments.

2. Impulsive Stimulated Raman Scattering (ISRS)

2.1 Theory of ISRS

When light propagates along a beam, it scatters (coherently, that is with the same wave surfaces) fractions of its amplitude without change of frequency, but with a phase-shift, usually a phase delay of $\pi/2$ (Rayleigh scattering). The interference of scattered light with exciting light usually produces a slightly delayed beam: this is refraction.

Is it possible to add Raman coherent scattering to Rayleigh coherent scattering? Generally not: because the Raman frequency $\nu \pm \rho$ is different from the incident frequency ν, the wavelengths are generally different, so that the phases of light arriving at a point X after scattering at points A, B, C,... generally differ, and interference cancels the scattered light.

A common trick is to use a convenient optically anisotropic crystal, for which wavelengths may be equal at two different frequencies. This is done, for instance, to double the frequency of infrared light and obtain a blue ray.

In a gas, another trick is adopted: light pulses are used to broaden the width of a spectral line, so that the profiles of exciting and scattered lines may mix. In this way, an incident and a scattered frequency may interfere. G. L. Lamb, Jr. established a simple condition: *The length of the pulses must be* *shorter than all time constants involved, i.e.*, the quadrupolar (Raman) period, and the collision time [Lambg*].

An elementary Fourier computation shows that interference leaves only a single intense line, the frequency of which is intermediate between the incident and scattered lines, in proportion to their amplitudes.

This ISRS is used, with femtosecond laser pulses, to study the evolution of chemical reactions.

If one assumes that polarisability does not depend on frequency, the relative frequency shift $\Delta\nu/\nu$ does not depend on ν. But, like Rayleigh scattering, Raman scattering depends on dispersion, so that $\Delta\nu/\nu$ is not exactly independent of ν.

2.2 Variation of ISRS with length of light pulses.

By Lamb's condition, assuming optimal conditions, increasing the length of pulses by a factor k results in a decrease of Raman shift ρ by a factor k, and an identical decrease of ISRS. Stokes and anti-Stokes Raman effects produce opposite effects, so that the shift is proportional to the difference of populations in the quadrupolar states, which, at thermal equilibrium, is proportional to the quadrupolar frequency: this means that ISRS is decreased by factor k. Collisional time must be increased by k, which requires a decrease of pressure by k. Thus, frequency shift decreases roughly proportionally to the cube of pulse length. A laboratory path in gas, which provides an easily observable frequency shift with 10 femtosecond pulses, must be multiplied by 10^{15} if 1 nanosecond pulses, which make up ordinary time-incoherent light, are used: with ordinary light, astronomical distances are needed.

2.3 Coherent Raman Effect acting on Incoherent Light. (CREIL).

A Raman effect populates the quadrupolar levels involved, which, in the absence of collisions, remain populated, and ISRS decreases. But suppose that several ISRS are simultaneous, so that the populations of quadrupolar levels remain constant: the gas becomes a catalyst which allows exchanges of energy between several light beams. ISRS thus becomes a "parametric effect"--CREIL. Simply put, by the laws of thermodynamics, entropy must increase through a cooling of hot beams, which decreases their frequencies, and a heating of cold beams. Cold beams of thermal radiation are always present.

It is interesting to note that Lamb's condition on pulse length applies only to the shortest pulses which limit interaction time, avoiding a reduction of frequency shifts by means of de-phased interactions.

3. Propagation of light in low pressure atomic hydrogen.

A CREIL frequency shift requires a quadrupolar resonance having a period longer than 1 nanosecond, that is a frequency lower than 1 GHz, but as large as possible for a strong effect. The 1420 MHz hyperfine resonance of atomic hydrogen in the ground state is too high. With a principal quantum number $n=2$, the hyperfine frequencies 178 MHz in state $2S_{1/2}$, 59 MHz in $2P_{1/2}$ and 24 MHz in $2P_{3/2}$ are convenient. In more excited states, the quadrupolar frequencies are much lower, so that CREIL works, but is weak. Now, $n=2$ atoms are generated in space in various conditions.

3.1 Propagation of light in hydrogen plasma

We assume that the size of a source is small, compared with distance between it and the region in which the propagation of light is studied. Thus, the source may be considered as a point.

If a plasma of pure hydrogen is very hot, all atoms are split into electrons and protons. If there is no external field, and if the density of plasma is low, these particles are free, so that they do not have a resonance frequency, and the plasma is perfectly transparent. If the hydrogen is not pure, there may be interactions of light with other atoms, absorptions or amplifications of light resulting from the value of Einstein's B coefficient.

At a lower temperature (200,000 K), some atoms are dissociated, while others may be excited, in particular in states 2P or 2S. A CREIL effect transfers energy from light to the thermal background: the light is thus redshifted. If the temperature is high enough (5000 K) for dissociation of H2 molecules but too low for excitation, that is lower than 50,000 K, there is no CREIL effect.

If a cloud of hydrogen is heated by a galaxy, or by hot stars, its radial dimension is directly increased through the application of Hubble's law, which measures not the distances, but, approximately, the column density of excited atomic hydrogen. The transverse dimensions are not increased in the same proportion because a small angle of observation is the ratio of a *local* transverse erroneous dimension to a *globally* erroneous distance. This results in the appearance of an anisotropy that some astronomers see on the maps, making the Earth appear to be at the centre of the universe.

The bubbles which are created give the maps a spongiform appearance, with filaments between close sets of bubbles.

3.2 Redshifts caused by atomic hydrogen pumped by light

Suppose that a hot object (a star) is surrounded by a cloud of hydrogen. Suppose that pressure and temperature are a decreasing function of altitude R. Suppose that the star emits a continuous spectrum in the UV-X region. Close to the star, the pressure is too high for a CREIL effect, and Lyman lines of H atoms are absorbed. Assume that where pressure becomes low enough for a CREIL effect, the temperature is too low for strong thermal excitation of atoms.

Where pressure becomes low enough for a CREIL, light cannot pump the atoms efficiently, because the Lyman spectrum has been absorbed. But the remaining thermal excitation provides a few $n=2$ atoms, and thus a weak redshift, so that the absorbed Lyman α line (denoted Ly_α) takes on a frequency slightly lower than a frequency ν_α of Ly_α. The atoms are pumped to the $n=2$ state, and a stronger redshift appears. The absorptions are diluted by the frequency shift, so that they are not visible in the spectrum.

If an *absorbed line* has Ly_α frequency, it will not pump atoms to the 2P state, thereby stopping the redshift. Assuming that the hydrogen is pure, the first absorbed line shifted to Ly_α frequency will be Ly_β. While the redshift effect is absent, all lines of the gas are imprinted onto the spectrum. The Lyman spectrum is thus imprinted twice onto the light, one at its own frequencies, and the other at frequencies shifted by redshift $Z_{\beta\alpha} = (\nu_\beta - \nu_\alpha)/\nu_\alpha$ which moves the Ly_β frequency to Ly_α frequency.

Since high frequency Lyman lines are absorbed while the redshift is absent, high atomic levels are excited, and these produce a weak redshift. The decay of the high levels may produce a weak redshift which moves the absorbed line away from frequency ν_α. This causes the redshift to resume.

The resumption requires an efficient pumping to higher states of H, due to Ly_β, Ly_γ, ... absorption. But, in the event of emission by a blackbody, the spectral radiation given by Planck's law decreases rapidly at high frequencies, so that this radiation may be too low to cause a resumption of redshift.

Thus, the beginning and the end of the entire process have a large probability of occurring when an absorbed Ly_β or Ly_γ acquires Ly_α frequency. Neglecting absorption by Ly_δ and higher frequency lines, the total redshift is the sum of redshifts $Z_{\beta\alpha}$ and $Z_{\gamma\alpha}$.

Space is therefore split around a hot star into spherical shells in which light is either redshifted or not redshifted. From the Rydberg formula (without Rydberg constant which cancels):

$$Z_{\beta\alpha} = \frac{\nu_\beta - \nu_\alpha}{\nu_\alpha} = \frac{\nu_\beta}{\nu_\alpha} - 1 = \frac{8/9}{3/4} - 1 = \frac{32}{27} - 1 = 0.185 = 3 * 0.0617$$

$$Z_{\gamma\alpha} = \frac{\nu_\gamma - \nu_\alpha}{\nu_\alpha} = \frac{\nu_\gamma}{\nu_\alpha} - 1 = \frac{15/16}{3/4} - 1 = \frac{5}{4} - 1 = 0.25 = 4 * 0.0625$$

Generally, the process starts and ends during an absorption, and the redshift of the star is a sum of these redshifts, which may be written

$$Z_{star}(n) = nK',$$

where n is a multiple sum of 3 and 4, and $K' = 0.062$.

3.3 Applications in astrophysics.

3.3.1 Redshifts of quasars and galaxies

Halton Arp [Arp1*] remarked that a quasar and a star which appear to be connected, for instance by an arc of matter, may have very different redshifts, showing that the usual interpretation of Hubble's law is incorrect. More generally, Arp and other authors have observed that hydrogen plasma seems to redshift light. The CREIL is a simple explanation, and it would appear to be the best available because it explains the following numerical coincidences:

Karlsson [Karlsson*], Burbidge [Burbidge*], Arp and more recent authors showed that the redshifts of most quasars and "compact, nearby galaxies" are close to $Z(n) = nK$, where n has integer values 3, 4, 6,... and $K = 0.061$. The high coincidence of both parameters shows that CREIL explains Karlsson's formula well, while no other theory does. Karlsson's formula does not apply to large or distant galaxies because with many sources, space cannot be divided into regions which shift frequencies of light, and regions which do not.

For a redshift $Z_{\beta,\alpha}$, a frequency F_β of an absorbed Lyman line β is multiplied by the ratio F_α / F_β to obtain frequency F_α. This multiplication applied to other frequencies would be valid if the redshift is a Doppler or a cosmological redshift. However, a spectrum shows that the result is not perfect: a frequency shift has the same dispersion as a refraction. This dispersion requires an interaction with matter that is it is not a cosmological redshift. It produces only a small distorsion of the spectrum, but it does not increase the number of lines between the redshifted Ly_α and Ly_β emission lines. Rauch M. and Murdin P. (ISBN: 0333750888) write that various molecules absorb these lines. Another process involving only H atoms contributes to "forests".

During a $Z_{\beta\alpha}$ redshift, low pressure hydrogen excites H atoms in their ground state to produce the 2P atoms required for the redshift. The density of atoms in an excited state increases and the gas becomes a stronger and stronger amplifier, though the temperature corresponding to the excited atoms remains necessarily lower than the temperature of starlight at frequency shifted to the local Lyman α frequency. When population 2P is sufficient for a large Einstein amplification coefficient B, in a sto-

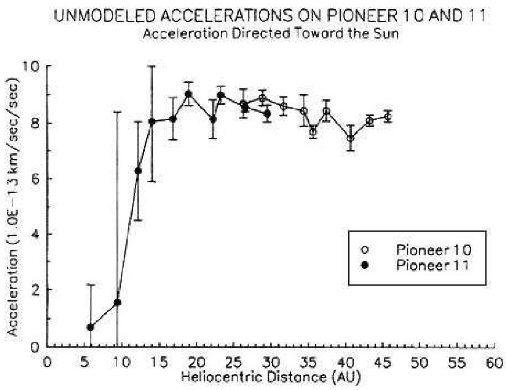

Figure 1. From Anderson *et al.* [Anderson*] Cooling of expanding solar wind creates excited atomic hydrogen between 10 and 15 AU.

chastic direction, a ray becomes strongly superradiant so that, if this flash bursts into the direction of Earth, a flare is observed close to the quasar.

Each flash emission strongly absorbs energy from atoms and light, writing a sharp absorption line in the observed spectrum. The same process of redshift and flashes works using, in place of β, any absorbed line, in particular redshifted γ and β lines absorbed during any stop of redshift.

3.3.2 Accreting neutron stars are called quasars

As the origin of the redshifts of quasars is mainly spectroscopic, Arp's demonstrations are sound, and most quasars are relatively close to our galaxy. Their temperatures are high, while they are not very bright, so they are small stars. In searching for radio-emitting stars, astronomers find weak neutron stars outside nebulae, and, inside nebulae, brighter, more redshifted stars that they call "quasars." As a result, in the classification of neutron stars, the "accreting neutron stars" category remains empty.

3.3.3 Blueshifts of cold radiation

From Planck's law, low frequency electromagnetic beams are generally cold, while light is generally hot. Solar wind expands and cools, so that at 10 AU, electrons and protons react, making excited atomic hydrogen. At 15 AU, atomic hydrogen is de-excited.

The density of the solar wind is not constant, and its spatial variation is bound to the ecliptic. So the density of excited H atoms able to transfer energy from sunlight to thermal radiation is bound to the ecliptic. Consequently, thermal radiation received from the universe is also bound to the ecliptic, as observed.

Transfer of energy from sunlight to microwaves crossing this region produces frequency shifts. Microwaves used to transmit information be-

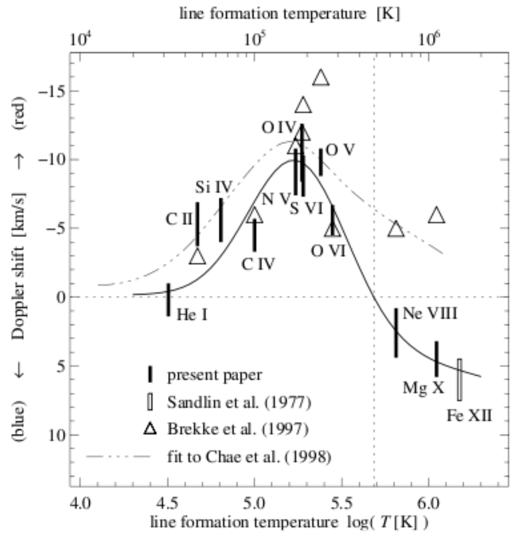

Figure 2 . From Peter & Judge [Peter*]. Variation of Doppler shift at center of Sun's disk, with formation temperature of the line. Assuming the Sumer calibration is good, the direction of the shift should be reversed.

tween probes and the Earth may cross the shell of excited hydrogen, in which energy is transferred from sunlight to microwaves.

As long as the distance of the probes (Pioneer 10 and 11; Figure 1) is less than 10 UA, the observed frequency shift of microwaves is exactly the Doppler shift computed from celestial mechanics. When the probe is between 10 and 15 AU, there will be a gradual increase of observed frequency, which is commonly considered to be due to an "anomalous acceleration."

3.4 Is it possible to obtain a stronger CREIL using dense matter?

A parameter which weakens CREIL is collisional time. In standard spectroscopy, collisions may be avoided and sharp lines obtained using crystals, but it is impossible to make very large crystals. However, it is possible to fix atoms or molecules tightly using high pressure, so that lines become sharp, and the mechanical exchanges of energy with the exterior are low.

We make an exception in this section, using uncertain arguments while in the remainder of this paper we use only well-established physics.

It is generally assumed that the frequency shifts of far UV spectral lines of the Sun result from the Doppler effect due to vertical movements of matter. Thus, the frequency shifts should be larger at the centre of the disk than at the limb.

H. Peter and P. G. Judge ([Peter*] have studied the UV spectrum of the Sun observed by the SUMER spectrometer on the SOHO aircraft (Figure 2). As they did not believe in the SUMER calibration, they calibrated the spectra assuming that the lines were not shifted at the limb and using chromospheric lines.

Suppose that the SUMER calibration is good, and that a CREIL frequency shift is larger at the limb than at the center of the disk. The sign of the shift on Peter and Judge's figure would have to be changed, so that the Fe XII line is redshifted while the O V line is blueshifted. The shift is larger at the limb because the path of light in a pseudo-crystal is larger for an emission of an X line at a frequency fixed by temperature, and thus fixed depth.

The CREIL explanation of all these results is simple: While the Fe XII line propagates from the hot deep region where it was emitted, it heats colder radiation, in particular the O V line, … When the O V line propagates to the surface, interaction with Fe XII radiation causes heating, adding more energy than was lost to heat the colder radiation: the O V line is thus blue-shifted.

4. Superradiance

Light beams are not strongly altered by coherent interactions, allowing observation of distant images, despite possible deformation by refraction, for instance.

For a long time, Einstein's theory of coherent interactions of light with matter was ignored, or neglected. After the discovery of lasers, physicists began studying and applying optical coherence. However, following Menzel, astrophysicists did not. An astrophysicist might say: We do not ignore lasers and masers: we have found them in space. Unfortunately, what they have found are *superradiant sources,* whereas lasers and masers are combinations of superradiant sources with electromagnetic wave resonators. It would appear to be difficult to find the precision required for these resonators in nature.

4.1 Theory of superradiance

In the introduction we recalled that in 1911, Planck [Planck*] corrected the formula he had found in 1900 for the radiance of light beams inside a blackbody: The absolute spectral radiance of a polarized beam propagating in a blackbody is:

$$I_\nu = \frac{h\nu^3}{2c^2}\left[1+\frac{2}{\exp\left(h\nu/kT\right)-1}\right] \qquad \text{(1911 Planck's law [Planck*])}$$

where ν is the frequency and T the temperature of the blackbody.

This *absolute* radiance differs from *relative* radiance for which the first "1" is omitted. This is used to compute energy, which depends on the square of the field. Using relative radiance introduces a common error which is large (a factor of 2) at low energies, for instance in photon counting. We must therefore always use absolute radiance. Planck's formula enables us to find the temperature of a light beam from its frequency and absolute radiance.

In a paper he published in 1917 [Einstein*], Einstein introduced coherent propagation of light in matter by means of thermodynamics. Coherent propagation requires a large number of identical scattering sources. "Identical molecules" must have the same behaviour in an electromagnetic field, *i.e.*, they must have the same spectrum. The spectrum of colliding molecules depends on conditions of collision, and it evolves during collision: thus, two sets of two colliding molecules are different.

In atmosphere, Rayleigh coherent scattering produces refraction, while Rayleigh incoherent scattering by colliding molecules produces the blue of sky. As collisions become rarer in the stratosphere, the sky becomes dark.

The Einstein theory defines the variation dI_ν of absolute spectral radiance I_ν along a length of path dx as $dI_\nu = B_\nu I_\nu dx$, where B_ν is Einstein's coefficient, which depends on frequency ν and on the state of the medium being crossed. With usual thermal sources in the visible range, $h\nu$ is much larger than kT, so that radiance is close to zero point radiance $I_{\nu 0}$, and dI_ν is proportional to dx. But, in a plasma, such as in laser tubes, assuming a constant B, the increase of radiance is exponential, so I_ν may become much larger than $I_{\nu 0}$.

Suppose that two beams cross in a volume V of a source. The amplification of the beams de-excites the high levels involved, so that B decreases: the amplification of the weakest beam is decreased by the amplification of the strongest. This "competition of modes" is observed in gas laser tubes where transverse radiation at the laser's frequency is reduced nearly to zero when the laser beam starts up. Usually, a beam is called "superradiant" if its radiance is at least twice the zero point radiance.

4.2 Superradiance of Strömgren spheres

Strömgren studied a model consisting of a hot star surrounded by low pressure hydrogen [Strömgren*]: UV radiated by the star ionizes hydrogen into protons and electrons. The temperature is assumed high enough within a sphere of radius R to prevent any significant combination of protons and electrons. Close to the surface of the sphere, some atoms appear. They are highly excited and radiate strongly, cooling by means of collisions of the electrons and protons, which may combine and start an exponential cooling of the system.

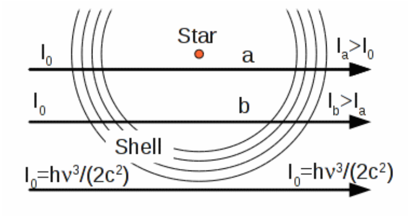

Figure 3. Variation of absolute radiances of polarized rays crossing a Strömgren shell (see text).

The sphere thus becomes surrounded by a spherical shell which radiates strongly. Strömgren was probably not aware of superradiance and competition of modes.

In Figure 3, the shell is split virtually into infinitesimal concentric shells. Compare the absolute, unpolarized radiances of rays a and b: in any infinitesimal shell, the path of b is greater than the path of a, which is closer to the star. When the distance r between the star and the ray is increased, the amplification increases until r reaches the radius of sphere R. It then decreases to zero. Thus, the rays tangent to the sphere are amplified the most.

By competition of modes, only rays tangent to the sphere are bright: the image of the sphere is reduced to the limb. If superradiance is large, competition of modes may work between the rays which define a limb: the limb is thus punctuated.

4.3 Observation of Strömgren spheres

Strömgren spheres are not necessarily static and relatively dense. For example, the solar wind forms a Strömgren sphere, the radius of which is around 10 AU. Is it dense enough to be observable from outside?

Many types of Strömgren spheres appear in the sky: bubbles, circles, dotted circles with or without a central star. For instance, Einstein's Cross (Figure 4) may be an image of a Strömgren sphere rather than a set of images resulting from a gravitational lensing by a massive star, of light emitted by a well aligned, bright star.

Suppose that a Strömgren shell is slightly less powerful than that in SNR B0509-67.5 (Figure 5), so that the bubble is invisible. Suppose that there are many weak stars in the background. The light beams emitted from stars to Earth, which are nearly tangent to the sphere, are strongly amplified at Lyman hydrogen frequencies, and bright stars appear on a circle.

It is remarkable that H. Arp observed such a circle of stars around SDSS 122524.87+092307.1. [Arp2*].

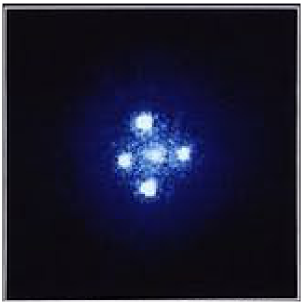

Figure 4: Einstein cross :The European Space Agency's Faint Object Camera on board NASA's Hubble Space Telescope.

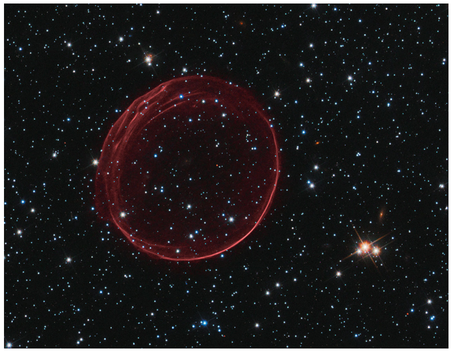

Figure 5: SNR B0509-67.5, "giant red gas bubble" Hubble telescope, NASA, EESA.

As few beams are strongly superradiant, cooling of hydrogen by radiation is not fast, so that the Strömgren shell is thick and thus able to amplify light at Lyman frequencies in all directions. In particular, light emitted by the star which creates the Strömgren system is amplified at Lyman frequencies. This amplification may function like the emission of a multimode laser, so that the star has many "images" and may appear as a "compact, nearby galaxy," *i.e.*, a pseudo-galaxy.

It would be easy to detect whether a galaxy, or any set of points, such as Einstein's cross, is generated by superradiant amplification with competition of modes or corresponds to different objects: in the first case, there is a coherence between the spots, which may be detected by the appearance of interferences by superposition of two images caused by the introduction of a bi-prism somewhere on the path of light.

Note that amplification of light works on the Lyman lines, so that other regions of the initial spectrum keep their low intensity: *this resets the frequency shift of the lines to zero*. Thus, the observed redshifts around SDSS 122524.87+092307.1[Arp2*] have the same orders of magnitude. Different sizes of spots may result from initial superradiances at various frequencies.

Good spectroscopy of the sets of points and a much simpler comparison of their phases would be necessary.

5. Multiphoton interactions in SNR1987 A

After the explosion of SN1987A (Figure 6), light emitted by the star was scattered by a region surrounding the star having the shape of an hourglass. Three rings then appeared at the limbs of the hourglass, while the star disappeared. We believe that the hourglass is a Strömgren shell

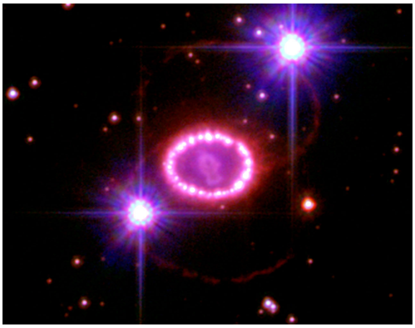

Figure 6: Hubble space telescope. While the smaller ring is over-exposed, the two large rings are hardly visible. Two bright, overexposed stars are surrounded by diffraction rings of the telescope. Close to the rings, their intensities may be amplified by the supernova shell.

pinched by the presence of one or more satellites which partially absorb light emitted by the star in their orbital plane.

The standard explanation of rings is a collision of winds. But this does not explain the fact that the star disappeared exactly when the rings appeared. It does not explain the permanent brightness of the rings.

We may imagine that the hydrogen atoms forming the hourglass absorb energy radiated by the star at Lyman and other H frequencies, so that the hourglass remains excited. But this does not explain the fact that about half of the energy emitted by the star is transferred to the rings.

Some lasers are energized by light emitted by flash lamps surrounding the active medium. The power emitted on the laser lines is higher than the power able to pump the atoms directly. We may imagine a lot of indirect pumping, but all required transitions are simultaneous, in a nonlinear absorption/emission process.

The radiance of light beams emitted by the star is very large at all frequencies. It is possible to add or subtract several frequencies to obtain a resonance frequency of the hydrogen atoms. The whole spectrum may therefore be absorbed, causing the superradiant rays to be amplified. All these steps in energy transfer from the star's white light to superradiant rays are combined into a single parametric effect which transfers a large fraction of the star's very hot white radiation to the much less hot superradiant radiation. *The onset of this parametric effect explains the disappearance of the star when the rings appear.* (See Figure 7.)

Michael *et al.* (Figure 8) have studied the light emitted inside the small ring of SNR1987A., *i.e.*, the rays a or b in Figure 3. Assume that the gas inside the sphere contains traces of non-hydrogen atoms, the spectrum of which is flat in the Lyman alpha region of H. Assume that density of H at-

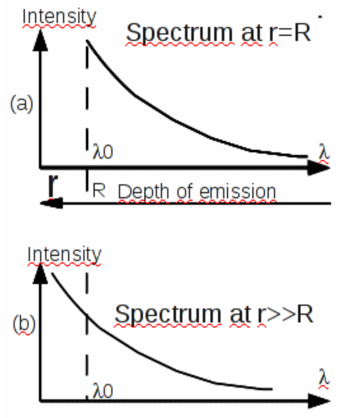

Figure 7a: Radial emission in Ly_α of a Strömgren sphere: in the centre, it is more redshifted because the path through excited hydrogen is long, and weaker because the atoms are rare.
Figure 7b: Blueshift of (a). In the shell irradiance by superradiant rays is large and excited atoms are abundant.

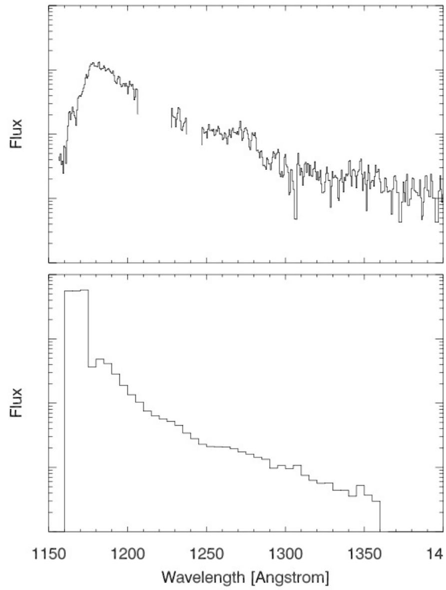

Fig. 8 From Michael *et al.*: "Lyα" interior" emission profiles. Top: The observed profile from a region inside the ring. Bottom: The Lyα profile produced by one-dimensional Monte Carlo simulation of resonant scattering in the Lyα line. Although photons in this profile are originally produced on the near side of the remnant, they can emerge from the remnant substantially redshifted." Note that by Monte-Carlo computation, the maximum flux which saturates the recorder is much higher than mean flux.

oms increases exponentially depending on the distance r to the star, up to the surface of the sphere ($r = R$), where superradiance appears.

Deep inside the hourglass, Ly_α emission is low and propagates through a region containing more and more H atoms: redshift is thus high because irradiance from the starlight is low (the star is distant) while background irradiance is nearly a constant. When r increases, emission increases and redshift decreases. For $r = R$, the flux of emitted light is at its maximum, and there is no more redshift. For $r > R$, irradiance by superradiant beams appears and is much stronger than irradiance by the star or background, so the spectrum is blueshifted. The spectrum computed by Michael *et al.* using Monte-Carlo simulation and incoherence is very different because the flux becomes very large (probably, it saturates the recorder) on the low side, while our spectrum is cut by the output of light from the sphere, and its blueshift is explained. Our triangular spectrum is frequently observed in astronomy.

While this local emission of light is observed inside the small ring, no background stars are visible: the ring is an optical black hole.

6. Conclusion

While optical coherence explains numerous observations, it is limited here to models involving pure hydrogen: the introduction of other atoms or molecules will require good experimental and theoretical spectroscopy. A comparison of phases of bound spots is much easier and could help to distinguish between sets of light sources and sets of optical modes.

The Big Bang theory requires many additional hypotheses and theories (variation of fine structure constant, dark matter and energy, MOND, *etc.*) to explain observations. The use of correct spectroscopy offers simpler explanations. The medieval-style persecution of scientists like Halton Arp, Jean-Claude Pecker, Fred Hoyle, and others has caused science to lose a lot of time and cost our society a lot of money.

Acknowledgments

I would like to thank Roy Keys and Chris Fulton for helpful comments and suggestions.

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Two Radio Arcs Emanating from SDSS J095951.46+012033.7

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We researched existing observations in order to investigate what appear to be two arcs of radio isophotes emanating from the spiral galaxy SDSS J095951.46+012033.7

Key words: galaxies: active, quasars: general, EM continuum: general

1. Introduction

Our attention was drawn to the spiral galaxy SDSS J095951.46+012033.7 by two arcs of radio isophotes apparently emanating from the galaxy in roughly opposite directions out to an angular distance of ~35′. We have reviewed and presented herein the existing object and photometric observations within 45′ of the central galaxy[1]. We discuss the implications of these observations and suggest additional observations that could be obtained to establish that ejection has occurred and to elucidate the ejection mechanism and aftermath.

2. Existing Observations

Figures 1 and 2 show optical images of the central galaxy, and Figure 3 shows its spectrum. The galaxy has $g = 18.3$ and $z = 0.101$ and shows up in the infrared at 3.769 μm and in the optical at 4680 Å. Additional attributes of the galaxy are given in Appendix A. We examined objects and photometry in the surrounding environment of the central galaxy. The object environment is detailed in Appendix B and the photometric environment is detailed in Appendix C. The optical and radio photometry provide significant insights, whereas the available photometry in the other EM bands is only marginally informative.

[1] The object catalogues represented are 2dFGRS (Croom *et al.* 2001), 2MASX (Skrutskie *et al.* 2006), 2QZ (Sadler *et al.* 2002), APMUKS (Maddox *et al.* 1990), CGCG (Zwicky & Wild 1968), FGC (Karachentsev *et al.* 1999), IRAS (Moshir *et al.* 1989), LSBC (Schombert *et al.* 1997), NSC (Lopes *et al.* 2004), NVSS (Condon *et al.* 1998), PKS (Wright & Otrupcek 1990), RXS (Brinkman *et al.* 1999), SDSS (York *et al.* 2000), SN (Barbon *et al.* 1999), TXS (Douglas *et al.* 1996), UGC (Cotton *et al.* 1999), [PCd91] (Parma *et al.* 1991), and [SCS2004] (Schinnerer *et al.* 2004).

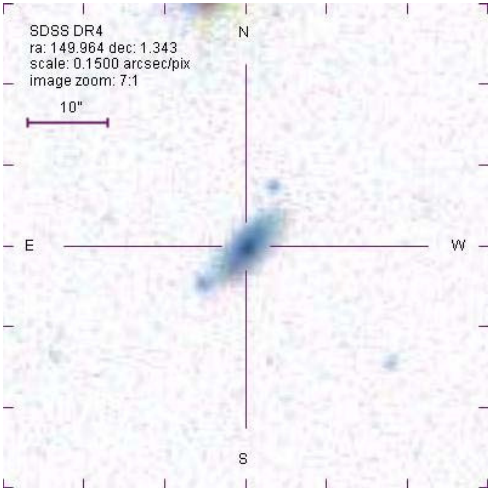

Fig. 1 — SDSS Optical Image of a 60 Square Arcminute Area around SDSS J095951.46+012033.7.

Visualizing the radio arcs and the central galaxy together requires an encompassing circle around the galaxy of radius $\sim 45'$, as shown in the NVSS image in Figure 4. A close-up of the northerly arc is shown in Figure 5 and of the westerly arc in Figure 6. In each radio figure the central galaxy and the eleven suspected arc member radio blobs are indicated with boldface letters **a** through **k**.

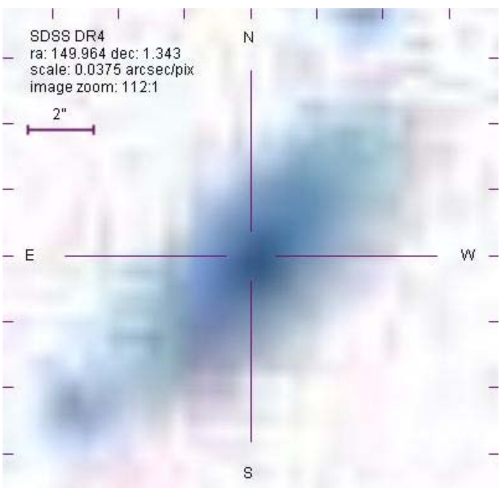

Fig. 2 — Close-up SDSS Optical Image of SDSS J095951.46+012033.7.

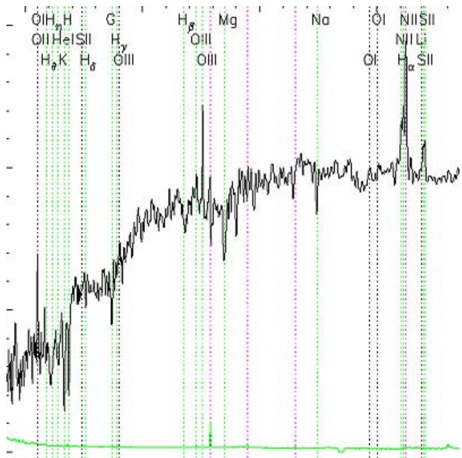

Fig. 3 — SDSS Spectrum of SDSS J095951.46+012033.7.

3. Discussion

We have selected the eleven radio blobs indicated in Figures 4, 5, and 6 as suspected arc member radio blobs, but we also concede the possibility that other isophotes in the area that are not aligned with an arc may also have an association with the central galaxy. We do suggest that the majority, if not all, of the radio isophotes leading away from the central galaxy and aligned with the apparent arcs have been ejected from the galaxy.

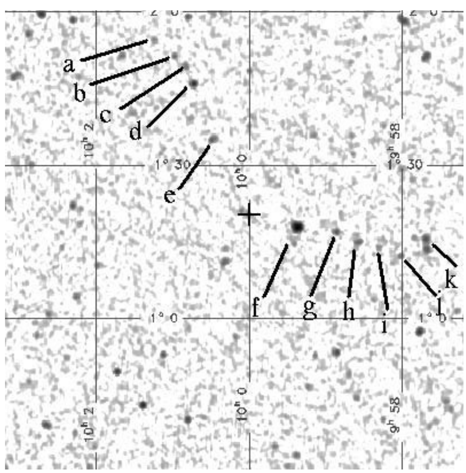

Fig. 4 — NVSS Radio Image of a 90 Square Arcminute Area around SDSS J095951.46+012033.7. The central galaxy is marked with a plus sign. The boldface letters indicate suspected arc member radio blobs.

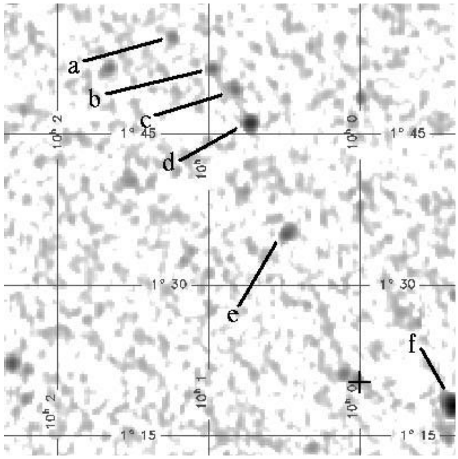

Fig. 5 — Close-up NVSS Radio Image of Northerly Radio Arc. The central galaxy is marked with a plus sign. The boldface letters indicate suspected arc member radio blobs.

3.1. The Northerly Radio Arc

In the northerly radio arc blobs **d** and **e** lie almost exactly in a straight line away from the central galaxy and the remaining northerly radio blobs make a gradual turn toward the E, giving the overall impression of an arc. Some of the radio blobs are clearly connected by radio trails. There is a complete radio trail linking blob **b** to **c** and another trail linking blob **c** to **d**. There is also a clear radio trail emanating from the central galaxy that points directly toward blob **e** and that reaches approximately three

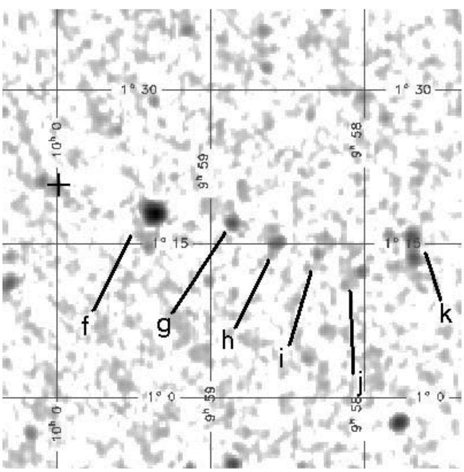

Fig. 6 — Close-up NVSS Radio Image of Westerly Radio Arc. The central galaxy is marked with a plus sign. The boldface letters indicate suspected arc member radio blobs.

quarters of the distance to that blob. Between blobs **a** and **b** and between blobs **d** and **e** there are additional radio isophotes, but not in the form of distinct trails. Nevertheless, the respective positions of these radio blobs make them likely members of the northerly radio arc.

3.2. The Westerly Radio Arc

In the westerly radio arc blobs **f** through **j** suggest an overall curvature that dips somewhat to the S, but on close examination this arc is actually more complex. There is a radio trail emanating from the central galaxy that points to blob **f** and that reaches approximately three quarters of the distance to that blob. This trail is the same in relative extent and appearance as the trail between the central galaxy and blob **e** in the northerly arc, but the westerly arc initial trail differs in that it is curved rather than straight. It starts toward the SW but turns to the W and comes level with blob **f**. From there outward the line of radio isophotes curves back to the WSW, straightens out approaching blob **j**, and then turns up quickly, going NNW to blob **k**. Blob **k** may indeed not be a member of the radio arc, but membership is suggested by its proximity to the other blobs and by the similarity of distances between the blobs leading up to it. There are also radio isophotes between the consecutive blobs from **f** through **k**, but, as with some of the blobs in the northerly arc, there are no distinct trails linking the blobs.

3.3. Nearby Galaxies and EM Sources

Figure 7 is a plot of a two square degree field around the central galaxy showing nearby galaxies with redshifts that are close to that of the central galaxy ($0.100 < z < 0.102$). There are other galaxies in the field at different redshifts as well as galaxies for which redshifts have not been obtained. Three of the same redshift galaxies that lie within 15′ could conceivably be contributing to the radio emission in the immediate vicinity and there are three more to the N that could contribute to the radio emission in the northerly arc. While some of the radio emission in the area may be produced by these other galaxies, the preponderance of the isophotes in the northerly radio arc would

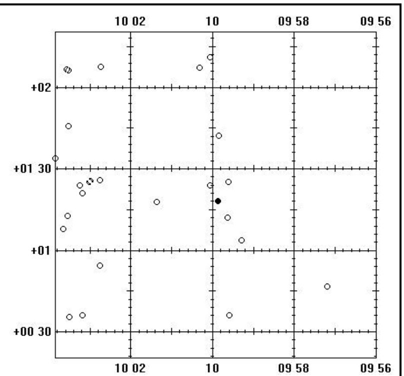

Fig. 7 — Plot of Galaxies Near the Central Galaxy. The central galaxy is indicated by a closed circle and nearby galaxies with $0.100 < z < 0.102$ are indicated by open circles.

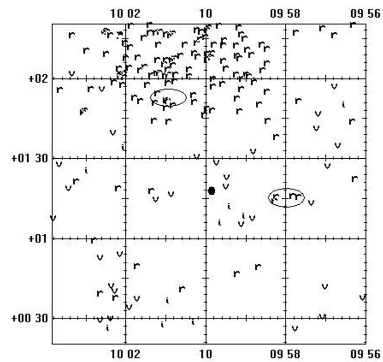

Fig. 8 — Plot of Infrared, Radio, and Visual Sources Near the Central Galaxy. The central galaxy is indicated by a closed circle and nearby infrared, radio, and visual sources are marked with i, r, and v respectively. An open ellipse encloses the radio sources that reside at the terminus of each radio arc.

seem to be attributable to the central galaxy if consideration is given only to the radio emission morphology along the arc. On the other hand, the westerly radio arc appears to be free of these potential intermingling effects.

Figure 8 is a plot of the same two square degree field around the central galaxy showing nearby infrared, radio, and visual sources. The area within ~20′ of the central galaxy is completely devoid of radio sources, but at precisely the apparent terminus of each radio arc there is a cluster of four radio sources, as indicated in the figure by an ellipse encircling the suspected sources associated with each arc. As can be seen on the plot, the terminus of the northerly arc occurs at the southern perimeter of a very dense collection of radio sources with which the northerly arc terminus happens to intermingle. The vast majority of sources in this collection are radio identifications from the VLA-COSMOS Survey Pilot Project (Schinnerer *et al.* 2004), including all four of the sources deemed to be associated with the northerly arc terminus. At the terminus of the westerly arc the four selected radio sources, all from NVSS (Condon *et al.* 1998), are well isolated from other radio sources, thus strengthening their proposed association. Table 1 lists the radio sources at each arc terminus with their positions and angular separa-

Object	R. A.	Dec	Separation
(At northerly arc terminus)			
[SCS2004] J100050.04+014945.9	10 00 49.99992	+01 4945.99840	32.7′
[SCS2004] J100058.06+015128.8	10 00 58.09992	+01 5129.00160	35.1′
[SCS2004] J100100.21+015150.3	10 01 00.19992	+01 5150.00040	35.7′
[SCS2004] J100113.52+015432.6	10 01 13.50000	+01 5433.00120	39.7′
(At westerly arc terminus)			
NVSS J095740+011542	09 57 40.80000	+01 1542.99840	33.0′
NVSS J095749+011554	09 57 49.69992	+01 1554.00000	30.8′
NVSS J095814+011531	09 58 14.70000	+01 1532.00040	24.7′
NVSS J095817+011400	09 58 17.80008	+01 1400.99960	24.3′

Table 1 — Radio Sources at Arc Terminus as indicated in Figure 8.

tions.

Figure 9 is a plot of the same two square degree field around the central galaxy showing nearby QSOs and X-ray sources. There are four QSOs within 15′ of the central galaxy that have redshifts that fit Karlsson peaks (Karlsson 1971) when the redshifts are transformed to the rest frame implied by the redshift of the central galaxy. The detection of this quasar family is described in Appendix D. The X-ray sources lie far out to the NW along the plane of the central galaxy and exhibit only their obvious pictorial alignment as a possible indicator of association with the central galaxy. There are no other X-ray observations available.

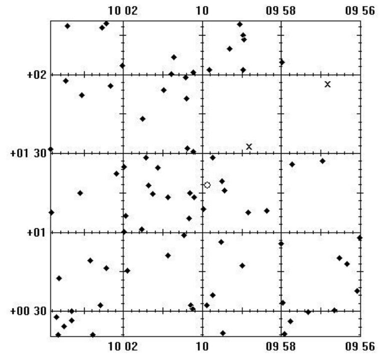

Fig. 9 — Plot of QSOs and X-ray Sources Near the Central Galaxy. The central galaxy is indicated by an open circle and nearby QSOs by closed diamonds. There are also two X-ray sources marked with an x.

4. Suggested Observations

We suggest the observations itemized below to establish for certain the parentage of the radio arcs, to more closely examine the central galaxy itself, and to elucidate the mechanism and aftermath of the presumed ejection in the nucleus and in the close vicinity of the galaxy.

- Close up infrared and optical imaging of the nucleus of the central galaxy could provide insight into the ejection mechanism and into current activity of the galaxy.

- In Figure 2 it appears that the central galaxy may have two optical companions, one to the SE and another to the NNW. The one to the SE appears to be connected to the central galaxy by an optical bridge. Neither object has been separately measured. Close up imaging and redshifts of these objects could be obtained.

- Higher resolution imaging in the radio along the arcs could establish whether all of the radio blobs in these arcs are indeed connected by radio trails that are too fine to be detected in existing observations.

5. Acknowledgments

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Appendix A. Attributes of Central Galaxy

Table 2 lists attributes of SDSS J095951.46+012033.7. Table 3 lists alternate names for the galaxy.

Attribute	Value
z	.101
SDSS u mag	20.21
SDSS g mag	18.44
SDSS r mag	17.48
SDSS i mag	17.01
SDSS z mag	16.61

Table 2 — Attributes of SDSS J095951.46+012033.7

Source Designation	Object Name
2dFGRS	TGN420Z123
APMUKS(BJ)	B095716.79+013458.2
SDSS	J095951.46+012033.8

Table 3 — SDSS J095951.46+012033.7 Other Names.

Appendix B. Object Counts around Central Galaxy

In order to establish the general character of the objects in the surrounding environment of SDSS J095937.17+012641.2 we obtained object counts within three radial regimes of the central galaxy. The object counts are detailed by object type in Table 4 and by survey in Table 5.

Object Type	NED[2]	15′	30′	45′
Galaxy	G	147	480	949
Galaxy Cluster	GClstr	4	12	16
Galaxy Group	GGroup	0	1	1
Galaxy Pair	GPair	2	2	2
Quasar	QSO	8	30	63
Infrared Source	IrS	0	0	1
Radio Source	RadioS	0	12	63
Visual Source	VisS	7	11	18
X-ray Source	XrayS	0	1	1
Supernova	SN	0	1	1
Star	*	2	14	31
Total		170	564	1146

Table 4 — Object Counts by Object Type

Survey	15′	30′	45′
2dFGRS	10	34	80
2MASX	11	47	89
2QZ	12	29	61
APMUKS(BJ)	98	324	629
CGCG	0	1	2
FGC	0	0	2
IRAS	0	0	1
LSBC	0	1	1
NSC	1	3	3
NVSS	0	4	15
PKS	1	1	1
RXS (RX)	0	1	1
SDSS	34	95	193
SDSS CE	3	9	13
SDSSCG	0	4	4
SN	0	1	1
TXS	0	0	1
UGC	0	1	1
[PCd91]	0	1	1
[SCS2004]	0	8	47
Total	170	564	1146

Table 5: Object Counts by Survey

Appendix C. Photometry around Central Galaxy

We conducted searches of the photometric environment of the central galaxy in all EM passbands in each of three square areas that exactly encompass the respective search circles of the three radial regimes used for the object searches described in Appendix B. The search results are detailed in the following subsections.

C.1. Photometry within 45'

The photometry in the 45′ regime of the central galaxy is detailed in Table 6. In the infrared, photometry is available for a large number of galactic objects at 1.240, 1.662, and 2.159 μm, for a very large number of galactic objects, a large number of quasars and radio sources, a few infrared sources, a number of visual sources, and a single X-ray source at 3.769 μm, and for a few galactic objects at 60 and 100 μm. In the optical, photometry is available for a few galactic objects at 4400 Å, and for a very large number galactic objects and two quasars at 4680 Å. In the radio, photometry is available for a single galactic object at 6, 11, 21, 73, and 82 cm, for a number of radio sources at 21 cm, and for a single radio source at 6 and 82 cm.

Passband	λ	G	QSO	IrS	RadioS	VisS	XrayS
Infrared							
J	1.240 μm	117	0	0	0	0	0
H	1.662 μm	117	0	0	0	0	0
Ks	2.159 μm	117	0	0	0	0	0
L′	3.769 μm	1247	80	2	87	23	1
IRAS	60 μm	3	0	2	0	0	0
IRAS	100 μm	1	0	1	0	0	0
Optical							
B	4400 Å	3	0	0	0	0	0
J	4680 Å	1148	2	0	0	0	0
Radio							
5.0 GHz	6 cm	1	0	0	1	0	0
2.7 GHz	11 cm	1	0	0	0	0	0
1.4 GHz	21 cm	1	0	0	21	0	0
408 MHz	73 cm	1	0	0	0	0	0
365 MHz	82 cm	1	0	0	1	0	0

Table 6 — Photometry within 45' of Central Galaxy

C.2. Photometry within 30'

The photometry in the 30′ regime of the central galaxy is detailed in Table 7. In the infrared, photometry is available for a large number of galactic objects at 1.240, 1.662, and 2.159 µm, for a very large number of galactic objects, an appreciable number of quasars, a number of radio and visual sources, and a single X-ray source at 3.769 µm, and for two galactic objects at 60 µm. In the optical, photometry is available for two galactic objects at 4400 Å and for a very large number galactic objects and two quasars at 4680 Å. In the radio, photometry is available for a single galactic object at 6, 11, 21, 73, and 82 cm.

Passband	λ	G	QSO	IrS	RadioS	VisS	XrayS
Infrared							
J	1.240 μm	59	0	0	0	0	0
H	1.662 μm	59	0	0	0	0	0
Ks	2.159 μm	59	0	0	0	0	0
L′	3.769 μm	594	41	0	18	11	1
IRAS	60 μm	2	0	0	0	0	0
Optical							
B	4400 Å	2	0	0	0	0	0
J	4680 Å	546	2	0	0	0	0
Radio							
5.0 GHz	6 cm	1	0	0	0	0	0
2.7 GHz	11 cm	1	0	0	0	0	0
1.4 GHz	21 cm	1	0	0	6	0	0
408 MHz	73 cm	1	0	0	0	0	0
365 MHz	82 cm	1	0	0	0	0	0

Table 7 — Photometry within 30' of Central Gala

C.3. Photometry within 15'

The photometry in the 15′ regime of the central galaxy is detailed in Table 8. In the infrared, photometry is available for a number of galactic objects at 1.240, 1.662, and 2.159 μm, for a large number of galactic objects and a number of quasars and visual sources at 3.769 μm, and for a single galactic object at 60 μm. In the optical, photometry is available for a single galactic object at 4400 Å and for a very large number galactic objects at 4680 Å. In the radio, photometry is available for a single galactic object at 6, 11, 21, 73, and 82 cm.

Passband	λ	G	QSO	IrS	RadioS	VisS	XrayS
Infrared							
J	1.240 μm	16	0	0	0	0	0
H	1.662 μm	16	0	0	0	0	0
Ks	2.159 μm	16	0	0	0	0	0
L′	3.769 μm	185	9	0	0	7	0
IRAS	60 μm	1	0	0	0	0	0
Optical							
B	4400 Å	1	0	0	0	0	0
J	4680 Å	169	0	0	0	0	0
Radio							
5.0 GHz	6 cm	1	0	0	0	0	0
2.7 GHz	11 cm	1	0	0	0	0	0
1.4 GHz	21 cm	1	0	0	0	0	0
408 MHz	73 cm	1	0	0	0	0	0
365 MHz	82 cm	1	0	0	0	0	0

Table 8 — Photometry within 15' of Central Galaxy

Appendix D. The Quasar Family of Central Galaxy

The galaxy SDSS J095951.46+012033.7 was found in a catalogue of families of companion quasars around parent galaxies as detected by C. Fulton and H. Arp. The detection algorithm is described in a paper on periodicity in quasar families by Fulton & Arp (2012). Table 9 shows the catalogue entry, which tabulates the position, the parent or companion measured redshift z_c, the computed residual redshift velocity z_v, the angular separation in arcminutes from the parent galaxy s, the position angle of the companion relative to the parent galaxy PA, the B magnitude of the object, and the object type and object name as recorded in NED.

R. A.	Dec	z_C	z_v	s	PA	B_{mag}	Type	Object
09 59 51.49	+01 20 34.00	0.101				18.40	Galaxy	SDSS J095951.46+012033.7
09 59 25.50	+01 15 33.00	1.695	+0.016	8.2′	52	19.00	QSO	SDSS J095925.54+011532.6
10 00 12.12	+01 13 20.60	1.627	−0.010	8.9′	324	19.77	QSO	2QZ J100012.0+011320
09 59 45.60	+01 30 32.00	1.104	−0.025	10.1′	172	20.40	QSO	SDSS J095945.61+013032.1
10 00 08.10	+01 33 06.99	1.171	+0.006	13.2′	198	20.50	QSO	SDSS J100008.14+013306.4

Table 9 — The Quasar Family of SDSS J095951.46+012033.7

The Arp Small Number Hypothesis and other Coincidences

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In many fields of study, like fluid mechanics or meteorology, combining constants so that they form numbers with no units has led to a better understanding. But in cosmology it has only led to more confusion. Dirac noticed that many of these numbers that contained Hubble's constant were very similar to other numbers and suggested that they were equalities. If the Hubble constant is interpreted as a measure of the universe's expansion, these equalities suggested that some constants varied in time. This upset many established careers and there was a great effort made to prove that these coincidences had no statistical significance. Some of these proofs bordered on silly, but they became accepted dogma none the less.

Recently, Volkmar Mueller has made observations that suggest Hubble's constant should have a different interpretation. This should lead to a reinterpretation of the Dirac Numbers. Halton Arp has also questioned the conventional interpretation of Hubble's constant. Arp has also maintained that the number 1.23 is present in too many *ad hoc* formulas describing astronomical quantization to be a coincidence.

The aim of this paper is to explain the strongest coincidences in the most fundamental terms without any hidden assumptions, and so that they can be understood by anyone with an interest in science.

Introduction

When scientists write equations to describe the natural world they must insert constants into these equations to make the quantities come out right.

These constants are dependent upon the system of units used. To look for more fundamental relationships, these equations can be combined so that the units cancel out yielding equations written in terms of pure numbers. These equations often involve ratios of time periods, distances, or forces. When physicists calculated the ratios of certain time periods, distances, and forces several coincidences became apparent. The ratios tended to cluster around 10^{40}, its square, and its cube root. Later a coincidence was noticed between the fine structure constant, a nondimensional number from microphysics, and nondimensional numbers that describe relationships between the mass, angular momentum, and magnetic fields of astronomical bodies.

Starting in the 70's, a few astronomers started noticing that redshifts of different objects tended toward certain values. Halton Arp derived an empirical formula for redshifts in quasar clusters which had an empirical constant of 1.23. Later this number was found in descriptions of planetary masses, planetary orbital radiuses, and fractal dimension of the nearby universe.

Very recently, Volkmar Mueller noticed some coincidences where other quantities, when written in the same units as the Hubble constant, had very close magnitudes. This is a challenge to the conventional interpretation that the constant describes the expansion of the universe. This affects the interpretation of the coincidences and is at the heart of explaining redshift quantization, so we will start there.

The Mueller-Hubble Hypothesis (MHH)

When observing the universe, it is easy to measure the first two dimensions on the sky. But measuring distance to an object outside our galaxy is more complicated. We know that the energy received from a star is inversely proportional to its distance squared. So if we can estimate the energy the body should be giving off, we can estimate the distance. If the redshift (or blue shift) of an object is assumed to be completely Doppler, then it's velocity toward or away from earth can be calculated. Edwin Hubble plotted redshift versus the distance of galaxies inferred from their brightness and found that within classes of galaxies there was a linear relationship. The further away a galaxy was, the greater its redshift. Others referred to the slope of a linear fit to all of the data as Hubble's constant, and interpreted it as a measure of the universe's expansion.

The constant is usually given as 72km/s per kiloparsec, but if we convert kiloparsecs to kilometers and cancel units, we get $H = 2.3 \times 10^{-18}$/sec.

Volkmar Mueller observed:

1) The slowing of the earth's rotation rate is usually given in fractions of a second per day per year. If all of the times are converted to

seconds we get 2.9×10^{-18} per second. This value is just slightly higher than the Hubble constant. Allowing that some of the slowing may be due to tidal friction, this value is very close. Another way of putting it would be if we compared an electromagnetic clock to a clock based on the earth's rotation, the discrepancy would be very close to Hubble's constant.

2) The increase in lunar orbit is usually given in cm per year. But if we divide the rate by the distance to the moon and express a year in seconds, we get 3.15×10^{-18} per second.
3) The Pioneer spacecraft was launched to probe the distant solar system. Its velocity is measured from the redshift of a signal it emits. When compared to the theoretical deceleration, the signal shows an excess deceleration. This anomalous acceleration divided by the speed of light is 2.9×10^{-18}/sec.
4) The distance between the North and South Pole is increasing by 0.5 millimeters per year as measured by satellite. This is usually interpreted as post glacial rebound. Estimates of earth expansion put the lower limit at 0.5 mm/year. If we divide 0.5mm/yr by the earth's diameter and change years to seconds we get 2.5×10^{-18}/sec.
5) Dokkum (2005) surveyed a cluster of very high redshift elliptical galaxies. The galaxies were found to have a typical radius 1/5th the radius of contemporary galaxies even though they had approximately the same number of stars. If we infer their age from their redshift, they are 1/5th the age of the universe as given by Big Bang cosmology. Therefore, the galaxies must be expanding at the same rate as typically calculated for the universe. Or if we do not believe in the big bang, (*the speed of light – redshift of the galaxies)/speed of light* = 1/5th. The same relationship is true of a cluster of even higher redshift galaxies observed by Oesch *et al.* (2010). This coincidence alone is remarkable. But we must be careful about what assumptions we make when we interpret it. Both a galaxies diameter and distance are inferred assuming that Hubble's relation applies to all bodies. These objects could be much younger, much closer, and even more compact.

Meuller hypothesizes that the similarity between these quantities is a manifestation of the same phenomena. That structures dominated by gravity alone had one set of clocks and rulers and structures dominated by electromagnetism had another set. The difference between the two was Hubble's constant; and that Hubble expansion existed at all scales dominated by gravity. But it could also have a different explanation. (Ellman, in publication) suggested a contraction of length to explain some of the same phenomena.) Many theories have postulated that gravity is something left over after the Coulomb forces of the positive and negative charges cancel out. Maybe rethinking Hubble will show us how that happens.

The Arp Small Number Hypothesis

According to standard cosmology, galaxy redshifts, quasar redshifts, planetary masses, and planetary spacing should be random. But there is a substantial literature showing that these quantities tend to favor certain values or ratios and appear to be quantized.

Quasar quantization

Quasars are objects with very high redshift. Because of their high redshift they are assumed to be very far away. This creates a problem. If they really are this far away they must be more energetic than any other objects that we have observed. Arp (1994, 1997) observed that clusters of high redshift quasars appear to be physically connected to galaxies of much lower redshift. They are not unusually energetic, but their redshift must not indicate their distance. Furthermore, the redshifts of these clusters are quantized and obey a simple formula,

$$\frac{1+z_{k+1}}{1+z_k} = 1.23 \tag{1}$$

where z_k is the redshift for a given quasar, z_{k+1} is the redshift for the quasar with the next higher redshift in the group, and k is an integer.

A lower mass electron would redshift an emission spectrum. The simplest mechanism (Kokus and Barut 1993) to create these quantized redshifts would be for the electron mass to vary according to

$$m_e = m_0 \left(1.23\right)^{-n} \tag{2}$$

where m_0 is the mass of the electron in the lowest redshift quasar, m_e is the mass of the electron in one of the other quasars, and n is an integer.

Large scale organization of the universe

Kokus (1994a,b, 2012) made the observation that the fractal dimension of the universe as measured by Peebles (1980) and Mandlebrot (1983) on the night sky was 1.23, the same as Arp's empirical constant. One of the things that this means is that when measuring the mass contained in a sphere placed somewhere in the universe, the mass would increase proportional to the radius to the 1.23 power,

$$M = M_0 r^{1.23} \tag{4}$$

This contradicts big bang cosmology where on larger scales the mass should increase by a power of 3. This calculation was made by looking at the distribution of similarly redshifted galaxies on the sky. This technique made very few assumptions. Arp has often suggested that newly created particles gain mass as they interact with older matter. Kokus (1993, 1999) has shown that if matter exists in the nearby universe in discrete clumps that obey (4), then the mass of a newly created particle would hop in discrete quantities that would obey (2).

Others have used pencil beam surveys to estimate fractal dimension. In a pencil beam study galaxies are looked at over a very deep range of redshifts but only within a very narrow angle. Making the assumption that redshift was convertible to distance, they calculated that mass would increase with volume proportional to r squared,

$$M = M_0 r^2 \qquad (5)$$

Baryshev and Terrikorpi (2012) have pointed out that the pencil beam studies are actually measuring the fractal dimension in redshift space. The ratio of the exponents, $2/1.23 = 1.615$, is almost identical to the Fibonacci ratio, 1.618, which is often seen in systems which are self similar. That is, the system has the same structure as viewed at different scales. This might offer an insight into the origin of this phenomenon.

