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The Many Directions of Time

A modern revolution in physics and cosmology

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As there are nearly 400 references, it was not practical to create hyperlinks for each reference. However, convenient individual PDF bookmarks exist for each of the 14 pages of references. Those for the first 7 pages of references are at the top of the bookmark list and those for the last 7 pages are at the bottom of the list. Use these bookmarks to jump to the page of a reference. You may then use a bookmark to conveniently return to the beginning of the section you are reading. Open the bookmark list using the icon shown below on the ADOBE READER toolbar on the left.

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Statistics

Words:	~89k
Equations:	138
Figures:	105
Tables:	5
Bibliographic entries:	62
References:	397
Direct quotations:	~100 (~25% of references)

Mathematics
This text assumes knowledge of complex numbers as well as differential and integral calculus. Appealing to a broad technically educated audience in addition to professional mathematicians and physicists, it does not require knowledge of more esoteric mathematical disciplines.

Dedication

This book is dedicated to the memory of Stanford University Professor Jeffrey Alan Willick and thus to the loving hope he had for his children and so for their entire generation on this Earth.

Dr. Willick authored Chapter 6 “Measurement of galaxy distances” in the textbook *Formation of structure in the Universe* (Cambridge University Press, 1999).

JEFFREY ALAN WILLICK 1959 – 2000

On 18 June 2000, Dr. Jeffrey Alan Willick, an assistant professor of physics at Stanford, brought his laptop to a coffee shop and was working there. In the most unlikely of tragic chance events, he died at age forty when a car crashed through the window of the café and struck him. Our world lost a loving son, husband and father and a talented scientist and educator. Jeff taught a popular class at Stanford called *The Nature of the Universe* and was considered an exceptional teacher by his students. He wrote on his Website:

> My interests are in the area of cosmology and the large-scale structure of the Universe. My work addresses the “big questions” facing contemporary cosmology: Is the universe flat? Is there a non-zero cosmological constant? Did structure in the contemporary universe emerge from the very nearly uniform primordial distribution of matter solely via the process of gravitational instability? What is the nature of the “dark matter” believed to constitute 90 percent of the total mass of the universe? I pursue these questions by observing the distribution and peculiar velocities of galaxies. The methodology is primarily observational; I obtain and analyze data from large optical and infrared ground-based telescopes.

As is true for many of my teachers whose work has guided and inspired me, I never had the opportunity to speak to Jeff. I know him only through his writing and the memories of his friends and students. I would have liked to share with him the revolutionary new ideas in this book, which may soon be accepted as providing definitive answers to all of his “big questions”.

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The entire contents of this book, which involves critical discussion of topics of wide interest to the global scientific community and the general public is being made freely available on the Internet for the purposes of education, scholarly research and stimulation of scientific progress for the benefit of all mankind. Significant advances in science are generally associated with *synthesis* in which previously distinct ideas or empirical observations are unified into a new cohesive body of thought. The syntheses in this book have required the organization, logical connection and occasional reinterpretation of previously published scientific research. In many circumstances, it is only appropriate to directly quote the original author(s) rather than to merely refer to their work or attempt to paraphrase them. This ensures complete accuracy in communicating their ideas and contribution to science. The following are excerpts from the *Wikipedia* article on fair use:

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> … U.S. Copyright Act of 1976, 17 U.S.C. § 107:
>
> > The fair use of a copyrighted work for purposes such as criticism, comment, news reporting, teaching (including multiple copies for classroom use), scholarship, or research, is not an infringement of copyright. In determining whether the use made of a work in any particular case is a fair use the factors to be considered shall include—
> >
> > 1. the purpose and character of the use, including whether such use is of a commercial nature or is for nonprofit educational purposes;
> > 2. the nature of the copyrighted work;
> > 3. the amount and substantiality of the portion used in relation to the copyrighted work as a whole; and
> > 4. the effect of the use upon the potential market for or value of the copyrighted work.
>
> …the classic opinion of Joseph Story in Folsom v. Marsh, 9 F.Cas. 342 (1841):
>
> > [A] reviewer may fairly cite largely from the original work, if his design be really and truly to use the passages for the purposes of fair and reasonable criticism.
>
> Fair use tempers copyright's exclusive rights to serve the purpose of copyright law, which the U.S. Constitution defines as the promotion of "the Progress of Science and useful Arts" (I.1.8). Some commentators have also suggested that the First Amendment's protection of free speech necessitates some form of fair use defense, because some things simply cannot be said without some amount of copying. This principle applies particularly well to the case of criticism.
>
> The first factor questions whether the use under consideration helps fulfill the intention of copyright law to stimulate creativity for the enrichment of the general public, or whether it aims to only "supersede the objects" of the original for reasons of, say, personal profit. To justify the use as fair, one must demonstrate how it either advances knowledge or the progress of the arts through the addition of something new. A key consideration is the extent to which the use is interpreted as transformative, as opposed to merely derivative.[1]

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Quotations

Advances are made by answering questions. Discoveries are made by questioning answers.

– Bernard Haisch

We don't know what we are talking about. … The state of physics today is like it was when we were mystified by radioactivity. … They were missing something absolutely fundamental. We are missing perhaps something as profound as they were back then.

– David Gross, 2004 Nobel laureate in Physics
"Nobel laureate admits string theory is in trouble", *New Scientist* **2529**, 6 (10 Dec. 2005)

The Emperor's New Clothes is a Danish fairy tale written by Hans Christian Andersen, first published in 1837. The story is a type of fable or morality play with a cautionary message: Just because everyone else believes something is true, doesn't mean it is.

– *Wikipedia*

The mathematical education of the young physicist [Einstein] was not very solid, which I am in a good position to evaluate since he obtained it from me in Zürich some time ago.

– Hermann Minkowski (c. 1907)

"Something completely new has to be found," [Einstein said to me], "something that is somehow based on the ideas of General Relativity."

– Ernest J. Sternglass, *Before the Big Bang* (2001), pp. 55-56.

We are to admit no more causes of natural things than such as are both true and sufficient to explain their appearances. To this purpose, the philosophers say that Nature does nothing in vain, and more is in vain when less will serve; for Nature is pleased with simplicity, and affects not the pomp of superfluous causes.

– Isaac Newton, *Principia*: Book III: Rules of Reasoning in Philosophy (1687)

Science alone of all the subjects contains within itself the lesson of the danger of belief in the infallibility of the greatest teachers in the preceding generation ... Learn from science that you must doubt the experts. As a matter of fact, I can also define science another way: Science is the belief in the ignorance of experts.

– Richard Feynman, *The Pleasure of Finding Things Out* (1999)

Doth any man doubt, that if there were taken out of men's minds, vain opinions, flattering hopes, false valuations, imaginations as one would, and the like, but it would leave the minds, of a number of men, poor shrunken things, full of melancholy and indisposition, and unpleasing to themselves?

– Francis Bacon, *Of Truth* (c. 1601)

Apropos the above: "Don't worry, be happy." – Bobby McFerrin (1988)

Forward

Albert Einstein's Special Theory of Relativity (SR) established the foundation of the new modern physics in 1905. A decade later, Einstein raised a second pillar of modern physics with the General Theory of Relativity (GR), superseding Isaac Newton's 17th century Law of Gravitation. A key distinction between Einstein's two theories is that SR is conventionally an algebraic theory while GR is a geometric theory. This book begins by showing in a simple and intuitive way that SR must also be considered a kind of geometric theory. However, the key geometric nature of *special* relativity was initially obscured by a flawed conceptual and mathematical model of time. GR is known for its dramatic empirical verifications, yet recently it has become widely understood that there is somehow a hidden flaw in the theory, for its original incarnation is fundamentally incompatible with quantum mechanics.[2] Because special relativity lays the groundwork for general relativity, a change in how we interpret and express SR leads to profound illuminating new insights relevant to resolving this and other outstanding problems in physics.

The collection of innovative ideas and related compelling empirical evidence presented in this book has a breadth that goes far beyond what is suitable for even an extended journal article. Completion of the book, providing a comprehensive integrated picture, had to precede formal summary articles. Also, for a communication that must ultimately touch many lives and scientific careers, it is ideal if as many people as possible can rapidly comprehend the new ideas and perhaps immediately leverage them to advance their own work. This goal has been achieved using a rigorous approach, yet one that does not require unusually arcane mathematical formality to effectively and convincingly communicate the fundamental new ideas that are presented.

Due to the expected wide general interest in the broader issues that are discussed, effort has been expended to make this initial communication accessible to select motivated students and amateurs. The far-reaching implications can generally be understood directly from the prose while technical details expressed in what may be opaque mathematical form for some may be filled in over time through additional study or discussion with knowledgeable and more practiced members of the scientific community who have become familiar with the new ideas.

There is a strong underlying current of logical, technical and scientific fundamentals in this book with the *convergence of theory and empirical evidence* as the primary goal to be achieved. Professors Edwin Taylor of MIT and John Wheeler of Princeton University are among the world's most respected physicists who have specialized in the field of relativity. Taylor made the following comments during his acceptance speech for the prestigious Oersted Award in 1998.

> Those of us who are not professionals in general relativity have a fuzzy impression of a mystical, terrifying tangle of equations inhabited by monsters called tensors. I have asked questions about general relativity of several experts in the field. With one exception, every single expert has started answering my question by writing down a tensor. That one exception is John Archibald Wheeler. In our thirty years of collaboration on teaching relativity, he never once wrote down a tensor. Never. How is this possible? I believe it is because Wheeler feels that tensors are not fundamental; during our collaboration, he disciplined himself to talk only about what lies behind the formalism.[3]

In keeping with John Wheeler's approach, unusual specialized study in mathematics is not required in order to fully comprehend the discussion, although GR plays a leading role; the background in calculus normally attained by those who have pursued a technical degree at university is sufficient. In addition, students, journalists and others who lack facility with the mathematics may readily "read between the equations" and still develop a good understanding of the thesis. While a more sophisticated development that addresses some important quantitative details remains the exclusive dominion of a quite small group of professional specialists who communicate using the acme of mathematical formality, the content of this book is appropriately aimed at a broad yet sophisticated global audience that is two to three orders of magnitude larger. It is anticipated, perhaps with undue optimism, that about 0.01% of the current global population (i.e., several hundred thousand people) have the necessary background required to read this book.

For over three decades, each subsequent fashionable evolution of string theory has failed to provide any progress in the task of unifying quantum mechanics and gravity. Due to the absence of any empirical predictions from string theory during this extended period and the now established forecast that no such predictions will ever evolve from it, the field is effectively washed up, in spite of its current popular status in academia. *Without predictions confirmed by repeatable experiments carried out by skeptical professional scientific peers, theoretical physics becomes a useless and illusory academic exercise.* When many otherwise exceptionally capable people fail at a task over a period of several decades, this suggests that they need a new idea or perspective in order to be successful. Long before the rise of string theory, Richard Feynman, who was arguably second only to Einstein in 20th-century theoretical physics, wrote home to his wife in 1962 from a "gravity conference" while waiting for food to arrive at his dining table. This private assessment of his peers is quite harsh and perhaps overly critical, but it is the valuable perspective of an undeniably great mind that is applicable to modern string theory conferences. Note that Feynman initially maintains that "this field is not an active one", while later seeming to contradict himself by saying that "there is a great deal of 'activity in the field' these days". In context, the initial reference to "inactivity" implies "achieving nothing". The subsequent use of the word "activity" is literal, referring to people simply going through the motions, thus merely *pretending* to accomplish something (i.e., "straightening out deck chairs on the sinking Titanic").

> I am not getting anything out of the meeting—I am learning nothing. This field (because there are no experiments) is not an active one, so few of the best men are doing work in it. The result is that there are hosts (126) of dopes here—and it is not good for my blood pressure—such inane things are said and seriously discussed—and I get into arguments outside the formal sessions—say at lunch—whenever anyone asks me a question or starts to tell me about his "work." It is always either—(1) completely un-understandable, or (2) vague and indefinite, or (3) something correct that is obvious and self-evident worked out by a long and difficult analysis and presented as an important discovery, or (4) a claim, based on the stupidity of the author that some obvious and correct thing accepted and checked for years is, in fact, false (these are the worst—no arguments will convince the idiot), (5) an attempt to do something probably impossible, but certainly of no utility, which, it is finally revealed, at the end, fails (dessert arrives—is eaten), or (6) just plain wrong. There is a great deal of "activity in the field" these days—but this "activity" is mainly in showing that the previous "activity" of somebody else resulted in an error or in nothing useful or in something promising, etc.—like a lot of worms trying to get out of a bottle by crawling all over each other. It is not that the subject is hard—it is just that the good men are occupied elsewhere. Remind me not to come to any more gravity conferences.[4]

One of the central topics of this book is cosmology, a subject of scientific inquiry that is also widely accepted to form the root foundation of philosophy and religion. Because an empirically verified revision to the current cosmological model is put forward that is based on compelling new analysis of existing observations, it is reasonable to predict that the new ideas advanced in this book will have a profound influence on realms of thought influencing society beyond various academic pursuits. This can be expected to stimulate a wide readership and broad popular interest in these ideas. Therefore, scientists of many persuasions will want to be prepared to debate various issues that are discussed herein. This is the primary reason that this book is initially being made freely available in electronic format. The e-book format also makes it convenient for readers to search the text, rapidly access the many online references, and to instantly Google® an unfamiliar term, name, or concept, which greatly enhances and accelerates the learning process.

Science in general and cosmology in particular are like a puzzle to which we occasionally add another piece. The creative artwork of renowned science artist Lynette R. Cook that graces the cover was chosen to express this. Because we do not know in advance how the Universe that we study works (what the completed puzzle ultimately looks like) this generally makes it difficult to add another piece. However, on occasion, we correctly and clearly envision some section of the puzzle and for a time this makes the placing of a considerable number of new pieces far easier and quicker than is normally the case. Such a productive period gives the global community of mathematicians and physical scientists no shortage of exciting challenges to pursue and the Nobel Foundation in Stockholm no shortage of worthy individuals to recognize, who have made lasting contributions to science that are of an empirical nature.

This book got its start as a less ambitious project. The initial intent, begun in October after the announcement of the 2006 Nobel Laureates in Physics, was to write a formal scholarly paper limited to introducing the innovative concept of geometric cosmic time and its implications for cosmology and the interpretation of the COBE, WMAP and supernovae data. However, it soon became clear that a complete discussion of all of the connected ideas was necessary. The result, in the form of this book entitled *The Many Directions of Time*, stands on its own merits and it may be judged exclusively on its ability to make correct empirical predictions that can be repeatedly verified by skeptical scientific peers. The book is a complete revision of an existing writing project dating back to 2004, previously published only in the form of some PowerPoint® slides on a Website that was originally hosted by Stanford University.

In the Forward to *A Brief History of Time*, Stephen Hawking states,

> "Someone told me that each equation I included in the book would halve the sales. I therefore resolved not to have any equations at all. In the end I *did* put in one equation, Einstein's famous equation $E = mc^2$. I hope that this won't scare off half my readers." [5]

This book is concerned with teaching real physics and cosmology, rather than maximizing sales to the public, so it includes 138 equations. As its reputation grows as a readable book that makes fertile new ideas in science understandable and exciting, many people will likely make the effort to read it, even those who do not immediately understand all of its many equations. It may even stimulate some to pursue further study of mathematics, to better comprehend the new ideas.

Several outstanding fundamental questions of our time are convincingly answered by the new ideas that are put forward herein, in particular those concerning the conundrums of "dark matter" and "dark energy". There are also a number of technological systems critical to the collective interests of humanity that stand to benefit from practical application of new theory. These include deep space navigation, the process of global timekeeping, satellite navigation (i.e., GPS), and other systems that depend on geographically distributed precision timing and synchronization. There are lifetimes of inquiry opened up in various fields of study as well as immediate opportunities to contribute new or additional empirical verifications, important additional theoretical and mathematical structure, and improvements to engineering systems. A wide variety of professionals and students will be able to profit from the new ideas presented here for peer review and further development.

Richard Feynman said, "Our imagination is stretched to the utmost, not, as in fiction, to imagine things which are not really there, but just to comprehend those things which *are* there."[6] It must be difficult for an Amazonian, born and raised in the jungle, to imagine Earth as a sphere. Incapacity to do so implies limitations. It may be equally difficult for a student or professor at a university to imagine *many directions of time*. Incapacity to do so will also have its consequences.

Readers should keep in mind the importance of each previous step that has been made in contributing to the process of scientific advancement, including those ideas that will ultimately be abandoned. Over past decades, many people have struggled with the "big questions", in physics and cosmology, contributing to a global team effort with many centuries of history. These efforts, including those which will prove to have yielded unsuccessful discarded theories, all played an important role in finding a new path forward on our endless human journey of scientific and spiritual discovery.

23 May 2007
Oakland, California

1. Introduction

This book presents a new model of time based on the principles of relativity as mathematically formalized by H. Minkowski and demonstrates that many things believed to be factual in physics and cosmology in the first years of this new century require substantial revision as a consequence. In particular, reliable corroborating empirical evidence matching a new cosmological model developed to incorporate the concept of *geometric cosmic time* demonstrates conclusively that the implausible Big Bang *singularity* (i.e., *crisis* in physics) at a "beginning of time" never existed.

"What is time?" Everyone knows what the question is about, but definitions of time are varied, subject to personal and cultural bias, and it is difficult to establish a shared definition among a large and diverse group of people. Our awareness and experience of time is clearly not identical throughout our lives, nor can we expect that different people experience time in the same way. Time is something self-evident, yet also an enigma, perceived not by the any of our five normal senses, but by what we may call our individual evolving "feeling-awareness" of time. Who may claim that perception of time over a lifetime from infancy to old age is the same? Does time itself imply God? — Some say that there is no evidence for the existence of God, yet it is necessary to have a precise shared definition of God before it is meaningful to discuss this topic. However, an acknowledged *beginning* of time makes it difficult to conceive of God as *Eternal Being*.

Putting philosophical considerations aside, this book concerns *physics*, and in physics we accept *a priori* that time exists as a measurable quantity that separates events. Take a moment now to think about how you envision time. If you are like the majority, particularly in a modern Western-influenced culture, you envision time as an ordered series of events with coordinates along a single timeline, typically modeled by consecutive calendar days. This model of time best meets our everyday practical needs with a span of time resolution employed within various scientific pursuits from about 10^{16} seconds (~1 billion years) to the realm of 10^{-18} second (attosecond laser pulses).[7] In comparison, one Earth day is somewhat less than 10^{5} seconds.

Often there exists a distinction between the most practical everyday model of a phenomenon and a less naïve, more physically accurate model. — Does it naturally occur to anyone that the local plumb lines separated by some observed distance of a few kilometers on the Earth are not parallel? When, if ever, does anybody in their daily life take into consideration that they are living their lives on a large ball that has many different directions of the localized altitude coordinate? With the exception of a relatively few technically educated elite, the majority of humans blissfully imagined the world to be flat throughout most of history. While the *practical concept* of the Earth best suited to everyday needs is of a flat contoured plane, there is an obvious distinction between this and reality. Might not there be a similar distinction for the phenomenon of time?

This book begins by showing in a simple and intuitive way that there is just such a distinction. The theory of relativity, inclusive of the relativity of simultaneity, requires us to think about the time coordinate as a *multidimensional* phenomenon, rather than the everyday practical model of time represented by a single universal timeline. In hindsight, this will seem to be obvious, but it represents for our century the same kind of revelation and paradigm shift that occurred in about the 1st century when academic elites all agreed that the local altitude coordinate was not parallel everywhere on the surface of the Earth. The altitude coordinate was therefore *multidimensional* (i.e., pointing in many directions), allowing for a finite boundaryless surface of the curved Earth. Multidimensional time similarly implies *many directions of time* in spacetime (i.e., the cosmos).

In 1900, just prior to the momentous upheaval in physics that was about to take place, the venerable Lord Kelvin addressed an assemblage of physicists at the British Association for the Advancement of Science stating, "There is nothing new to be discovered in physics now. All that remains is more and more precise measurement."[8] About a century later, another physicist from Cambridge University stated in his trendy book, "There are grounds for cautious optimism that we may now be near the end of the search for the ultimate laws of nature."[9] Just like Lord Kelvin, Stephen Hawking did not anticipate the coming upheaval that would turn his world upside down, and thus end nearly a century of fashionable but myopic and incorrect "consensus science"…

2. The geometry of time

Virtually every physical scientist today is familiar to some extent with the concept of relativistic time measurement introduced by Albert Einstein in 1905. It is well understood that time as measured in one frame of reference is not generally the same as time measured in another. Knowledge of the constancy of the speed of light makes it possible to conceive of simple thought experiments that reveal the symmetric effect of time dilation caused by constant-velocity relative motion, now ubiquitously expressed in textbooks as the following algebraic quotient. This relationship is one of the most thoroughly tested and conclusively verified predictions in physics.

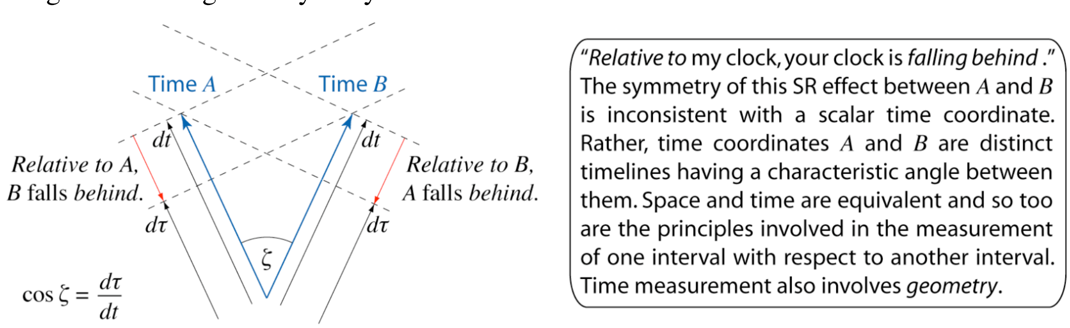
$$\frac{dt}{d\tau} = \frac{1}{\sqrt{1-\dfrac{v^2}{c^2}}} \equiv \gamma \qquad 1$$

Each observer is entitled to hold that the ideal rest-frame clock of the "moving" observer (τ) is slower than the local ideal rest frame clock (t). Although the algebra describing the temporal effects of special relativity (SR) is firmly established and easily derived from first principles, a shortcoming of the mathematics is that it fails to *explicitly* model the inherent symmetry of the time dilation phenomenon. — At face value, Eq. (1) could possibly be erroneously interpreted to mean that one clock (t) is experienced to be faster than the other. Upon thoughtful consideration, the only way to avoid a logical paradox in accurately modeling the phenomenon of *symmetric* relativistic time dilation, conceptually and mathematically, is by invoking *geometry*. A familiar spatial analogy is helpful in understanding and adopting this important perspective. —

The odometer in a typical car measures a spatial interval. However, it does not incorporate in its scalar measurement the direction in which measurements are made. Two cars start at the same zero point and travel the identical distance at the same speed in different directions at an acute angle to one another. Their respective odometers will accordingly display the same reading. However, each driver is entitled to hold that the other driver is falling behind, *relative to* the local preferred direction of travel. If each car has a special second odometer that measures the progress of the other car in the same direction that the real odometer is measuring, that odometer will turn over slower and record less distance in proportion to the angle between the respective paths of the two cars. It is also a fact that each driver must literally turn his head and look *behind* in order to view the other car having the identical real odometer reading. Though each driver may claim that the other car is "behind", in spite of the identical distance traveled, there is clearly no paradox. The situation is immediately understood to be one of symmetric relative geometric perspective.

An unambiguous description of symmetric temporal effects in special relativity requires the same essential geometric model. In SR, the perspective of what is space and what is time in spacetime is dependent on relative motion. If time as measured in one reference frame is understood to be a *mixture* of both space and time as measured in another, it naturally follows that the time coordinate in each incorporates only a subset or a *geometric component* of the time coordinate as measured in the other.

Figure 1 – The geometry of symmetric relativistic time dilation in SR: *distinct* timelines



With a leap in thinking beyond the interpretations presented in current textbooks, we arrive at the natural although not immediately intuitive idea that time is always measured in a particular *variable* "direction" in spacetime. However, like odometers, clocks are instruments that record only the magnitudes of vectors, but not their direction. So, when both of two observers are each entitled to say, "Your clock is falling behind my clock," the fundamental *mathematical* reality is "Your time coordinate and my time coordinate (i.e., our distinct timelines) are not parallel," implying a relative relationship. It is *assuredly not*, "Your timeline is *shorter* than my timeline," which implies an absolute relationship. The symmetric relative measurement of time intervals in spacetime is essentially identical to the symmetric relative measurement of distance intervals in space. The implied symmetric relativistic time dilation effect is accurately modeled by simple geometric projection of the time coordinate for either reference frame onto the distinct time coordinate of the other. One must acknowledge that the relativity of simultaneity is a natural *consequence* of symmetric time dilation, not a fundamental explanation of it.

According to this symmetric geometric relationship, an observer in either reference frame must determine that the ideal clock in the other reference frame ($d\tau$) is *falling behind* a similar local rest frame clock (dt). The resulting relativistic time dilation may be expressed as a *geometric* ratio based on the symmetric projection in terms of an angle ζ between dt and $d\tau$ shown in Fig. (1).

$$\frac{d\tau}{dt} = \cos\zeta \quad \rightarrow \quad \frac{dt}{d\tau} = \sec\zeta \equiv \gamma \qquad 2$$

The essential difference between Eq. (1) and Eq. (2) is that the variable τ in the latter equation represents the symmetric *geometric projection* of the remote time coordinate on the local time coordinate, rather than the perceived time recorded by the remote clock *per se*. This conceptual and mathematical model of time dilation in special relativity more naturally reflects the symmetry of the phenomenon than the treatment presented in existing textbooks, which does not clearly discuss relativistic time measurement in the context of *temporal geometry*. In the case where the cause of the measurable temporal phenomenon is due to relative motion, ζ (*zeta*) is elegantly expressed in terms of the relative velocity v between two inertial reference frames according to

$$\zeta = \sin^{-1}\beta \qquad \left[\beta = \frac{v}{c}\right] \qquad 3$$

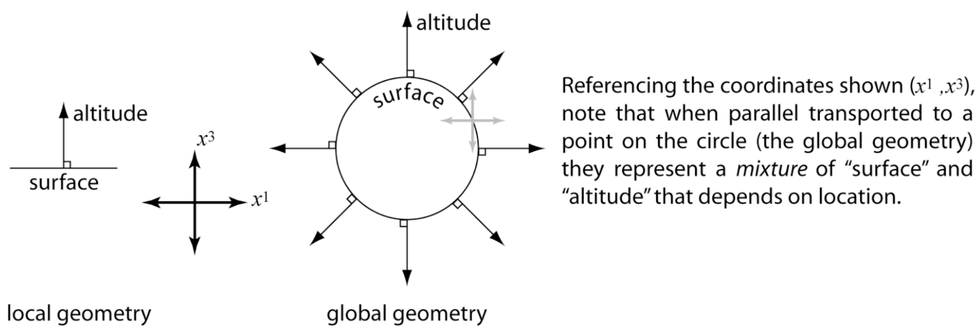
3. Geometric cosmic time

Motivated by Copernicus, in 1933 Edward Milne put forward his *Cosmological Principle*, which states that the Universe is *on the whole* homogeneous and isotropic; no observer may look out from a galaxy at the imagined "edge of the Universe" where in one direction can be observed many other galaxies and in the other a limitless void bereft of galaxies.[10] This is the only rational foundation of a cosmological model. It assumes that on a sufficiently large scale, the local density of the galaxy population is about the same everywhere. — According to the literature, popular scientific opinion now holds that the Universe is in effect topologically flat, based in large part on measurements of the cosmic microwave background radiation fluctuations.[11] However, we must be careful how empirical observations are interpreted, because the nature of gravity and the Cosmological Principle constrain the symmetry and topology of a finite Universe *a priori*. We must also bear in mind that these constraints do not apply to space *per se*, but to the four-dimensional "world" of *spacetime*. For a Universe of finite volume and energy content, populated by a finite number of galaxies, there is only one parsimonious topology that meets the requirements that there be no preferred cosmic location such as an identifiable center and also that there be no spatial boundary: the volumetric S_3 *surface* of a Riemannian hypersphere. This four-dimensional geometric object allows for every possible direction of travel in three-dimensional space to result in a circular geodesic that returns to the original point of departure.