Planetary mass quantization

Jess Antem (Arp 1995) observed that the ratio of the Earth's mass to Venus's mass was 1.23. Arp (1995) then investigated the remaining planets and found that :

$$M_P = M_{Earth}\left(1.23\right)^{-n} \qquad (6)$$

was an excellent fit where M_P is the mass of any planet in the solar system, M_{Earth} is the mass of the Earth, and n is an integer that can either be positive for planets larger than the earth or negative for planets smaller. The probability that the masses would fit this well is 7.8×10^{-4}. He then went on to fit the natural satellites of the planets and achieved an excellent fit with one modification, dividing the exponent by 2:

$$M_{satellite} = M_{Earth}\left(1.23\right)^{n/2} \qquad (7)$$

Continuing, he (Arp 1995, 1998) found that the sun and large bodies also fit equation (6).

The equation that describes planetary mass quantization is the same as the one describing the electron masses (Kokus and Barut 1993) that would explain quasar redshift quantization. It now appears probable that masses obey similar laws of quantization over a very wide range.

Planetary distances

Arp also looked at other quantities in the solar system to see if they obeyed similar relationships. Although unsuccessful with orbital velocities or angular momentum, planetary distances did show remarkable agreement with

$$R = R_0 1.23^n , \tag{8}$$

where R is the orbital radius of a planet, R_0 is the radius of Earth, and n is an integer or an integer plus a half. This relationship applies not just to the planets but also to the satellites of planets. In this way we are already seeing a self similarity.

Other redshift quantization coincidences

Stars and redshift

Problems first started with the Doppler interpretation of redshift when it was used to calculate the rotation rate of stars. When we look at light from a star in our own galaxy, the spectral lines have acquired a width. This is assumed to be due to the rotation of the star. One side of the star is rotating toward us and the opposite side is rotating away from us. So the Doppler effects would be opposite. This would give us the means of calculating the rotation rate of the star. But the breadth of these lines, if interpreted as velocity, cluster tightly around 72 km/sec (or plus and minus 36km/sec) (Tifft 1977b). This is very unusual, because this would mean that not only would the stars have to have the same rim velocity, but also the same orientation with respect to earth. This was the first hint that there was something wrong with assuming that velocity was the only cause of redshift. The response of many established astronomers was predictable. Instead of questioning their assumptions, they rushed to discredit the researcher.

Arp (1998) has also made a strong argument that part of the redshift of certain stars must be other than Doppler.

Redshifts within galaxies

Galaxies are also rotating and the motion of the spiral arms is calculated from their redshift. There is general agreement that there is a problem with the rotation rates of stars about the galaxy center. The rotational velocity should drop as the stars become more distant from the galactic center. They do, but not enough. The standard explanation is that there is "dark matter" distributed throughout the galaxy, creating a greater attractive force toward the center as one gets further from it. This would require the stars to travel faster to maintain equilibrium. Some models require that the dark matter make up well over 90% of the galaxies mass. But there is another problem.

M31 is a very large, nearby galaxy enabling it to be observed in detail. When Rubin and Ford (1971) measured the redshift of the spiral arms in galaxy M31 they discovered several discontinuities. Tifft observed that the redshift jumped 72 km/sec at certain points along an arm.

Galaxy redhift

Galaxy redshift quantification has been measured in several ways. William Tifft (1977a) at the University of Arizona, Stewart Observatory, showed the difference in redshift between pairs of galaxies comes in integer multiples of 72 km/s. Looking at groups of galaxies has shown a 72 km/s, a 36 km/s (half of 72) quantization (Tifft 1977b). For large catalogs of galaxies, Napier (1994), Napier and Guthrie (1997) and Tifft (1978, 1993, 1997) have shown a universal quantization of 37.5 km/s, but this was only after the redshifts were adjusted for the local motion of our earth with respect to the cosmic background radiation or for the local motion of the sun around our galaxy. Bajan *et al.*, with a sample of 2522 galaxies which contained a lot of "noise," found periodicities of 73 and 24 km/sec at the 95% confidence level.

The 72km/sec coincidence

Finding discrete jumps of 72 km/s in 3 areas (across stars, across galaxy arms, and between galaxies) is a remarkable coincidence.

Link between quasar and galaxy redshift; another coincidence

A lower mass electron would redshift an emission spectrum. The simplest mechanism (Kokus and Barut 1993) to create Arp's quantized redshifts for quasar clusters would be for the electron mass to vary according to

$$m_e = m_0 \left(1.23\right)^{-n} \tag{9}$$

where m_0 is the mass of the electron in the lowest redshift quasar, m_e is the mass in one of the other quasars, and n is an integer. This equation is of the same form as the one Arp fit to planetary masses.

Kokus and Barut (1993) worked on several models linking quasar and galaxy redshift. For the hydrogen spectra from pairs of galaxies they achieved a superior fit to the data than just assuming a constant quantization between galaxies. They assumed that the proton's mass also obeyed an equation like (9) and varied independently of the electron's mass. If the nucleus of a hydrogen atom were lighter, it would absorb some of the energy that the electron usually has. This reduced mass effect brings the energy levels of the electron closer together, redshifting its emissions. The reduced mass effect on the nucleus resulted in quantized redshifts which were an excellent fit to the galaxy pairs, but the model broke down for large clusters. The basic coincidence to be explained is the ratio of successive redhift differences between successive quasars to galaxy redshift is the ratio of proton and electron masses:

$$\frac{z_{n+1}-z_n}{37.5\,\mathrm{km/s}\big/c}=\frac{m_p}{m_e}\frac{\left(z_{n+1}-z_n\right)}{37.5\ \mathrm{km/s}\big/c}=\frac{m_p}{m_e} \tag{10}$$

This implies a self similarity between the very small and the very large.

Dirac Large Number Hypothesis, LNH

The electrostatic attraction between the proton and the electron in a hydrogen atom is about 10^{39} times larger than the gravitational attraction. The radius of the observable universe, *c/H*, is about 10^{39} times larger than some very small distance, usually chosen to be the classical radius of an electron. The classical radius of an electron is one where the potential electrostatic energy of an electron is equal to $m_e c^2$. Dirac (1937, 1938) equated the two large numbers and hypothesized a link between them. Unfortunately, he and most everyone else, assumed that the Hubble relationship meant that the universe was expanding and one side of the equation was getting bigger. This meant that the other side had to be getting bigger and the most likely culprit was the denominator getting smaller. Or the gravitational attraction was decreasing.

To summarize the established response: If the gravitational force was decreasing then the only explanation would be that the gravitational constant had to be decreasing. If we put a decreasing *G* in the orbital equation, the planets should be moving outward. They could be measured precisely enough to show that *G* could not be varying that fast. Therefore it is just a coincidence.

Actually, the LNH could be satisfied if $Gm_p m_e$ decreased (Adolphe Martin 1994,1995) and orbits would not be affected.

There are other coincidences associated with the LNH. The critical density of the universe is the density where the universe is stable. It is not so dense that it will collapse into a single ball. If that density is multiplied by the volume of the observable universe we get 10^{78} or $[10^{39}]^2$ protons and neutrons in the universe. If this was part of the equality then particles would appear as the universe ages. Where would they appear? Where mass already exists or uniformly scattered in space? But this is also has a different interpretation. The critical density is dependent on gravity and the mass of particles, so what we really are saying is that the local density and gravity are entwined.

Houtermans-Jordan Hypothesis

If a proton or neutron goes into an excited state it will generally return to its original state with a half life of about 10^{-9} seconds. The force involved is the strong nuclear force. In beta decay a nucleus ejects an electron and a neutron turns into a proton. This is caused by the weak nuclear force and the half lifes are around 10^3 seconds. The ratio of the two time periods is about 10^{12} or about $[10^{39}]^{1/3}$. Recently, Sturrock *et al.* (2011) alleged that beta decay rates are not constant but vary with distance to the Sun squared. The further the earth is from the Sun the slower the decay rates. Jenkins and Fischbach (2009) showed that beta decay decreased during a solar flare; and Sturrock *et al.* (2010) found a period in beta decay variation comparable to the 11 year solar cycle. This is consistent with the original Houtermans and Jordan (1945) hypothesis that the weak force is decreasing in time as the universe expands and density decreases. Taken together with the Meuller-Hubble Hypothesis, this suggests that clocks dependent on different forces are measuring something different.

Rephrasing the LNH

Another way of interpreting the LNH is that a fundamental force times a characteristic distance is equal to a constant; or,

> The strong nuclear force X the radius of a nucleus = the electrostatic force X the radius of a Bohr atom = the weak nuclear force X the mean distance between atoms in the universe = the gravitational force X the radius of the observable universe

In other words, the strength of a force is inversely proportional to the distance where it is typically cancelled out. The products can also be interpreted as a torque or energy.

The fine structure coincidences

Mass and angular momentum

If mass is being created where mass already exists, what is its angular momentum? Zero, the same as the mass that is already there, or something else? A hint is provided by Peter Brosche (1980). He asks that since microphysics is dominated by three (four in SI units) constants that combine into a dimensionless number, why should not macrophysics? If we are looking for another connection between microphysics and macrophysics, that would be a good place to start. The three constants for microphysics are *e*, the charge of an electron, *ħ*, Planck's constant, and *c*, the speed of light (plus *k*, the electrostatic constant in SI units) which combine into the fine structure constant, $\alpha = ke^2 / \hbar c = 1/137$. Gravity has only two constants, *G*, the universal gravitational constant, and *c*. In order to create a nondimensional number for macrophysics we would need a new constant, ρ, with dimensions of angular momentum, *J*, over mass squared, M^2. Was there such a constant governing the behavior of large bodies? Investigating, it was found that for large bodies, under gravitational influence only, ranging from planets, to stars, to galaxies, to galaxy clusters; the relation,

$$J = \rho M^2 \tag{11}$$

holds fairly well (See also Wesson 1979, 1981). This is definitely not expected from big bang cosmology. If we create a dimensionless number that includes these constants, $G/pc = 1/360$.

Gyromagnetism

Planetary magnetic fields have always been a source of wonder. Gyromagnetism is the theory that a mass spinning on its own will possess a magnetic field. Several experiments done with small masses spun manually tended to refute the idea. But recently Ahluwalia and Wu (1978) and Sirag (1979) showed a strong correlation for astronomical bodies between spin angular momentum, S, and magnetic dipole strength, $\underline{U}$. They got $S = qU$ where q is the constant of proportionality. When q is combined with other constants to form a dimensionless number we get $c^2/q^2G = 1/130$.

Barut Gravitation-Magnetic Hypothesis

Barut (1982,1988) and Barut and Gornitz (1985) made the observation that if planets had a net electrical charge sufficient to cause a force equal to their gravitational force, then their spinning would create a magnetic field equal to that observed. This also reinforces the hypotheses that gravity is something left over after the Coulomb forces cancel out.

Landau-Sternglass-Lepinard Fine Structure-Large Number Hypothesis

Lev Landau (1955), Earnest Sternglass (1984), and Denys Lepinard (1998) independently observed that $2^{137} = 10^{39}$. Sternglass (1984) and Kokus (2003) explain it with a rotating hierarchy cosmology.

Discussion

Some of these coincidences may simply be just that, coincidences. But the probability that they all are coincidences is really quite small. The problem with interpreting them is that we might be misinterpreting some of the constants. What we think of as the gravitational constant, Hubble's constant and the fundamental particle masses may not be constants at all. They might be unique to the local age and distribution of matter.

Halton Arp made a strong case that the mass of fundamental particles changes with age. Young particles gain mass as they interact with older particles. Do the older particles loose mass to the younger particles? Are particles always coming to a new equilibrium? If the charge to mass ratio of a fundamental particle is always changing does that affect the way we measure space and time? Does it affect all the ways we measure space and time the same way? Is this constant change of particle mass what we are interpreting as expansion of the universe? Is gravity the result of particles interacting with older particles that were in a different equilibrium? Is this the connection between gravity and the Hubble constant?

Arp (1995) said:

> A glimpse of this clear pattern beckons us to a more profound understanding of the relation of the smallest to the largest and youngest to oldest entities in the universe.

This is just "a glimpse." The best tribute to Arp's memory would be to keep mapping the "pattern" and trying to understand the "relation."

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Halton Arp and 1.228

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Halton Arp observed that quasar redshifts tended to occur near curtain values which obeyed a simple formula where 1.23 is a constant. Later, he and others observed this constant in planetary masses, planetary spacing, and the fractal dimension of the universe. The constant was later refined to 1.228, and can be derived from a simple model of rotating bodies that are in resonance. The constant is related to the Fibonacci series by a simple formula.

Introduction

According to standard cosmology, galaxy redshifts, quasar redshifts, planetary masses, and planetary spacing should be random. But there is a substantial literature showing that these values tend to favour certain values or ratios and appear to be quantized.

Quasar quantization

Quasars are objects with very high redshift. Because of their high redshift they are assumed to be very far away. This creates a problem. If they really are this far away they must be more energetic than any other objects that we have observed.

Arp (1994, 1997) observed that clusters of high redshift quasars appear to be physically connected to galaxies of much lower redshift. They are not unusually energetic, but their redshift must not indicate their distance. Furthermore, the redshifts of these clusters are quantized and obey a simple formula,

$$\frac{1+z_{k+1}}{1+z_k} = 1.23 \tag{1}$$

where z_k is the redshift for a given quasar, z_{k+1} is the redshift for the quasar with the next higher redshift in the group, and k is an integer.

A lower mass electron would redshift an emission spectrum. The simplest mechanism (Kokus and Barut 1993) to create these quantized redshifts would be for the electron mass to vary according to

$$m_e = m_0\left(1.23\right)^{-n} \tag{2}$$

where m_0 is the mass of the electron in the lowest redshift quasar, m_e is the mass in one of the other quasars, and n is an integer.

Large scale organization of the universe

Kokus (1994a,b, 2012) made the observation that the fractal dimension of the universe as measured by Peebles (1980) and Mandlebrot (1983) on the night sky was 1.23, the same as Arp's empirical constant. One of the things that this means is that when measuring the mass contained in a sphere placed somewhere in the universe, the mass would increase proportional to the radius to the power 1.23,

$$M = M_0 r^{1.23} \tag{3}$$

This calculation was made by looking at the distribution of similarly redshifted galaxies on the sky. This technique made very few assumptions.

Planetary mass quantization

Jess Antem (Arp 1995) observed that the ratio of the Earth's mass to Venus's mass was 1.23. Arp (1995) then investigated the remaining planets and found that :

$$M_P = M_{Earth}\left(1.23\right)^{-n} \tag{4}$$

was an excellent fit where M_P is the mass of any planet in the solar system, M_{Earth} is the mass of the Earth, and n is an integer that can either be positive for planets larger that the earth or negative for planets smaller. The probability that the masses would fit this well is 7.8×10^{-4}. He then went on to fit the natural satellites of the planets and achieved an excellent fit with one modification, dividing the exponent by 2:

$$M_{satellite} = M_{Earth}\left(1.23\right)^{n/2} \tag{5}$$

Continuing, he (Arp 1995, 1998) found that the sun and large bodies also fit equation (6).

The equation that describes planetary mass quantization is the same as the one describing the electron masses that would explain quasar redshift quantization. It now appears probable that masses obey similar laws of quantization over a very wide range.

Planetary distances

Arp also looked at other quantities in the solar system to see if they obeyed similar relationships. Although unsuccessful with orbital velocities or angular momentum, planetary distances did show remarkable agreement with

$$R = R_0 1.228^n \tag{6}$$

Where R is the orbital radius of a planet, R_0 is the radius of Earth, and n is an integer or an integer plus a half. This relationship applies not just to the planets but also to the satellites of planets. In this way we are already seeing a self similarity.

Discussion

The planetary distance relationship provides several clues to understanding the origin of 1.228. First of all, since we often get a fit with n equal to half an integer, maybe the constant we are looking for is really $1.228^{1/2}$ or 1.108 and

$$R = R_0 1.108^n, \tag{7}$$

where n can only be an integer. The other clue is that there are many relationships between the orbital periods of the planets and the periods are linked to the distances by Kepler's 3rd Law, $T^2 = R^3$.

Recently, Scafetta (2014) published a review of resonances and quasi resonances found in the solar system. Of interest, the orbital periods of most planets have a simple relationship with the orbital periods of adjacent planets. The ratio of their time periods is often the ratio of two Fibonacci numbers. Sometimes the numbers are adjacent in the series (8 and 13), sometimes they are one apart (2 and 5). There are various explanations for this, but it is a fact that these relationships exist.

Five Mercury years are about 2 Venus years. Thirteen Venus years are 8 Earth years. Five Mars years are about 2 Ceres (the largest asteroid) years. Five Ceres years are 2 Jupiter years. Five Jupiter years are 2 of Saturn's. Two Uranus years are 1 of Neptune's. And 3 of Neptune's years are 2 of Pluto's. Similar relationships are found in the satellites, hinting at some type of fundamental self similarity.

Now the ratio of two adjacent Fibonacci numbers is approximately ϕ, the Fibonacci ratio, and the ratio of two Fibonacci numbers that are separated by another number is approximately ϕ^2. So if we look at a sequence of planets where all of the adjacent periods are Fibonnacci ratios, then the planets orbital periods could be approximated by $T_n = T_0\phi^n$.

Substituting into Kepler's 3rd Law and rearranging

$$R_n = R_0\left(\phi^{2/3}\right)^n \tag{10}$$

and

$$\phi^{2/3} = 1.378 \tag{11}$$

Now a relationship of this type can also be satisfied by any root of $\phi^{2/3}$. If we try the cube root of $\phi^{2/3}$ or $\phi^{2/9}$ (1.11285, 0.4% greater than $1.228^{1/2}$), a curious thing happens. As could be predicted, the ratio of orbital radiuses of most adjacent planets is either $(\phi^{2/9})^3$ or $(\phi^{2/9})^6$. But now the exceptions can be easily fit into the same type of formula. The ratio of Mars's orbit to Earth's is $(\phi^{2/9})^4$ and the ratio of Uranus orbit to Saturn's becomes $(\phi^{2/9})^7$. This may be an undiscovered property of systems with multiple resonances.

Also remember that most of the planet orbital ratios are ratios of two Fibonacci numbers separated by another number in the series, so their orbital radius ratios would be approximately $(1.378)^2$ which is approximately 1.228^3. So that is another way to explain the goodness of Arp's fit.

The Fibonacci ratio to the $\frac{2}{9}$ th power is 0.4% greater than the square root of 1.228, but if we take the $\frac{2}{9}$ th power of a weighted average of the actual ratios found in the solar system, we obtain a value that is 0.5% less. Remember also that the resonances are "almost." This is actually good agreement.

Conclusion

There is a simple relationship between the Arp and Fibonacci numbers. The fact that the Arp number can be found in phenomena of vastly different scales and that it can be related to self similarity and resonance at one scale hints that the greater universe may be organized very differently from the current model. We may be surrounded by a hierarchy of large bodies that are moving in resonance with each other.

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Unification, the *apeiron*, and Chip: A Remembrance of a Man and Ideas

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It may be possible to unify the fundamental forces with a theory that is basically classical. It requires a radically different vision of the universe and what unification means. Particles and space are one. We perceive them as separate. Particles are spherical rotations or combinations of spherical rotations and other simple motions in a primordial "substance" that comes before everything else, the *apeiron*, something that is different. It has already been shown that spherical rotation can explain electromagnetism and other phenomena usually explained by quantum mechanics. If we make certain permitted assumptions about the structure and behavior of the *apeiron* and the universe, other forces and phenomena can be explained by ensembles of spherically rotating particles in a constantly evolving universe. The universe and the electron are self similar. They are both spherical rotations of *apeiron*.

All inertial reference frames are local. Inertial reference frames may not be observed as inertial frames from other inertial reference frames or from an inertial frame of very different scale. Assuming that they can, results in the need for dark matter or other fictions. Ensembles of spherically rotating particles and the creation of new particles can give rise to the other forces and other observed phenomena.

Prologue and memories

For the first half of my life, my scientific views were rather conventional with three exceptions. I never accepted the Dirac Large Number Hypothesis as a coincidence. I always had my doubts about plate tectonics, and I was always intrigued by patterns in earthquakes that had no explanation within accepted models. In the 1980's, I started seriously examining the connection between these patterns and alternatives to plate tectonics and general relativity. This led me to rethink the arguments against these theories. I ended up challenging everything I was taught.

I came to the conclusion that some things that I was taught and I believed in had to be wrong. In particular, something that I was taught was a constant had to vary. If we looked at any reasonable history of the earth's radius, rotation rate, and surface gravity, we would have to start doubting standard theories in gravity, geology and astronomy. I was drawn to theories of gravity that were not general relativity, to theories of elementary particles without quarks, and to cosmologies without a big bang. I also came to the political conclusion that plate tectonics was a house of cards being propped up by the sociology of the science and that its over throw would be the best thing that could happen for seismic prediction.

About this time, I was starting to encounter the terms "discordant redshifts" and "quantized redshifts." William Corliss suggested that I read Halton Arp's *Quasars, Redshifts, and Controversies*. I quickly realized that we were looking at two faces of the same problem and that the reaction of the mainstream was identical in both instances.

Asim Barut and I worked on several models where particle masses would assume discrete values causing a non-doppler redshift that would be quantized. There were some interesting results, but the effort did not go anywhere. I gave up and went on to other things. Quite by accident I picked up an issue of *Scientific American* that discussed the quantized redshift results for galaxies by Napier and Guthrie. I plugged their values into the previous models and came up with a coincidence that could be interpreted in various ways. Essentially, the ratio of Arp's quasar redshift quantization to Napier and Guthrie's galaxy redshift quantization was equal to the ratio of proton mass to electron mass. I wrote up these results and mailed them to everyone I could think of.

Then one morning I answered the phone, "This is Chip Arp calling from Munich." He suggested that I publish the paper in *Apeiron* [Kokus 1993]. I had never heard of the word or the publication. Later both the concept and the publication proved to be very useful. We had a long talk and I broached the subject of earth expansion and seismic prediction. He did not understand what I was talking about. A month later, he called again and was an expert on the subjects. We made plans to meet in September 1993 at a conference in Olympia, Greece.

The 1993 Frontiers of Fundamental Physics Conference was unique. It included dissidents from astronomy, cosmology, quantum mechanics, gravitation, and geology. At the beginning there was a clash of paradigms and personalities. I was afraid that an opportunity would be lost. During the last day, we broke into groups. Chip led a group of astronomers and cosmologists – Bill Napier, David Roscoe, Victor Clube, Roy Keys, and Jack Sulentic – into a room of earth expansionists – Warren Carey, Giancarlo Scalera, John Davison, Warren Hunt, Lorwence Collins, Stavros Stassos, Stephan Cwordzinski, and myself. Non big bang astronomy met non plate tectonic geology. We stayed there late into the Greek September night. There was a meeting of the minds I have not seen since. I felt we were witnessing a scientific revolution being born. It was the highpoint of my optimism.

During that conference, I pointed out that a number that figured prominently in Chip's formula for redshift quantization, 1.23, was also the fractal dimension of the near universe as measured on the sky [Peebles, 1980 and Mandelbrot, 1983] and that if electrons grew in mass as they interacted with other particles then one would follow from the other [Kokus, 1994]. During the coming years, I kept getting letters from Chip pointing out other places where the number appeared [Arp 1995]. Since 1.23 is a small number, I will refer to these coincidences as Arp's Small Number Hypothesis.

We also discussed the relationships between astronomy and geology. They both involve time scales that cannot be replicated in laboratory experiments. Mistaken assumptions in one field would most likely turn up as mistaken assumptions in the other.

There is no shortage of attempts to explain away redshift quantization, but the simplest explanation is that the mass of an elementary particle such as an electron changes in discrete jumps as the particle ages. Arp and others hypothesized that new particles are created, expelled from galaxies, and acquire mass as they interact with more and more particles. Since matter is distributed in clumps, the change in mass would occur in jumps. Of course standard theories have no mechanism for this. According to standard theory if particles are created, there must be an equal number of antiparticles created. Where are they? How could particles acquire mass from other particles?

There is a great deal of evidence for earth expansion. The theory supposes that the continental plates were formed when the earth had a much smaller radius and the entire surface was covered with one large continent. The ocean basins were formed as the earth expanded and newer material up welled forming the ocean floor. The simplicity is appealing. The problems are the lack of a mechanism for an expansion of that magnitude; and if the earth did expand that much, its rotation rate should have slowed more than it has. One mechanism for expansion, a decrease in the universal gravitational constant, contradicts another finding; the earth's surface gravity must have been much less in the past. So we are looking for a mechanism, where the volume and mass of the earth increases and its angular momentum increases proportionately. Matter must be created where matter already exists and it must be created without the corresponding antimatter. It must also have the angular momentum of the body it is created in.

But perhaps the most interesting thing about the history of the Earth's radius is that the expansion is episodic. It occurs in discrete intervals and the growth rate when averaged is exponential. The growth rate of the mass is proportional to the mass. So just as the mass of an electron would grow in jumps and in proportion to its mass in order to explain redshift quantization, so too, would the mass of an astronomical body.

Arp (1995) has made the suggestion that planetary masses also occur at preferred values which also fit the formula for electron masses. Kokus (2011) has shown that this is consistent with what is proposed by earth expansion.

Sometime around 1995, Chip asked the late Milo Wolff (1990) to send me some papers and a book which discussed a theory of particles which was in part based on the concept of spherical rotation. Spherical rotation can be visualized by starting with a medium which is everywhere continuous. If a piece of this medium is initially rotated 180 degrees about the x axis, it can then be rotated continuously about the z axis without the medium tearing. But what is this medium? It is something that gives rise to both particles and what we think of as space. The term aether has many different interpretations, is thought of as something that particles move through, and it has a history which only serves to confuse. The closest term to what is waving and rotating is "the *apeiron*," something which is different. I spent the next 20 years imagining how ensembles of spherically rotating *apeiron* would behave, which disturbances in the *apeiron* would correspond to which particles, and the origin of the four forces and other phenomena such as the General Allais Effect and the Allais Eclipse Effect.

This led to a lively correspondence with Chip concerning the large scale motion of the universe. Both Chip and I rejected the Big Bang. But what about a motion like spherical rotation. Chip was initially very skeptical and was positive that it was contradicted by what was already known. Again, he emailed me back in a month saying that there was no observational evidence to contradict it and some observational evidence to support it.

I have pursued the ideas we hatched and will continue to do so. The following is an outline of the progress.

Introduction

A unified theory should:

1) eliminate some constants;
2) be an obvious simplification, conceptually, if not mathematically;
3) explain coincidences between non-dimensional constants;
4) provide a mechanism for redshift quantization and non-Doppler redshifts;

5) explain gravitational or inertial anomalies associated with 3 body problems like the General Allais Effect and various eclipse effects; and
6) create a feeling of enlightenment.

The last requirement should not be underestimated. Unification should not be thought of as a collection of equations; it is fundamentally an idea, a way to look at the universe and our place in it. The basic idea should be understandable independent of the mathematics. This paper intends to just explain the idea.

I will hypothesize that everything we know is made of the *apeiron*. The *apeiron* is something that is different. It is a concept more basic than space or matter. There is no particle/space/wave dichotomy. Everything is the *apeiron* or a disturbance in the *apeiron*. If a piece of *apeiron* is displaced from the local equilibrium it will return to its original position in a finite time. The type of displacement does not matter. The return of the piece of *apeiron* can be interpreted by assigning the *apeiron* a restoring force and a mass, but this is an unnecessary complication. All we need to hypothesize is that the wave the disturbance makes will propagate at the speed of light relative to the local *apeiron*. The *apeiron* is the most fundamental of all things. It cannot tear because what would occupy the gap. It has to be continuous as are its derivatives.

The other assumption is really a non assumption. It must be stated because the opposite assumption is so often made without coming right out and stating it. In many aether theories it is assumed that in the absence of a disturbance the aether is laying there motionless as we imagine space. There is no good reason to assume this. Motion may be the natural state of the *apeiron*. The local *apeiron* defines the local inertial reference frame. An inertial reference frame may not appear as one from another inertial reference frame (contrary to one of Einstein's basic assumptions which is not challenged enough). The *apeiron* at one location may be moving compared to the *apeiron* at another. An inertial reference frame may not appear as one when observed at a different scale. If you observe an inertial reference frame from another point you can introduce a fictitious force and a fictitious dark matter to balance it.

All physics is local. The local reference frame is determined by the local motion of the *apeiron*. There is no reason to assume that the *apeiron* does not have large scale motions. In fact, we later will assume that it does.

There are many models of particles which consist of something spinning, such as a point charge, a ring of charge, or simply a piece of space. The motion is almost always a rotation about a fixed axis. One drawback is that the models still require postulating a charge.

Even in the case where a particle is described as a vortex or a similar deformity in space there are still problems. First they require equal and opposite deformities that correspond to the electrical charges because an axis can be rotated so that the direction of spin can correspond to the direction of spin about another axis. Second, and more subtle, is that if a piece of space is rotating continuously about an axis, there must be a discontinuity somewhere between the vortex and the rest of space. Therefore there is little difference between hypothesizing a vortex model and hypothesizing a space/ particle dichotomy.

There have also been hypotheses that the Universe consists of a rotational hierarchy. As the planets revolve about the Sun, the Sun revolves about the Milky Way, the Milky Way revolves around the Local Group, and so forth. There is no evidence in the nearby Universe that contradicts this, but it is usually ruled out for much larger scales because the distant Universe is too isotropic. These problems can be solved with the introduction of spherical rotation, a three dimensional vortex.

The term "spherical rotation" was coined by Battey-Pratt and Racey (1980) (hereafter BPR) who wrote the definitive paper on the subject (See also Speiser,1964; Wolff,1990; and Kokus, 1997a, 1997b, 1999). BPR wanted to differentiate spherical rotation from cylindrical. The easiest way to understand the distinction is to imagine a ball at the origin of a Cartesian coordinate system with six ribbons representing each positive and negative axis. For now imagine that each ribbon is anchored at the appropriate infinity. If the ball is first rotated 180^0 about the x axis, it can then be rotated continuously about the z axis without any of the ribbons building up stress. The ribbons will receive a torsion that will oscillate with half the balls spin rate. This is the simplest motion that satisfies the criteria that the medium be continuous (or that the curvature and torsion of the medium be smooth and well behaved) everywhere including the particle itself. An excellent animation is available at http://rwgrayprojects.com/WSM/SphericalRotations/SR.html.

BPR (1980) and Wolff (1990) have shown that this is the simplest model which has SU(2) as its covering group. SU(2) is the group used to describe leptons (electrons, positrons, and neutrinos).

BPR (1980) formulated an equation for the waves emanating from the vortex and identified corresponding terms with the Klein-Gordan equation for an elementary particle. The rest mass would be given by $m=\hbar\omega/c^2$, where ω is the spin frequency. (Note that the apparent mass would then vary if observed from a reference frame with a different angular velocity.) The wavelength away from the interior would be given by h/mc, the Compton wavelength. They have also shown that the mass inferred by an observer moving at velocity, v, would be given by $m=m_0/(1-v^2/c^2)^{1/2}$. This is consistent with Lorentz's interpretation of relativity.

Further development of spherical rotation

While the concept of spherical rotation is straight forward conceptually, the mathematics is not so simple. The author spent much time building physical models in order to develop intuition for the motion of the *apeiron* for ensembles of spherically rotating particles and later developed the math.

We will look at two types of waves emanating from a spherically rotating piece of *apeiron*. The first is in the plane perpendicular to the axis of spin. To develop an intuition for this, take a spool of thread. Hold it by one end with one hand and wind up the thread without letting go of the spool and moving only the spool. All the time, keep the spool in one place. The contortions of your hand and arm replicate the wave. It is described by two equations. The displacement perpendicular to the plane is given by

$$A=\pm(\pi/2r)\sin(kr\pm\omega t/2-\phi) \qquad (1)$$

where A is the amplitude measured in radians from the center of rotation and ω is the angular velocity of the spin. The sign in front of the right side corresponds to the initial 180^0 rotation and the charge. The sign of ω corresponds to the direction of the spin. The displacement parallel to the plane is given by

$$B=\pm(\pi/2r)\cos(kr/2\pm\omega t-\phi) \qquad (2)$$

To understand the waves traveling in the direction of the axis of rotation take the end of a neck tie and start twisting it. You will keep building up a torsional stress. If you instead bend the tip of your tie 180^0 and proceed to twist the tip of it while allowing the rest of the tie to take the path of least resistance, the tip can keep spinning while the torsion just oscillates. The tie approximates the wave form traveling along the axis of spin. As we get a short distance away from the center, the displacement of the wave away from the axis would resemble a screw with a distance of $c/2\pi\omega$ between threads. The torsion along the filament oscillates with the same wave length. Note that the waves leaving opposite "poles" are mirror images of each other.

At first glance it may appear that we are only looking at two types of particles but when they start interacting with each other, we see four different types of interaction, and that is all that is observed. A way to look at it would be that the initial torsions that cause the 180^0 rotations would come in pairs that would cancel out. After the new born particles accumulate spin, they will only be able to sustain a standing wave between them if they maintain their original orientation.

Before we look at types of standing waves that can be created by ensembles of particles we will introduce the Minimum Amplitude Principle (MAP): The total amplitude of all particle waves seeks a minimum (Wolff

1990). This has several observable classical analogs. Oscillating floats on a liquid surface will position themselves to minimize the waves as will turbulent eddies. This provides a mechanism for the synchronization of the rotation rates of different particles. If a particle is created its spin rate may be different than the average of particles in the universe. It will achieve equilibrium with other particles as it interacts with them. If the distribution of matter is discrete, then the particles mass will increase in jumps leading to a quantization of redshifts (Kokus 1997b). It also provides a mechanism for the transfer of angular momentum from one body to another distant body.

If we start looking at groups of particles it is easy to imagine an arrangement where most of the waves are canceled and there are standing waves between the particles. When we introduced the spherical rotation model we assumed that the filaments or coordinates were anchored at infinity. They are actually anchored in other particles. The types of standing waves are complicated because each wave has two components and the conditions at the ends of the wave, the particles, are more like antinodes. To fully understand the problem it is best to build physical models. From there it is obvious that the sign of the original 180^0 rotation corresponds to the charge and standing waves are only possible between opposite charges. If the direction of spin determines the north and south poles, then we could only have standing waves between opposite poles (Kokus 1997b).

The strong force

Another possibility exists for a standing wave. If we take one complete wavelength from a wave emanating from the center and bend it around in a circle we would get a wave similar to the one already traveling around the particle. So if two positrons were to orbit an electron at a distance corresponding to a circumference of one wavelength we would have a very compact particle with a net charge of +1. This could be, in agreement with Barut's suggestion, a model for two positrons orbiting an electron to form a proton (Kokus 1997a).

Angular momentum of astronomical bodies and spherical rotation

Peter Brosche (1980) and Paul Wesson (1987) have suggested a link between the angular momentum of an astronomical body and its mass. They reason that since microphysics is dominated by three constants (four in SI units) that combine into a dimensionless number, why should not macrophysics? If we are looking for a connection between microphysics and macrophysics, that would be a good place to start. The three constants for microphysics are e, the charge of an electron, $\hbar$, Planck's constant, and c, the speed of light (plus k, the electrostatic constant in SI units) which combine into the fine structure constant, $\alpha=ke^2/\hbar c=1/137$. Gravity has only two constants, G, the universal gravitational constant, and c. In order to create a non-dimensional number for macrophysics we would need a new constant, ρ, with dimensions of angular momentum, J, over mass squared, M^2. Was there such a constant governing the behavior of large bodies? Investigating, it was found that for large bodies, under gravitational influence only, ranging from planets, to stars, to galaxies, to galaxy clusters; the relation

$$J = \rho M^2$$

holds fairly well. This is definitely not expected from big bang cosmology. If we extrapolate this relationship to include all of the mass of the universe, we would get a universe which is rotating. Observations refute the possibility of the universe rotating about an axis, but they do not refute the possibility of a spherical rotation.

When p is combined with G and c we create a non-dimensional number close to the fine structure constant, $G/pc = 1/360$. [Kokus and Ricard, this volume]

Large scale structure and rotation of the universe

In the standard model of the universe it is generally assumed that on a large scale motion is random and there is no large scale rotation. As important as these assumptions are there is no direct evidence to support them. While simple rotation can be ruled out, there is little evidence to contradict a motion like spherical rotation. In fact Ralston *et al* [1998] observed that the plane of polarization of light tended to rotate over very long distances which is consistent with a spherically rotating universe. Longo [in publication] has shown that there is a preferred handedness for spiral galaxies as observed from earth which would support a large scale motion consistent with spherical rotation. Sivaram and Arun [in publication] have shown that the universe is rotating at all scales with no upper limit but the axis of rotation changes which again is consistent with a spherical rotating universe.

If a particle at the edge of the universe were orbiting the universe at a velocity that would put in rotational equilibrium, the velocity would be

$$v = (GM/R)^{1/2}$$

where G is the gravitational constant, M is the mass of the universe, and R is the radius of the observable universe. Now v is close to the speed of light. This coincidence is usually interpreted in terms of potential energy but we could also interpret it as the orbital velocity of a particle orbiting the universe as approaching c. If $J = pM^2$ were extrapolated to the entire universe we would get $v = c$, but v would be interpreted as orbital velocity. The universe could be composed of a hierarchy of spherically rotating bodies, if there were a mechanism or force to add a torsion to the otherwise orbital motion.

Gyromagnetism

Magnetic fields of astronomical bodies have always been enigmas. A recurring theory is gyromagnetism, in which a rotating mass will create a magnetic dipole. Of course there is nothing in the traditional laws of physics that would account for this, but it is supported by empirical evidence. The theory was quite popular until the 1950's when several experiments refuted a popular version of it. After a period of disrepute the theory was resurrected by observations of bodies ranging from planets to pulsars. With the exception of Mars (which has a complicated magnetic field) there is a linear relationship between magnetic moment and angular momentum. When the proportionality constant is combined with the gravitational constant and the speed of light we get a number close to the fine structure constant. (For a review see Kokus 1994b or Sirag 1979, 2002.) Barut and Gornitz [1985] suggested that each elementary particle has a magnetic dipole, and if the angular momentum of an astronomical body was due to the angular momentum of its particles partially aligning, then the particles magnetic fields would add constructively resulting in the body's magnetic dipole. Barut [personal communication] points out that if gravitational bodies possessed a net electrostatic charge sufficient to account for the gravitational attraction between them, then rotating them at their observed speeds would produce the observed magnetic field. This is a coincidence that hints at the origin of gravity as something "left over" from electromagnetism.

The General Allais Effect

The Allais Eclipse Effect is quite well known. It concerns the anomalous behavior of a pendulum or like instrument during an eclipse. A typical pendulum in the Northern Hemisphere will precess clockwise as observed from above. Allais observed that prior to an eclipse the precession slows and then catches up afterward. Similar effects have been observed for a variety of devices. The common thread to the observations is that there appears to be an anomalous counter clockwise (in the Northern Hemisphere) torque prior to the eclipse and an anomalous clockwise torque afterward [Munera 2011]. What is less well known is the General

Allais Effect (GAE) [DeLoly 2011]. It also involves the anomalous precession of a pendulum but with a much smaller anomaly. As the pendulum approaches a point under the Sun (noon) there is a weak counter clockwise torque followed by a clockwise torque as it passes. Similar anomalies are reported for the pendulum's behavior as it passes under the moon or a particular reference point in space near the galactic center.

One of the more curious phenomena of spherical rotation ensembles occurs when one particle is revolving about another which is stationary in regards to a third particle. The axis of the revolving particle would have to flip back and forth to maintain continuity of space [Kokus 1997b, 2015]. Because of the Minimum Amplitude Principle, the motion would be partitioned among all of the particles and they would experience an oscillating torque with the period of occultation. This might be the origin of the General Allais Effect.

A possible model of the General Allais Effect

When a large number of spherically rotating particles is combined, most of the waves would be anchored in nearby particles. But if the earth's magnetic field and angular momentum were the result of some of the particles' waves adding constructively, then there may be evidence of a spherically rotating *apeiron* on a large scale. If some of the particles are aligned then the waves coming from them would have to be anchored in distant bodies which also had some of their particles aligned. An observer on the surface of the earth would see a slight torsion in the *apeiron* and therefore the observed reference frame as it would approach a position underneath a body like the sun or moon. There would be a mechanism for all of the aberrations alleged by Maurice Allais, Dayton Miller and others. There would also be a very complicated situation near an eclipse or other occultation.

Spherically rotating hierarchies

Many of us have watched a blunt object, like a paddle, move through the water. At first we get a large turbulent eddy which in turn breaks down into smaller eddies and then smaller ones. Eventually, the turbulence becomes random motion. The universe is something like that, but with differences. Spherically rotating eddies must reach equilibrium with each other and therefore will have the same rotation rate and size. If the original condition is one large spherical rotation, then as the three dimensional turbulence progresses, it may appear random at certain scales but it will always contain a certain asymmetry. The original spherical rotation would be partitioned among the levels. [Kokus, 1997b]

The weak force

The asymmetric weak force presents a problem for most approaches to unification. If we assume that motion in the universe is nonrandom and asymmetric, that could be an obvious origin of the weak force. If all of the spherical rotations of the individual particles add up to a spherical rotation of the known universe, what would an observer of intermediate size see? If we look at larger scale objects we would see an asymmetry of rotation of bodies and an excess of galaxies rotating in one direction (Longo, in publication). But what about looking at a smaller scale than the observer? At first glance elementary particles would appear to have a random motion and orientation, but if they add up to a spherical rotation there would have to be an asymmetry (a very weak one) at all scales. There would appear to be a weak asymmetric force at the scale of the observer. If the observer were on the scale of the force and at rest with it, the force may appear symmetric. But if observed at a larger scale which would have a different inertial frame, one would introduce an asymmetric force.

Gravity

There are many attempts to treat gravity as something "left over" from electromagnetism and one of them may be right. Others (see Munera 2012 and this volume) have suggested that gravity and some aspects of the Allais Effect can be explained by assuming that we are in a sea of particles ("Sagions") that are pushing in all directions. The force of these particles will cancel out unless another body is shielding them from a certain direction. This will create the illusion that the original body is being attracted to the shielding body when it is actually being "pushed" from the other direction. Gravity is simply a shadow effect.

The Dirac Large Number Hypothesis has also given rise to many interpretations of gravity. Of interest is Wolff [2008]. Some of these approaches can be incorporated into a simpler theory based on spherical rotation. In spherical rotation a piece of *apeiron* rotates 180 degrees about one axis and then rotates continuously about an axis perpendicular to the original. The rate of the second rotation increases as the particle interacts with older particles. The apparent force between the particles also varies with the difference between the spin rates and the geometry of the local, older particles which may be very asymmetric. Initially, if a particle is created with little spin, and is near to a number of particles spinning at a much higher rate, the Minimum Amplitude Principal would require that the younger particle move away in order to minimize the total amplitude of all interacting waves. This could explain the ejection of young quasars from their parent galaxies. As the spin rate of all younger particles increases, the net force on it would lesson. As the particle moves into a more homogeneous distribution of particles, it would encounter forces from all sides that would tend to cancel. As the new particles mature, they would achieve equilibrium with the older particles. But then younger particles would be born and they in turn would slow down the spin rate of the original particle. So now our new particle would be slowing down at the rate of the older surrounding particles. So according to the Minimum Amplitude Principle, it will try to move away from the surrounding particles, though at a slower rate than when it was younger. If there was a particle of the same age nearby, it would "absorb" the waves from the more distant particles behind it. This would create the appearance of the nearby particle attracting our original particle. While generalizing this would give rise to the appearance of gravity, there would also be other terms that would give rise to the Allais effect. The mass of a particle would increase quickly after it is created and then very slowly decrease as Chip suggested [personal communication].

Other observations and thoughts

The author first got involved in this area of study by observing patterns in seismic activity [Kokus 2011a, 2011b]. There were definitely cycles observed that could be linked to periods in solar and lunar position. An exhaustive effort has been made to explain these patterns in terms of tidal triggering, but all attempts have failed. There is only a weak correlation with local tidal stress. When comparing the influence of different tidal terms, the only ones that showed any correlation were those that were also found in the General Allais Effect [Kokus 2011b]. The same can be said of planetary influence on solar activity. And perhaps the most curious coincidence is that the average time between magnetic pole reversals is the same as the time it takes our solar system to revolve around the Milky Way [Kokus 1997b]. This would also be consistent with planetary magnetic fields being the result of spherical rotation effects.

This is not even close to a final theory, but it should be a compelling argument for looking at another approach. But I can say for certain that none of this would have been noticed had it not been for Halton Arp.

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Arp's Indomitable Universe

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We present some aspects of the work and personality of Halton Christian Arp (1927-2013).

We are used to being astonished by beautiful images of galaxies, splendorous arrangements of stars, gas and interstellar dust. The Sun and its planetary system are located in one of them, the Milky Way galaxy, a giant spiral galaxy, with the Sun sitting in the periphery of its disk. Our similar-sized neighbor is the Andromeda galaxy, another spiral, formidable and harmonious, especially when contemplated with a telescope. Incidentally, the Andromeda galaxy is the most distant cosmic object visible with the unaided eye.

But galaxies, like people, can also be complicated and strange, and interact in a very peculiar way. And that is what we shall deal with here – with such a complex and, to a degree, indomitable universe.

One of the first astronomers to embrace the "weird" galaxies was the American Halton Christian Arp* (1927-2013), born in New York City, United States, and well-known among his friends and close colleagues by the nickname "Chip." He graduated in astrophysics in 1953, but even before this date, he had worked under Edwin Hubble (1889-1953). In 1957 he began working at the Palomar Observatory, which then had the largest telescope in the world, the 200 inch Hale telescope. Arp worked for 29 years at Palomar until he finally moved to the Max Planck Institute for Astrophysics, in Germany in 1983, where he stayed active in astronomy until his death in 2013.

Our story begins with Arp's interest in galaxies with strange shapes, in the majority of the cases caused by gravitational interactions with their close neighbors. Some of them are clearly in the process of merging. Two or more galaxies interact so strongly that their original shapes are destroyed and the interacting group quickly turns into a single object made up of the aggregation of stars and all material present in the original galaxies. As soon as he began his work at Palomar, he started to look for galaxies of this kind. After quite some time, in 1966 he published the result: an atlas of "weird" galaxies, the *Atlas of Peculiar Galaxies*, which, to this day, is still used in astronomical research dedicated to understanding the evolution of galaxies.

The Atlas consists of a set of 338 sky fields, presented in rectangular format, identified by "Arp nnn," where "nnn" is the number of the field. Each field shows one or more galaxies that always exhibit some peculiar structure, often caused by the gravitational interaction between them. The field sizes range from – the smallest – 2 arcminutes wide, up to 1 degree wide (Arp 318). The fields were observed with the 200 inch telescope and with the 48 inch Schmidt telescope, the latter well suited for the larger sky fields. The images were engraved on photographic emulsions specially designed for astronomical use.

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* After being ill for some time, Halton *Chip* Arp passed away on December 28, 2013 in Munich, Germany. He was born on March 21, 1927 in New York City, United States. Arp is well known for his non orthodox views in astrophysics and especially in cosmology. He is the author of the renowned *Atlas of Peculiar Galaxies* (1966), of innumerable scientific publications and of the books *Quasars, Redshifts and Controversies* (1987) and *Seeing Red: Redshifts, Cosmology and Academy* (1998). Arp was living in Germany since 1983 where he was a researcher at the Max Planck Institute for Astrophysics. According to a communication from our colleague Hilton Ratcliffe "His legacy will live on with anyone who is concerned with objective scientific reason. Chip was a fine man and a very dear friend and colleague. His final paper is currently with the referees of *ApJ*, and I shall let you all know when it is published."

Figure 1 – Halton "Chip" Arp. [Overbye, 2014]

Arp sorted the general features of his *Atlas* into four large groups.

- Arp 1 to 101 – Spiral galaxies that have: low brightness, subdivided spiral arms, arms with detached segments, three arms, one arm, faint companions and elliptical galaxies as companions.
- Arp 102 to 145 – Elliptical galaxies with the following features: connected to spirals, close to disturbed spirals, close to galaxy fragments and close to apparently ejected material.
- Arp 146 to 268 – Galaxies (not included in previous groups) that have rings, jets, filaments, tails, amorphous spiral arms and loops adjacent to the main body.
- Arp 269 to 338 – Double galaxies connected by stellar arms (bridges) and with long filaments, galaxy groups and galaxy chains.

Photographic illustrations of these groups, obtained by Arp, are available online at:

http://nedwww.ipac.caltech.edu/level5/Arp/frames.html.

The field Arp 81, shown in Figure 2, is a pair of spiral galaxies which began colliding, *i.e.*, at closest approach, 100 million years ago. During this period, the original shapes of the galaxies became very disturbed. Their original nuclei and signs of what were their stellar disks are readily visible. At the top of the image is a "tail" produced by the gravitational force of one galaxy over the stellar disk of the other, in this case, the largest one NGC 6621, to the left. Such a structure is called a "tidal tail." The formation of this tail is due to the very same phenomenon that produces ocean tides on Earth, from which it gets its name. Ocean tides are caused by the com-

Figure 2 – The field Arp 81, a pair of galaxies in strong gravitational interaction. The galaxy on the left is NGC 6621 and on the right is NGC 6622. Arp 81 is 300 million light years from us. One of the main consequences of these kind of interactions is an increase in star formation in the galaxies (Credit: Hubble Space Telescope/NASA).

bined gravitational forces of the Moon – mainly this – and of the Sun on the terrestrial oceans.

The field Arp 244, shown in Figure 3, is another example where tidal tails clearly show up. This system is known as the *Antennae Galaxies* because of its peculiar shape. The tails are definitely formed by the gravitational interaction between stars belonging to the disks of the two spiral galaxies that form the system.

This was demonstrated for the first time by the brothers Alar Toomre, astronomer and mathematician, and Juri Toomre, astronomer, by means of numerical simulations performed with a computer in the late 1960s. Alar and Juri Toomre were born in Estonia. In 1949 they immigrated to the United States where they graduated and furthered their astronomical research.

Arp 244's galaxies were represented by stellar disks, each one with 120 particles. These particles, which represent the galaxy's stars, undergo the action of the gravitational force exerted by both galaxies. Initially the galaxies were perfect disks, and then they were "thrown" into in a mutual elliptical orbit. Through the action of the gravitational forces, stars gradually abandon the original disk-like distribution in the subsequent orbital motion. As illustrated in Figure 4, some of the stars move far away from the majority of stars that formed the disks. The Toomre brothers chose an appropriate angle of view of the simulated system in order to obtain an image that is similar to the real system.

The simulations, of this system and others, performed by the Toomres showed, for the first time in the history of astronomy, that the shapes of interacting galaxies were the result of gravitational interactions among the

Figure 3 – The field Arp 244, another pair in strong interaction (NGC 4038 and NGC 4039). The tidal tails that emerge from both galaxies in the pair give the impression of insect antennae, hence the popular name of this system, "Antennae Galaxies" (Credit: Brad Whitmore/STScI).

constituents of the interacting system. Astronomy, the study of the locations of celestial bodies in space and time, is here supplemented by a physical law – Newton's law of universal gravitation – and becomes authentic astrophysics.

After the publication of Alar and Juri Toomre's investigation in *ApJ*, in 1972, the study of interacting galaxies by means of numeric-computational simulations became a topic of great interest in the astronomical community. This kind of simulation is known as "N body simulation," where the systems involved in the interactions are represented by systems with N particles. In the simulation of Arp 244, N = 240. Nowadays, with the development of supercomputers, N can easily reach 100 thousand. Furthermore, galaxies are represented by more realistic models with the inclusion of gas and dust, which are important components of many galaxies. Other processes are also considered such as the chemical evolution of galaxies and the consequent changing in their stellar populations, and hydrodynamic interactions, typical of gaseous components.

The indomitable universe cannot only be seen in the cosmic dimension. It also marked Arp's attitude throughout his entire scientific life.

He is known for his strong opposition to the standard model of cosmology. The orthodox scientific community acclaims the standard model, the Big-Bang model. Nevertheless, its critics point to its many inconsistencies, especially when the predictions of the theory are confronted with astronomical observations. Most of Arp's ideas in this and other scientific topics were publicized, for the specialist and non-specialist, in his three books, *Quasars, Redshifts and Controversies* (1987), *Seeing Red* (1998), and *Catalogue of Discordant Redshift Associations* (2003).

In 2003 one of the authors, MCDN, met Halton Arp twice in Italy. The first meeting happened in Naples, at the Istituto Italiano per gli Studi

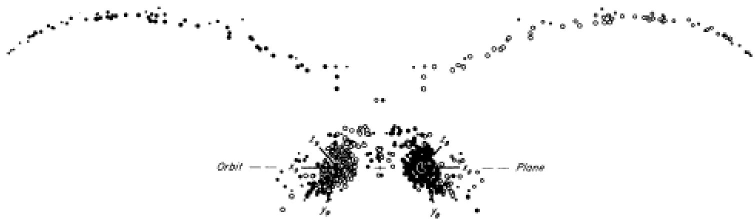

Figure 4 – Result of the numerical simulation of the Antennae Galaxies. Filled little circles represent stars of one galaxy and open circles stars of the other. The orbital plane of the original galaxies, initially disks of stars, is indicated by "Orbital Plane." The mutual gravitational forces act in such a way that they pull disk stars out to form tidal tails. Compare this with the previous figure, which is an image of the real system (Credit: Alar Toomre and Juri Toomre).

Filosofici, at Palazzo Serra di Cassano, during the International Congress on Science and Democracy, organized by Marco Mamone Capria.* The second meeting took place in Pavia at the International Workshop on Alternative Cosmologies, organized by Enrico Giannetto.

It was a great pleasure for MCDN to meet him. Three years later he invited Arp to write a paper for the *Acta Scientiarum* journal of the Universidade Estadual de Maringá (Brazil), as MCDN was responsible for the section on natural sciences of this publication. He accepted the invitation and published the paper "Cosmology and Physics."† In this work he considered the observation of extra-galactic bodies, showing that their redshifts were a function of their age, instead of being a function of their recessional velocities. Arp believed that a model like the big bang was not necessary in order to understand the behavior of the universe. In this paper he pointed out that the analysis of new data indicated the need for a new physics in order to satisfy experiments which had up to now been based on Einstein's theory of relativity (TR). He believed that the present situation requires simple logic rather than mathematical formulae for new solutions. It also requires new rules which are outside the normal scope of TR. He criticized the paradigms which confine science to the news media by an inadequate use of an old physics which is not open to the new possibilities required for a deep understanding of nature and the universe.

He concluded this paper as follows:

> Probably many of these independent researchers have wondered whether Academia is a doomed institution. Has 800 years of uncritical approval

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* [Fanuzzi, Gargano and Chiaro, 2010].

† [Arp, 2000].

> and acceptance led to senescence? Has a self-serving feedback loop between academia and the news media convinced the two parties that fundamental assumptions can never be questioned?
>
> What is to be done? Press with logic and insistence on both estates? Of course! Press ahead with independent research and mutual support from all such researchers. Of course! It is my hope that by putting forth the candid thoughts of this paper, we may use each other's results and concepts to unify science on all scales, and across all disciplines, in a way that will lead to more fruitful discussions and understandings in the future.

Below we present a few of the events which took place in Italy, organized by the Istituto Italiano per gli Studi Filosofi,* in which Arp participated. The participants are also listed to give an idea of the persons with whom he was probably in contact during these meetings.

- **NEW IDEAS IN ASTRONOMY,** In collaborazione con l'Istituto Veneto di Scienze, Lettere ed Arti, il Dipartimento di Astronomia dell'Università di Padova e l'Osservatorio Astronomico di Padova. Venezia, 5-7 maggio 1987. Relazioni di: C. Maccagni, F. Hoyle, J. Heidmann, R. Kraft, A. Renzini, C. Chiosi, L. Rosino, V. Ambartsumian, R. Dickens, M. Roberts, R. Wolstencroft, S. Bonometto, M. Capaccioli, G. Bertin, M. Burbidge, S. Di Serego-Alighieri, E. Khachikian, P. Rafanelli, I. Pronik, J. Sulentic, N. Sharp, G. Schnur, S. Cristiani, H. Arp, W. Tifft, W. Napier, W. Saslaw, W. Alfven, L. Woltjer, G. Burbidge, A. Treves, A. Zensus, J. Narlikar, J. P. Vigier, G. Börner, R. Sanders, J. C. Pecker, K. Rudnicki, J. Wampler, W. Brinkmann, A. Cavaliere, D. Sciama, V. Clube, R. Ruffini.
- **KOSMOS: LA COSMOLOGIA OGGI TRA FILOSOFIA E SCIENZA (COSMOS: COSMOLOGY BETWEEN PHILOSOPHY AND SCIENCE)**, In collaborazione con l'Istituto Gramsci Veneto e il Goethe Institut), Venezia, 8-9 maggio 1987. Relazioni di Umberto Curi, Livio Gratton, Halton C. Arp, Dennis W. Sciama, Jayant V. Narlikar, Enrico Bellone, Geoffrey Burbidge, Jean-Pierre Vigier, Oddone Longo, Nicola Badaloni, Dieter Wandschneider, Fred Hoyle, Carlo Sini, Jean Heidmann, Paolo Zellini, Jean-Claude Pecker.
- **IL PRINCIPIO ANTROPICO (THE ANTHROPIC PRINCIPLE)**, In collaborazione com l'Istituto Gramsci Veneto, il Goethe Institut, il Dipartimento di Astronomia dell'Università di Padova), Venezia, 18-19 novembre 1988. Relazioni di: John Barrow, Oddone Longo, Brandon Carter, Hubert Reeves, Fred Hoyle, Livio Gratton, Dennis W. Sciama,

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ton Arp, Ya. Baryshev, H. C. Kandpal, Eric J. Lerner, Jacques Moret-Bailly, Marcos Cesar Danhoni Neves, Georges Paturel, Francesco Sylos Labini.

In honor of his brilliant work and the bravery he always showed in his constant fight against the establishment, two of the authors (AKTA and DSLS) have done a Portuguese translation of one of his books.*

Randall Meyers, the celebrated composer, especially known for the music he composed for the Hollywood film "The English Patient," who directed and produced the documentary film "Universe: The Cosmology Quest,"† published on his official website‡ a precious short film in memory of Fred Hoyle, showing his meeting with Chip Arp. In this encounter we perceive the power of anti-paradigmatic arguments against the *establishment*. It is vitally important to keep alive the memory of this great warrior of modern science.

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† [Meyers, 2004].

‡ [Meyers, 2012].

The Lunar Wake as Cause of the Allais Effect

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Recently I have found a very strong correlation between unsolicited motions of a special torsion balance and instabilities of the geomagnetic field. I argue that these geomagnetic variations, if steep enough, might induce eddy currents into the metallic mass of the balance. Such currents would generate magnetic fields which could urge the balance to rotate. Geomagnetic instabilities arise when the solar wind is unstable as an effect of solar activity. I have noticed that such instabilities occur, for an observer at Earth, even when the sun is calm and the solar wind is stable, but the observing point is swept by the effects of the "lunar wake", i.e. the vacuum of solar wind which extends from the moon in the anti-sunward direction. This happens around solar eclipses. I think that the lunar wake could account for the so called "Allais Effect" (abnormal behavior of Foucault pendulums and other devices around solar eclipses) by the above mentioned mechanism. Actually I have found the magnetic signature of the lunar wake in geosynchronous satellite data around the occurrence of solar eclipses during which it was claimed a detection of the Allais Effect. In this article I present both satellite and torsion balance data for some eclipses. I think that the elusive and somewhat mysterious Allais effect falls into the realm of commonly accepted physics. The geomagnetic activity depends on the interaction of the solar wind with the magnetosphere. The effects of the lunar wake in the near-Earth environment has not been well studied yet, and I suggest that the "all American" August 2017 solar eclipse would be a good opportunity for further investigation

1. Introduction

By "Allais Effect" is meant an abnormal precession of the swinging plane of a Foucault-style pendulum. It was first observed by the French Nobel laureate (in economics) Maurice Allais during the solar eclipse of June 30th 1954 [1].

Later, some abnormal behavior was noticed by other workers on other instruments such as, just to mention, gravimeters by Wang *et al*. [2], torsion pendulum by Saxl & Allen [3], stationary pendulums by Iovane [4], and more swinging pendulums [5][6].

The unexplained effect captured the interest of NASA, which in 1999 promoted a worldwide eclipse experiment [7] whose results have never been published.

I had been participating in that experiment getting a positive result [4], and since then I have spent several thousand hours making equipment and experiments.

The mysterious effect was initially supposed to be of gravitational nature.

Among other workers, very interesting results were achieved by Prof. Alexander Pugach of the National Academy of Sciences of Ukraine, with the use of a special torsion balance of his own design. This very delicate and sensitive balance is described in [8][16] and some results have been published in [9][10]. In short, the balance consisted of a thin aluminum disc of about 12 cm in diameter, weight 0.1g, suspended in the center by a single filament of natural silk, closed in a sealed container but not empty of air, electrostatically but not magnetically shielded, with an automatic monitoring system of the azimuth of a reference on the disc. The system was in an isolated environment, away from people and electrical noise in a closed unattended ambient, etc ... Pugach called this special balance "torsind". A great merit of Pugach is to have made measurements over a long period of time, covering different phases of the current solar cycle from minima to maxima. I have been in contact with Pugach for several years, and had the opportunity to look at his data. We also had a personal meeting.

Pugach has published several articles in which he claims to have observed anomalous behavior of his instrument in conjunction with solar eclipses (such as [9][10]). His articles are credible, as around solar eclipses actually a strange behavior is observed in a family of devices that have the common feature of having a freedom of movement around a pivot point (pendulums, spring-mass gravimeters, torsion balances) as above mentioned.

Anyway there was a main issue with all of the above mentioned "positive" results: most of the times the observed anomalies were shifted in time relative to the optical eclipse, sometimes by hours such as in [11].

No solid explanation of all of the above mentioned phenomena was available as of late 2013.

At the end of 2013 I had the idea that the vacuum of solar wind which occurs on the anti-sunward side of the moon, i.e. the well known lunar wake, could be responsible for the observed effects, causing the induction of eddy currents into the test device at Earth by the below explained mechanism.

2. The Torsind Reaction

Around eclipses of the sun, the Pugach's disc rotated a little. This during periods of calm sun in late last decade. With the passage of time (which "a posteriori" means practically with the approach of maxima in this solar cycle) the disc rotated sometimes in the absence of eclipses. The more time passed, the more this happened . From Pugach's data and official sunspot number data, I saw that there was a gross correlation over the long period between the two things. But in the short term there was no correlation. Pugach reported this [16]. Nothing clear at that time, only a rough correlation and no idea of the mechanism.

At one point I had the intuition that, as an effect of fast variable geomagnetic field, some eddy currents could arise in the disk, with associated magnetic fields and associated effects (such as the disk of old style watt-hour power meters). Hence I begun to study the correlation between solar wind and magnetosphere.

3. The Mechanism

It is common knowledge that the solar wind is always present, and is responsible for the shape of the magnetosphere . Under conditions of quiet sun the solar wind is uniform and the magnetosphere is quiet, without disruption of the equilibrium of electrical currents and of lines of force of the Earth's magnetic field which pervades it. When there is solar activity, the solar wind can be disturbed, with accelerated and diverted gusts and more. This occurs in coarse correlation with the sunspot number, but not always the solar wind disturbances do hit the Earth. The sun emits the wind all around, and only if a disturbance is emitted in a favorable direction it would reach Earth. The solar wind is blocked by the magnetosphere, as it is well known, and a non-uniform wind is likely to cause geomagnetic storms and other minor geomagnetic disturbances. A non-uniform solar wind disturbs the tranquility of the magnetosphere. An unsettled geomagnetic field has easily measurable effects on Earth-based and satellite-based magnetometers. Geomagnetic storms are capable of producing effects from delicate (aurora borealis, deviation of compass needles) to dramatic (such as the Carrington event [12]). They induce currents into the ground, into pipelines and power lines, and most likely into the masses used for Allais Effect tests.

As I have found magnetic signatures of the lunar wake in satellite data around the occurrence of solar eclipses, I suggest that the lunar wake is responsible for geomagnetic effects similar to those caused by geomagnetic storms, even if to a lower and somewhat local extent.

4. The Correlation

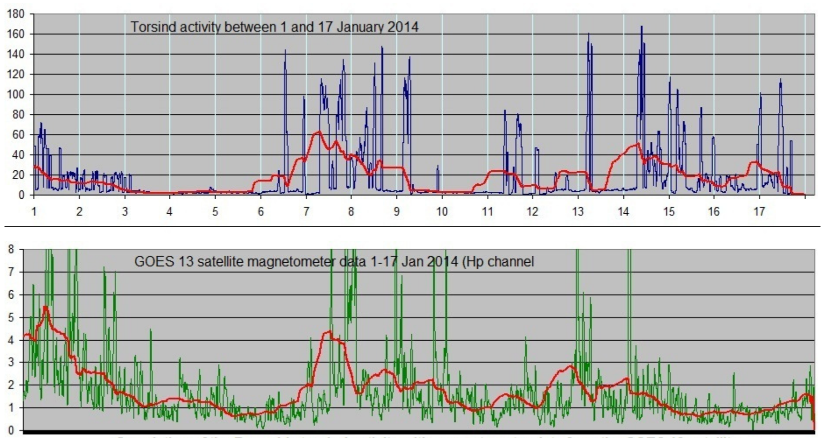
I needed to find data on geomagnetic activity to be correlated to Pugach's data, and I found them in NOAA archives with respect to geostationary satellites carrying magnetometers on board. The correlation was striking. In January 2014, the rotations of the disk due to geomagnetic activity were orders of magnitude greater than the rotations observed during solar eclipses in periods of calm sun. In such conditions as in January a solar eclipse would not be "seen" by a torsind, being much under, say, the noise level.

In January 2014, a non-eclipse epoch, the situation was as in Figure 1. By torsind activity we mean rotations of the torsind about its vertical axis. Note that the observing point (Kiev) and the GOES13 satellite are at different longitudes. It is worth mentioning that with calm sun, and no eclipse, both curves are flat or near flat.

5. Eclipse Data

What is likely to happen around solar eclipses? After having seen what happens to a torsind when the sun is active, let's consider the condition of calm sun and uniform solar wind. The lunar wake, i.e. the "eclipsed" solar wind, causes a localized imbalance in the magnetosphere and hence a local geomagnetic instability, inducing currents into conductive materials such as genuine geomagnetic storms do.

It is worth mentioning that most of the time the lunar wake is not co-axial with the optical shadow of the moon, for at least these reasons: a) the solar wind comes angled to Earth, as it follows the "Parker spiral" [14]; b)



Correlation of the Pugach's torsind activity with magnetometer data from the GOES 13 satellite

What is plotted in both cases is the standard deviation computed over a moving window of 60 data points (1 hour, blue and green lines). These computed SD have then been smoothed over a 1000 points moving window (red lines).

Fig. 1 — Torsind data credit Pugach, satellite data credit NOAA

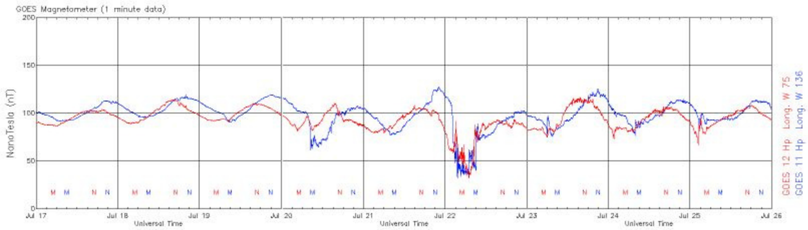


Fig. 2 – Magnetometer data from NOAA satellites showing geomagnetic unrest in the morning of July 22 2009, the day of a solar eclipse.

the wake is turbulent as it is gradually refilled by surrounding particles of the solar wind (this is common knowledge). In my view some experimental results seem to suggest that the lunar wake might exhibit a Kelvin-Helmholtz instability [15] causing periodicities in the observed anomalies [4]. That said, the apparent direction of origin of the lunar wake is not easily predictable, and it could reach the magnetosphere above an observing point before, during or after an optical shadow. This is what most of the experimental results do show. Looking at the presented data, please consider that the satellites are at longitude W75 and W135, while the observing sites at Earth are at different longitudes. As an example Kiev is at E30. This means that a given disturbance might be detected at different times from different instruments, but also that some instruments could not detect it at all, depending on where they are located relative to the lunar wake trace at Earth. It is worth recalling that the shape of the lunar wake might be not well defined and is turbulent. Further, generic geomagnetic disturbances are known to have possible reverberations and persistence, and this could also be the case of lunar wake induced disturbances. I would emphasize that I found traces of the lunar wake in satellite data in correspondence of eclipses in periods of calm sun in which Pugach and others had detected rotations of the torsind or abnormal behavior of pendulums, and in correspondence of anomalies that I had detected with a stationary pendulum during an eclipse. Let's examine some cases. (Note that a calm magnetometer trace aboard a geosynchronous satellite is a clean slowly-varying quasi-sinusoidal curve with a diurnal periodicity, such as in the first days of Figure 2).

1) Solar eclipse in Shanghai on July 22 2009. Li, Olenici *et al.* had observed abnormal behavior of a ball-born swinging pendulum [5]. The GOES11 and GOES12 satellite magnetometers say that the geomagnetic field was disturbed in the morning of July 22, see Figure 2. Note some persisting noise in the days after. On July-August 2009 the sun was spotless (sunspot number = 0) since July 12 and up to August 30. The July 22 solar eclipse occurred in a period of very quiet sun. Nevertheless the satellite magnetometer data for the period 17-25 July say that in the morning of

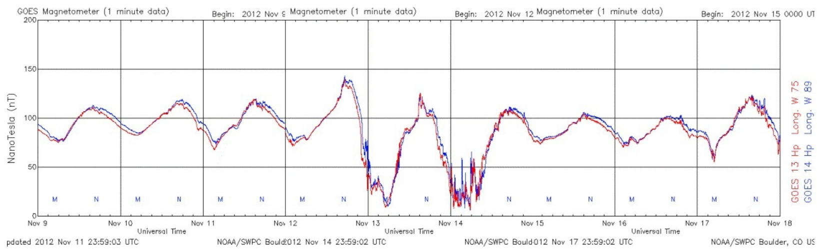


Fig. 3 – Geomagnetic disturbances in the night between November 13 and 14 2012.

July 22, the solar eclipse day, there was a remarkable magnetic disturbance. I interpret this disturbance as an effect of the lunar wake on the magnetosphere.

2) Solar eclipse over Australia and Pacific Ocean in the night (UT) of November 13-14 2012. Olenici *et al.* observed anomalies both with torsinds and pendulums [13]. The satellite graph of Figure 3 (credit NOAA), shows that the geomagnetic field was disturbed in that night and early morning.

3) Solar eclipse of November 3 2013 over Atlantic Ocean and Africa. Pugach detected abnormal behavior of three torsinds. The satellite data

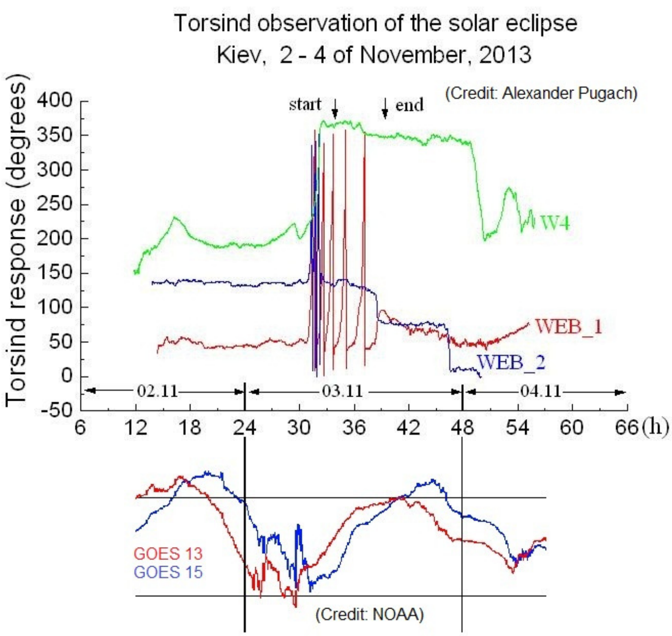


Fig. 4 – Pugach's torsind activity and satellite data of November 3 2013. I interpret the geomagnetic disturbance as a trace of the lunar wake.

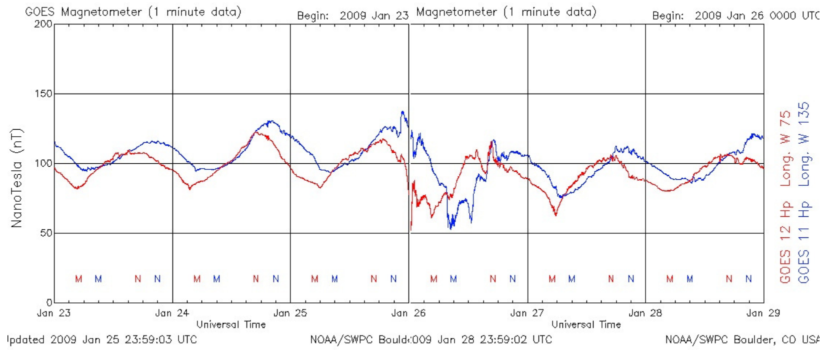


Fig. 5 – Geomagnetic disturbances of January 26 2009. No doubt that the abnormal behavior of the instruments was correlated to these disturbances.

show a disturbed geomagnetic field in the morning of November 3, see Figure 4.

4) Solar eclipse of January 26 2009. Pugach and Olenici observed correlated abnormal behavior of torsind and paraconical pendulum. Figure 5 is the satellite magnetometric trace showing steep variations in the morning of January 26. I interpret them as being caused by the lunar wake.

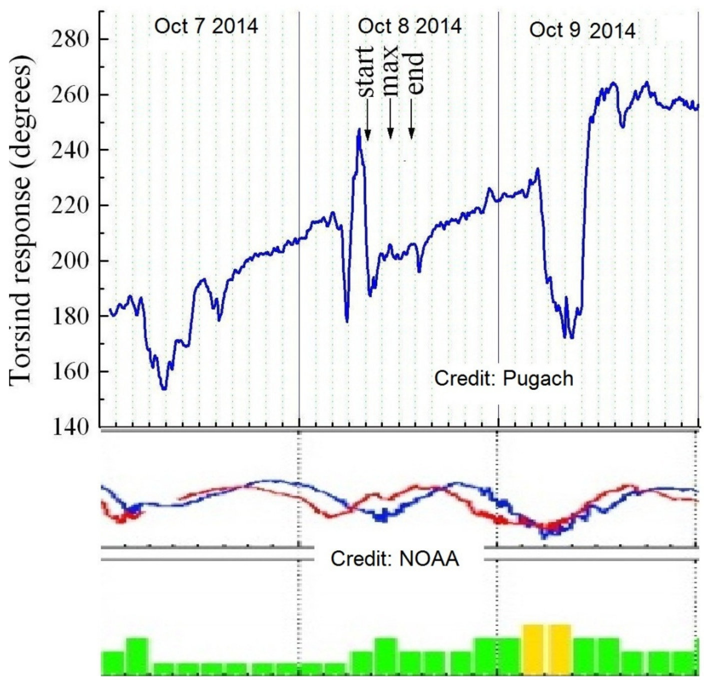


Fig. 6 – Top: Torsind data for October 7-8-9 2014. Bottom: Satellite magnetometer data and averaged estimate of the planetary magnetic Kp index. On October 8 there was a lunar eclipse, marked in the figure by start-max-end.

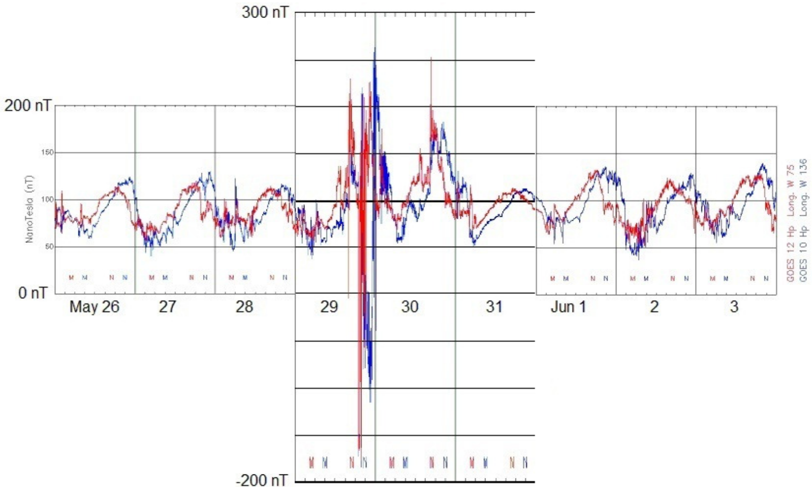


Fig. 7 – Heavily disturbed geomagnetic field in the days around the 31 May 2003 solar eclipse makes the lunar wake not distinguishable.

5) LUNAR eclipse of October 8 2014 (moon at opposition). Recently Pugach installed a new torsind at a different location. He recorded the trace of Figure 6 which shows torsind activity in the mornings of October 7, 8 and 9 2014. This interesting new test, made at a new location with a new device, confirms that the torsind responds to instability of the geomagnetic field. The bottom of Figure 6 shows the satellite data for the same period. In this case the torsind detected ordinary geomagnetic disturbances, stronger in a non-eclipse day, and not the lunar wake which was on the other side. The eclipse was a coincidence.

6) Solar eclipse of May 31 2003 early morning. Iovane [4] recorded abnormal tilts of a stationary pendulum, as shown in Figure 7. Unluckily he recorded only 8 hours centered on the eclipse, while the geomagnetic field was strongly disturbed since a couple of days, and the effect of the lunar wake is not clearly visible due to the general geomagnetic conditions.

7) It is interesting to have a look at the solar eclipse of August 1 2008. Goodey *et al.* claimed to have observed correlated anomalies on their instruments[6], but there is no strong evidence of the lunar wake in satellite data, see Figure 8. In this case the satellites I'm using as a reference might have not seen all the effects of the lunar wake, because their longitudes were too far from the longitudes of the eclipse path. Anyway the August 1 curve is not completely free of disturbances, and as an example the blue curve, instead of being quasi-sinusoidal, shows a "V" shaped dip.

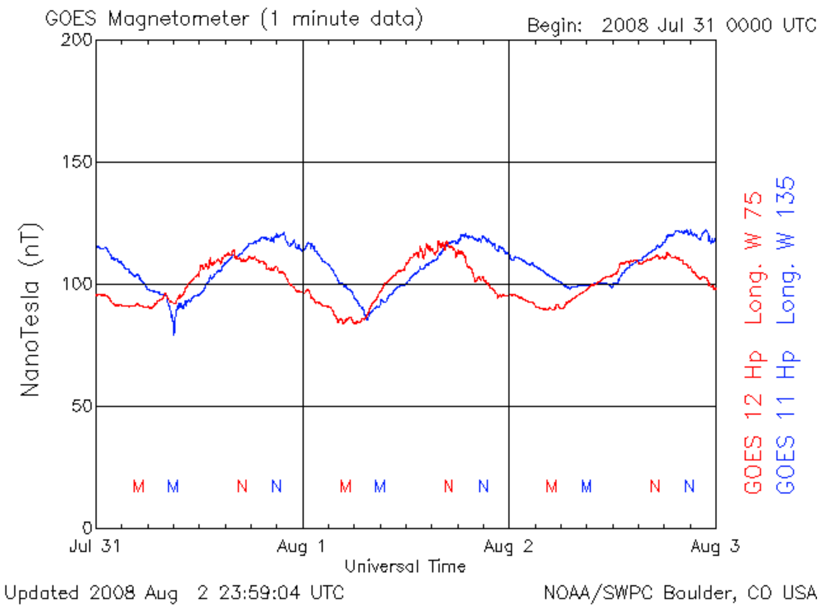


Fig. 8 – Rather calm geomagnetic conditions as seen by satellites away from the eclipse path.

6. Conclusion

The lunar wake as a cause of disturbances at the magnetosphere level left its signature in magnetometer data around the occurrence of solar eclipses, which is a circumstance in which such a wake is Earth-directed. It appears that the lunar wake is the cause of something like geomagnetic storms, even if with limited amplitude and extension. Such lunar-wake-induced “storms” might have effects similar to known effects of genuine geomagnetic storms, such as the induction of eddy currents into conductive masses. These currents would in turn generate magnetic fields which, interacting with the Earth’s magnetic field, might cause these masses to move, typically to rotate if pivotally mounted, provided that such masses have sufficiently low or virtually null friction.

The Allais Effect has been elusive since its discovery. Sometimes it was detected, sometimes it was not. Its correlation with the optical solar eclipse has been loose most of the time, and no predictions on its detection have ever been successful based on the optical eclipse geometry. I suggest that the abnormal behavior of the Allais Effect test devices is due to eddy currents induced into the test masses by the geomagnetic disturbances caused by the lunar wake hitting the magnetosphere. The effects might be cumulative on swinging pendulums, causing abnormal precession of the swinging plane of Foucault-style pendulums. On pendulums of which the period is monitored, such as torsion or even ordinary pendulums, the period might vary following a variation of the magnetic braking effect of the local magnetic field. Spring-mass gravimeters with a feedback circuit, such as the often used LaCoste Romberg model D, might have currents induced somewhere into the circuit, falsifying the feedback signal. The fact that these gravimeters have a limited susceptibility to static magnetic fields doesn’t mean that they would not be adversely affected by quickly varying magnetic fields.

Acknowledgment

I wish to thank Prof. Alexander Pugach for his permission on using his data and for all the cooperative work.

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Gravity from Classical Fluid Theory: Prediction and Retrodiction of Quantized Planetary Structures

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The formal analogy between electromagnetism (EM) and gravitation was noted by Maxwell in the mid-18th century, and by Heaviside in the 1890s; analogy that was extensively invoked in the gravitomagnetism of the 20th century. A connection between EM and fluid theory is explicit in Maxwell's work, while the equivalence of Maxwell equations (ME) to various wave equations is explained in electrodynamics textbooks; in particular, the validity of ME concurrently requires the validity of the vector and the scalar homogeneous wave equations.

In the 1990s the present author found novel solutions for the classical homogeneous wave equation in spherical coordinates (CHWE); of particular interest are the nonharmonic functions of the first-kind $S_l(h)$, which are equivalent to the unified force of nature proposed around 1760 by Boscovich from philosophical considerations, but without a formal mathematical basis. Our finding thus provides a mathematical basis for Boscovich's force, which in turn implies quantization in energy and distance — a fact noted by J. J. Thomson, several years before Bohr's quantum theory. More important is that Boscovich's force is consistent with empirical findings in nuclear, atomic and molecular fields. Here, we explore the application of our $S_l(h)$ to a gravitational situation.

Associated with spherical surfaces in gravitational equilibrium, the family of even $S_l(h)$ described here predicts quantized structures at different scales, as the solar system and the moons of Jupiter, Uranus, Saturn, Neptune, Pluto, Mars, and Haumea. Each calculated radius is compared to the semimajor axis of the orbits of all moons/planets in our solar system: correlation and R2 coefficients are in general well above 99%. As an appetizer for forthcoming work, a preliminary discussion is included on the capability of our theory to describe the structure of the rings of Saturn; a geometrical approach to calculate orbits of Trojan moons is also mentioned

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1. Introduction

The twentieth century witnessed an extraordinary technological progress, but at the same time it also saw a reversal in the attitude of professional scientists towards their object of study: a return to science as a religion. Currently, the final arbiter for the validity of a theory is not empirical observation and testing, as it was until the end of the 19th century and as it should be in any *hard* science. Rather, if empirical results are in conflict with predictions from an established theory, or even of a simple hypothesis (as it happens, for instance, in the regulation of radiation), the empirical observations are discredited, or ignored, or hidden, or rejected as wrong. Moreover, under the unprecedented coverage of media, several scientists have been deified by both laymen and the establishment scientists—Einstein is a well- and world-known example. A minute criticism to any academic god is suicidal, for it inexorably leads to academic death. The current situation is worse than the Inquisition of the Middle Ages—that bent Galileo on his knees, but let him live. Halton Arp's case serves as an illustration: the mere suggestion that something could be wrong with the (by then) recently enthroned cosmological paradigm led to limiting his access to observational time at a top Californian institution. Is that the current definition of free scientific inquiry and *bonafide* search for the truth?

The present writer did not have the privilege of meeting Halton Arp personally, but our life-paths and scientific interests often coincided. I read his books *Quasars, Redshifts and Controversies* published in Berkeley (1987) [1], and *Seeing Red* published in 1998 by Apeiron [2]; inspired by the first one, in the early 1990s a classical Newtonian model was developed by this author to explain redshift, and presented in a paper that was published in Apeiron in 1998 [3]. The first paper in the same issue of Apeiron was contributed by Arp [4]. Let us take this opportunity to thank Roy Keys for founding his publishing house Apeiron and its namesake journal, a house that has been always open to heterodox ideas in gravity and cosmology.

In the year 2000, John Chappel invited me to attend the Natural Philosophy Alliance (NPA) conference held at the Storrs campus of the University of Connecticut. On that occasion I joined the NPA, and was delighted when some years afterwards Halton Arp was named as the first recipient of NPA's Sagnac Award. In November 2014 the present writer had the privilege of joining Arp in the list of recipients of the same Sagnac Award. My talk at the 2014 NPA meeting summarized the neo-Cartesian fluid theory of Nature that I have been slowly developing over the past 25 years.

My fluid approach implicitly contains Le Sage's pushing gravity [5], a mechanism that explains both the generation and the propagation of gravitational force; the first chapter in Le Sage's book is a foreword contributed by Arp [6]. In this foreword Arp made two conceptual remarks with which I completely concur:

- "Is space-time curvature valid? At this point the elementary question that should have been asked long ago by scientists and non-scientist alike is: *With any reasonable definition of space, how can one "curve" it?* (If you have trouble visualizing curved space, try curved time!). Curved space-time appears to be, and always to have been, as Tom Phipps casually remarked, an oxymoron!" [6, p2].
- "... The hallowed relativity theory, which is supposed to have no primary reference frame. But the existence of the microwave background certainly reminds us that an average over the detectable universe certainly represents an obvious, primary reference frame" [6, p5].

Additionally, Arp noted that quantization had been observed at cosmological scale in several cases, as in the redshifts of galaxies, dependent on a power series 1.23^n, and

> the most astonishing result was then pointed to by Jess Artem, that the same quantization ratio that appeared in quasar redshifts appeared in the orbital parameters of the planets in the solar system. This first manifested itself in the ratio of planetary semi-major axes occurring in some high power of n in 1.23^n [6, p5].

After describing several phenomenological quantization rules, Arp wonders "whether they are all *different approximations of a more fundamental law* is a mystery at the moment. But it is clear that the properties of the planets are not random and that they are in some way connected to cosmological properties" [6, p6] (emphasis added).

As homage to Halton Arp's distinguished career, in the following pages it is argued that all forces of Nature arise from classical fluid theory [7], and it is shown how the present author's novel solutions [8-10] for the classical homogeneous wave equation (CHWE) immediately lead to quantum physics. As an illustration, two quantum features of planetary systems are considered: the quantized structure of planetary distances, and the ring structure.

2. Classical fluid theory and the unified force law

It is well known that to develop his electromagnetic (EM) theory Maxwell was guided by the transport of fluids [11, 12]; for instance, regarding Faraday's lines of force Maxwell wrote:

> If we consider these curves not as mere lines, but as *fine tubes* of variable section carrying an *incompressible fluid*, ... then we might represent the intensity of the force as well as its direction by the motion of the fluid in these tubes. This method of representing the intensity of a force by the velocity of an *imaginary* fluid in a tube is applicable to any conceivable system of forces, but it is capable of great simplification in the case in which forces are

> ... varying inversely as the square of the distance, such as those observed in electrical and magnetic phenomena." [11, p158-159] (emphasis added).

The fluid theory of nature proposed by the present author [7] rests upon the assumption that the fluid described by Maxwell is not merely *imaginary*, but that it is a real fluid formed by extended energy-like discrete entities called sagions, which are the elementary constituents of photons. It is stressed that this fluid is formed by energy-like, not by matter-like objects; it is close to the concept of *apeiron* proposed by Anaximander of Miletus in the 7th century BC. The development of our current model started at the International Workshop on Lorentz Group, CPT and Neutrinos held in Zacatecas (Mexico) in 1999, where the present writer argued that the physical content of GTR is very similar to the classical equations of fluids, based on conservation of linear momentum and of total energy [13]. It was noted there that Einstein did not succeed in finding a unified force of Nature because he interpreted his GTR as a representation of a deformable space-time (which, as quoted in the Introduction, was considered by Arp to be an oxymoron). On the contrary, my own interpretation was that being an equation for fluids, it obviously had to represent a dynamic fluid aether filling our absolute space, which, in agreement with Arp, may be operationally identified with the background radiation reference frame. The ensuing unified force was used to obtain the usual EM forces as a particular case of the unified force equation [13, 14].

The analogy between electromagnetism (EM) and gravitation has been known for a long time. The first example is Coulomb's law, which has the same structure as Newton's gravity law, but seems to be more general because it contains both attraction and repulsion. It led Maxwell to consider the possibility that gravity could be due to "*action of the surrounding medium*" [12, p492], finding that such assumption

> leads to the conclusion that every part of this medium possesses, when undisturbed, an enormous intrinsic energy, and that the presence of dense bodies influences the medium so as to diminish this energy wherever there is a resultant attraction [12, p493].

However, Maxwell immediately added that

> as I am unable to understand in what way a medium can possess such properties, I cannot go any further in this direction in searching for the cause of gravitation [12, p493].

It is rather surprising that Faraday was not a strong supporter of aether, which is implicit in Newton´s and Maxwell's thinking. In one of his philosophical notes Faraday [15] conjectured that his lines of force could vibrate,

> a notion which, as far as it is admitted, will *dispense with the aether*, which, in another view, is supposed to be the medium in which these vibrations take place", rather Faraday was for a "view of the nature of matter which considers its *ultimate atoms as centres of force*" [15, p345] (emphasis added).

Faraday had put forward the latter conjecture in a paper published two years before (*Phil. Mag.*, vol. xxiv, p136, 1844) — an idea inspired by Boscovich's unified force [16]. This was explicitly acknowledged by Faraday:

> we may compare together the matter of the aether and ordinary matter ... both consisting of mere centres of force, according to Boscovich's theory and the view put forward in my speculation [15, p346].

As shown below in the present paper, it turns out that Boscovich's force [16] is an explicit consequence of the equations representing the fluid aether, so that Faraday's expectations regarding the end of aether were not right. Actually, what is required is to dispense with the Newtonian assumption that force is a primitive notion, and adopt instead the Cartesian approach [17], where the primitive notion is linear momentum — propagated by the motion of sagions in Patrizi's physical space [18].

In a paper practically unknown today, the English engineer Oliver Heaviside suggested in 1893 that a field similar to the magnetic one should also exist in gravitation [19]. In his extension of Newton's theory of gravitation to time-dependent systems, Oleg Jefimenko [20] obtained Heaviside's equations, and to the magnetic-like field he gave the name of cogravitational field; Jefimenko gave due credit to Heaviside, and reprinted his pioneering paper as an appendix. However, the majority of modern and contemporary authors neglect or ignore Heaviside's work — published more than twenty years before Einstein's general theory of relativity (GTR). Instead, those authors start from GTR to obtain Heaviside's field, which is called by them gravito-inertial or gravito-magnetic field; some examples are [21-24]. As is well known, Heaviside's work may explain the precession of Mercury's perihelion (obviously, without invoking GTR). Further analogies between EM and relativistic gravity have been discussed by many other writers, *e. gr.* [25, 26]; analogies and differences between EM and gravity are stressed in a recent authoritative review [27].

In our present model [7] the sagion fluid is described by the standard macroscopic equations of classical fluids [28, p74-81]. Two equations are needed: conservation of mass according to a scalar continuity equation (1), and conservation of linear momentum according to a vector equation (2), written here in terms of the substantial derivative D_t, which is intuitively more appealing than the tensor dyadic product previously used in [7, 13, 14]:

$$\partial_W(\rho C^2) - 2\rho C\partial_W C + \nabla\cdot(\rho C\mathbf{V}) = C^{-1}\left(s_W\delta(\mathbf{r}-\mathbf{r}_0) + \nabla\cdot\mathbf{s}\right), \qquad (1)$$

$$\rho D_t\mathbf{V} = \rho C\partial_W\mathbf{V} + \rho\mathbf{V}\cdot\nabla\mathbf{V} = -\nabla p - \nabla\cdot[\tau], \qquad (2)$$

$$w \equiv Ct, \qquad (3)$$

$$D_t \equiv C\partial_W + V_X\partial_X + V_Y\partial_Y + V_Z\partial_Z = C\partial_W + \mathbf{V}\cdot\nabla\,. \qquad (4)$$

The variables in equations above are $\mathbf{V}$, ρ and p representing the local velocity, mass density, and pressure of the sagion fluid, and the 3×3 matrix $[\tau]$ representing the coefficients of viscous transfer of momentum from one Cartesian coordinate to another, both by sagion-sagion and by sagion-matter interactions (say, photon scattering). Time t is treated as a length w defined by Eq. (3), and the differential operator D_t is defined by Eq. (4). The average speed of sagions in a region of interest — say the neighbourhood of our earth — is C, which by definition is a local spatial constant, but may vary slowly over time:

$$\partial_W C \neq 0, \quad \nabla C = 0 \,. \tag{5}$$

The source/sink terms s_W and $\mathbf{s}$ in the continuity equation may be positive/negative and represent appearance/disappearance of sagions by photon-matter interactions (recall that photons are stable solitons formed by sagions). In particular, the source s_W, in energy per unit time, is due to localized processes in time t_0 and space $\mathbf{r}_0$ according to a 3D-Dirac delta function $\delta(\mathbf{r}- \mathbf{r}_0)$ in $(\text{length})^{-3}$; examples are creation of photons by annihilation of matter, emission of gamma-rays in nuclear transitions, emission of X-rays in atomic transitions; likewise, there are also localized sink processes as conversion of photons into matter, or absorption of photons by nuclei, or by atomic electrons —for information on photon-matter interactions see, for instance, [29]. The spatially extended processes, which evidently also occupy some lapse of time, are represented by the source vector $\mathbf{s}$ (dimensions: energy per unit time per unit area); an example is the conversion of mechanical energy of fast particles into photons by *bremsstrahlung*. As a companion to the fluid equations for sagions, in regions where there is matter, there also exist fluid equations for matter, in which the roles of the sources/sinks are interchanged. Evidently, in regions without matter, Eq. (1) contains no sources.

Although the Newtonian concept of force is not a primitive concept in the Cartesian approach to mechanics, force still is a *convenient* name for the average exchange of linear momentum in a collision, or for the flow of linear momentum at some spatial location [17]. Then, the unified force density $\mathcal{F}$ associated with the sagion fluid is obtained from Eq. (2) as:

$$\mathcal{F} \equiv -\nabla p = \rho C \partial_W \mathbf{V} + \rho \mathbf{V}\cdot\nabla\mathbf{V} + \nabla\cdot[\tau], \tag{6a}$$

$$\mathcal{F} = \rho C \partial_W \mathbf{V} + \rho\nabla(V^2/2) - \rho\mathbf{V}\times(\nabla\times\mathbf{V}) + \nabla\cdot[\tau]. \tag{6b}$$

where a well known vector identity was used to pass from (6a) to (6b). To connect with conventional EM formulations let us define the vector potential $\mathbf{A}$, and the electric and magnetic fields $\mathbf{E, B}$ as

$$\mathbf{A} \equiv \rho C\mathbf{V}, \quad \mathbf{B} \equiv -\nabla\times\mathbf{A}, \quad \mathbf{E} \equiv \partial_W \mathbf{A} + \nabla(\rho C^2) \tag{7}$$

Substituting in Eq. (6b), and after some straightforward algebra we get

$$\begin{aligned}\mathcal{F} = \mathbf{E} + \frac{\mathbf{V}}{C}\times\mathbf{B} - \mathbf{V}\left(\rho\partial_W C + C\partial_W\rho + \mathbf{V}\cdot\nabla\rho\right) + \\ + \frac{\rho}{2}\nabla V^2 + \left(V^2 - C^2\right)\nabla\rho + \nabla\cdot[\tau]\end{aligned} \quad . \tag{8}$$

As expected, the unified force given by Eq. (8) contains the standard Coulomb force **E**, and the Lorentz force of EM, which in the case of gravitation respectively become Newton's force and the gravitomagnetic component discovered long-ago by Heaviside. Additionally, there are three more forces: (i) a drag force opposing the direction of motion, which is not a surprise in a fluid; (ii) A force dependent on V^2 associated with local variations of kinetic energy; (iii) A force arising from asymmetric transfer of momentum between the three spatial directions, captured by the viscous terms. Cases (i) and (ii) depend on temporal and spatial variations of sagion density. It is clear that in regions where the sagion flow is inviscid, and the sagion density constant, the electric and Lorentz forces dominate, as observed in our terrestrial neighbourhood.

3. Fluid equations and the classical homogeneous wave equation

The fact that the EM fields of Maxwell equations (ME) must obey wave equations is well known [27, 30], and is thoroughly explained in electrodynamics textbooks [31]; an almost unknown paper by Malet [32] demonstrated that the validity of Maxwell's theory concurrently requires the validity of one scalar and one vector homogeneous wave equation, which in our case are

$$\Box(\rho C^2) \equiv \partial_W^2(\rho C^2) - \nabla^2(\rho C^2) = 0, \quad \Box(\rho C\mathbf{V}) = \Box\mathbf{A} = 0\ . \tag{9}$$

The D'Alembertian operator $\Box$ is implicitly defined in the first Eq. (9), which in the following will be collectively referred to as CHWE (classical homogenous wave equation). In the present fluid theory the vector potential **A** represents the average transport by convection (at speed *C*) of the linear momentum $\rho\mathbf{V}$ carried by sagions. The solution for **A** obtained from Eq. (9) is also a solution of Maxwell's equations via the definitions contained in Eqs. (7). For some particular cases, Maxwell's equations lead directly to CHWEs for **E** and **B**; in those cases the fields **E** and **B** can be directly obtained from the solutions to the corresponding CHWE.

It may be emphasized that the classical wave equations (9) intrinsically exhibit gauge invariance, a concept introduced by Weyl around 1919 [27], and that was not widely known at Malet's time; additionally, Eq. (9)

was obtained without invoking Einstein's special theory of relativity (STR). However, modern writers view the CHWE as a special case of the relativistic Proca equation when the photon mass is zero, or, equivalently, as the homogeneous Klein-Gordon equation [27]; in such context, in a symposium to homage Proca in his native Romania, the present writer demonstrated the existence of (longitudinal) helical solutions associated with the homogeneous Proca equation, *i.e.* with the CHWE [33].

4. Novel solutions of the CHWE and Boscovich force

The standard procedure to solve the CHWE is based on travelling harmonic waves containing sines and cosines of the variable ($\mathbf{k}\cdot\mathbf{r}$-ωt). In the early 1990s the present author revisited this subject and explicitly extracted all solutions that are conventionally ignored because they presumably do not have any physical meaning. In the search process, additional novel solutions were found for the particular case of spherical coordinates [8-10] — the more detailed paper (written in Spanish) is [10].

Our procedure to solve the CHWE consisted in separating the angular coordinates (θ, φ) from the time and radial distance coordinates (t, r). The partial differential equation for the directional part $D(\theta, \varphi)$ is the same as the corresponding part of Schrödinger′s equation (SE), so that the difference between the non-relativistic quantum wave mechanics described by SE and the presumably relativistic CHWE has to be contained in the partial differential equations dependent on (t, r). In that context we searched for and, as a matter of fact, we found nonharmonic solutions, rather than the harmonic solutions — well-known and widely used in classical mechanics and in electromagnetism.

The present author is not particularly fond of quantum mechanics (QM), which is a powerful calculational tool, but provides little insight into the inner functioning of Nature, so that the connection between QM and our novel solutions was not pursued any further; as a result, our mathematical solutions have been hibernating during the past 20 years. Meanwhile, my time has been occupied by gravity, and the search for the unified force. In that context I have been aware of Boscovich's work [16] for several years, but I did not pay enough attention to his force because Boscovich associated it with mathematical points and with action-at-a-distance; both aspects are incompatible with the postulates of my Cartesian theory of Nature —which is based on spatial extension and on the transfer by contact of linear momentum. The turning point was at the Vigier IX Symposium held in Baltimore in November 2014, where I mentioned some philosophical ideas of Boscovich relevant to my model of Nature [7]. After my talk, Roger Anderton directed my attention to his translation of a Serbian report on the importance of Boscovich's force and its connection to QM [34]. ¡Many thanks Roger! It immediately clicked that my dormant novel solutions for the CHWE contained Boscovich's force.

As reported in [34], several nuclear, atomic and molecular potentials (all of quantum nature) are consistent with Boscovich's force. Does it imply that Boscovich's force has a hidden QM nature? Such possibility is, however, in contradiction with the fact that my novel solutions were obtained for a classical wave equation, rather than being applicable to Schrödinger's QM wave equation. So, more reflection was needed.

In that mood I checked another reference also mentioned in [34]: the lectures given in the Spring of 1906 by J. J. Thomson at the Royal Society of London, where the discovery of the electron suggested that Boscovich's force could be used to explain some recently observed discrete spectra [35, p160-161]. That was long before Bohr's quantum theory.* So, that is good. Even if Boscovich's force has a classical origin, it still can explain discrete spectra independently of Bohr's theory.

Having realized that fact, a deeper implication followed: quantum physics can be derived from the CHWE without recourse to Schrödinger's equation (SE). So, how was SE derived? According to a well-known textbook, Schrödinger was looking for an equation with

> two basic properties. First, it must be linear, in order that solutions of it can be superposed to produce interference effects ... second, the coefficients of the equation must involve only constants such as *h* and the mass and charge of the particle,…

the reason being

> to leave open the possibility of superposing solutions that belong to different values [36, p21].

The first candidate considered by Schrödinger was

> the most familiar one-dimensional wave equation, that which describes the motion of transverse waves on a string or plane sound waves in a gas [36, p21],

given by

$$\partial_t^2 \psi = \gamma \partial_X^2 \psi ; \quad \gamma = \omega^2 / k^2 = E^2 / p^2 = p^2 / 4m^2 . \tag{10}$$

The candidate in Eq. (10) was rejected because it depends on the momentum p of the particle. However, our CHWE given by Eq. (9) is not liable to the same criticism because instead of γ there appears C^2, which, at cosmological or planetary scales, is a local constant with the properties defined by Eqs. (5). So that, from this viewpoint, our novel solutions of the CHWE may constitute the mathematical basis to develop viable quantum

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* By the way, it is rather surprising that Bohr, who spent several months as a visitor at Thomson's Cavendish Laboratory did not pursue Boscovich's lead.

physics along the original idea of Schrödinger's. This subject will be pursued elsewhere.

Before abandoning this section, a further comment on superposition and linearization is in order. Given the state of development of mathematical theory in the 18th and 19th centuries, and the lack of computing power at that time, it is completely comprehensible and coherent that physical problems were linearized to make them solvable. However, that practical fact does not imply that Nature intrinsically behaves in a linear manner. Then, the first desideratum listed above — that effects from two agents or two processes should or could be linearly superposed — does not lead to the most comprehensive representation of Nature. Therefore, it follows that if SE indeed fulfills that desideratum, then QM may be an incomplete theory because it leaves out all non-linear phenomena. In this respect the present writer has always been on Einstein's side [37].

5. Mathematics of the novel solutions of the CHWE

Let a generic time-dependent vector $\Phi(w, \mathbf{r})$ obey the CHWE given by Eq. (9); for the purposes of this paper it may represent **A**, **E**, or **B.** The general solution for the CHWE contains time-independent and time-dependent components:

$$\Phi(w,\mathbf{r}) = I_\eta^l(r)D(\theta,\phi) + H_\eta^l(h)D(\theta,\phi), \quad h \equiv w / r\,. \tag{11}$$

As already mentioned, the directional function $D(\theta, \varphi)$ is also a solution of SE, and the function $I_\eta^l(r)$ is a familiar structure in the solution of many time-independent wave equations; for details see [7] and [9,10]. The time-independent component means that the presence of a spherical material body located at the origin of coordinates creates a permanent stationary structure in the fluid itself. When a test body is placed in such fluid it immediately senses a force which usually is mistakenly interpreted as action-at-a-distance or as transmission at infinite speed of a force from the spherical material body to the test body.

The definition of the independent variable h merits some comments. Firstly, time w and radial distance r are inextricably together, but it does not follow that space and time conform a single entity (as in Einstein's GTR). Any one of the nonharmonic functions may be viewed as a time-solution or as a space-solution. In the former an observer at a fixed location sees how the value of the function, say $S_l(h)$, evolves as time passes; for instance, somebody sitting at the seaside watches how the waves come and go. In the second case, an observer at a high-altitude, say in a satellite, takes a photograph of a large portion of the sea; alternatively somebody deploys a very large number of cameras along a straight line over a flat ocean, each

Table 1. Twelve nonharmonic functions of the first kind $S_l(h)$

l	$S_l(h)$*
1	$\lvert 1-h^2\rvert\{h^0 + 0\}$
2	$h\,S_1(h)\{h^0 + 0\}$
3	$S_1(h)\{h^2 - 1/5\}$
4	$S_2(h)\{h^2 - 3/7\}$
5	$S_1(h)\{h^4 - (2/3)h^2 + 1/21\}$
6	$S_2(h)\{h^4 - (10/11)h^2 + 5/33\}$
7	$S_1(h)\{h^6 - (15/13)h^4 + (45/143)h^2 - 5/429\}$
8	$S_2(h)\{h^6 - (7/5)h^4 + (7/13)h^2 - 7/143\}$
9	$S_1(h)\{h^8 - (28/17)h^6 + (14/17)h^4 - (28/221)h^2 + 7/2{,}431\}$
10	$S_2(h)\{h^8 - (36/19)h^6 + (378/323)h^4 - (84/323)h^2 + 63/4{,}199\}$
11	$S_1(h)\{h^{10} - (15/7)h^8 + (30/19)h^6 - (300/323)h^4 + (30/323)h^2 - 6/4{,}199\}$
12	$S_2(h)\{h^{10} - (55/23)h^8 + (330/161)h^6 - (330/437)h^4 + (825/7{,}429)h^2 - 33/7{,}429\}$
	*A few misprints in [8, 9] have been corrected.

one taking a photograph at the *same instant* of time (recall that we are in a classical, non relativistic context).

The novel part in Eq. (11) is $H_\eta^l(h)$ defined as

$$H_\eta^l(h) = AS_l(h) + BT_l(h) + \eta U_l(h) \text{ for } l = 1,2,3\ldots, \tag{12}$$

where $S_l(h)$, $T_l(h)$, and $U_l(h)$ are the novel nonharmonic functions of the first, second and third kinds, A and B are (real) integration constants, and η is a dimensional separation constant. Table 1 shows the polynomials defining $S_l(h)$ for $l = 1, 2, ..., 12$; functions $T_l(h)$ and $U_l(h)$ are listed in [9, 10] for $l = 1, 2, 3, 4$.

Boscovich's force crosses several times the horizontal axis; the open question is how many times the axis is crossed. Functions $S_l(h)$ and $T_l(h)$ also cross the h-axis one or more times, the number of crossings being dependent upon the parameter l, thus providing an answer to the open question. Let us focus on the connection between Boscovich's force and the solutions of the CHWE, and assume that $\Phi(w, \mathbf{r})$ is a force density [recalling remarks under Eq.(9), it could also be a vector potential]; consideration is restricted here to nonharmonic functions of the first kind (NHF-1K) only, deferring analysis of functions of the second- and third-kinds for future work.

It may be seen in Table 1 that the NHF-1Ks exhibit a recurrent structure according to the value of l, forming a repetitive pattern in groups of four. Firstly, note that for even l it holds that $S_l(h) \to 0$ when $r \to \infty$, and that for odd l it holds that $S_l(h) \neq 0$ when $r \to \infty$. Secondly, when $r \to \infty$ the force may be positive (*i.e.* repulsive in our convention), or it may be negative (*i.e.* attractive in our convention).

The four groups of NHF-1Ks are then:

Group 1: $l=4n-1$ (for $n=1, 2, ...$): Force is attractive at large distance, and tends to a non-zero negative value when $r \to \infty$. This novel force may explain the flat rotation rate observed in some types of galaxies.

Group 2: $l=4n$ (for $n=1, 2, ...$): Force is attractive at large distance, and tends to zero from below when $r \to \infty$, as in Newton's force and in Coulomb′s attraction between opposite charges.

Group 3: $l=4n+1$ (for $n=1, 2, ...$): Force is repulsive at large distance, and tends to a non-zero positive value when $r \to \infty$. The analysis of this case is deferred to a forthcoming paper on nuclear and atomic forces.

Group 4: $l=4n+2$ (for $n=1, 2, ...$): Force is repulsive at large distances, and tends to zero from above when $r \to \infty$, as in Coulomb's force between charges of same sign.

It turns out that Titius-Bode-like structures and ring structures are due to the nonharmonic functions of the first kind in group 2. Function $S_l(h)$ may be plotted versus h thus obtaining a useful representation of the temporal variation of $S_l(h)$ at a fixed location r. The complementary representation is a graph of $S_l(g)$ versus $1/h$, thus depicting the spatial variation of $S_l(h)$ over radial distance r at a fixed time. As an illustration, Figure 1 shows both representations for $l=12$; it may be seen that there are three positive or repulsive peaks. For group 2, it holds in general that n is the number of repulsive peaks, where $n=l/4$. Then, the number of crossings from attractive force to repulsive force is finite and depends on parameter l, thus providing an answer to the question posed earlier regarding Boscovich's force. As described in next section, for a given l the number of quantized structures is also finite. The classical Newtonian gravitational law goes from R_{Newton} to infinity, as seen in the central panel of Figure 1.

6. Distance and energy quantization from the CHWE

At each crossing of the h-axis (or, the $1/h$-axis) the fluid exerts a null force upon a test particle, which may remain there in dynamic equilibrium. Intermediate positions cannot be occupied by a passive particle because a non-zero attractive (repulsive) force pushes the particle towards (away from) the center along the radial ray. Hence the only positions that may be occupied by a test particle are the finite number of crossings at radial distances R0, R1, R2u, R2s,..., Rju, Rjs,..., Rnu, Rns, thus qualitatively explaining Titius-Bode planetary structures. Of course, a space vehicle provided with an engine can be at rest at any place, even if there is a non-zero force.

Since each radial distance R0, R1, R2u, R2s, ... corresponds to a distance from the origin along an arbitrary direction (θ,φ), it follows that when all angular directions (θ,φ) are considered, each radius actually defines the surface of a sphere — henceforth called SSDE (spherical surface of dy-

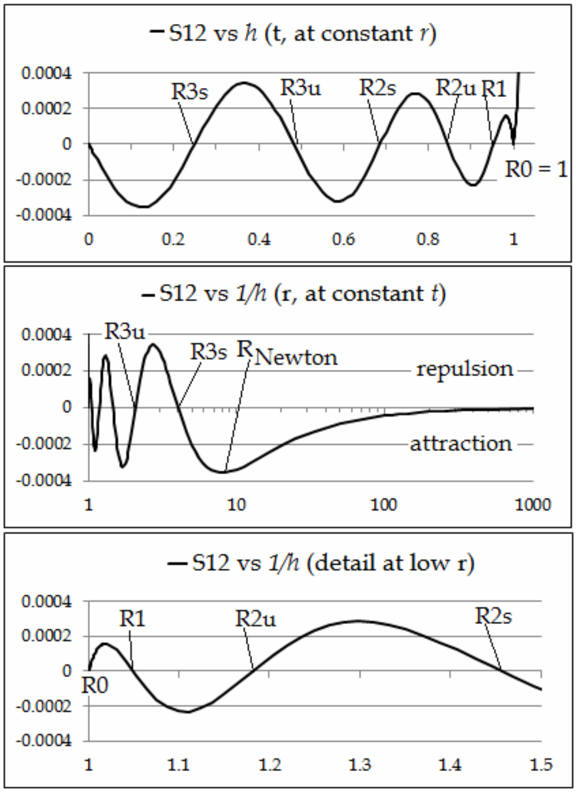

Figure 1. $S_{12}(h)$, nonharmonic function of the first kind for l = 12. Upper panel: $S_{12}(g)$ versus h. There is a cusp at h = 1, thus defining a sphere of radius R0 = 1. Central panel: $S_{12}(h)$ versus $1/h$ (logarithmic scale), depicting variations over radial distance r at a fixed time; note the three repulsive peaks. Repulsive peak 1 (barely visible) is the closest to the origin; repulsive peak 3 is the farthest from origin; it extends from distance R3u to distance R3s. The classical Newtonian regime begins at R_{Newton} and extends to infinity. Lower panel: detail of $S_{12}(h)$ versus $1/h$, showing the intercepts of the two inner repulsive peaks, numbered as 1 and 2 according to distance from the origin. For further details see section 6.

namic equilibrium) — where particles may remain in stable (or, unstable) equilibrium, according to whether an incoming crossing is from attraction to repulsion (or, conversely, from repulsion to attraction). By *dynamic* equilibrium is meant that the particle may be at rest on the surface, or it may move upon it, say in a circular orbit. In the innermost peak 1, R1 is stable, and R0 is unstable (as usual), but in contrast to the other peaks the unstable surface is the locus of infinitely many cusps (*i.e.* singularities) surrounded by repulsive slopes on both sides, so that *any* radial perturbation sends the particle outwards — toward R1.

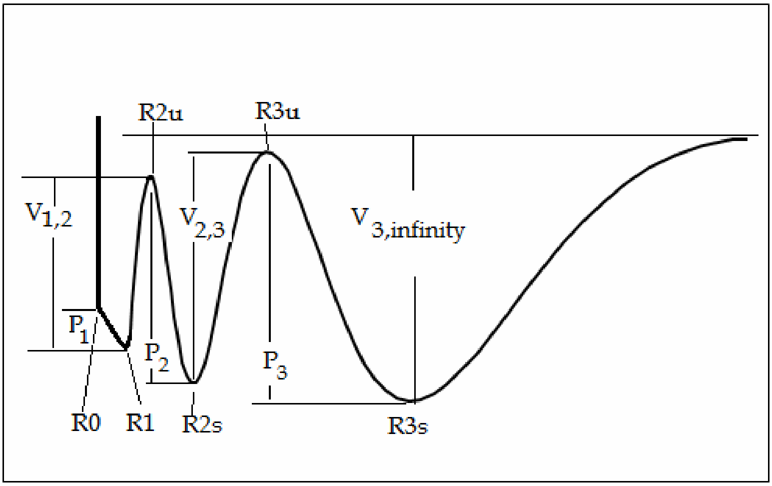

Figure 2. Qualitative curve for the potential energy (vertical axis) vs radial distance in the horizontal axis; this is the energy plot for the force shown in Figure 1. A test particle at the potential energy peaks R2u and R3u would be in unstable equilibrium: a small perturbation sends the particle downhill to the valleys on either side. Likewise, a particle at the cusp R0 is also in unstable equilibrium. But a particle at the valleys R1, R2s or R3s is in stable equilibrium (see text for further details).

The cusp at $h = 1$ is the only feature of the nonharmonic functions of the first kind, for $l = 4n$, that was missed by Boscovich in his universal force [16]. It corresponds to $r = w = Ct$, and in a relativistic context it might be related to the "photon sphere". However, in fairness to Boscovich, it should be mentioned that he also noted that he would expect that the innermost repulsion from his force should act before actual contact, in a sort of action-at-a-distance (AAAD); so, if actual contact is identified with R0, the repulsive peak from R0 to R1 could be identified with the repulsion attributed by Boscovich to AAAD. Since our fluid theory is non-relativistic, an alternative interpretation for the SSDE at R0 is to consider it as the surface of the central material body; in such context the innermost repulsion peak 1 is generated by sagions moving outwards after being backscattered on the surface of the SSDE at R0. In the case of our Earth the human race lives on the spherical surface at R0, and the air of our atmosphere is repelled outwards relative to R0, but cannot cross the surface of the sphere at R1, because there is a push inwards in the region beyond R1. The foregoing process could be the microscopic mechanism for Archimedean buoyancy, and for other phenomena at the surface of liquid fluids (say, evaporation).

Consider now a perturbation of a particle in dynamic equilibrium on a SSDE. To fix ideas, let us focus on the repulsive peak 3, shown in the central panel of Figure 1, whose base extends from the inner radial distance R3u to the outer distance R3s. A test body at R3s will remain in stable dynamic equilibrium, because any small radial perturbation will bring it back to R3s; this is more intuitive in terms of potential energy as in Figure 2. The SSDE at R3s corresponds, therefore, to a 3D-bowl; which is more general than the 2D-valleys at the bottom of the ripples in a water pond, and the 1D-valleys along each central ray (the latter are the minima in the plot of potential energy versus distance in Figure 2). When the directional dependence is acknowledged, a one-dimensional maximum is usually described as a saddle; in that context the SSDEs would be 3D-saddles. On the contrary the equilibrium of a test body at distance R3u is unstable because a small perturbation to the left will send it down the attractive valley towards R2s, whereas a perturbation to the right sends the particle up the repulsive peak towards R3s; in both cases the particle gains kinetic energy (see Figure 2).

In general the kinetic energy V acquired by a particle in the process of traversing an attractive valley from the outermost to the innermost boundary is given by:

$$V_{1,2} = -k\int_{R1}^{R2u} S_{4n}(h)dr, \ldots, V_{j-1,j} = -k\int_{R(j-1)s}^{Rju} S_{4n}(h)dr, \ldots, V_{n,\infty} = -k\int_{Rns}^{\infty} S_{4n}(h)dr \quad (13)$$

where k is a dimensional constant to express V and P in appropriate energy units. Likewise, the kinetic energy P acquired by a particle in the process of traversing a repulsion peak from the innermost to the outermost boundary is given by:

$$P_1 = k\int_{R0}^{R1} S_{4n}(h)dr, \ldots, P_j = k\int_{Rju}^{Rjs} S_{4n}(h)dr, \ldots, P_n = k\int_{Rnu}^{Rns} S_{4n}(h)dr. \quad (14)$$

Returning to the example in Figure 1, consider what happens to the particle at R3u when it is perturbed to the right. It climbs the third repulsion peak gaining kinetic energy, when it arrives at R3s its kinetic energy is P_3. In this case, it is qualitatively evident that $P_3 < V_{3,\infty}$, so that the energy of the particle is not enough to escape. The particle continues outwards to the right spending all its energy against the attractive force in the valley, until all kinetic energy is gone; this process defines the major axis of the orbit. Then, the particle starts the return back to R3u, gaining speed in the attractive valley, and losing its energy in the repulsive peak. As usual, the minor axis of the orbit will depend on the initial transversal speed of the particle, *i.e.*, on the angular momentum and other details of the initial perturbation.

Consider now what happens to the particle at R3u when it is perturbed to the left. It goes down the attractive valley gaining kinetic energy, when it arrives at R2s its kinetic energy is $V_{2,3}$. In this case, it is qualitatively evident that $V_{2,3} > P_2$, so that the particle jumps over peak 2, and reaches R2u with kinetic energy $V_{2,3} - P_2$; it goes down the next attractive valley

Table 2. Radii from $S_{40}(h)$ vs. observed a for the five inner planets of our sun [38, 39]

SSDE	Calculated radii		Object name	Observed semimajor axes, a	
	1/h	Relative to R2s		In million km	Mercury units
R0	1.0000	0.9686	===		
R1	1.0045	0.9730	===		
R2u	1.0152	0.9833	===		
R2s	1.0324	1.0000	Mercury	57.9	1.0000
R3u	1.0567	1.0235	===		
R3s	1.0888	1.0546	===		
R4u	1.1300	1.0945	===		
R4s	1.1818	1.1447	===		
R5u	1.2464	1.2073	===		
R5s	1.3269	1.2853	===		
R6u	1.4278	1.3830	===		
R6s	1.5554	1.5065	===		
R7u	1.7193	1.6653	===		
R7s	1.9349	1.8742	Venus	108.2	1.8687
R8u	2.2277	2.1577	===		
R8s	2.6435	2.5605	Earth	149.6	2.5838
R9u	3.2744	3.1716	===		
R9s	4.3352	4.1991	Mars	227.9	3.9361
R10u	6.4702	6.2671	===		
R10s	12.9015	12.4965	Jupiter	778.3	13.4421
			Correlation coefficient		99.91%
			R^2 coefficient		99.83%

getting energy $V_{1\text{-}2}$, so that when it is at R1 the particle has $V_{2,3} + V_{1,2} - P_2$, and jumps over peak 1 to reach R0 with energy $V_{2,3} + V_{1,2} - P_2 - P_1$. If R0 is the surface of the central body, that energy is dissipated forming a crater (*i.e.*, going up the very steep hill below $1/h < 1$). Of course, if the initial perturbation involved some transversal speed, the test particle may not collide with the central body, and could enter an orbit (details dependent on the initial angular momentum).