In 1908, with the introduction of the "world-postulate" in which space and time were unified into a holistic reality, Hermann Minkowski discovered that space and time coordinates have a well-defined geometric relationship according to the principles of special relativity.[12] For a freefalling reference frame, the imaginary time coordinate of its Minkowski metric is orthogonal to each of the three real space coordinates. Therefore, the local proper time coordinate can be envisioned as a kind of "local vertical" to a three-dimensional topological surface (S_3) in four dimensions similar to how gravity is the local vertical to Earth's geoid (S_2) in three dimensions.

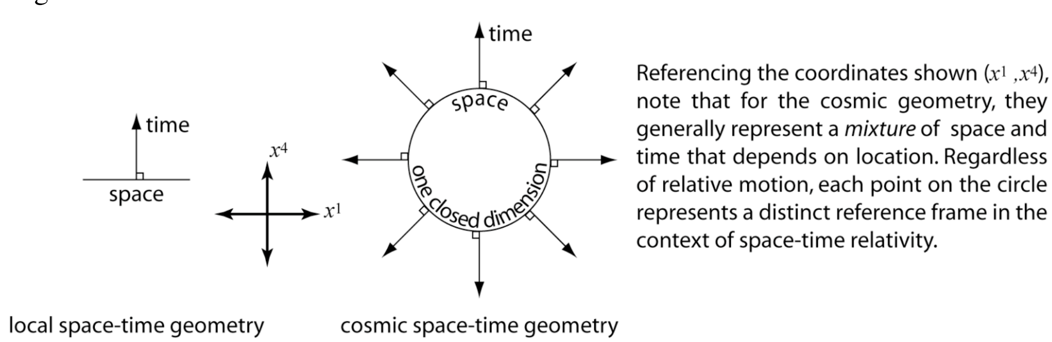
If three-dimensional space curves back on itself, not in space, but in *spacetime*, to create a finite boundaryless volume (S_3), then for every point in space there is a *locally defined* fourth dimension corresponding to the distinction of local "vertical" to the curved S_3 surface there. According to Minkowski's formalization of the principles of relativity, this dimension corresponds to the measurement of time there. The strictly local "fourth dimension" (i.e., time) then has similar *geometric properties* in cosmological spacetime to the familiar "third dimension" on Earth. This realization is easily understood with the aid of two similar illustrative diagrams.

Figure 2 – The familiar distinction between the local and global "third dimension"



Relativity implies that we are not entitled to restrict the measurement of time to a single dimension of spacetime, which is reflected by Kip Thorne's perspicacious statement describing Einstein's relativity, "*what I call space must be a mixture of your space and your time, and what you call space must be a mixture of my space and my time*."[13] Therefore, what is identified as a time coordinate and what are identified as space coordinates in the four-dimensional "world" of spacetime is dependent on the reference frame (i.e., *geometric perspective*) of the observer.[14] Herein "space-time" refers to a local distinction in which the *generic* coordinates of "spacetime" or Minkowski's "world" are resolved into distinct space and time coordinates. The perimeter of the circle in Fig. (3) represents a *single* closed (i.e., boundaryless) dimension of space, curved not in space, but in the intangible "world" of *spacetime*. The interior of the circle need not represent physical space. The two coordinates shown (x^1, x^4) do not have a fixed physical interpretation in the "world" and generally represent a *mixture* of space and time that depends on the physical location mapped by a point on the circle. Also, in the same way that "negative gravity" does not exist in Fig. (2), the experience of local proper time in Fig. (3) is ordinary everywhere.

Figure 3 – The *local* cosmic time coordinate is *similar* to Earth's local altitude coordinate



The following passages are critical excerpts from *Space and Time*, the lecture given by Minkowski in 1908 only a few months prior to his premature death from a ruptured appendix in January 1909.[15] In this lecture, Minkowski implied that *Einstein*, lacking "mathematical culture," had not grasped the true meaning and full implications of the principle of relativity.[16]

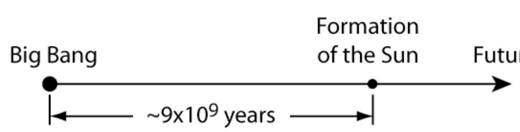
> The views of space and time that I wish to lay before you have sprung from the soil of experimental physics, and therein lies their strength. They are radical. Henceforth space by itself, and time by itself, are doomed to fade away into mere shadows, and only a kind of union of the two will preserve an independent reality.
>
> …
>
> we may—also without changing the expression of the laws of mechanics—replace x, y, z, t by $x - \alpha t$, $y - \beta t$, $z - \gamma t$, t with any constant values of α, β, γ. Hence we may give to the time axis whatever direction we choose towards the upper half of the world, $t > 0$. Now what does the requirement of orthogonality in space have to do with this perfect freedom of the time axis in an upward direction?
>
> …
>
> *We should also then have in the world no longer space, but an infinite number of spaces, analogously as there are in three-dimensional space an infinite number of planes.* Three-dimensional geometry becomes a chapter in four-dimensional physics. Now you know why I said at the outset that space and time are to fade away into shadows, and only a world in itself will subsist. [emphasis added]
>
> …
>
> But the credit of first recognizing clearly that the time of the one electron is just as good as that of the other, that is so say that t and t' are to be treated identically, belongs to Einstein. Thus time, as a concept unequivocally determined by phenomena, was first deposed from its high seat. Neither Einstein nor Lorentz made any attack on the concept of space, perhaps because in the above-mentioned special transformation, where the plane of x', t' coincides with the plane of x, t, an interpretation is possible by saying that the x-axis of space maintains its position. One may expect to find a corresponding violation of the concept of space appraised as another act of audacity on the part of the higher mathematics. Nevertheless, this further step is indispensable for the true understanding of the group G_c, and when it has been taken, the word relativity-postulate for the requirement of an invariance with the group G_c seems to me very feeble. Since the postulate comes to mean that only the four-dimensional world in space and time is given by phenomena, but that the projection in space and in time may still be undertaken with a certain degree of freedom, I prefer to call it the *postulate of the absolute world* (or briefly, the world-postulate).
>
> The world-postulate permits the identical treatment of four coordinates x, y, z, t. By this means, as I shall now show, the forms in which the laws of physics are displayed gain in intelligibility. In particular, the idea of acceleration acquires a clear-cut character.
>
> …
>
> We can determine the ratio of the units of length and time beforehand in such a way that the natural limit of velocity becomes $c = 1$. If we introduce, further, $\sqrt{-1}\ t = s$ in place of t, the quadratic differential expression
>
> $$d\tau^2 = -dx^2 - dy^2 - dz^2 - ds^2$$
>
> thus becomes perfectly symmetrical in x, y, z, s ; and this symmetry is communicated to any law which does not contradict the world-postulate. Thus the essence of this postulate must be clothed mathematically in a very pregnant manner in the mystic formula
>
> $$3 \cdot 10^5\, km = \sqrt{-1}\ \text{secs.}$$ [17]

The passage emphasized within the box is of particular importance. What Hermann Minkowski is saying here is that the "world" (i.e., Universe) can exist as a finite boundaryless volume of three-dimensional physical space without the need to be embedded in higher-dimensional space. Because what is a time coordinate in one location is effectively exchanged for a space coordinate elsewhere and vise versa, the Universe can have a finite boundaryless space, yet avoid the need for a *dedicated* fourth spatial dimension (or any other higher dimensions) that one might assume necessary. *This is the essence of Einstein's relativity theory as it was formalized by Minkowski.* However, this fundamental abstract physical implication was not recognized in the past.

To a geometer, it is obvious that a finite closed space of *n* dimensions must be embedded in a space of n+1 dimensions (e.g., the curved S_2 surface of a sphere can only exist in 3-space). However, while the geometer assumes that all dimensions are spatial, a physicist or cosmologist can change the definition of a global reference coordinate in the four-dimensional "world" to a generally abstract *mixture* of space and time as defined for one reference frame in comparison to another. The idea depicted in Fig. (3) is an exceedingly simple one, yet it does require some intellectual adaptation for the uninitiated. Each point on the circle represents a distinct "space" having its own distinct local time coordinate; *spacetime* (four generic coordinates) is a plurality of an infinite number of seamlessly connected *space-time* manifolds (i.e., reference frames). However intuitively obvious this may later come to be, it at first represents a creative leap beyond "common sense" and one's textbook pedagogy.

Particularly in Western cultures, it is so natural to model time with a single linear dimension that the term "timeline" is ubiquitous. Historic and future events are often plotted as points on a line having an appropriate arbitrary scale. A single ray extending from a point of origin models the naïve concept of cosmic time developed during the 20th century. The ray's origin is known as the Big Bang and its arrow points towards an indefinite cosmic evolutionary future. A similar collinear ray also models the temporal existence of any particular entity in the Universe that may form prior to the eventual termination of that thing's existence. The essential difference between the two rays is that the origin of the latter ray is an event in spacetime corresponding to a particular coordinate on the cosmic timeline, while the origin of the former ray is paradoxically alleged to represent an *event* (in time) that is the literal *beginning of time*. It should now be clear that this is a naïve conceptual model of time in the context of the theory of relativity.

Figure 4 – The conventional 20th-century model of cosmic time



(see http://map.gsfc.nasa.gov/m_ig/060915/CMB_Timeline75.jpg)

It is certainly the case that time as generally measured in a reference frame that *locally* encompasses the Milky Way Galaxy can be accurately modeled by a single timeline. For example, upon this timeline may be plotted events associated with the evolution of our galaxy relative to the present, such as the formation of the Solar System, dated by various corroborating methods to have occurred about 4.6 billion years ago. However, the idea that the scale of this particular linear timeline may be applied to all events in the entire spacetime of the cosmos is a naïve assumption that is inconsistent with basic physical principles and new empirical evidence. Though now prevalent, this soon to be abandoned idea is the modern day cosmological equivalent of anachronistic belief in a "flat Earth" in which the third dimension of space, observed to be the local vertical, is imagined according to immediate perception to be everywhere parallel.

When a person understands that the world we live upon is essentially the finite boundaryless surface of a sphere, it is also implicitly understood that the direction of the local vertical in space changes from one location to another, although too subtly to be readily perceived. If this is not the case, then the person in question must imagine either that the surface of the Earth is a contoured

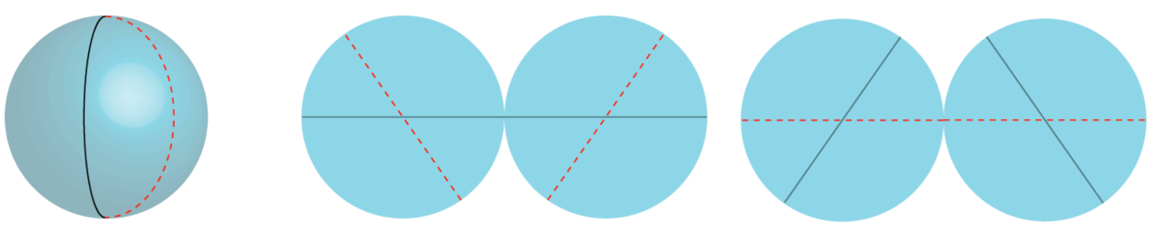
Euclidean plane of infinite extent or that somewhere one might find a boundary, the place where some medieval artists imagined errant sailing ships falling off the edge of a finite flat Earth. Similarly, when one understands that the Universe we live in must be the finite boundaryless surface of a Riemannian hypersphere, it is also implicitly understood that the direction of the "local vertical" *in spacetime* changes from one location to another over large distances. In this situation, space (x^1, x^2, x^3) has a *local* vertical (x^4) representing the *local* proper time coordinate.

As first pointed out by Minkowski, the Lorentz transformation equations dictate that the time coordinate for a localized freefalling reference frame is imaginary in contrast to the three real space coordinates. Therefore, in a subtle but unequivocal way, nature tells us that space and time are intrinsically orthogonal to one another for an unaccelerated reference frame of restricted size. Regardless of how abstract the geometric relationship between space and time that is depicted on the *left* side of Fig. (3) may seem to be, it is a fundamental aspect of the Universe. If we combine Minkowski's discovery with the intuitive idea of a finite boundaryless Universe, we arrive at the natural relativistic model of geometric cosmic time shown on the *right* side of Fig. (3). The model of time shown in Fig. (4) is a last residual of Newtonian ideas that must be abandoned. Fully embracing the concept of *relativistic* time in cosmology, we must rather adopt the simple idea that the time coordinate is a *local geometric property* of a finite boundaryless cosmos [Fig. (3)].

4. Finite boundaryless space

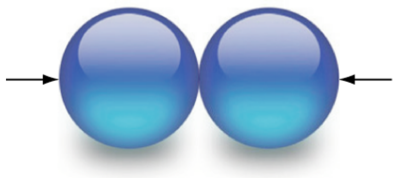
It is understandable that a primitive person must typically imagine the surface of the Earth to be a contoured plane of limitless extent. Use a ball as a model to describe the Earth, and they will likely be incredulous that they live their lives bound to a sphere that has a finite area but presents no boundary, thus allowing for terrestrial circumnavigation. Without a suitable model of the globe, it would be difficult to describe to them the Earth's topology using a conventional paper world map, because the edges are too easily interpreted as boundaries. However, the curved surface of a sphere can be abstractly represented by two circles, each showing opposing hemispheres of an orthographic projection. Any diameter of either circle represents a great arc of *pi* radians. While the circles can only be depicted touching each other at a single common perimeter point at a given time, it can be made clear that there is a one-to-one correspondence between each point on the perimeter of one circle with each identical point on the perimeter of the other circle by simultaneously rotating the circles. This projection of a sphere, while less practical in some respects, is the most intuitive two-dimensional representation of the globe, when it is made clear that the perimeters of the two distinct circles represent the identical set of points.

Figure 5 – Two great circles on a 3-sphere ($\mathbb{S}^3$) and each mapped as one line in $\mathbb{S}^2$



Even many physicists and astronomers typically have difficulty visualizing the geometry of a Riemannian hypersphere, which seems to the majority an otherworldly mathematical abstraction. However, it is not difficult to do so with an appropriate projection. All of the area on the S_n surface of an (n+1)-sphere, which is curved in (n+1) dimensions, can be represented mapped in an n-dimensional projection. So, the total *volume* of the S_3 *surface* of a 4-sphere, which is curved in four dimensions ($\mathbb{S}^4$), can be mapped in a three-dimensional projection. Instead of the two circles in the plane as shown in Fig. (4), this projection manifests as two solid spheres.

Figure 6 – A projection mapping the finite boundaryless *volumetric* S_3 surface of a 4-sphere ($\mathbb{S}^4$)



The volume of the two spheres maps the finite boundaryless S_3 surface of an $\boldsymbol{S}^4$ hypersphere. The spheres may rotate freely without slipping. *Every set of matched diameters between the fixed arrows represents a great circle.*

While the two spheres can only be visualized touching each other at a single point in space, there is a one-to-one correspondence between each point on the surface of one sphere with a point on the surface of the other sphere (they are identical points). Any great circle on the surface of a sphere represents a path of circumnavigation. In addition, any diameter of a sphere represents a great arc of *pi* radians. If the spheres are rotated in any direction without slipping, any two such corresponding diameters connect both at the point of contact and at the two peripheral points indicated by the arrows, creating a closed circular path. The infinite number of possible distinct straight lines between the arrows, according to the infinite number of unique possible points of contact between the spheres, each represent cosmic great circles circumnavigating the volume.

If we extend the Milky Way Galaxy's axis of rotation out indefinitely, the resulting closed geodesic curve in a finite boundaryless Universe corresponds to one of these paired diameters. Likewise, if we extend the plane of the galactic disk out to arbitrary distance, the resulting closed curved S_2 surface of cosmological extent corresponds to the finite surface area of either of the two spheres, which together and inclusive of their respective interior regions map all of the Universe's finite boundaryless three-dimensional space. A finite Universe with no identifiable center and no boundary requires what is locally perceived to be an arbitrary plane in Euclidean space to be a differential plane area tangent to a curved surface. This curved surface is the cosmological equivalent of one particular great circle among an infinite number that may pass through a point on the surface of a 3-sphere. As an example of the above, we can associate the Milky Way Galaxy's arbitrary location in the Universe with the single point of contact in Fig. (5), having the plane of the disk oriented into the page and tangent to both spheres. This three-dimensional map then clearly shows how it is that an imagined spacecraft can depart the Milky Way in any direction, circumnavigate the entire Universe in a great circle, and return to the starting point.

5. The cosmological redshift

Vesto Melvin Slipher, Director of the Lowell Observatory in Flagstaff, Arizona, who managed a staff including the young Edwin Hubble, first discovered the preponderance of redshifts for the spiral nebulae.[18,19,20] It is worthwhile to note as an aside that Slipher made some remarkable comments for the time in a 1917 paper. It is clear that the modern understanding and definition of a galaxy had been intuited long before this distinction was officially confirmed in the literature and formally adopted by the academic community.

> For us to have such motion and the stars not show it means that our whole stellar system moves and carries us with it. It has for a long time been suggested that the spiral nebulæ are stellar systems seen at great distances. This is the so-called "island Universe" theory, which regards our stellar system and the Milky Way as a great spiral nebula which we see from within. This theory, it seems to me, gains favor in the present observations.[21]

There are absolute constraints on the phenomenon responsible for the observed cosmological redshift. A so-called "tired light" model in which photons lose energy in direct proportion to the distance traveled is immediately excluded from consideration due to the observed time dilation of supernovae light curves.[22,23] Additionally, the change in the energy of photons cannot be associated with a change in momentum that would cause a blurring of distant images. In the laboratory rest frame, ubiquitous specific electron transitions in atoms such as hydrogen cause the emission of photons of a particular frequency. The astrophysical phenomenon that is called the cosmological redshift is an observed identical increase in the wavelength of these and other signature photons across the entire electromagnetic spectrum that is unequivocally associated with distance to the source galaxy. This conclusion is not put in doubt by reported observations of apparent non-cosmological perturbations that may occur for some linked optical binaries.[24]

Edwin Hubble collaborated with Richard C. Tolman, a physicist and professor at Caltech, on a paper published in the *Astrophysical Journal* in 1935 entitled “Two Methods of Investigating the Nature of the Nebular Redshift”. The methods used were comparing nebular dimensions with apparent luminosity and nebular counts with apparent luminosity. Providing an unusual historical perspective of a time before the idea of an expanding Universe became more firmly established, the brief *Introduction* section of their paper is reproduced here in its entirety.

> Light arriving from the extra-galactic nebulae exhibits a shift toward the red in the position of its spectral lines, which is approximately proportional to the distance to the emitting nebula. The most obvious explanation of this finding is to regard it as directly correlated with a recessional motion of the nebulae, and this assumption has been commonly adopted in the extensive treatments of nebular motion that have been made with the help of the relativistic theory of gravitation, and also in the more purely kinematical treatment proposed by Milne. Nevertheless, the possibility that the redshift may be due to some other cause, connected with the long time or distance involved in the passage of light from nebula to observer, should not be prematurely neglected; and several investigators have indeed suggested such other causes, although without as yet giving an entirely satisfactory detailed account of their mechanism.
>
> Until further evidence is available, both the present writers wish to express an open mind with respect to the ultimate most satisfactory explanation of the nebular red-shift and, in the presentation of purely observational findings, to continue to use the phrase “apparent” velocity of recession. They both incline to the opinion, however, that if the red-shift is not due to recessional motion, its explanation will probably involve some quite new physical principles.[25]

In May of of the year of his death (1953), Hubble delivered the UK Royal Astronomical Society George Darwin Lecture entitled “The Law of Red-Shifts” in which he stated:

> Red-shifts, for instance, will be used for the fractions, $d\lambda/\lambda$, by which details in the spectra are shifted. The shifts cannot be distinguished from Doppler shifts; they are constant throughout any given spectrum within the errors of measurement, the most reliable tests being those made on emission lines in large-scale spectra from Hα to λ 3727. The term “apparent velocity” will be discarded, and replaced by “velocity” signifying $c \cdot d\lambda/\lambda$, or red-shifts expressed on a scale of velocities. The procedure is not formally correct but it is convenient.[26]

Measurement of photon wavelength is fundamentally associated with the measurement of time. Let a photon measured in the rest frame at the point of emission have a natural frequency f_0 according to the local proper time t. If a remote observer finds that a local ideal clock records time faster than the clock in the photon emission rest frame, then according to this observer, the identical number of cycles corresponding to the photon’s natural frequency are counted in a greater amount of local proper time t. The imagined “observed” frequency f of the remote photon at its point of emission is therefore necessarily lower than its natural frequency f_0 in proportion to the clock rate differential. However, when the remotely emitted photon actually arrives locally, this is its actual measured frequency according to the local clock; no imagination is required.

$$\frac{f}{f_0} = \frac{d\tau}{dt} \qquad 4$$

A photon’s frequency is related to its wavelength by the speed of light c, so the ratio between observed and emitted wavelengths is the inverse of that between frequencies.

$$\frac{\lambda}{\lambda_0} = \frac{dt}{d\tau} \qquad 5$$

An observed shift in the wavelength of electromagnetic radiation (z) is defined to be the difference between the observed wavelength (λ) and the natural rest wavelength (λ_0) divided by the natural rest wavelength. It follows that z is zero when the wavelengths are identical ($\lambda = \lambda_0$), positive for a redshift ($\lambda > \lambda_0$) and negative for a blueshift ($\lambda < \lambda_0$).

$$z = \frac{\lambda - \lambda_0}{\lambda_0} \equiv \frac{\lambda}{\lambda_0} - 1 \qquad 6$$

Combining Eqs. (5) and (6) yields

$$\frac{dt}{d\tau} = z + 1 \qquad 7$$

When we measure the redshift of a very distant galaxy, the frequency shift contributed by its "peculiar motion" induced by adjacent gravitational fields is insignificant in comparison to its measured cosmological redshift. If we come to the conclusion that the space-time geometry of the Universe requires the relative rate of a remote ideal clock to be slower than a similar local clock in some correlation to its cosmological distance, then the observed redshift of distant galaxies is not predicated on a general recessional velocity caused by a ubiquitous cosmic expansion. Rather, with this redshift measurement we are measuring the rate of ideal clocks associated with the local time coordinate of that galaxy's cosmic region relative to our own ideal clocks.

Symmetric temporal relativity is an exceedingly peculiar, yet it is commonly experienced and measured in the microphysics realm of particle accelerators in conjunction with velocity. Might not the identical phenomenon occur when a cosmological distance separates two ideal clocks? When we combine the intuitive geometric model of symmetric time dilation shown in Fig. (1) with the required topology of a finite boundaryless Universe shown in Fig. (3), a distant ideal clock is perceived to be slower than a similar local clock simply because it is far away. The relative geometry of distinct local time coordinates implies a ubiquitous cosmological redshift-distance relationship for the Universe, yet no recessional motion need be invoked to account for its observation. Then, observation of galactic redshifts cannot be attributed to a general expansion. The immediate task at hand is to rigorously quantify the relativistic temporal effect implied by *geometric cosmic time* and to compare it against what we see through our various telescopes. If the theoretical model's predictions match the empirical observations, then Edwin Hubble and Richard Tolman's suspicion was correct; the observed cosmological redshift is attributable to a phenomenon other than an *imagined* general recession of the galaxies. Moreover, if this is indeed the case, then galaxies and their gravitationally bound clusters may be *much* older than the current estimated Hubble Time of less than 14 billion years. In this new context, the source of the cosmic microwave background radiation and the abundance of the light elements require explanations that are not predicated on a dense hot primeval state of the Universe.

Geometric cosmic time implies that when we measure a redshift of $z = 1$, then relative to time as generally measured in the immediate local Universe, time passes in that observed remote region of the Universe at only half our local rate ($dt/d\tau = 2$). Conversely, and somewhat strangely, observers in that region of the Universe experience time passing in our region of the Universe to be half their own local rate. It follows that from our point of view, their galaxy is aging at half the rate of our galaxy, yet from their perspective it is our galaxy and everything in its vicinity that is aging at half the rate of their galaxy. At a redshift of $z = 4$, time passes (and objects age) at only one fifth the locally measured rate ($dt/d\tau = 5$). It is apparent that on a cosmological scale the meaning of "age" is not so clear as common experience would lead one to believe.

6. The Hubble constant

The redshift-distance relationship became known as Hubble's Law; the recessional velocity of a distant galaxy was modeled to be directly proportional to its distance from the observer with the constant of proportionality being the empirically determined Hubble constant, H_0.

$$\mathrm{v} = H_0 \cdot d \qquad 8$$

In a plot of redshift vs. distance, this "law" implies a straight line with slope H_0 that must necessarily pass through the origin. Then, in theory, just a single accurate measurement of distance correlated with cosmological redshift should establish the Hubble constant, providing the distance-redshift relationship for all astronomical objects. Table (1) provides a selection of measurements of the Hubble constant, including the original 1929 estimate of 500 (five hundred) by Edwin Hubble. As compared to measurements of the speed of light or the rest mass of an electron, the Hubble constant does not seem constant. Indeed, it apparently does not exist.