Evidently, in the foregoing process gravitational energy may be gained or lost in packages, quite the same as electrons in the famous Franck-Hertz experiment (1913) — that provided the final impetus for developing quantum physics.

7. Quantized planetary structures in our solar system

The Titius-Bode law is a phenomenological rule (TBR, henceforth) — hinted by David Gregory in 1715 and Christian Wolff in 1724 — usually attributed to the German citizens Johann Daniel Titius (who formulated the rule in 1766) and Johann Elert Bode (who popularized it in 1772). In modern terms, the semimajor axis of a planet a is given in astronomical units (AU) by the progression

Table 3. Radii from $S_{40}(h)$ vs. observed *a* for seven outer planets/asteroids [39, 40]

SSDE	Calculated radii		Object name	Observed semimajor axes, *a*	
	1/h	In R2s units		In million km	Jupiter units
R0	1.0000	0.9686	===		
R1	1.0045	0.9730	===		
R2u	1.0152	0.9833	884 Priamus	772.4	0.9924
R2s	1.0324	1.0000	Jupiter	778.3	1.0000
R3u	1.0567	1.0235	===		
R3s	1.0888	1.0546	===		
R4u	1.1300	1.0945	944 Hidalgo	859.4	1.1043
R4s	1.1818	1.1447	===		
R5u	1.2464	1.2073	===		
R5s	1.3269	1.2853	===		
R6u	1.4278	1.3830	===		
R6s	1.5554	1.5065	===		
R7u	1.7193	1.6653	===		
R7s	1.9349	1.8742	Saturn	1428.0	1.8348
R8u	2.2277	2.1577	===		
R8s	2.6435	2.5605	===		
R9u	3.2744	3.1716	===		
R9s	4.3352	4.1991	Uranus	2872.0	3.6901
R10u	6.4702	6.2671	Neptune	4498.0	5.7793
R10s	12.9015	12.4965	KB-peak at 62 AU	9275.2	11.9173
			Correlation coefficient		99.93%
			R^2 coefficient		99.86%

$$a = 0.4 + 0.1n, \text{ where } n = 0, 3, 6, 12, 24, \ldots, \tag{15}$$

where the value of n is doubled for $n > 3$. When the TBR was applied to the seven planets from Mercury to Saturn known at that time, it agreed with the positions of Uranus and Ceres discovered in 1781 and 1801; but it did not agree with the position of Neptune discovered in 1846. However, Pluto discovered in 1930 seemed to fit the TBR instead of Neptune [38].

To demonstrate the predictive capabilities of our novel solutions of the CHWE, as a first-order approximation, here we only use the nonharmonic function of the first kind $S_l(h)$, thus leaving out the contribution to discretization of the functions of the second- and third-kinds (see section 5). For the present preliminary calculations we have used a spreadsheet that only carries fifteen significant digits, which limits the scope of our calculation to $l \leq 52$. For $l = 44$, 48, 52 the calculation of $S_l(h)$ touches down below 10^{-15}, thus bringing in numerical noise (for further comments see section 9).

For the calculations in this section, the radius *(1/h)* of a given SSDE is expressed in units of the ray-distance of the innermost planet (or moon) to its central body; in the case of the solar system, the radii of the SSDEs are expressed in terms of Mercury's distance from the sun. It is found that for $40 \leq l \leq 52$ the radius of the last SSDE corresponds to Jupiter's distance from the sun, so that for planets/asteroids beyond Jupiter we make use of scale-invariance —typical of fractal-like phenomena, including fluids.

The twenty SSDEs associated with the ten peaks of $S_{40}(h)$ may be used to represent the inner planetary structure of our sun; actually the general shape of the discrete structures is not very sensitive to the exact value of l, so that other values as $l = 44, 48, 52$ could be used as well. Assuming that all the inner planets occupy *stable* SSDEs, Table 2 shows a possible distribution of planets according to our nonharmonic $S_{40}(h)$.

The second column in Tables 2 and 3 shows the radii of the inner and outer spheres limiting the ten peaks in terms of $1/h$, and the third column is the same information relative to the radius of R2s (this is similar to the standard astronomical units, AU, used in our solar system). The correlation coefficient between the occupied slots in column 6 and the corresponding calculated values in column 3 of Table 2 is 99.91%, and the corresponding R^2 coefficient is 99.83%, both of them quite good. The reference planet (Mercury in this case) is not included in the calculation of the correlation coefficients because it was used for calibrating the distance scale. For comparison, the correlation and R^2 coefficients for the TBR respectively are 99.98% and 99.96%; those high correlations are expected for TBR because Eq. 15 was fitted (or, adjusted) by Titius to the empirical data.

It may be noted that in Table 2 the empty SSDE at R10u between Mars and Jupiter corresponds to an *unstable* location, which is consistent with the observed fact that there exists an asteroid belt rather than a planet. If Ceres is placed in the empty slot between Mars and Jupiter, the TBR still exhibits the same correlation and R^2 coefficients quoted above (namely, 99.98% and 99.96%), whereas our model falls to 99.75% and 99.50%, still fairly good. However, in the same asteroid belt there are various bodies [39] that would produce a better correlation; for instance: 4 Vesta, 7 Iris, 44 Nysa, 6 Hebe, 19 Fortuna, 623 Chimaera, 29 Amphitrite, 5 Astraea. This simply means that the present comparison cannot be meaningfully pursued any longer, and that a ring should be considered instead (see section 9).

It must be stressed that in contrast to the phenomenological origin of the TBR, our predictions result from the mathematical solution of the CHWE, which represents fluids, thus suggesting that, in general, gravity may be modelled as a fluid. Invoking the fractal-like nature of fluids*, in Table 3 Jupiter is taken as the unit of distance for the outer planets; the correlation and R^2 coefficients for Saturn, Uranus and Neptune are 99.77% and 99.54%. If asteroids 884 Priamus and 944 Hidalgo are included in the evaluation of the coefficients, they improve somewhat to 99.88% and

* In particular, turbulent fluids exhibit scale-invariance

Table 4. Radii from $S_{40}(h)$ vs. observed *a* for six trans-Neptunian objects [39-41]

SSDE	Calculated radii		Object name	Observed semimajor axes, *a*	
	1/h	In R3s units		In 10^6 km	Neptune units
R0	1.0000	0.9184	===		
R1	1.0045	0.9225	===		
R2u	1.0152	0.9324	===		
R2s	1.0324	0.9482	===		
R3u	1.0567	0.9705	===		
R3s	1.0888	1.0000	Neptune	4,498.0	1.0000
R4u	1.1300	1.0378	===		
R4s	1.1818	1.0854	===		
R5u	1.2464	1.1447	===		
R5s	1.3269	1.2187	===		
R6u	1.4278	1.3113	Pluto	5,900.2	1.3117
R6s	1.5554	1.4285	Cubewanos*	6,582.4	1.4634
R7u	1.7193	1.5791	1:2 KB** resonance (twotinos)	7,135.9	1.5865
R7s	1.9349	1.7771	2:5 KB resonance	8,228.0	1.8293
R8u	2.2277	2.0459	KB-peak at 62 AU	9,275.2	2.0621
R8s	2.6435	2.4279	===		
R9u	3.2744	3.0073	===		
R9s	4.3352	3.9816	===		
R10u	6.4702	5.9424	===		
R10s	12.9015	11.8491	===		
*Mode of the distribution			Correlation coefficient		99.77%
** KB: Kuiper belt			R^2 coefficient		99.54%

99.78%. Finally, if the Kuiper belt (KB) peak at 62AU [40] is also included the coefficients increase to 99.93% and 99.86%, as shown in Table 3.

In the same spirit of scale-invariance, for the trans-Neptunian objects (TNOs) Neptune is taken as the unit of distance. If Neptune is located at R2s, which was the distance used for calibration in the previous two cases (Tables 2 and 3), the correlation and R^2 coefficients would be 99.26% and 98.53%, which are quite good. However, the correlations improve to 99.77% and 99.54% if Neptune is located at R3s and the TNOs are distributed as shown in Table 4; the correlations are now very good. It may be noted that the majority of objects in Table 4 are of recent discovery [39-41].

Summarizing, there is an excellent agreement between discrete planetary structures calculated with our nonharmonic function of the first kind $S_{40}(h)$ and the observed planetary structures associated with our sun at three scales: inner planets, outer planets, and trans-Neptunian objects. The lowest correlation coefficient is 99.77%, and the lowest R^2 coefficient is 99.54%.

Table 5. Radii calculated from $S_8(h)$ vs. observed *a* for Martian moons [39]

SSDE	Calculated radii		Moon	Observed semimajor axes, *a*	
	1/h	Relative to R1		In 1,000 km	Phobos units
R0	1.000	0.900	===		
R1	1.111	1.000	Phobos	9.4	1.000
R2u	1.477	1.329	===		
R2s	2.754	2.478	Deimos	23.5	2.501

8. Quantized moon structures of the solar planets

Passing now to the moons and asteroids associated with the planets of our solar system, let us begin with the simplest case: Mars and its two moons. Table 5 lists the values of intercepts along the *1/h*-axis of $S_8(h)$, the non-harmonic function of the first kind for $l = 8$. There are two repulsion peaks where Phobos and Deimos may safely orbit on stable SSDEs of radii R1 and R2s respectively. The calculated R2s = 2.478 for Deimos compares quite well with the observed semimajor axis (2.501) [39]; the ratio of predicted to observed radial distance is 99.07%, or in terms of the error between prediction and observation is 0.93%, *i.e.* less than 1%.

In the same manner, Table 6 shows the same exercise for the two moons of the trans-Neptunian object (TNO) Haumea —the moons were discovered in 2005 [41]. There are five repulsion peaks associated with our function $S_{20}(h)$. If Namaka is located at R2s and Hi'iaka is placed at R3s = 1.2669, there is in excellent agreement with the observed semimajor axis (1.2692). The ratio of predicted to observed radial distance is 99.82%, or in terms of difference between prediction and observation is 0.18%, *i.e.* less than one-fifth of 1%. The remaining slots in Table 6 are empty for the time being.

When a solar planet has several moons the procedure is similar to the

Table 6. Radii calculated from $S_{20}(h)$ *vs*. observed *a* for the moons of Haumea[41]

SSDE	Calculated radii		Moon	Observed semimajor axes, *a*	
	1/h	Relative to R2s		In 1,000 km	Namaka units
R0	1.0000	0.8793	===		
R1	1.0177	0.8949	===		
R2u	1.0616	0.9335	===		
R2s	1.1373	1.0000	Namaka	39.0	1.000
R3u	1.2563	1.1046	===		
R3s	1.4408	1.2669	Hi'iaka	49.5	1.2692
R4u	1.7366	1.5270	===		
R4s	2.2517	1.9799	===		
R5u	3.3114	2.9117	===		

process followed in section 7 for the planetary system of our sun. Scale invariance is used in most cases for inner and outer moons, but in two cases (Saturn and Uranus) three scales of distance were used for inner, intermediate and outer moons. For consistency, all planets and their moons are compared to a single nonharmonic function of the same kind: $S_{48}(h)$, which has twenty four SSDEs associated with twelve repulsive peaks.

The natural satellites of Jupiter are divided into two groups: inner and outer moons. For the inner group, the innermost moon Metis is located at R1 and is used to calibrate distance. The distribution of the other seven moons is summarized in the Appendix in Table A1; to save space, the unoccupied SSDEs are not shown. Comparison between the occupied slots in column 6 and the calculated radii in column 3 leads to a correlation coefficient of 99.75%, and a R^2 coefficient of 99.50%, which are quite good. As stated already in section 7, the reference moon (Metis in Table A1) is not included in calculating statistical indicators.

For the 59 outer Jovian moons and asteroids, the semimajor axis of Themisto is used to calibrate distance. For consistency, Themisto is located at R1, the distribution of the other 58 moons and asteroids is summarized in Table A2 in the Appendix. The structure of Jovian moons in the outer region is more complex than in the inner case. In addition to some double-orbitals associated with R7s, R8u and R9s, there are 17 asteroids associated with R10u in a ring-like structure, and 33 asteroids associated with R10s, also in a ring-like structure. For the present preliminary calculation, all asteroids were compared to the average radius of each main SSDE (*i.e.*, R7s, R8u, R9s, R10u, R10s), without taking into account variation of distance within each ring. The correlation coefficient still is a high 98.15%, and the R^2 coefficient is 96.34%; these values may be improved by taking into account the detailed structure of the various rings (calculation deferred for a future paper). To facilitate comparisons between the accuracy of our predictions for all the moon structures, correlation coefficients associated with the predictions of our fluid theory are collated in Table 7 below.

Saturn moons and asteroids are divided into three groups (inner, intermediate and outer) shown in Tables A3, A4 and A5 in the Appendix; distances are measured in all cases relative to R4s —the fourth stable SSDE. The correlation and R^2 coefficient for the 21 moons in Table A3 are 99.36% and 98.72% (see also Table 7). If Titan and Hyperion are included at the end of Table A3, the correlation and R^2 coefficients for the 23 inner moons slightly decrease to 99.12% and 98.25%. For Rhea, Titan, Hyperion and Iapetus form Saturn's intermediate group, Rhea serves to calibrate distance. The correlation and the R^2 coefficients are very high: 99.98% and 99.96% (see Tables A4 and 7). Distances of the four outer Saturn moons are measured relative to Iapetus, which for physical consistency is also located

Table 7. Consistency of predicted quantized structures with observation

Central body	Calibrating body and position	Number of bodies/scale	Details of distribution	Coefficients in %	
				Correlation	R^2
Sun	Mercury at R2s	5/inner	Table 2	99.91	99.83
Sun	Jupiter at R2s	7/outer	Table 3	99.93	99.86
Sun	Neptune at R3s	6/TNO*	Table 4	99.77	99.54
Jupiter	Metis at R1	8/inner	Table A1	99.75	99.50
Jupiter	Themisto at R1	59/outer	Table A2	98.15	96.34
Saturn	S/2009 S1 at R4s	21/inner	Table A3	99.36	98.72
Saturn	Rhea at R4s	4/interm	Table A4	99.98	99.96
Saturn	Iapetus at R4s	5/outer	Table A5	99.69	99.38
Uranus	Cordelia at R1	16/inner	Table A6	99.91	99.82
Uranus	Miranda at R1	5/interm	Table A7	99.84	99.69
Uranus	Francisco at R1	9/outer	Table A8	99.14	98.28
Neptune	Naiad at R1	8/inner	Table A9	99.93	99.85
Neptune	Nereid at R1	6/outer	Table A10	99.87	99.73
Pluto	Charon at R4s	5/single**	Table A11	96.49	93.09
Mars	Phobos at R1	2/single**	Table A5	99.07***	
Haumea	Namaka at R2s	2/single**	Table A6	99.82***	
*TNO: trans-Neptunian object			***Ratio of predicted radius to observed orbital axis		
** Only a single scale is used					

at R4s; correlation coefficients are also quite good (see Table A5 and Table 7).

As shown in Tables A6, A7 and A8 of the Appendix, the moons of Uranus are also divided into three groups (inner, intermediate and outer), calibrated with respect to Cordelia, Miranda and Francisco, located at R1 in all cases. For the sixteen inner moons the correlation and R^2 coefficients shown in Table A6 are 99.91% and 99.82%. The distribution of the five intermediate moons from Miranda to Oberon is in Table A7, leading to quite good correlation and R^2 coefficients (99.84% and 99.69%). The distribution of the nine outer moons of Uranus is in Table A8; the correlation and R^2 coefficients (99.14% and 98.28%) are at the lower end of accuracy in Table 7 above.

Neptune moons were classified into eight inner and six outer moons/asteroids, summarized in Tables A9 and A10 of the Appendix. Distance was calibrated with Naiad and Nereid respectively, which were located at R1 in both cases. For the inner moons the correlation and R^2 coefficients are very good: 99.93% and 99.85%; and for the outer natural satellites the correlation and R^2 coefficients also are similar (99.87% and 99.73%).

Four moons of Pluto were discovered at the beginning of the 21^{st} century, while the oldest one Charon was first observed in 1978. The reference body is Charon located at R4s; the other moons are distributed as shown in Table A11 of the Appendix. The correlation and R^2 coefficients are 96.49% and 93.09%, which are the lowest found in the present work. The low

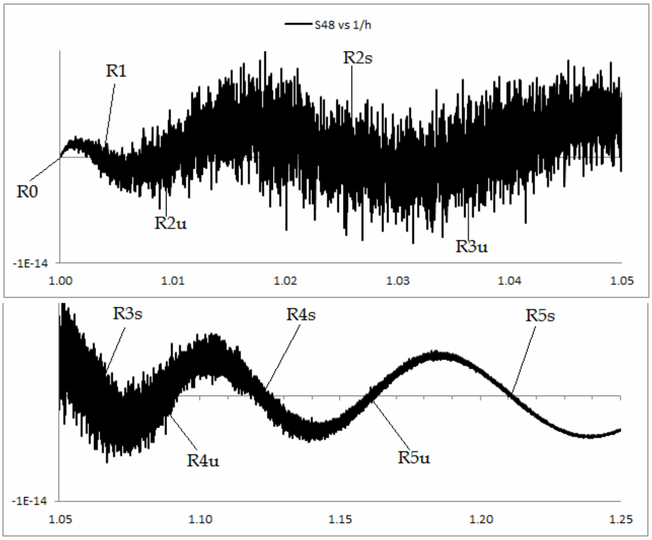

Figure 3. The nonharmonic function of the first-kind for l = 48 has twelve repulsive peaks associated with a central body located at $1/h$ = 0. In the upper panel peaks 2 and 3 are almost hidden by large oscillations, which, as shown in the lower panel, decrease outwards starting with peak 4.

value of both coefficients is entirely due to Hydra; indeed, if that moon is ignored the correlation and R^2 coefficients jump to 99.999% and 99.998%. Considering the great consistency between predictions and observation found for all other moons considered in this work (see Table 7), one is tempted to suggest that Hydra may exhibit some special features (physically, astronomically, or otherwise).

9. Ring structures

By analogy with the configuration of electrons in the atomic shells and sub-shells [42, p272-278], it may be expected that if the nonharmonic functions of the first-kind $S_l(h)$ describe the shells, then the superposition of nonharmonic functions of the second- and third-kinds will provide a description of sub-shells and more detailed structure. In the case of the planetary problem, such description would be applicable to various asteroid belts, and to the rings of Saturn and other bodies (Rhea?) observed in our solar system [39, 41, 43]. In such context, the present author calculated $S_l(h)$ in steps of four l = 8, 12, ..., 52; things ran smoothly up to l = 44 when there appeared the first symptoms of instability in the curves, that initially were *entirely* attributed to numerical instability associated with the intrinsic resolution of the software — quite similar to the situation that in the 1970s gave origin to the theory of chaos.

Figure 3 shows the five innermost repulsive peaks of $S_{48}(h)$, which has twelve repulsive peaks associated with the central body located at $1/h = 0$. In the upper panel the first small peak is clearly visible, but peaks two and three are almost hidden by large oscillations; as shown in the lower panel, the oscillations decrease from the fourth peak outwards. Figure 4 is a close look to the intercepts limiting the fifth peak, on the inner unstable side (R5u) and in the outer stable side (R5s). As already explained in the context of Figure 1, a single crossing of the horizontal axis defines the radius of the surface of a sphere in dynamical equilibrium (SSDE), but if there are several sub-crossings as shown in the right (or left) panel of Figure 4, then there exist at that intercept a whole family of a few (or many) concentric SSDEs —those groups of SSDEs constitute the subshells found in atomic structure.

In the gravitational case, each SSDE may be occupied by one or more asteroids, thus providing an explanation for the existence of asteroid belts near the Earth, or between Mars and Jupiter. Furthermore, in general, the size of the planets, moons and asteroids that may occupy a given SSDE depends on the separation between two nearby SSDEs. In the particular case of Figure 4, the size of asteroids that may occupy the SSDEs in the right panel is larger than those occupying the SSDEs associated with the left panel. Also, note that the number density of sub-crossings increases as the distance *(1/h)* to the central body decreases, reaching a very tight packing in the upper panel of Figure 3. Those closely spaced SSDEs can only be occupied by very small particles —as dust or ice grains— as observed in the rings of Saturn.

Previous remarks indicate that it is likely that the oscillations present in the curve of Figure 3 are partially due to numerical noise, and partially represent real physical phenomena. If that turns out to be the case, the nonharmonic functions of the first-kind could directly explain rings with-

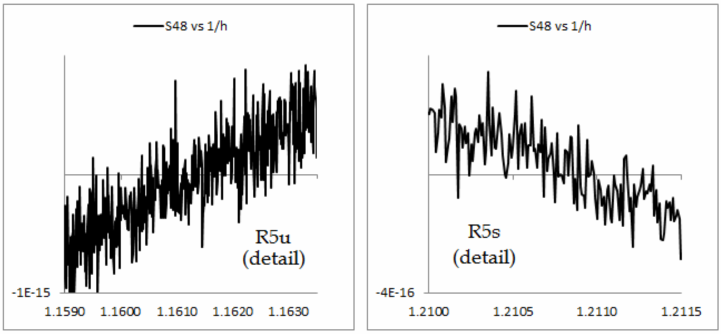

Figure 4. Detail of the crossings at the horizontal axis that delimit peak 5 (shown in Figure 3, bottom panel). Note that the number density of sub-crossings increases as the distance *(1/h)* to the central body decreases.

Table 8. S0: Calculated radii from $S_{48}(h)$ *vs.* observed features in Saturn rings [39, 43]

SSDE	Calculated radii		Ring feature	Observed distance to features	
	1/h	Relative to R1s		In 10^3 km	Units: ring-D low
R0	1.0000	0.9964	===		
R1	1.0036*	1.0000	D-ring low**	66.9	1.0000
R2u	1.0093*	1.0057	===		
R2s	1.0243*	1.0206	===		
R3u	1.0393*	1.0355	===		
R3s	1.0644*	1.0605	D-ring avg**	70.7	1.0569
R4u	1.0842*	1.0802	===		
			D-ring hi**	74.5	1.1138
R4s	1.1220*	1.1180	C-ring low	74.7	1.1160
R5u	1.1617*	1.1575	Titan ringlet	77.9	1.1640
R5s	1.2109*	1.2065	===		
R6u	1.2695*	1.2648	C-ring avg	83.3	1.2456
			Maxwell ringlet	87.5	1.3078
			1.470Rs-ringlet	88.7	1.3261
R6s	1.3402*	1.3354	1.495Rs-ringlet	90.2	1.3478
			C-ring hi	92.0	1.3752
			B-ring low	92.0	1.3752
R7u	1.4256	1.4204	===		
R7s	1.5294	1.5238	B-ring avg	104.8	1.5664
R8u	1.6570	1.6510	===		
			B-ring hi***	117.6	1.7575
			Huygens ringlet	117.8	1.7616
R8s	1.8162	1.8096	Cassini avg	119.9	1.7919
			A-ring low***	122.2	1.8262
R9u	2.0186	2.0113	A-ring hi	136.8	2.0445
			F-ring	140.2	2.0954
			J/E**** ring low	149.0	2.2272
R9s	2.2825	2.2742	J/E ring avg	151.5	2.2646
			J/E ring hi	154.0	2.3019
			G-ring low	166.0	2.4813
R10u	2.6385	2.6289	G-ring high	175.0	2.6158
			E-ring low	180.0	2.6906
R10s	3.1418	3.1303	Pallene ring low	211.0	3.1540
			Pallene ring hi	213.5	3.1913
R11u	3.9024	3.8882	===		
R11s	5.1777	5.1589	E-ring avg	330.0	4.9327
R12u	7.7394	7.7113	E-ring high	480.0	7.1749
R12s	15.4465	15.3904	===		

*Value calculated from the average intercept on the *1/h*-axis; **low/hi: inner/outer edge, avg: average; ***Also, Cassini inner/outer; ****J/E: Janus/Epimetheus

out the help of the nonharmonic functions of the second- and third-kinds. To solve this issue, in forthcoming calculations we will use software capable of handling more than 15 significant digits.

Assuming for the time being that $S_{48}(h)$ is capable of explaining the rings of Saturn, Table 8 summarizes the structure of such rings versus distance, and relates features of the rings to the SSDEs calculated from $S_{48}(h)$. The lower edge of the D-ring was chosen as the reference to calibrate distance, thus obtaining a fourth scale of distance (S0) for Saturn, located below the other three scales (S1, S2, S3) already defined in section 8 to describe the moon structure of Saturn. This choice seems appropriate. Indeed, the upper edge of the D-ring is between R4u and R4s in Table 8, a region that precisely coincides with the end of the large and spatially tight oscillations seen in the lower panel of Figure 3. The qualitative agreement between the rings and the structure of our function $S_{48}(h)$ is fairly obvious, but we refrain from making any further comment until the issue of numerical (un)stability is completely solved.

10. Concluding remarks: advantages of fluid theory

Fluids have been used as an analogy for gravity in the context of Einstein's GTR for a long time. For instance, an authoritative textbook introduces a "cosmological fluid" and *treats galaxies as "particles" of a "gas" that fills the universe* [44, p711]. This may be contrasted with our fluid approach to nature, where galaxies are just another instance of scale-invariance. The same textbook makes several analogies between GTR and electrodynamics (for instance, sections 14.5 and 27.1 [44, p348 and 705]). It is noted that any similarity between gravity and electrodynamics implicitly implies analogy to a fluid. In the same relativistic vein, various models for cosmological relativistic fluids [45] are still in use. In contrast, in this paper the fluid is not a mere analogy, it is treated as the basic building block of all nature.

The fluid theory of nature proposed here involves a photon-like fluid and a matter fluid, both described by the equations of classical fluids; the matter and photon-like fluids are coupled via photon-matter interconversion. Both, conservation of linear momentum and of total energy are strictly obeyed in our Cartesian approach, which shares with Einstein the notion that force is not a fundamental concept. Rather, the so-called fundamental forces arise from momentum exchange between matter and the photon-like sagion fluid. The sagion fluid obeys the classical homogeneous wave equation (CHWE), Eq. (9) in the present paper, which is the same condition that was required by Malet [32] for consistency with Maxwell's equations. The CHWE also arises in the context of GTR (see Eq. (22) in [27]); as clearly explained in [27], the homogeneous Proca, which is equivalent to the CHWE, implies zero mass for both the photon and the graviton, and is fully consistent with the original version of gauge invariance.

The sagion fluid is isotropic in free space (*i.e.* regions without matter), but it is perturbed by the presence of large material bodies: absorption, scattering and reflection (*i.e.* back-scattering). A spherical body — as the sun or any object in hydrodynamic equilibrium — induces a sagion distribution at large distances that mimics a $1/r^2$ force; at the same time, the same spherical body also induces at shorter distances a finite number of quantized structures in the fluid near the surface of the body. At any elementary volume near the said spherical body there may be sagions that arrived without being perturbed in the journey from remote regions of the universe, and sagions that were recently reflected at the surface of the neighbour spherical body. In this manner, fluid theory is consistent with Mach's principle and completely avoids the thorny issue of action-at-a-distance. When one places a test body at any elementary volume at time t, the test particle interacts with whatever sagions are *already* there (*i.e.*, it feels "force" in the Newtonian sense). It is stressed that "force" is not propagated in the context of fluid theory: simply, the nearby large body affects the distribution of sagions in its neighbourhood, and when the test body is placed there it immediately senses the existing sagion distribution. That process usually is mistakenly interpreted as action-at-a-distance or as transmission of "force" from the spherical material body to the test body at a very large, even infinite, speed. Of course, after the test body is placed, there will be a re-accommodation of the sagion distribution, giving origin to a transient process that eventually will reach a new dynamic steady state.

The present paper recalled the novel solutions to the CHWE found by the present writer in the 1990s, and indicated that our nonharmonic functions of the first-kind are similar to the unified force of nature proposed around 1760 by Boscovich — from philosophical considerations, but without a formal mathematical basis. As is well known, Boscovich's force immediately leads to quantization in energy and distance, features that were used here to predict quantization in our planetary system. From there, we obtained the distribution of solar planets, and the distributions for the moons of each individual planet in the solar system. The correlation coefficients and the R^2 coefficients typically are well above 99%, thus providing a first empirical support for our fluid theory of nature.

The fluid-theory-approach-to-nature (FTATN) advocated here, together with our novel solutions of the CHWE, constitutes a coherent method to derive quantum physics from the classical wave equation, and, of course, it also leads to Maxwell's EM. As shown here, the unified force derived from the fluid equations lead to quantization of planetary structures. Since both the quantum and the electrodynamic interactions depend on the composition of matter, it follows that when the unified force is applied to gravitational problems it evidently also depends on composition of matter. This fact represents a distinct advantage of our FTATN over Einstein's GTR, the latter based on the postulated equivalence of inertial and gravitational mass — thus independent of chemical and nuclear composition. Since GTR is also a fluid equation, it means that our FTATN is a cover theory for Einstein's GTR, which only holds when the principle of equivalence is valid. Then, our fluid theory approach is a possible answer to the open question of the residual compositional effect in the old Eötvös experiment — residual uncovered by the Fischbach group in the mid-1980s [46], and that still is unexplained [47]. The present writer has recently argued that the Eötvös-Fischbach residual may be accounted for by Le Sagian atomic-type gravity [48].

Gravitational quantization is a subject that is currently receiving a renewed attention. For the particular case of a two-body problem, Giné derived the relevant quantization aspects of the Titius-Bode law, using Newtonian physics and finite propagation of gravity [49]. Such results are consistent with the present paper — entirely based on the classical laws of physics — but without any need to explicitly add the speed of gravity propagation. We can also answer Giné's rhetorical question: "Is gravitational quantization another consequence of general relativity?" [24]. No, it is a consequence of fluid theory. According to the procedure used in [24], it seems that GTR is a second-order approximation to the general equations of fluid theory. Those approximations are required to impose the principle of equivalence to the more general fluid (and Maxwell's) equations.

Another significant advantage of any fluid theory is that it implicitly exhibits scale-invariance, a feature that was extensively used throughout the present paper. It was also briefly mentioned that our approach may also explain planetary ring structures, for instance the asteroid belt, or the rings of Saturn. So, we have provided an affirmative answer to Arp's conjecture regarding whether the Titius-Bode rule of planetary structure was an "*approximation of a more fundamental law*" [6, p6].

Finally, the concept of the surface of a sphere in dynamic equilibrium (SSDE), developed here, may be also used to calculate in a straightforward geometric manner the orbits of Trojans, a subject that is currently experiencing a dynamic revival [50-52]. Our method will be reported elsewhere, and, for completeness, it is mentioned that the same three-body problem also appears in the calculation of the electronic structure of some diatomic molecules.

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Appendix: Quantized structure of Moons in the Solar System

The distribution of moons of planets in the solar system (according to the nonharmonic function of the first kind for $l=48$) are summarized in the present appendix. There are 11 tables, as follows: two for Jupiter, three for Saturn, three for Uranus, two for Neptune, and one for Pluto.

Table A1. J1: Radii from $S_{48}(h)$ vs. observed a for eight inner Jovian moons [39, 41]

SSDE	Calculated radii		Moon name	Observed semimajor axes, *a*	
	1/h	Relative to R1		In 1,000 km	Metis units
R0	1.0000	0.9964	===		
R1	1.0036*	1.0000	Metis	128.0	1.0000
R2u	1.0093*	1.0057	Adrasta	129.0	1.0078
R7u	1.4256	1.4204	Amalthea	181.4	1.4172
R8s	1.8162	1.8096	Thebe	221.9	1.7336
R10s	3.1418	3.1303	Io	421.8	3.2953
R11s	5.1777	5.1589	Europa	671.1	5.2430
R12u	7.7394	7.7113	Ganymede	1,070.4	8.3625
R12s	15.4465	15.3904	Callisto	1,882.7	14.7086
*Average of ring-like intercepts			Correlation coefficient		0.9975
			R^2 coefficient		0.9950

Table A2. J2: Radii from $S_{48}(h)$ vs. observed a for 59 outer Jovian moons [39,41]

SSDE	Calculated radii		Moon or asteroid	Observed semimajor axes, *a*	
	1/h	Relative to R1		In 1,000 km	Themisto units
R0	1.0000	0.9964	===		
R1	1.0036*	1.0000	Themisto	7,284	1.0000
R7s	1.5294	1.5238	Leda	11,165	1.5328
		1.5238	Himalia	11,451	1.5721
R8u	1.6570	1.6510	Lysithea	11,717	1.6086
		1.6510	Elara	11,741	1.6119
R8s	1.8162	1.8096	S/2000 J11	12,570	1.7257
R9u	2.0186	2.0113	===		
R9s	2.2825	2.2742	Carpo	17,058	2.3418
		2.2742	S/2003 J12	17,833	2.4482
R10u	2.6385	2.6289	Euporie**	19,304	2.6502
		2.6289	Ananke**	21,276	2.9209
R10s	3.1418	3.1303	S/2003 J15***	22,630	3.1068
		3.1303	Kore***	24,543	3.3694
R11u	3.9024	3.8882	S/2003 J2	28,455	3.9065
R12s	15.4465	15.3904	===		
**Plus 15 asteroids between Euporie and Ananke			Correlation coefficient		0.9815
***Plus 31 asteroids between S/2003 J15 and Kore			R^2 coefficient		0.9634

Table A3. S1: Radii from $S_{48}(h)$ vs. observed *a* for 21 inner Saturn satellites [41]

SSDE	Calculated radii		Moon or asteroid	Observed semimajor axes, *a*	
	1/h	Relative to R4s		In 1,000 km	S/2009 S1 units
R0	1.0000	0.8912	===		
R4s	1.1220*	1.0000	S/2009 S1	117.00	1.0000
R6u	1.2695*	1.1314	Pan	133.58	1.1417
R6s	1.3402*	1.1945	Daphnis	136.50	1.1667
		1.1945	Atlas	137.67	1.1767
		1.1945	Prometheus	139.38	1.1913
		1.1945	Pandora	141.72	1.2113
R7u	1.4256	1.2705	Epimetheus	151.41	1.2941
		1.2705	Janus	151.46	1.2945
R8u	1.6570	1.4768	Aegaeon	167.50	1.4316
R8s	1.8162	1.6187	Mimas	185.54	1.5858
		1.6187	Methone	194.44	1.6619
		1.6187	Anthe	197.70	1.6897
R9u	2.0186	1.7990	Pallene	212.28	1.8144
R9s	2.2825	2.0342	Enceladus	238.04	2.0345
R10u	2.6385	2.3515	Tethys	294.67	2.5185
		2.3515	Telesto	294.71	2.5189
		2.3515	Calypso	294.71	2.5189
R11u	3.9024	3.4780	Polydeuces	377.20	3.2239
		3.4780	Dione	377.42	3.2258
		3.4780	Helene	377.42	3.2258
R11s	5.1777	4.6146	Rhea	527.07	4.5049
R12s	15.4465	13.7665	===		
			Correlation coefficient		0.9936
			R^2 coefficient		0.9872

Table A4. S2: Radii from $S_{48}(h)$ vs. observed *a* for 4 intermediate Saturn moons [39]

SSDE	Calculated radii		Moon name	Observed semimajor axes, *a*	
	1/h	Relative to R4s		In 1,000 km	Rhea units
R0	1.0000	0.8912	===		
R4s	1.1220*	1.0000	Rhea	527.07	1.0000
R10u	2.6385	2.3515	Titan	1221.87	2.3182
R10s	3.1418	2.8000	Hyperion	1500.88	2.8476
R12u	7.7394	6.8976	Iapetus	3560.84	6.7559
R12s	15.4465	13.7665	===		
			Correlation coefficient		0.9998
			R^2 coefficient		0.9996

Table A5. S3: Radii from $S_{48}(h)$ vs. observed *a* for five outer Saturn moons [39, 41]

SSDE	Calculated radii		Moon name	Observed semimajor axes, *a*	
	1/h	Relative to R4s		In 1,000 km	Iapetus units
R0	1.0000	0.8912	===		
R4s	1.1220*	1.0000	Iapetus	3,560.84	1.0000
R10s	3.1418	2.8000	Kiviuq	11,110.00	3.1201
		2.8000	Ijiraq	11,124.00	3.1240
R11u	3.9024	3.4780	Phoebe	12,947.78	3.6362
R11s	5.1777	4.6146	Paaliaq	15,200.00	4.2687
R12s	15.4465	13.7665	===		
			Correlation coefficient		0.9969
			R^2 coefficient		0.9938

Table A6. U1: Radii calculated from $S_{48}(h)$ vs. observed *a* for 16 Uranus moons [41]

SSDE	Calculated radii		Moon or asteroid	Observed semimajor axes, *a*	
	1/h	Relative to R1		In 1,000 km	Cordelia units
R0	1.0000	0.9964	===		
R1	1.0036*	1.0000	Cordelia	49.8	1.0000
R4u	1.0842*	1.0802	Ophelia	53.8	1.0803
R5s	1.2109*	1.2065	Bianca	59.2	1.1888
R6u	1.2695*	1.2648	Cressida	61.8	1.2410
		1.2648	Desdemona	62.7	1.2590
		1.2648	Juliet	64.4	1.2932
R6s	1.3402*	1.3354	Portia	66.1	1.3273
R7u	1.4256	1.4204	Rosalind	69.9	1.4036
R7s	1.5294	1.5238	Cupido	74.4	1.4938
		1.5238	Belinda	75.3	1.5120
		1.5238	Perdita	76.4	1.5345
R8u	1.6570	1.6510	Puck	86.0	1.7269
R9u	2.0186	2.0113	Mab	97.7	1.9626
R10u	2.6385	2.6289	Miranda	129.9	2.6084
R11u	3.9024	3.8882	Ariel	190.9	3.8333
R11s	5.1777	5.1589	Umbriel	266.0	5.3414
R12s	15.4465	15.3904	===		
			Correlation coefficient		0.9991
			R^2 coefficient		0.9982

Table A7. U2: Radii from $S_{48}(h)$ vs. observed *a* for 5 intermediate Uranus moons [41]

SSDE	Calculated radii		Moon or asteroid	Observed semimajor axes, *a*	
	1/h	Relative to R1		In 1,000 km	Miranda units
R0	1.0000	0.9964	===		
R1	1.0036*	1.0000	Miranda	129.9	1.0000
R7s	1.5294	1.5238	Ariel	190.9	1.4696
R9u	2.0186	2.0113	Umbriel	266.0	2.0477
R10s	3.1418	3.1303	Titania	436.3	3.3587
R11u	3.9024	3.8882	Oberon	583.5	4.4919
R12s	15.4465	15.3904	===		
			Correlation coefficient		0.9984
			R^2 coefficient		0.9969

Table A8. U3: Radii from $S_{48}(h)$ vs. observed *a* for 9 outer Uranus moons [41]

SSDE	Calculated radii		Moon or asteroid	Observed semimajor axes	
	1/h	Relative to R1		In 1,000 km	Francisco units
R0	1.0000	0.9964	===		
R1	1.0036*	1.0000	Francisco	4,276	1.0000
R8u	1.6570	1.6510	Caliban	7,231	1.6911
R8s	1.8162	1.8096	Stephano	8,004	1.8718
R9u	2.0186	2.0113	Trinculo	8,504	1.9888
R10u	2.6385	2.6289	Sycorax	12,179	2.8482
R10s	3.1418	3.1303	Margaret	14,345	3.3548
R11u	3.9024	3.8882	Prospero	16,256	3.8017
		3.8882	Setebos	17,418	4.0734
R11s	5.1777	5.1589	Ferdinand	20,901	4.8880
R12s	15.4465	15.3904	===		
			Correlation coefficient		0.9914
			R^2 coefficient		0.9828

Table A9. N1: Radii from $S_{48}(h)$ vs. observed *a* for 8 inner Neptune moons [41]

SSDE	Calculated radii		Moon or asteroid	Observed semimajor axes	
	1/h	Relative to R1		In 1,000 km	Naiad units
R0	1.0000	0.9964	===		
R1	1.0036*	1.0000	Naiad	48.23	1.000
R3u	1.0393*	1.0355	Thalassa	50.08	1.0383
R4u	1.0842*	1.0802	Despina	52.53	1.0891
R6u	1.2695*	1.2648	Galatea	61.95	1.2846
R7s	1.5294	1.5238	Larissa	73.55	1.5250
R9s	2.2825	2.2742	S/2004 N1	105.28	2.1831
		2.2742	Proteus	117.65	2.4394
R12u	7.7394	7.7113	Triton	354.80	7.3569
R12s	15.4465	15.3904	===		
			Correlation coefficient		0.9993
			R^2 coefficient		0.9985

Table A10. N2: Radii from $S_{48}(h)$ vs. observed *a* for 6 outer Neptune moons [41]

SSDE	Calculated radii		Moon or asteroid	Observed semimajor axes	
	1/h	Relative to R1		In 1,000 km	Nereid units
R0	1.0000	0.9964	===		
R1	1.0036*	1.0000	Nereid	5,513.4	1.0000
R10u	2.6385	2.6289	Halimede	15,728	2.8527
R11u	3.9024	3.8882	Sao	22,422	4.0668
		3.8882	Laomed	23,571	4.2752
R12u	7.7394	7.7113	Psamate	46,695	8.4694
		7.7113	Neso	48,387	8.7763
R12s	15.4465	15.3904	===		
			Correlation coefficient		0.9987
			R^2 coefficient		0.9973

Table A11. P1: Radii obtained from $S_{48}(h)$ vs. observed *a* for the 5 moons of Pluto [41]

SSDE	Calculated radii		Moon or asteroid	Observed semimajor axes	
	1/h	Relative to R4s		In 1,000 km	Charon units
R0	1.0000	0.8912	===		
R4s	1.1220*	1.0000	Charon	17.5	1.0000
R10u	2.6385	2.3515	Styx	42.0	2.3951
R10s	3.1418	2.8000	Nix	48.7	2.7776
R11u	3.9024	3.4780	Kerberos	59.0	3.3645
R11s	5.1777	4.6146	Hydra	64.7	3.6923
R12s	15.4465	13.7665	===		
			Correlation coefficient		0.9649
			R^2 coefficient		0.9309

From the Classical Aethers of Descartes and Newton to Cosmons and Sagions

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The present paper highlights the huge difference between the dynamic aethers proposed to explain the propagation and generation of gravity and the stationary, even solid, aethers proposed to support the transversal motion of electromagnetic waves. The vast majority of 20th century criticisms are addressed to the second class of aethers; besides, such critiques completely disregard the dynamical Hertzian aether, which underlies his Galilean-invariant electromagnetic theory. The Michelson-Morley experiment (MMX) is usually cited as the crucial evidence to abandon cherished notions of classical mechanics and instead adopt Lorentz invariance. Contrariwise, it is argued here that whatever the outcome of the MMX there was no need to abandon the concept of aether, and even less to assume that the Newtonian notions of space and time were *démodé*. Instead, three alternative interpretations of the MMX are offered here, one of them is the comparison between two models of propagation of light in the terrestrial laboratory: (a) relative to the boundary layer of earth and the fluid aether, or (b) relative to the bulk fluid aether. We end with three independent efforts by the end of the 20th century to explain all forces of nature with classical aether: (i) the cosmological gaseous aether proposed by Charles K. Thornhill, from which he derived an electromagnetic theory which is equivalent to Hertzian electromagnetism, (ii) the cosmonic gaseous aether proposed by Adolphe Martin to explain the existence of forces and particles, and (iii) our own fluid aether formed by discrete extended energy-like sagions which obey the laws of classical mechanics and the homogeneous wave equation. We briefly discuss the deeper meaning of our novel solutions for the classical wave equation, which lead to a unification of gravity, electromagnetism and quantum phenomena.

> *Physical knowledge has advanced very much since 1905, notably by the arrival of quantum mechanics, and the situation has again changed. If one reexamines the question in the light of present-day knowledge, one finds that the aether is no longer ruled out by relativity, and good reasons can now be advanced for postulating an aether.*
>
> P. A. M. Dirac, Nobel Laureate in Physics, 1933

> *Quite undeservedly, the ether has acquired a bad name. There is a myth, repeated in many popular presentations and textbooks, that Albert Einstein swept it into the dustbin of history. The real story is more complicated and interesting ... Einstein first purified, and then enthroned, the ether concept... At present, renamed and thinly disguised, it dominates the accepted laws of physics.*
>
> Frank Wilczek, Nobel Laureate in Physics, 2004

I. Introduction

In the epigraph Dirac starts from his new theory of electrodynamics, and defines a velocity that appears in "*all points of space-time, playing a fundamental part in electrodynamics. It is natural to regard it as the velocity of some real physical thing. Thus with the new theory of electrodynamics we are rather forced to have an aether*" [60]. For his part, Wilczek starts from the contrived notion of space-time, which has "*become a dynamical medium —an ether, if ever there was one*," and then describes various shortcomings of previous notions of ether [61]. In contrast, it is argued here that our atomistic three-dimensional extended sagions remedy the well known weaknesses of classical aethers.

Gravity is the most pervading and easiest to perceive force in Nature. Cavemen were surely aware that bodies tended towards earth, but the ancient Babylonian, Egyptian and Greek astronomers did not realize that motion of planets and stars was related to the apparent attraction of matter by the earth. In contrast to our lowly terrestrial world, for Aristotle the heavens were perfect, immutable, and subject to divine laws. Until, at last, in the first half of the 14^{th} century Jean Buridan at the University of Paris dared to suggest that the heavens could be studied in the same way as the rest of nature [1, p. 53]; additionally, the immutability of the heavens suffered a lethal blow with the observation by Tycho Brahe of a new star — the 1572 nova. The time was ripe for a final assault, which lasted 150 years, from 1543 when Copernicus published *De Revolutionibus Orbium Caelestium* until Newton's first edition of the *Principia* in 1687. In this long process contributions were also made by Kepler, Galilei, Descartes, Huygens, Hooke, and so on [2-6]; sadly, some of them have not received the credit they deserve.

Many have wondered why Newton did not publish his *Principia* around 1666. According to Reichenbach [2, p. 26]:

> Newton ... put his calculations away in a closet ... only twenty years later could the mistake be explained. The length of the earth's radius, taken by Newton as the basis of his calculations, had been inexact; new estimates on the astronomer's part gave a new measurement with which Newton's reflections about the moon proved to be in full accord.

Kuhn's account on this matter is much more detailed and does not put the blame on earth's radius [3, p. 257-258]:

> Newton ... was himself intensely aware of the metaphysical inadequacy of his working concept of gravity. That awareness probably accounts for at least part of his delay in announcing the results of his early work in celestial physics. In fact, the *Principia* did not appear until Newton, in 1685, succeeded in resolving one of the apparent conflicts between gravity and the corpuscular philosophy and until he had expended much fruitless effort in attempting to resolve the other.
>
> The first conflict between corpuscular premises and Newton's early theory of gravity appears in the calculation of 1666, which compared the earth's attraction for the distant moon and a nearby stone ... In 1685 he proved that, whatever the distance to the external corpuscle, all the earth corpuscles could be treated as though they were located at the earth's center. That surprising discovery, which at last rooted gravity in the individual corpuscles, was the prelude and perhaps the prerequisite to the publication of the *Principia*.

We have quoted this passage at length because the introduction of the center of mass in Newtonian mechanics allowed spatially extended bodies to be treated *as if* they were mathematical points with mass. Unfortunately, when quantum physics was developed at the beginning of the 20th century, particles were defined as mathematical points with mass, the "as if" part having been forgotten. Let us continue with Kuhn's second reason for the delay in publication of the *Principia* [3, p. 258-259]:

> The great virtue of Descartes's system had been its complete elimination of all such "occult qualities." Descartes's corpuscles had been totally neutral; weight itself had been explained as the result of impact; the conception of a built-in attractive principle operating at a distance therefore seemed a regression to the mystic "sympathies" and "potencies" for which medieval science had been so ridiculed. Newton himself entirely agreed. He repeatedly attempted to discover a mechanical explanation of the attraction, and though forced at last to admit his failure, he continued to maintain that someone else would succeed, that the cause of gravity was not "uncapable of being discovered and made manifest" [8]. [Again and again he insisted that gravity was not innate in matter.]

In retrospect, the answer was at hand even at Newton's time: mechanics based on the Cartesian principle of conservation of linear momentum. To answer criticisms from the Cartesians, in the General Scholium written in 1713 for the second edition of the Principia, Newton explicitly recognized that: "*I have not been able to discover the cause of those properties of* *gravity from phenomena, and I frame no hypotheses...*" [7, p. 45]. However, in his private letters he conjectured on the origin of gravity, as in a letter to Boyle dated February 28 1678/79 discussed in II.C below.

For the general public of the 20th and 21st centuries the best known sentence of Newton is "I frame or feign no hypotheses"; for them, Westfall's comment may be illuminating [4, p. 158]:

> I feign no hypotheses —*hypotheses non fingo*. In one sense the words are obviously false; Newton did feign hypotheses, and rather grandiose ones at that. In the sense that he maintained a rigid distinction between demonstrated conclusions and hypotheses meant to explain them, and refused to dilute demonstrations with speculations, however, the statement can stand. Thus force was to Newton a concept necessary to the description of phenomena in mechanical terms. Its validity rested on its utility in demonstrations, not on hypotheses that might explain its origin.

The intention of the present paper is not to take sides on the bitter dispute that followed publication of the *Principia*, between the supporters of Newton (mainly) in Great Britain, and his opponents (mainly) in the European continent, or on a personal level where "*the case for Newton ... became steadily a case against Descartes*" [5, p. 312]. On the contrary, after the necessary *aggiornamento*, our purpose is to take the middle road, between a radical rationalism that forbids all unexplained assumptions, and a radical pragmatism where any brute-force assumption is acceptable provided that it leads to "correct" results.

Newton's pragmatic approach to science, epitomized by the *Principia*, was adopted by many scientists, and is the currently dominant paradigm for doing science in western countries. However, pragmatism has costs. For instance, over the years Newton's gravity became an innate property of matter and an action-at-a-distant force, both views strongly resisted by Newton himself [3, p. 259]; this in turn led to the necessity for a new gravitational theory taking into account a finite speed. During the 20th century the pragmatic approach eventually led to logical incoherence, such as a *vacuum* having "physical" properties, or a *vacuum* that instead of being empty by definition is filled with something, say dark matter. In our opinion, logical incoherence is unacceptable.

So, let us proceed from the cosmological origin of the Cartesian and Newtonian concepts of an ether to some contemporary proposals.

II. Gravity and ether

A. Towards Newtonian gravity

As a context for his ether let us briefly recall the main steps leading to Newton's universal law of gravity. Kepler carefully analysed astronomical data collected since antiquity, plus more recent data gathered by Copernicus and Tycho Brahe; he identified some clear patterns and managed to express them as mathematical relations — Kepler's laws. Newton *assumed* the existence of *pulling* forces between cosmic bodies, and by 1666 he found that, in particular, an inverse-square force could explain Kepler's laws. But Newton did not publish at that time. For completeness, two centuries later Bertand demonstrated that only forces proportional to r and $1/r^2$ could lead to elliptical motion [9].

But why is 1666 important? In that year, at the end of a lecture at the Royal Society of London, Robert Hooke showed the audience a conical pendulum as a model of the two dynamical elements present in circular (or in elliptical) planetary motion: inertial motion and a force towards the center [3, p. 249-256]. In Kuhn's words [3, p. 249]:

> Much influenced by Descartes, Hooke began with a complete conception of inertial motion and of the identity of terrestrial and celestial laws ... A moving planet ought ... to continue its motion uniformly in a straight line through space, because the senses reveal nothing to push or pull it. Since its motion is not straight ... the immediate evidence of the senses must be misleading. There must be an additional attractive principle or force operating between the sun and each planet.

The attractive force is represented by the tension in the cord of the conical pendulum (Figure 50 in [3, p. 250]). Hooke put his ideas in writing in 1674, noting that gravity should depend on distance, but recognizing that he had not been able to find by experiment the functional dependency; in Hooke's words "*what these several degrees are I have not yet experimentally verified*" [10]. According to Kuhn [3, p. 256] "*if his own subsequent dating of the discovery is reliable, Newton had used the conceptions to determine Hooke's 'several degrees' of gravitational attraction eight years before the passage above was written.*" Note the contrast between Hooke's experimental efforts and Newton's theoretical approach.

It is also remarkable that in 1666 Hooke already had a clear understanding of the implications of the principle of inertia, which leads to tangential escapes from circular motion, without any need for postulating centrifugal forces — which according to rigorous classical mechanics merely are *fictitious* forces that do not exist in inertial frames [11]. Hooke's insight was a non-trivial achievement; just remember that as late as the mid-20th century some top-class physicists still believed in the existence of *real* centrifugal forces!

Regarding the origin of gravity, Newton often insisted that it was not an intrinsic property of bodies, as "*Not that I affirm gravity to be essential to bodies ... their gravity is diminished as they recede from earth*" [7, p. 5]. In his second letter to Bentley (17 January 1692/3) Newton noted that "*You sometimes speak of gravity as essential and inherent to matter. Pray do not ascribe that notion to me, for the cause of gravity is what I do not pretend to know*" [7, p. 53]. For Newton's origin of gravity see II.C below and Jammer's book on the concept of force [1, p. 133-142].

B. Cartesian physics

It is well known that from simple experiments with inclined planes Galileo clearly intuited the existence of the principle of inertia, but the role of Descartes is less known. According to Cohen [6, p. 153] "*the earliest known statement*" of the principle of inertia was in the book *Le Monde* (The World) that Descartes decided not to publish after learning of the condemnation of Galileo by the Roman Inquisition; the law of inertia appeared in *Principia Philosophiae* (The Principles of Philosophy) published in 1644, and afterwards posthumously published in *Le Monde* in 1650.

Cartesian physics was based on rules of impact that can be traced to the sixth century with John Philoponus in Byzantium, and even perhaps to Hipparchus in the second century before our era [1, p. 70; 3, p. 119]. Most impact rules formulated by Descartes were empirically incorrect, but the overall idea was right; the general and correct vector formulation was found by Huygens in the period between 1652 and 1656, and later on by Wallis and Wren around 1668 [12]. Those papers originated the modern principle of conservation of linear momentum (CLM). According to Davies [12, p. 9], Huygens fifth law is:

> The quantity of motion of two bodies may be increased or decreased by their collision; but the same quantity always remains in any direction, after subtracting the quantity of contrary motion.
>
> The first part may have been contrasting his law with the incorrect formulation of Descartes. In the second part the emphasis on directions and the need to subtract contrary motions was crucial; it was *copied very closely by Newton in Principia* (emphasis added).

On the contrary, Cartesian cosmology has always been subject to strong criticism. The Cartesian model of the universe was a static three-dimensional (3D) space completely filled by three different substances in permanent motion: ordinary matter, ether that fills the heavens, and light forming the sun and stars. Cartesian matter was infinitely divisible, and filled all space leaving no voids; the permanent collisions of moving matter led to the formation of vortices, and gravity was due to ether particles revolving faster than Earth, thus pushing down ordinary terrestrial matter. [5, p. 116-120]. Cartesian vortices have always been the main issue.

C. Newtonian aether

In the *Principia* ether receives only a passing mention in the last paragraph of the General Scholium of the second edition [7, p. 45]:

> And now we might add something concerning a certain most subtle spirit which pervades and lies hid in all gross bodies, by the force and action of which spirit the particles of bodies attract one another at near distances and cohere, if contiguous; and electric bodies operate to greater distances, as

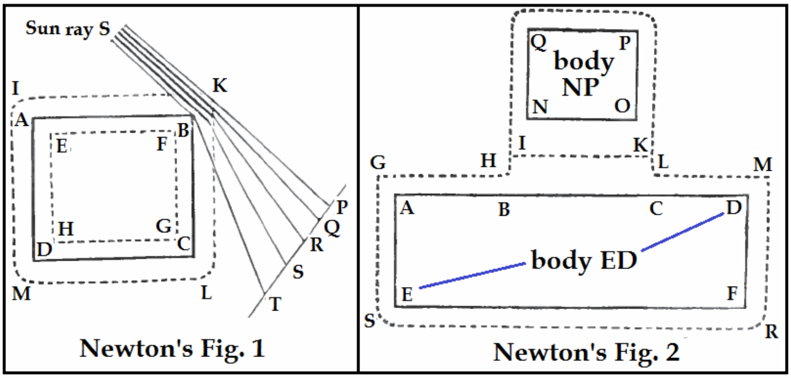

Figure 1. Newton's Figures 1 & 2 in [124]. Left panel: In supossition 3 Newton describes the "space between the limits EFGH and IKLM ...of the aether's graduated rarity" which is awfully close to the modern concept of a boundary layer in fluid theory. Right panel: Boundary layer grows to line IK when two bodies are close together (see supposition 4).

> well repelling as attracting the neighboring corpuscles; and light is emitted, reflected, refracted, inflected, and heats bodies;...

In his *Opticks* and in private letters Newton was a strong advocate of ether as a medium required for the propagation of gravity. For instance, the third letter to Bentley (dated 25 February 1692/3) states that [7, p. 54]:

> It is inconceivable that inanimate brute matter should, without the mediation of something else which is not material, operate upon and affect other matter without mutual contact, as it must be if gravitation, in the sense of Epicurus, be essential and inherent in it. And this is one reason why I desired you would not ascribe innate gravity to me. That gravity should be innate, inherent, and essential to matter, so *that one body may act upon another at a distance through a vacuum, without the mediation of anything else, by and through which their action and force may be conveyed from one to another, is to me so great an absurdity* that I believe no man who has in philosophical matters a competent faculty of thinking can ever fall into it. Gravity must be caused by an agent acting constantly according to certain laws, but whether this agent is material or immaterial I have left to the consideration of the readers (emphasis added).

In a letter to the chemist Robert Boyle on February 28, 1678/9, Newton described aether as a gas formed by discrete corpuscles. The letter is partially reproduced without figures in [7, p.112-116], more complete with figures on the James De Meo web-site [124], and herein as Figure 1. Newton enumerated aether's properties as five suppositions, reproduced almost completely below because they amount to a modern model to generate force from the gradient of the number density of aether corpuscles:

> Firstly, I suppose, that there is diffused through all places an aetherial substance, capable of contraction and dilatation, strongly elastic, and, in a word, much like air in all respects, but far more subtile.

> 2. I suppose this aether pervades all gross bodies, but yet so as to stand rarer in their pores than in free spaces, and so much the rarer, as their pores are less; and this I suppose (with others) to be the cause why light incident on those bodies is refracted towards the perpendicular; why two well-polished metals cohere in a receiver exhausted of air; why mercury stands sometimes up to the top of a glass pipe, though much higher than thirty inches; and one of the main causes why the parts of all bodies cohere; also the cause of filtration, and of the rising of water in small glass pipes above the surface of the stagnating water they are dipped into; for I suspect the aether may stand rarer, not only in the insensible pores of bodies; but even in the very sensible cavities of those pipes; ...
>
> 3. I suppose the rarer aether within bodies, and the denser without them, not to be terminated in a mathematical superfices, but to grow gradually into one another; the external aether beginning to grow rarer, and the internal to grow denser, at some little distance from the superfices of the body, and running through all intermediate degrees of density in the intermediate spaces; and this may be the cause why light, in Grimaldo's experiment, passing by the edge of a knife, or other opaque body, is turned aside, and as it were refracted, and by that refraction makes several colours. Let ABCD be a dense body whether opake or transparent, EFGH the outside of the uniform aether, which is within it, IKLM the inside of the uniform aether, which is without it; and conceive the aether, which is between EFGH and IKLM, to run through all intermediate degrees of density between that of the two uniform aethers on either side. This being supposed, the rays of the sun SB, SK, which pass by the edge of this body between B and K, ought in their passage through the unequally dense aether there, to receive a ply from the denser eether, which is on that side towards K, and that the more by how much they pass nearer to the body, and thereby to be scattered through the space PQRST, as by experience they are found to be. Now the space between the limits EFGH and IKLM I shall call the space of the aether's graduated rarity.

From our modern viewpoint, it is remarkable that to explain an electromagnetic phenomenon as decomposition of light, Newton introduced in supposition 3 the concept of a boundary layer with number density *n(r)* increasing as distance *r* increases outwards from the surface of the material body. This mechanism is one of the possible explanations discussed in section IV.D below for the observed intriguingly small speed of earth relative to ether in the Michelson-Morley experiment. Supposition 4 offers details on the mutual interaction of two boundary layers (Newton's Figure 2 on right panel), and the shadowing mechanism leading to a decrease in *n(r)* between two approaching bodies, which leads to coherence of matter described in supposition 5:

> 4. When *two bodies moving towards one another come near together, I suppose the aether between them to grow rarer than before*, and the spaces of its graduated

rarity to extend further from the superficies of the bodies towards one another; and this, by reason that the aether cannot move and play up and down so freely in the strait passage between the bodies, as it could before they came so near together: thus if the space of the aether's graduated rarity reach from the body ABCDFE only to the distance GHLMRS, when no other body is near it, yet may it reach further, as to IK, when another body NOPQ approaches. And as the other body approaches more and more, I suppose *the aether between them will grow rarer and rarer*. These suppositions I have so described, as if I thought the spaces of graduated aether had precise limits, as is expressed at IKLM in the first figure, and GMRS in the second ; for thus I thought I could better express myself. But really I do not think they have such precise limits, but rather decay insensibly, and, in so decaying, extend to a much greater distance than can easily be believed or need be supposed.