Table 1 – Some "measurements of the Hubble constant" in the literature 1929 – 2004

H_0 (km s^{-1} Mpc^{-1})	Principle Author	Method	Year
68–74 ±10%	**G. Altavilla**	**Type Ia supernovae**	**2004**
48 ±3	**C. Kochanek**	**Gravitational Lens Time Delays**	**2004**
75 +7 / -6	**L. Koopmans**	**Gravitational Lens B1608+656**	**2003**
58 +17 / -15	**V. Cardone**	**Quadruply Imaged Gravitational Lens Systems**	**2003**
81 ±5 & 75 ±8	**N. Tikhonov**	**Distances to Galaxies of the NGC 1023 Group**	**2002**
91	**D. Russell**	**H I Line Width/Linear Diameter Relationship**	**2002**
60 ±10	**Y. Tutui**	**CO-Line Tully-Fisher Relation**	**2001**
72 ±8	**W. Freedman**	**Multiple (HST Key Project to Measure the H0)**	**2001**
46.9 +7.1 / -6.2	**M. Tada**	**Gravitational lens system PG1115+080**	**2000**
50.3 +10.2 / - 10.9	**S. Patel**	**Sunyaev-Zel'dovich Effect and X-ray spectroscopy**	**2000**
62	**R. Tripp**	**Supernovæ**	**1999**
30 +18 / -7	**C. Lineweaver**	**Cosmic Microwave Background**	**1998**
64 ±13	**T. Kundic**	**Time delay of gravitational lens system 0957+561A,B**	**1997**
50 – 55	**S. Goodwin**	**Galaxy Linear Diameters**	**1997**
70 ±10	**S. Kobayashi**	**Sunyaev-Zel'dovich Effect**	**1996**
67 ±7	**A. Reiss**	**Supernovæ**	**1995**
42 ±11	**A. Sandage**	**Luminous spiral galaxies**	**1988**
67 ±4	**N. Visvanathan**	**Virgo cluster distance**	**1985**
55 ±7	**G. Tammann**	**Cepheids, brightest stars, H II regions, luminosity classes**	**1974**
100 ±10	**D. de Vaucouleurs**	**Survey of nearby groups of galaxies**	**1972**
47	**G. Abell**	**Luminosity Function of the Elliptical Galaxies in Virgo**	**1968**
500	**E. Hubble**	**Cepheids**	**1929**

Because the Hubble parameter is expressed in units of velocity (*km*/*sec*) per distance in millions of parsecs (*Mpc*), the spatial units cancel so that the inverse of the parameter is expressed simply in units of time. Inverting H_0 then yields the "Hubble Time" *T*, indicating about how long of a time objects have been receding from one another since the occurrence of the Big Bang, when all matter in the Universe must be assumed to have shared the same infinitesimal volume of space. Actual attempts to calculate "the age of the Universe" are complicated by assumed values of various parameters concerning geometry, density, etc. However, for the special idealized case of an extreme low-density Universe, the Hubble Time is ostensibly the age of the Universe since the beginning of the expansion, which puts an upper constraint on the age of every object or assembly of objects observed within it. Due to the obvious uncertainty in the value of H_0 reflected by Table (1), it is often expressed using the variable *h*, which for generally accepted modern interpretations of observations typically takes on a value of about 0.7

$$H_0 \sim \frac{100 \cdot h \;\; km\ s^{-1}}{Mpc} \quad \rightarrow \quad T = \frac{\sim 10^{12}}{H_0}\, years \qquad 9$$

It follows from this equation that a value of 50 for H_0 implies an age of ~20 billion years, a value of 60 implies ~17 billion years, a value of 75 implies ~13 billion years and Edwin Hubble's original 1929 measurement of 500 implies that the Universe is only about two billion years old. In what is known as an Einstein – de Sitter Universe, the Hubble Time is only two thirds (2/3) of these values. It is clearly the case that the Hubble parameter cannot be so great as to imply that the Universe is younger than the known minimum age of objects within it. Given this constraint, astronomers are forced to interpret observations accordingly.[27,28] Either ancient stars in globular clusters, at one time estimated to be at least 17 billion years old, must be dated to be considerably less than 14 billion years old to be consistent with the Hubble Time, or the Hubble constant has to be reduced to allow for old objects in the Universe. The apparent antiquity of observed objects has created a strong bias in favor of a lower Hubble constant, implying a greater subjective distance measurement estimate corresponding to a given objective redshift measurement. If one entertains the idea that the cosmological redshift may not after all be indicative of a general expansion, a series of cascading assumptions that all depend on this initial assumption lose their status as empirical constraints. First among these is the idea that the age of all objects and sets of objects in the observable Universe cannot exceed on the order of 10^{10} years.

Fritz Zwicky (1898–1974) studied physics at the ETH in Zürich (Einstein's alma mater) and at various times worked under Herman Weyl as well as Nobel laureates P. Debye and R. Millikan. Zwicky was considered one of the most brilliant and productive astrophysicists of the 20th century and among other accomplishments coined the terms "supernova" and "neutron star" to describe his original ideas while working at Caltech.[29] At the time, apparently unconstrained in his thinking by the cosmological age limits that later came to dominate all subsequent thinking in astrophysics, in 1960 Zwicky published a paper that claimed the following.

> The age of 10^{18} years for rich compact clusters of galaxies may be shortened somewhat by considering certain interactions between galaxies that lead to more inelastic and resonant encounters between galaxies. Unless, however, far greater efficiency for the transfer of energy and momentum is postulated for such interactions than is compatible with our present-day knowledge of physical phenomena, the age of rich spherically symmetrical and compact clusters of galaxies is clearly greater than 10^{15} years. [30]

However fashionable current ideas might influence opinions about the "preposterous" galaxy cluster age estimates that Zwicky asserted in 1960, just the fact that such magnitudes could be considered by a highly competent, informed and practical luminary in the field at such a late date must give one pause. Zwicky was no fool and no crackpot. He had decades of highly respected observational experience and results. Lest we forget, prior to the advent of geology through the work of James Hutton (1726–1797), particular historical interpretations of Biblical creationist themes that colored scientific thought had given an age for the Earth of about 6,000 years. Though generally accepted throughout a sophisticated European and American academia for centuries (Cambridge, Oxford, Harvard, etc.), it was off by about *six orders of magnitude*. Moreover, the anachronistic idea of a brief creation event for Earth about 6,000 years ago is still surprisingly prevalent in large groups of literate people within modern society, particularly in the United States. This mass delusion promoted by leaders of certain religious sects perpetuates in spite of a "creation" date that is very reliably some 25,000 years *after* the charcoal drawings of rhinoceroses roaming France were made in the cave of Chauvent-Pont-d'Arc.[31] Did some socially and politically driven need to match a scientific cosmogony with naïve interpretations of the Biblical *Genesis* story that were even more prevalent a century ago prevent a more sober and skeptical approach to cosmology by the scientific establishment, in the 20th century? Arguably this is the case, beginning in large part with the apparent existential angst of an MIT astrophysics student and ordained Catholic priest named Georges Lemaître, who originally conceived of the Big Bang as what he called the "Cosmic Egg exploding at the moment of Creation". It can be proven scientifically that no such imagined singular cosmological creation event ever took place.

7. The Big Bang theory

The idea that the Universe had a beginning in space and time is credited to a Catholic priest. Ordained in 1923 at age 29, Abbé Georges Lemaître later proposed this idea in the same year he earned his PhD in astrophysics from MIT (1927). His deep religious training may have inspired Lemaître to find parallels between the developing science of cosmology and the Biblical *Genesis*. The original paper, based on Lemaître's understanding of the cosmological implications of Einstein's general theory of relativity, was not widely read by the international astrophysics community as it was written in French and appeared in a little-known Belgian scientific journal.[32] The English translation of Lemaître's paper, entitled "A Homogeneous Universe of Constant Mass and Increasing Radius Accounting for the Radial Velocity of Extra-galactic Nebulæ", appeared in the mainstream journal *Monthly Notices of the Royal Astronomical Society* in 1931, more than a year after Edwin Hubble proclaimed that the Universe was expanding.[33] It is clear from Lemaître's initially obscure 1927 paper in the original French that the interpretation of galactic redshifts, the idea of an expanding Universe and even the "*Hubble Law*" itself originated with the Belgian Catholic priest, not the American astronomer. What distinguished Hubble's celebrated 1929 paper was that it was based on his observational data, which suggested to him a linear plot of redshift versus distance for galaxies in the nearby Universe out to a redshift of about "1000 *km*/*s*".[34] However, Hubble's observations and data analysis leading to this conclusion yielded a Hubble constant of 500 *km*/*s*/*Mpc*, which was later determined to imply a Universe that was younger than reliable geologic estimates of the age of the Earth. In order to conform to the geologic record and other independent astrophysical age estimates, the expansion rate of the Universe determined by astronomers had to be reduced to less than 100 *km*/*s*/*Mpc*. This is easily achieved by manipulating free parameters. To date there is still significant controversy as to claimed measurements of the cosmic expansion rate due to the questionable upper bounds placed on the age of all observed astrophysical phenomena.

The simplistic initial interpretation of the observed galactic redshifts was that they were due to a Doppler shift that increased with distance. Later it was determined that this interpretation was naïve and untenable. Rather than the galaxies rushing away from one another into an existing void of space, the redshift was interpreted to imply that the space between the galaxies was itself expanding and moving them apart, similar to grains of sand stuck to the surface of an inflating rubber balloon. The initially controversial theory of the expanding Universe and its origins became popularly known as the Big Bang theory, although this moniker was originally intended by its author, famed British astronomer Sir Fred Hoyle, to mock what he felt was a ludicrous idea.

Penzias and Wilson's 1965 discovery of the cosmic microwave background radiation (CMBR) lent credence to the theory as this radiation was assumed to prove the predicted existence of the ubiquitous cooled remnants of heat generated by a primordial cosmic explosion. Also, it is known that the stellar nucleosynthesis process in stars of all sizes results in a net consumption of deuterium rather than its production. The measured cosmic abundance of deuterium and other light elements suggests a non-stellar source of intense heat and pressure, further lending credence to the Big Bang theory and its cosmic primordial phase. The late 20^{th}-century surge in high technology enabled more accurate redshift-luminosity (distance) measurements. In 1998, astronomers were surprised when the interpretation of the new measurements of unprecedented accuracy implied an accelerating expansion rather than one that was anticipated to be slowing down due to the effects of gravity.[35] This interpretation requires a mysterious and inexplicable ubiquitous cosmic energy source to fuel the phenomenon, which has been dubbed "dark energy".

While the Big Bang theory evolved since the 1960s to become a fixture of modern science, the theory does not explain the totality of astrophysical observations in a simple and consistent way. The fact that the theory requires an incredible event representing the literal *beginning of time* presents one of its greatest scientific challenges. No satisfactory explanation exists of how an event that produces spacetime and the physical Universe can occur *when time itself does not exist* prior to this purported event. The purported "singularity" at T=0 defies logical analysis.

8. Cosmological latitude

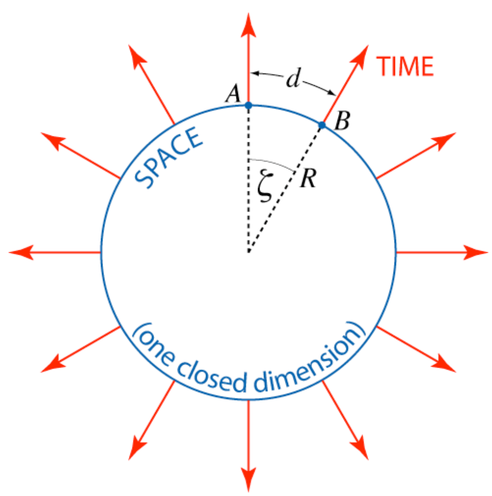
The physical implications of the cosmological temporal model shown in Fig. (3), in which the relative measurement of time by ideal clocks is affected by their spatial separation, can be readily quantified and confronted with empirical observation. To reiterate, this relativistic temporal effect is exclusive of the effects of relative motion, such as that incurred by a purported general cosmic expansion or random "peculiar velocities" of galaxies caused by regional gravitational forces.

Let us first define the concept of cosmological latitude relative to the Milky Way Galaxy. This parameter is unrelated to astrometry, pertaining exclusively to a remote object's distance from an arbitrarily chosen point of observation in the Universe and not to its position in the sky. As is intuitively true for the surface of a sphere, there is no preferred location in space for a finite boundaryless Universe. Therefore, the particular vantage point from which humans view the observable Universe known as the Milky Way Galaxy may be arbitrarily selected as the origin of a concentric cosmological map. Its cosmological latitude ζ (zeta), which is a *relative* coordinate rather than an absolute coordinate, is therefore defined to be zero. An observer in any other galaxy is entitled to do the same thing. Unlike conventional latitude, which is measured relative to an equator between positive and negative antipodes, cosmological latitude is measured directly between antipodes. Therefore, ζ is always a positive value ranging between zero and *pi* radians.

Let point *A* in Fig. (7) represent the location of our galaxy in space and let point *B* represent the location of some observed distant galaxy whose cosmological redshift may be accurately measured. The circle represents the closed total cosmological extent of what is locally determined to be an arbitrarily defined single dimension of space, for example the Milky Way Galaxy's axis of rotation. The cosmological latitude of a distant galaxy at point *B* is its angular cosmological displacement from the observer up to and inclusive of *pi* radians, which represents the location of the cosmological antipode. Note that point *A* can just as well represent any arbitrary location in the Universe from which an observer looks out to some other distant object labeled *B*. The effective radius of the Universe in the epoch of observation is *R*, so the spatial distance d_{AB} between points *A* and *B* is directly proportional to the cosmological latitude of the distant object.

$$d_{AB} = R \cdot \zeta_{AB} \tag{10}$$

Figure 7 – Cosmological latitude ζ (zeta)



A difference between a space measurement and a time measurement produces a new space measurement. In other words, in the space measurements of one man there is mixed in a little bit of time, as seen by the other. …Now in [the Lorentz transformations and the Minkowski metric] nature is telling us that time and space are equivalent; *time becomes space*; they should be measured in the same units.[36] –Richard Feynman

If we interpret Fig. (7) in the context of geometric time depicted in Fig. (1), then it is clear that the cosmological latitude ζ correlates to a symmetric relativistic time dilation between A and B. Combining Eqs. (2) and (7), one arrives at a simple relationship between the directly measured cosmological redshift of a distant extragalactic object and its cosmological latitude.

$$z = \sec\zeta - 1 \qquad 11$$

$$\zeta = \cos^{-1}\left(\frac{1}{z+1}\right) \qquad 12$$

The model yields an important result that provides a completely new yet intuitive concept in cosmology. At cosmological latitude $\pi/2$ (i.e., 90º), the measured redshift of a galaxy at that distance is arbitrarily large. Thus, if too great a spatial distance ($d \geq R\pi/2$) separates two observers, it is impossible for them to exchange information of any kind. Then relative to every observer, there is an effective radial boundary or ***cosmological redshift horizon*** beyond which the remaining more distant galaxies in the Universe (i.e., those in the antipodal "hemi-4-sphere") are fundamentally *invisible*. There is nothing intrinsically unusual about this boundary; it is simply a *relative* cosmological coordinate. To imagine that time flows backward beyond this boundary is as naïve as to imagine that people living on the opposite side of the Earth somehow live their lives "upside down". Moreover, the space-time geometry of the Universe will *itself* not cause lensing or multiple adjacent images of a distant object, nor can the closed spatial geometry of the Universe produce two diametrically opposed images of the same object. The Universe will accordingly provide the clever visual *illusion* of being flat, although it is finite yet boundaryless. For any two observers in different galaxies who are capable of observing the other's signal, each will hold that the other's ideal clock is slower than the local reference clock in some relation to the distance of separation. This implies that a remotely-sourced electromagnetic signal must incur a redshift that is related to the distance traveled by the signal, which is independent of a redshift caused by any relative motion between the source and the absorber caused by any means.

The orthogonality of space and time for locally Lorentzian reference frames established by Minkowski is among the most basic ideas in physics. It rests upon the fundamental principles of special relativity and so it is supported by all of the experiments supporting the principles of SR. The cosmological model shown in Fig. (7) is the result of a natural synthesis between this idea and the simple geometric constraints for a finite boundaryless Universe. In contrast to recently upheld conventional thinking, it is radical, yet this model rests on only two simple ideas whose logic is irrefutable. Indeed, geometric cosmic time is as indisputable a new idea for today as was the geometric revision of the Solar System model by Copernicus in the 16^{th} century.

In *Our Cosmic Habitat* (Princeton U. Press, 2001) Martin Rees, Astronomer Royal of Great Britain and Royal Society Research Professor at Cambridge confessed "99 percent confidence" in the convincing picture of conventional cosmological wisdom that was built up over the last century. Yet, he also stated,

> I would prudently leave the other one percent for the possibility that our satisfaction is as illusory as that of a Ptolemaic astronomer who had successfully fitted some more epicycles. Cosmologists are sometimes chided for being often in error but never in doubt.[37]

Theoretical physicist Richard Price, in the introduction to *The Future of Spacetime*, in which he collaborated with celebrated cosmologist Stephen Hawking and others (Norton, 2002), made some insightful comments on this same theme.

> For the centuries of pre-Copernican astronomers there was no question whether the Earth was the center of the world. If difficulties arose, they would look elsewhere for remedies. Those astronomers constructed an extraordinarily complex calculational method to

predict and explain the motion of heavenly bodies. An originally simple method of prediction was found to be inadequate when observations of planetary motion improved. Mathematical constructions, "epicycles," were invoked to improve the predictions, and the basic theory was coerced into an appearance of working. This cycle of improvements continued, first in adding astronomical observations, then in adding more unwieldy features to the method.

When we look back at what they were doing, we are incredulous. How could they not see that the simple elegant idea of a Sun-centered world explained everything? They had not so much missed what now seems obvious, as they had been seduced, step by step, down the wrong path. The beginning of the path pointed in a reasonable direction, and from well along the path it was hard to see that there were alternative paths.[38]

According to the geometric cosmic time model in Fig. (7), it is immediately clear that two distant observers A and B, though at relative rest, are each entitled state to the other, "*What I call space must be a mixture of your space and your time, and what you call space must be a mixture of my space and my time*." (Thus, A and B are not in the same reference frame.) The phenomenon of a symmetric relativistic time dilation effect is implied, causing a geometrically defined redshift-distance relationship. This effect is not predicated on relative motion of any kind, only on the natural geometric relationships for a finite boundaryless spacetime that duplicates for the Universe in all three dimensions of space the same topological effect found for the finite boundaryless surface of the Earth. In taking this new approach with the relativistic relationship between widely distributed freefalling reference frames in the cosmos, it is not necessary to invoke general relativity (GR), which deals with accelerated frames and asymmetric relativistic time measurement. One may think of GR as analogous to the study of mountains and valleys and cosmology as a more comprehensive perspective like that of observing Earth from the Moon. Approaching cosmology as a GR problem could not yield the insight of geometric cosmic time.

Combining Eqs. (10) and (12) yields an expression for the absolute distance to an *observable* remote galaxy in terms of its measured cosmological redshift z and the cosmological parameter R. *Skeptics with a conventional cosmology mindset should refrain from prejudging Eq. (13) prior to consideration of Sections 9 and 10, which demonstrate a most striking correlation between the cosmological model that evolves from this equation and the latest empirical astrophysical data.*

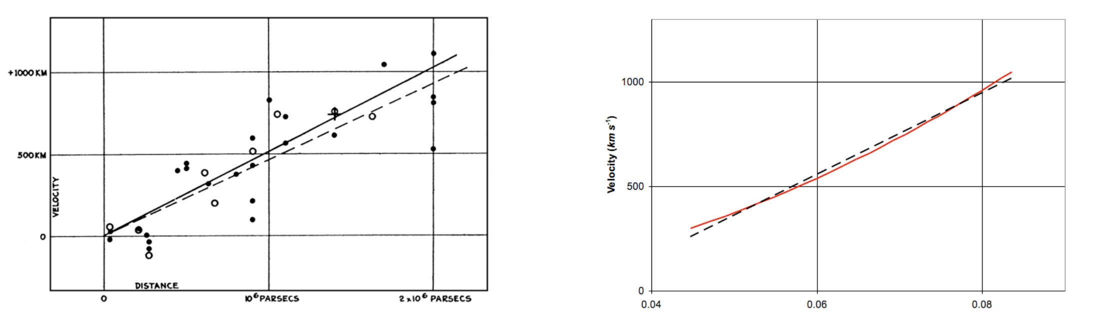
$$d = R\cos^{-1}\left(\frac{1}{z+1}\right) \qquad 13$$

Figure 8 – Original Hubble Diagram vs. Eq. (13) for to z ~0.002

Note that the x-axis for the Eq. (13) graph at right starts at $0.04R$, not zero.

Original Hubble Diagram, 1929 [39]

Equation 13: $300\ km/s < v < 1{,}000\ km/s$

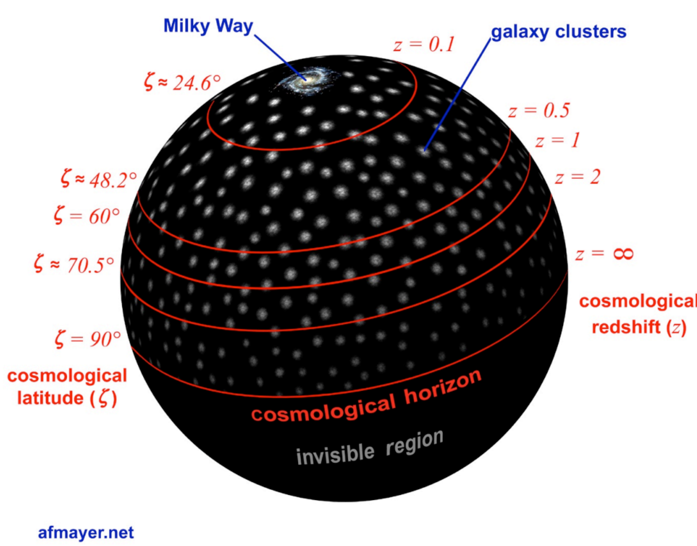


Eq. (13) is an uncalibrated distance expressed in terms of the unknown parameter R, which must be determined by observations that reliably correlate the independently determined distances to a population of remote galaxies and their measured redshifts. The solid curved red line on the right of Fig. (8) plots this equation in the nearby Universe over the same redshift range measured by Hubble in the 1920s. It is easy to see how data from observation of local galaxies with significant peculiar velocities as a fraction of the cosmological redshift might erroneously be interpreted to imply a general linear redshift-distance relationship, suggesting a uniformly expanding Universe. The dashed black straight line on the right of Fig. (8) is the linear fit to the slightly curved plotted function [Eq. (13)] shown in red.

In contrast to Hubble's 1929 claim of a linear redshift-distance relationship and published interpretations of modern observations in support of this popular paradigm, the redshift-distance relationship defined by Eq. (13) is markedly non-linear. This is made abundantly clear in Fig. (9), which depicts the entire cosmological extent of the closed curved surface of what is locally perceived to be a single plane in Euclidean space (e.g., the plane defined by the Galactic disk). Because an infinite redshift must correspond to a finite distance and volume of enclosed space, this immediately suggests a non-linear redshift-distance relationship. Note that the while this non-linearity is less readily perceived over short distances in the relatively nearby Universe [Fig. (8)], it becomes increasingly noticeable at high redshift. *It is critical to appreciate that the familiar inverse square law for luminosity ($1/R^2$) does not apply to isotropic luminous objects observed at cosmological distances for a boundaryless Universe, whose finite spatial volume is the S_3 surface of a 4-sphere*. The inverse square law commonly applied to the apparent luminosity of an isotropic light source assumes a Euclidean spherical dispersion of photons. The dispersion of photons in our finite boundaryless Universe subscribes to a quite different non-Euclidean equation, yet one that is equally well defined by simple geometric rules.

Another important idea that is modeled by Fig. (9) concerns the total volume of space enclosed by a particular redshift radius. The uniform large-scale mass density of the Universe dictated by the Cosmological Principle is reflected in the uniform distribution of galaxy clusters on the surface of the sphere. *It is clearly predicted that galactic redshift surveys must reveal a post-peak exponential decline in population growth of galaxies with redshift to a degree much faster than could be expected to occur due to extinction and dispersion.* Contrary to conventional wisdom, let us also assume that intrinsically bright active galactic nuclei (AGN), many of which are classified as quasars or "QSO", are ubiquitous and have a uniform space density distribution, in spite of previous appearances. Then the *interpreted* intrinsic luminosity of QSO of a spectral class based on their observed apparent magnitude and their calculated distance according to the conventional redshift-distance scale will give the illusion of an unlikely "luminosity evolution" whereby all QSO seem to get intrinsically brighter with increasing redshift.

Figure 9 – A partial model of the cosmos showing the relationship between ζ and z



Liberal artistic license was used in depicting the Galaxy and clusters. The sphere's *surface* represents the total cosmological extent of the plane of the Milky Way Galaxy disk. The location of the Milky Way is an *arbitrary* point on the sphere, which has no preferred origin on its surface and no preferred axis of symmetry. The concentric circles are shown at relative distances to the arbitrary location of the origin. Two such spheres are required to map the entire Universe [Fig. (5)]. As this sphere is a *projection,* the *metric* operating in modeled space *does not correlate to the geometry of the sphere's surface.*

9. The geometry of the Universe

Approximating Earth ($\mathbb{S}^3$) to be a unit ball, the Geoid surface area is 4π in units of square Earth radii. Taking a similar approach for the $\mathbb{S}^4$ Universe, its radius is conveniently normalized (R=1). Accordingly, the line element of a unit 4-sphere is

$$ds^2 = d\psi^2 + \sin^2\psi\left(d\theta^2 + \sin^2\theta\, d\phi^2\right) \tag{14}$$

The total volumetric "surface area" S_3 of a 4-sphere of unit radius is $2\pi^2$ according to

$$S_3 = \int_0^{\pi} d\psi \int_0^{\pi} \sin\psi\, d\theta \int_0^{2\pi} \sin\psi \sin\theta\, d\phi \tag{15}$$

$$S_3 = 4\pi \int_0^{\pi} \sin^2\psi\, d\psi \tag{16}$$

$$S_3 = 4\pi\left(\frac{\psi}{2} - \frac{\sin 2\psi}{4}\right]_0^{\pi} = 2\pi^2 \tag{17}$$

The surface area S_2 enclosing S_3, being the derivative of S_3, is then (trivially) from Eq. (16)

$$S_2 = 4\pi \sin^2\psi \tag{18}$$

Referencing Fig. (9), it should be clear that the cosmological latitude ζ corresponds to the value of ψ in the foregoing equations ($\zeta \equiv \psi$). What is modeled as a great arc through cosmic spacetime ($R{\cdot}\zeta$) is the radial distance measured over the shortest possible distance through space between the telescope and a remote galaxy (i.e., the path of light between the two points). Conveniently having adopted a cosmological unit radius (R = 1), referencing Eq. (12) yields

$$\sin\zeta = \sqrt{1-\cos^2\zeta} = \left(1 - \frac{1}{(z+1)^2}\right)^{\frac{1}{2}} \tag{19}$$

$$S_2 = 4\pi\left(1 - \frac{1}{(z+1)^2}\right) \tag{20}$$

Eq. (17) yields

$$S_3(\zeta) = 2\pi\left(\zeta - \frac{\sin 2\zeta}{2}\right) \tag{21}$$

$$\sin 2\zeta = 2\cos\zeta \sin\zeta = 2\left(\frac{1}{z+1}\right)\left(1 - \frac{1}{(z+1)^2}\right)^{\frac{1}{2}} \tag{22}$$

$$S_3(z) = 2\pi\left[\cos^{-1}\left(\frac{1}{z+1}\right) - \left(\frac{1}{(z+1)^2} - \frac{1}{(z+1)^4}\right)^{\frac{1}{2}}\right] \tag{23}$$

Based exclusively on geometric relationships and involving no free parameters, Eq. (20) gives the light dispersion area as a function of redshift and Eq. (23) gives the physical volume of space enclosed by the radial distance corresponding to a particular redshift. Note that the curvature of the Universe shown in Fig. (9) is in *spacetime*, not in space. The equatorial circumference is not 2π, but rather π^2, so Euclidean geometry holds and the simple inverse of Eq. (13) provides the *theta-z* relationship plotted in Fig. (13). Then, Fig. (14) shows the corresponding relative sizes of a standard ruler as compared to empirical observation shown in Fig. (15).