5. Now, from the fourth supposition it follows, that when two bodies approaching one another come so near together as to make the aether between them begin to rarefy, they will begin to have a reluctance from being brought nearer together, and an endeavour to recede from one another; which reluctance and endeavour will increase as they come nearer together, because thereby they cause the interjacent aether to rarefy more and more. But at length, when they come so near together *that the excess of pressure of the external aether* which surrounds the bodies, above that of the rarefied aether, which is between them, is so great as to overcome the reluctance which the bodies have from being brought together; then will that excess of pressure drive them with violence together, and *make them adhere strongly to one another*, as was said in the second supposition. For instance, in the second figure, when the bodies ED and N P are so near together that the spaces of the aether's graduated rarity begin to reach to one another, and meet in the line I K, the aether between them will have suffered much rarefaction, which rarefaction requires much force, that is, much pressing of the bodies together; and the endeavour which the aether between them has to return to its former natural state of condensation, will cause the bodies to have an endeavour of receding from one another. But, on the other hand, to counterpoise this endeavour, there will not yet be any excess of density of the aether which surrounds the bodies, above that of the aether which is between them at the line I K. But if the bodies come nearer together, so as to make the *aether in the mid-way line I K grow rarer than the surrounding aether*, there will arise from the *excess of density of the surrounding aether* a compressure of the bodies towards one another, which, when by the nearer approach of the bodies it becomes so great as to overcome the aforesaid endeavour the bodies have to recede from one another, they will then go towards one another and *adhere together*... (emphasis added).

So, Newton had it clear around 1678/9 that force F of adherence and coherence could be attributed to variations of aether pressure P:

$$F \propto -\partial P / \partial r \qquad (0)$$

This is the same mechanism invoked in our neo-Cartesian unified fluid theory [63, 104, 105, 125], see V.D below. Qualitatively, Eq. (0) is similar to variation of atmospheric pressure over the surface of earth, which depends on terrestrial gravitational acceleration *g*;. Note that in the atmospheric case, *g* is the cause, and the pressure gradient is the effect, while in Eq. (0) the relationship cause-effect is opposite. At any rate, Newton did not realize that gravity could have the same explanation as coherence, and introduced another (unnecessary in our view) supposition, which has been widely quoted [1, p.135], [7, p. 115]:

> I shall set down one conjecture more, which came into my mind now as I was writing this letter; it is about *the cause of gravity*. For this end I will suppose aether to consist of parts differing from one another in subtilty by indefinite degrees; that in the pores of bodies there is less of the grosser aether, in proportion to the finer, than in open spaces ... (emphasis added).

D. Cartesian aether versus Newtonian aether

This may be the place to include some remarks contrasting Cartesian and Newtonian ideas. Firstly, both of them considered that material bodies were extended and impenetrable, in the sense of occupying a portion of 3D-space at some instant of time. In the rules for reasoning in philosophy (Book III of the *Principia*) Newton stated [7, p. 4]:

> Because we perceive extension in all that are sensible, therefore we ascribe universally to all others also ... That all bodies are impenetrable, we gather not from reason, but from sensation ...thence conclude impenetrability to be a universal property ... hence we conclude the least particles of all bodies to be also extended, and hard, and impenetrable, and movable, and endowed with their proper inertia.

Newton states here a difference with Descartes: his own beliefs had empirical origin, not pure reason. Our own opinion is that neither pure reason alone, nor empirical observation alone suffice. There was a sterile discussion for several centuries as to whether material bodies were hard or soft, or they were penetrable or not, see for instance [13, 14]. With the advent of high speed photography in the mid-20th century it was easy to see that a ball hit by a tennis racquet or by a bat is heavily deformed, even billiard balls are deformed in head-on collisions.

A significant difference is that for Descartes matter was infinitely divisible, whereas Newton was a convinced atomist. Actually, Newton invoked the authority of ancient Greek atomists in query 28th of *Opticks* [7, p. 155], and again in query 31st Newton mentions "*atoms*" several times as hard, solid and unbreakable particles of which "*all material things seem to have been composed*" [7, p. 175-177].

Perhaps the most important difference between Descartes and Newton is that Descartes had it very clear that his particles interacted by exchange of momentum, whereas Newton could never set his mind on what his ether was, and even less on how the ether corpuscles interacted. For instance, in Book I of the *Principia* (Scholium to Section XI) Newton said [7, p. 39]:

> I here use the word *attraction* in general for any endeavour whatever made by bodies to approach to each other, whether that endeavour arises *from the action of the bodies themselves*, as tending to each other or agitating each other *by spirits emitted*; or whether it arises from the action of the ether or of the air, or of any medium whatever, whether corporeal or incorporeal, in any manner impelling bodies placed therein toward each other ("attraction" in italics in the original, further emphasis added).

The two emphasized ideas pinpoint Newton's hesitations regarding the origin of force, gravity attraction in particular. One senses some contradiction here, or at least ambiguity, in the face of Newton's protestations regarding non-innate gravity (quoted in sub-section II.A above).

Newton continued all his life searching for a mechanism to generate gravity. Newton's *Opticks* was published for the first time in 1704, successive editions up to the fourth in 1730 differed mostly in the content of his conjectures: the queries. Query 31st, and last, stated that since

> …the variety of motion which we find in the world is always decreasing, there is a necessity of conserving and recruiting it by active principles, such as are the cause of gravity, by which planets and comets keep their motions in their orbs and bodies acquire great motion in falling" [7, p. 175].

It is remarkable that Newton disqualified the principle of conservation of linear momentum as a viable candidate for the role of "active principle," with which he was familiar (recall section II.B above). It may be conjectured that Newton did not fully grasp the far reaching implications of the *vectorial* conservation of linear momentum as opposed to the scalar variations of the magnitude of quantity of motion. In the same Query 31st Newton explicitly said [7, p. 174]:

> The *vis inertiae* is a passive principle by which bodies persist in their motion or rest, receive motion in proportion to the force impressing it, and resist as much as they are resisted. By this principle alone there never could have been any motion in the world. Some other principle was necessary for putting bodies into motion; and now they are in motion, some other principle is necessary for conserving the motion. For from the various composition of two motions, *it is very certain that there is not always the same quantity of motion in the world* (emphasis added).

In support of his claim Newton offers the example of two globes joined by a slender rod, revolving about the common centre of mass (CM) at constant speed, while the CM moves at constant velocity. There is nothing paradoxical in this simple system where linear and angular momenta are both *separately* conserved. However, Newton intriguingly claimed that "*the sum of the motions of the two globes*" was different between two orientations of the rod relative to the linear motion of the CM. That is true, but the CLM refers to vectors, not to scalars. It is a pity that Newton's fixation on demonstrating that Descartes was wrong* did not allow him to see that the three Newtonian laws were closely related to the powerful Descartes-Huygens principle of CLM; this connection is common knowledge today [15, p. 13-23]. All in all, Newton did not succeed in proposing a working microscopic mechanism for gravity, perhaps because his emphasis was on dynamics (*via* his second law) rather than on kinematics, *via* the CLM. Despite the great success of Newtonian gravity, the basic mechanism for its propagation has been a mystery for three centuries; as briefly described below, the present writer has recently proposed a Le Sage-type approach that works [16], thus solving the conundrum.

E. Fatio's aether

The Swiss Nicolas Fatio de Duiller was more successful than Newton in advancing a mechanism to explain gravity. Fatio was Newton's disciple and, for some time, his close friend; he suggested in 1685 that gravity might be due to a "*fierce current of exceptionally subtle matter that flows from all possible directions towards the centre of the earth, pushing all bodies downwards*" [17, p. 48]. Initially Newton supported Fatio's idea, but later on – apparently after their closeness ended — Newton changed his mind. Other contemporary scientists in London, like Huygens, Halley and Hooke, were not convinced.

By 1700 Fatio moved to the European Continent where he corresponded with Jacob Bernoulli, and later entered into some competitions in Paris to explain celestial gravitation. Eventually a copy of Fatio's work came into the hands of the Genevan mathematics professor Gabriel Cramer, who passed some of those ideas to his student Jalabert in 1731. For an entertaining account of Fatio's adventurous life see [17].

F. Le Sagian aether

Interest has recently revived in the work of another Swiss citizen, the Genevan George Louis Le Sage (1724-1803), who came onto the scene 100 years after Newton [18, 19]. At age thirteen Le Sage became interested in gravity, and some years later he was acquainted with the corpuscular theory of gases developed by Daniel Bernoulli in his *Hydrodynamics* published in 1738. After four years of pondering, Le Sage hit on his mechanism on 15 January 1747 at 11:30 in the evening: a continuous flow of tiny ultramundane corpuscles bombarding our world from all directions with extremely high speed — much larger than the speed of light.

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* This obsession was shared by Newton's closest associates: Roger Cotes, Richard Bentley and Samuel Clark. For instance, from their correspondence preceding the second edition of the *Principia* –in particular the writing of a General Scholium by Newton and a Preface by Cotes– it surfaces that a chief objective was to "*crush the Cartesians*." [7, p. 198-201]

To honour Le Sage, his ultramundane corpuscles (with the few additional properties listed in section V below) are here called sagions; the name may be also interpreted as carriers of wisdom. If an isolated material body is hit by sagions from all directions the net effect on the body is null, but if two material bodies are close enough, they shadow one another from the flow of sagions, resulting in net attraction: gravity.

Le Sage was an honest investigator. In 1749 Cramer told Le Sage that his ideas — independently developed by him at the beginning of 1747 — were similar to Fatio's ideas; thereafter, "*Le Sage scrupulously gave him credit in all his writings and often mentioned Cramer and Jalabert as well*" [20, p. 21]. This is a telling example for some well-known physicists, before and after Le Sage, who have difficulty acknowledging their intellectual debt to their predecessors. As is often the case, independently and about the same time as Le Sage, the Russian M.V. Lomonosov developed a very similar model for gravity [21].

G. Vortex atoms and the kinetic theory of gravity

Theoretical hydrodynamics initially addressed the simplest case of irrotational fluids, in particular those describable by velocity potentials; the Swiss Leonhard Euler and the French Joseph Louis Lagrange made significant contributions in the 18th and beginning of the 19th centuries. Then in 1858 Helmholtz published a paper in German dealing with vortex rings formed in a rotational fluid, that was published in English in 1867 [22], apparently translated by professor Peter Guthrie Tait —who shared with William Thomson the chair of mechanics at the University of Edinburgh, and was quite impressed with Helmholtz's findings. Tait devised a method to produce vortex rings in the classroom using fumes from some chemical reactions; Thomson was greatly impressed by Tait's demonstration, in particular by the stability and the dynamical properties of the smoke rings. Within a month Thomson gave a talk on vortex atoms at the Royal Society in Edinburgh [23]. During the whole second half of the 19th century, Thomson (later Lord Kelvin) was a firm ether propounder, and published a significant number of papers on that subject [24]. At that time atoms were of interest both in chemistry and in the recently proposed kinetic theory of gases; in that context Taylor reviewed several kinetic theories of gravity [25].

Lord Kelvin was also sympathetic to Le Sage's gravity, and stressed its similarities with the kinetic theory of gases. In 1876, Picart in France proposed a gaseous ether formed by elastic atoms moving with high speed in every direction, whose collisions against a surface would generate pressure; he then described a shadowing mechanism to generate gravity which was the same as Le Sage's one-hundred year old proposal [26]. Since Le Sage is not mentioned, it may be conjectured that Picart rediscovered the shadowing mechanism. Le Sagian ideas suffered a significant drawback due to Maxwell's criticism in 1878 that the absorption of sagions would heat matter [27]; several decades later Poincaré presented the same argument [28, p. 242-249]. Those criticisms almost killed Le Sage's theory.

Mainly in the context of electromagnetic theory, other well known British scientists also supported various versions of ether vortices, such as Leahy's oscillatory twists [29], Hill's spherical vortex [30], Pearson's vibrating spheres and ether squirts [31], and J.J. Thomson's ether filaments as late as 1931 [32] — after J.J. Thomson's discovery of the electron, the rise of Einstein's special theory of relativity, and the advent of quantum mechanics. In the USA, the inventor Charles Brush also propounded a kinetic theory of gravity [33].

As a close to this section it is stressed that the gravitational ether proposed by Fatio and Le Sage was endowed with motion in all directions of three-dimensional space, and that there was a clear distinction between 3D-space and the ether that moved in that space.

III. Electromagnetism and ether

In the mid 19th century Maxwell developed his theory of electromagnetism by analogy with the transport of fluids [34, 35]. However, it is rather curious that his equations contain partial derivatives, rather than total derivatives which explicitly contain the speed V of the terrestrial laboratory. This may be interpreted in two different senses: (a) Maxwell's aether was stationary, (b) Maxwell's equations are only valid in absolute space Σ, as usual in Newtonian mechanics. For further comments see section III.C below on Hertzian dynamical ether and Galilean invariant electrodynamics. Let us turn now to various proposals for luminiferous ethers existing prior to Maxwell's theory — some of those ethers were not fluids, but elastic solids.

A. The luminiferous ether

In 1839 Samuel Earnshaw read a paper before the Cambridge Philosophical Society in which he criticized other authors for the "*symmetrical arrangements of the particles of the ethereal medium ... [that] it has never been shewn that such arrangements do exist in Nature, nor even that they can exist in Nature*" [36, p. 97]. So, he concentrated in arrangements which are not "*peculiar to the luminiferous ether*," and

> Assumed that the ether consists of detached particles; each of which is in a position of equilibrium, and when slightly disturbed is capable of *vibrating in any direction*. (Many solid as well as aerial bodies transmit sound, which is generally supposed to imply the existence of the same properties in them

as are here assumed to be true of the ether) [36, p. 98] (emphasis in the original).

From the development in Earnshaw's paper it follows that his equilibrium is not dynamical (say, a planetary orbit) but simply means ether particles at rest in the 3D-physical space; actually, his ether is closer to a liquid or solid at rest. Then, one may infer that the "*symmetrical arrangements*" that he criticized referred to crystals formed by ether particles.

For completeness it is mentioned that the paper just quoted is the implicit demonstration of Earnshaw's theorem used in contemporary electromagnetic theory: "*a charged particle in empty space cannot remain in stable equilibrium under electrostatic forces alone*" [37, p. 418]. This result may be inferred from the assumption made by Earnshaw in his paper that his ether "*particles exert attractive forces as well as repulsive forces*" [36, p. 109]; note that Earnshaw treats force as an inherent trait of matter.

Then, the meaning of ether is not unique. As Max Jammer notes in the foreword to Kostro's book [38, p. iii]: "*in the middle of the nineteenth century fourteen disparate ether concepts had been in use at one and the same time.*" Among the properties assigned to the luminiferous ether was elasticity, which at that time was deemed necessary to support propagation of the transversal electromagnetic waves. According to the Webster's dictionary, elastic means "*having the property of immediately returning to its original size, shape, or position after being stretched, squeezed, flexed, expanded, etc.*" Such properties describe solids rather than fluids — as the gravitational ethers were. Readers interested in details of electromagnetic ether may read Whittaker's history [39].

B. Ether and three-dimensional space confounded

In 1845 the French Barré de Saint-Venant argued strenuously against the Newtonian concept of force, which, of course, is based on the faulty definition of mass in Newton's first paragraph of the *Principia*. Saint-Venant proposed instead a definition of mass based on the principle of conservation of linear momentum; twenty years later the Austrian Ernst Mach proposed a similar definition of mass [1, p. 215-217], and in the 1890s Heinrich Rudolf Hertz made similar criticisms in Germany [40]. In the context of the positivistic attitude towards science prevailing at that time, the Newtonian concepts of absolute space and absolute time were highly suspect as well.

Given the positivistic environment, it is not surprising that the physical three-dimensional space where the universe exists was identified with the solid elastic ether in which light and electromagnetic phenomena vibrate. For instance, in his model of ether the English professor Oliver Lodge assumed that "*the aether is the vehicle and medium of all stresses that exist. Stresses exist solely in the aether*" and that "*the aether as a whole is at rest, and velocities referred to it are absolute velocities*" [41, p. 422].

Einstein's father was the co-owner of a factory that built machines for electricity generation, so that it is no great surprise to learn that the young Einstein was interested in the ether, and that by about 1894 or 1895 he had written a note on ether and the magnetic field, which, of course, reflected the then current notion of an ether sustaining elastic strains and elastic deformations [38, p. 13-15].

According to Kostro, "*Einstein denied the existence of the ether for 11 years only, i.e. from 1905 to 1916*" [38, p. 27], and after the formulation of the general theory of relativity (GTR) Einstein reintroduced the concept again; in his monograph Kostro discusses at length the three different kinds of ether that are present in Einsteinian theories.

However, it seems that the 19th century identification of ether and space was still present in Einstein's mind when he delivered a lecture on May 5th, 1920 at the University of Leyden:

> Newton might no less well have called his absolute space 'Ether'; what is essential is merely that besides observable objects, another thing, which is not perceptible, must be looked upon as real, to enable acceleration or rotation to be looked upon as something real [42, p. 17].

C. Hertz's dynamical ether

Towards the end of the 19th century a separate development appeared in Germany: the *dynamical* ether proposed by Hertz in his posthumous book on classical mechanics [40; 43, p. 305-377]. This ether was intended as a basis for Hertz's electromagnetic theory, which was automatically Galilean invariant. Unfortunately, neither the Hertzian ether, nor his electromagnetism received proper attention due to Hertz's premature death.

Currently, there is a revival of Hertzian ideas, which requires changing Maxwell's partial derivatives for the total derivatives that rule the general theory of fluids. For details see Phipps's book [44], where he notes that if the velocity V appearing in Hertz's equations is interpreted as the velocity of the detector relative to the inertial frame, then it follows that Maxwell's electromagnetic theory is the particular case of the Galilean invariant Hertzian theory for $V = 0$. Let us stress it again: Maxwell's theory merely is the particular case of a detector at rest in the inertial frame [44, p. 17-25]. Therefore, any theory that adopts Maxwell's equations as a starting point — as Einstein's special theory of relativity did — is intrinsically limited. For completeness, toward the end of past century Thornhill [45] rediscovered the superiority of the Hertzian approach, but he never realized that he had been anticipated by Hertz (see V.A below).

IV. Pre-relativistic interpretation of the MM experiment

A. The Michelson and Morley experiment

While Michelson was a graduate student of Helmholtz he carried out his first experiment to measure the relative motion of the earth and the luminiferous ether; the measurements started in Berlin, but, to avoid tram vibrations, the interferometer was moved to Postdam [46]. The experiment was conceived within the then current model of an ether at rest in physical space, so that the motion of earth relative to physical space would be perceived in the terrestrial laboratory as an ether wind. To the present day, the majority of discussions on the interpretation of the Michelson and Morley (MM) experiment [47] are cast in those terms.

The interferometer used by Michelson was not very rigid, and the empirical results were not of good quality. Michelson's initial paper published in 1881 [46] is almost unknown today, but it is important because this is where he reported the assumptions made in the design of the experiment; in particular, he explains why he expected to observe fringe shifts smaller than one fringe shift. Michelson assumed that our sun moves relative to physical space with a low speed of 30 km/s, a figure that was reasonable by the end of the 19th century, but it is 10 to 20 times smaller than current solar and local group speeds relative to the CMB (369 and 627 km/s) [65].

After returning to Cleveland, Michelson joined efforts with Morley to repeat the experiment that failed in Germany. To avoid vibrations they placed the interferometer on top of a stone floating in mercury; after the stone was set in rotation (one turn in 6 minutes), readings were taken every 22.5°; this means that the experimenter had to run around the stone to chase the telescope on top of the stone to take a reading *every 22.5 seconds*, while the stone continued its motion. The observer looked at the position of the reference fringe, which *a priori* was interpreted as a fraction of one fringe. Actually, the observer did not have time to read anything else — even if he had the desire, or the means, to find out how many fringe shifts had rolled by in the interval between two consecutive readings. The Michelson-Morley (MM) experiment consisted of six sessions, three at noon, and three at six p.m., carried out on July 8, 9, and 11, 1887. There were six turns of the interferometer in each session, so that each point reported by MM was actually the average of six readings, whose standard error was not provided [47]. The six curves for the six sessions did not have the same general shape — some of them depicted harmonic variations compounded with an *increasing* overall trend, while others exhibited *decreasing* overall trends. Without apologies, MM simply averaged the curves of the six sessions, thus smoothing out the variations. The resulting average amplitude of the sinusoidal oscillations was interpreted as an ether speed close to 8 km/s, *i.e.* about a quarter the expected orbital motion of the earth of 30 km/s.

Despite the (controversial) process of data reduction, *the measured value was non-zero*, although — not surprisingly — smaller than expected by MM. At the end of their paper MM simply jumped to the conclusion that the small speed that they calculated was consistent with no relative motion of earth and ether, but they never presented any statistical analysis to substantiate their claim. On the contrary, the paper claimed that the experimental error was quite small. *Given the difficult and hasty process of reading the telescope during running, the origin of that claim is a mystery*.

In Holland, Lorentz took the MM claims at face value and developed a theory for the electron that would account for these novel experimental findings (!!??); by the same token, in Ireland Fitzgerald proposed a length contraction as a possible explanation for the null-result of the MM experiment. Of course, Einstein's special theory of relativity (STR) predicts an *exactly* null result in the MM experiment, so that even the small speed (8 km/s) calculated by MM is inconsistent with STR predictions.

The conventional null-interpretation of the MM experiment was strongly disputed by Miller, who in 1902 worked together with Morley in several repetitions of the experiment, and continued alone for more than twenty years after Morley's death. In stark contrast to the scanty number of thirty-six turns in the MM experiment, Miller carried out observations involving one to two *hundred thousand turns* of his interferometers [48]. Miller consistently claimed that his results were *never* null.

B. Physical space interpretation of interferometer experiments

In the early 1990s the present writer revisited the empirical basis of the STR [49], and found himself in agreement with Miller's claims [48]. The expected fringe shifts in Miller's interferometers were calculated using modern values of solar motion relative to physical space; a preferred inertial frame of coordinates, denoted by Σ, is anchored to a cosmic body (Aries), as in Newton's fixed stars. The speed of light is assumed to be constant along every direction in Σ; effective speeds of light along different directions in a terrestrial laboratory are calculated by Galilean vector addition [50]. In our calculations ether is never mentioned (let alone ether wind).

The speed of light in a terrestrial laboratory thus depends on direction, time of day, and epoch of the year. It follows that the shape of the fringe shift curves obtained with interferometers indeed depends on time of day, and epoch of the year, as also observed by Miller [48]. Of course, the calculated amplitude of the fringe shift depends on the solar motion relative to Σ — both speed and direction of motion. For the currently accepted values of solar speed it may be immediately concluded that the fringe shift amplitude in both MM and Miller's interferometers was always larger than one fringe shift. This is in contradiction with the experimental protocols of MM and Miller, thus casting serious doubts on their overall empirical validity. In the case of Miller's protocol, most contemporary commentators have missed the fact that when the reference fringe had drifted by more than one interference band, Miller hung a small weight at the end of one of the interferometer arms, thus changing its length [48]. From the foregoing, the present writer has concluded that there was no evidence for Lorentz contraction at the beginning of the 20th century [51]. Consequently, Einstein's STR had no empirical support at the outset.

Rather than enter sterile and never ending discussions regarding the experimental protocols of the MM and Miller experiments, and the details of the data reduction processes, and the details of how they interpreted the results of their data reduction process, the present author decided to repeat the experiment using laser light and an interferometer at rest in the laboratory, so that a 24-hour rotation was provided by the earth; readings were automatically collected every minute, rather than every 22.5°. It is stressed that the orientational *resolution of our experiment was 90 times better than MM and Miller experiments*; the latter are equivalent to one interferometer reading every hour and half (90 minutes) instead of every minute. In addition, our data reduction process included stochastic correction to subtract the contribution of the environmental variables (pressure, temperature and humidity), corrections absent in the MM and Miller experiments. Our experiment lasted more than two years, and the observations turned out to be consistent with our theoretical expectations [50]. Our empirical data was used to solve the inverse problem: calculation of the speed and direction of solar motion in the reference frame Σ; as reported at two international conferences [53, 54], our results are compatible with current values of solar velocity.

From the foregoing, the present writer feels entitled to entertain serious doubts regarding the empirical validity of STR. As a consequence, in the rest of the present paper the clock of history is wound back 120 years to the time of Hertz, Heaviside and Poincaré — but, of course, taking into account the new physical facts discovered in the 20th century, such as the existence of the photon, the annihilation of matter into photons, and the inverse phenomenon of matter creation from photons in electron-positron pair production, for example.

C. Distance and the Pythagoras theorem

The formulation of the special theory of relativity (STR) in 1905 opened the door to long standing controversies regarding whether length contraction, time dilation and mass increase were or were not physical phenomena, or mere artefacts of changing coordinates between systems in relative motion

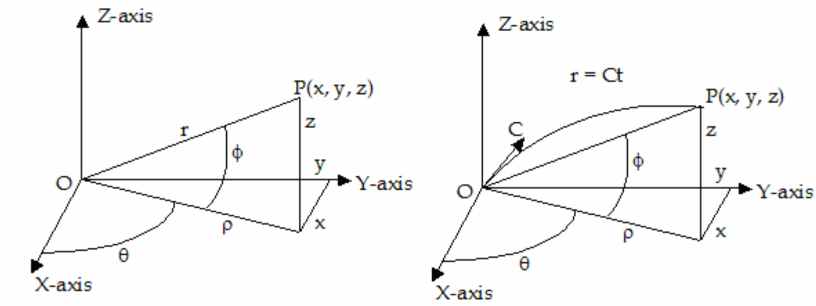

Figure 2. Left side: Point P in Cartesian, cylindrical and spherical coordinates. Right side: Measurement of distance r using a high speed bullet with muzzle speed C; the parabolic trajectory is exaggerated.

— some discussion is still ongoing. Two issues are the Lorentz transformation introduced to explain the *presumed null-result* of the MM experiment, and the new definition of simultaneity introduced by Einstein; Lorentz invariance [55] and Galilean invariance [56] are recurrent questions. The present writer will not enter into such discussions; instead, it is our contention that to bring common-sense into these abstruse subjects, the assumptions implicit in classical measurements should be made explicit; eventually one would obtain a formal theory similar to quantum and relativistic theories of measurement. To start the process, some extremely elementary comments are offered next.

Consider a non-rotating planet K at rest in the Euclidean physical space that contains our universe, and let O be the origin of a Cartesian system of coordinates. By rest, it is meant that the orientation of the laboratory relative to two very far cosmic objects (say, two fixed stars of Newtonian mechanics) does not change during the duration of the observation to be performed. Consider a point $P(x, y, z)$ described by the Cartesian coordinates (x, y, z). In cylindrical coordinates the same point is described as $P(\rho, \theta, z)$, and in spherical coordinates by $P(r, \theta, \phi)$ —see left side of Figure 2.

Further assume that the inhabitants of planet K have already developed units for length and time, similar to the standard meter and second of the 19th century. Let us evaluate the distance from O to P, say on top of a building. Using a rod calibrated against the standard of length, numerical values can be assigned to (x, y, z), and hence, r is evaluated using the theorem of Pythagoras:

$$r^2 = \rho^2 + z^2 = x^2 + y^2 + z^2 . \quad (1)$$

Consider now a good quality gun that always fires small rubber bullets with the same muzzle speed C. Observers at O and P are provided with previously calibrated clocks; the experimenter at O fires his gun towards P at time t_0, the observer at P registers t_1, the arrival time of the bul-

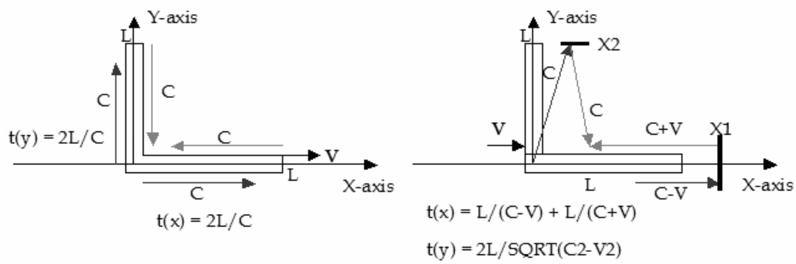

Figure 3. Two arrangements for a ballistic MM experiment. Arrangement 1 (left side): guns are at rest on the apparatus. Arrangement 2 (right side): guns are at rest in the inertial laboratory; the guns for the X-axis arm point along the X-axis, while the guns for the Y-axis arm point along the sides of an isosceles triangle.

let; time of flight is $t = t_1 - t_0$, and to a first approximation $r = Ct$. If the clocks are very accurate they may register the difference between the idealized straight line path (only valid in the absence of gravity) and the real path, which is parabolic when gravity is present — see right side of Figure 2. Then,

$$r^2 = C^2t^2 = x^2 + y^2 + z^2 \Rightarrow C^2t^2 - (x^2 + y^2 + z^2) = 0\,. \tag{2}$$

In the classical era of mechanics, up to the end of the 19th century, numerical differences between r and Ct in Eq. (2) were consistently attributed to experimental errors in the measurement of t and C, and to the presence of gravity, wind, air friction, and so on. Only after all those possibilities were exhausted, one could start considering deeper explanations, such as changes in the nature of space, time or velocity. Assume now that there are two different guns A and B, capable of shooting bullets with different muzzle speeds C_A and C_B. The same procedure leading to Eq. (2) is repeated firstly with gun A, and then with gun B, to get

$$r^2 = C_A^2 t_A^2 = C_B^2 t_B^2 \quad \Rightarrow C_A^2 t_A^2 - r^2 = C_B^2 t_B^2 - r^2 = 0\,, \tag{3a}$$

$$C_A^2 t_A^2 - (x^2 + y^2 + z^2) = C_B^2 t_B^2 - (x^2 + y^2 + z^2) = 0\,. \tag{3b}$$

Three further comments: (a) the time intervals t_A and t_B are obviously different, but the difference cannot be attributed to fundamental changes in the nature of time, or changes in the internal operation of the clocks. (b) The structure of Eq. (3b) is similar to Lorentz invariance. However, here Eq. (3b) only means that Pythagoras theorem is valid independently of the method used to measure r, without any need to contemplate a redefinition of time. And, (c) Jacques Trempe in the 1970's [56] started from Eq. (3) for his kinematic derivation of the Lorentz transformations in Galilean invariant space-time, with one of the two observers moving with speed V, *i.e.* comoving with the object being observed. Trempe's purely geometric approach is equivalent to Einstein's transformations, but without space-time entanglement and deformation.

D. MM experiments with bullet guns

Consider now two macroscopic versions of the MM experiment in the inertial laboratory of the previous section. In arrangement 1 there are four guns that are part of the interferometer and move with speed V along the X-axis; there are two guns at O, respectively pointing along the X- and Y-axes, and one gun at the end of each arm pointing back to the origin O. The guns at O are simultaneously fired at some arbitrary time t_0, bullets travel with speed C *relative to the apparatus*; when a bullet reaches the end of its arm at distance L, the gun at that end fires a bullet with speed C back towards the origin — see Figure 3, left side. The travel time along the X- and Y-axes respectively are $t(X)$ and $t(Y)$ given by

$$t(X) = 2L/C, \quad t(Y) = 2L/C \quad \Rightarrow \Delta t = t(X) - t(Y) = 0\,. \tag{4}$$

It is evident that in arrangement 1 there is no time difference for signals travelling along the two perpendicular arms. Consider now arrangement 2 with the guns attached to the ceiling of the laboratory. There are two guns hanging from point O, one oriented parallel to the X-axis toward $X1$, the other gun along a line from O to $X2$. A third gun hangs over point $X1$ and points toward O, and a fourth gun hangs over $X2$ and points along the other side of the isosceles triangle, as shown in the right side of Figure 3; all bullets travel with speed C *relative to the laboratory*. The apparatus moves with constant speed V parallel to the X-axis; when the vertex of the interferometer passes underneath point O the two guns fire simultaneously; the guns at $X1$ and $X2$ fire when they receive their respective bullet from O. In this case the travel times $t(X)$ and $t(Y)$ are given by

$$t(X) = L((C-V)^{-1} + (C+V)^{-1}), t(Y) = 2L(C^2 - V^2)^{-1/2}\,, \tag{5a}$$

$$\Delta t = t(X) - t(Y) \neq 0\,. \tag{5b}$$

Summarizing, in arrangement 1 no time difference is expected, whereas in arrangement 2 there is a nonzero time difference that would produce fringe shifts; actually, Eq. (5) is the same one given in the original MM paper [47].

The simple ballistic model just explained leads to a deep reformulation of the objectives of the MM experiment. Three (pre-relativistic) classical alternative interpretations of the MM experiment are offered next.

- **Alternative 1: comparison of light emission theories.** The experiment determines whether the light emitted by the source in the experiment moves with constant speed C relative to (1) a coordinate frame attached to the apparatus, or (2) relative to a coordinate frame attached to the inertial laboratory. If fringe shifts are observed the answer is (2), if no fringe shifts are observed the answer is (1).

- **Alternative 2: comparison of EM theories.** As shown in III.C above, Maxwell's theory is the particular case of an electromagnetic detector at rest relative to the dynamical fluid of Hertzian theory. Then, the experiment determines whether arrangement 1 or arrangement 2 is a correct representation of nature. Explicitly, a null result in the MM experiment supports Maxwellian EM theory, while a non-null result supports Hertzian EM theory. The MM experiment, the thousands of turns in Miller experiments, and our empirical findings [53, 54] clearly support Hertz.
- **Alternative 3: thickness of the boundary layer.** In any classical macroscopic fluid, the material surface and the fluid are at relative rest at the innermost layer of the boundary layer. However, the thickness of the boundary layer at the ether-earth interphase is unknown. If the boundary layer is a few meters thick, then the MM interferometer would be immersed in the boundary layer, and the MM experiment corresponds to arrangement 1. But if the thickness of the boundary layer is less than one meter (the laboratory table top), then the interferometer and the ether would not be at rest, as in arrangement 2. Since all of the classical repetitions of the MM experiment gave a non-zero speed [49], there is strong indication that there is some motion between earth and ether. That the observed speed was smaller than expected suggests a region of transition in the fluid, from complete rest at the boundary layer to maximum ether speed at the bulk of the fluid; such a mechanism was suggested by Newton in 1678/9 (see II.C). Such a transition region may also *partially* explain the difference between the large fringe shifts observed with our *laser* light [53, 54], and the earlier MM and Miller experiments with *non-coherent* light [49].

V. Unified field and ether

Toward the end of the 20th century several individuals proposed various dynamical ether models [57, 58, 59], plus Dirac's ether [60], and the dark matter of the current majority view [61]. In the tradition of Le Sage, Tom van Flandern returned to inelastic absorption of corpuscles, and — to avoid criticisms similar to those of Maxwell [27] and Poincaré [28] — he assumed the existence of two separate ethers: a light carrying medium or Elysium, and a gravitational fluid [57]. In our view, such an approach is unnecessarily complex.

The present writer finds interesting several traits of Wallace's fluid ether but does not assign inherent attraction to fundamental particles, as Wallace does [58] (note that most modern writers forget Newton's advice that force is not an inherent trait of matter). Wallace's paper also denounces an almost unknown case of cover-up regarding a violation of the second postulate of Einstein's STR observed in the reflection on the surface of Venus of radar signals; indeed, the propagation of signals is consistent with Galilean vector addition, rather than the Einsteinian STR rule [58, p. 385-386; 62].

Whealton [59] classically derived "*Schrödinger and Klein-Gordon equations for free, structureless particles ... from two different continuum approximations to a Boltzmann equation ... of a mixture,*" thus bringing to the fore a deep connection between quantum and relativistic descriptions of nature. In our approach, both gravitational and quantum phenomena arise from our novel mathematical solutions for the classical wave equation, which represents the sagionic fluid [63, 64]. Let us briefly describe three classical kinetic ethers independently proposed by Thornhill, Martin and Múnera to explain the structure and/or forces in nature.

A. Thornhill's rediscovery of Hertzian electrodynamics

In 1985 the Englishman Charles Kenneth Thornhill (1917-2007) proposed a kinetic theory of electromagnetic radiation, where he cogently argued that [45, p. 263]:

> Planck's energy distribution for a black-body radiation field can be simply derived for a gas-like ether with Maxwellian statistics. The gas consists of an infinite variety of particles, whose masses are integral multiples *n* of the mass of the unit particle.

Thornhill was inspired by the photoelectric effect which indicates "*that in interactions between matter and radiation energy exchanges occur, at any frequency* ν*, in integral multiples of some minimum quantity* $h_0\nu$*,*" that he identified with the mass m of the unit ether-particle. Then, from the thermodynamical description for a gas at $T = 2.7$ K, Thornhill calculated that "*the mass of a unit ether-particle is* $m = 0.497 \times 10^{-39}$ kg" [45, Eq. 4.7]. This result requires a reinterpretation of Planck's equation as:

$$E = nm = n\hbar\nu = nhf \ . \tag{6}$$

If the electron is one of the particles of Thornhill's gas, then its mass $m_e = 9.109 \times 10^{-31}$ kg [65] contains 1.83×10^9 unit ether-particles.

In a second paper [66], Thornhill starts with Maxwell's equations and works backwards towards fluid theory. For that purpose Thornhill modifies the *partial* time-derivatives appearing in Maxwell's theory and changes them into *total* time-derivatives or convective derivatives. In that way, Thornhill unknowingly rediscovered Hertz electromagnetic theory. Thornhill argued that

> …in a gas-like ether, the duality between the oscillating electric and magnetic fields, which are transverse to the direction of propagation of electromagnetic waves, becomes a triality with the longitudinal oscillations of motion of ether…

in that way electromagnetic waves become "*analogous to sound waves in a material gas*" [66, p. 273]; Thornhill worked out the refraction of light in stationary and moving media [67].

In 1993 Thornhill generalized his ideal-gas-like ether to the case of "*unsteady flow of a general fluid ... at least, when the effects of viscosity and heat-conduction can be neglected*" [68, p. 495]. Since Thornhill accepted the null-outcome of the MM experiment, his theoretical development was strongly constrained; explicitly, he had to accept the validity of Maxwell's equations (see our comments in IV.D above), and assume that ether locally moves with constant velocity relative to the reference frame (Appendix 2 in the original manuscript [68]). Thornhill noted that the alternative interpretation

> …that a null result from the Michelson-Morley experiment implies that the apparatus is moving with the local ether, has always been rejected, on the grounds that it is impossible for experimental apparati, moving with different velocities, all to be moving with the uniform ether demanded by Maxwell's equations.

Hence, at that time, Thornhill was unaware of the properties of the boundary layer between the ether and the surface of earth (briefly mentioned above in IV.D); however, in 2001 Thornhill incorporated the boundary layer in his theory (see below).

In his 1996 paper [69], Thornhill continued his search for an alternative interpretation for the *presumed or claimed* null-result of the MM experiment, and conjectured "*that the Michelson-Morley experiment demonstrates only that the ether has viscosity*." Obviously, Thornhill was aware that the Galilean invariance of Hertzian electromagnetism is far superior to Maxwell's equations, "*which led, by a mathematical freak, to the Lorentz transform*" [69, p. 209]. The null result of the MM experiment led Thornhill in 2004 to address the foundations of relativity; he stated once again that [70, p. 499]

> Maxwell's equations were, and still are, derived for a uniform stationary ether and are not, therefore, the general equations of electromagnetism. The true general equations, for an ether in general motion, have been derived and given in the literature for many years, but are continually ignored.

Thornhill was talking in that context about his own work; it seems that he never realized that his Galilean invariant equations were anticipated by Hertz in the late 19th century, and that, indeed, they had been almost ignored!

In 2001 Thornhill formally developed his *non-singular ethereal cosmology* [71], work that this author read on May 28, 2015, in the final stage of writing the present paper; I found significant coincidences in our thinking, and sincerely I wish that I had read it earlier. In the abstract Thornhill noted that "*the universe may be finite and have a finite boundary with a true vacuum or void*," a concept that closely resembles the physical space proposed by Francesco Patrizi in 1593 [72], space that the present writer denotes as Σ and adopted as one of the metaphysical principles for our theory of nature [73]. Thornhill's ether [71] and our sagionic ether [63, 73] both obey the same homogeneous classical wave equation; let us quote the beginning of Thornhill's paper [71]:

> **The ether concept**. It has been shown [66, 68] that the characteristic wave hypersurfaces and the wave hyperconoid for Maxwell's equations are exactly the same as those for the standard wave equation
>
> $$\nabla^2\varphi = (1/C^2)\,\partial^2\varphi/\partial t^2 \tag{7}$$
>
> in which *C* is a constant wave speed. It is also well-known that Maxwell's equations reduce precisely to the single equation (7) when there is no current or charge distribution. The equation (7) is also found to be [68] the equation which governs the propagation of condensational oscillations or sound waves in any general fluid which is in a uniform state at rest. As such, equation (7), its characteristic wave hypersurfaces and its wave-hyperconoid are not invariant under transformation but unique to one reference frame. [Numbering of references and equation adapted to present paper].

We concur: in our approach, the same wave equation (7) is valid in the preferred frame Σ attached to Patrizi's physical space. In the context of this book to honor Halton Arp, it is relevant to mention that Thornhill correctly noted in the abstract for his cosmological ether that [71]

> It is first necessary to clarify what is meant by 'seeing', 'distance' as distinct from radius of curvature of observed incoming light-waves, curvilinear rays in an unsteady non-uniform flow, and red-shift as distinct from trivial case of Doppler's principle in a uniform medium at rest.

Thornhill elaborated his ideas in section 1.3 of the main text of [71], describing two different measures of red-shift — wavelength and frequency, see his equations (1.3.2) and (1.3.3) — noting that "*in practice it is the frequency red-shift z_ν which is important, since it is the emission frequency which is recognised as the universal signature of a particular atom.*"

Regarding the Michelson & Morley experiment, our boundary layer interpretation (IV.D above) agrees with Thornhill's new view of 2001 expressed in his ether paper [71, section 1.8]:

> The Michelson-Morley experiment is usually interpreted in terms of the non-ether concept and this leads to the Lorentz transform and relativity which, in the present context, are considered to be mathematically unten-

> able. In terms of the ether concept and Newtonian mechanics the results of the Michelson-Morley experiment mean, quite simply, that the ether is moving locally with the apparatus and this implies no more than the ether like any other gas, has viscosity. When a body, like the Earth, moves relative to a surrounding fluid that has viscosity a viscous boundary layer is formed around its surface across which the relative velocity between the body surface and the fluid tends to zero as the surface is approached. Thus, experiments near the surface of the Earth will give null results or will, at best, over greater ranges which are still small compared with the boundary layer thickness, determine a relative velocity much less than the true velocity of the Earth relative to the mainstream flow outside its boundary layer.

Our conceptual models agree in many aspects, but we disagree on the physical content of the MM experiment: null in the case of Thornhill, positive in our opinion [49, 50, 51], and backed by our own observations [53, 54]. Thornhill and the present writer thoroughly agree on the Euclidean nature of our space, which leads to a Pythagorean definition of distance in section IV.C above; on his part Thornhill emphasizes the components of speed in 3D-space, and criticizes the Einsteinian approach thus [71, section 1.5]:

> The term 'space-time', in fact, is used indiscriminately both to refer to the real four-dimensional metric (x_i, Ct) in which the right spherical hypercone is located, and to the imaginary four-dimensional Riemannian metric (x_i, iCt) associated with the Lorentz transform and special relativity.

Note that our 4D aether model [104, 105] refers to the real four-dimensional metric. Finally, we also agree regarding the similar nature of sound and light waves, both of them propagating in a fluid. Regarding waves and the many classes of the ether, Thornhill wrote [71, section 1.2]:

> One of the last of these, prior to the advent of the non-ether concept, suggested that the ether must behave like an elastic solid, since Maxwell's equations show that the electromagnetic waves are transverse. Oscillations in the electromagnetic field-strengths, however, are not condensational oscillations of an ether, and so the suggestion could not be a valid one.

Our approach for demonstrating the sound and light equivalence was different: it has been shown that, contrary to conventional wisdom, Maxwell's equations also contain longitudinal components [74].

Thornhill and this writer disagree regarding the overall state of the ether and the mechanism for the generation of gravity. Reasoning by similitude with his experience at the British Ministry of Defence during the second world war, Thornhill considered that the universe, including the ether will go on expanding forever, so that a frame of reference attached to the ether is accelerated, and according to Newtonian mechanics [71, section 1.9]:

> This force per unit mass towards the centre of the universe experienced by all masses (matter and ether) in the rest-frames of all material observers is seen to provide completely for the phenomenon of gravitation.

On the contrary, currently we do not have any opinion regarding whether the universe —including the ether— is expanding or not, but we both agree that the behaviour of ether in 3D-space is described by equation (7), whose solutions up to now are only harmonic. However, we consider more relevant our novel solutions, found in the mid 1990s, which contain longitudinal and nonperiodic components [75]. Regarding gravity, we have proposed a Le Sagian mechanism for the generation and propagation of gravitation [16]; our approach incorporates scattering in addition to absorption, thus becoming immune to the destructive criticisms of Maxwell [27] and Poincaré [28, p. 242-249].

Towards the end of his long and productive life, in 2006 Thornhill wrote on stellar aberration [76], and his last unpublished short note on universal physics ends thus [77]:

> If Maxwell had been acquainted with Euler's general equations of fluid motion he would have derived the general electromagnetic equations for an ether in general motion rather than the particular equations for a uniform stationary ether. No one, then, would ever have heard of Relativity.

B. Trempe's Lorentz transformations à la Galileo Galilei

In the obituary that Adolphe Martin (1919-2008) wrote for his friend Jacques Trempe (1919-1990) he recalled that they met in 1948, and that shortly afterwards he (A.M.) started work on his gaseous ether; in early 1960 Martin and Trempe started regular meetings every Friday evening in downtown Montreal "*trying to interpret the Lorentz transformation in Galilean space-time*" [78]. Martin also recalls that in 1970 Trempe found that if the Lorentz equations are written in Costa de Beauregard hyperbolic form, then [78]:

> The Lorentz transformation is applicable to Galilean space-time, where the laws of classical mechanics are invariant ... [which] unites classical mechanics with electromagnetism.
>
> After 1971, we each investigated a different but complementary problem. Jacques was assigned to determine if the new transformations would be based upon different coordinates, but keep the same angles in both Einsteinian and Galilean space-time. I, meanwhile, looked into the possibility of retaining the Einsteinian coordinates in Galilean spacetime with different angle measurements.

The results of those three decades of work were published mostly in the early 1990s; Trempe's findings as [56, 79, 80], and Martin's as [81, 82]. In Martin's words his achievement was [82, p. 47]:

> By interpreting Relativity in Galilean space and time, it was found that the time of light reception by an observer moving relative to a source is a different event from the reception of the same light by an observer at rest. The

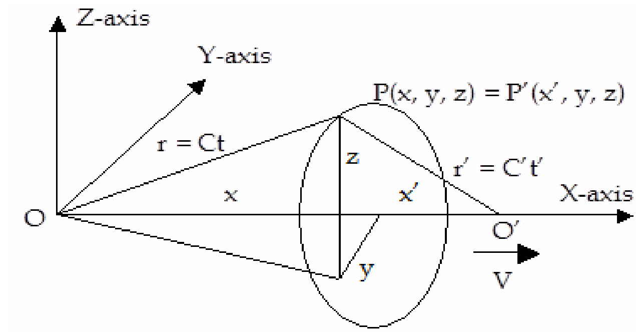

Figure 4. The foci of an ellipse on the X-Y plane are at O and O'; a point P on the ellipse is at distances *r* and *r'* from foci O and O'. Distance may be calculated with Pythagoras theorem, Eq. (1), using (*x, y, z*) measured with a calibrated rod; alternatively, distance *r* may be obtained from the time-of-flight *t* of a bullet travelling with speed *C* from O to P. A similar procedure is valid for observer O'. An ellipsoid is generated by rotating the ellipse around the X-axis, so that point P = P' describes a circle.

> Einstein viewpoint considers these two events to be the same, thus introducing the Special Relativity paradoxes.

Trempe summarized his findings thus [79, p. 121]:

> A new theory of light propagation is introduced by showing that the Lorentz transformation is applicable in Galilean-invariant space-time ... This form of the equation of an ellipse is then shown to be a Lorentz transformation, proving that the Lorentz transformation is a pure geometrical transformation of spatial coordinates, with no inherent relationship to space-time.

In short, Trempe considered two observers O and O′ at the origins of two systems of coordinates in relative motion with speed V along the X-axis. As shown in Figure 4, the coordinates of point P on an ellipse measured by O and O′ respectively are (x, $w = Ct$) and (x', $w' = C't'$). Trempe found that those coordinates are related by a Lorentz transformation. However, such geometrical relationship has nothing to do with the nature of space and time.

It is well-known that the process of measurement is at the heart of the foundations of both Einstein's STR and quantum mechanics, and as such received significant attention during the whole 20th century. In contrast, in classical mechanics the meaning of measurement when observers (or, detectors) and emitters are in relative motion received little attention. It was not clear how to handle simple situations, as the motion of light along the transversal arm of the Michelson interferometer [46], leading to a mistake in Michelson's 1881 calculations; error that was noted by Lorentz, and corrected by Michelson & Morley in the 1887 paper [47]. Perhaps, some years before, immediately after the experiments of Fizeau involving relative motion of light and water, the need for a classical theory of measurement was already evident —but neither the discussion of Fizeau experiment, nor the M&M experiment was ever stated in terms of (a lack of a) theory of measurement.

So, when the procedure for data reduction used by Michelson & Morley led to a relative velocity between light and ether that was smaller than Michelson's expectations, they did not know what to do. Last paragraph in the main text of the 1887 M&M paper is a naïve description of the bewilderment and hopeless confusion that M&M felt [47, p. 458-459]:

> It appears from all that precedes reasonably certain that if there be any relative motion between the earth and the luminiferous aether, it must be small; quite enough entirely to refute Fresnel's explanation of aberration. Stokes has given a theory of aberration which assumes the aether at the earth's surface to be at rest with regard to the latter, and only requires in addition that the relative velocity has a potential; Lorentz then proposes a modification that combines some ideas of Stokes and Fresnel, and assumes the existence of a potential, together with Fresnel's coefficient. If now it were legitimate to conclude from the present work that the aether is at rest with regard to the earth's surface, according to Lorentz there could not be a velocity potential, and his own theory also fails.

For the present writer it is unbelievable that those confused sentences mean that Michelson and Morley found a so called "null" result; further, I also find difficult to reconcile the sense of hesitation that transpires in the quoted conclusion of the M&M paper with Poincaré's assertive view: "*les résultats indubitables des expériences de Michelson*" [83, p. 316; 84, p. 253]. Be it as it may, the historical fact is that to explain the presumed null-result of the M&M experiment, Lorentz and, independently, FitzGerald advanced hypotheses of length contraction in the direction of motion; then —to explain Lorentz hypothesis— Henri Poincaré proposed his principle of relativity [85, 86]. According to the translation of the Palermo Rendiconti [86] by Schwartz [87, p. 1288], Poincaré said:

> It seems that this impossibility to disclose experimentally the absolute motion of the earth is a general law of nature; we are led naturally to admit this law, which we call the *Postulate of Relativity*, and to admit it unrestrictedly. Although this postulate, which up till now agrees with experiment, must be confirmed or disproved by later more precise experiments, it is in any case of interest to see what consequences can flow from it.

It is evident that for Poincaré his principle of relativity did not have logical or metaphysical status, but only an empirical origin. The principle could be overthrown by further observations. According to Poincaré, the Lorentz transformations in modern notation were [86, p. 132; 87, p. 1289]:

$$x' = \gamma l(x - \beta w),\ w' = \gamma l(w - \beta x), \quad \gamma = (1-\beta^2)^{-1/2}\,, \tag{8a}$$

$$y' = ly, \quad z' = lz, \quad l = l(\beta)\,. \tag{8b}$$

Although it is not obvious that Poincaré actually read the original papers as hinted by the "*indubitable result*" quoted above, Poincaré was extremely impressed by the *claimed* null-result of the MM experiment, but it is not clear whether he meant the 1881 Michelson experiment [46], or the 1887 Michelson & Morley experiment [47]. Some examples of Poincaré's flattering words for Michelson are:

> One day Michelson thought out a much more delicate process [28, p. 219].
>
> Methods were diversified; finally Michelson carried precision to its utmost limits; nothing came of it [83, p. 311; 84, p. 248].
>
> Michelson has shown, as I have said, that the methods of physics are powerless to put absolute motion in evidence; I am convinced that in the case of *astronomical methods it will be the same*, no matter how far precision may be carried. However that may be, the data which astronomy will furnish in this direction will one day be valuable to the physicist. In the mean time I believe that the theorists, keeping in mind the experiments of Michelson, may count on a negative result, and ... (emphasis added) [83, p. 321; 84, p. 257].

It is worthwhile to stress that Poincaré only mentions Michelson as the creator of the famous ether experiment — he never mentioned Morley. The only occasion that Poincaré mentioned Michelson and Morley in the 1904 conference [84, p. 314; 85, p. 251] was for the repetition of Fizeau's experiment carried out around 1886 upon a recommendation of Lord Kelvin to Morley during the Baltimore Lectures. At any rate, that passing mention indicates that Poincaré was following in some detail the development of Michelson's work, so that it is rather strange that he disregarded strong criticisms addressed to the M&M experiment between 1898 and 1902 by Sutherland [88] and Hicks [89] in prestigious journals (such as *Nature* and *The Philosophical Magazine*) easily available to Poincaré. Also note that Poincaré was quite convinced that the relativity principle would be supported in the future by astronomical observations.

Against the previous backdrop, the works of Trempe [56, 78, 79] and Martin [80, 81] may be considered pioneering efforts towards a classical theory of measurement along the lines started by Poincaré. In his theory of the electron Poincaré considered "*a sphere carried along with the electron in its uniform translational motion*" and noted that the Lorentz "*transformation will change it into an ellipsoid whose equation is easily found*" [86, p. 133; 87, p. 1290]. The ellipsoids of Poincaré and Trempe might be related, but the present writer will not delve into that matter. Likewise, for the time being, I do not take sides in the controversy regarding Einstein's and Poincaré's principles of relativity [39, 90].

One may wonder what would be the position adopted by Poincaré if he were alive at the beginning of the 21st century. As quoted above, he clearly stated that his principle of relativity "*up till now agrees with experi-*

ment, must be confirmed or disproved by later more precise experiments" [87, p. 1288]. The following new information could be given to Poincaré:

- Relative to cosmic microwave background radiation (CMB), the local group of galaxies moves at speed of 627 km/s and our sun at 369 km/s in well defined directions [65]. This demonstrates that it is possible to detect motion relative to an energy-like substance (i.e. the CMB) that fills the 3D-space, thus avoiding the need for *material* beacons, such as Newton's fixed stars! Moreover, the 2006 Nobel Prize in physics was awarded to John C. Mather and George F. Smoot for measuring the CMB anisotropy.
- Almost all MM-type experiments have produced (large or small) positive results, thus casting doubts on the *interpretation* of the MM experiment. Examples are: the 1887 MM experiment itself [47], Miller's thousands of measurements [48], all other MM-type experiments up to 1930 [49], and my own work [53, 54].
- Even the outcome of a well-controlled experiment involving cavity-stabilized oscillators performed by a prestigious group at Stanford University shows diurnal harmonic oscillation: see Figure 2(a) in reference [91]. In 2002 the present writer predicted daily variations in a stationary MM-experiment [50], which are clearly supported by the observations of the Stanford group. However, they did not consider the possibility that the observed harmonic variation was related to the motion of earth, arguing instead that "*mechanical disturbances occasionally gave rise to a perceptible drift of the beat frequency amounting to a few mHz per day. We therefore fitted each record with*" a harmonic function defined by their Eq. (4) [91]. In their Table 1, the Stanford group listed the parameters of their fitting function for *thirteen* instances (in days 1, 3, 18, 26, 59, 78, 80, 95, 98) of the so called "*occasional ... perceptible drift*"; the fitted-curve —which represents the contribution of earth motion to the velocity of light— was *subtracted*, and the residual plotted as Figure 2(b) [91]. Of course, the residual does not contain any harmonic effect on the frequency of electromagnetic radiation —as the effect was eliminated by the subtraction. The residual was then interpreted as a more precise limit for Lorentz invariance! Obviously, the residual should be zero after the baby had been thrown out with the bathwater!

My personal guess is that Poincaré would recant, abandoning his principle of relativity. Then, there would be a place for a classical theory of measurement *without* the constraints of a null-result in the M&M experiment. The present writer intends to tackle that problem in the near future along the line of thought in IV.D above.

C. Adolphe Martin's cosmons

Let us continue now with Martin's gaseous atomic ether, which he claimed was capable of explaining all known physical phenomena [92 - 95]. As a fitting environment for an atomistic theory, the first paper was delivered in Olympia, Greece; the introduction stated [92, p. 209]:

> Assuming the existence of a gas permeating all space and matter, we conclude that the mechanical properties of gases, known for over a century, are sufficient to explain the known physical phenomena such as electromagnetism, light propagation, gravitation, quantum mechanics and the structure of elementary particles, including the photon.

Martin's ether obeys the equations of the kinetic theory of gases, and is formed by discrete objects behaving as a "*gas ether*" [92, p. 212]:

> The ether particles are considered the smallest entities in the Universe, they are also the only substantial entities. These grains of cosmos will be referred to as "cosmons." Cosmons are individual spheres of a definite diameter and volume. Between cosmons we assume that there is an absolute void which cannot transmit any signal. Thus at the cosmon level there are no fields or forces. As the cosmons have no moving parts, they possess no internal energy and, according to Einstein, no rest mass (inertial or gravitational), no charge (electric or color) and no spin, since friction does not occur at this level. Hence, a cosmon is a boson.

Ten years later, Martin still held the same view [95(b), p.1]: "*cosmons are assumed the smallest units and only substance in the Universe.*" It is not the first time in the history of science that several people at well separated locations have reached the same idea at about the same time. In this case Thornhill in England and Martin in Canada worked over the same time-span on a very similar kinetic gas model for the ether. My personal approach (see next section) focusses on the general fluid equations applied to a fundamental fluid formed by energy-like sagions (that may be identified with Martin's cosmons as described above). The only differences being that I explicitly identify "*substance*" as energy, and that I stress that ether behaves as a fluid, rather than the more limited notion of a gas. However, Martin acknowledges that "*cosmonic gas can behave as a liquid when concentration N nears N_{max} with mean free path approaching cosmon diameter... It can even take the form of a solid crystal at $N = N_{max}$ with no mean free path...*" [95(c), p. 4]. Regarding the speed of cosmons, Martin stated:

> Due to their agitation and lack of rest mass, cosmon velocities vary from zero to indefinitely high values. Interchange of velocity components when cosmons encounter other cosmons produces a velocity distribution similar to Maxwell's [92, p. 213].

> Cosmon speeds, due to mutual encounters, follow the Maxwell velocity distribution of gas kinetic theory. This gives cosmon speeds from zero to tremendously high speeds > 10^{10}c, but with number densities reducing asymptotically to zero toward the two extremes [95(c), p. 4].

In contrast, the present writer considers that speeds of sagions have a more complex probability distribution. Indeed, both sagion-sagion and cosmon-cosmon interactions conserve linear momentum and kinetic energy, but sagion-matter interactions may be inelastic in the sense that kinetic energy is not conserved. Rather, internal energy of matter may increase or decrease in a sagion-matter interaction — of course, always obeying conservation of total energy. The added complexity of sagion-matter interactions may lead to a non-Maxwellian probabilistic distribution of sagion speed.

I also have a further comment regarding the logical existence of cosmons with $V = 0$. By definition, a cosmon is immaterial, so that it does not have rest-mass, and, if it is at rest in the absolute Galilean 3D-space, it carries no energy. So, what kind of substance is the cosmon with $V = 0$, without mass and without energy? This implies that Martin should have defined that Probability $\{V = 0\} = 0$, rather than $\lim_{V \to 0} \Pr\{V\} = 0$, as implicitly done in the quotation above [95(c), p. 4].

Using the standard kinetic theory of gases Thornhill calculated that "*the mass of a unit ether-particle is* $m = 0.497 \times 10^{-39}$ kg" [45, Eq. 4.7], and Martin [94, p. 157] estimated a similar "*cosmon mass-energy equivalent* ($= 5kT/(2c^2)$, $T = 2.736$ K)" as 1.0506×10^{-39} kg [95(a), p. 45], thus agreeing in the order of magnitude — as expected since both of them invoked Maxwell's distribution for the particles of the gas. The properties of our sagion are different [125].