Figure 10 – Plot of Eq. (13): geometric distance vs. z

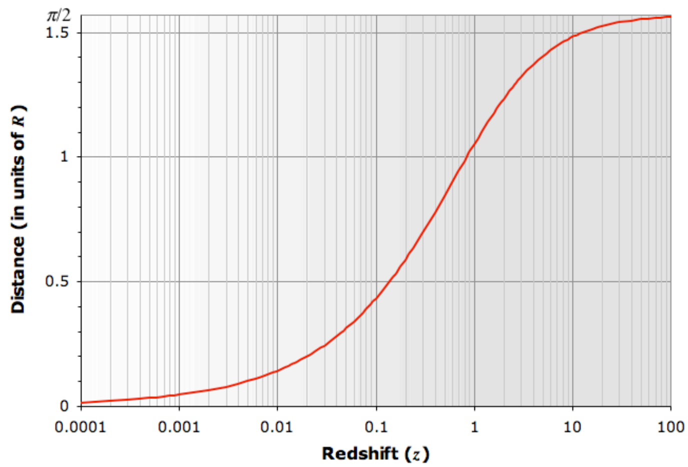


Figure 11 – Plot of Eq. (20): Light dispersion area vs. z

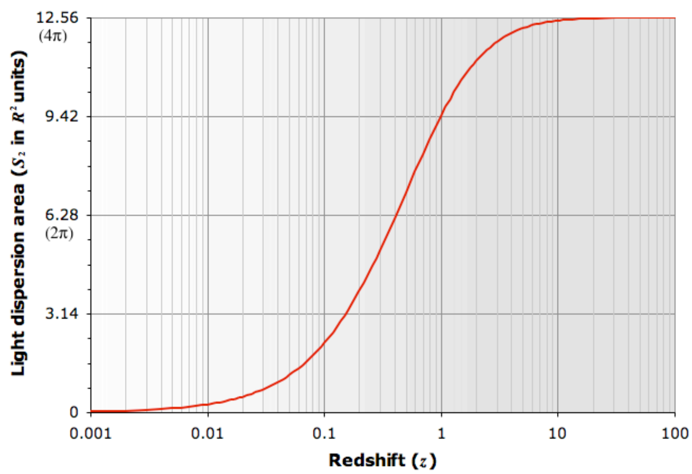


Figure 12 – Plot of Eq. (23): Enclosed volume vs. z

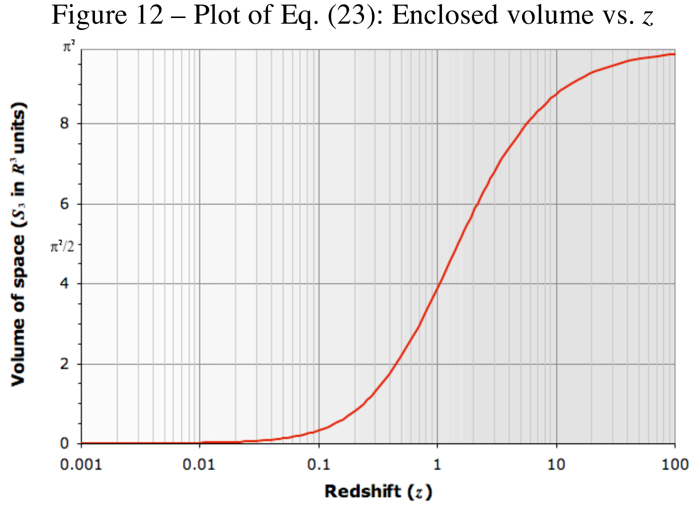


Figure 13 – The inverse of Eq. (13) gives the *theta-z* relationship

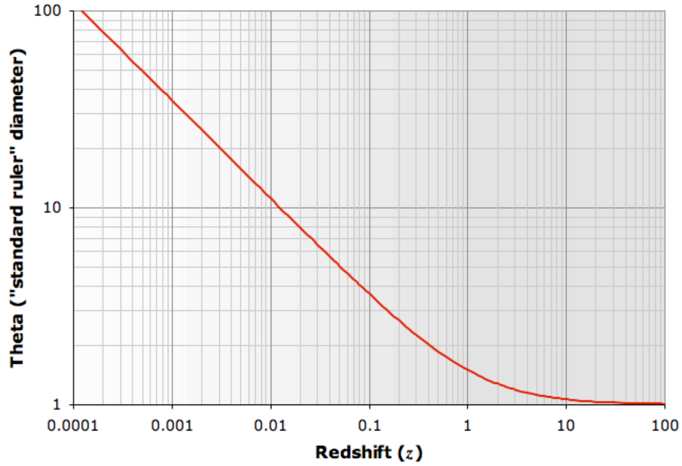


Figure 14 – The implied *relative* apparent size of a standard ruler vs. redshift

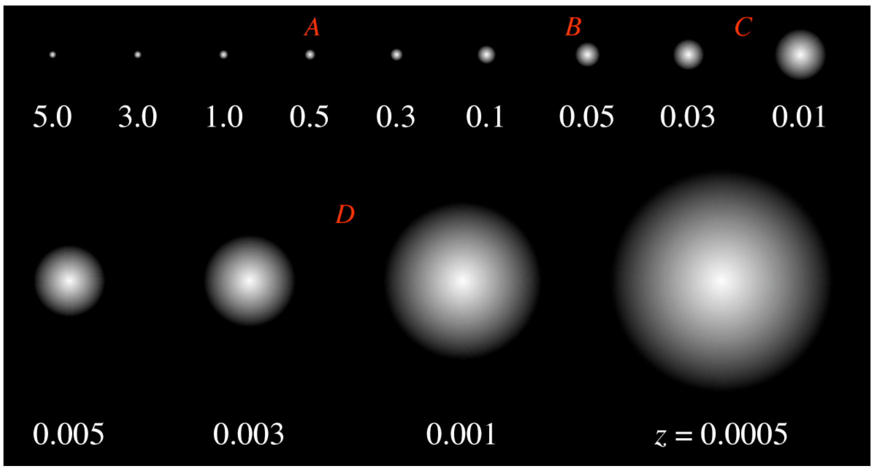
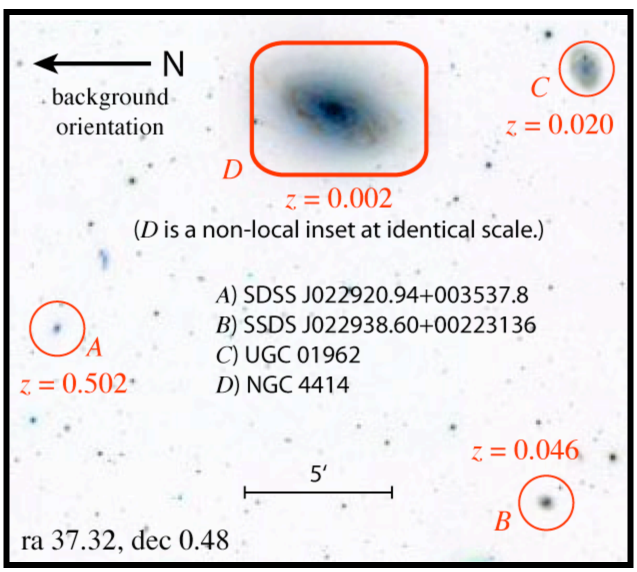


Figure 15 – An empirical assessment of Fig. (14)



Telescope images courtesy Sloan Digital Sky Survey

For comparison to the above, Ned Wright's online cosmology calculator (ver. Feb. 2007) was used to produce the following three graphs for the currently popular "Lambda-Cold Dark Matter" cosmological model, also known as the "concordance model of Big Bang cosmology".[40] The luminosity distance required a log-log plot in order to provide detail at low redshift. Note that the redshift scale on these graphs rises *three orders of magnitude higher* than the preceding graphs. This historical model is inconsistent with empirical observations and is unsalvageable.

Figure 16 –Lambda-CDM comoving radial distance

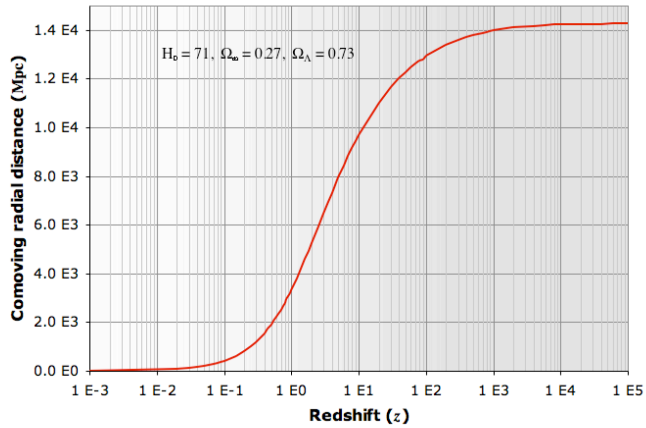


Figure 17 – Lambda-CDM luminosity distance

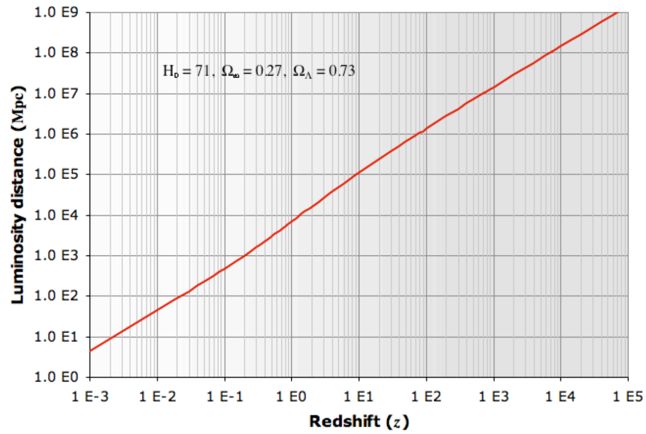
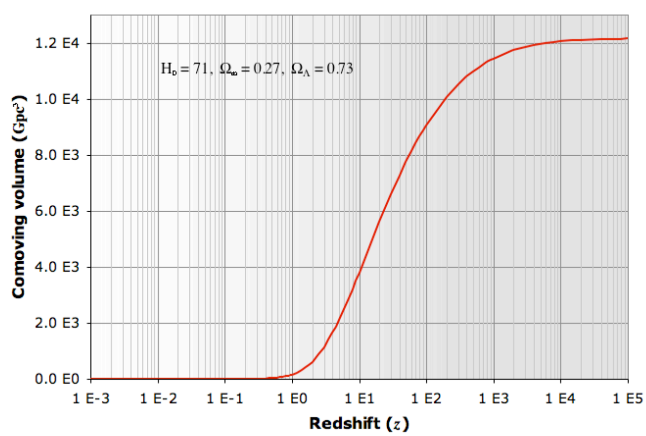


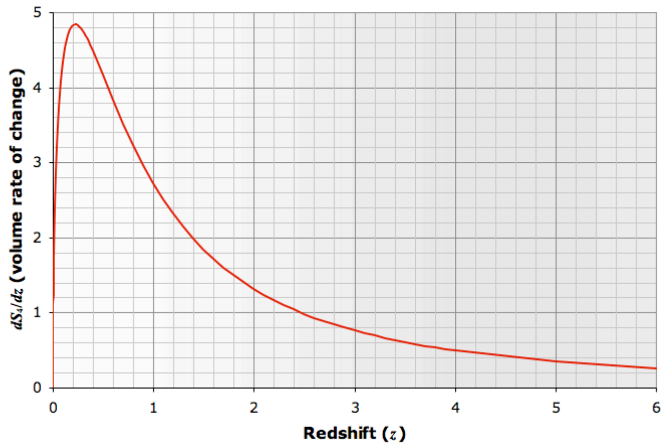
Figure 18 – Lambda-CDM comoving volume



Differentiating Eq. (23) with respect to z yields a formula for the spatial volume rate of change as a function of redshift. Because the integral of this function is equal to the volume function, the area under the graph of Eq. (24) out to a selected redshift value corresponds to the total volume of space enclosed by the corresponding radial distance. Although the value of Eq. (24) is defined only for $z > 0$, that it is undefined at the origin does not affect its utility.

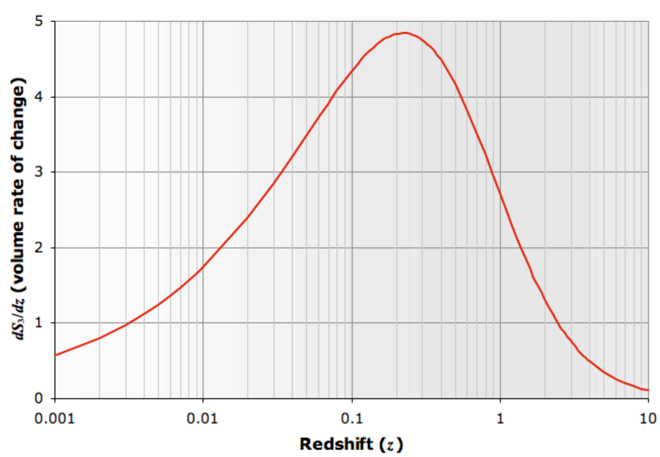
$$\frac{dS_3}{dz} = 2\pi\left[(z+1)^{-2}\left[1-(z+1)^{-2}\right]^{-\frac{1}{2}} + \left[(z+1)^{-2}-(z+1)^{-4}\right]^{-\frac{1}{2}}\left[(z+1)^{-3}-2(z+1)^{-5}\right]\right] \qquad 24$$

Figure 19 – Plot of Eq. (24); the area under the graph is $S_3(z)$



Assuming a uniform galaxy space distribution, it should be clear that, when normalized, this graph represents the predicted probability density function (PDF) for galaxies in redshift space. A log plot of Eq. (24) provides the detail required to accurately compare theoretical predictions of the galaxy population density function with empirical measurements. Note that the Fig. (20) plot represents expected empirical results for a "perfect" telescope that counts all existing objects regardless of their apparent luminosity. Because a real telescope resolves a smaller proportion of objects with increasing redshift, the peak of the empirical curve will be shifted to the left and the entire curve will be narrowed to some degree as compared to the empirical curve, depending on the survey instrument's resolution. The lower the resolving power of the telescope used for a redshift survey, the more the peak of the empirical curve will be shifted to the left as compared to the predicted curve. In addition, the high-redshift tail of the empirical curve will be considerably steeper than the theoretical curve as only the very brightest objects are seen at extreme distances.

Figure 20 – Log plot of Eq. (24); predicted galaxy population density

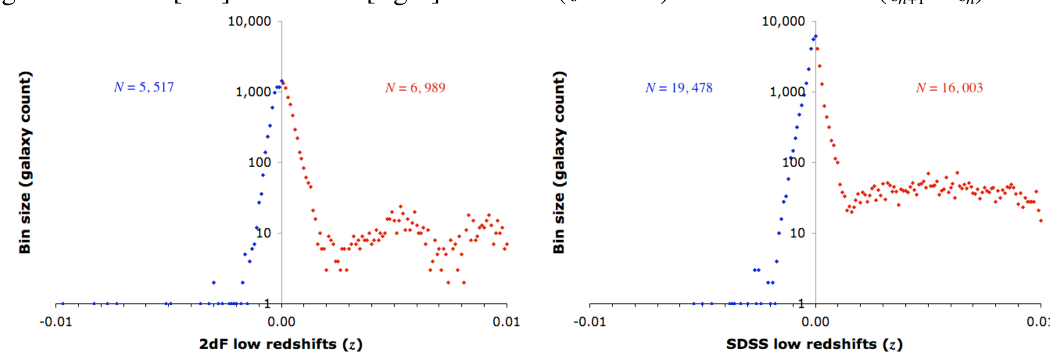


10. Galaxy redshift surveys

The Two Degree Field Galaxy Redshift Survey (2dFGRS) was completed in June 2003 following six years of observations with the Anglo-Australian Telescope at Sliding Springs Observatory in New South Wales, Australia.[41] Its online-accessible database contains accurately determined redshifts for over 200,000 objects in the *southern sky*.[42] The Sloan Digital Sky Survey (SDSS), which is being conducted from the Apache Point Observatory in New Mexico, completed its first five-year phase of operations in June 2005 with the second phase slated for completion in June 2008. SDSS is in the process of determining the fundamental observational parameters of more than one million galaxies and quasars over about one-quarter of the sky. Version 5 of the SDSS database, published in 2006, includes accurate redshift data on over 500,000 objects in the *northern sky*. Because they were conducted in opposite hemispheres, these two pioneering cosmic mapping surveys of massive scale obviously incorporate data on different sets of galaxies. Because they were conducted by different teams using different instruments, correlations between the data sets are almost certain to reflect underlying empirical insights about the cosmos, rather than artifacts caused by common systematic errors in data acquisition and analysis.

The following two histograms show binned redshift data from both surveys selected to reveal the large total number and proportion of observed blueshifted galaxies observed within the local ($|z| < 0.01$) Universe. The *symmetry* of the prominent central peak has a number of possible contributing causes including galactic orbital velocity of the Solar System, effects of the Local Supercluster on the Local Group, or random velocities of local galaxies relative to one another instead of the expected Hubble Flow. The Structured Query Language (SQL) database queries that generated the plotted data points in these and following graphs appear in the Appendices.

Figure 21 – 2dF [left] and SDSS [right] redshifts ($z \leq 0.01$) with bins of size $(z_{n+1} - z_n) = 0.0001$



Benoît Mandelbrot coined the term "fractal" in 1975, derived from the Latin *fractus* meaning "fractured".[43] A fractal is in part defined as stochastically self-similar geometric object with a *Hausdorff dimension* which is greater than its topological dimension. Soon thereafter, brave theorists first proposed that that the Universe had a fractal architecture. The empirical peak that appears in both these graphs has never before appeared in the literature, but it was anticipated…

> Mandelbrot's cosmological principle – that the observers attached to the material structure elements are equivalent – is close to what Milne presented. Thus, the fractality of the universe perfectly satisfies Milne's Cosmological Principle. It also automatically makes what Igor Karachentsev has called "the ecological correction to the Copernican principle" – the real observer can *live* only on or close to a material celestial body. …
>
> The emerging fractality brings about surprises for all of us who have used to think in terms of ordinary "ideal gas"-like distributions. For example, the observer sees the density of matter decreasing outwards, <u>as if he stood on top of a mountain</u>. And this is true for every observer, which radically distinguishes fractality from usual clumpiness. If not aware of fractality, each observer will think that he is the true center of the universe.[44]

There can now be little doubt that the Universe does indeed have a fractal architecture…

When we look at the data beyond the local Universe, we see the curves shown below of nearly identical shape having a striking correlation to the theoretically predicted observable in accord with Fig. (20). Note that the peak of these curves is shifted somewhat to the left of z = 0.2 as expected and that the rise of the curves is a matching five normalized units. The precipitous decline in the empirical curve after z = 0.1, in contrast to the theoretical curve, correlates with the rapid rise thereafter in the light dispersion graph shown in Fig. (11). In this regime, time dilation effects also increasingly contribute to significantly reducing the photon flux of distant galaxies on a charge-coupled device (CCD). The fractality of the local Universe will depress the low-redshift tail of the empirical curve, as observed. It is apparent that the differences between the theoretical curve shown in Fig. (20) and the empirical curves shown below are expected differences between these particular graphs rather than being indicative of a poor match between the prediction and the observable. The matching features at about z = 0.035 and the other obvious large-scale density fluctuations are almost certainly indicative of a fractal cosmic architecture.

No correlation exists between the rise and fall of these empirical curves and the predictions of galaxy population density in redshift space that arise from any conventional cosmological model. It can be unequivocally concluded from observations that all of these prior models are incorrect.

Figure 22 – 2dF redshifts ($z \geq 0.001$) with bins of size $(z_{n+1} - z_n) = 0.0001$

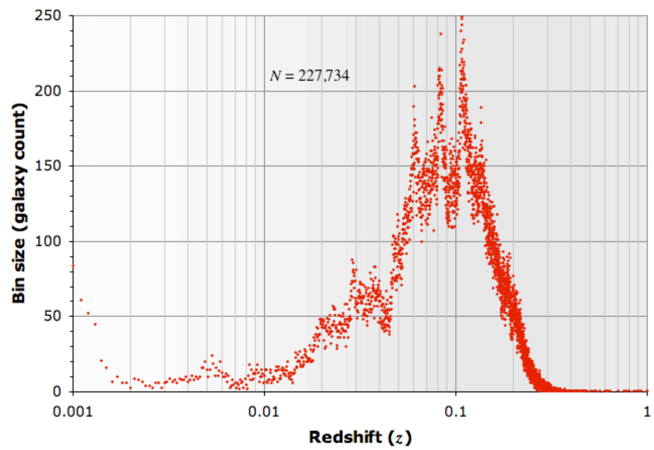
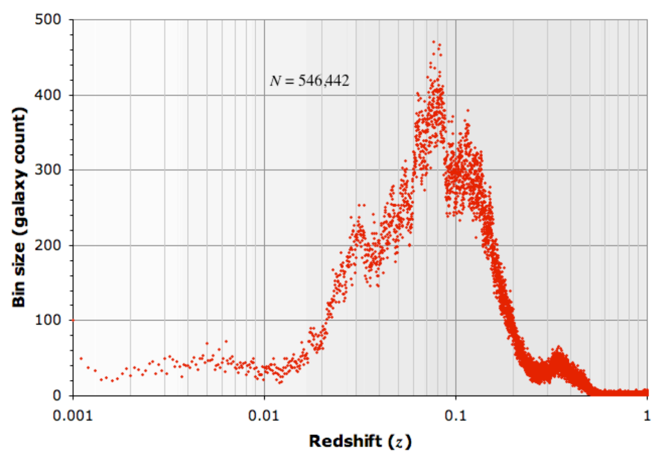
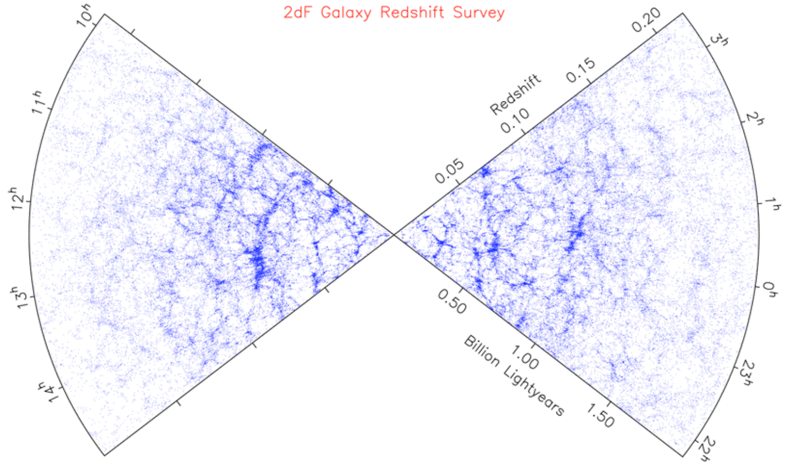


Figure 23 – SDSS v5 redshifts ($z \geq 0.001$) with bins of size $(z_{n+1} - z_n) = 0.0001$



Conventional cosmology (see arXiv:astro-ph/9905116), which is predicated on the Hubble expansion interpretation of galactic redshifts, assumes an approximately linear redshift-distance relationship in the nearby Universe. This is reflected by the assumed distance scale corresponding to the measured redshift in the following diagram published by the 2dF team.

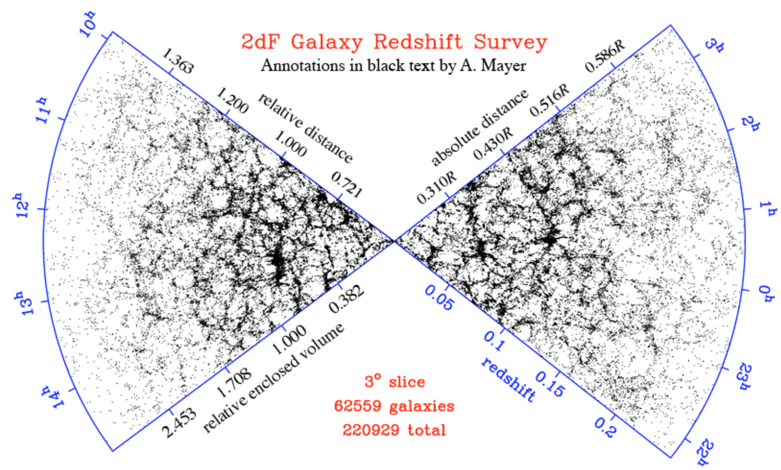
Figure 24 – 2dF survey showing conventional redshift-distance relationship



Courtesy Matthew Colless, Anglo-Australian Observatory

Note that the distance scale in Gly is slightly non-linear as compared to the linear redshift scale (i.e., the measured length from the origin to 1.50 Gly is slightly greater than to the z = 0.15 tick). A second graphic of the same 2dF data, which in the original shows no distance scale, conveniently allowed the author to provide an annotation corresponding to Eq. (13) and Fig. (10).

Figure 25 – 2dF survey annotated in black text with *new model* predictions



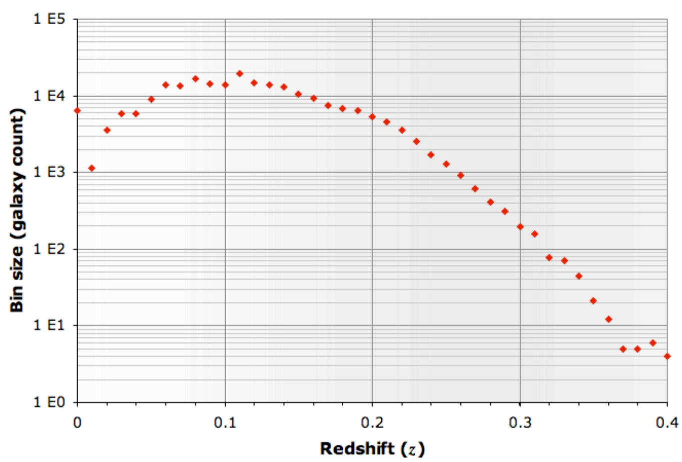
Source image courtesy Matthew Colless, Anglo-Australian Observatory

It is apparent that Big Bang cosmology generally models objects to be farther away than they really are; the apparent size of an object will then be interpreted to imply an intrinsic size that is increasingly exaggerated with increasing redshift. — A classic test of cosmological models involves the apparent angular size–redshift relation or what is known as the "theta-z" (θ-z) relation for objects referred to as "standard rulers" that are understood to have approximately identical size. From historical observational evidence and its interpretation, spiral galaxies seem to vary considerably in size. However, a *systematic* trend of *increasing* size with redshift seems clearly indicative of an erroneous redshift-distance relationship.

> The problem with [Sc I] galaxies is that, if their linear diameters are calculated, based upon their angular diameters and their redshift distances, they become larger and larger with increasing redshift. It would appear that if redshift [as conventionally interpreted] is a totally reliable distance indicator, Sc I galaxies at earlier epochs were bigger than the current examples.[45]

The z-axis into the page of Fig. (24) and (25) is a 3º thick slice of sky for which over 62,000 galaxies have been plotted in redshift space out of a total population of about 221,000. Two properties are prominent in these images. The first is the complex almost organic filamentary structure; the second is the rapid radial decrease in the galactic population density in redshift space with increasing redshift. What we see here with intuitive visual impact on the shorter scale ($z < 0.25$) is the same kind of trend that we see in the Fig. (22) and (23) graphs. If we query the online 2dF database that lies behind this image, we find that the galaxy redshift data actually goes out as far as $z = 3.5$, but none of the higher redshift data beyond $z = 0.25$ is included in any of the published 2dF graphical images. The reason for this is that after $z \sim 0.1$ there is *exponential decay* in the galaxy count with redshift, which can be clearly seen in the plot of the numerical data shown in the Fig. (26) graph. This causes a paucity of objects at high redshift that is impossible to explain in the context of the conventional cosmological model. If the image in Fig. (24) and (25) included the galaxies in the 2dF database just out to redshift $z = 0.35$, the extrema of the image would be virtually empty of dots representing galaxies in what is supposed to be an enormous roughly uniformly populated volume of space. The farther out we went, the emptier space would seem to get, if we interpret the empirical data according to the conventional cosmological model.

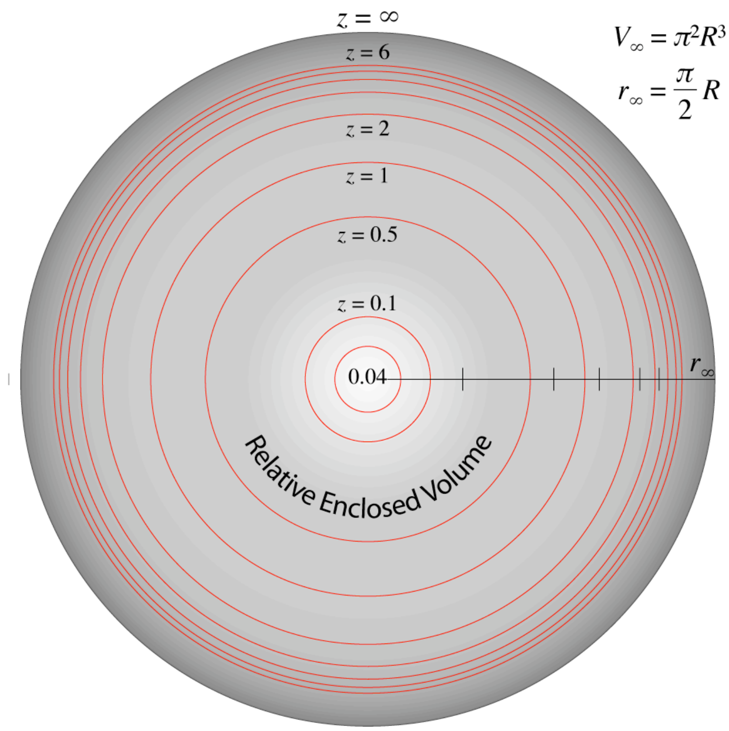
Figure 26 – 2dF redshifts with bins of size $(z_{n+1} - z_n) = 0.01$



A cosmological model and its theoretical redshift-distance relationship that is in accord with the Cosmological Principle must interpret the observed exponential decay of galaxy counts in redshift space in the context of a generally even distribution of galaxies in physical space. This implies that the volume of space as a function of redshift must correspond to the galaxy population as a function of redshift to keep the large-scale mass density similar everywhere. Otherwise, the brilliant observational achievements of modern astronomy simply do not make sense. Fig. (20) clearly indicates that the rate of volume increase with redshift after $z = 0.25$ has a precipitous decline. What the graph in Fig. (19) tells us in particular is that a correct geometric model of the Universe must yield a very substantial percentage of its total observable volume (within the high-z redshift horizon) within the boundary $z < 1$. Note that the S_3 volume of the cosmos represented in Fig. (15, 19) is measured in normalized units of "cubic Universe radii".

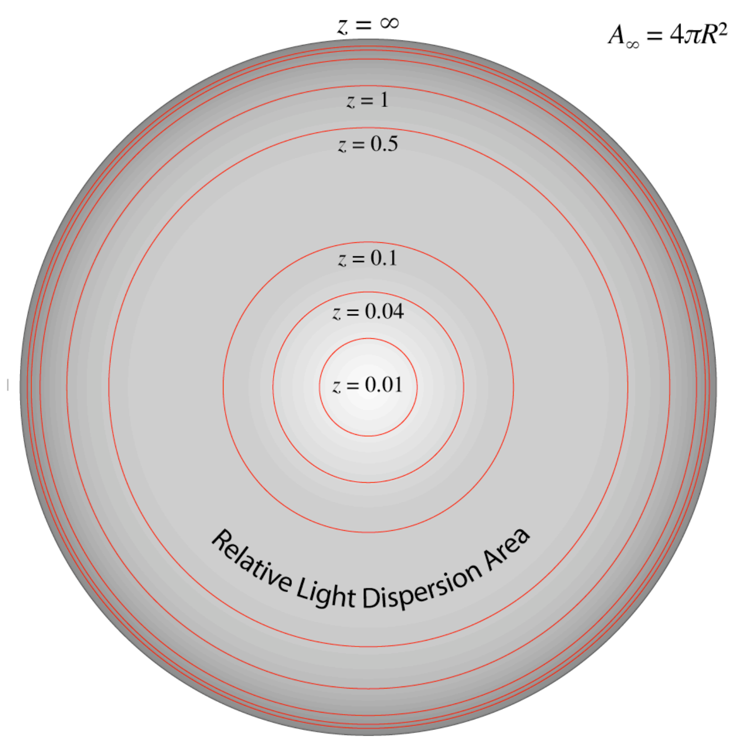
It is intuitive that an arbitrarily large redshift must correspond to a finite volume of space and that the rate increase in total enclosed volume with redshift (radial distance), while exhibiting a sharp peak for the nearby Universe, must exhibit an exponential decline thereafter. In Fig. (27), the grey circle represents the entire π^2R^3 volume of the observable half of the Universe. The enclosed areas of the concentric red circles represent the proportion of this volume enclosed at various redshifts. Fig. (28) provides a similarly intuitive diagram of the surface area enclosing each volume of space out to the maximum of $4\pi R^2$ at the redshift horizon ($z = \infty$).

Figure 27 – Area plot of Eq. (23)



Conclusion: most of all there is to see of the Universe is within $z = 2$ but over 15% is at $z > 6$. (The small marks at the 3 o'clock position show relative *distance* from $z = 0.1$ out to $z = 3$.)

Figure 28 – Area plot of Eq. (20)



Conclusion: only *time dilation effects* appreciably decrease apparent brightness after $z = 2$. Figures (14, 28, 29) provide new insight into analysis of the *Hubble Ultra Deep Field*.

11. The conventional 20th-century cosmological model

The idea that a holistic cosmology could be addressed independently of general relativity was historically never considered. It was naturally assumed that since gravity was the dominant force on the cosmological scale, the cosmological model must necessarily evolve from Einstein's relativistic theory of gravity. In 1917, the Russian mathematician Aleksander Friedmann, working in a purely mathematical context, arrived at the idea that the Einstein field equations implied a dynamic, rather than a static Universe. In the 1920s, Friedmann communicated with Einstein, who initially rejected his ideas, but later, after learning about Hubble's "expanding Universe", Einstein came to accept them and to modify his thinking accordingly. The Friedmann Equation for an expanding Universe, which may be somewhat naïvely derived from Birkhoff's Theorem and the conservation of energy is

$$\left(\frac{1}{R}\cdot\frac{dR}{dt}\right)^2 = \frac{8\pi G}{3}\rho_m - \frac{kc^2}{R^2} \qquad 25$$

Here R is the radius of the Universe [$R(t)$] that may change with time, ρ_m is the mass-energy density of the Universe, G is the gravitational constant, c is the speed of light and k is the curvature constant specifying either positive (+1) negative (-1) or zero (0) curvature. The left side of this equation is identically equivalent to the square of the Hubble parameter whose inverse, having units of time, would ostensibly represent the age of the Universe (the time since the beginning of expansion at coordinate $R=0$).

$$H = \frac{1}{R}\cdot\frac{dR}{dt} \qquad 26$$

Define a "critical density" ρ_c and a mass-energy density parameter quotient omega (Ω_m)

$$\rho_c = \frac{3H^2}{8\pi G} \qquad \Omega_m = \frac{\rho_m}{\rho_c} \qquad 27$$

Then Eq. (25) might be written in the following compact form

$$kc^2 = H^2R^2\left[\Omega(R) - 1\right] \qquad 28$$

The three possible values of k are then dependent on the value of Ω, so the interpretation is that the topology of the Universe is dependent on the density. Einstein's "cosmological constant" lambda (Λ), which he added to create a static Universe from his equations, implies an effective density that is independent of R and can even be negative. Einstein appropriately called this creative but unphysical idea, which could be used to artificially and arbitrarily modify the density parameter, "my greatest blunder".

$$\Omega_\Lambda = \frac{\rho_\Lambda}{\rho_c} \quad \rightarrow \quad \Omega = \Omega_m + \Omega_\Lambda \qquad 29$$

What is called an Einstein-de Sitter Universe is the special case of $\Omega_M=1$ and $\Omega_\Lambda=0$. For the case of an extreme low-density Universe where the Hubble Time simplifies to $T = H_0^{-1}$, both free parameters are zero.

In the late 1930s, Howard Percy Robertson of Caltech and Arthur Walker at Liverpool Univ. collaborated on expanding Friedmann's ideas and firming up its mathematical foundation.[46] Rather little is written or generally known about Robertson as he was a private man and quite intimately connected with classified programs in defense and intelligence. The Robertson-Walker metric describes what is referred to as a Friedman-Lemaître-Robertson-Walker (FLRW) Universe that is isotropic, homogenous and has the property of "cosmic time" t measured to be the same everywhere. This is the mathematical representation of the idea shown in Fig. (4). The metric does not specify a topology, but rather leaves this as a free parameter.

$$ds^2 = c^2dt^2 - R^2(t)\left[dr^2 + S_k^2(r)\left(d\theta^2 + \sin^2\theta d\phi^2\right)\right] \quad \begin{array}{rcl} S_{+1}(r) & = & \sin(r) \\ S_{-1}(r) & = & \sinh(r) \\ S_0(r) & = & r \end{array} \qquad 30$$

In the 1930s, Hubble's interpretation of the observed cosmological redshift fell in fertile theoretical ground and enjoyed steady acceptance through the following decades. George Gamow (1904–1968) was an American physicist born in Ukraine who gained initial recognition for his theoretical description of radioactive alpha particle decay and spent most of his career as a professor of theoretical physics at George Washington University.[47] He made important initial contributions to the theory of stellar evolution and was particularly well known as an ardent early supporter and developer of Lemaître's cosmological ideas.[48] He is perhaps best known for his 1948 collaboration with Ralph Alpher in describing a theory of the origin of the light elements, having adding the legendary Hans Bethe[49] as a silent third author for the famous so-called $\alpha\beta\gamma$ (Alpher-Bethe-Gamow) paper that discusses a hot radiation-dominated early Universe, although with some naïveté as concerns the subtleties of the nucleosynthesis problem.[50] Gamow made it a point to popularize his own theories and science in general by public speaking and writing a number of popular articles and books on science and cosmology that included the *Mr. Tompkins* series. His bibliography includes eleven articles in *Scientific American* and nineteen science books for the layman including *The Creation of the Universe* (Viking, 1952).

In encyclopedias, educational films, websites, secondary and university textbooks, etc., one is today confronted with constant repetition of something similar to the following quote:

> "Hubble observed that the galaxies, on the whole, were moving away from each other.
> Thus we live in an expanding Universe."

However, neither Edwin Hubble nor any being in the Universe will have ever observed proper motion of a distant galaxy millions of light years away. In contrast to this sophistic statement, the sober, exact, and correct scientific description of the historical empirical facts is as follows. — Vesto Slipher's spectrograph indicated that photons emanating from distant fuzzy patches of light ("nebulæ") that collectively had the well-known spectrographic signature of particular electron transitions in the atoms of particular elements (e.g., the Lymann emission lines of hydrogen) exhibited an increase in wavelength $\Delta\lambda$ as compared to the rest frame wavelength, apparently in some proportion to Earth's distance from the source. Through eternity, all intelligent beings in the Universe who examine the spectrum of photons arriving from distant galaxies will experience exactly the same thing, but at no time will any such being observe a galaxy millions of light years distant to be "moving" in any away. The idea that the galaxies are receding is an *interpretation* of the observed cosmological redshift that is not necessarily correct. When one considers that this interpretation requires the mass-energy of some 10^{11} *galaxies* to have once shared a spatial volume smaller still than a single *proton*, it seems both absurd and profoundly naïve. Indeed, this silly idea is indistinguishable from bizarre arbitrary beliefs associated with religious fanaticism.

British astronomer and knighted Cambridge University professor Sir Fred Hoyle (1915–2001) who, tongue in cheek, coined the term "Big Bang" for the prevalent cosmological model espoused by Gamow never accepted the prevailing theory.[51] It was Fred Hoyle's opinion that this all-too-easy interpretation of astronomical observations that did not seem to match all the data was on par with the Earth-centered cosmological model, which persisted for many centuries, as it seemed so obviously correct according to many observations. Of course, the "flat Earth" proved patently incorrect upon more subtle and vigorous investigation...

> Fred believed that, as a general rule, solutions to major unsolved problems had to be sought by exploring radical hypotheses, whilst at the same time not deviating from well-attested scientific tools and methods. For if such solutions did indeed lie in the realms of orthodox theory upon which everyone agreed, they would either have been discovered already, or they would be trivial.[52]

However, Hoyle was never able to put forward a cohesive and convincing explanation for the totality of astronomical observations that was superior to the accepted conventional model. Throughout his life, Hoyle and his few ardent supporters of a "steady-state" Universe were understandably considered intransigent and were not well received by a scientific community intolerant of scientifically and socially unpopular ideas. However, Hoyle's disdainful moniker for the popular theory he detested struck a chord with both the scientific and lay communities. As the "Big Bang" so perfectly describes the Hubble recession cosmological model, the name stuck.

Given the assumption that the cosmological redshift implies expansion of the Universe, if one imagines going backward in time according to a local clock, the Universe is contracting. Then the mass-energy that we see today in the form of perhaps 100 *billion* galaxies and countless diffuse clouds of matter making up the intergalactic medium is concentrated into a smaller and smaller totality of space. This eventually implies a condition in which the entire mass-energy content of the Universe is contained within an "infinitely dense" region of arbitrarily small volume. Such "infinite density" has no more physical meaning than "500 degrees below zero".

Can the mass-energy of more than 10^{11} *galaxies* have shared a spatial volume smaller still than a single proton? In the 13th century, St. Thomas Aquinas penned *Summa Theologica* and in great seriousness stated that two angels could not occupy the same place at once, prompting the question of how many angels could fit on the head of a pin. Either of the preceding questions might be futilely argued indefinitely, but disciplined thinking constrained by the scientific method does not allow for "anything is possible". On this note, if the Universe exists in eternal dynamic equilibrium, rather than a state of expansion, then there must exist a mechanism that prevents eventual gravitational implosion. This mechanism, which will eventually be discussed, must be explicable within the boundaries of physical law and observed astrophysical phenomena.

12. The apparent luminosity of extragalactic supernovae

In order to better appeal to a broad scientifically literate audience who may not all be familiar with fundamentals of astronomy and astrophysics, this section initially includes some quite basic background information that will be familiar review material for readers expert in the topic. Equations (31-39) and associated discussion are all sourced from standard textbooks and should not be confused with the majority of original creative material that is presented herein.

Absolute luminosity L is an intrinsic and generally dynamic property of an astronomical object. It is a measure of how much energy is being released in the form of some observed bandwidth ν of radiation per second and so is synonymous with power, which we measure in units of watts. This bandwidth will generally be restricted by a bandpass filter to some narrow portion of what are identified as the radio, microwave, infrared, optical, ultra-violet, x-ray or gamma ray frequencies of the spectrum. If the total emitted energy of all measurable frequencies across the spectrum is measured, this is called the "bolometric" luminosity. At a particular location, we receive only a portion of the total luminosity according to how spread out the radiation has become. The perceived intensity or "apparent brightness" b of observed radiation is typically the photon flux on a CCD and is measured in $Watts/m^2$. Over non-cosmological distances, the flux is measured according to the understanding that light disperses evenly over a Euclidean spherical shell centered at the source of the radiation. This assumption does not hold in the case of a narrowly focused beam.

$$b_\nu = \frac{L_\nu}{4\pi d^2} \tag{31}$$

Hipparchus (190–120 BCE) was an accomplished Greek astronomer who completed the first star catalog numbering some 850 entries in about 130 BCE. To distinguish between their apparent brightness, Hipparchus assigned each star a magnitude from 1 to 6 with the "first magnitude" assigned to the brightest objects and the "sixth magnitude" assigned to the dimmest he could see with the unaided eye. This ancient legacy of Hipparchus of using a *smaller* number to represent a *brighter* object lives on today. Norman Pogson, a 19th-century British astronomer at Oxford, mathematically formalized the existing system of stellar magnitudes handed down through antiquity. This was done according to a logarithmic scale with a 100-fold increase in apparent brightness being equal to a difference of exactly five magnitudes.[53] His equation imitated the magnitude classification system introduced by Hipparchus as he noticed that a difference in magnitude of the old scale corresponded roughly to a 2.5 times increase in brightness. Using a close approximation of Pogson's ratio ($100^{1/5} \approx 2.512$) Pogson's equation for the observed apparent magnitude m is

$$m = C - 2.5\log(b) \tag{32}$$

The arbitrary constant C is set by convention to determine what observed value of b corresponds to a magnitude of zero. This convention uses the observed constant brightness of the star Alpha Lyrae (Vega) to set the zero-point of the scale.

So-called "standard candles" are astronomical objects of known luminosity and are critical tools in cosmology. In contrast to the apparent magnitude of a standard candle, which varies with the distance of observation, its absolute magnitude M quantifies its estimated intrinsic luminosity. By convention, the absolute magnitude is defined to be the apparent magnitude an astronomical object would have if it were at a distance of ten parsecs (32.6 *light years*). Generally, absolute magnitudes are quoted for the visual band. The V filter, which is designed to provide measurements that closely resemble those of the human eye, has a central wavelength of 550 *nm* and a bandpass range of ~505–595 *nm*. In contrast, the B filter, among about ten common filters in use, has a central wavelength of 440 *nm* and a bandpass range of ~390–490 *nm*.[54] The filter used for a particular measurement is generally denoted by a subscript as follows.

$$M_V = m_V - 2.5\ \log(d/10)^2 \tag{33}$$

Applying basic rules concerning logarithms yields the commonly used distance modulus, μ

$$\log x^y = y\log x \qquad \log\frac{x}{y} = \log x - \log y \tag{34}$$

$$\mu = m - M = 5\ \log(d) - 5 \tag{35}$$

If the absolute luminosity of a standard candle is known to a good approximation according to some calibration, the observed apparent luminosity yields the distance to the observed object.

$$d = 10^{(m-M+5)/5} \tag{36}$$

Particulate matter between the source and observer will often block some portion of the photons. This estimated "extinction" reduces the apparent magnitude by some amount A. In addition, time dilation due to significant cosmological redshift of a target implies that its photons observed in the V-band will have been sourced at shorter wavelengths. As a consequence, the observed apparent magnitude will not correlate with the M_V that would be measured if the target's photons suffered no such redshift. A so-called "K-correction" is applied that is related to spectroscopic properties.[55] Thus, the inferred distance to an astronomical object involves two directly measured parameters m and z plus three more indirectly determined parameters (M, A and K). Moreover, and this is an important point, calculations are based on the implicit *assumption* that the inverse square law applies to apparent luminosities of standard candles as a function of their distance.

$$\mu_0 = m - M = 5\log(d) - 5 + A + K \quad 37$$

$$d = 10^{(m-M+5+A+K)/5} \quad 38$$

The apparent brightness of a distant object is clearly dependent on the geometric dispersion of its photons. In familiar experience, at double the distance the apparent luminosity of an isotropic light source drops by a factor of four because the photon dispersal surface area, which is a spherical shell, is four times as great at double the distance. The key point to appreciate is that the rate of change in apparent luminosity of an object is not related to increase in range *per se*, but in the increase in the light dispersion area at the point of observation that such a change represents.

Interpretation of objects at significant cosmological distances ($z > 0.1$) in an expanding Universe involves more complex calculations than more local observations. The conventional cosmology discussed earlier employs what is called a "co-moving" system of coordinates, so that in spite of the purported expansion, an object with no peculiar velocity maintains the same coordinates over time. The term "peculiar velocity" refers to what was historically an unexpected observation in the context of Big Bang cosmology. Instead of exhibiting uniform expansion away from a central point like grains of sand stuck to an inflating balloon's surface, galaxies exhibit significant independent velocities and group flows with respect to what was originally expected to be a far more dominant Hubble recessional velocity. For instance, according to various estimates, our Local Group has a peculiar velocity on the order of $10^{-3}c$ due to infall into the Coma-Virgo Supercluster and other observed peculiar velocities are several times this value.[56,57]

The conventional cosmological model must incorporate assumptions concerning the rate of expansion (H_0) the density of the Universe (Ω_M) the effects of a cosmological constant (Ω_Λ) and the geometry of the Universe (open, closed, flat). A rather complex series of calculations leads to the conclusion that the bolometric surface brightness (flux over a solid angle) scales as $(1+z)^{-4}$. There is also the distinction between the physical volume and the co-moving volume that generally involve complicated equations that incorporate all of the same free parameters.[58,59] In the simplest case of an Einstein-de Sitter Universe, the co-moving volume is calculated to be

$$V(z) = \frac{32}{3}\pi\left(\frac{c}{H_0}\right)\left(1 - \frac{1}{\sqrt{1+z}}\right)^3 \quad 39$$

Other conventional volume calculations involve a considerably more complex series of integral equations. For historical purposes, the subject may be reviewed in *Peebles* (Princeton U., 1993).

The surface area S_2 *enclosing* the S_3 surface of a 4-sphere behaves differently from the surface of a 2-sphere. Combing Eqs. (18) and (19) yields a formula for the relative area of photon dispersion as a function of the redshift. To determine the actual physical area requires multiplication by the scale factor R^2, which must be determined observationally.

$$S_2(z) = 4\pi\left(1 - \frac{1}{(z+1)^2}\right) \quad 40$$

Then the bolometric flux of a standard candle solely due to geometric dispersion of photons is

$$F(z) = \frac{L}{4\pi\left(1 - \frac{1}{(z+1)^2}\right)} \quad 41$$

However, the time dilation effect of the redshift will cause fewer photons to impinge on a CCD per unit time by a factor $(z+1)^{-1}$ and will additionally reduce their energy by a factor of $(z+1)^{-1}$. This means that the bolometric energy flux we measure will be reduced accordingly; to account for this well-known requirement, we must multiply Eq. (41) by $(z+1)^{-2}$.

$$F(z) = \frac{L}{4\pi\left[(z+1)^2 - 1\right]} \qquad 42$$

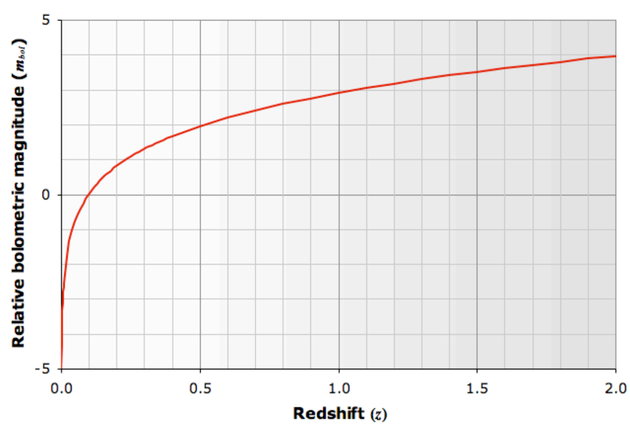
In Eq. (42) the redshift z and the flux F are both directly measurable quantities and there are no free parameters. It is convenient to convert the apparent brightness (flux) into bolometric apparent magnitude.

$$m_{bol}(z) = C - 2.51\ \log\left(\frac{L}{4\pi\left[(z+1)^2 - 1\right]}\right) \qquad 43$$

We choose the arbitrary constant C so that $z = 0.1$ is the zero point of an uncalibrated relative magnitude scale with L normalized to unity. Note that Eq. (44) does not model the effects of *extinction*, whereby the apparent magnitude of distant extragalactic objects is reduced through absorption or scattering by the intergalactic medium or source and target galactic halos.

$$m_{bol}(z) = -1.06 - 2.51\ \log\left(\frac{1}{4\pi\left[(z+1)^2 - 1\right]}\right) \qquad 44$$

Figure 29 – Plot of Eq. (44): $m_{bol}(z)$ *extinction not modeled*



Recall from Eq. (35) that the distance modulus μ differs from the apparent magnitude m by the absolute magnitude M. However, by definition, M is a constant for a standard candle, so in this case a plot of $m(z)$ only differs from a plot of $\mu(z)$ by a constant scale factor.