For completeness it is mentioned in passing that in the context of non-zero photon rest-mass, in the 1990s Vigier interpreted the claimed null-result of the MM experiment as a relativistic rest-mass of the photon of 10^{-68} kg [96]. The present writer carried out a similar calculation using Newtonian velocity addition obtaining a rest-mass of the photon between 10^{-38} and 10^{-37} kg depending on the value selected for the motion of earth (30 to 300 km/s) [97], values equivalent to around ten to a hundred cosmons. However, my present view is similar to Martin's in the sense that the photon is formed by energy-like sagions, and hence it does not have intrinsic rest-mass. Therefore, my previous calculations must be interpreted from this new viewpoint.

Continuing with the parallel between Martin and Thornhill, both of them emphasized the importance of polytropic gases, and the right-hand (three-finger) rule in hydrodynamics and electromagnetism — Martin in [94] and Thornhill in [66].

Martin and Thornhill differed on the description of the ether gas; as already mentioned in section V.A, Thornhill emphasized Euler's conservation equations, while Martin chose the thermodynamic description of the gas, and focussed on the equations for the ideal and non-ideal gas. According to Martin, the ideal gas equation accounts for QED, while gravity is represented by the volumetric term appearing in the Clausius equation for a non-ideal gas [92]: the temperature-dependent volume *b* of the gas molecules is interpreted by Martin as proportional to the constant "*cosmon sphere of exclusion*" [94, p. 156]. Martin's mechanism for gravity involves local cooling "*which transforms the internal energy of each element of volume into kinetic energy of free fall*" [94, p. 159].

In contrast to Thornhill, who merely scratched the surface of the subject [77], Martin obtained a model to represent all fundamental particles as circular and spherical (or spin) vortices [93, 95], thus reviving the 19$^{\text{th}}$ century smoke-ring models of Helmholtz and Kelvin [22, 23, 24]. Martin's work on this subject was simultaneous with other more detailed revivals of vortices, such as Ginzburg's spiral field theory [98].

D. Sagions

After discovering the new nonharmonic solutions for the classical wave equation in the mid 1990s [75], the present writer started a revision of some properties usually ascribed to Maxwell's equations, such as the conventional belief that the electromagnetic field *only* contains transversal components. I was also curious about Dirac's idea that a magnetic monopole should also exist from symmetry considerations; in this latter regard it was surprisingly found that simple vector algebra over the pair (**E**, **B**) leads to *symmetrized* Maxwell's equations *without* a magnetic monopole in terms of (**P**, **N**), where $\mathbf{P} = \mathbf{B} + \mathbf{E}$, $\mathbf{N} = \mathbf{B} - \mathbf{E}$ [99]. So, to my mind it was crystal clear that the magnetic monopole belongs in the realm of the unicorn; however, as of 2014 the search still goes on: "*isolated supermassive monopole candidate events have not been confirmed*" [65, p. 179]. Of course!

The symmetrized Maxwell's equations [99] also uncovered significant redundancies in the standard Maxwell equations:

(i) If the continuity equation is an independent condition (as it should be because it represents conservation of total energy in the fundamental fluid), then only one source and one induction equation are independent; or, alternatively, the continuity equation is a useless condition, overdetermined by the redundancies.

(ii) To convert Maxwell's equations into wave equations, the Coulomb gauge is not necessary, which immediately implies that the standard Maxwell's equations over (**E**, **B**) are also compatible with longitudinal solutions, a prediction that was immediately confirmed [74]. The existence of a longitudinal component is also consistent with Dirac's formal theory; as a result, a longitudinal component was added to Majorana's photon [100, 101]. At a deeper level, longitudinal components in EM imply that (at least, some) electromagnetic waves are similar to sound waves, thus making both of them compatible with a *fluid* ether, rather than a solid ether.

(iii) The fact that the pair of vectors (**E**, **B**) may be expressed in terms of a single vector potential **A**, and a scalar potential ϕ, implies that the pair (**A**, ϕ) is both more economical and more fundamental than the triplet (**E**, **B**) and ρ (the electric source). Therefore, Maxwell's theory reduces to two classical wave equations for (**A**, ϕ) —one vector and one scalar wave equation. The only remaining challenge was to find the physical (as opposed to mathematical) meaning of the independent variables (**A**, ϕ).

A related question is the meaning of the EM field — in particular whether it is a mere mathematical construct or whether, on the contrary, it contains some elements of reality [102]. For instance, what happens to the EM fields associated with an electron and a positron when the particles suddenly disappear by mutual annihilation at time t_a. Explicitly, assume that at t_a the EM fields are acting upon a test particle; there are two possibilities: (a) the fields instantly disappear, which brings in the thorny issue of instantaneous propagation of information; or (b) the fields continue acting during some time $t > t_a$ which means that they are somehow independent of the charges that caused them. A similar situation arises in the reverse process of production of a pair of charged particles from a photon interacting with a strong EM field [103]. For the present writer infinite speeds and action-at-a-distance both belong in the realm of magic, so that alternative (a) is rejected. Therefore, alternative (b) implies that the field is not a mere mathematical tool, but also has existence of its own, or, even better, that "field" is a short name for processes taking place in an objective substance that we have identified with the ether. Assuming that ether behaves as a classical fluid, it then obeys the classical wave equations. This provides a clear physical meaning for the potentials (**A**, ϕ).

In May 1999, while preparing a paper [100] to be presented at the CPT symposium in Zacatecas, I suddenly realized that Einstein's tensor equation of general relativity is simply the same as the scalar and the vector classical wave equations for a fluid. It was an instance of what Poincaré calls *mathematical discovery*, where "*one is at once struck by these appearances of sudden illumination, obvious indications of a long course of previous unconscious work*" [28, p. 55]. Later on I was advised that my "mathematical discovery" was a mere rediscovery of a fact well known to the specialists. Be it as it may, electromagnetism and gravity can be described by the same ether. The organizers of the CPT conference were kind enough to allow me to present an additional late paper containing some hasty ideas on a realistic four-dimensional hydrodynamic ether interpreted as a unified field equation [104]. For the particular case of non-viscous and uncompressible fluid ether, a straightforward calculation leads to an electromagnetic force containing a couple of additional terms [105]. Here the force density is given by the gradient of aether pressure, as forehadowed in 1678/9 by Newton in his letter to Robert Boyle (see II.C above).

In my 1999 model the 3D-Euclidean space was a projection along the w-axis of a Riemannian four dimensional space ($w = Ct, x, y, z$). In that early paper, ether was formed by *preons*, described as non-rotating* discrete *material* particles in permanent motion, each one occupying a portion of 3D-space; two preons could not occupy the same portion of 3D-space over the same lapse of time. A flow of preons entering 3D-space **fro**m the fourth dimension w constitutes the source of a repulsive force (say electric), while a flow of preons leaving 3D-space towards the fourth dimension w acts as the source of an attractive force (either gravitational or electric), thus solving the problem of infinities that still plagues physics. In that context the photon was modelled as composite particle [106, 107]. It was reassuring to find two years later, that Arthur Schuster had suggested the same far-fetched idea in 1898, i.e. a hundred years before I did [108].

My 4D-model had the advantage of directly unifying EM and gravity, without the Einsteinian assumption that space-time is a sort of deformable object; in our case, the "deformable object" is ether, which may adjust and change its shape in the same way as the macroscopic fluids around us (air, water, *etc*.). Furthermore, some of my novel solutions in spherical coordinates [75] have the nice property of being the same under Lorentz-invariant transformations and neo-Galilean invariant transformations (see next section), thus making equivalent the interpretation of the fundamental fluid as existing in a 3D-space which is a projection of 4D-space, and the interpretation that the said fluid exists in a 3D-Euclidean space plus a temporal dimension.

During the first eight years of the 21st century I taught Newtonian mechanics for physics majors at the department of physics of National University in Bogotá. As soon as I started teaching in 2000 when explaining Newton's concept of mass, I felt the same uneasiness Hertz reported in the 1890s [40]. Looking for a solution, in several courses I started from conservation of linear momentum, rather than from Newton's laws; this pro-

* In my current view, the energy-like sagions also exhibit inherent spin [125].

cedure is very economical in principle, and according to Ockham's rule is thus preferable [109]. It also means that force is no longer a primitive notion; instead, it is just a name for the average exchange of momentum. So, there is no need to find a mechanism for the propagation of force (gravitational or otherwise). The gravitational problem thus reduces to finding a viable classical mechanism to explain the inverse-square law with collisions. One possible mechanism is the shadowing of ether proposed by Le Sage in the 18th century [18, 19], and earlier by Fatio (see II.E above), and foreshadowed by Newton himself (see II.C). To solve the heat problem addressed to Le Sagian aether by Maxwell [27] and Poincaré [28, p. 242-249], this writer analysed the preon-matter interaction in more detail, and introduced scattering in addition to absorption [16]. To honor Le Sage's pioneering work, our 1999 preons were renamed sagions in 2011.

After solving the heat problem in gravity [16], by the end of 2011 I could again continue extending my ether model to other forces. As is well known, the first unified force of nature is due to Boscovich [110], who placed his force at point centers; this force also had the property of acting before actual contact between particles. I immediately dismissed the Boscovich force for three reasons: it seemed to be *inherent* to mass, and emanated from a presumably *point* center, and when at short range, it *acted at a distance*. However, Boscovich was a good philosopher (while I am not a philosopher at all), so I checked for the reasons behind his choices, which appear in his *Theoria Philosophiae* [110], and also in Jammer [1, p. 170-178]. In short, Boscovich argues that all Cartesian exchanges of linear momentum violate the Leibnizian principle of continuity. Indeed, Boscovich's argument is correct if material bodies cannot deform, but it is incorrect when one allows for deformability of material bodies. Then, if one accepts *both* Leibnitz's principle of continuity and the principle of conservation of linear momentum in collisions between material particles (as I do), one is implicitly assuming that matter is soft and *deformable* at all scales. This has a deep implication: matter has internal structure and contains internal parts down to the smallest bit of matter. Thus, the smallest bit of matter can *not* possibly be a structureless sagion.

The logical Leibnizian principle and the physical principle of linear momentum conservation can be harmonized if the sagion is redefined as an *energy-like* object, rather than a material object; if it is an energy-like object, the rest-mass of the sagion strictly is zero, and all other properties of the sagion remain the same [16]. My current theory of nature was presented at two conferences held in Baltimore in November 2014 —the Vigier IX [63] and the NPA [73] meetings; in short, the fundamental fluid is formed by energy-like sagions pervading a strictly 3D-Euclidean space, and Newtonian time is a completely different dimension. Force is not a primitive notion, but merely describes the exchange of linear momentum in interactions between sagions and matter. Every sagion occupies a portion of 3D-space and is the smallest object in Nature. Photons are solitons in the sagionic fluid, formed by myriads of sagions. The smallest bit of matter is a bi-sagion, which is formed at rest in the 3D-Patrizi space as the outcome of a slanting collision of two extended sagions. Furthermore, matter and sagions are interconvertible in both directions, via the annihilation and materialization processes discovered in the 20th century [103].

E. Classical wave equation in spherical coordinates

Consider the spherical coordinates *(r, θ, ϕ)* shown in the left side of Figure 2. Lorentz transformations are conventionally expressed in Cartesian coordinates, with an observer O′ in motion with speed *V* along the positive direction of the *X*-axis. One may arbitrarily choose the direction of a ray *r* in spherical coordinates so that it coincides with the direction of the *X*-axis; then, the Lorentz transformations defined by equations (8) become

$$r' = \gamma l(r - \beta w), w' = \gamma l(w - \beta r), \quad \gamma = (1-\beta^2)^{-1/2}. \tag{9}$$

Given that the Euclidean 3D-space is isotropic, the Lorentz transformations are valid for any ray *r*, independently of the direction *(θ, ϕ)*, thus making the conventional Eq. (8b) unnecessary.

As argued in previous sections, our sagionic ether is described by the 3D-classical wave equation (7) for $\Phi(x, y, z, t) = \Phi(r, \theta, \phi, t)$ in spherical coordinates. The D'Alembertian □ is implicitly defined as:

$$\Box\Phi(r,\theta,\varphi,t) \equiv (\nabla^2 - \partial^2 / \partial w^2)\Phi = 0, \quad w \equiv Ct\,. \tag{10}$$

Our novel solution for Eq. (10) is [75]:

$$\Phi(r,\theta,\varphi,w) = Y(\theta,\varphi)I(r) + Y(\theta,\varphi)Q(q), \quad q \equiv w / r\,. \tag{11}$$

The novel solution is formed by two inherently quantized components:

A *time-independent* quantized background $\Phi_0(r, \theta, \phi) = Y(\theta, \phi)I(r)$, where $Y(\theta, \phi)$ is the standard spherical harmonic function, and $I(r)$ is a polynomial dependent on the quantum number $\ell = 0, 1, 2, \ldots$ [75]. The permanent existence of this term in the ether fluid accounts for many thus far unexplained phenomena in the conventional quantum theory based on the Schrödinger equation rather than on the non-linear equation (10).

A *time-dependent* Lorentz-invariant and Galilean-invariant quantized spherical flow $\Phi_1(r, \theta, \phi, w) = Y(\theta, \phi)Q(q)$. Instead of being harmonic, as in the conventional Fourier-type solution $\exp\{i(\omega t+\mathbf{k}\bullet\mathbf{r})\}$, our quantized solution is formed by three new nonperiodic functions of the first, second and third kinds $S_\ell(q)$, $T_\ell(q)$, $U_\ell(q)$, called quingal functions and defined in [75], [125]:

$$Q(q) = K_1 S_\ell(q) + K_2 T_\ell(q) + \eta U_\ell(q)\,. \tag{12}$$

As usual, the values of the arbitrary constants K_1 and K_2 are selected to comply with the boundary and initial conditions; the third constant η is another novel quantum number, which plays the role of the principal quantum number in the non-relativistic Schrödinger's quantum theory. Let us briefly stress two significant properties of our new solutions (for additional details see [125]):

1) **Quantum mechanics from the fluid equation.** It is well known that at the beginning of the 20th century Schrödinger's first choice for representing quantum phenomena was the classical wave equation (10), that he disregarded from considerations based on superposition. Before Bohr and Schrödinger had proposed their theories of quantum mechanics, J. J. Thomson noted in 1907 [111] that the Boscovich force [110] could explain various recently discovered quantum phenomena, but at that time the Boscovich force was not attractive because it lacked mathematical support; for a recent list of phenomena that may be explained by the Boscovich force see [112]. What is the connection with our novel solutions for the wave equation? Simply, the Boscovich force is one of the families of our functions $S_\ell(q)$ of the first kind.
2) **Function Q(q) is Lorentz-invariant and neo-Galilean-isomorphic.** The Lorentz invariance of the classical wave equation (10) has been well known since Poincaré [85, 86]. Our solutions have distance and time variables combined in the novel variable q. Substituting the Lorentz transformation Eq. (9) one gets q' for an observer in motion:

$$q' = w'/r' = \{\gamma l(w - \beta r)\} / \{\gamma l(r - \beta w)\} = (w - \beta r)/(r - \beta w)\,. \qquad (13)$$

It is noteworthy that the controversial parameter γ linked to length contraction and time dilation has simply disappeared from Eq. (13). Also note that the right-hand side of Eq. (13) is the same (i.e. *isomorphic*) for any arbitrary functional form of γ and l, which includes the case of a neo-Galilean transformation defined as

$$r' \equiv r - Vt, \quad t' \equiv t - \beta r / C\,. \qquad (14)$$

For a neo-Galilean observer in motion, the value of q' is obtained from equations (14) as

$$q' = Ct'/r' = C(t - \beta r / C)/(r - Vt) = (w - \beta r)/(r - \beta w)\,. \qquad (15)$$

The extreme right-hand side of Eqs. (13) and (15) is the same, so that the function has the same value under a Lorentz-transformation or a neo-Galilean transformation. Therefore, the novel function $Q(q)$ has the extraordinary property of being the same for a large class of observers in motion, which includes Lorentz-invariant and neo-Galilean transformations. As such, it may be part of a covering group for relativistic and classical theories — a conjecture that is left open for mathematicians to elucidate.

As described in a companion paper [64], the new surprise is that the novel solutions of the classical wave equation immediately lead to quantized gravitational structures in the sagionic ether [123].

VI. Concluding remarks

The three ethers independently propounded by Thornhill, Martin and Múnera towards the end of the 20th century are all dynamic fluids, constituted by discrete objects called unit ether-particles by Thornhill, cosmons by Martin and sagions by Múnera. The three ethers share several properties: all of them are formed by discrete entities exhibiting 3D-extension and motion. Martin's cosmon is a boson, and Múnera's sagion is an energy-like object, both with strictly zero rest-mass; although the lines of reasoning leading to cosmons and sagions were different, the two objects are very similar. In all cases the speed V is variable, and the average speed is assimilated to the local speed of electromagnetic radiation. The three ether models are intended to be general theories of nature, including an explanation of all forces; however, we differ in our emphasis. Thornhill concentrated on Galilean invariant electrodynamics, Martin on modelling particles, and I on electrodynamics, in Le Sagian gravity, and in the microscopic interactions. But there are some differences in the descriptions of the fluid, in the external constraints imposed, and in the mechanisms to explain electromagnetic and gravitational forces.

For Thornhill and Martin ether is a gas, while Múnera describes it as a fluid, which in our local solar system may be treated as a gas, but it may behave as liquid at earlier times, or in other regions of the universe. However, Martin also acknowledges that his gas may behave as a liquid or a solid under some conditions [95(c), p. 4]. Martin distinguishes between a contiguous medium (like water) and a discrete medium (like air) [95(c), p. 2], while we stress the fact that our fundamental fluid is formed by discrete objects (the sagions); the apparent continuity of water or any other liquid or solid is a mere artefact of the resolution of the instrument (say, the microscope) used to observe the liquid or solid [125]. Then, a fluid is not continuous in a mathematical sense. To describe his ether Martin chose the ideal gas law, and the extension of Clausius to non-ideal gases. Thornhill's description of his ether in terms of Euler's equations allows a natural extension to regions where, or to epochs when, the ether did not behave as a gas. For both Thornhill and Múnera the ether obeys the homogeneous classical wave equation (10).

Thornhill and Martin both accepted the conventional interpretation of the Michelson & Morley experiment as null. Martin explains the null MM experiment *via* Trempe's geometrical Lorentz transformations in Galilean space and time; as discussed in V.B, Trempe's findings might be related to Poincaré's ellipsoids. To explain the MM experiment, Thornhill proposed a boundary layer between the aetherial fluid and the earth in relative motion, which is consistent with usual fluid theory, with Newton's views in his 1678/9 letter to Boyle, and also with my own view stated in section IV.D. In the boundary layer interpretation, the M&M experiment is related to the thickness of the boundary layer, and has nothing to do with contrived contractions of length, or with far-fetched effects upon time and space. In the language of the 19th century ether, the discussion focussed on entrained versus non-entrained ether — qualitative notions that might be related to the boundary layer of fluid theory.

Thornhill and Martin are both Newtonians, thus facing the difficult task of explaining the origin or mechanism leading to the generation of Newtonian forces. It may be recalled that Newton himself insisted that gravity was *not* an inherent property of matter, but in the *Principia* he did not commit himself to any mechanism that might explain the origin of force. In Múnera's neo-Cartesian approach, force is a straightforward result of sagion-matter collisions. In this regard, many authors have noted a deep connection between the Cartesian and Einsteinian approaches to gravity, for instance [1, p. 260]:

> Gravitation in general relativity has not the character of a force. It is a property of space-time. Mechanical events are thus accounted for by purely geometrico-kinematic conceptions. Descartes's program has finally been carried out by Einstein! It is only natural, therefore, that general relativity does not include —at least not as a rigorous law— the principle of action and reaction nor its most important dynamical consequence concerning the motion of the center of mass.

In some senses the sagionic ether described by the homogeneous classical wave equation goes farther than Einstein's general relativity. For instance, our neo-Cartesian approach strictly obeys (at least) local conservation of linear momentum, and, as a consequence, Newton's action-reaction principle is strictly fulfilled. Furthermore, the novel solutions for the ether equation are consistent with both Lorentz-invariance and neo-Galilean invariance, and also lead to a non-linear quantum theory, thus unifying gravity, electromagnetism, and quantum phenomena. Consequently, the sagion ether would seem to be the answer to Einstein's dream for a unified force of nature. Einstein failed because he interpreted his general relativity equation as a representation of space-time, while we interpreted our similar fluid equation (10) as a straightforward 3D-fluid.

For completeness we mention another little known effort towards unification: as an extension of his kinetic theory of gravity [33], Brush carried out several experiments to find connections with electromagnetism, leading him to suggest in 1929 a unified spectrum for electromagnetic, gravitational and quantum phenomena [113]. In Brush's spirit, Table 1 shows all scales of nature as a spectrum of sagionic ether waves; of particular interest is the identification in the 1990s of ultra low frequency (ULF) electromagnetic waves associated with earthquakes [114-117]. The conventional view is to search for gravitational waves over "*a considerable frequency range from 10^{-4} Hz for large black hole interactions through 10^{-3} - 10^{-2} Hz for fast binary stars to 10^{3} Hz for stellar collapses*" [118, p. 111]. The lower region of this frequency range coincides with ULF and with telluric and seismic waves. In our unified approach to nature ULF waves and gravity waves are manifestations of a common phenomenon: ether waves. The boundary between small and local scale phenomena (usually described as electromagnetism) and large scale phenomena, (conventionally described as gravity) is in the ULF region. In this regard, note that the conventional upper limit for the rest-mass of the photon [65] coincides with the 5 mHz frequency of the Spitak (Armenia) earthquake [117], which is the lowest ULF measured thus far; also it may not be a coincidence that the wavelength of such ULF is the same as the sun-earth distance, which in turn defines the gravitational dynamics of our earth. Likewise, the conventional upper limit for the graviton mass [65] coincides with the energy of an ether wave whose wavelength equals the observable universe.

Table 1. Spectrum of sagionic ether waves

f, Hz	λ, m 3 x	E, eV 4.14 x	Distances, sizes, frequencies & comments
10^{-18}	10^{+26}	10^{-33}	Observable universe: 1.3×10^{26} m. Graviton mass < 6×10^{-32} eV [65]
10^{-15}	10^{+23}	10^{-30}	Diameter of local galactic group: 3.1 Mpc = 9.6×10^{22} m
10^{-12}	10^{+20}	10^{-27}	Sun- Milky Way galaxy center: 2.6×10^{20} m
10^{-9}	10^{+17}	10^{-24}	Closest star: 4.1×10^{16} m. Oort cloud > 7.5×10^{15} m
10^{-6}	10^{+14}	10^{-21}	Eris aphelion: 1.5×10^{13} m. Photon mass < 1×10^{-18} eV [65]
10^{-3}	10^{+11}	10^{-18}	Sun-Earth: 1.5×10^{11} m. ULF: Spitak earthquake f = 5 mHz
10^{0}	10^{+8}	10^{-15}	Earth-Moon: 3.8×10^{8} m, ULF, Allais pendulum f=1Hz
10^{+3}	10^{+5}	10^{-12}	Surface earth to ionosphere: 1.5×10^{5} m; VLF
10^{+6}	10^{+2}	10^{-9}	Medium (long) radio waves: f = 1MHz (f = 10 kHz).
10^{+9}	10^{-1}	10^{-6}	GPS, cell phones, radar and microwaves: f = 1 GHz
10^{+12}	10^{-4}	10^{-3}	At T = 2.73 K: λ = 5.6 mm, f = 54 GHz, E =2.2×10^{-4} eV
10^{+15}	10^{-7}	10^{0}	Blue light: λ = 3.8×10^{-7} m, f = 7.9×10^{14} Hz
10^{+18}	10^{-10}	10^{+3}	X-rays
10^{+21}	10^{-13}	10^{+6}	Gamma-rays from electron-positron annihilation: 0.511 MeV
10^{+24}	10^{-16}	10^{+9}	Proton radii and mass ≈ 0.78–0.88 $\times 10^{-15}$ m and 0.94 GeV [65]
10^{+27}	10^{-19}	10^{+12}	Brush's "gravitation" and "quanta waves": f = 1.2×10^{27} Hz [113]
10^{+43}	10^{-35}	10^{+28}	Planck length and mass: 1.6×10^{-35} m and 1.2×10^{28} eV [65]

According to Zwicky, there are no clusters of clusters of galaxies [119], but Table 1 may provide a slightly different view, as follows. The energy of ether waves in the large-scale region (say 4.14×10^{-30} eV) suffices to hold together a cluster of galaxies such as our local group, and the energy of ether waves at the scale of the universe (4.14×10^{-33} eV), suffices to hold together the universe, which is then a cluster of clusters of galaxies.

Coming down to the terrestrial scale, for thirteen years in the 1940-1950s Guido Buffo carried out observations with a Foucault pendulum in Argentina; he claimed that his pendulum exhibited erratic behaviour several days before an *earthquake* [120, p. 39-40]; the frequency of oscillation of a 25 meter long Foucault pendulum is around 0.1 Hz, similar to the frequency of ULF associated with large magnitude earthquakes ($f < 0.1$ Hz) [113-117]. Likewise, the frequency of the Allais pendulum is about 1 Hz, similar to the frequency of an ether wave whose wavelength equals the distance earth-moon. Then, the anomalous behaviour of Allais pendulum during solar eclipses might be related to resonance with stationary ether waves between earth and moon. The possible connection between pendulums and resonant ether waves opens a new avenue for interpretation of gravity anomalies during solar eclipses.

For completeness, Table 2 shows the scale that the late Adolphe Martin proposed for the microworld, seeming *"to have a quantum step of 10^{-5}"* [95(c), p. 5].

Table 2. Scales of the microworld according to Adolphe Martin

Scales	In meters	Comments
Human	1	
Molecules MFP	10^{-5}	MFP: mean free path
Molecules, atoms	10^{-10}	Orbits of electrons
Electrons, nucleons	10^{-15}	Orbits of quarks
Quarks	10^{-20}	
Cosmons	10^{-25}	
Planck length	10^{-35}	

The present author will not enter into sterile controversies with those claiming that *"modern ether theory is relativistic"* [121, p. 25], further stating that [121, p. 16-17]:

> It will require *hundreds* of undisputed detections of ether drift, carried out by impartial investigators in first class laboratories, all over the world, with impartial witnesses, and publication of meticulous records, before the normative status of Einstein's relativity is called into question (emphasis added).

It is simply stated that modern day zealots do not understand Popper's principle of falsification, which requires only one experiment to falsify a theory. Einstein accepted the principle. Regarding Dayton C. Miller's work, Einstein clearly accepted that [122, p. 2283]

> The existence of a not trivial positive effect would affect very deeply the fundaments of theoretical physics as it is presently accepted.

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From Hubble to Arp

Christopher C. Fulton

We take a multi-tiered journey across eight decades of astronomical and cosmological observation and theory. Important events begin with the discovery of Cepheid variables and the velocity-distance relation and arrive in the midst of recent discoveries about the dynamics, mechanics, and processes of the enigmatic objects known as active galaxies and quasars. Important personae begin with the pragmatic, steadfast observational astronomer, Edwin Hubble, and progress to another pragmatic, steadfast, controversial observational astronomer, Halton Arp. The primary purpose of the journey is to expose a rift in cosmological thinking regarding the interpretation of redshifts. The rift began to form during Hubble's tenure and by the mid-1960s it managed to pervade the research of virtually every observational and theoretical astronomer and cosmologist. We put forth the proposition that redshifts are at a minimum not all due to velocity and that in the extreme all velocity-generated redshifts are local phenomena rather than cosmological.

1. Introduction

A lot of observational and theoretical work has been done since the word "redshift" was first introduced into the vernacular of astronomy. The word itself has not changed in its original meaning. It still refers to the shifting of the characteristic absorption or emission lines of chemical elements in the light received from distant objects as they are observed spectroscopically. What did change early on is how redshifts were interpreted. During the time of Edwin Hubble and Milton Humason, redshifts were given tentative status as indicators of the distances of astronomical objects. Once Hubble's linear velocity-distance relation was accepted, it became standard practice to use redshift as a convenient synonym for velocity and to refer to the Hubble law as the redshift-distance relation. At this juncture, mainstream cosmology adopted redshifts as distance indicators of astronomical objects. It is this adoption, and its persistence to this day that forms the basis of the arguments presented in this paper against conventional cosmology as it relates to the observational evidence acquired over the last fifty years.

2. The Redshift Rift

With his research and discoveries, Edwin Powell Hubble began a number of new observational and theoretical threads in astronomy and cosmology. Each thread has of course had its own consequences as to knowledge gained and technical advances, but when the threads are woven together, they form a tapestry that is the basis for the astronomical and cosmological paradigm as it has emerged for any period during or since his tenure.

There is now a gap of almost ninety years since Hubble found Cepheid variable stars in the Andromeda Nebula, the starting point for this narrative. Each decade has roiled with controversy as observation and theory took turns pushing each other to the brink of the next revelation. This is the way all science is done, and there is no extant argument against using this method. However, there is a particular idea embedded in this controversy that has received unusual status as an axiom, namely that redshifts are, without exception, indicators of the relative velocity of the objects measured. It is a powerful assumption, but has it been verified? If we suppose for a moment that the axiom is true, then the current paradigm can carry forth as usual, albeit with some significant problems to solve and questions to answer. If we suppose instead that the axiom either requires modification or is altogether false, then the current paradigm must be replaced *in toto*, because it hinges entirely on the truth of the assumption. There are cogent arguments and observational evidence that while some redshifts may be due to velocity (extrinsic redshifts,) there are in fact also redshifts that are not due to velocity (intrinsic redshifts) [12]. We submit, therefore, that since the extrinsic redshift axiom has not been verified and is at least questionable, its continued use imperils the validity of any research that assumes it *a priori*. In other words, there is a rift in current cosmological thinking, a rift that could be called the "redshift rift." This paper investigates the historical context, cosmological implications, and validity of interpreting redshifts as being extrinsic, intrinsic, or both.

3. Hubble

Edwin Powell Hubble was a steadfast observational astronomer with a keen insight. He worked at two of the most renowned observatories of the twentieth century, at Mount Wilson and Mount Palomar, and with three of the most renowned telescopes, the 60-inch and 100-inch Hooker at Mount Wilson shown in Figure 1, and the 200-inch Hale at Palomar. He was either a direct participant in or a key formulator of observatory programs that led to explosive astronomical and cosmological discoveries. We outline below certain pieces of Hubble's research as they pertain to our discussion.

3.1. Cepheid Variables

In 1923 Hubble began a systematic search for novae in what was then called the Andromeda Nebula, chosen because it was deemed to be one of the most easily observed nebulae. On 6 October Hubble took what proved to be a historic photograph of Andromeda. Through careful examination of previous photographic plates taken of the same region, he discovered that a star he had originally identified as a nova was actually a Cepheid variable star [30]. It appeared on more than sixty plates dating back to 1909, with variations in brightness from magnitude 19th to 18th [40]. He found numerous other examples and found these stars to be intrinsically very luminous, in spite of being very dim on the plates, as exemplified by

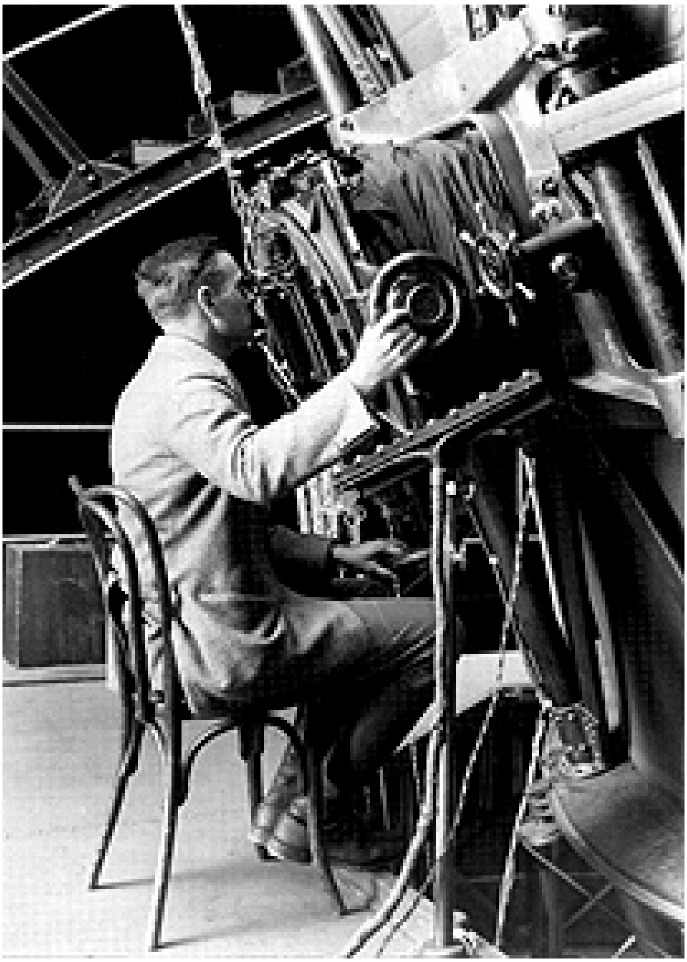

Fig 1 — Edwin Powell Hubble. Edwin Hubble at the 100-inch Hooker telescope at Mount Wilson Observatory.

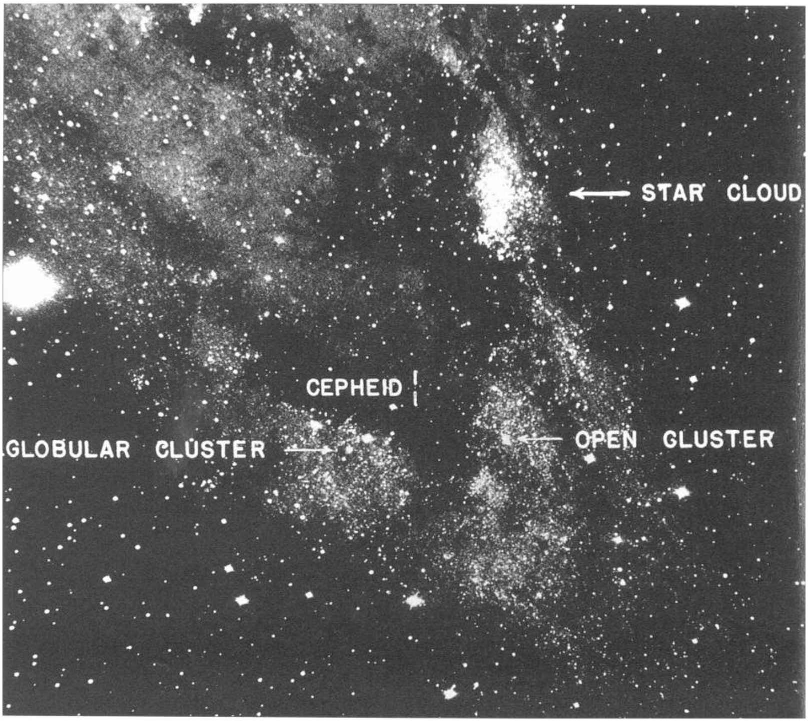

Fig 2 — Cepheids in Andromeda. This photograph of a region of the Andromeda Nebula was taken with the Mount Wilson 100-inch telescope. A very faint Cepheid is indicated by a crosshair [30].

the photograph shown in Figure 2. His discovery led to the inescapable conclusion that the Andromeda Nebula was both much farther away and much larger than anyone had previously imagined. It was also the beginning of the realization and general acceptance by astronomers that "island universes," first proposed in 1755 by Immanuel Kant [22], actually existed outside the Milky Way.

3.2. Radial Velocities and Distances

In 1914 Vesto Slipher had measured the velocities of thirteen spiral nebulae with confidence [22]. By 1921 Carl Wirtz had shown that there was at least a rough relationship between the recession velocities of spiral nebulae and their presumed distances as inferred from their apparent diameters [44]. By 1925, Slipher had determined the radial velocities of a total of forty-five nebulae [30]. From 1925 on, working in conjunction with Milton Humason, Hubble took the velocity-distance idea further. Humason worked on the program at Mount Wilson to obtain radial velocities of the most distant known spiral nebulae [22], while Hubble established the

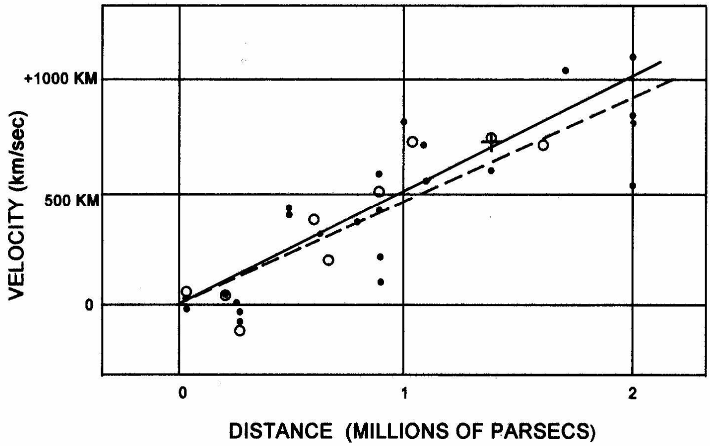

Fig 3 — The Velocity-Distance Relation. This plot of radial velocity (km/s, corrected for solar motion) versus distance (parsecs) shows the data Hubble used to derive his velocity-distance relation, $v = H_0 d$ [33].

distances to these nebulae. The distances presented particular problems for the fainter, and presumably more distant, nebulae. Hubble could detect Cepheid variables only for the nearest objects, so he developed a steppingstone technique (still in use today) to estimate the greater distances. He first measured the luminosities of the brightest stars in galaxies for which he could detect Cepheids. He typed these stars, which were between 50 and 100 times brighter than the Cepheids, and used them as standard objects to seek out and measure in more distant galaxies [30].

Hubble was acutely aware of the pitfalls of his steppingstone methodology and took the extra time required to do the work in meticulous fashion. Hubble used a large portion of his observing time on the 100-inch telescope, and ultimately also on the 200-inch telescope, in an effort to determine the relationship suggested by Wirtz, measuring twenty-four galaxies by 1929 [30]. This work ultimately led to the velocity-distance relation, shown in Figure 3, for which Hubble became famous, and to the current expanding universe cosmology. The relation is

$$v = H_0 d,$$

where v is the velocity, d is the distance, and H_0 is what came to be known as the Hubble constant.

3.3. Redshifts

In the beginning of the twentieth century, in their efforts to quantify the motion of nebulae with respect to the Sun, astronomers (Slipher, Paddock, Kapteyn, Wirtz, and others) used an equation of the form

$$v = v_{\oplus} \cos \lambda + K = v_r ,$$

where λ is the angular distance on the celestial sphere between the object under scrutiny and the apex of the Sun, moving with respect to the nebulae at a total velocity $v_{\oplus}$. The so-called *K*-term, previously introduced by astronomers for stars, was first introduced for nebulae by Paddock [44] as a quantitative increment to the solar velocity. A positive value for this term was taken to indicate a recessional velocity of *K*, although it could be due to gravitational effects implied by general relativity. It is believed that Wirtz was the first to use the term "red-shift" for the *K*-term [44].

After Hubble established the linear velocity-distance relation, subsequent re-searchers used the term "redshift" in describing the velocity, although Hubble would often use the term "velocity shifts" in his writings [33]. Hubble emphasized the empirical nature of his work [26]. His steppingstone methodology allowed him to construct the velocity-distance relation without invoking redshifts as distance indicators. He was always cautious about stating unequivocally that redshifts were true indicators of spatial expansion [33]. In general he was not very enthusiastic about testing theoretical predications [44], although he did hold relativity theory in high esteem [26]. He recognized, as did Wirtz [30], that the velocity-distance relation could be representative of Willem de Sitter's solutions to Einstein's equations for general relativity [44]. Hubble pursued the measurement of fainter galaxies in an effort to extend the redshift-apparent magnitude relation to greater distances. The work of determining redshifts and distances continued at the Mount Wilson Observatory until 1950 and was reinitiated at the Palomar Observatory in 1953 [33].

In his 1951 Penrose lecture, two years before his unexpected passing, Hubble included the need for redshift determinations prominently in the outline of his vision of future cosmological research at the Palomar Observatory [42]. Great effort has since been expended in measuring redshifts accurately [33], [42]. Along with these early and later continuing measurements came a natural tendency to interpret redshift as being due to expansion of the universe, due at least in part to a desire to invoke a simple theory that could explain all of the observations.

3.4. The Hubble Constant

Once the redshift-apparent magnitude linear relation was observationally established in the 1930s, a theoretical framework emerged to interpret the relation based on the Friedman-Lemaitre solutions to Einstein's equations. This framework seemed to favor the expansion of the universe as the reason for the observed relation. Consequently the measurement of redshifts became presumed measurements of H_0. One interesting turn of events during this period serves to illustrate this point. In an effort to study the large-scale structure of the universe, Hubble had begun a program on the Mount Wilson 100-inch telescope to determine the distribution of galaxies in space. He counted galaxies as a function of their apparent magnitude. He also attempted to measure any changes in redshift over time. Walter Baade, who had become a colleague of Hubble at Mount Wilson, was of the opinion that not enough was known about galaxies to use them as cosmological goal posts. Hubble and Humason had priority access to the moonless nights on the telescope, so this access, in combination with Hubble's notorious persistence, meant that the galaxy count program continued. Subsequently, when Hubble prepared research programs for the 200-inch Palomar telescope, he proposed an upgraded program of galaxy counts. However, in a huge disappointment to him, Hubble did not receive the directorship of the Palomar Observatory, which went instead to Ira S. Bowen [35]. When a decision was made whether or not to continue with galaxy counts, Hubble was overridden, in part due to a contrary view by theoretician Martin Schwarzchild [33]. Baade's point about lack of extragalactic knowledge was well taken at the time. He was also on firm ground, even in 1936, in criticizing Hubble's assumption of an intrinsically constant value of extragalactic luminosity. However, the decision not to continue Hubble's line of investigation had more to do with the common drive to measure redshifts and determine H_0. In fact, Baade's reasoning could have been used equally well against the headlong plunge of the astronomical community into acceptance of the assumed linearity of the Hubble relation at increasing redshifts. This assumption has pervaded almost all observational data acquisition and theoretical supposition ever since.

4. Interlude

It has been suggested that, had Edwin Hubble not died in 1953, he and Milton Humason would likely have shared the Nobel prize for their discovery of the redshift-apparent magnitude relation [33]. Hubble would undoubtedly have accepted the accolade, but, as already mentioned, Hubble was cautious about applying theory to observations. If a new principle were to become recognized or if new observational data were to contraindicate the trend to linearity at greater distances, he was fully prepared to abandon the interpretation of redshifts as velocity indicators [6]. This willingness to reexamine accepted views about redshifts was not shared by the majority of subsequent investigators, as will be shown in the following sections.

4.1. Enter the Steady State Theory

In 1948 Fred Hoyle, Hermann Bondi, and Thomas Gold, uncomfortable with the idea that the universe had a beginning and an end, proposed what they called a "steady state" theory as an alternative to what Hoyle called the "big bang" theory [30]. They surmised that galaxies were rushing away in response to the constant creation of new galaxies out of matter created in interstellar space [30]. Their proposal came during a pivotal period for observational cosmology. Prior to and during World War II, all observational work was done using optical telescopes, mostly at the Mount Wilson and Lick observatories, by a handful of individuals, most notably Edwin Hubble, Milton Humason, Nicholas Mayall, Joel Stebbins, and Albert Whitford [33]. After the war the landscape of cosmology changed dramatically due to several factors outlined nicely by Hoyle *et al.* [33]:

> In 1948 the 200-inch Palomar telescope (the Hale telescope) came into operation. It had been advertised as the instrument with which the cosmological problem would be solved. In the 1950s, following the death of Hubble in 1953, Sandage together with Humason started a new program to extend the redshift-apparent magnitude relation to much larger redshirts using that telescope.
>
> Radio astronomy opened a new window on the universe, and while initially the bulk of the discrete radio sources were thought to lie in our Galaxy, by the early 1950s it was known that many were extragalactic, and even while most of them remained unidentified they started to be used for cosmological investigation.
>
> A number of physicists, of whom the most visible was George Gamow, with his students, Robert Herman and Ralph Alpher, but also some of the most distinguished, including Enrico Fermi, Maria Mayer and Edward Teller, began to tackle the problem of the origin of the chemical elements in an early universe while one of us (FH) looked at the same problem from another viewpoint. This followed the work of Hans Bethe who had finally solved the problem of the energy generation in the stars. In particular George Gamow and his colleagues in the period 1948-1958 tried very hard to understand how the elements could be built up by rapid neutron capture in the early phases of an evolving universe... In 1946 one of us (FH) had shown that iron peak elements could be built in stellar interiors. Following that it was then shown that the CNO group could also be built in stars.

> The first direct challenge to the approximately 20 year old view that we live in an evolving universe had been made by the development in 1948 of the steady-state cosmology by Hoyle and separately Bondi and Gold.

From about 1950 until 1965, there appeared to be at least a pitched battle between the proponents of the steady state and the big bang theories, even though the latter had a decidedly larger contingent.

4.2. Tracking the Hubble Constant

The calibrations of the distance scale by Hubble and Humason were based on the brightest stars, thought to be supergiants, in a sample of nearby galaxies. The absolute luminosities of these stars were calibrated by using similar stars in M31 and M33. The distances of the latter stars were determined from Cepheid variables, with the period-luminosity law zero point being calculated from the statistical parallax measurements made by Shapley and Wilson [33]. It was known by 1940 that there were actually two types of pulsating stars, the classical Cepheid variables, called Population I stars, and the RR Lyrae stars, called Population II, and that these types had two different period-luminosity relations. As corrections were made to account for these and other discoveries, the Hubble and Humason value of $H_0 = 558$ km/s/Mpc was successively reduced, first to 180 km/s/Mpc and subsequently by Sandage to 75 km/s/Mpc [33]. There was general acceptance by the late 1960s that the value of H_0 was smaller than the original Hubble and Humason value by a factor of ten. Additional modifications by Sandage and Tammann brought H_0 down to 57 ± 6 km/s/Mpc [33]. Other investigators, even recently, have claimed values as high as 100 km/s/Mpc. Hoyle *et al.* [33] reviewed all of the methodologies used, the observations done, and the investigators involved. They found that the methods used sometimes gave very different results and that the same methods in the hands of different investigators could also give different results. The differences are due mainly to intrinsic dispersion in the properties of the objects chosen as standard candles and to the uncertainty in the distance to the Virgo cluster. Hoyle *et al.* believed that the best standard candle is the absolute magnitude at maximum of supernovae of Type Ia and that Sandage and Tammann, having used this supernova method in their original determination some 20 years ago, had already determined a correct value at that time. Hoyle *et al.* concluded that the final value for H_0 lies in the range of 58 km/s/Mpc with a high of 68 km/s/Mpc and a low of 53 km/s/Mpc. Figure 4 gives estimates of the distance to the Virgo cluster and Figure 5 gives values of H_0 from Sandage [33].

Table 4.1 *Estimates of the distance to the Virgo cluster (in Mpc)*

Method	Distance		
	Sandage (ref. 19)	van den Bergh (ref. 21)	Jacoby *et al.* (ref. 22)
Globular clusters	21.1 ± 2	19.7 ± 2.3	18.8 ± 3.8
Novae	20.6 ± 4	18.2 ± 2.5	21.1 ± 3.9
Supernovae	21.2 ± 2.2	19.1 ± 6 22.9 ± 5	19.4 ± 5
$D_n - \sigma$	23.4 ± 2	—	16.8 ± 2.4
21 cm line widths	20.9 ± 1.4	15.0 ± 1.4	15.8 ± 1.5
Size of the Galaxy	20.0 ± 1.8	—	—
Size of M31	—	17.0 ± 4	—
Size of M33	—	10.5 ± 2.5	—
Size of LMC	—	12.0 ± 2.5	—
Surface Brightness Fluctuations	—	14.9 ± 0.9	15.9 ± 0.9
Planetary Nebulae	—	14.1 ± 0.3	15.5 ± 1.1
Red Supergiants in NGC 4571	—	13.8	—
Red Supergiants in NGC 4523	—	13.2	—

Fig 4 — Distance to the Virgo Cluster. Table from Hoyle *et al.* [33] giving estimates of the distances to the Virgo cluster by various investigators.

Regardless of whether or not the Hubble relation remains linear at larger distances, there is still great value in measurement of H_0 as a barometer of at least the local structure of the universe.

4.3. The Age Problem

The view that we live in an expanding universe first became widely accepted in the 1930s. At that time the mechanism of energy production in stars was not well understood and consequently the ages of stars were still in doubt. Eddington had estimated earlier that the value might be as large as 10^{13} years based on the assumption that a large fraction of the mass of a star was consumed in the generation of luminosity. Since there was no physical theory to back up this assumption, the estimate could only be thought of as an upper limit to the ages of known stars [33].

Meanwhile, the work on spontaneous radioactive decay led to an age of rocks of about 1.3×10^9 years and an age for the Earth of about 3×10^9 years [33].

Later work on nucleosynthesis using Rutherford's method involving Th^{232}, U^{235}, and U^{238}yielded an age for the elements in the solar system of $\sim 10 \times 10^9$ years [33].

It appears now that, regardless of which cosmology one chooses to support, the measurements of H_0 locally, the ages of the oldest stars, and

Table 4.2 *Values of H_0 from Sandage (ref. 19)*

Method	H_0 [km s^{-1} Mpc^{-1}]
Virgo Distance	55 ± 2
ScI Hubble Diag.	49 ± 15
M101 Diameters	43 ± 11
M31 Diameters	45 ± 12
Tully–Fisher	48 ± 5
Supernovae (B)	52 ± 8
Supernovae (V)	55 ± 8
Unweighted mean	50 ± 2
Weighted mean	53 ± 2

Fig 5 — Sandage H_0 Values. Table from Hoyle *et al.* [33] giving values of H_0 from Sandage.

the ages of the chemical elements are becoming well determined. The results are converging on values in the range from ~10×10^9 to ~15×10^9 years [33]. What is of particular note and a fundamental result in its own right is that all three age determinations are rather closely in agreement [33]. This means that, in spite of recent claims to the contrary, conventional cosmology does not have its age problem solved.

4.4. The Steady State Theory Assailed

In 1965 Arno Penzias and Robert Wilson were tracking down the source of noise in a radiating horn antenna that they had built for Bell Telephone Laboratories [30]. Meanwhile, at Princeton University, Robert Dicke and others had just done theoretical computations on the physics of the early universe predicting that there should be a detectable level of radiation left over if a big bang had actually occurred [33]. When Penzias and Wilson determined that their noise corresponded to a blackbody radiation temperature of about 3K and was present in every direction on the sky, they consulted Dicke as to the possible cause, only to discover that Dicke was actively searching for just what they had found [30]. This serendipitous connection was soon heralded as proof that the big bang hypothesis was correct [33], and was thus the final assault on the steady state theory. Unfortunately, it was also a further fall of cosmology into the already wide redshift rift. Hoyle *et al.* write [33]:

> … All that was needed from the past was to know that Gamow had predicted a microwave background and had obtained a temperature of 5K for it. Whence it was argued that the hot big bang, as it became called, was correct, and any other models were just as obviously wrong. To point to a prediction of 4.5×10^{-13} erg/cm3 for some form of an infrared background ...

carried no weight in itself. To have carried weight the simple addenda contained in [the calculation of thermodynamic temperatures] were needed.

When issues come to turn on such inconsequential minutiae, one can feel that a degenerative moment has been reached. And so it proved. After a few years in which some progress was made, notably in the quality of the calculations leading to results for the synthesis of the light elements in big-bang models, a quarter century of near stagnation set in. Of course, to those who live in real time, the impression is not one of stagnation. The impression is one of progress, frantically so at times of stagnation, according to historic examples. Yet we think that in future decades, this is what the period of 1970-95 will be seen to have been.

5. Arp

Halton C. Arp (Figure 6) was a staff astronomer at the observatories known as the Mount Wilson and Palomar Observatories. He received his bachelor's degree from Harvard College in 1949 and his Ph.D. from the California Institute of Technology in 1953, both *cum laude*. From just after the discovery in 1965 of the cosmic microwave background (CMB) onward, evidence began to accumulate that redshifts of certain extragalactic objects were not caused by recession velocity [6]. It was these discoveries, made partly through research done by Arp, that were to launch him on a journey across the redshift rift.

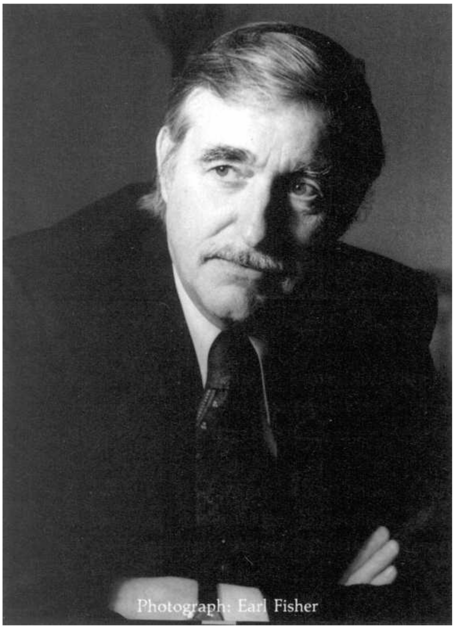

Fig 6 — Halton Arp.

5.1. A Peculiar Atlas

In 1967 Arp had just finished his Atlas of Peculiar Galaxies. He had used his staff member's observing time to study the best examples of companions on the ends of spiral arms. He relates the first of many similar experiences he would have over the next few decades tangling with proponents of conventional cosmology [12]:

It was well understood at that time that the journal in which important papers were published was the *Astrophysical Journal*. The long-

> time editor of that journal was Subrahmanyan Chandrasekhar, a theoretician of great renown and generally considered a tough but fair guardian of its reputation. I don't know now how I ever could have imagined that he would have been pleased by these interesting new observational results. He returned the paper with a handwritten message scrawled across the top: 'This exceeds my experience.'
>
> It took a little while for it to penetrate my stunned senses that he had rejected the paper without ever sending it to a referee. I suddenly felt a cold shudder of apprehension as I realized that my prospects in astronomy were not very bright if I had alienated the editor of the *Astrophysical Journal*. What to do? First I felt I had to safeguard the observations by getting them published somewhere they could be read and referenced. The only possibility seemed to be the journal that was just starting up in Europe called *Astronomy and Astrophysics*. With some trepidation, I submitted the paper there. After some anxious weeks the paper came back. A new jolt of panic hit when I saw it had been refereed by another renowned and conservative astronomer, Jan Oort.
>
> Forcing myself to read on I was overjoyed to find that, although he did not agree with the interpretation, he found the observations valuable and interesting and accepted the paper for publication... Many years later when he was nearing 90, after a warm dinner at his house, he wrote me a letter urging me to give up my radical ideas and once again participate in the privilege of doing mainstream astronomy. I thanked him and answered him with a quote from my wife: 'If you are wrong, it doesn't make any difference, if you are right it is enormously important.'

Arp has continued his work in the same vein ever since, unafraid to propose his "radical ideas." Sometimes this meant writing a book to publish data that he could not get past a referee. Another time it meant moving to Germany to continue his research — he subsequently did all of his astronomy from the Max Planck Institut für Astrophysik.

5.2. Discordant Objects in Compact Groups

Discordant (non-velocity) redshifts have been found in compact groups of galaxies. The standard reaction to such data is that the discordant galaxies must be background objects. Arp has presented data and a line of reasoning that demonstrates that a certain minimum number of these galaxies cannot be background objects. Arp first defines $\Delta cz < 1000$ km/s as the difference in redshift from the brightest galaxy in the group. This number is selected because it is about four times the velocity required to escape from a large Sb galaxy such as M31, thus ensuring that most of the examined galaxies are indeed bound dynamically to the group under study. 1000 km/s is also close to an important empirically determined range of redshifts, 800-900 km/s, that is consistently found in galaxy group

TABLE 1

HICKSON GROUPS

GROUP NUMBER	Δmag	TYPE	POSITIVE REDSHIFT DIFFERENCES (Δcz)[a] Accordant	POSITIVE REDSHIFT DIFFERENCES (Δcz)[a] Discordant	NEGATIVE REDSHIFT DIFFERENCES (Δcz)[a] Accordant	NEGATIVE REDSHIFT DIFFERENCES (Δcz)[a] Discordant
1……	0.60	Sc	+29	…	−181, −117	…
2……	0.80	SBd	+40	+17014	−91	…
3……	0.56	Sc	+558, 502	+4243	…	…
4……	1.47	Sc	+766, 118	+10383	…	−1032
5……	0.97	Sab	+74, 342	…	…	−3932
6……	0.10	S0a	…	…	−292, 702, 235	…
7……	0.38	SBc	…	…	−156, 128, 250	…
8……	0.83	E5	+327	+1073	−48	…
9……	0.61	E2	…	…	…	−2429, 10749, 9855
10……	0.08	SBb	…	…	−286, 488, 528	…
11……	2.33	SBbc	…	+7791, 7400, 4182	…	…
12……	1.47	S0	+549, 162, 62	…	−166	…
13……	0.64	SBab	+124	…	−369, 229, 260	…
14……	0.60	E5	+564	+3051	−220	…
15……	0.08	Sa	+255, 150, 230	…	−723, −725	…
16……	0.34	SBab	…	…	−175, 301, 305	…
17……	0.07	E0	…	…	−384, 64, 164, 312	…
18……	0.11	Im	Missing redshifts	…	Missing redshifts	…
19……	0.46	E2	Missing redshifts	…	Missing redshifts	…
20……	0.06	E1	…	…	−55, 608, 720, 752	−4471
21……	0.25	Sab	+46	+1267, 1275	−212	…
22……	1.66	E2	+23	+6637, 6801	−80	…
23……	0.10	Sab	+123, 218	+5352	−236	…
24……	0.34	SBa	+111, 146, 186	…	−358	…
25……	0.59	SBc	+123, 116	+5894, 4680, 4579	−6	…
26……	0.2	E0	+346, 286, 291, 294	…	−199, 39	…
27……	0.35	SBc	…	+7570, 7514, 7726, 7822	−190	…
28……	0.02	E5	…	+18716	−48, 199	…
29……	2.51	CI	…	+18386, 18341, 17496	…	…
30……	0.78	SBa	…	…	−72, 189, 31	…
31……	1.81	Im	+103	+22832	−26	…
32……	1.48	E2	…	…	−422, 563, 234	…
33……	0.06	E1	+436, 253, 197	…	…	…
34……	2.08	E2	+623, 395	…	−180	…
35……	0.43	E1	+19, 435	…	−419, 540, 8	…
36……	1.48	Sb	…	+2525, 4827, 11860	…	…
37……	1.53	E7	+612	…	−4, 538, 382	…
38……	0.49	SBd	+21, 31	+15, 543	…	…
39……	0.36	Sb	+57	…	−452, 71	…
40……	1.09	E3	+214, 262	…	−136, 3	…
41……	0.57	Sab	+680	+5966, 3490	…	…
42……	2.23	E3	+573, 380, 451	…	…	…
43……	0.05	Sb	…	+9342	−76, 247, 533, 527	…
44……	0.10	Sa	+85, 286	…	−75	…
45……	2.04	Sa	+384	…	−12	−1076
46……	0.02	SB0	+498, 868, 203	…	…	…
47……	1.06	SBb	…	…	−94, 52, 110	…
48……	1.42	E2	+31	+1189	−629	…
49……	0.43	Scd	+71	…	−9, 13	…
50……	0.10	E0	+676	…	−700, 472, 220	…
51……	0.28	El	+487, 4	+1206	−167, 164	…
52……	0.76	SBab	+61	…	−349	−6686
53……	1.82	SBbc	…	+2809	−95, 201	…
54……	2.22	Sdm	+15, 23, 273	…	…	…
55……	0.63	E0	+250	+21060	−340, 130	…
56……	0.74	SB0	+326, 191, 427, 5	…	…	…
57……	0.33	Sb	+295, 354, 250, 265, 867, 689	…	…	…
58……	0.10	Sb	+365, 132	…	−35, 86	…
59……	(0.12)	Sa	+238	+19591	−201, 243	…
60……	(0.96)	E2	+270	…	−689, 707	…
61……	0.23	Im	…	+2853, 2829, 2657	…	…
62……	0.40	E3	+4 } No plot	…	−704, 232 } No plot	…
	2.01	E3+S0	+356, 120 }		… }	…
63……	0.70	SBc	+114	…	−205	−4118
64……	0.00	Sd	…	+4953, 4576, 4449	…	…
65……	0.83	E3	+595, 138, 300	…	−372	…
66……	1.12	El	+784, 113, 162	…	…	…
67……	1.15	E1	+382, 168	…	−191	…
68……	0.09	S0	+473, 151, 246, 239	…	…	…
69……	0.00	Sc-S0	…	No plot	…	…
70……	0.25	S0a	…	+10772, 11005, 10879, 10608	−40, 159	…
71……	1.15	SBc	+15	+11270	−870	…

Fig 7a — Hickson Groups. Table 1 from Arp [10] is derived from the values given in the Atlas of Compact Groups of Galaxies [28]. The columns are the Hickson group number, the difference in apparent magnitude between the brightest and second brightest galaxy in the group (Δ*mag*,) the brightest galaxy morphological type, and the positive and negative redshift differences (Δcz) broken down into accordant and discordant differences.

surveys. Arp next determines the brightest galaxy in the group under

TABLE 1—*Continued*

Group Number	Δmag	Type	Positive Redshift Differences (Δcz)[a]		Negative Redshift Differences (Δcz)[a]	
			Accordant	Discordant	Accordant	Discordant
72......	1.62	Sa	+556, 52	+1444, 11544	−150	...
73......	2.92	Scd	...	+7872, 7518, 7752, 22772	...	...
74......	1.01	E1	+11	...	−145, 574, 766	...
75......	0.30	Sb	+310, 64, 106, 72, 852	...	...	...
76......	0.29	E2	+52, 661, 148, 326, 214	...	−159	...
77......	0.24	S0	+182 } No plot	+8490, 8308	...	...
	1.39	Im	+50 }	...	...	...
78......	0.26	SBb	+945	+1401, +9601	...	...
79......	0.57	S0	+57	+15363	−152, 300	...
80......	1.07	Am	+621, 587, 145	...	...	...
81......	0.26	Sc	+474, 374, 278	...	...	...
82......	0.48	E3	+508	...	−730	−1082
83......	0.05	E0	+882, 960, 0	...	−60	...
84......	1.01	E2	+146, 296	+15846	−100, 301	...
85......	0.50	E1	+967, 757, 745	...	...	...
86......	0.50	E2	+22	...	−645, 258	...
87......	1.13	Sbc	+278, 226	+1506	...	...
88......	0.06	Sb	+50	...	−23, 1	...
89......	0.78	Sc	+135, 22, 7	...	...	...
90......	0.21	Sa	+121, 203	...	−50	...
91......	1.85	SBc	+364, 487, 363	...	...	...
92......	0.65	Sd	...	+5813, 5844, 5978, 4998	...	...
93......	0.57	E1	+33	+3741	−468, 8	...
94......	0.62	E1	+80, 969, 210, 888	+1160	−66	...
95......	0.92	E3	+462	...	−251, 326	...
96......	0.96	Sc	+55, 277	...	−82	...
97......	0.29	E5	+30	...	−915, 671, 331	...
98......	2.02	SB0	+104, 290	+7095	...	...
99......	0.06	Sa	+141, 302	...	−489, 62	...
100......	1.24	Sb	+161	...	−47	...