Type Ia supernovæ, (Sne Ia) are relatively brief and exceedingly luminous events believed to be cataclysmic explosions specifically resulting from the thermonuclear disruption of hydrogen-deficient carbon-oxygen white dwarf stars in binary systems. These now frequently observed phenomena have remarkably homogeneous observational properties, which allows the intrinsic luminosity (absolute magnitude) of distant events to be accurately estimated based on observation of other nearby events. The radiation signature of Sne Ia is characterized by strong absorption near 6150Å (Å ≡ 10^{-10} m), which differentiates them from similar phenomena (Sne Ib and Sne Ic) that do not exhibit this characteristic.[60] Unlike Type II supernovæ, which are believed to result from the catastrophic gravitational collapse of massive stars, Type I do not exhibit hydrogen spectral lines. Because of their extreme luminosity and the ability to study examples in the nearby Universe, Type Ia supernovae have proven to be unparalleled as a precise distance indicator, probing out to great distances well beyond $z = 1$.

The Supernova Cosmology Project at Lawrence Berkeley Laboratory led by Saul Perlmutter and the International High-Z Supernova Search Team led by Brian Schmidt are the two leading global teams involved in Supernova Research among many that now exist. When initial work began in the mid 1990s, the goal was to help pin down an accurate value for the Hubble constant. The natural expectation was that the observational evidence would clearly show that a rapid initial expansion from the purported Big Bang explosion had been slowed down over time by the mutual gravitational attraction of the galaxies. However, in the same year (1998) paper titles went from **A** to **B** and evolved from there…

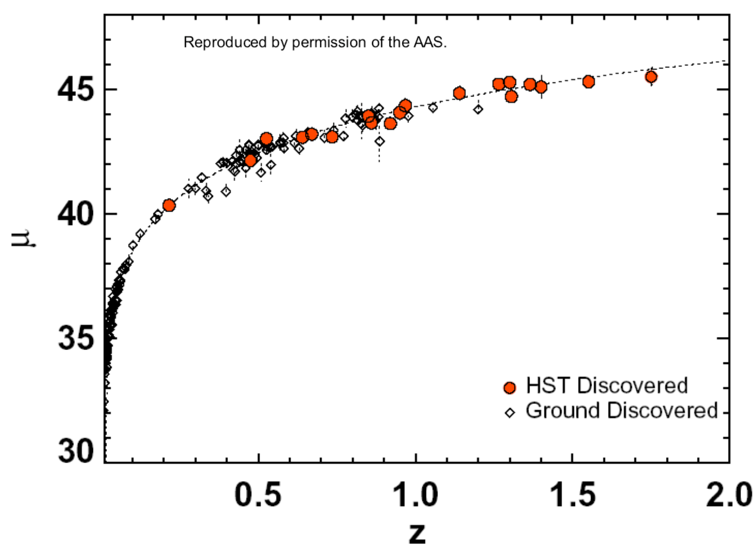
A) Schmidt *et al.*, "The High-Z Supernova Search: Measuring Cosmic Deceleration and Global Curvature of the Universe Using Type Ia Supernovae", *Astrophysical Journal* **507**, 46 (1998).

B) Riess *et al.*, "Observational Evidence from Supernovae for an Accelerating Universe and a Cosmological Constant, *Astronomical Journal* **116**, 1009 (1998).

The following is a quotation from a 2004 paper in the *Astrophysical Journal* by Adam Reiss *et al.* of the High-Z Supernova Search Team, prefacing the graph that appears in the same paper, here reproduced in Fig. (30).

> Distance estimates from SN Ia light curves are derived from the luminosity distance,
>
> $$d_L = \left(\frac{L}{4\pi F}\right)^{\frac{1}{2}},$$
>
> where L and F are the intrinsic luminosity and observed flux of the SN within a given passband, respectively. Equivalently, logarithmic measures of the flux (apparent magnitude, m) and luminosity (absolute magnitude, M) were used to derive extinction-corrected distance moduli, $\mu_0 = m - M = 5 \log d_L + 25$ (d_L in units of megaparsecs). In this context, the luminosity is a "nuisance parameter" whose value is unimportant for kinematic (and most cosmological) studies.[61]

Figure 30 – The empirical distance modulus for Type Ia supernovae



Courtesy Adam G. Riess *et al.*, Copyright 2004 *Astrophysical Journal*.[62]

http://arxiv.org/abs/astro-ph/0402512, p 59.

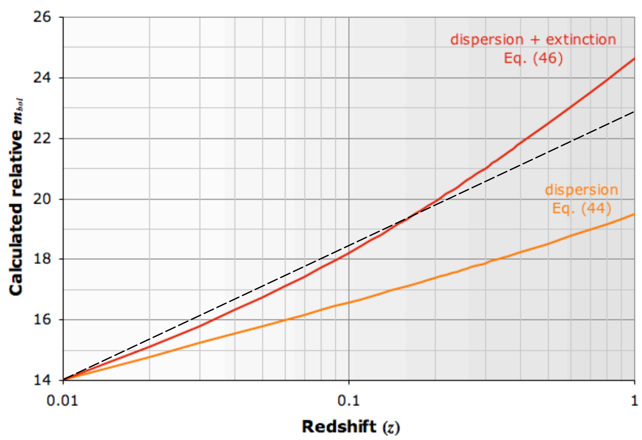
Over cosmological distances, the intergalactic medium (IGM) is assumed uniform in density over large distances, so that the corresponding extinction rate is closely approximated by a linear function of the light travel distance. As the distance is directly proportional to the cosmological latitude, which is a known function of z, we can set the rate of extinction according to observations. *A simple linear model is only an approximation* because extinction is dependent on the wavelength of light; longer (redder) wavelengths penetrate the intergalactic medium better than shorter (bluer) wavelengths. Therefore, the light of nearby galaxies is disproportionately extinguished over the distance to them as compared to the redder light from more distant galaxies over that same nearby space.

$$A = \varepsilon \cdot \zeta = \varepsilon \cos^{-1}\left(\frac{1}{z+1}\right) \tag{45}$$

The data underlying Fig. (30) shows a domain of ($0.104 \le z \le 1.755$) and a corresponding range of ($33.21 \le \mu \le 45.53$). This implies a value of $\varepsilon = 5.67$ and the value of C may be adjusted to fit empirical observations as is done for the point (0.01, 14) in Fig. (31).

$$m_{bol}(z) = C - 2.51\ \log\left(\frac{L}{4\pi\left[(z+1)^2 - 1\right]}\right) + 5.67\cos^{-1}\left(\frac{1}{z+1}\right) \tag{46}$$

Figure 31 – Theoretical redshift-magnitude curves



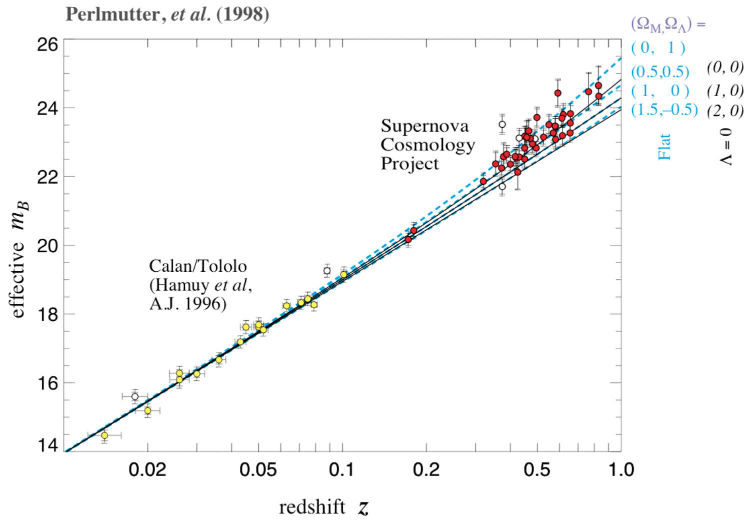
The dashed straight line in Fig. (31) is a reference annotation, which emphasizes the increasing slope of the predicted redshift-luminosity curve. It has been suggested that ultra-relativistic particles observed in cosmic ray detection experiments may originate at cosmological distances. If true, this puts constraints on the average density and thus the extinction effects of the IGM. It must be determined whether the value of ε in Eq. (46) required to achieve an increase of ~10 magnitudes from $z = 0.01$ to $z = 1$ is reasonable. If not, either the proposed new model is incorrect or *processing* of observational data [Fig. (32)] incorporates assumptions that *artificially* straighten the reported empirical curve and increase its slope. The latter option is strongly suggested by the unlikely interpretation of quasar redshift data presented in the following section. Constrained by the conventional cosmological paradigm, the analysis process that transforms raw astrophysical data into published *interpreted* data reveals the main trend but is arguably not entirely accurate.

The Big Bang paradigm, in which the cosmological redshift is interpreted to imply a general expansion of the Universe, became the modern-day equivalent of Aristotle's cosmological work *On the Heavens*, which dominated scientific thought for eighteen centuries, from the 4th century BCE until Copernicus in the early 1500s. Paraphrasing and *revising* a previous quotation:

Until the advent of geometric cosmic time in the first decade of the 21st century, there was no question whether the Universe was expanding. If difficulties arose, astronomers would look elsewhere for remedies… This cycle of improvements continued, first in adding astronomical observations, then in adding more *unwieldy features* to the theory.

When we look back at what they were doing, we are incredulous… They had not so much missed what now seems obvious, as they had been seduced, step by step, down the wrong path…

Figure 32 –Supernova Cosmology Project redshift-magnitude plot



According to conventional wisdom, the empirical data shown in Fig. (30) and (32), which was *processed to fit within the constraints of the Big Bang paradigm*, led to an interpretation that is best communicated by excerpts from the abstract of the paper submitted by Adam Riess *et al*.

> We have discovered 16 Type Ia supernovae (SNe Ia) with the *Hubble Space Telescope* (*HST*) and have used them to provide the first conclusive evidence for cosmic deceleration that preceded the current epoch of cosmic acceleration. … The luminosity distances to these objects, and to 170 previously reported SNe Ia, have been determined using empirical relations between light-curve shape and luminosity. A purely kinematic interpretation of the SN Ia sample provides evidence at the > 99% confidence level for a transition from deceleration to acceleration or similarly, strong evidence for a cosmic jerk.[63]

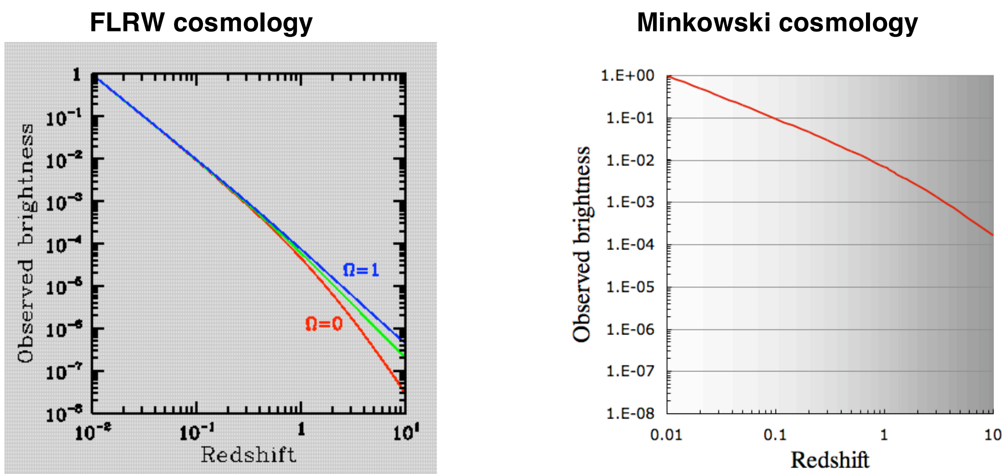
The conventional interpretation of the increasing slope that is evident in Fig. (32) has lead to the preposterous conjectures of "dark energy" and a "cosmic jerk". The result is the present crisis in which the vast majority of the *interpreted* energy content of the Universe is inexplicable. In contrast, the concept of geometric cosmic time implies that measurements rather demonstrate that the cosmological redshift is a temporal relativistic effect and that there is no need to invoke the existence of "dark energy" ad hoc. The supernovae observations are consistent with the Fig. (9) cosmological model, which rests on only two simple ideas: the fundamental geometric relationship between space and time established by special relativity and the rational assumptions that the Universe is neither infinite in volume nor has a physical boundary.

If one references the *exact* relationship predicted by Eq. (42) based on observables and one has the ability to quite accurately estimate the intrinsic luminosity of a standard candle, then equally accurate extinction values can be determined from various astronomical observations. This model allows for *no free parameters* that can be adjusted ad infinitum in an attempt to fit observations to the model. The only parameter that can be adjusted is the rate of extinction, which must be a linear function of the light travel distance allowing for possible local discontinuities due to a particularly large and dense region of the IGM including galactic halos.

13. Quasar redshift surveys

Fig. (33) compares predictions of observed brightness versus redshift made by the conventional Hubble expansion FLRW cosmology and the proposed dynamic equilibrium cosmology, which is not predicated on a general expansion. This new cosmological model is most appropriately called the "Minkowski cosmology", in deference to a truly great mathematician, because the concept that space and time have a geometric relationship provides the foundation of the model. Also, had Minkowski lived beyond January 1909 to normal old age, he would very likely have corrected the errant path of relativistic physics and cosmology that ensued after his death.

Figure 33 – Comparison of $m(z)$ between the two cosmological models



FLRW graph courtesy Emad Iskander, Douglas Scott & Martin White[64]

Eq. (42) is the source of the plot on the right of Fig. (33) and (0.01, 1) is arbitrarily chosen as a convenient common reference point. If the predicted redshift-luminosity relationship of the Minkowski cosmology is correct, the FLRW cosmology predicts high redshift objects to appear orders of magnitude dimmer than they will actually appear. Given such a modeling error, the observed brightness (apparent magnitude *m*) of high redshift objects will be interpreted to imply objects that have an intrinsic luminosity (absolute magnitude *M*) that is very far in excess of the actual luminosity of the object. It follows that what is in fact simply a distant example of an identified nearby class of objects (e.g., a Seyfert galaxy), will be erroneously misclassified as an entirely different class of object (a "quasar", "quasi-stellar object" or "QSO") with a modeled energy output enormously greater than the nearby object.

In accord with the foregoing conclusion, Fig. (34) represents the conventional interpretation of recent data concerning spectroscopic and luminosity measurements of a large population of QSO, which we may identify more generically as active galactic nuclei (AGN). The vertical axis is the measured redshift *z* and the horizontal axis is the *interpreted* absolute magnitude M of color-selected QSO ($18.25 < b_J < 20.85$) calculated from the observed apparent magnitude and an assumed redshift distance that is based on conventional Big Bang cosmology with the parameters given. The b_J astronomical filter used is for 4500Å or blue to indigo light.[65] The approximately constant width of $\Delta M_b = 2.6$ in absolute magnitude for the dots (2QZ) represents about a factor 11 in intrinsic luminosity between the dimmest and the brightest QSO observed at a particular redshift.[66] Inclusive of the brighter objects ($16.0 < b_J < 18.25$) selected from the 6dF Galaxy Survey (6QZ) this range increases to a factor of about 100. Recall that what we are looking at in this graph is the *interpreted* intrinsic luminosity of QSO of a spectral class based on their observed apparent magnitude and their *assumed* distance, which is based on the conventional cosmological model and a number of assumptions that are used to subjectively manipulate the data (i.e., Ω_M, Ω_Λ, H_0). According to this graph, the intrinsic brightness of all QSO increases enormously with increasing redshift. If redshift is interpreted as a "lookback time" to the infancy of an evolving Universe, there is an apparent "luminosity *evolution*" in the data.

Figure 34 – QSO apparent "optical luminosity evolution"[67]

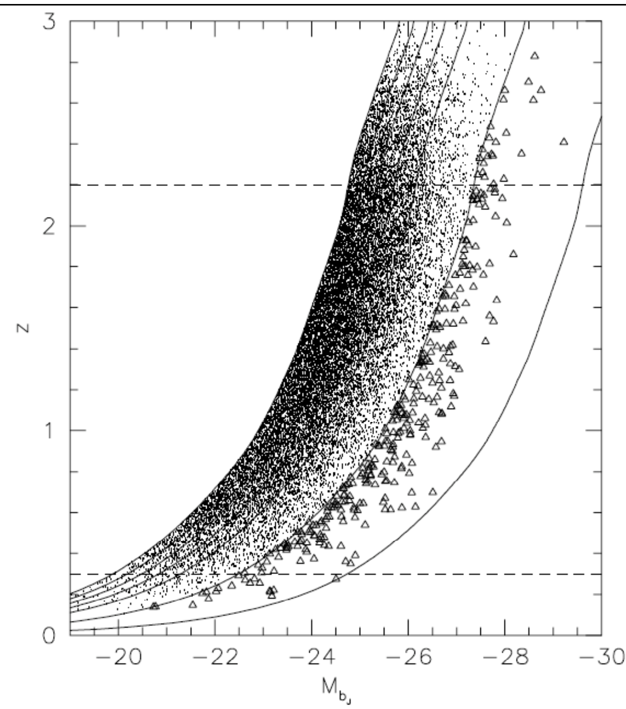


Figure 25. The redshift–absolute-magnitude distribution of 2QZ (small points) and 6QZ (triangles) QSOs used in our analysis. The solid lines denote the apparent magnitude limits applied to the data, while the dashed lines show the redshift range used. A *WMAP*/2dF cosmology is assumed.

Taking all of the 2QZ data at face value, the "dim point" (M, z) of the bottom of the curve at low redshift is (19.0, 0.2) while the "bright point" there is (21.6, 0.2). If we represent the dimmest QSO here by a 20-watt light bulb, then the brightest QSO in the 2QZ selection is a 220-watt bulb. At high redshift, the dim point near the top of the curve is (25.0, 2.4) while the bright point is (27.6, 2.4). Over this range of redshift, the dimmest QSO have become brighter by 6 magnitudes and the brightest QSO have also become brighter by 6 magnitudes, or a factor of 251. That means the 20-watt bulb is now over 5,000 watts and the 220-watt bulb is over 55,000 watts.

If the redshift is interpreted as a general expansion, the observed AGN redshift-luminosity relationship implies "luminosity evolution" of active galactic nuclei. Similarly, if the Earth is modeled to be at the center of the Solar System, then the observed retrograde motion of the planets implies epicycles. With some thought, we have no choice but to discard the former idea just as the latter was discarded some centuries ago. Does physics allow for time evolution of the properties of fundamental particles or better yet, fundamental mathematical relationships? In other words, can we have a Universe in which the electron charge, the proton mass, or the value of π or e changes over time? The answer is no; these things are immutable and it can be shown that any change literally invalidates the existence of the Universe, itself. Similarly, does physics allow for time evolution of the fundamental nature of physical processes? For instance, can we rationally think that the thermonuclear process that we observe now in stars and in the laboratory did not exist at some time in the past but has replaced some completely different prior process? Again, the answer is no; the nature of fundamental physical processes are as immutable as the properties of the fundamental particles that constrain these processes, whatever they may be.

QSO are easily identified by a set of common characteristics that establish this common species within the astronomical zoo. However, constrained to a quite narrow *range* of redshift, say $\Delta z \sim 0.01$, due to the wide range in luminosities and other variable properties, clearly we are looking at a large and varied population of AGN at any particular redshift. We similarly identify many different kinds of stars with different properties and at different stages of evolution within a particular galaxy and we see galaxies with different population statistics of these star types. Barring population statistics, what we do *not* see are galaxies with fundamentally different kinds of stars of which there are no similar specimens whatsoever in other galaxies. This is because the particles and physical processes that create stars are ubiquitous. Similarly, there is every reason to believe that the physical processes that are responsible for AGN are ubiquitous. Moreover, the Minkowski cosmology does not associate high redshift with *intrinsic* "lookback time". There is no region of the observable Universe that is either older or younger than another; there are only particular objects and conglomerations of objects within the Universe that are older or younger than others. Just as we see stars with various properties and at various stages of evolution, we also see AGN with various properties and at various stages of evolution. Arguably, *time evolution* as well as various different kinds of AGN are quite clearly reflected in Fig. (34) along the *horizontal* luminosity axis, not the vertical redshift axis.

For much the same reason that fifty statistically averaged atomic clocks are better for telling time than two clocks, what is even better than a standard candle is a "population candle" of objects that have some common trait other than intrinsic luminosity. The plethora of intrinsically bright and broadband emission AGN is an ideal such "population candle". It is entirely reasonable to assume that the span of absolute AGN magnitudes representing various distinct and shared intrinsic properties and evolutionary stages is the same throughout the observable Universe. Applying this postulate in the context of the Minkowski cosmology, the observational achievements of recent QSO surveys take on new meaning. A theoretical cosmological model that interprets observations to imply no *special* AGN at high redshift is appealing. We may reasonably interpret the curve of increasing absolute magnitudes in Fig. (34) as an artifact of a modeling error that erroneously correlates high redshifts with absolute magnitudes interpreted from apparent magnitudes that are considerably greater than actual values. A correct model will correlate observations of AGN with a vertical band of data points in such a graph and a roughly uniform space density, consistent with the Cosmological Principle. *Reanalysis of quasar redshift data in the context of the Minkowski cosmology to produce the modeled vertical column of data points will yield an independent measurement of extinction rate. This may then be employed in the analysis of supernovae data to confirm the new cosmological model beyond reasonable doubt.*

The apparent population evolution with redshift, which Fig. (34) does not make immediately obvious, is graphed in Fig. (35) with binned data taken from the 2QZ catalogue with a total graphed population of 24,578 QSO. The similarity in the shape of the curve to Fig. (22) and (23) is immediately obvious. However, it is also apparent that the peak of the graph is shifted considerably to the right and the curve is quite narrow in comparison to the Fig. (20) curve. This is because QSO are imagined to be inordinately bright objects that typically exist at high redshift. Thus, with decreasing redshift, selection criteria remove a proportionately greater number of objects that are in fact of the same class. When QSO lose their "special" status as ultra-luminous distant objects and are understood to simply be ubiquitous AGN, they will then be grouped with the objects of identical type that appear at lower redshift. Thus, the low-redshift tail will extend to $z = 0.01$ and the peak of the curve will shift dramatically to the left.

Figure 35 – 2QZ redshifts (NGP and SGP) with bins of size $(z_{n+1} - z_n) = 0.01$

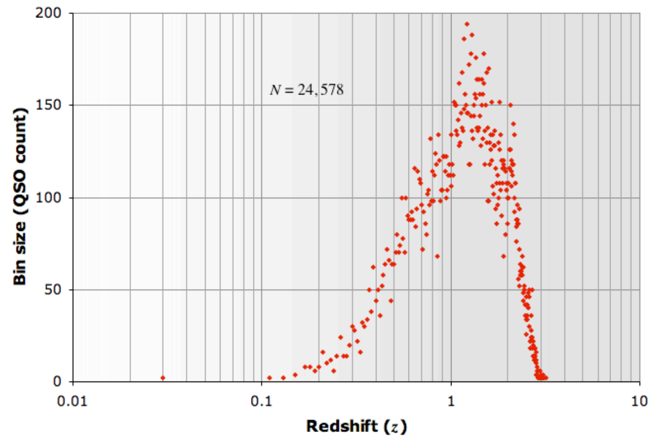
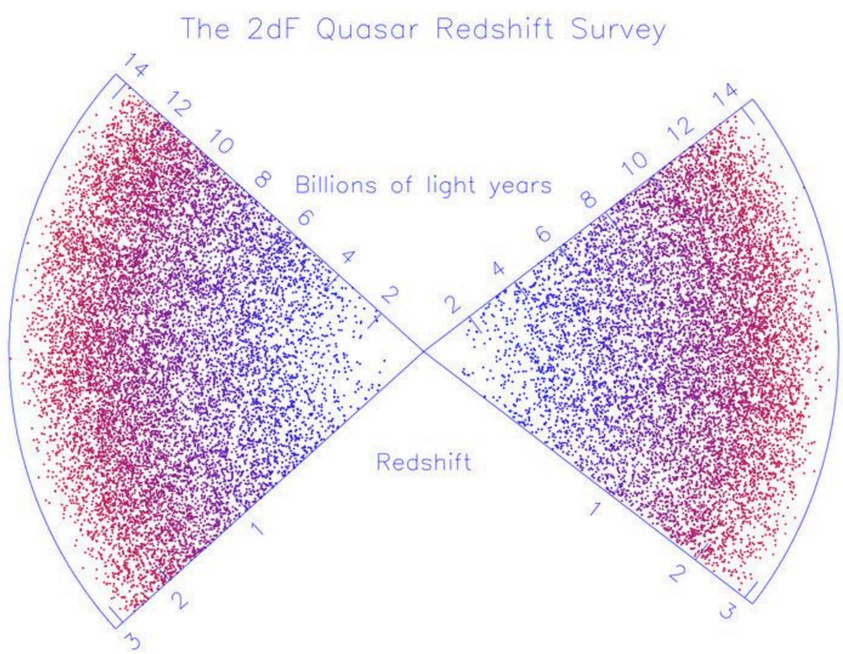


Figure 36 – The 2dF Quasar Redshift Survey with conventional distance scale



Courtesy 2dF QSO Redshift Survey Team, Anglo-Australian Observatory[68]

As previously discussed, a "luminosity evolution" interpretation of AGN arguably defies the most fundamental tenets of physical science. In addition, the Minkowski cosmology sweeps away a large body of convoluted ideas and equations and replaces them with a parsimonious theory having an immediate foundation in the formidable principles of special relativity, which rests securely on a huge foundation of experimental physics beginning with the Michelson-Morley Experiment.[69] Other than estimates of extinction, there are no parameters whatsoever to manipulate; the theory makes precise theoretical predictions concerning empirical observations. In the final sentence of the 1935 paper that he co-authored with Richard Tolman of Caltech, Edwin Hubble wrote the following, which proves to have some ring of truth to it.

> It also seemed desirable to express an open-minded position as to the true cause of the nebular red-shift, and to point out the indications that spatial curvature may have to play a part in the explanation of the existing nebular data.[70]

14. Ancient galaxies observed at high redshift

The "lookback time" of an object is the time required for its light to have traveled from the source to the telescope. High redshift objects are associated with significant lookback time; we see these objects as they existed some billions of years before the present, according to when the received photons were emitted *in reference to our local clock*. There is much current discussion about alleged observations of the "infant Universe" at high redshift. This is because lookback time is imagined to be *absolute*, thus occurring over a single shared cosmic timeline back towards a common beginning in time of a Universe that began an evolutionary process less than fourteen billion years ago [Fig. (4)]. However, this naïve perspective fails to make a distinction between the non-relativistic linear time of practical human experience and relativistic geometric cosmic time. The conventional linear model of cosmic time has the same kind of *psychological* roots as the common notion among primitives that the Earth is flat, which is a product of immediate experience rather than the abstract thought necessary to imagine a spherical planet. Unlike the Big Bang paradigm, the Minkowski cosmology does not associate the lookback time of an object with the *intrinsic* age of that object. In this respect, there is no difference between a distant galaxy and any star in the Milky Way; distance to either object has no bearing on the intrinsic age of that object at the time the light reaching us was originally emitted by that object.

In stark contrast to the Big Bang paradigm, the Minkowski cosmology predicts that galaxies of any intrinsic age may be found at any redshift. In particular, galaxies and clusters exhibiting observational properties associated exclusively with advanced age may be found at arbitrarily high redshift. Therefore, galaxies with spectroscopic signatures identical to local galaxies including those with old metal-rich stars and gravitational interactions of fully formed galaxies should be visible at high redshift. *Properly interpreted*, the high-redshift Universe looks no different whatsoever from the local Universe because the lookback time of an object has no bearing on its age. However, this reality does not jibe with the Big Bang paradigm, which requires high redshift objects to be intrinsically youthful. Moreover, no large bright objects whatsoever should exist at redshifts greater than five, let alone those approaching $z = 10$. When such observations are made, empirical evidence overthrows the Big Bang cosmological model and lends additional credence to the Minkowski cosmology. However, before the qualitative and quantitative development of this new cosmological model, empirical observations that failed to support the Big Bang were regarded as impossible and summarily rejected. Observations like the following two will continue to confirm intrinsically ancient objects at high redshift.

> In this paper, we test the viability of several dark energy scenarios in the light of the age estimates of the high-redshift (z= 3.91) quasar APM 08279+5255. … An age of 2.1 Gyr is set by the condition that Fe/O abundance ratio (normalized to solar values) of the model reaches 3.3, … Therefore, a high value of the Fe/O abundance ratio for a quasar is strong evidence that the quasar is old, which represents a severe constraint for cosmological scenarios. … *Even considering less-stringent age limits, only cosmological models that predict a considerably old Universe at high-z can be compatible with the existence of this object.*[71]

The Big Bang paradigm simply does not allow galaxies to be observed at $z \sim 10$, but the Minkowski cosmology allows for galaxies to be observed at any redshift. Indeed, there is an increase of only one magnitude in apparent luminosity between $z = 6$ and $z = 10$ [see Fig. (32)].

> We report the first likely spectroscopic confirmation of a z ~10.0 galaxy from our ongoing search for distant galaxies with ISAAC/VLT. Galaxy candidates at z >~ 7 are selected from ultra-deep JHKs images in the core of gravitational lensing clusters for which deep optical imaging is also available, including HST data. The object reported here, found behind Abell 1835, exhibits a faint emission line detected in the J band, leading to z = 10.0 when identified as Ly-a, in excellent agreement with the photometric redshift determination. Redshifts z < 7 are very unlikely for various reasons we discuss. The object is located on the critical lines corresponding to z = 9 to 11.[72]

The XMM-Newton X-ray observatory spacecraft, a joint NASA/ESA mission, was launched by the European Space Agency (ESA) on 10 December 1999. The following is an excerpt from a 9 July 2002 news release that summarizes a more academic discussion.[73] This news release is prophetically entitled "Is the Universe older than expected?" The emphasis is in the original.

> APM 8279+5255 is 13.5 thousand million light years away. Scientists know this because they have estimated a property of its light known as the red shift, which is caused by the expansion of the Universe stretching the wavelengths of light emitted by the celestial object. XMM-Newton's data showed that iron was three times more abundant in the quasar than in our Solar System.
>
> Since iron is released by exploding stars, according to precise physical phenomena, and scientists think it builds up across the Universe gradually with time. The Solar System formed just 5 thousand million years ago, so it should contain more iron than the quasar, which formed over 13.5 thousand million years ago. The fact that the quasar contains three times more iron than the Sun is therefore a major puzzle.
>
> One possible explanation is that something is wrong with the way astronomers measure the age of objects in the Universe. The almost-holy red shift-distance-age conversion would therefore be wrong. Fred Jansen, ESA's project scientist for XMM-Newton, explains that this would mean rewriting the textbooks. "*If you study the evolution of the Universe, one of the basic rules is that we can tie redshift to age. One distinct possibility to explain these observations is that, at the redshift we are looking at, the Universe is older than we think.*"[74]

A December 1994 NASA Communication sourced from the Space Telescope Science Institute (STScI) is entitled "Hubble [Telescope] Uncovers New Clues to Galaxy Formation". The ironic title of the first of five sections is "The Paradox: Grown-up Galaxies in an Infant Universe". This critical communication written over a decade ago is no longer available on either NASA or STScI public information Internet archives, perhaps because it was an embarrassment to the status quo. However, it can be found on the Website of the Observatorio ARVAL in Caracas, Venezuela.[75]

> Hubble Space Telescope's recent observations identify fully formed elliptical galaxies in a pair of primordial galaxy clusters that have been surveyed by teams lead by Mark Dickinson of the Space Telescope Science Institute and Duccio Macchetto of the European Space Agency and the Space Telescope Science Institute. Although the clusters were first thought to be extremely distant because of independent ground-based observations, the Hubble images provide sharp enough details to confirm what was only suspected previously.
>
> The surprise is that elliptical galaxies appeared remarkably "normal" when the universe was a fraction of its current age, meaning that they must have formed a short time after the Big Bang.
>
> Dickinson, in studying a cluster that existed when the universe was nearly one-third its current age, finds that its red galaxies resemble ordinary elliptical galaxies, the red color coming from a population of older stars.
>
> This has immediate cosmological implications, since the universe must have been old enough to accommodate them.
>
> Cosmologies with high values for the rate of expansion of space (called the Hubble constant, which is needed for calculating the age of the universe) leave little time for these galaxies to form and evolve to the maturity we're seeing in the Hubble image, Dickinson emphasizes.[76]

Andrea Cimatti *et al.* published critical observations in a July 2004 issue of *Nature*. The following is the abstract from their article entitled "Old galaxies in the young Universe".

> More than half of all stars in the local Universe are found in massive spheroidal galaxies, which are characterized by old stellar populations with little or no current star formation. In present models, such galaxies appear rather late in the history of the Universe as the culmination of a hierarchical merging process, in which larger galaxies are assembled through mergers of smaller precursor galaxies. But observations have not yet established how, or even when, the massive spheroidals formed, nor if their seemingly sudden appearance when the Universe was about half its present age (at redshift $z < 1$) results from a real evolutionary effect (such as a peak of mergers) or from the observational difficulty of identifying them at earlier epochs. Here we report the spectroscopic and morphological identification of four old, fully assembled, massive (10^{11} solar masses) spheroidal galaxies at $1.6 < z < 1.9$, the most distant such objects currently known. The existence of such systems when the Universe was only about one-quarter of its present age shows that the build-up of massive early-type galaxies was much faster in the early Universe than has been expected from theoretical simulations.[77]

Astronomer Laura Ferrarese made the following comment in 2003.

> It has been pointed out that at a redshift of 5 we are [supposed to be] looking back in time to when the age of the Universe (about 1 billion years) was approximately equal to the dynamical timescale of a typical galaxy — roughly speaking, the stellar orbital time, or the time it takes a galaxy to communicate with itself through its own gravitational potential. Thus, the very existence of quasars at such high redshifts is a challenge to models of structure formation.[78]

Professor Hans Jörg Fahr of Universität Bonn in Germany exhibits exceptionally rare vision and courage for a professional academic in the field with the following insights.[79]

> When galactic objects are seen at redshifts larger than $z = 6$ then it means that they must have emitted their light at a phase when the Universe only had a radius of one seventh (i.e., a volume of 1/350!). According to most of the cosmological models, this phase can only be less than one billion years after the Big Bang event. Since these galactic objects for sure should have ages of more than one billion years, they thus cannot be objects of this Big Bang universe, unless present cosmologies are completely wrong. Then the idea may be suggested as a solution that possibly the Universe may not have an age at all, it only runs through cycles of always repeating processes of production and destruction of objects and hierarchical cosmic structures at all scales of time and space. The Universe is something like a self-sustaining system of nonlinearly interacting non-equilibrium subsystems, dissolving themselves at some places and thereby driving action flows which create identical cosmic entities at other places (see Hoyle *et al.*, 1993, Fahr, 1996, 2002).[80]

The final straw is the discovery by Christopher R. Mullis *et al.* of what is described most accurately by the European Southern Observatory (ESO) in a March 2005 press release.[81]

> Combining observations with ESO's Very Large Telescope and ESA's XMM-Newton X-ray observatory, astronomers have discovered the most distant, very massive structure in the Universe known so far.
>
> It is a remote cluster of galaxies that is found to weigh as much as several thousand galaxies like our own Milky Way and is located no less than 9,000 million light-years away.
>
> The VLT images reveal that it contains reddish and elliptical, i.e. old, galaxies. Interestingly, the cluster itself appears to be in a very advanced state of development. It must therefore have formed when the Universe was less than one third of its present age.
>
> The discovery of such a complex and mature structure so early in the history of the Universe is highly surprising. Indeed, until recently it would even have been deemed impossible.[82]

Readers are encouraged to visit Dr. Mullis' Website at the following current URL.

http://www.astro.lsa.umich.edu/~cmullis/research/xmmuj2235/index.html

15. The cosmic microwave background radiation

In the late 1940s and the 1950s when the Big Bang concept was still considered a tenuous theory, George Gamow and his graduate student collaborators, Ralph Alpher and Robert Herman, made a historic prediction. They posed that if there had indeed been a hot Big Bang followed by an expansion of the Universe, then some heat from the explosion must remain that had cooled with the expansion. Gamow initially predicted that the radiation temperature would be about 50° K, which was later reduced to about 5° K by Alpher and Herman, although the latter stated that actual temperature measurements would be higher due to the contribution of thermal energy produced by stars in addition to the calculated residual primordial heat.[83,84,85]

In 1965, Arno Penzias and Robert Wilson of the Bell Telephone Laboratories made the following observation, which was published in the *Astrophysical Journal*. This is the entire abstract of their paper. Emphasis of the word *possible* has been added.

> Measurements of the effective zenith noise temperature of the 20-foot horn-reflector antenna (Crawford, Hogg, and Hunt 1961) at the Crawford Hill Laboratory, Holmdel, New Jersey, at 4080 Mc/s have yielded a value of about 3.5 K higher than expected. This excess temperature is, within the limits of our observations, isotropic, unpolarized, and free from seasonal variations (July, 1964 - April, 1965). A *possible* explanation for the observed excess noise temperature is the one given by Dicke, Peebles, Roll, and Wilkinson (1965) in a companion letter in this issue.[86]

The following passage is from the paper by the Princeton University team of Dicke, Peebles, Roll and Wilkinson to which Penzias and Wilson referred. It is this famous paper and its forty-year legacy that has given Princeton a large stake in continued support of the Big Bang theory.

> Could the universe have been filled with blackbody radiation from this possible high-temperature state? If so, it is important to notice that as the universe expands the cosmological redshift would serve to adiabatically cool the radiation, while preserving the thermal character. The radiation temperature would vary inversely as the expansion parameter (radius) of the universe…
>
> While all the data are not in hand we propose to present here the possible conclusions to be drawn if we tentatively assume that the measurements of Penzias and Wilson (1965) do indicate blackbody radiation at 3.5º K. We also assume that the universe can be considered to be isotropic and uniform, and that the present energy density in gravitational radiation is a small part of the whole. Wheeler (1958) has remarked that gravitational radiation could be important.
>
> For the purpose of obtaining definite numerical results, we take the present Hubble redshift age to be 10^{10} years.[87]

The *coincidence* between the discovery of the cosmic microwave background (CMB) and the search for a predicted cooled remnant of a primordial explosion assumed to have started the Universe was not considered to be a coincidence. The discovery was quickly accepted as the definitive proof of the Big Bang; Penzias and Wilson shared the 1978 Nobel Prize in Physics for their discovery. What nobody suspected in 1965 was that the cosmological redshift could be explained as a relativistic effect based on the rather obvious (in hindsight) geometric relationship between local proper time coordinates in a finite boundaryless Universe. This being the case, the assumption of a general recession of the galaxies is eradicated at a stroke and with it the fundamental premise for an expanding Universe. There is then no reason to suppose that the CMB is the cooled heat from a primordial state. The only alternative is that it must be the result of a ubiquitous real-time radiation emission.

In order for the Minkowski cosmology to be accepted as a tenable new cosmological theory, the source of the CMB must be definitively identified. The radiation source must be clearly described by theory and unambiguous experimental observations must show that it is generated in real time and has nothing whatsoever to do with an imagined primordial event. Recent observational facts concerning the CMB yielded by the WMAP mission lead to an immediate understanding of its true real-time source. It will be shown in a later section of the book that a component of the CMB has a particular empirical signature that is unmistakable, leaving absolutely no room for doubt as to its actual origins. This will involve a radical yet surprisingly obvious amendment to the general theory of relativity.

It is often quoted that observation of the cosmic microwave background radiation established the Hot Big Bang paradigm beyond reasonable doubt and provided firm observational evidence for an evolving Universe with a well-defined beginning. What this statement reveals is that the cosmological redshift was not itself considered proof of an expanding Universe beyond reasonable doubt. In other words, the redshift was appropriately considered to be subject to a possible alternative explanation. The common perception that the redshift and the CMB are corroborating *independent* proofs of the Big Bang is false; the conventional interpretation of the CMB is in fact predicated on the idea of an expanding Universe. Because of this, no alternative explanation for the CMB has ever really been considered a possibility. The following is a brief cogent quote from an article in the January 2005 issue of *Physics World* referencing work published in the 26 November 2004 *Physical Review Letters*.[88] Its implications seem to have been summarily discounted by the majority of the academic community.

> The cosmic microwave background is often called the echo of the Big Bang, but recent research suggests that some of its features might have their origins much closer to home. Although most cosmologists think that the tiny variations in the temperature of the background are related to quantum fluctuations in the early universe, Glenn Starkman and colleagues at CERN and Case Western Reserve University in the US have now found evidence that some of these variations might have their roots in processes occurring in the solar system. If correct, the new work would require major revisions to the standard model of cosmology. … "Each of these correlations could just be an accident," says Starkman. "But we are piling up accident on accident. Maybe it is not an accident and, in fact, there is some new physics going on." [89]

The assumption of a Big Bang event a finite time ago leads to the second assumption that microwave photons sourced from a singular event long ago and far away *must* exist. However, the isotropic uniformity of the background *portion* of the microwave radiation that is detected leads to the horizon problem. Considering the finite speed of light, how is it possible for causally disconnected regions of the Universe to have the same temperature? Inflation was invented to solve this problem. The inflation theory alleges that the Universe grew by a factor of 10^{50} in 10^{-33} seconds at ultra superluminal ($\gg c$) speed.[90] This is an ad hoc solution employing an implausible unphysical phenomenon in order to rescue the Big Bang paradigm spawned by Hubble's interpretation of the redshift. In contrast, the concept of geometric cosmic time is fundamental science based on quite simple and irrefutable mathematical and physical principles.

In November 1989, NASA launched the Cosmic Background Explorer (COBE) spacecraft.[91] Its Far Infrared Absolute Spectrophotometer (FIRAS) instrument determined that the CMBR has a nearly perfect blackbody spectrum with a temperature of 2.73°*K*. Over a decade later, the Wilkinson Microwave Anisotropy Probe (WMAP) named after WMAP science team member Professor David Wilkinson of Princeton University was launched into orbit on 30 June 2001 from the Kennedy Spaceflight Center and inserted into the second Lagrange Point (L2) about 1 million miles beyond Earth on the Solar-Terrestrial radial.[92] Its accomplished two-year mission was to make the first detailed full-sky map of the microwave background radiation with 13' angular resolution, or about 33 times better than COBE. There is no doubt that the making of this map was a significant technical achievement and the team must be applauded for their historic accomplishments. However, they must also be chastened for the *content* of the WMAP Website. Instead of exhibiting proper scientific decorum and communicating sober scientific observational facts and humbly suggesting one particular interpretation of them, the Website seems to literally preach a "revealed truth". One is confronted with *manipulated* scientific data communicated in a flashy style that implies that there is *no room for doubt*. It apparently never occurred to anyone on the team that the *scientific* goal of properly interpreting the meaning of the empirical data gathered by the WMAP instruments might remain to be achieved.

From the WMAP Website under the ironic title, "Some Theories Win, Some Lose" we learn what the "winning" theories are.[93] The emphasis in the last bullet point has been added. Indeed, an unexpected thing has happened; the 1929 interpretation of the cosmological redshift is certainly incorrect and therefore all of the WMAP team's confident conclusions outlined below actually have no bearing on empirical reality.

- Universe is 13.7 billion years old, with a margin of error of close to 1%.
- First stars ignited 200 million years after the Big Bang.
- Light in WMAP picture is from 379,000 years after the Big Bang.
- Content of the Universe:
    - 4% Atoms, 23% Cold Dark Matter, 73% Dark Energy.
    - The data places new constraints on the Dark Energy. It seems more like a "cosmological constant" than a negative-pressure energy field called "quintessence". But quintessence is not ruled out.
    - Fast moving neutrinos do not play any major role in the evolution of structure in the universe. They would have prevented the early clumping of gas in the universe, delaying the emergence of the first stars, in conflict with the new WMAP data.
- Expansion rate (Hubble constant) value: H_o= 71 (km/sec)/Mpc (with a margin of error of about 5%)
- New evidence for Inflation (in polarized signal)
- For the theory that fits our data, the Universe will expand forever. *(The nature of the dark energy is still a mystery. If it changes with time, or if other unknown and unexpected things happen in the universe, this conclusion could change.)*

The above authoritative precise scientific claims supporting the Big Bang theory do not hold up to scientific scrutiny and this can be proven by empirical observations guided by a corrected theoretical foundation. If the CMBR is produced in real-time, rather than having been sourced in a primordial event, then conservation of energy implies that the production of the CMBR is fed by a real-time phenomenon in which microwave radiation is emitted in a ubiquitous process of energy transformation. This process has already been definitively identified.

16. A subtle error in the genesis of general relativity

Because neither Einstein nor his contemporaries who worked on general relativity properly understood Minkowski's legacy (i.e., the concept of geometric time) Einstein's geometric theory of gravity contained a critical flaw from its inception. Nevertheless, GR successfully described the majority (but not the entirety) of previously unsuspected relativistic gravitational phenomena. Empirical verification of these predictions lead to rapid acceptance of the theory and it has since been generally treated as if it were a dependable unflawed model of nature, with the exception of its apparent incompatibility with quantum mechanics. It can be shown according to first principles and existing empirical evidence that the Schwarzschild geometry, derived as a solution to the Einstein field equations, is not entirely accurate, for it does not model *all* of the geometric implications of the synthesis between special relativity, accelerated reference frames and the Equivalence Principle. This error has led to numerous unexplained anomalous observations as well as the attribution of empirical phenomena to causes that do not exist, including the assumed primordial source of the CMBR.

By definition, the path of light establishes a geodesic between two points in space, for there is no shorter distance between those points than that measured along this path:

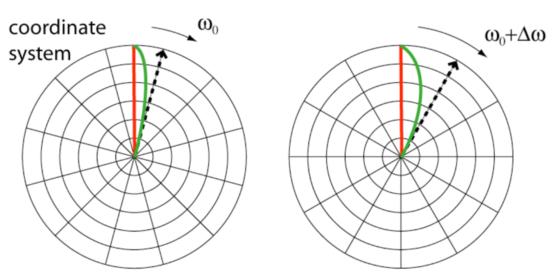
> All length-measurements in physics constitute practical geometry in this sense, so, too, do geodetic and astronomical length measurements, if one utilizes the empirical law that light is propagated in a straight line, and indeed in a straight line in the sense of practical geometry.[94] – A. Einstein

Imagine a red laser beam that is fixed in space relative to an inertial reference frame. Directly on top of this red laser is a green laser attached to a rotating motor so that relative to the red beam, the green beam sweeps out a complete circle with some angular frequency ω [see Fig. (37)]. Thus, the green laser beam establishes a rotating frame of reference relative to the red beam's inertial frame. The angular coordinate of the rotating coordinate system relative to the inertial coordinate system is established by measuring the instantaneous angle between the green beam and the red beam near their collocated point of emission. The path taken by the green laser beam defines the physical radius of the rotating reference frame, and this radial geodesic through the space of that frame is distinct from the geometrically defined radius of the abstract polar *coordinate system* fixed to the rotating laser. That radius is distinctly defined by the red beam.

It is clear that due to the finite speed of light, photons emanating from the lasers require some amount of time to propagate to an arbitrarily chosen radius. In this time, the green laser beam and its geometrically defined rotating Euclidean polar coordinate system will have advanced by some angular displacement relative to the red laser beam. The fundamental distinction between the green beam and its rotating coordinate system is that the photon beam is physically real, while the rotating coordinate system defined by the angular rotation of the beam's source is a mathematical abstraction. At any given radius, subsequent photons from the red beam constantly strike a new angular coordinate of the rotating frame over a complete revolution. In contrast, at a given radius, photons from the green beam strike the same angular coordinate of the rotating frame, so long as the angular speed of the green laser remains constant. However, with increasing angular speed of the green laser, this coordinate must change, as the beam will increasingly *curve* relative to the rotating *coordinate system*. Yet, according to an ideally co-rotating observer, the green beam does not curve; it always pursues a "straight line" through space. Put a circular piece of paper on a uniformly rotating turntable. Sweep the pencil in a straight radial line at *uniform speed* across the rotating paper disk from center to edge at different rotation speeds. The increased curvature of the arc drawn at higher rotation speed demonstrates the same principle that applies to the green laser's beam of photons. The path of this beam *in the rotating frame* defines the physical *geodesic* radius of the frame, as an imagined ideally co-rotating observer would measure it.

The rotating reference frame defined by the green laser is an accelerated reference frame. If an observer rotates ideally at a fixed (r, θ) coordinate in this frame, acceleration is experienced that is proportional to the radius. Moreover, in this accelerated frame, the measured distance ρ from the center of the frame to this eccentric point is measured along the path of the green laser beam, *not* the radius r of the rotating Euclidean coordinate system. It is a fundamental consequence of the principles of relativity that the faster the beam rotates, the greater the resulting curvature of the beam relative to the coordinate system. For a given radial coordinate, if an observer measures a greater acceleration there due to increased angular speed, then the measured distance back to the center of the frame along the geodesic that is established by the radial light beam will also be greater. There are two distinct radii associated with a peripheral location. The straight line made by the red laser in the inertial frame is used to measure the *coordinate radius*. The curved line made by the green laser in the rotating system is used to measure the co-moving *physical radius*.

Figure 37 – A rotating reference frame has a curved radial geodesic defined by light



The measured radial geodesic of a rotating frame of reference as defined by a comoving rotating radial light beam is curved relative to the concentric rotating coordinate system. Increasing ω increases the curvature and length of the rotating frame's physical radius ρ out to a particular coordinate radius r.

The dashed black arrow is the *fixed direction* in which the green laser points *within the rotating frame* ($\theta = 0$).

The foregoing has established that the principles of relativity imply an "excess radius" in the direction of the acceleration gradient for an accelerated reference frame. *Here*, by "excess" we mean that while the coordinate radius and the physical radius are identical for a reference frame at rest in inertial space, the physical radius of a rotating frame as measured by a co-moving observer is greater than its coordinate radius. The difference between the two is the "excess radius". Surprisingly, this fundamental implication of relativity concerning a rotating frame of reference that is summarized in Fig. (37) never occurred to anyone during the prior century. However, in 1909, Einstein's close friend and colleague, Prof. Paul Ehrenfest, noted the less subtle fact that the *circumference* of a rotating frame of reference must experience relativistic dilation from the perspective of the inertial frame because of its tangential velocity.[95] It is readily apparent that special relativity requires a standard measuring rod along the periphery of a rotating frame to contract relative to the inertial frame. A greater number of these contracted rods will fit around the perimeter in the inertial frame than identical rods that are not moving. It can therefore be concluded that the direction tangent to the acceleration gradient experiences a relativistic spatial dilation such that an excess circumference exists for observers in the accelerated reference frame. Again, by "excess" we mean that if an observer at a fixed coordinate radius measures the corresponding circumference when at rest and again when rotating, in the latter case the measurement will be greater than it was in the former case due to relativistic effects. As the complimentary excess radius matching this excess circumference was not recognized in 1909, conclusions drawn at that time concerning the geometry of a rotating reference frame implied by relativistic effects were inconsistent with the actual geometry dictated by physical law.

Historically, the rotating frame of reference shown in Fig. (37) was imagined in the mind's eye as a rotating "rigid disk". This probably stemmed from a 1909 paper published by Max Born in which he discussed the relativistic treatment of rigid bodies.[96] Subsequently, Ehrenfest put forward the idea that Born's relativistic local rigidity criterion implied that a rotating disk's circumference will incur relativistic effects, while the disk's radius will incur no such effects, as the center of the disk remains stationary in the inertial reference frame. Because the radius has no velocity *per se*, this was a natural although clearly incorrect assumption. Indeed, the realization that the finite speed of light causes the physical radius *defined by a radial light beam* to curve relative to the rotating coordinate system is quite subtle and easily overlooked.

For some time prior to Ehrenfest's paper, Einstein, then aged 29, had tried and failed to find a synthesis between special relativity and gravity. Ehrenfest's flawed insight clearly electrified him. Einstein put forth the following seemingly cogent argument in his popular book on relativity in the section entitled *Behavior of clocks and Measuring-Rods on a Rotating Body of Reference*.

> If the observer applies his standard measuring-rod (a rod which is short as compared to the radius of the disc) tangentially to the edge of the [rotating] disc, then, as judged from the Galileian system [inertial frame *K*], the length of this rod will be less than 1, since, according to Section 12, moving bodies suffer a shortening in the direction of the motion. On the other hand, the measuring-rod will not experience a shortening in length, as judged from *K*, if it is applied to the disc in the direction of the radius. If, then, the observer first measures the circumference of the disc with his measuring-rod and then the diameter of the disc, on dividing the one by the other, he will not obtain as quotient the familiar π=3.14…, but a larger number, whereas of course for a disc that is at rest with respect to *K*, this operation would yield π exactly. This proves that the propositions of Euclidean geometry cannot hold exactly on the rotating disc, nor in general in a gravitational field, at least if we attribute the length 1 to the rod in all positions and in every orientation.[97]

He also points out that the laws of special relativity hold exclusively for the inertial system *K*.