Notes.—Group number 7: If the Sb is taken as central galaxy, $\Delta cz = +28, +156, -94$.

Number 22: The bright galaxy is NGC 1199. A very peculiar, compact object of $cz = 13{,}300$ km s^{-1} was found in its southwest edge, *silhouetted in front of the low-redshift, E galaxy*. The log intensity image shown by Hickson confirms this crucial example! (See Arp 1978 for original paper.) In some photographs, evidence for an absorption connection leading from the high-redshift object back to the center of NGC 1199 is seen. It would be a key object for which to obtain further high-resolution, high–signal-to-noise observations.

Number 27: If the Sb is taken as central galaxy, $\Delta cz = +190, +8012, +7916, +7704, +7760$.

Number 28: If the Sb is taken as central galaxy, $\Delta cz = +48, -151, +18{,}764$.

Number 29: Galaxy a better classified Am.

Number 38: Galaxy a better classified SBbpec.

Number 47: Galaxy a better classified SBb.

Number 53: Galaxy a better classified Sbcpec.

Number 54: Galaxy a better classified Spec (not Sdm).

Number 56: Not noted by Hickson, this chain is VV/50, Arp 322, and it is in the edge of the large SB galaxy NGC 3718. Galaxy b, the brightest, is a Seyfert (Arp 1973).

Number 59: Galaxy c magnitude presumably fainter than listed; 15.40?

Number 60: Galaxy b obscured; it might be the brightest in the group.

Number 61: If galaxy a is taken as the brightest in the group of three, $\Delta cz = +172, +196$.

Number 62: If galaxies a and b are taken as a single galaxy, $\Delta cz = +356, +120$.

Number 64: If galaxy a (better classified Spec) is taken as the brightest, $\Delta cz = +127, +504$.

Number 68: If galaxy c (Sbbc) is overbright, Δmag ≈ 0.4.

Number 69: If S0 is taken as the central galaxy, $\Delta cz = +310, 161, 603$.

Number 71: Galaxy a better classified as SBcpec.

Number 74: Galaxy a is a radio source.

Number 77: Galaxy d is a knot in extreme dwarf c (no plot), although $\Delta cz = +182, +8490, +8308$.

Number 80: Galaxy a is definitely an Am (starburst galaxy).

Number 91: Galaxy a better classified as SBpec.

[a] Differences between companions and the brightest galaxy, in units of km s^{-1}.

Fig 7b — Hickson Groups. Table 1 from Arp (continued) [10].

study (Figure 7) and uses it to take magnitude and *cz* differences between it and every other galaxy in the group (Figure 8.) The resulting plot shows that as the brightest galaxy becomes more dominant, the companions become more systematically redshifted on average. Arp accounts for differences in luminosity as due to differences in mass that can affect the choice of the brightest galaxy. The conclusion is that the fainter galaxies in compact groups have at least a component of intrinsic redshift, as is the case for all other well-investigated groups. Classically accepted companions in the Local Group are essentially all redshifted by 50 to 300 km/s. As an example, out of twenty-two groups of the M31 and M81 groups combined, all are redshifted relative to the dominant Sb galaxy. Statistically this yields a chance of accidental occurrence 2.5×10^{-7} [8]. Narlikar and Arp [39] have delineated a unified working model to explain

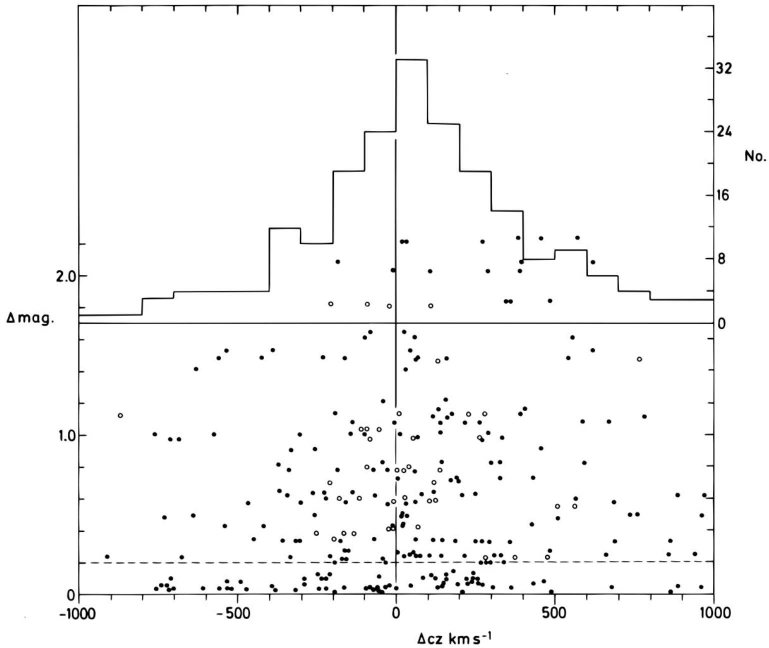

Fig 8 — Magnitude versus Redshift Difference. The magnitude of each galaxy in a compact group is plotted against the difference between its redshift and the redshift of the brightest galaxy of the group. As the brightest galaxy becomes more dominant, the companions become more systematically redshifted on average. The data from the Atlas of Compact Groups of Galaxies (Figure 7) is plotted for magnitude differences greater than 0.2 [10].

the intrinsic redshifts that are required by the observational evidence. This or any theoretical model must explain the variations in redshift found in systems of companions and compact groups. Arp describes the model in which ejection of newly created matter is the driving force behind the various phenomena observed [10]:

> As younger material is ejected, it can entrain material through which it passes that is the same age and same redshift as the parent galaxy. The ejected material itself can be of varying younger ages and hence varying higher redshifts. This encompasses ejected quasars, high-redshift galaxies, and multiple companions only slightly higher in redshift than the parent galaxies. This sequence represents decreasing amounts of intrinsic redshift and presumably an evolutionary sequence.

This model is drawn purely from attempts to explain observational evidence, not just for compact groups, but also for other physically associated but differently redshifted objects, such as quasars. Arp notes that companions tend to be multiple and that objects in groups tend to be high surface brightness compact ellipticals or irregulars, or non-equilibrium spirals. This reinforces the correlation between high redshift and recent activity and also suggests that these objects are sites of recent secondary ejection activity. This cascading, hierarchical generation of matter is also what would be required for associated quasars with large redshift differences to have a strong tendency to associate with companion galaxies, as is frequently observed. When we look at more distant galaxies, the brightest galaxies in compact groups have the lowest redshifts, and this is exactly the trend found in the nearest, best-known groups, in large galaxies with companions, and in large galaxy clusters. So in general, the fainter the galaxy, the greater is the intrinsic redshift.

An excellent case in point is Stephan's Quintet. There is a large Sb galaxy, NGC 7331, only 30′ away from the quintet that has a redshift very close to that of NGC 7320. The latter is a dwarfish, low-redshift galaxy that has always been accepted as a quintet member. NGC 7331 has companions that are the same in apparent magnitude, number, surface brightness, and excess redshift as the high-redshift companions around NGC 7320. In other words, NGC 7331 is the only major matter concentration in this large sky area and it has both high and low redshift companions. Conventional cosmology has no choice but to claim that these companions are background objects, but clearly they are not.

5.3. The Origin of Companion Galaxies

Main stream cosmological theory fails to explain a number of key types of observations made over the last fifty years. Arp [11] summarizes these as follows:

1. The general alignment of companion galaxies along the minor axes of larger galaxies
2. The systematic redshift of companion galaxies
3. The pairing of high redshift quasars across active galactic nuclei
4. The intrinsic redshifts of quasars associated with active galaxies
5. The excess redshift of peculiar galaxies in the $cz = 5000$ km/s to $z = 0.1$ range
6. The quantization of galaxy and quasar redshifts
7. The very narrow alignment of galaxies in the Local Group along the minor axis of M31, including nebulous, dust like material.

The following sections discuss these observations in detail and present possible explanations of the available empirical evidence.

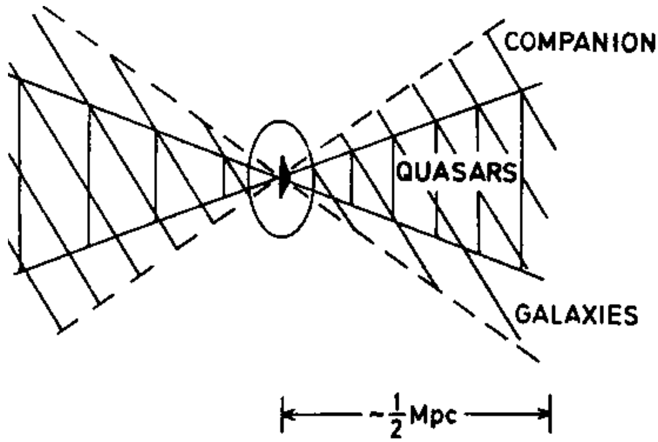

Fig 9 — Distribution of Companion Objects. Schematic distribution of companion galaxies and quasars along the minor axes of ejecting disk galaxies. The companion ejections occur at angles of approximately ±35°, and the quasar distributions are at angles of about ±20°.

5.3.1. Minor Axis Alignments

Numerous cases have been found of galaxy companions that are aligned along the minor axis of larger galaxies. A study by Holmberg [29] of 174 nearby spiral galaxies showed that the companions were preferentially distributed along the minor axis of the central spiral. Sulentic, Arp, and diTulio [46] studied 96 non-equilibrium peculiar galaxies and showed that these disturbed galaxies are physical companions of spirals and that they avoid the regions in the direction of the major axis of the central galaxy. Zaritsky *et al.* [51] studied 115 galaxies that are satellites of isolated spirals and found them to be preferentially aligned in the direction of the disks' minor axes. These alignments away from the major axis and toward the minor axis appear to be due to ejection of material, namely the satellite galaxies, away from the central galaxies. The ejected objects can emerge from the nucleus with little angular momentum, thus preserving their radial orbits. The ejecta can also escape without having to penetrate populations of material present near the galactic plane.

Conventional cosmology cannot allow these alignments because they invariably involve associating objects with discordant redshifts. To make matters worse, it is statistically impossible to explain the formation of straight lines by the objects if the relatively highly redshifted ones are taken to be background objects.

5.3.2. Systematically Redshifted Companions

The systematic redshifting of companion galaxies was first reported by Arp [1]. This discovery added to the redshift controversy because it again required the existence of intrinsic redshifts. The effect is present in all of the companions of major clusters of galaxies, including nearby well known groups such as M31 and M87. Arp has since computed the chance of accidental occurrence in the latter groups at one in four million [8]. Others have attempted to explain away the discordances by claiming that inclusion of background galaxies in the sample is what causes the effect. But it is important to select group members without biasing the sample with fainter (positive magnitude difference) galaxies, as has been routinely done by less careful researchers. In fact, the fainter companions clearly show fewer positive residuals. Also, any background objects should rapidly increase in number as their apparent magnitude grows fainter, but it turns out that the observed number of positive redshift residuals actually decrease in this direction. [11]. Figure 9 gives a schematic overview of how companions appear to be distributed around an active central galaxy [12].

5.3.3. Pairing of High-Redshift Quasars

The number of quasars that are demonstrably associated with the most active galaxies is continuing to grow. Many of these associations include pairs of quasars with similar discordant redshifts straddled across galactic centers (Figure 10). Arp [11] recently chose a number of cases as representative examples of quasars presumably ejected from spirals along the minor axis of the parent galaxy. The examples are purposely restricted to those pairs of X-ray quasars that have confirmed redshifts and for which an accurate position angle (PA) is known for the central Seyfert galaxy. Of these examples, NGC 4258, NGC 2639, NGC 4235, and NGC 1097 are discussed here.

TABLE 1

COMPANION OBJECTS AROUND SPIRAL GALAXIES

Number	Companions	$\Delta\Theta_1$ (deg)	$\Delta\Theta_2$ (deg)	$r_1 r_2$ (kpc)	Reference
2…………	Quasars across NGC 4258	13	17	25–30	Pietsch et al. 1194
2 + (4)……	Quasars across NGC 2639	0	13(31)	10–400	Fig. 3
2…………	Quasars across NGC 4235	2	12	500–600	Fig. 4
4…………	Quasars nearest NGC 1097	~ 20	~ 20	100–500	Arp 1987a
6…………	Quasars nearest NGC 3516	± 20	± 20	100–400	Chu et al. 1997
218………	Companions around 174 spirals	~ 35	~ 35	40	Holmberg 1969
96………	Distributed companions around 99 spirals	~ 60	~ 60	150	Sulentic et al. 1978
115………	Companions around 69 spirals	~ 35	~ 35	500	Zaritsky et al. 1997b
12………	Companions of M31	~ 0	~ 0	(700)	Arp 1987a, 1987b

Fig 10 — Companion Objects Around Spirals. Table 1 from Arp [11] giving identifications, properties, and references for companion objects around spiral galaxies, analyzed for likely origin.

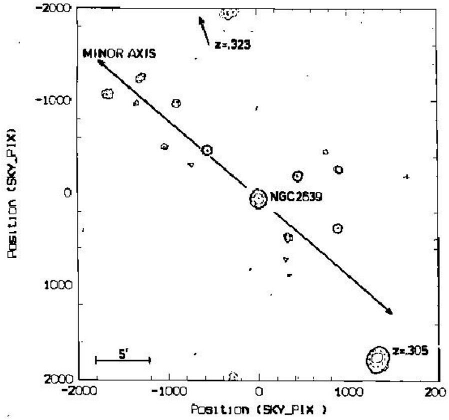

Fig 11 — NGC 2639 X-ray Field. ROSAT X-ray map of 33′ x 33′ field around the Seyfert NGC 2639. The northeast minor axis passes through seven X-ray sources of which four are identified optically as BSOs or Bcgs (Figure 13.) The outermost pair of quasars with z = 0.323 and 0.305 are aligned at about 15° from the minor axis. They are the strong compact sources designated No. 3 and No. 8 by Burbidge (Figure 12.)

NGC 4258 NGC 4258 is a Seyfert bracketed by a quasar pair, one with $z = 0.65$ situated at 13º from the PA of the central galaxy minor axis, and one with $z = 0.40$ at 17º from the minor axis. NGC 4258 has been known for ejection activity since 1961 [11]. Burbidge & Burbidge [20] have recently reviewed the available evidence for ejection of gaseous (optical), radio, and X-ray material from NGC 4258 and have concluded that the observations taken as a whole indicate that the ejection is directed out roughly along the minor axis of the galaxy. In this case the quasar pair is within 3.3º of being

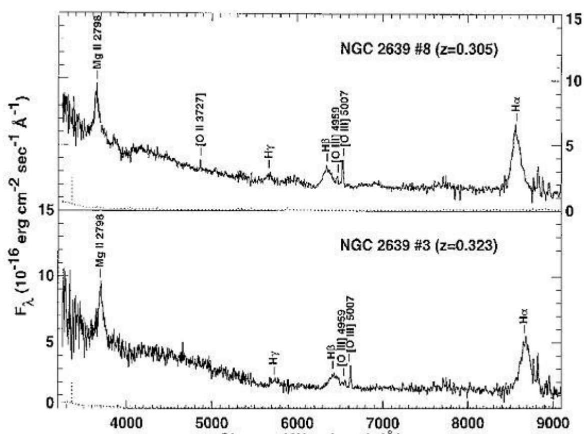

Fig 12 — Spectra of Two X-ray Sources Near NGC 2639. Spectra of Two X-ray sources near NGC 2639, designated No. 3 and No. 8, obtained at the Lick Observatory by E. M. Burbidge [18].

perfectly aligned across the nucleus of the galaxy. It is as if there has been an ejection in the direction opposite to, but rotated 15º from, the projection of the minor axis.

NGC 2639 NGC 2639 is a Seyfert galaxy bracketed by a pair of strong X-ray sources with redshifts of $z = 0.323$ and 0.305 (Figure 11.) The probability of chance occurrence of this is ~10^{-6}. There are also seven fainter X-ray sources coming out to the northeast along the minor axis of the Seyfert, four of which are at the positions of blue stellar objects (BSOs) or blue compact galaxies (Bcg.) Burbidge [18] has obtained and analyzed the optical spectra of two of the BSOs to confirm their redshifts and to compare the objects. The above redshifts were confirmed and the spectra of the two objects are remarkably similar (Figure 12.) Figure 13 shows Arp's tabulation of the objects in the NGC 2639 field with their identifications and relevant properties [11].

NGC 4235 NGC 4235 is a bright Seyfert 1 galaxy bracketed by a pair of extremely strong X-ray sources with redshifts of $z = 0.334$ and 0.136. The first source is a quasar 2º off of the minor axis of the galaxy. The other source is a BL Lac object 12º off of the minor axis. Arp has shown that BL Lac objects are quasar-like and are statistically strongly associated with Seyfert galaxies [9]. These objects are the first in the sequence of physical properties from high to low redshift quasars to exhibit the characteristic of an underlying stellar population. They form an evolutionary link from the central

TABLE 2

PROPERTIES OF X-RAY SOURCES IN THE NGC 2639 FIELDS

Name	X-Ray (counts^{-1})	R.A.[a] (2000)	Decl.[a]	Off Axis[b]	Identification
		Bright X-Ray Sources in Fig. 4			
RX J08443+5031......	37.8	08 44 19.0	+50 31 36	20.6	QSO $z = 0.323$
NGC 2639..............	13.5	08 43 37.9	50 12 09	0	Seyfert $z = 0.011$
NGC 2639 U10........	25.7	08 42 30.0	49 57 51	17.7	QSO $z = 0.305$
		X-Ray Sources Northeast of NGC 2639 (Fig. 4)			
NGC 2639 NE a	2.4	08 44 46.1	50 22 54	14.9	BSO 19.2 mag
NE b	4.1	08 45 04.4	50 21 30	16.4	No identification
NE c.......	2.0	08 44 25.3	50 20 37	11.0	Ambiguous
NE d	1.3	08 44 48.7	50 20 34	13.8	BSO 19.9 mag
NE e.......	1.4	08 44 31.8	50 16 50	9.5	BSO 18.3 mag
NE f	2.6	08 44 07.2	50 16 28	6.0	Bcg 18.8 mag
NE g.......	1.2	08 44 17.0	50 15 09	6.7	...

[a] Values of right ascension are given in hours, minutes, and seconds; declination in degrees, arcminutes, and arcseconds.

[b] Off axis is deviation from minor axis in degrees.

Fig 13 — Properties of X-ray Sources Near NGC 2639. Table 2 from Arp [11] showing the properties and identifications of X-ray sources in the NGC 2639 field.

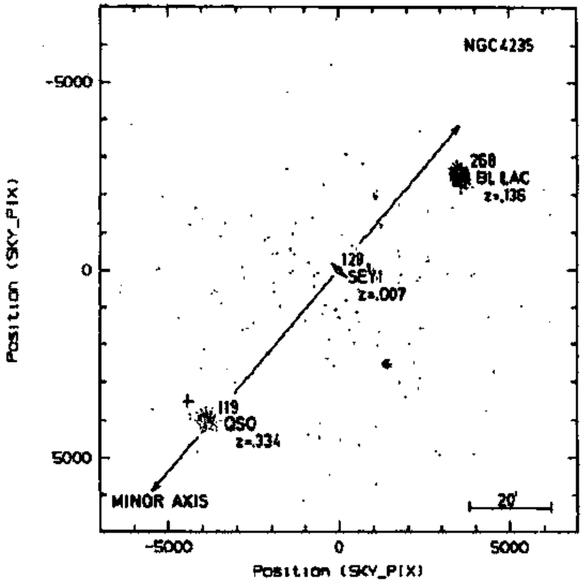

Fig 14 — NGC 4235 X-ray Field. ROSAT X-ray map of the area around the Seyfert NGC 4235. The minor axis is well defined by the QSO with z = 0.334 and the BL Lac object with z = 0.136.

galaxy to its companions [11]. Figure 14 shows the identifications of the objects in the NGC 4235 ROSAT X-ray field as analyzed by Arp.

NGC 1097 NGC 1097 is an active Seyfert hot-spot starburst galaxy with the longest straightest low surface brightness optical jets of any galaxy known [12]. In 1984 Arp, Wolstencroft, & He reported 30 associated quasars in the vicinity of NGC 1097 and Arp subsequently demonstrated that there are about 40 of them concentrated around the galaxy [6]. Since it is a barred spiral, it is difficult to measure the position of its minor axis. However, with an estimated position good to ±10º, the four brightest and nearest quasars are oriented within 20º of the minor axis. To test the hypothesis of ejection of clusters Arp examined the region around NGC 1097 in the Abell Catalogue of galaxy clusters. Figure 15 shows the area of NGC 1097 and all Abell clusters brighter than $m = 17.0$ and all galaxies brighter than apparent magnitude 10.9. If the four optical jets in NGC 1097 are extended outward, they include within their ejection angles all of these Abell clusters! Figure 16 shows a true color enhanced, star removed composite photograph taken by Jean Lorre with the 4-meter Cerro Tololo telescope. On one side between the brightest optical jets there is a concentration of 5 or 6 bright quasars that have been shown to represent excess redshifts by a fac-

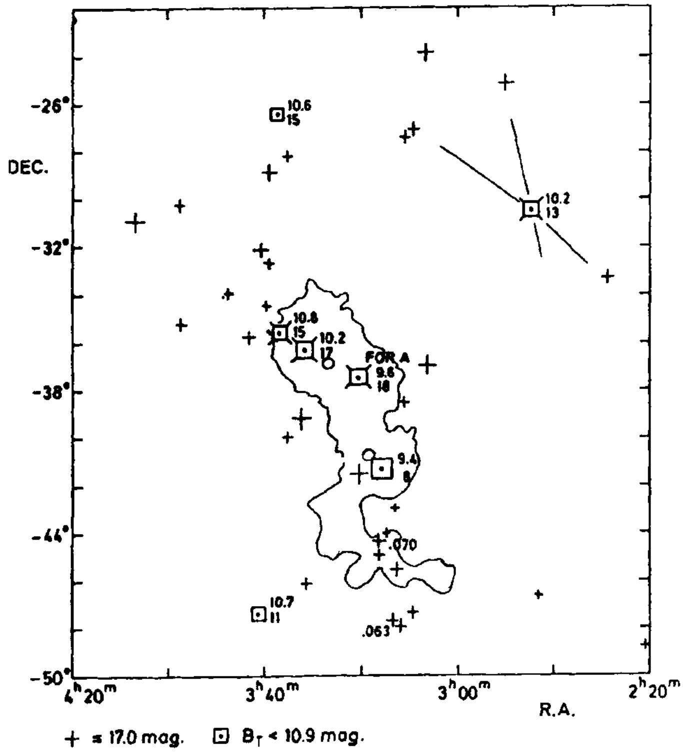

Fig 15 — Abell Clusters Near NGC 1097. All Abell clusters brighter than m = 17.0 and all galaxies brighter than apparent magnitude 10.9 are plotted in the vicinity of NGC 1097. The redshifts are indicated in 100's of km/s below the apparent magnitudes. Abell clusters in the south of the Fornax cluster are also indicated. Strong radio sources are x-marked [12].

tor of 20 over expected background values. The association of quasars with NGC 1097 was established in the early 1980s through the efforts of a number of researchers [12]. By looking at the appearance of spectra the Chinese astronomer X.T. He picked out candidate quasars in the inner 2.85 × 2.85° center of an objective prism plate taken with the U. K. Schmidt telescope in Australia. Arp was later able to verify the vast majority of He's quasar identifications [12].

Subsequently X-ray results from ROSAT confirmed earlier observations by the Einstein X-ray observatory, verifying and extending the large number of X-ray sources in the NGC 1097 field. The brighter sources in the field were more than 50 percent in excess of average control fields, and the brightest quasars fell just between and along the strongest optical jets (Figure 17.) Since it is clear and already accepted that the optical jets are ejected, it would be difficult to argue that the quasars are not also ejected.

5.3.4. Quantization of Galaxy and Quasar Redshifts

The first evidence for quantization of quasar redshifts appeared in 1967. Karlsson [36] observed that the redshift peaks go as $(1+z)/1.23n$, where $n = 1, 2, ...$ The most conspicuous peaks are at $z = 0.061, 0.30, 0.60, 0.96, 1.41$, and 1.96. Galaxy redshifts are found to be quantized also with particular affinity for periodicities of 72 km/s [48] and 37.5 km/s [25]. Hoyle, Burbidge, and Narlikar [32] have outlined a scenario, using a variable mass theory, in which new matter is created within or near high-velocity condensations of old matter. When the old matter condenses, creation commences. This leads to a natural pulsation cycle that creates matter of discrete ages and consequently discrete redshifts. Regardless of the exact mechanism of quasar redshift quantization, if redshifts diminish with time as the variable mass theory requires, the distance between consecutive redshift peaks must also diminish, because the redshifts decay faster at first and then progressively more slowly. The theory predicts that low-redshift galaxies will exhibit small quantized redshift steps, as is actually observed. Conventional cosmology is completely incapable of making these types of predictions.

5.3.5. Narrow Alignment of Galaxies in the Local Group

The companion galaxies in our own Local Group provide one of the most striking examples of alignment along a central galaxy minor axis. All of the

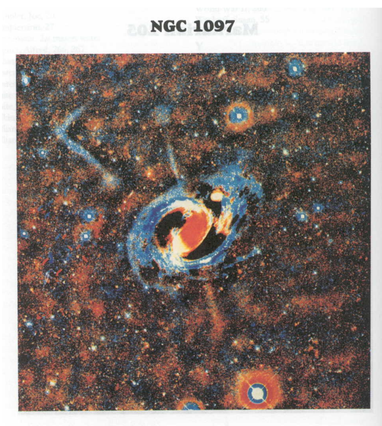

Fig 16 — Color Composite of NGC 1097. True color enhanced, star removed composite photograph of NGC 1097 taken by Jean Lorre with the 4-meter Cerro Tololo telescope [12].

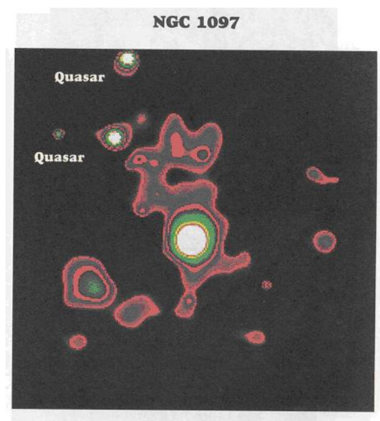

Fig 17 — NGC 1097 Central Region in X-rays. High resolution X-ray image of the central region of NGC 1097 shown in false color with the faintest surface brightness regions in red. Quasars No. 26 and No. 27 are bright X-ray sources in the direction of material leading out from the nucleus [12].

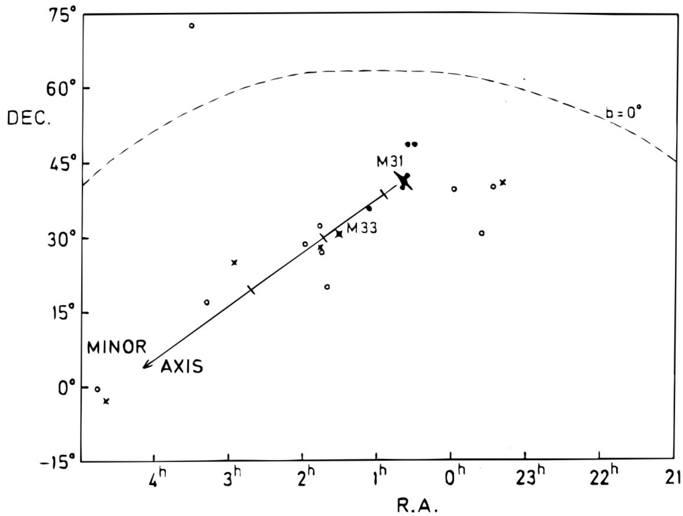

Fig 18 — Conventional Local Group Members. Conventional members of the Local Group (cz0 < 300 km/s) are plotted as filled symbols. Open symbols (dwarfs) and crosses (spirals) represent all galaxies with 300 < cz0 < 700 km/s. The southeast minor axis of M31 is drawn in and the tick marks represent projected distances of 50, 200, and 500 kpc [11].

certain (accepted) companions of M31 (Figure 18) define an exact line directly along the minor axis in the southeast direction. If less certain companions are included, the distribution forms a cone out to ~30º from the minor axis [37]. In the northeast direction there are three H_I clouds that, when measured from the Sun, have the highest redshifts of any H_I clouds in the sky. Our high galactic rotation in this direction in the Local Group in combination with the close proximity of the H_I clouds to M31 indicates that the clouds belong to M31. They have redshifts relative to M31 of –130 km/s to +60 km/s [5], [6].

The exact alignment along the southeast minor axis of M31 has been investigated further [11] by plotting all Local Group galaxies known with $cz_0 < 700$ km/s. Galaxies are conventionally accepted as Local Group galaxies if they have $cz_0 < \sim 300$ km/s, but it has been demonstrated that other groups have characteristic redshift ranges of 800 km/s and above [34] [7]. In any case all of the selected galaxies lie very precisely along the southeast minor axis of M31. Conventional theory has no explanation for this precise alignment of the Local Group galaxies.

5.4. Distribution of High-Redshift Quasars

The Westerbork radio telescope was used to do a uniform search of two star fields. The fields are notable because they contain a splatter of four blue radio galaxies brighter than $F = 16.9$ magnitude and eight quasars and AGNs with redshifts centered around $z = 2$.

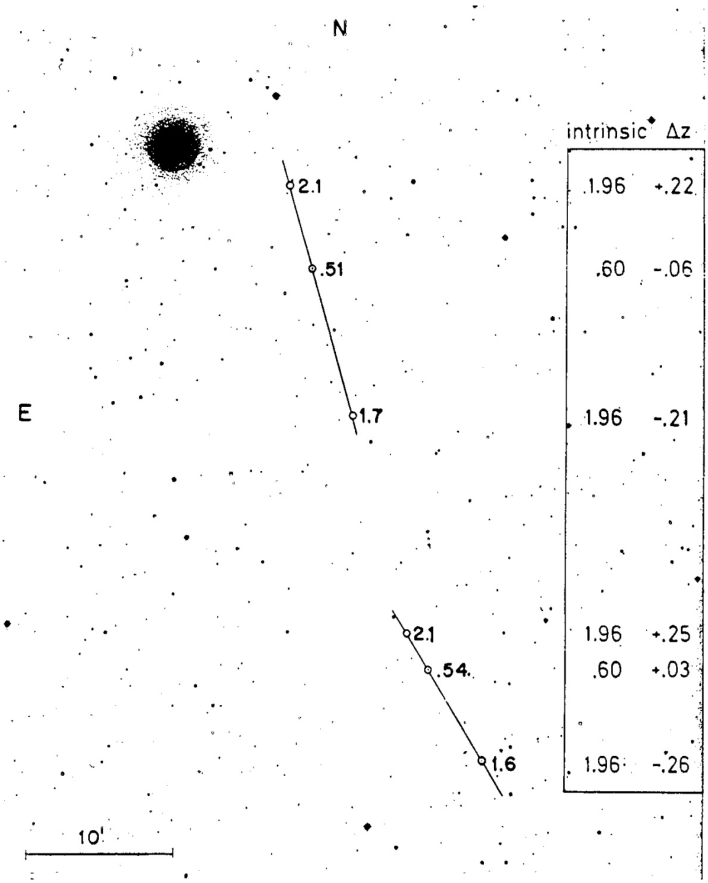

Fig 19 — Arp/Hazard Triplets. The Arp/Hazard triplets discovered in 1980. Note the similarity in the numerical values of the quasars to those of the new triplet (Figure 20). The panel at the right indicates toward and away ejection velocities in z from quantized values of redshift.

One of the galaxies, 53W003, is a radio emitter and blue in color, making it similar to Seyferts and spirals with blue nuclei. The central body of 53W003 is broken into three distinct pieces and large plumes are emanating from it. Such galaxies are rare, and its close proximity to a large grouping of high-redshift objects is of interest because numerous investigations have shown that active galaxies are physically associated with quasars and other high-redshift objects [9] [41].

53W003 is the only blue radio galaxy in the entire Her II field, with a redshift of $z = 0.05$ and an apparent magnitude $F(1600\text{Å}) = 16.1$. The adjoining Her I field has three blue radio galaxies, one with $z = 0.02$ at $F = 15.1$ magnitude, its companion with $z = 0.29$ (quantization rule is 0.30) at $F = 20.9$ magnitude, and a blue radio galaxy with $z = 0.09$ at $F = 16.9$

TABLE 1

THREE-QUASAR TRIPLETS

Quasar	r (arcmin)	Number	$p(r_1, r_2)$	P_{align}	$p(z - z_0)$	$P\Delta z$	P_{tot}
0.51......	...	...	...	...	...		
2.15......	5.9	6	0.18		...		
1.72......	10.3	6	0.54		...		
				1×10^{-3}		...	1×10^{-3}
0.54......	...	...	...		0.012		
2.12......	2.8	6	0.04		0.03		
1.61......	7.0	6	0.24		0.11		
				1×10^{-4}		4×10^{-5}	4×10^{-9}
0.55......	...	...	...		0.016		
2.14......	9.6	4.4	0.35		0.01		
1.84......	12.0	4.4	0.57		0.12		
				2×10^{-3}		2×10^{-5}	4×10^{-8}

Fig 20 — Data on Three Quasar Triplets. Data for the three known quasar triplets. The quasars are identified uniquely by their redshifts. Their distances *r* from the central objects are given in arcminutes. The density of quasars in the first two fields is taken from the discussion in Arp & Hazard [2].

magnitude. There are two quasars in the Her II field with $z = 2.4$ that fall very close to (about 9′ from) 53W003. This is just about the redshift difference and distance away that would be expected if 53W003 were the galaxy of origin of the quasars. Similarly, in the Her I field, there is a $z = 0.55$ quasar near a $z = 0.09$ active galaxy.

The Her I field is one of 20 fields that has been searched for quasars with the Canada-France-Hawaii telescope (CFHT). The search magnitude range was 16 to 21.5 and covered a radius of 27′ centered on Her I, thus overlapping much of the Westerbork radio field for Her I. The CFHT search found three quasars. A $z = 2.31$ quasar lies 6′ away from the northern most Westerbork blue radio galaxy. Quasars with $z = 2.14$ and 1.84 bracket the $z = 0.55$ radio companion of the blue radio galaxy to the east. This means that all of the high-redshift ($z \sim 2$) quasars are in the immediate vicinity of Westerbork blue radio galaxies. An especially notable feature of the CFHT searches is that they were done to fainter apparent magnitude than usual, resulting in even very high redshift quasars being detected. These quasars, being unusually faint, are more distant than most catalogued high-redshift quasars and therefore appear conspicuously close to their galaxies of association [13].

In 1980 Arp and Hazard reported on two pairs of three aligned quasars discovered on objective-prism-plates of the UK Schmidt telescope. The exact alignment of each quasar "triplet" individually is fairly unlikely to be an accident but in combination the two triplets in proximity on the sky are exceedingly unlikely to be by accident. There is also a remarkably

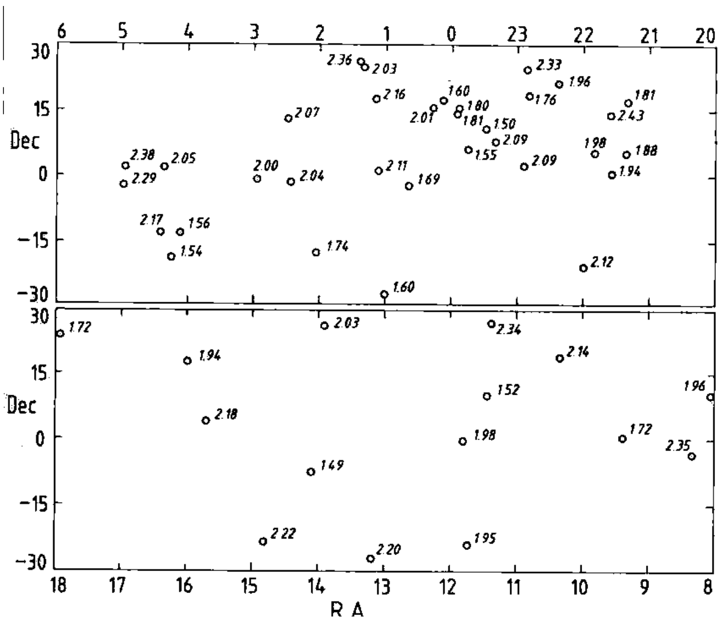

Fig 21 — High-Redshift Quasars Around the Sky. A plot of high-redshift quasars all around the sky. Redshifts are written next to the position of each quasar. The center of the Local Group of galaxies is at roughly R.A. = 0h40m, Dec. = +41°.

close parallel in the distribution of redshifts along each triplet (Figure 19). It turns out that the Her I field also contains a quasar triplet, and this newly discovered triplet has a redshift distribution astonishingly close to the UK Schmidt triplets. Figure 20 shows a table taken from Arp [13] with vital statistics on all three triplets.

If we accept the triplets as actual associations, as is only reasonable, the next step is to make an attempt to interpret their significance. The central quasars are of medium redshift, making them similar to the BL Lac objects discussed in connection with NGC 4235, except that these are in a particularly active state. The panel on the right side of Figure 19 shows the (intrinsic) Δz of the two 1980 triplets. The Δz of the new Her I triplet is ±0.15 for the bracketing quasars, which falls in line nicely with the values of the bracketing quasars in the 1980 triplets.

The two high-redshift quasars in the new triplet obey the quasar quantization rule quite nicely. We can average their redshifts to remove the ejection velocity (Δz) component of their redshifts. This yields a redshift of 1.99, very close to the rule value of 1.96, and the central quasar at $z = 0.55$ is very close to the rule value of 0.60. The 1980 triplets exhibit a similar close fit. If all quasars are lumped together without regard to apparent magnitude, they appear to be roughly homogenous in their distribution over the sky (Figure 21). However, quasars of a given redshift have brighter appar-

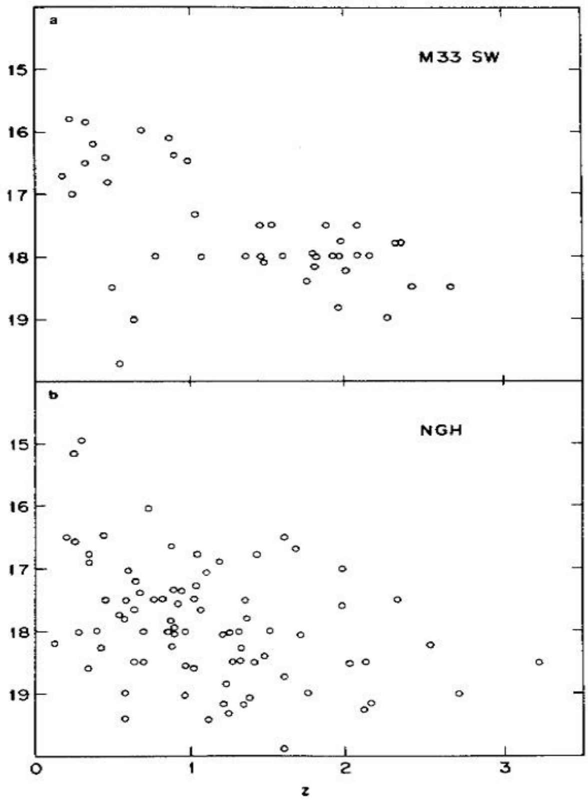

Fig 22 — Apparent Magnitude versus Redshift for Radio Quasars. Apparent magnitude versus redshift for (a) all Parkes and 3CR radio quasars from Hewitt & Burbidge [27] within an area southwest of M33 and (b) all Parkes and 3CR radio quasars over a large area in the Local Supercluster direction (NGH) from Arp [3].

ent magnitudes the closer they are to the observer, so when they are grouped by magnitude the apparent homogeneity dissolves. Figure 22 from Arp [13] plots apparent magnitude *versus* redshift for all Parkes and 3CR radio quasars in an area southwest of M33 (M33 SW) and over a large area in the direction of the Local Supercluster (NGH). There are 3 or 4 times as many $z \sim 2$ quasars in the half of the sky in the direction of the Local Group than there are in the direction of the center of the Local Supercluster (Figure 22). This indicates that there is a concentration of $z \sim 2$ quasars toward the center of our Local Group and a respective thinning out away from the Local Group. To keep this reasoning consistent and in line with the fact that our galaxy is situated near the edge of the Local Group, we should expect not to see $z \sim 2$ quasars as we look further away from the Local Group and at fainter and fainter apparent magnitude. This is in fact the case. For example, if we look in the direction of the Local Supercluster

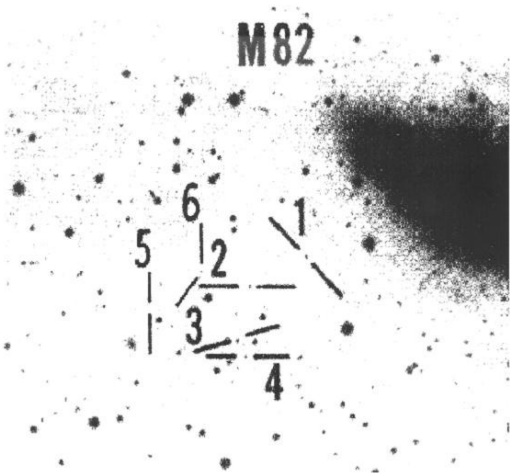

Fig 23 — Faint High-Redshift Quasars. Identification of faint, mostly high-redshift ($z > 2$) quasars near the bright starburst galaxy M82 from Boller *et al.* [17].

center at around 20 Mpc, we do not see $z \sim 2$ quasars until we reach approximately $V = 18$. Figure 22 shows that in the direction of M33 $z \sim 2$ quasars are numerous at this magnitude, whereas in the direction of the Local Supercluster center $z \sim 2$ quasars are virtually absent.

There are 6 high-redshift other quasars to discuss with four in the range $2.04 \leq z < \sim 2.29$. These are situated only 8′ from M82 (Figure 23,) which is a disturbed ejecting, starburst galaxy. The quasar marked number 5 is very faint and its redshift is not certain. The other five are roughly within a 2′ circle, representing a sky density of 1.4 quasars per square degree, or about 30 times the average density of quasars near magnitude 21. This is the same density as in the area south of 53W003 if only the three quasars are taken into account. These close groupings are notably unexplainable with standard cosmology. Additional checks should be made of the redshift of the less certain objects in these areas. Given the overall object density of the area, for each new medium or high redshift established, the case against extrinsic redshifts as the only redshifts becomes that much stronger.

Conventional interpretations cannot explain the phenomena present in the Her I and Her II regions without running into severe difficulties with the uniqueness of the extant observations. For example, let us suppose that the various medium and high redshift objects just discussed are interpreted as very distant unassociated objects representing the large-scale structure of the universe. Let us also suppose that these objects were created in an early epoch of the universe. We would then expect to see many more such groups, and we would on average *not* expect them to be in the same vicinity as close in disturbed or active galaxies or even closely associated with one another. Conventional cosmology cannot deal with the unmistakable tendency of high-redshift quasars to hover closer to ejecting galaxies than do the lower redshift quasars. Conventional cosmology attempts to invoke sheeting and filamentation of galaxies to explain redshift discretization, disregarding the fact that the quantized redshifts found by various investigators [49] [7] [38] are actually small and regular. Arp [13] states a glaring inconsistency on this point:

> The quasar periodicities, with the smallest peak going down to $z = 0.61$, are also very regular, following the empirical Karlssen formula and suggesting that our Galaxy is located at the center of a universe of concentric shells – if the redshifts are interpreted as velocity.

In less polite terms, conventional cosmology is advancing a pre-Copernican philosophy for its explanation of redshift quantization, which by its very definition must fail. A similar fate awaits the suggestion that gravitational lensing can be used to explain redshift anomalies in a velocity-only redshift model.

The objects and associations described here lend themselves to an explanation that at a minimum includes ejection of objects from a central nucleus, and, following as a result of ejection, the close association of the ejected objects on the sky. Arp and others have proposed a set of rules to model these ejections and the resulting properties of these objects. The rules are empirical – they grow out of an attempt to formulate a theory that explains the observations, rather than to mold the observations to fit an extant theory. Arp, Hoyle, Burbidge, and Narlikar have taken the empirical results and developed an extension of Einstein's general relativity to explain them. The empirical rules and the theory explain the extant observations.

5.5. Ejection of X-Ray-Emitting QSOs from AGNs

There are many examples to support the hypothesis that X-ray emitting quasars are ejected from active galactic nuclei. Some of these are described in the discussion of pairing of high-redshift quasars across galactic nuclei. We discuss here Arp 220 and NGC 6217 as examples specific to the subject of ejection.

5.5.1. Arp 220

Arp 220 (IC 4553) is a close by very bright infrared galaxy with $z = 0.018$. It is a strong source of X-rays surrounded closely by a number of fainter objects with larger redshifts. Arp has used the photon event files in the ROSAT archives to analyze the X-ray field around the galaxy. There are four compact X-ray sources in the area that coincide with stellar images on Palomar sky survey plates. They are Arp 2, Arp 9, 20.3N, and 20.3S, the

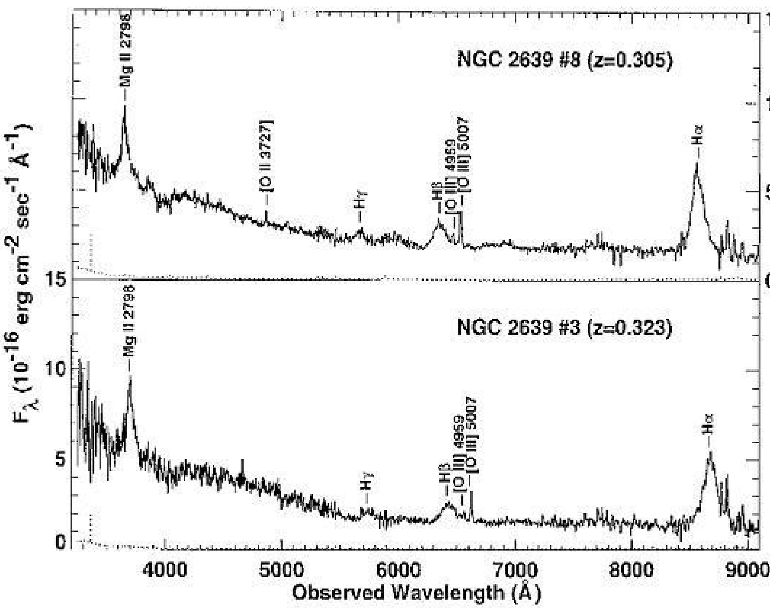

Fig 24 — Spectra of Arp 2 and Arp 9. Spectra of the two quasars, Arp 2 and Arp 9, with z = 1.26 (top panel) and z = 1.35 (bottom panel,) obtained from the 3 m Shane telescope of Lick Observatory [15].

latter two being named for their ROSAT counts per second. The objects are well aligned across Arp 220. The mean redshifts of these four QSOs are respectively $z = 1.26$, 1.25, 0.232, and 0.458. The spectra of Arp 2 and Arp 9 are remarkably similar (Figure 24.) Their redshifts are almost identical, and they are at almost exactly the same angular distance from Arp 220, so this configuration is highly unlikely to be accidental. The second QSO pair is less symmetrical and the redshifts of these QSOs are different, but they are about the same magnitude at 16.3 and 17.7. For two such bright but unrelated QSOs to be in such close proximity on the sky is also highly unlikely. Arp *et al.* [15] therefore think it most likely that all of these objects have been ejected from Arp 220 and that their redshifts are mostly intrinsic. 20.3N and 20.3S conform to the usual pattern of quasar ejection, with the different redshifts bracketing one of the redshift quantization peaks at $z = 0.30$. Arp 2 and Arp 9 may be so similar in redshift because they happen to have been ejected along the line of sight, but it could also be that they were ejected exactly along the minor axis, whereas 20.3N and 20.3S were not ejected directly along the minor axis. In the latter case, the ejected material may have interacted strongly with the material of the ejecting galaxy, reducing the ejection velocity and therefore drastically reducing the redshifts. In the case of Arp 220, this would also explain its extreme disruption.

5.5.2. NGC 6217

Three quasars of $z = 0.358$, 0.376, and 0.380 were recently discovered close to the X-ray jet galaxy NGC 6217. The $z = 0.376$ and 0.380 objects are well aligned across the central galaxy. In a fashion similar to Arp 220 the third quasar and one of the other two are extremely red, suggesting that ejection material was entrained as already described for Arp 220 above.

5.6. Surroundings of Disturbed, Active Galaxies

A froth of new discoveries and papers has recently risen above the sea of main stream thinking that has pervaded cosmology for 50 years. Some of these have been discussed in previous sections. The 1997 paper by Halton Arp on discordant compact groups marks an approximate beginning of this surge. The paper we now review follows in the same vein but is notable in its depth of coverage of the surroundings of disturbed active galaxies in an impressive array of wavelengths: X-ray, optical, infrared, and radio. Ultraluminous infrared galaxies (ULIRGs) have associated material that encompasses apparent diameters of one full degree on the sky. A number of object types appear to be ejected from active galactic nuclei, including gas, dust, X-ray material, and quasars, and the entities are all unquestionably nearer than their velocity redshifts as presumed by conventional cosmology.

A number of studies have been done that suggest a physical association between active galaxies and quasars in areas covering about 1º on the sky. These have been summarized by Radecke [41], Arp [9] [12], and Burbidge [19].

Interpreting the empirical evidence is unquestionably a challenge. We must ask questions like the following:

- Are there transition cases between outlying low redshift associated quasars and similarly redshifted but associated companion galaxies?

- Some central galaxies have high redshifts, high degrees of morphological disturbances, broad line emission spectra, and high luminosity. If these galaxies are placed at their standard redshift distances it is difficult to differentiate their properties from those of a quasar. Would these galaxies then be associated with high redshift quasars? If this is the case we would need to determine the

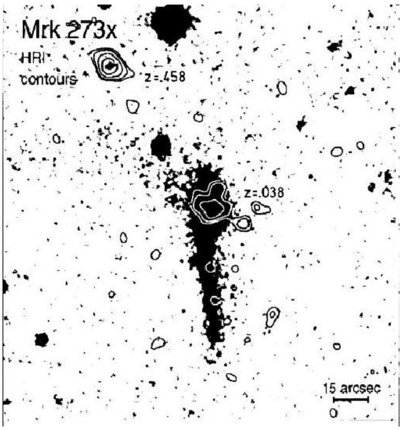

Fig 25 — X-ray Contours of Mrk 273/273x. X-ray contours on a POSS II R image of Mrk 273 and 273x [14]

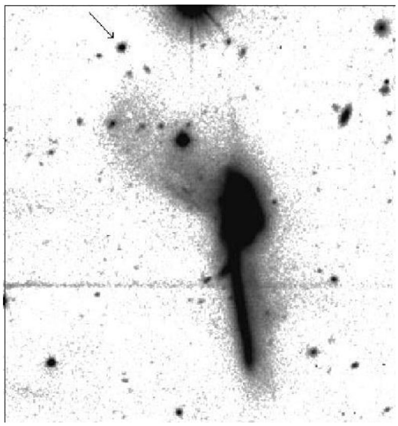

Fig 26 — Deep R Image of Mrk 273/273x. Deep R image from the University of Hawaii 88 inch (2.2 m) telescope. Arrow points to Mrk 273x [14]

nature of the association. We might also legitimately ask if these central galaxy types have both extrinsic and intrinsic redshift components.

The central galaxies just described, when placed at their standard redshift distances, have been classified as "ultraluminous" and have been well investigated. However, the fields around these objects have typically been omitted from analysis. Fortunately there is fairly complete archival data for the brightest ULIRGs, and these have been analyzed by Arp *et al.* [15]. They are Mrk 273, Mrk 231, Arp 220, and NGC 6240. Arp *et al.* have also examined the field around radio galaxy 3C31/NGC 383. We describe in some detail below the observations for Mrk 273 and Mrk 231.

5.6.1. Mrk 273

Mrk 273 with $z = 0.038$ and a compact object Mrk 273x with $z = 0.458$, both strong X-ray sources, are shown with X-ray contours in Figure 25 and optically in Figure 26. Note the strong jet emerging to the south from the central region of Mrk 273. Figure 27 is a smoothed and contoured HR I X-ray image of the same region showing connected isophotes covering the area between Mrk 273x and Mrk 273. If Mrk 273x were a background object, the isophotes would be more rounded and unconnected. The optical object at the position of Mrk 273x has a magnitude of R = 19.6 and a redshift of $z = 0.458$, and this appears to be connected back to a disturbed Seyfert 2, of V = 14.9 magnitude, in both the optical and X-ray images. As with other examples discussed elsewhere in the current paper, Mrk 273x can be argued to be an object ejected from Mrk 273 on the basis of its close

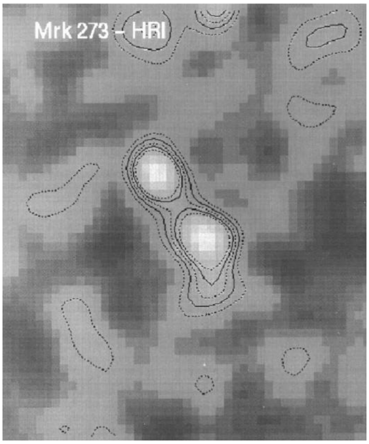

Fig 27 — X-ray Smoothed Contours of Mrk 273/Mrk 273x. Smoothed and contoured HRI X-ray image of Mrk 273 and Mrk 273x [14]

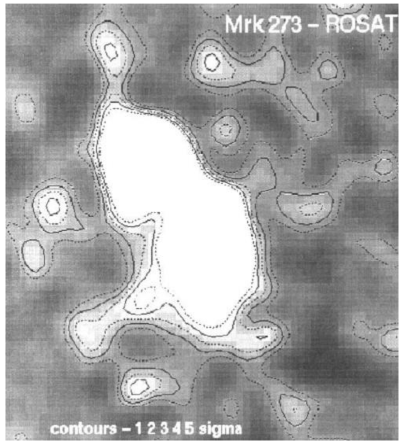

Fig 28 — X-ray Deep Low Resolution of Mrk 273. Deeper, lower resolution PSPC X-ray image smoothed and contoured [14]

association with Mrk 273 and its similarity to higher redshift quasars and quasar-like objects. Also, again as discussed for 20.3N and 20.3S near Arp 220, when disturbed galaxies eject material in a direction other than along the unimpeded minor axis, the ejected material interacts with stationary material of the ejecting galaxy, disrupting this material and generating fragmentation, entrainments, and disturbed morphologies.

An X-ray image smoothed and contoured at lower resolution (Figure 28) shows that Mrk 273x and Mrk 273 are indeed connected and therefore at the same distance. This same image also shows another X-ray jet emerging from the southeast of Mrk 273 and a hint of emerging X-ray to the northwest. Figure 29 is a map of the Mrk 273 region in radio wavelengths. The radio image clearly shows the significant radio contours in these same directions, confirming an overall ejection from Mrk 273 at position angles of about 130º and 310º.

Another conspicuous feature on the Mrk 273 radio image is the strong radio source to the southwest about 5.5′ away. This source happens to be exactly aligned across Mrk 273 with Mrk273x, which is also a strong radio source, again lending support to the conclusion that Mrk 273x is an ejected object.

Figure 30 is another radio contour map that resolves fainter radio extensions to the northwest and southwest. These extensions are in the same general directions as the radio and X-ray jets of Figure 28. Figure 31 is an X-ray Position-Sensitive Proportional Counter (PSPC) field of 50′ radius also centered on Mrk 273. The labeled sources are itemized in Figure 32. The arrow in Figure 30 marks the southeast X-ray jet of Figure 28. The objects marked with crosses in Figure 30 are the objects marked in Figure

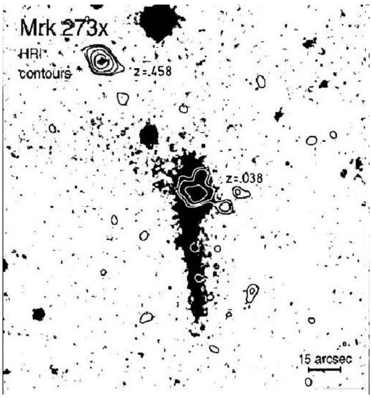

Fig 29 — VLA 20 cm Map of Mrk 273. VLA 20 cm continuum map of Mrk 273 [14]

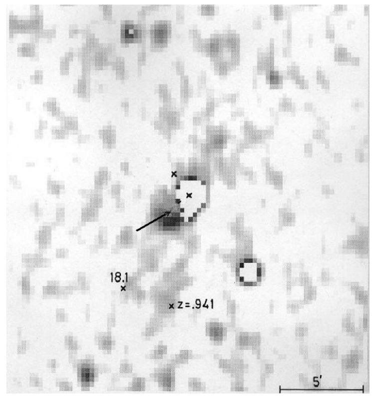

Fig 30 — VLA Radio Map of Mrk 273. VLA radio continuum map of Mrk 273 from survey (NVSS.) Strong X-ray sources are marked with crosses, including a quasar of z = 0.941 and a BSO of E = 18.1 magnitude [14]

31 as 21 (north one of two) and 38 (the only one) and are two very strong X-ray sources that terminate low surface brightness radio filaments extending from Mrk 273. One object is a quasar with $z = 0.941$ and the other is a blue stellar object (BSO) with an apparent magnitude of 18.1. These data are consistent with the southeast objects being a quasar pair and have been confirmed as such by cross correlation of recent data from Burbidge, Chu, and Arp [15]. The probabilities that these two strong X-ray sources and Mrk 273x are background sources so proximal to Mrk 273 are 0.003, 0.01, and 0.04, making the combined chance that only these three objects would project from the background in this way is about one in a million!

Figure 33 is a plot of all infrared sources greater than 0.5 Jy flux density at 100μM in a 1º radius about Mrk 273 identified from the IRAS Faint Sources Catalog of 173,044 sources. This is another clear indication of ejection from the center of Mrk 273 in the southwest direction. It is consistent with the ejection direction of Mrk 273x to the northeast and its radio counterpart to the southwest as well as with the ejection direction of X-ray material.

It is generally accepted that AGNs exhibit radio ejections. The three closest radio sources to Mrk 273 have been investigated by Becker, White, and Edwards [16]. These radio sources lie closely along the same northeast-southwest line already discussed. It is clear from all of these considerations that material is being ejected from Mrk 273 in numerous wavelengths and in numerous self consistent directions. It is no coincidence that this same material includes associated objects of medium

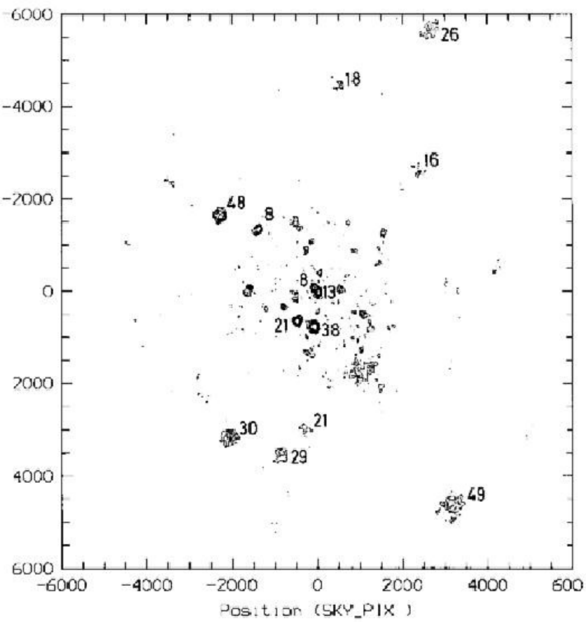

Fig 31 — X-ray Photons Around Mrk 273. X-ray photons in a 50′ radius PSPC field. Brighter quasars from the standard detection algorithm are marked in counts/ks. Mrk 273 is at the center, with 13 counts/ks, and Mrk 273x with 8. The two strong candidate X-ray quasars in are marked '21', referred to in the text as 21N for north, and '38'. The data on the labeled sources are given in Arp [14] Table 1 (Figure 32.) Note the elongation of the source distribution north-east to southwest through Mrk 273 and also pairs of sources southeast to northwest [14].

and high redshift. Again, this is clear evidence that the redshifts are at least partially if not entirely intrinsic and/or ejection-velocity induced.

5.6.2. Mrk 231

Figure 34 is a juxtaposition of high and low resolution radio data, X-ray data, and optical data done by Arp *et al.* [14] to illustrate various relationships to be elucidated in the Mrk 231 system. Mrk 231 is bracketed by a double radio source around 7.5′ to the west and by a triple radio source around 2.2′ to the east. The bottom panel of the figure shows radio material being ejected to the east as well as an apparent ejection in the opposite direction. There is an optically identified BSO to the east that maps to the same position as an X-ray source. The BSO also has radio contours extending to the northeast. A faint but recognizable X-ray jet emerges to the north, again accompanied by radio extensions. There is also an extended radio source south of Mrk 231 [21] and a strong north-south triple source [50] [47]. In general the ejection pattern around Mrk 231 is

TABLE 1

BRIGHT X-RAY SOURCES IN MRK 273 FIELD

Counts ks^{-1}	R.A. (2000)	Decl. (2000)	E	$O-E$	ID	Remarks
49...........	13 41 36.2	55 14 37	16.93	1.99	cg	
26...........	13 42 06.3	56 39 15	16.52	1.20	BSO	47″ off position
16...........	13 42 21.6	56 14 50	19.88	0.73	BSO	
18...........	13 44 13.5	56 30 34	18.30	0.34	BSO	
21S	13 44 57.3	55 28 22	18.9	0.85	?	Extend?
38...........	13 44 47.3	55 46 56	17.76	0.77	QSO	$z = 0.941$
13...........	13 44 42.1	55 53 13	14.9[a]	0.77[a]	S2	Mrk 273
8	13 44 47.1	55 54 10	19.25	1.78	cg	Mrk 273x
21N	13 45 12.0	55 47 59	18.1	0.57	BSO	
29...........	13 45 33.4	55 24 06	19.26	0.66	BSO	
8	13 46 06.7	56 04 29	19.08	0.28	BSO	
30...........	13 46 38.9	55 27 09	19.44	0.32	BSO	
48...........	13 46 59.1	56 07 04	18.21	1.49	BSO	

NOTE.—Units of right ascension are hours, minutes, and seconds, and units of declination are degrees, arcminutes, and arcseconds. BSO: Blue stellar object; cg: compact galaxy.

[a] B and $B-V$ magnitudes.

Fig 32 — Bright X-ray Sources Around Mrk 273. Field Tabulation of bright X-ray sources in the Mrk 273 field [14]

similar to other cases discussed herein, with ejections of material at multiple wavelengths and in multiple opposing directions. Of particular note is the double X-ray source that is aligned through the double radio source back to the Mrk 231 nucleus. One reasonable interpretation of this

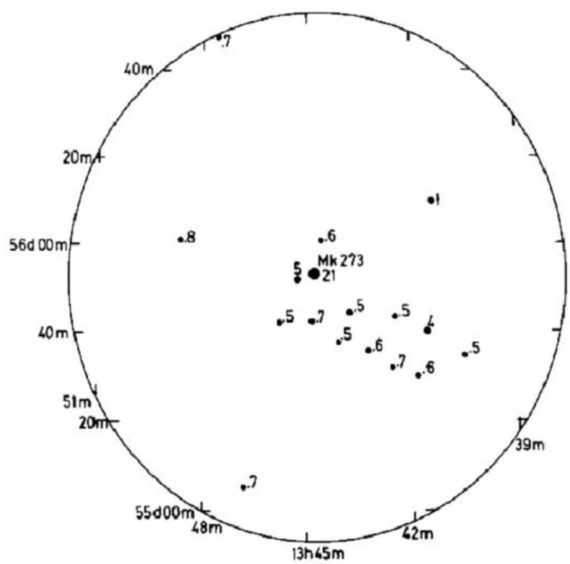

Fig 33 — Infrared Sources Around Mrk 273. Plot of all infrared sources of greater than 0.5 Jy flux density at 100 μm within a 1° radius of Mrk 273 [14]

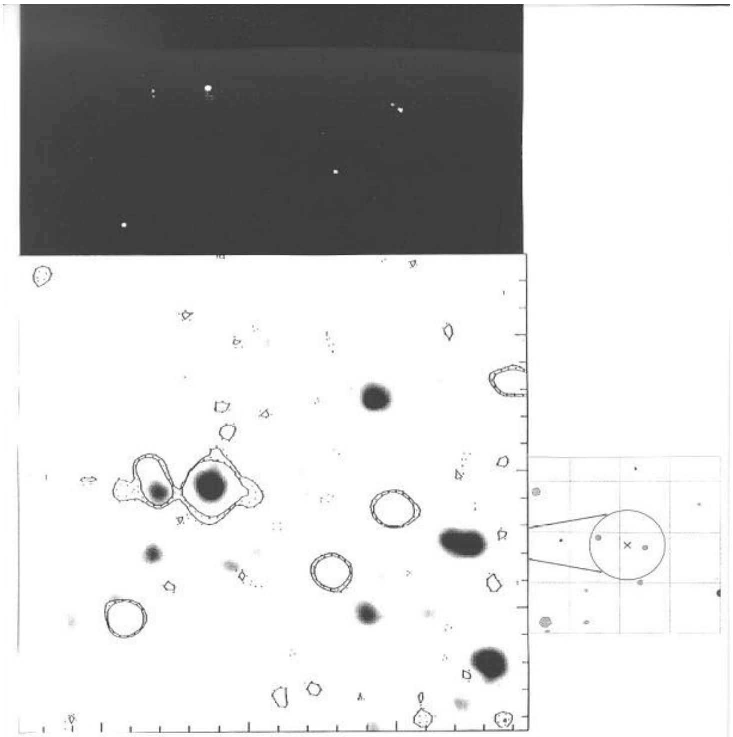

Fig 34.— High-Resolution Radio Around Mrk 231. Top left: High-resolution radio map of 10.4′ x 20.7′ field around Mrk 231, from the 20 cm VLA FIRST survey. Note the pairs of double radio sources flanking the central galaxy. Bottom left: At the same scale as above, a PSPC X-ray exposure (sources are dark) overlaid with contours of radio sources from the low-resolution VLA survey. Right: Optical map of double X-ray source consists of a z = 1.272 quasar and an optical magnitude of 19.9 (BSO) at PA 75° (NVSS) [14]

conjunction is that as it was ejected, and that the X-ray source was stripped of its radio plasma by entrained material. Another similar morphology occurs at a slightly greater angle to the southwest in which an X-ray source is trailed by a radio source at about half the distance from the Mrk 231 nucleus. In these two cases the radio sources lie slightly above a direct line back to the nucleus, suggesting that whatever stripped off the radio plasma was rotating counterclockwise at a low rate. This explanation for the observed morphology either needs to be verified or it needs to be supplanted with one that can be verified. In any case, elucidation of the actual mechanism would help to unravel a number of extant puzzles about the ejection phenomena of active galaxy matter.

The morphology suggested here can be further supported by the detailed observations by Stockton & Ridgway [45] of the radio galaxy 3C 212. Figure 35 shows that the optical objects *f* and *g* have passed out

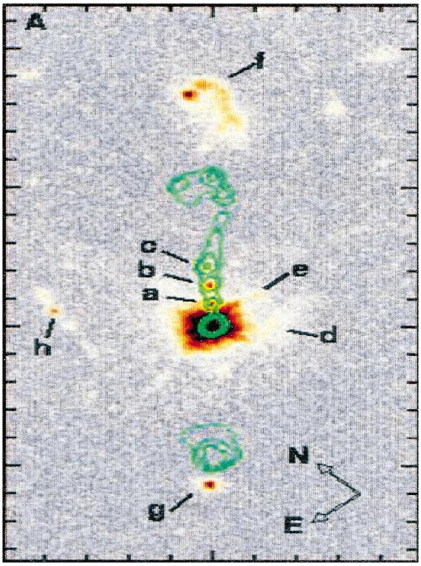

Fig 35.— Optical View of Radio Galaxy 3C 212. Radio contours superposed on an HST image of the radio galaxy 3C 212 [45]. Images marked f and g are optical objects.

beyond the radio material. The radio contours are peculiar and identical in shape and the optical material leaves no doubt that as the optical objects passed through the area of ejection their radio plasma was removed

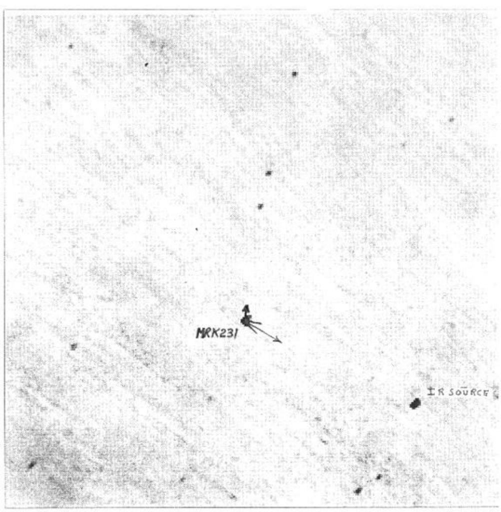

Fig 36 — Infrared Around Mrk 231. The infrared field around Mrk 231 at 60 m of area 6.1° x 6.1° from IRAS.

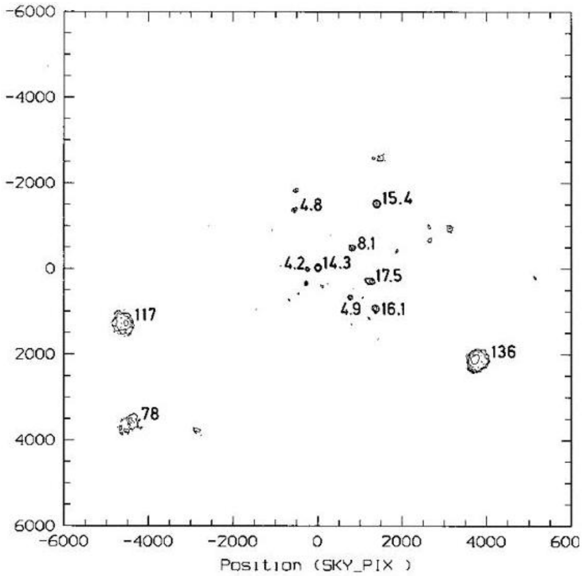

Fig 37 — X-ray Photons Around Mrk 231. X-ray photons within about 50′ from a PSPC exposure. Counts/ks are labeled for brighter sources. Mrk 231 has 14.3 counts/ks. The data on the labeled sources are given in Arp [14] Table 2 (Figure38.)

suddenly. It is also revealing to note that the redshift of the material in the galaxy is $z = 1.05$, whereas the optical object f has $z = 0.93$. Ejection velocities relative to the active objects, and presumably their surrounding medium, have been shown to be of the order of 0.1c [12]. If plasma stripping actually operates in this fashion, then we have a general explanation of why the radio emission, the X-ray objects, and the optical objects are generally, but not always, exactly aligned with one another. If it is found that the plasma-generating events in quasars are intermittent it might help us understand why some quasars are radio sources and some are not, in spite of appearing very similar in other respects. A higher percentage of quasars are identified with X-ray sources than with radio sources. The explanation may be that X-rays and optical synchrotron radiation would decay relatively quickly and become compacted closer in to the dense core of the quasar. Also, the multiple absorption-line systems of some quasars may be explained by periodic gas ejection events.

Figure 36 shows the infrared field around Mrk 231. The long arrow indicates the direction and distance of the 136 counts/ks X-ray source 3C 277.1 and the spread of the radio ejections around this direction. The short arrow shows the northern extent of the radio and X-ray ejection from Mrk 231. The IR source is in the direction of the radio and X-ray ejection at PA 243º. There are also three sources aligned to the north at about PA –10º.

TABLE 2

BRIGHT X-RAY SOURCES IN MRK 231 FIELD

Counts kpc^{-1}	R.A. (2000)	Decl. (2000)	E	$O-E$	ID	Remarks
136	12 52 26.2	56 34 20	16.47	1.17	BSO	3C 277.1
15.4	12 54 49.1	57 04 52	19.72	.47	BSO	
16.1	12 54 51.5	56 44 30	17.03	1.43	Bcg	
17.5	12 54 56.7	56 49 42	19.21	1.53	QSO	$z = 1.272$
17.5	12 55 02.9	56 49 54	19.24	0.65	BSO	See Fig. 12
8.1	12 55 24.7	56 56 14	19.53	0.23	BSO	
4.9	12 55 28.2	56 46 40	...	...	...	No candidate
14.3	12 56 14.2	56 52 25	13.84[a]	0.84[a]	S1	Mrk 231, $z = 0.041$
4.2	12 56 30.8	56 52 19	19.06	0.44	BSO	
4.8	12 56 48.3	57 03 45	19.77	0.63	BSO	
22.3	13 00 33.5	57 28 35	17.35	0.62	BSO	
78	13 00 43.3	56 21 28	19.	Blue	BSO	30″south of brightt star
117	13 00 52.1	56 41 05	16.27	0.88	BSO	See note
117	13 00 54.5	56 41 11	19.03	1.12	BSO	See note

NOTE.—Units of right ascension are hours, minutes, and seconds, and units of declination are degrees, arcminutes, and arcseconds. Optical identifications will be discussed after Arp 220. Of the objects with 117 counts s^{-1}, one or possibly both are QSOs. BSO: blue stellar object; Bcg: blue compact galaxy.

[a] V and $B-V$.

Fig 38 — Bright X-ray Sources Around Mrk 231. Tabulation of bright X-ray sources in the Mrk 231 field [14]

This is close to the inner X-ray and radio ejections toward the north at PA – 5º.

Figure 37 shows the distribution of the brightest X-ray sources around Mrk 231, which registers at 14.3 counts/ks. The extension of X-ray and radio sources is the same as that discussed in reference to Figure 34. The labeled sources are itemized in Figure 38. The strong X-ray source of 136 counts/ks, 36′ southwest of Mrk 231, overlays an optically bright BSO at E = 16.5 magnitude. There is a moderately strong radio source of 22.3 counts/ks 50′ to the northeast [14] that does not register on the PSPC exposure but that is present at the location of another bright BSO at E = 17.4 magnitude.

6. Judgements

Key judgments are often made in support of the conventional cosmology because the cosmology requires them, not because the observations require them. Arguments are subsequently made against alternative cosmologies based on these judgments. Some of the judgments dictated by conventional cosmology are discussed briefly below to emphasize our contention that observational empiricism is really the primary rule of conduct in directing the relationship between observation and theory.

6.1. On the CMB

In 1965 Penzias and Wilson serendipitously discovered the CMB. Subsequently, the Cosmic Background Explorer (COBE) space mission, and more recently the Wilkinson Microwave Anisotropy Probe (WMAP) and Planck space missions, demonstrated that the CMB is extremely smooth. So we have two data points that everyone can agree upon: there is a CMB and it is very smooth. The CMB discovery was heralded as a convincing confirmation that the universe came into being as an explosion of space-time. The COBE data is said to be a definitive demonstration that the universe does indeed have a beginning and that the CMB is a view unto that beginning. In fact the former only showed the existence of the CMB and the latter only showed its flatness. There is no reason to presume *a priori* that the existence or the smoothness of a CMB would not be characteristic of other available cosmologies. To our knowledge no such evidence has ever been either suggested or gathered.

6.2. Why No Blueshifts?

One of the questions posed in support of an extrinsic redshift only universe is "if redshifts are not cosmological (due to velocity), then why don't we also see blueshifts?" The question is meaningless because it presupposes the very idea that it supports, namely that all shifting is velocity induced and can therefore be expected to go in only one cosmological direction, in an expanding (redshifting) or contracting (blueshifting) universe. Let's restate the question with a more enlightened purpose: "if objects exhibit intrinsic redshifts but not intrinsic blueshifts, what does this say about the properties of these objects?" Only after we answer the rephrased question with empirical results from observations can we apply these results to our cosmological models, not the other way around. One possible answer may be embodied in the variable mass theory, discussed below as the underpinning of a new cosmology. This proposed new theory, which is drawn from the empirical observation of ejection phenomena, says that redshifts are proportional to particle masses and therefore also to the time since particle creation [12].

6.3. Creation of the Elements

By late 1945 astronomers had begun thinking about how chemical elements originated. Fred Hoyle noticed that the natural abundances of the elements peaked at mass numbers centered about the number 56. This is in the range where atomic nuclei are strongly bound, suggesting that the elements were produced in conditions of sustained thermodynamic equilibrium between protons and neutrons, suggesting further that the source was astrophysical. Hoyle proposed supernovae as a likely candidate source [31]. George Gamow and others argued instead that electron degeneracy in an early Friedman cosmology universe would allow large lumps of neutrons to form at high density, compensating for the mass-energy difference between a proton/electron pair and a neutron. It was thought that this scenario could explain the heavy element abundances [23]. The existence of gaps in the abundances at atomic numbers 5 and 8 later forced some modifications to the Gamow line of reasoning [24]. The key point in the element origin debate centered on the synthesis of helium as compared to hydrogen, with a ratio somewhere between 0.25 and 0.30. It was known that helium was produced in stars, but it was thought that the stellar production rates were too low to have a significant effect on this fraction. It was also presumed in the Friedman models that rest mass energy is much greater than that from radiation. These ideas in combination with a still very high value for the Hubble constant (~ 550 km/s/Mpc in 1950) lent support to the primordial synthesis argument. Subsequently, the Hubble constant declined significantly and the methods of calculating the He/H fraction and radiation temperature were refined. These developments have not, however, led to a reassessment of the resulting cosmology. Although it is now generally agreed that most of the elements are produced in supernova events, most astronomers and physicists have continued to support a cosmological origin for a selection of light elements: D, ^{3}He, ^{4}He, and ^{7}Li. On the basis that there is no extant evidence showing why nature should single out these specific elements, Hoyle *et al.* [33] argued that even these elements must have been produced astrophysically. An ability to create all of the elements astrophysically in ambient abundances obviates the need for any sort of primordial element creation mechanism.

7. A New Cosmology

The evidence for intrinsic redshifts has been quietly and laboriously piling up for more than forty years [12]. Over the past 30 years, numerous examples have been found of quasi-stellar-objects (QSOs) with large redshifts and demonstrable physical associations with galaxies having much smaller redshifts [33]. Within the last two decades numerous observational and theoretical bombshells have been dropped into the cosmological tug of war. We are now at a crossroads that requires at a minimum an alternative theory to the current conventional big bang cosmology. Such a theory has been offered up, and while it may not be entirely correct in the final analysis, it does have one distinct and essential-to-science advantage over the big bang theory — it explains the extant observations. The big bang theory is based on the Friedman solutions to Einstein's general relativity

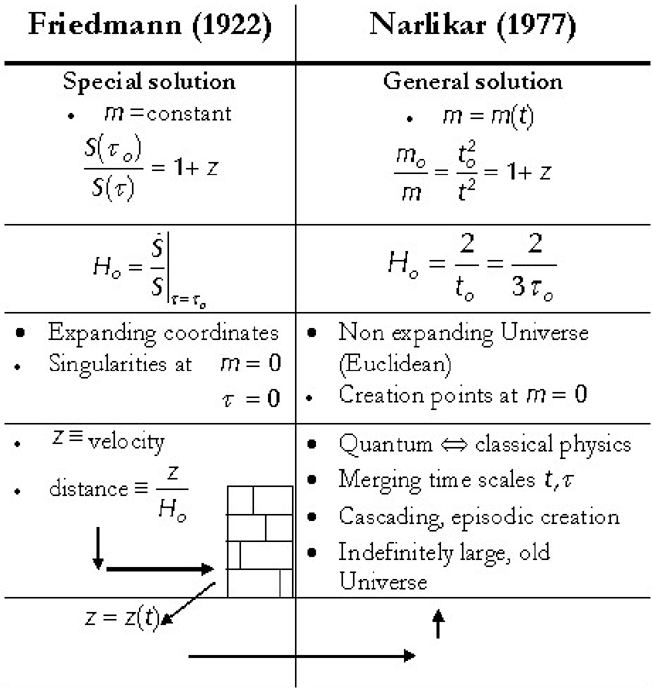

Figure 39 — Constant Mass Theory versus Variable Mass Theory. A schematic summary of the constant mass (Big Bang) theory (left hand side) versus the more general, variable mass solution (right hand side) of the general relativistic field equations. The conventional assumption that particle mass, m, is constant leads to an expanding universe and to direct conflict (Arp's "brick wall" is pictured) with the observation that redshifts are not generally velocity related, but rather primarily age related. The Machian solution on the right gives redshift (z) as a function of age (*t*) and predicts the correct Hubble constant. It turns conventional singularities into creation points of "new" matter and permits connection with non-local theories such as quantum mechanics[12].

theory. The new theory, attributed to Jayant Narlikar, proposes a Machian solution to general relativity. The salient differences between these theories are summarized in Figure 39, which is taken from Arp [12]. The Friedman solutions assume that mass is constant, leading to an expanding universe and to direct conflict with intrinsic redshift observations. The Narlikar (Machian) solutions allow mass to vary, making it possible for redshifts to be age-related phenomena, for the extant observations to predict a local value for the Hubble constant (local to the reference frame of the galaxy in question,) and for connections to be forged with non-local theories such as quantum mechanics. Conventional singularities become creation points for "new" matter [12].

8. Conclusion

The viewpoint that redshifts are unequivocally and exclusively extrinsic is typical of current main stream cosmological thinking. Donald Scott [43] provides us with an example:

> ... There is now no room for doubting that the redshifts of galaxies increase with distance from us. And the only viable interpretation is that the Universe as a whole is expanding... Results from the COBE satellite are one part of the clear picture we now have of how the Universe works.

Well, there is plenty of room for doubt about the unquestioned use of redshift as a distance indicator, and the flatness of the microwave background does not argue for or against any cosmology proposed to date. In addressing the issue of which cosmological theory supports the present evidence best, Michael Hoskin [30] states:

> Both Steady State and Big Bang presupposed the recession of galaxies in all directions; yet even this interpretation of the evidence can awake unease... There has indeed been something of a methodological dilemma: the theoretical cosmologist wanted the observing astronomer to produce the 'facts' that would determine which was the correct model of the universe, but the very reduction of raw observations to produce such 'facts' required the assumption of a cosmological model which the observations were supposed to verify.

There is as yet no definitive answer to the question "What do redshifts represent?" but some excellent ideas have been put forth that appear to match the observations. What is important now is that the proper investigations be carried out to determine the exact nature and origin of all redshifts. This must be done without making assumptions about the underlying cosmology as it pertains to distances. Redshifts cannot be used as distance indicators in these investigations without biasing the data or the conclusions. Either the distances must be determined by an independent measuring method, or distances to redshifted objects must be omitted from any objective analysis until an independent method becomes available. This is what Halton Arp has been doing for the past fifty years, often alone, and often in the face of unwarranted ridicule. Fortunately, there has also been a small contingent of other clear thinking scientists helping him along. Hopefully we will all soon emerge together from the gaping abyss of the redshift rift with a new awareness of how the universe actually operates.

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An Empirical Approach to Periodic Redshifts

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In this paper we attempt a theoretical explanation of the periodic redshifts in QSOs, first claimed by Karlsson (1977) and subsequently reported by several observers. The explanation is based on the variable mass hypothesis first proposed by Narlikar (1977) as an explanation of anomalous redshifts of quasars, and subsequently elaborated further by Narlikar and Arp (1993). As the data continue to build up it is felt that a pragmatic empirical approach is needed to understand the problem rather than a deep formal approach. A few observational examples are worked out in order to see how the simple approach works and also how effective galactic friction is in slowing down ejected quasars. A toy model is then proposed in which the observed Karlsson sequence is simulated by the simple harmonic oscillator of quantum mechanics.

Key words: Galaxy : Quasi-Stellar Objects, variable mass hypothesis, quantized redshifts

1. Introduction

The Quasi-Stellar Objects (QSOs) were discovered in 1963 and in the early days three options were considered for their spectacularly high redshifts: the Doppler effect, the gravitational redshift and the expanding universe paradigm. Eventually, as observational details accumulated, the option centred on the last possibility, *viz.*, the cosmological redshift. This option has one very definitive conclusion, often expressed as Hubble's law:

$$z = F\left(r\right). \tag{1}$$

Here z is the redshift and r a measure of distance which has its standard Euclidean value for small z when the function $F(r)$ tends to Hr/c, H being the Hubble constant and c the speed of light. This prediction implies that two neighbouring sources A and B will have nearly the same redshifts as measured by a distant observer. The qualification "nearly" allows redshift differences arising from the Doppler effect amounting to no more than $\sim 300-500$ km s^{-1}, that are normally expected from random motions in a typical cluster of galaxies.

However, suppose we have the following situation. Let source B be a QSO denoted by Q while A is a galaxy denoted by G. Suppose that the angular separation between the two images is very small, denoted by Δ arcsec. Are these sources physically associated or are they projected close to one another by chance? A statistical way to decide this is to consider the population of all QSOs brighter than Q. Let the number density of all such QSOs be n per square arcsec. Then the probability of chance projection of Q within the observed separation from G is

$$p = \pi.\Delta^2 n\,, \tag{2}$$

where p is expected to be of the order of but small compared to unity. If, however, p is very small compared to unity, say, if $p \sim 10^{-4}$, then as per rules of statistical inference we have to rule out the null hypothesis that Q is a background object that happened by chance to have been projected so close to G. Now if we measure the redshifts of these two objects and find them to be nearly the same then we have a vindication of Hubble's law and the cosmological interpretation of quasar redshifts. And, likewise, if we discover that the redshifts z_G and z_Q are different, then we have a discrepancy within the Hubble interpretation. We will refer to the discrepant cases as anomalous.

Apart from a purely statistical reason, we may also discover morphological reasons showing that the objects Q and G are interacting and are therefore close neighbours. Typical such reasons may indicate a tidal interaction or even more explicitly, a jet connecting the two objects.

Evidently such anomalous cases need to be specially investigated since their confirmation would bring considerable uncertainty in cosmology where redshift is automatically interpreted as a measure of distance. Likewise their rejection will increase the credibility of Hubble's law. Such cases have been reviewed from time to time with conclusions for or against Hubble's law. We are concerned here with anomalous evidence (see for example, Narlikar 1989, Arp 1987, Arp 1998). Over the years, the range of anomalous cases has expanded to include galaxies also and wavelengths beyond the optical, such as radio, x-rays and gamma rays.

The issue has further developed through claims that many of these redshifts appear predominantly in a discrete distribution showing an arithmetic progression (Tifft 1976) for small z and a geometric progression of $(1+z)$ for larger redshifts (Karlsson 1977). Thus it is claimed that redshifts are distributed in a quantized fashion with the majority bunched around a discrete set of values (Z_1, Z_2, ...Z_N, ...), where

$$\left(1+Z_N\right)=\lambda^N\times\left(1+Z_0\right). \tag{3}$$

Here λ is ~ 1.228, and $Z_0 = 0.06$. Evidently, if such an effect is real, it will be beyond the capability of the conventional Hubble law to explain it.

The majority of cosmologists choose to ignore these anomalous cases on the grounds that (1) there are comparatively very few of them, or that (2) they involve post-facto computation of probabilities, or that (3) the observed results are caused by some artefact, or (4) gravitational lensing increases the very low probabilities. For example in the fourth alternative, the effect of gravitational lensing is to amplify the luminosity of the source and so in the above example, the number density n used in (2) should relate to a population of intrinsically fainter QSOs and thus should go up. This correction helps increase the chance projection probability p to a value high enough to sustain the null hypothesis. However, this way out cannot explain all the anomalous cases as pointed out by Ostriker (1989).

The anomalous part of a given redshift may be defined as follows. Suppose a QSO Q with redshift z_Q is seen near a galaxy G with redshift z_G such that the two are believed to be physical neighbours. Further, it will be assumed that the QSO was created and ejected by the galaxy and its redshift contains an intrinsic component. Thus, in general, $z_Q \gg z_G$ so that the cosmological interpretation fails to explain all of the QSO redshift. In that case we define the anomalous part of the quasar redshift as an intrinsic redshift z_I given by the relation

$$\left(1+z_Q\right)=\left(1+z_G\right)\left(1+z_I\right). \tag{4}$$

Without entering into discussions of specific cases of anomalous redshifts, we will take a point of view that they are significant enough in their occurrence to warrant a theoretical explanation of them. Here, the alternative interpretations of redshifts, the Doppler and the gravitational, are already seen to be inadequate to explain the anomalies (Narlikar 1989). The objections to the Doppler and gravitational options basically come from these reasons. The Doppler effect can be both positive and negative, producing cases of blueshifts as well as redshifts. Moreover, in a population of uniformly luminous QSOs, those with blueshifts are brighter and therefore selectively easier to spot. Despite these 'advantages' we do not see any blueshifted QSOs. As for the gravitational redshift, the work by Bondi (1964) has placed stringent upper limits of the order $z \leq 0.63$ for surface gravitational redshifts of objects in equilibrium under the usual kind of forces. Although larger redshifts are possible for light rays emerging from the interior of a massive object such a scenario looks contrived (Das 1976).

So we will consider a new alternative to be described in the following section.

2. The Variable Mass Hypothesis

As stated earlier, it will be argued that the QSOs found in the vicinity of a galaxy were created and ejected by it. This mechanism is based on the Machian theory of gravity proposed by Hoyle and Narlikar (1964, 1966), which was adapted by one of us (JVN) to explain the anomalous redshifts in the above context. Rather than repeat the details here, we quote the relevant papers: Narlikar (1977), Narlikar and Das (1980) and Narlikar and Arp (1993, 1997). For discussing the dynamics of ejection we shall adopt the paradigm used by Narlikar, *et al.* (2002), referring to this paper as Paper I.

The field equations of the Hoyle-Narlikar theory are given by

$$\begin{aligned}\frac{1}{2}m^2\left(R_{ik}-\frac{1}{2}Rg_{ik}\right)&=-3T_{ik}+m\left(\Box m g_{ik}-m;_{ik}\right)\\&\quad+2\left(m;_i\, m;_k-\frac{1}{4}m;^l\, m;_l\, g_{ik}\right)',\end{aligned}\tag{5}$$

where m is the mass of a typical particle. Although one could generalize (5) to include masses of several different particle species, the above single particle species approximation is sufficient to illustrate the basic idea. The equations (5) admit the simplest solution as the Minkowski spacetime whose metric we will write as:

$$\mathrm{d}s^2=c^2\mathrm{d}\tau^2-\mathrm{d}r^2-r^2\left(\mathrm{d}\theta^2+\sin^2\theta\mathrm{d}\phi^2\right).\tag{6}$$

The mass-function in (5) is given by

$$m=a\tau^2\,,\tag{7}$$

where a is a constant related to the density of the universe.

The emergence of a 'static' solution may cause some doubt as to why the static universe does not collapse. The reason lies in the mass-derivative terms in equation (5) which are non-zero. These 'support' the spacetime against any tendencies of inward contraction. The next doubt comes from the origin of the redshift. How can we get a redshift *without* expansion or any other large scale motion of the universe? This is where the variable mass shows its effect.

The static universe given by the line element (6) has a 'beginning' at the cosmic epoch $\tau=0$, when all particle masses are zero. Notice that there is no spacetime singularity like that in the big bang universe: instead we have a zero mass hypersurface $m=0$ at this epoch. Mass continues to increase with epoch so that we are led to the following situation. At the present epoch $\tau=\tau_O$, say, an observer O (like us) sees a galaxy G at a distance d. Because of the look back time d/c, the observer sees the galaxy at epoch $\tau_G=\tau_O-d/c$. The ratio of masses of particles, say electrons in the reference frames of O and G, is

$$\frac{m_O}{m_G}=\frac{\tau_O^2}{\tau_G^2}\,.\tag{8}$$

Now consider the wavelengths in the typical spectrum of a hydrogen atom. The wavelengths λ of lines in it will be proportional to m^{-1} and so the light from the galaxy G will have wavelengths longer than those generated in O by the factor

$$1+z=\frac{\lambda_G}{\lambda_O}=\frac{m_O}{m_G}=\frac{\tau_O^2}{\tau_G^2}=\frac{\tau_O^2}{\left(\tau_O-d/c\right)^2}. \tag{9}$$

This is the redshift observed by O as per the variable mass effect. For this reason the idea is known as the *Variable Mass Hypothesis* which we will shorten to VMH.

As argued by Hoyle and Narlikar (1971) this redshift is in fact the same as that deduced in an expanding universe with constant particle masses, because the Hoyle-Narlikar theory is *conformally invariant* and the standard model of relativistic cosmology can be obtained from (6) by the following conformal transformation:

$$\mathrm{d}s_{GR}^2=\Omega\mathrm{d}s;\ \Omega=\beta\tau^2, \tag{10}$$

where β is a constant. The particle masses transform under this law as $m\propto\Omega^{-1}$, so that a constant mass results if we take Ω as above. The general relativistic metric therefore becomes

$$\mathrm{d}s_{GR}^2=\beta^2\tau^4\left[c^2\mathrm{d}\tau^2-\mathrm{d}r^2-r^2\left(\mathrm{d}\theta^2+\sin^2\theta\mathrm{d}\phi^2\right)\right]. \tag{11}$$

A coordinate transformation

$$t=\frac{1}{3}\beta\tau^3 \tag{12}$$

transforms the line element (11) to the familiar Einstein de Sitter form:

$$\mathrm{d}s_{GR}^2=c^2\mathrm{d}t^2-\left(9\beta\right)^{2/3}t^{4/3}\left[\mathrm{d}r^2+r^2\left(\mathrm{d}\theta^2+\sin^2\theta\mathrm{d}\phi^2\right)\right]. \tag{13}$$

The *t*-time in this case is the standard cosmic time of Friedmann cosmology and the redshift formula gives the same answer as (9) above. By requiring a constant particle mass at all epochs we are forcing the spacetime into a non-Euclidean form. It is the same requirement that leads to a spacetime singularity. As shown by Kembhavi (1978) under very general conditions, the zero mass hypersurface (in our above case the hypersurface at $t=0$) becomes singular under the conformal transformation $\Omega\propto m$ and *all* singularities covered by the singularity theorems are explained this way.

We now augment the above flat spacetime cosmology by adding the following postulate. Instead of assuming all matter to have originated at $\tau=0$ we open the possibility that matter is also created and ejected at later epochs through mini-explosions in the nuclei of existing galaxies. Thus in our earlier situation, we now consider the event of creation and ejection of a QSO at epoch τ_Q. The QSO is made of particles similar to those making up the galaxy *G*; however, these particles start with zero rest mass at τ_Q and these masses grow as the Machian interaction brings more and more distant particles into the ambit of the created QSO. A formal mathematical structure of the framework bringing this about is described in Narlikar (1977). Evidently, in place of equation (7), the particles in the QSO will have masses growing with time as

$$m_Q = a\left(\tau - \tau_Q\right)^2 \tag{14}$$

and correspondingly the redshift of the QSO as observed by O will be

$$1 + z_Q = \frac{m_O}{m_Q} = \frac{\tau_O^2}{\left(\tau_O - d/c - \tau_Q\right)^2}. \tag{15}$$

Thus it is that the quasar Q and galaxy G are at the same distance d from the observer but the observer finds the QSO to have a larger redshift than the galaxy. The observer as per formula (4) would ascribe an intrinsic redshift to the QSO of magnitude

$$z_I = \frac{\left(\tau_O - d/c\right)^2}{\left(\tau_O - d/c - \tau_Q\right)^2} - 1. \tag{16}$$

We should point out that if we go to the Einstein de Sitter conformal frame as done earlier, the galaxy masses will be constant but the quasar masses would increase with time in that frame. We now introduce the concept of periodic or 'quantized' redshifts.

3. The Karlsson Formula

To describe periodic redshifts, we first consider the data in a simple Minkowskian model. Table 1 lists accurately determined redshifts of pairs of quasars across active galaxies whose redshifts are also measured. The table lists the redshifts of the central galaxy (z_G) and the measured redshifts of the paired quasars (z_1, z_2). These observed quasar redshifts are then corrected to the central galaxy by means of $(1 + z_Q) = (1 + z_i)/(1 + z_G)$; $i = 1,2,...$ and compared to the nearest peak of quantized redshift which is identified from the sequence Z_n given by the difference relation:

$$\Delta\log(1 + Z_n) = \text{constant} = 0.089,\ Z_0 = 0.06. \tag{17}$$

This is the Karlsson formula (Karlsson 1977) and it generates the following sequence of redshifts for $n = 0, 1, 2,...$:

$$Z_n = 0.06, 0.30, 0.60, 0.96, 1.41, 1.96, 2.64, ... \tag{18}$$

The claim has been that the redshift distribution of quasars shows significant peaks at these redshifts (Arp, *et al.* 1990). In other words, the red-

Table 1.
Well Defined Pairs With Redshifts*

Galaxy	z_G	z_1	(peak)	z_2	(peak)	vel^1_{ej}	vel^2_{ej}	P(peaks)
NGC4258	0.002	0.653	(0.60)	0.398	(0.60)	0.031	−0.128	0.29
NGC4235	0.007	0.334	(0.30)	0.136	(0.30)	0.019	−0.132	0.28
NGC1068	0.0038	0.655	(0.60)	0.261	(0.30)	0.030	−0.034	0.09
NGC2639	0.0106	0.3232	(0.30)	0.3048	(0.30)	0.007	−0.007	0.005
IC1767	0.0175	0.669	(0.60)	0.616	(0.60)	0.025	−0.007	0.014
Mark205	0.070	0.464	(0.30)	0.633	(0.60)	0.052	−0.046	0.22
PG1211+143	0.085	1.28	(0.96)	1.02	(0.96)	0.072	−0.050	0.18
A/H#1	0.51	2.15	(0.96)	1.72	(0.96)	0.064	−0.081	0.26
A/H#2	0.54	2.12	(0.96)	1.61	(0.96)	0.034	−0.135	0.22
Her	0.55	2.14	(0.96)	1.84	(0.96)	0.034	−0.065	0.11

*Note: First 7 objects are discussed in Arp (1998) and last three in Arp (1999).

shifts of quasars seem to be preferentially distributed close to the members of this sequence. We take a cue from this claim in formulating the following hypothesis: The difference between z_Q and the nearest peak is assumed to represent the true Doppler ejected velocity of travel, i.e. $(1 + z_{ej}) = (1 + z_Q)/(1 + Z_p)$. These values are listed in the vel_{ej} columns, 7 and 8, of Table 1.

Barring the first two cases, Table 1 shows that the z_Q's associated with the nearest peak give one object moving away from the observer and one moving toward the observer. The only ambiguous cases are the low redshift members of the NGC 4258 and NGC 4235 pair which would be closer to a peak if they were falling back in, rather than still on the way out. It is also possible to argue that the low velocity of one member of the pair (0.031 compared to −0.128 for NGC 4235) is because it ran into resistance.

Further confirmations of the peaks in (18) have been made on large samples (Fulton and Arp 2012). Nevertheless it is impressive to see the conformity of the pairs listed in Table 1. The statistical significance of the peaks can be shown by the following calculation. In the last column following Arp, we calculate what the accidental probability is for the z_Q's of the two quasars to fall as close as they do to the nearest Karlsson peak. This is calculated by taking the difference between z_Q and the nearest peak Z_p in the reference frame of the galaxy and dividing it by 1/2 of the interval to the next nearest peak. Each member of the pair is treated as an independent trial and the combined probability of both falling as close to their peaks as they do is computed. The average probability of finding a pair of random redshifts in this interval is normalized to 0.5, so that the last column, P (peaks), gives the probability of finding the real pair of redshifts as close as is observed. Thus for NGC 1068, the first quasar is 0.030 away from the peak $Z_2 = 0.60$ in the range (0.60, 0.96). Hence the probability for it is 0.030/0.18. Similarly for the second quasar, the velocity of ejection −0.034 is negative with respect to the peak redshift 0.30, the relevant interval is (0.06-0.30) and the probability is 0.034/0.12. There being two trials, the chance probability is $2 \times (0.030/0.18) \times (0.034/0.12) = 0.09$. The joint probability for accidental occurrence for just the first five pairs is 9×10^{-6}. The last 5 give 4×10^{-3}. The chance that these pairs taken together accidentally fall so close to the quantized values is about 7×10^{-8}.

In addition to this quantization of the intrinsic redshifts, it is readily noticeable that the magnitudes of the ejection velocities in the pairs are fairly well matched, with the away velocity being similar in magnitude to the toward component. This is very impressive because there are several factors which could cause a mismatch even if the quasars were ejected initially at the same instant with the same velocity. One factor is that the initial ejection might not be exactly in opposite directions. That would cause different projections of ejection velocities to be observed in the away and toward directions. Another factor might be a collision or perturbation of the quasars on the way out. In general for these pairs these considerations do not seem major, although they could be involved in the few cases where the match is not as good as on the average. Another point, of course, is that the intrinsic redshifts must evolve downward in steps as they travel outward. Depending on how fast they transit from peak to peak, there will be some chance of catching some in transition between peaks.

Figure 1 shows a plot of the projected velocities as a function of the intrinsic redshift peaks to which the quasar belongs (as derived in Table 1). The most extreme negative velocity of ejection for the $Z_1 = 0.30$ peak is circled in Figure 1. If we exclude that point as anomalous, then we can describe Figure 1 as showing that the projected escape velocities of the quasars diminish as their intrinsic redshifts get smaller. We argue that the intrinsic redshifts get smaller with time so that this will demonstrate that the escape velocities of the quasars slow down as they separate and grow older.

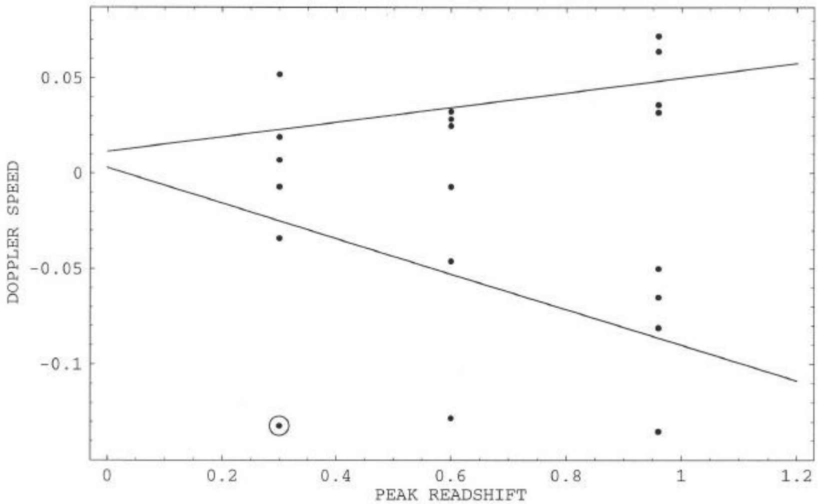

Fig. 1.— The Doppler speeds as shown in Table 1 are plotted against the peak redshift. One point shown circled seems anomalously high. If this is excluded, then there emerges a clear trend that the higher the intrinsic peak redshift, the higher the average Doppler speed, as shown by the 'average' lines in the figure and also by the entries of Table 2.

The most important quantity derived so far from the group of pairs in Table 1 then would be the average velocity of separation from the ejecting galaxy as a function of redshift. This is summarized in Table 2 below.

In terms of an empirical model this means that the ejected quasar must have slowed down from its original velocity, whatever that was, to about 28,000 km s^{-1} by the time the redshift evolved into the $z = 0.96$ peak. After that within a few hundred kpc, it must rapidly slow down to about 10,000 km s^{-1}. If the quasars are then to evolve into bound companion galaxies, they must essentially lose all their velocity by an apogee of about 500 kpc.

As seen from calculations in sections 2 and 3 of Paper I, the quasars arrive at their observed separations from the ejecting galactic nucleus with very low velocities. This is because, in a homogeneous universe, the particle masses take a long time to grow and therefore for the quasar intrinsic redshifts to decay to their observed values. In this long interval the outward velocities reduce to very small, calculated values. This result was therefore inconsistent with the conclusions from Table 2. Clearly, therefore, some change in the picture we have discussed so far is necessary. We will outline one possible way next.

Table 2.
Ejection Velocities

Peak	Projected Δz		Average absolute value	Deprojected Average Velocity ($\times\sqrt{2}$) (kms^{-1})
0.30	0.026	−0.021	0.023	9,729
0.60	0.029	−0.060	0.045	19,077
0.96	0.051	−0.083	0.067	28, 405

4. Quantized Ejection from the Parent Nucleus

One way to account for this difference is to have the quasars trapped in the nucleus, mature in incubation orbits, and then be blown out in later explosions at their observed velocities. For example, in the quasi-steady state cosmology proposed by Hoyle *et al*. (2000), it is argued that the creation of matter takes place at the expense of a scalar field of Machian origin as in the present theory. The creation of matter enhances the negative energy of the scalar field to a level when, because of the repulsive nature of negative energy, the parent nucleus fragments and ejects a coherent piece. We will assume here that the creation mechanism in the parent galaxy works in this way and that some quantum process controls the stages when ejection takes place. These stages, when the parent galactic nucleus ejects a proto-quasar, are precisely those when its redshift is at one of the Karlsson peak values. For convenience, in the following calculation we will use the t coordinate instead of the τ coordinate, of section 2.

Thus, unlike the situation discussed in the original Narlikar-Das picture, when a quasar is born at time t_Q, it is not immediately ejected with luminal speed, but is held captive in the parent galactic nucleus till an epoch t_E when it is ejected. By this time its redshift will have decreased to a value z_E given by

$$1+z_E = \frac{\left(t_O\right)^{2/3}}{\left(t_E^{1/3} - t_Q^{1/3}\right)^2}. \tag{19}$$

We assume that the instant t_E is determined by the requirement that z_E is a member in the Karlsson sequence Z_n. If this quasar is ejected with velocity v, at an angle with the line of sight, it will travel in that direction. During this motion, light left the quasar so as to reach the observer at the present epoch. The equations worked out by Narlikar and Das (1980) will describe the equation of motion of this quasar. For details of a worked out example see Paper I. Using the method described there, we suppose that the distance travelled by the quasar is R. Then we have the observed radial separation projected perpendicular to the line of sight, as given by

$$d_G \times \theta_{QG} \approx R \sin\alpha\,, \tag{20}$$

where d_G is the redshift distance of the parent galaxy, and θ_{QG} the angular separation of the quasar from the galaxy.

Integration of the equation of motion will also tell us the speed w of the quasar at this epoch. Using the Doppler effect formula, we can then relate the observed redshift z_Q to w and α by

$$1+z_Q = \frac{t_O^{2/3}}{\left(t_G^{1/3} - t_Q^{1/3}\right)^2} \cdot \left(1 \pm \omega\cos\alpha\right), \tag{21}$$

where we have used the composite formula for redshift, arising from the Doppler effect as well as from the VMH. Note that, for this calculation we can use the local spacetime [R, T] coordinates introduced in equation (9) of Paper I.

Now we use the data of Table 1 to pose the following problem. Imagine that two quasars were born at the same epoch t_Q and ejected in opposite directions at the same epoch t_E. Thus their ejection angles to the line of sight would be

$$\alpha_1 = \alpha, \qquad \alpha_2 = \alpha + \pi, \tag{22}$$

respectively. The question is, can one use the available data to determine all the ejection parameters (t_Q, t_E, α) in such a case? The answer is "yes", and the procedure is as follows.

For each quasar of the pair, assume a value for t_Q to begin with. Next choose the value from the Karlsson series that lies between the two observed quasar redshifts for z_E, and assume an arbitrary trial value for the velocity v of ejection. Then equation (19) will determine t_E. Next solve the differential equation of motion and determine both R and w, and use each of the equations (20) and (21) to determine α. In general these two values would not agree for the chosen ejection velocity v. So change the trial value of v. By varying this parameter, it is possible to arrive at a unique value when both the equations (20) and (21) yield the same value of α. Thus for our chosen t_Q we determine α for each quasar. Next vary the values of t_Q and essentially determine α as a function of t_Q. Each quasar will give a [t_Q, α] curve. Where the two curves intersect we have all the required parameters fully determined. The procedure is illustrated in Figure 2 for one pair from Table 1.

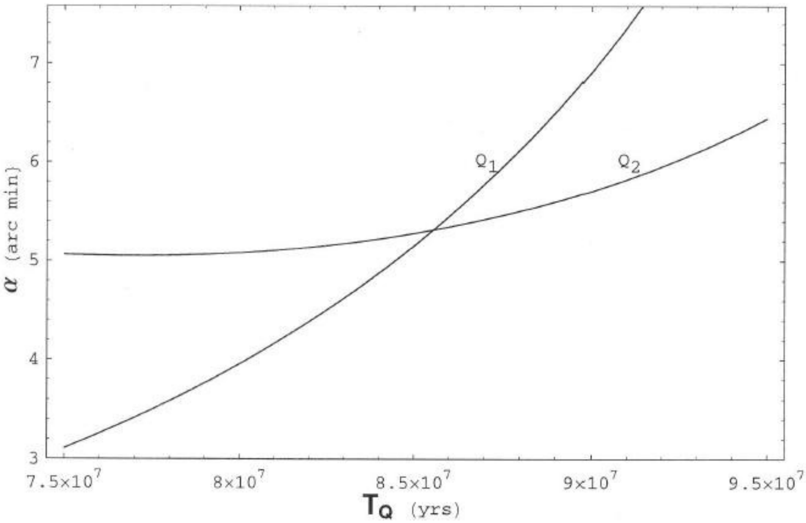

Fig. 2.— Illustration of ejection details of the first pair of quasars from Table 1 (those associated with NGC 4258). The two curves show how α changes with T_Q for each quasar of the pair. The point where the curves intersect gives the unique values of a and T_Q representing a simultaneous ejection in opposite directions.

We have carried out this analysis for the first three cases from Table 1, to illustrate the argument. The results are summarized in Table 3. Here the first column gives the name of the parent galaxy and its redshift, the next section, subdivided into four columns, gives the details of the ejected quasar #1, namely its redshift z_Q, angular separation θ_{QG} from the parent galaxy, its speed v of ejection and its speed w at the time of observation followed by similar details of the second quasar #2, while the third section subdivided into four columns, gives the values of α, t_E and t_Q for the pair and the peak redshift Z_p chosen from Karlsson's sequence. We may consider Table 3 the refined version of Table 1, which takes into consideration the dynamics of ejection of variable mass objects.

The following features stand out from these calculations:

1. The broad picture emerges in which galaxies eject quasar pairs when their redshifts have decreased to a value close to one of the peak redshifts.
2. The ejections are in opposite directions. If momentum is conserved, then we can assert that the masses of the two quasars ejected should be inversely proportional to these velocities. This

Table 3

Ejection Details of Quasar Pairs

Galaxy & (redshift)	Quasar pairs	θ_{QG} (arc min)	v (km/s)	w (km/s)	α (arc min)	t_Q (yrs)	t_E (yrs)	Z_p
NGC 4258 ($z_G = 0.002$)	Quasar # 1 ($z_Q = 0.65$)	9.7	26453.5	26178.2	5.32	8.6×10^7	1.2×10^{10}	0.60
	Quasar # 2 ($z_Q = 0.40$)	4.5	23458.1	23211.3				
NGC 4235 ($z_G = 0.007$)	Quasar # 1 ($z_Q = 0.334$)	46.1	27477.3	27288.4	66.2	1.0×10^7	1.2×10^{10}	0.30
	Quasar # 2 ($z_Q = 0.136$)	35.9	21422.7	21267.1				
NGC 1068 ($z_G = 0.0038$)	Quasar # 1 ($z_Q = 0.655$)	43.9	38399.4	37809.5	19.74	6.8×10^7	1.2×10^{10}	0.60
	Quasar # 2 ($z_Q = 0.261$)	49.4	43223.9	42563.4				

prediction may be tested by looking at the morphology of the ejected quasars to estimate their mass ratios.

3. The three cases studied in detail bear out the prima facie picture of 'ejection in opposite directions'. As emphasized in the previous section, there is no *a-priori* reason why this should turn out to be the case on a random basis. The differences from the peak redshift are made up partly by the VMH and partly by the Doppler effect.

5. The Effect of Galactic Friction

So far we have assumed that an ejected quasar travels through the parent galaxy without any resistance. However, it is worth exploring the effect of the interstellar medium by way of a frictional force. Does it reduce the speed of the ejected quasar significantly?

To find the answer to the above question we have formulated a model in which the frictional force in the galaxy is proportional to the velocity of the quasar and it is directed in the opposite direction to its motion. Formally it may be represented by a force $\Lambda \dot{R}(t)$ in the direction opposite to that of the moving quasar. The constant Λ is 'put in by hand', i.e., it is given a series of values to examine the effect of the frictional force. For any Λ we can restore the scale factors in the equation of motion to determine the relative magnitudes of friction and gravity. Thus, using the notation of Narlikar and Das (1980), the equation of motion is

$$\dot{x}+\left(1-x^2\right)\left[\frac{M}{R^2}+\frac{d}{dt}(\ln m)\left\{x-\frac{2R}{3T}\left(1-\frac{2M}{R}\right)\right\}\right]$$
$$+\frac{2R}{9T^2}\left[1-x^2-\frac{2R^2x\left(1-x^2\right)}{T\left(R-2M\right)}\right]+\Lambda\dot{R}=0 \tag{23}$$

where

$$\dot{R}=xe^{(\nu-\lambda)/2}\,. \tag{24}$$

In c.g.s. units we express the gravitational acceleration approximately as

$$F_G\sim\frac{GM}{R^2}\sim\frac{\frac{2}{3}\times10^{-7}\times10^{33}\times2\times10^{11}}{10^{43}}\sim10^{-6}\,. \tag{25}$$

Likewise the deceleration caused by friction may be estimated as

$$F_f\approx\bar{\Lambda}v/T\,, \tag{26}$$

where $\bar{\Lambda}$ (in c.g.s. units) is dimensionless and $T\sim2\times H^{-1}$, the Hubble time scale. Taking $v\sim10^4$ km s^{-1} and $\bar{\Lambda}\sim100$, we get

$$F_f\approx10^2\times10^9\times10^{-18}\sim10^{-7}\,. \tag{27}$$

Thus in our above example the frictional deceleration is an order of magnitude lower than the gravitational acceleration. Further, it is assumed to be significant only up to $1/10$ of the galactic radius.

When the calculations are modified to include frictional effects we notice that the observed velocities ω of the quasar are reduced from ~ 28,000 km s^{-1} to half the value; in any case not below 10,000 km s^{-1}. The reduction is not as much as expected because the boundary condition (22) seems in general to allow only those velocities that are of the above order.

In the last analysis therefore it is necessary to check by larger observational data of this nature what are the expected velocities of quasars ejected from galaxies, at the time of their observation.

6. A Toy Model for Quantized Redshifts

We now consider a quantum mechanical toy model to represent the periodic redshifts as per the Karlsson sequence. Since the discrete sequence of values $\ln(1+Z_n)$ here forms an arithmetic series, we write it as

$$L_n=\ln\left(1+Z_n\right)=\Delta+nK=\Delta-\frac{1}{2}K+\left(n+\frac{1}{2}\right)K\,, \tag{28}$$

where $\Delta = \ln(1.06) = 0.058$ and $K = \ln(1.228) = 0.205$; so that $\Delta - ½K \simeq -0.044$. We will now compare this empirical result with a simple harmonic oscillator in quantum mechanics.

A classical simple harmonic oscillator of mass M and circular frequency ω has the equation of motion

$$M\ddot{X} + M\omega^2 X = 0\,, \tag{29}$$

corresponding to the Hamiltonian

$$H = \frac{p^2}{2M} + \frac{1}{2}M\omega^2 X^2\,. \tag{30}$$

In quantum mechanics, the eigen states of the Hamiltonian correspond to energy values in the sequence

$$E_n = \left[n + \frac{1}{2}\right]\hbar\omega\,. \tag{31}$$

Consider now a quasar created at time τ_n passing the observer in galaxy G at the present epoch τ_G such that the observer sees a redshift Z_n in the quasar. From the VMH, we conclude that the particle masses in the quasar (M_n) and the galaxy (M_G) are related by

$$1 + Z_n = \frac{M_G}{M_n}\,. \tag{32}$$

Thus using (28) we can write

$$Y \equiv -\ln M_n = L_n + \text{constant}\,. \tag{33}$$

We can thus argue that the particle masses through [$\ln M_n$] are quantized with eigen values of Y rising in the arithmetic sequence very similar to that for the simple harmonic oscillator. This suggests the following 'toy' model of the periodic redshift phenomena.

As in the VMH we consider the quasar Q as created in the galaxy G at some epoch τ_Q but it does not move out immediately. It is held in 'hibernation' within the location of its creation until a suitable time τ_n when its particle mass attains a value M_n corresponding to a redshift Z_n in the Karlsson sequence. It then moves out. Although the particle mass continues to grow in the quasar, it does so in steps with values M_n falling in the Karlsson sequence.

So long as the mass function remained continuous as in (14) we could not get the Karlsson effect. To incorporate it we need to modify (14) so that the mass function jumps up at specific time intervals τ_N, say, and stays constant in between. So we define m_Q as going up by the factor λ of equation (3) at the end of each discrete interval. Thus (14) is replaced by

$$m_Q = \sum_n \left(M_n - M_{n-1}\right)\theta\left(\tau - \tau_n\right), \tag{34}$$

where the function $\theta(x)$ is the step function which takes the value 1 for positive argument and is zero otherwise. The time steps τ_n are defined by (14) corresponding to the discrete mass values M_n.

7. Concluding Remarks

In this paper we have taken the view that the claim made by certain quasar observers that the quasar redshifts are significantly peaked around the sequence first noted by Karlsson, deserves careful consideration. To this end we have looked for a theoretical explanation for the phenomenon. In a toy model we have drawn a comparison between the energy levels of a simple harmonic oscillator and the redshifts on the Karlsson sequence. Using the variable mass hypothesis we have further shown that as a new quasar is created by an active galaxy, its particle masses increase with time. In the classical version of the VMH it was found that the increase of mass leads to a steady and continuous decline of the quasar redshift. Thus the redshift declines from infinity in the beginning to finite values subsequently as the created quasar is ejected by the galaxy. The relationship mass × (1 + z) = constant, coming from the VMH then also suggests that particle masses in quasars should show the periodicity of the Karlsson sequence.

However, according to the toy model, the quasar is not immediately ejected but is kept in hibernation until the particle mass in it equals the value of a mass in the Karlsson sequence, thereby generating preferred intrinsic redshifts around that sequence. These elements of the toy model give a bare hint of a possible underlying theory which still needs to be extracted. An analogy (though somewhat exalted!) may be given with the role of Bohr's theory of the hydrogen atom. The discretization of the motions of an electron in a hydrogen atom as per Bohr's rule (of the angular momentum being of the form $n\hbar$ where n is an integer) looked ad hoc at first but it yielded the correct spectral frequencies. A deeper theory later justified those assumptions. Here we are at a comparable stage where *ad hoc* assumptions are justified only through their producing the right numerical results. A deeper theory to justify the toy model is still awaited.

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