> Throughout this consideration we have to use the Galileian (non-rotating) system K as reference body, since we may only assume the validity of the results of the special theory of relativity relative to K (relative to K' a gravitational field prevails).[98]

The historical record makes it clear that the analysis of a rotating rigid disk in the context of special relativity played a pivotal role in the development of general relativity. Early on in the pursuit of the theory, in a letter to Arnold Sommerfeld dated 29 September 1909, Einstein writes:

> The treatment of the uniformly rotating rigid body seems to me to be very important because of an extension of the relativity principle to uniformly rotating systems by trains of thought which I attempted to pursue for uniformly accelerated translation…[99]

In "Part 3" of his 1916 *Annalen der Physik* paper on general relativity, Einstein writes about a system of coordinates K' in uniform rotation relative to an inertial reference frame K:

> …we envisage the whole process of measuring [in K'] from the "stationary" system K, and take into consideration that the measuring-rod applied to the periphery undergoes a Lorentzian contraction, while the one applied along the radius does not. Hence Euclidean geometry does not apply to K'.[100]

In a 1921 lecture to the Prussian Academy of Sciences entitled "Geometry and Experience", Einstein made it clear that *the decisive step* leading to the method employed to develop his system of equations describing gravitation was the interpretation of Ehrenfest's rotating disk:

> In a system of reference rotating relatively to an inertial system, the laws of disposition of rigid bodies do not correspond to the rules of Euclidean geometry on account of the Lorentz contraction; thus if we admit non-inertial systems on an equal footing, we must abandon Euclidean geometry. Without the above interpretation the decisive step in the transition to generally covariant equations would certainly not have been taken.[101]

It is clear that Ehrenfest's original analysis of a rotating rigid disk in the context of special relativity motivated Einstein's thought process leading to his eventual conception of general relativity. What Einstein was searching for in the years 1907 to 1909 was a way to tackle the synthesis between special relativity and acceleration (i.e., *gravitation*). Ehrenfest's imagined rotating disk (an accelerated reference frame that exhibits relativistic effects that can also be interpreted in the context of special relativity) offered a panacea. This is because Einstein's Equivalence Principle implies that what is true for an accelerated observer on the surface of such a disk is also true for an accelerated observer in a gravitational field.

What Ehrenfest, Einstein and several generations of physicists who followed failed to realize was the simple fact that the measuring rods "applied to the disc in the direction of the radius" must be applied along the *curved* geodesic established by a radial light beam, from its central source to the point on the periphery where it terminates. *That point changes*. While in the mind's eye there exists a shorter radial path through space that does not curve with the light beam, this is a naïve idea born of faulty human instinct and assumption rather than rigorous logical analysis within the confines of established scientific principles. In the rotating frame where centripetal acceleration is experienced, no such "shortcut" exists because this abstract *geometrically defined* line no longer represents space *per se*; it instead represents an abstract *mixture* of both space *and* time. Because both the physical radius and the circumference of a rotating frame of reference expand in concert, the ratio between them always remains 2π. Nevertheless, the geometry of the rotating disk (i.e., its metric) is *not* Euclidean in the conventional sense, for it incorporates dynamic coefficients that vary with the radius according to the local characteristic acceleration. Thus, specific observable relativistic empirical phenomena are predicted to occur in accelerated reference frames that do not occur in an unaccelerated reference frame.

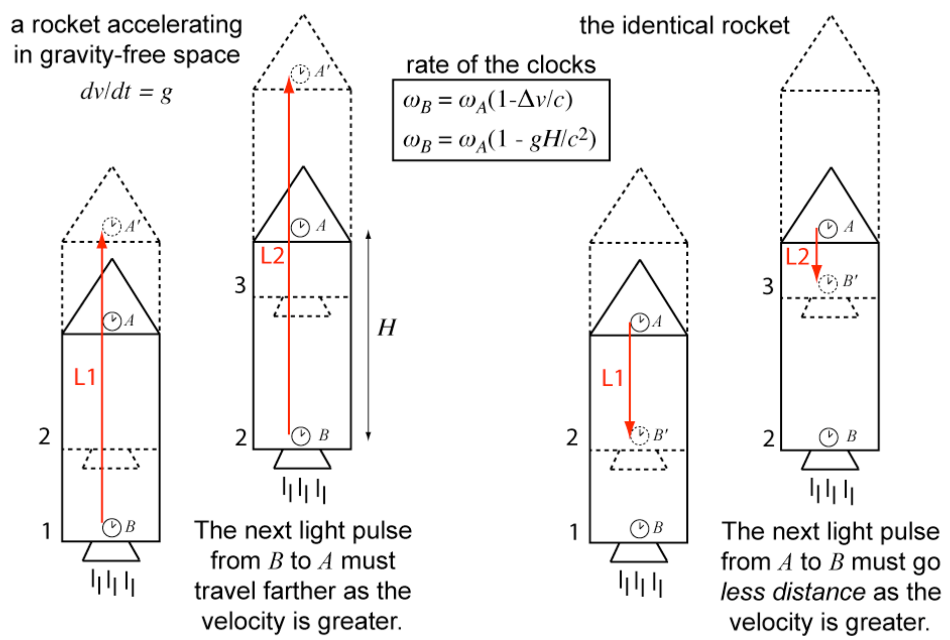
A common error made in theoretical physics is an incorrect assumption embedded in one's logic that typically eludes awareness. It is easy to make a small hidden mistake and even easier to be misled by the previous such mistake of a respected peer and close friend with a convincing argument that obscures some failure in thinking. Ehrenfest's analysis of the rotating disk was lacking in rigor due to a failure in making a distinction between the disk's curved *physical* radius, which is defined by the radial propagation of light, and the disk's immutable *coordinate* radius, which is defined by purely geometrical considerations. This small but critical error in the genesis concept that spawned Einstein's work on the field equations obscured the existence of an observable empirical phenomenon associated with relativistic effects of the gravitational field with far-reaching consequences for orbital mechanics, astrophysics and cosmology.

The fundamental misleading idea that Einstein brought away from Ehrenfest's thinking is that the geometry of space for an accelerated reference frame is *non-Euclidean*, specifically meaning that the ratio between the circumference and the radius is not equal to 2π. The Equivalence Principle led him to apply the same idea to the gravitational field. Thus, the logical foundations of the general theory of relativity were laid and a subtle and insidious error was made that would mislead a century of science. In short, the critical idea that was not appreciated by Einstein's generation and a century of physicists who followed was the simple concept of geometric time.

17. The geometry of time for inertially accelerated frames

It is easily shown and has long been well understood that acceleration causes an asymmetric *absolute* time differential between clocks. Accelerated clocks record time at a slower rate than inertial clocks. Moreover, an acceleration gradient causes an identical relativistic temporal effect; according to the principles of relativity, an ideal clock at a higher potential must record time at a faster absolute rate than a similar ideal clock at a lower potential. If we mount ideal clocks in the nose (A) and the tail (B) of an accelerating rocket in ideal gravity-free space, then according to an unaccelerated observer watching the rocket from an external vantage point, the light travel time from B to A is constantly increasing and the light travel time from A to B is constantly decreasing. If the identical clocks tick with flashes of light, an observer at B will perceive the clock at A to flash faster than the local clock. Contrariwise, an observer at A will perceive the clock at B to flash slower than the local clock. It may be concluded that due to the acceleration gradient, time passes (i.e., age increases) faster in region A than in region B. Richard Feynman discussed this gedanken experiment in his famous *Lectures on Physics* given to a freshman class at Caltech.[102]

Figure 38 – Flashing ideal clocks in the nose and the tail of an accelerating rocket

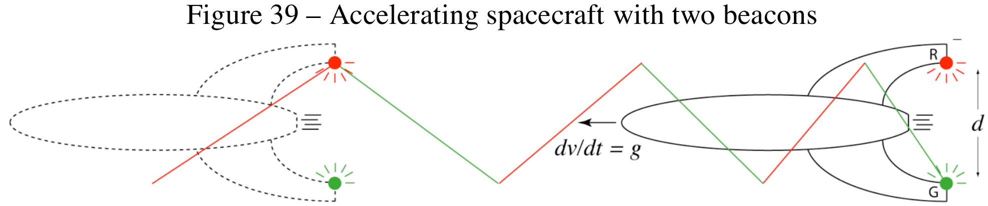


For similar reasons that the obvious idea that the Sun is at the center of the Solar System never occurred to anyone for centuries, it never occurred to Feynman, Einstein or anyone else that the identical principle that applies in Fig. (38) also applies to two clocks with the same axial coordinate. Though immediately apparent, it was simply not within the realm of intellectual imagination. The "common sense" concept of a classical equipotential surface is so fundamental that it is natural to assume that nothing can destroy it. Likewise, prior to Copernicus, it was thought that nothing could destroy the "common sense" concept of all observed heavenly bodies turning around the Earth. Repetitively, prior to Einstein, it was thought that nothing could destroy the "common sense" concept of absolute time. "Plus ça change, plus c'est la même chose."

Mathematical models can be deceptive because the symbolic representation of physical reality may incorporate incorrect assumptions that are not obvious. Logical physical models are less subject to this failing. Due to Hermann Minkowski's premature death at age forty-four in January 1909, subsequently developed mathematical models of relativity failed to recognize the geometric properties of time and so they failed to recognize and model the more subtle measurable physical effects of relativity. All of these effects ultimately rest on one simple fact: the speed of light through space in vacuum is perceived by a freefalling observer to be constant.

A flash of light is perceived by such an observer to be a spherical wavefront traveling radially outward from the point of emission at the speed of light. *Any relative motion of the light source has no effect on this observation.* The logical consequences of this phenomenon lead to insights into the subtle workings of the Universe that have no analogue in the everyday world. Imagine that you are an inertial observer floating in space, peering out from your window. You watch an *accelerating* spacecraft pass by. As shown in Fig. (39), there are two outboard beacon lights, one red and one green symmetrically placed at the tail of the spacecraft at the same axial coordinate. The spacecraft designer has incorporated a photomultiplier in the beacons. After being manually started with a single flash by one beacon, each beacon is designed to flash only when light from the other beacon hits the local beacon's photomultiplier, activating a single local pulse. Assuming an idealized situation that facilitates this gedanken experiment, the two beacons are then clearly designed to pulse sequentially. We ignore any delay in the activation mechanism and the fact that in practice the frequency of the beacons would be so high that they would appear to the human eye never to be extinguished. According to the principles of relativity and assuming the natural behavior dictated by physical law is observable, what do you see?

Figure 39 – Accelerating spacecraft with two beacons



effect of acceleration on light paths (angles) exaggerated for illustartive purposes

From your perspective, a flash of light from either beacon expands as a spherical wavefront at the speed of light from the point in space where the beacon was when it pulsed. Due to the fixed distance *on the spacecraft* between the two beacons, the expanding wavefront of one beacon will intersect with the photomultiplier of the other beacon only after some interval of time. Because the spacecraft is accelerating, then with each subsequent flash of a beacon, the spacecraft is moving faster in your inertial reference frame. From your point of view, the expanding wavefront of light from each beacon is in effect "chasing" the location of the other beacon's photomultiplier. In your reference frame, the photomultiplier of the complementary beacon is traveling at a greater speed away from the source of the remote flash of light with each subsequent event. It is then clear that from your point of view, each subsequent flash of light from a beacon must expand by a slightly greater radius in order to intersect with the moving location of the other beacon. Therefore, if you measure the time interval between each subsequent flash according to the ideal clock in your inertial reference frame, the interval between subsequent flashes as measured by your clock must steadily increase. This is a fundamental consequence of the fact that the speed of light is constant in your frame and that the motion of the spacecraft has no effect on how you see a flash of light expanding as a spherical wavefront from either of its beacons. In contrast, if the spacecraft's engine is shut off so that it is no longer accelerating, but rather moving relative to you at a constant velocity, the measured time interval between the flashes will remain the same.

Consider now the logical implications of your observations as an inertial observer watching the spacecraft, instead for an observer traveling with the spacecraft. From the point of view of this observer, the beacons are not moving in the spacecraft's reference frame. Therefore, the distance between a flash of light from one beacon and the other beacon's photomultiplier is fixed. When there is no acceleration, the beacon apparatus functions as a light clock with a "tick" of the clock corresponding to the flash of the local beacon *as stimulated by the flash of the remote beacon*. Thus, at constant velocity, the red beacon is sympathetically measuring time as measured at the location of the green beacon and vise versa. An observer in the spacecraft who is directly adjacent to either beacon can accurately measure the frequency of the beacon relative to an ideal clock. According to the foregoing discussion concerning the principles of relativity, when the spacecraft is *accelerating*, the beacon apparatus functions as a kind of accelerometer rather than a clock. Referencing an *immediately adjacent* ideal clock, the observer must measure the frequency of a beacon to decrease in correlation with both the magnitude of the acceleration as well as the separation distance between the beacons.

Imagine now that the original spacecraft beacon apparatus is replaced by a different design; local ideal clocks control each beacon. Each second, the clocks pulse their beacon and the flashes travel through space to the other beacon. The same principle applies to this situation as for the prior one. According to an inertial observer watching the accelerating spacecraft, with each subsequent flash, the radius of the wavefront must increase somewhat in order to intersect with the moving location of the other beacon. With this design, an observer at either beacon, who is accelerating with the spacecraft, must measure the frequency of the remote beacon to be somewhat less than that of the local beacon. Now, only the relative frequency of the *remote* beacon can be used as an effective accelerometer in reference to the local beacon, which now functions as an ideal clock. With greater acceleration of the spacecraft, the period of the remote beacon as perceived from the location of either beacon decreases. This behavior is consistent with a relativistic dilation of space between the beacons that is proportional to the measured inertial acceleration of the spacecraft. Indeed, this relativistic dilation of space in the direction *tangent* to the acceleration vector is the linear acceleration equivalent to the dilation of the circumference of a rotating frame, which is tangent to the centripetal acceleration (i.e., the Equivalence Principle).

The formal mathematics of conventional general relativity recognizes gravitational redshift, which causes an absolute clock rate differential for ideal clocks at different altitudes within a gravitational potential. However, because it does not incorporate the concept of geometric time, it does not recognize the symmetric time dilation effect between ideal clocks at the identical altitude (i.e., identical classical potential) caused by a separation distance, which is a simple logical consequence of the fundamental principles of relativity. One does not need to have exceptional talent in mathematics to appreciate this. It is only necessary to have a disciplined logical mind that is open to the possibility that the Newtonian concept of an equipotential surface does not hold when relativistic effects in an accelerated reference frame are taken into consideration. While the proposed relativistic phenomenon may appear to contravene conservation of energy, it is clear that this cannot possibly be the case; our understanding of energy conservation in the context of geometric time is equally in need of revision as the mathematics of general relativity.

Those with a stake in the status quo may invoke specious arguments in opposition to the foregoing simple arguments, but authoritative proclamations do not clothe a naked emperor. In practice, the magnitude of the predicted redshift effect transverse to the acceleration gradient is so small that it is difficult to measure, easily overlooked, and subject to misinterpretation if it is observed. The cause of the effect as revealed by the foregoing gedanken experiment is that the path of light between the two accelerating beacons *as perceived by an inertial observer* must cover a slightly greater distance for each subsequent cycle of the apparatus. A naïve but effective method of estimating the approximate order of magnitude of the effect in the idealized case of a small linear acceleration is to model the effect as a transverse Doppler shift. The calculation is based on the slight tangential velocity increase of the receiver relative to the source over the approximate time it takes light to travel between the beacons as observed by an inertial observer.

$$\Delta v = gt = g\frac{d}{c} \tag{47}$$

$$\omega \approx \omega_0\sqrt{1-\frac{\Delta v^2}{c^2}} = \omega_0\sqrt{1-\frac{g^2}{c^4}d^2} \tag{48}$$

Where g is equal to the acceleration on the surface of the Earth (~9.8 $m\ s^{-2}$), the quotient under the radical evaluates to nearly the same order of magnitude as Plank's constant (h ~10^{-33}).

$$\frac{g^2}{c^4} \approx 1.2\times10^{-32} \tag{49}$$

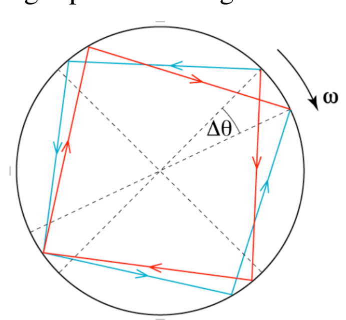
The Einstein Equivalence Principle (EEP) implies that if this relativistic effect occurs for an inertially accelerated reference frame, which is locally indistinguishable from a gravitational field, the same effect must occur for a real gravitational field. The most sensitive *ground-based* instrument whose design is consistent with measuring this predicted relativistic effect is the Laser Interferometer Gravitational Wave Observatory (LIGO). LIGO is a Fabry-Pérot with $f = 3\times10^{14}$ and $L = 4\ km$. The effect will appear as an obviously *undetectable* beat frequency of

$$\omega \approx \frac{2g^2L^2}{c^4}\cdot f = 1\times10^{-10}\ Hz \tag{50}$$

between n-pass light and the (n+1)-pass light. A more likely means of experimentally resolving the predicted effect involves exploiting the very long signal paths taken by precision telemetry signals from spacecraft. Similarities in observed periodic signal anomalies for the Pioneer-10 spacecraft and Global Positioning System (GPS) satellites, as well as numerous additional corroborating observations, provide compelling empirical evidence for a relativistic *transverse* gravitational redshift (*TGR*) effect that is unmodeled by conventional general relativity. This empirical evidence is discussed with considerable detail in later sections. —

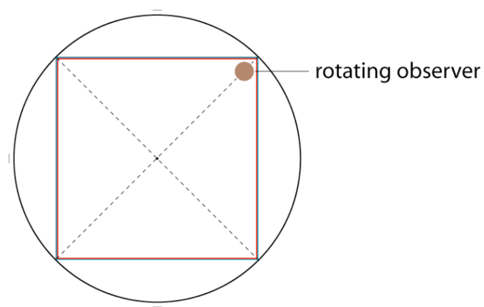
The ring laser gyroscope is a practical exploitation of a Sagnac interferometer, which is used in all modern inertial navigation systems. In a Sagnac interferometer, a single light source is split into two distinct beams that travel in opposite directions around a rotating stage and are then recombined after a complete round trip. From the point of view of an inertial observer, the beam propagating in the direction of rotation travels over a greater distance than the counter-rotating beam due to the rotation of the devise during the light round-trip time. This interpretation implies a phase shift between the beams proportional to the angular velocity of the devise, which is measured by an interferometer. The basic principle involved is simply illustrated in Fig. (40).

Figure 40 – Counter-rotating light paths of a Sagnac interferometer, inertial perspective



We now consider the Sagnac interferometer from the perspective of an accelerated observer rotating with the reference frame. From this observer's point of view, the mirrors that reflect the light beams around the rotating stage are at rest relative to one another in a peculiar kind of "gravitational field" with an inverted radial gradient. The idea that the speed of light is not isotropic in a rotating frame is an *invention* to account for the observed Sagnac effect while being ignorant of the concept of geometric time. A rotating observer clearly measures the distance between all of the mirrors to be identical and the speed of light through space in any direction to be the same. The rotation of the reference frame has no part to play in these measurements.

Figure 41 – Counter-rotating light paths of a Sagnac interferometer, co-rotating perspective



Accordingly, relative to the rotating system of coordinates, the two beams of light are observed to travel identical distances at identical speed (i.e., the speed of light) before they are recombined back at the source. Therefore, it is clear that the accelerated observer rotating in the reference frame cannot attribute the measured interference of the two beams to a phase shift. Then to what is the accelerated observer to attribute the observed Sagnac effect? Conventional physics offers no compelling answer to this puzzling question, however the concept of geometric time as a foundation for all observed temporal relativistic effects eliminates this apparent paradox.

The intuitive geometry of special relativity's symmetric time dilation depicted in Fig. (1) involves two intersecting straight lines representing the respective time coordinates of two inertial reference frames in relative motion. The angle between the lines is related to the relative velocity between the reference frames according to Eq. (3). It should be clear that if this velocity is not constant, because one of the reference frames is accelerating, the line corresponding to the time coordinate of the accelerating frame must *curve*. The intersection between the tangent to this curve and the other line forms an angle ζ specified by Eq. (3) according to the instantaneous relative velocity between the two frames. In the case of centripetal acceleration, the magnitude of the characteristic tangential velocity is constant, but the velocity vector sweeps out a circle over each rotation. Likewise, in congruence with the relativistic idea that space becomes time, the time vector for a particular rotating point similarly sweeps out a circle over each rotation. The large spiral shown on the right side of Fig. (42) is for simplicity of illustration. It should be envisioned quite differently from this image as a nearly vertical corkscrewing rhumb line on the surface of a narrow cone orthogonal to and expanding out of the plane of the page.

Figure 42 – Geometric time coordinates for linear and centripetal acceleration

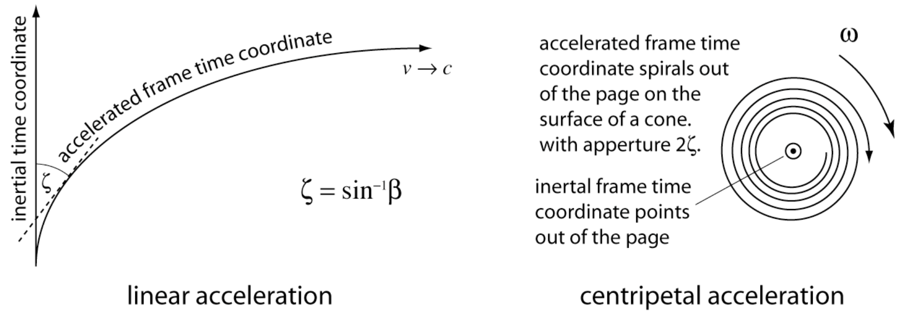
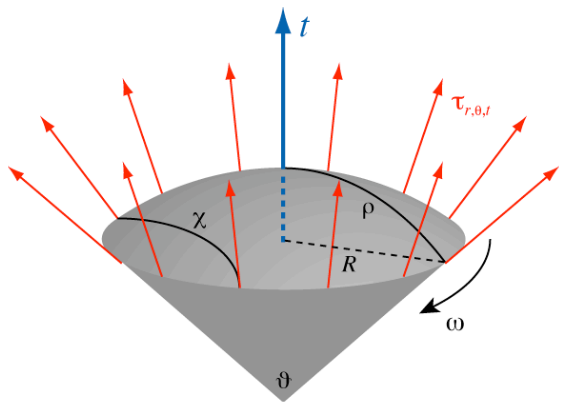


Fig. (43) depicts a different conceptual model of geometric time for a rotating reference frame. The curved radius ρ of the cap is the relativistically dilated physical radius that is curved not in space but *in spacetime* ("time becomes space") and the slant height represents the local time dimension (i.e., time vector $\tau_{r,\theta,t}$). The vertical blue axis labeled *t* represents the time coordinate of the inertial frame. Referencing Eq. (3), the aperture angle of the characteristic time vector cone for a perimeter tangential velocity of $v = \omega R$ at *coordinate* radius *R* is

$$\vartheta = 2\sin^{-1}\frac{v}{c} \quad \rightarrow \quad \vartheta = \frac{2v}{c} \quad [v << c] \qquad 51$$

Figure 43 – A conceptual model of geometric time for a rotating frame of reference



Using this artistically exaggerated geometric model, it is clear that at distinct radial coordinates (R, θ) of the rotating frame, the local slant height vectors ($\tau_{r,\theta,t}$) representing *local* time at that coordinate will not be parallel. It follows that the angle between these distinct time coordinates at constant coordinate radius $r = R$ increases as a function of angular displacement (θ). Thus, the direction of the local time coordinate in spacetime changes for light that propagates over a geodesic chord χ. This change implies a redshift according to Eq. (11).

With the aid of a gyroscope, an observer who experiences centripetal acceleration will always know that the acceleration is due to rotation. While this rotation has no part to play in the measurement of the symmetric path lengths of the two counter-rotating light beams from the perspective of the rotating frame, it does have to be taken into consideration when calculating the net change in the direction of time vectors between the reflecting mirrors. From the rotating observer's point of view, even though the mirrors are not rotating relative to one another, the cone in Fig. (43) representing the space-time reference frame rotates in synchrony with a gyroscope. Because the cone rotates by some small angle $\omega\Delta t$ in the time it takes for light to propagate over a chord, it is clear that target time vectors are *increasing* their angle relative to the source vector for light that pursues a concentric path *with* the direction of rotation. In contrast, target time vectors are decreasing their angle relative to the source vector for light that pursues a concentric path *against* the direction of rotation. Then, although the path lengths of the two light beams are equal as determined by measurements in the accelerated frame, the accelerated observer must calculate a larger net "time angle" change for the beam traveling in the direction of rotation as compared to the beam traveling in the opposite direction. According to Eq. (2), this difference implies a frequency differential between photons moving in opposite directions that return to their common source after a round trip. Therefore, an accelerated observer attributes the observed interference pattern between the two counter-rotating light beams as a result of a frequency differential between the beams arriving at the interferometer, rather than a phase shift incurred by a path length differential, which does not exist from the perspective of the rotating frame.

18. The synthesis between a rotating frame of reference and gravity

The Equivalence Principle implies that there is no distinction between gravitational and inertial acceleration. Early on, Einstein was aware of the relativistic temporal effects associated with acceleration portrayed in Fig. (38), so it was clear to him that relativistic phenomena must involve spatial effects for the radial coordinate of the gravitational field.[103] He was also appropriately convinced that what was true for a rotating system of coordinates must also be true for a gravitational field. In a February 1921 article for the journal *Nature*, Einstein writes:

> But perhaps Newton's law of field could be replaced by another that holds with respect to a "rotating" system of coordinates? My conviction of the identity of inertial and gravitational mass aroused within me the feelings of absolute confidence in the correctness of this interpretation.[104]

Einstein was correct in this conviction, yet he was clearly incorrect in assuming that the ratio between the radius and circumference of a rotating system of coordinates, *as it would be ideally measured by an observer in that reference frame*, is other than 2π. In the years 1909 to 1915 and beyond, in Einstein's mind the space-time geometry of the gravitational field had to be somehow "curved" to create a higher-dimensional analogue to a Riemannian surface in three dimensions; the geometry of the gravitational field would be like the relativistically altered non-Euclidean geometry of the rotating system of coordinates as *erroneously imagined* by Ehrenfest. A circle of latitude on a sphere has a Euclidean radius that cuts through to the axis of a sphere. However, if measurement is restricted to the curved surface of the sphere, the curved radius of the circle is clearly greater than the Euclidean radius. In this case, the measured "excess radius" implies the difference between "radius" as defined on a Euclidean manifold and on a Riemannian manifold.

Fig. (37) and its supporting arguments clearly show that relativistic effects must cause an expansion of the measured radius of a rotating reference frame with the similar expansion of the circumference in a way that preserves the ratio between them. According to the Equivalence Principle, the same phenomenon must occur for a gravitational field. Indeed, it does, and this is reflected by the coefficient to the second term of the Schwarzschild metric (52), which is greater than unity for finite values of r as compared to no coefficient for the dr^2 term in the Minkowski metric (53). In the former equation, r is the coordinate radius while the whole second term inclusive of the coefficient reflects the dilated "excess" physical radius of a gravitational field.

$$ds^2 = \left(1 - \frac{2GM}{rc^2}\right)dt^2 - \left(1 - \frac{2GM}{rc^2}\right)^{-1} dr^2 - r^2\left(d\theta^2 + \sin^2\theta\, d\phi^2\right) \quad 52$$

$$ds^2 = dt^2 - dr^2 - r^2\left(d\theta^2 + \sin^2\theta\, d\phi^2\right) \quad 53$$

It is immediately apparent upon examination that there is no distinction between these two metrics for the θ and ϕ terms. This is because the Einstein field equations admit no relativistic transverse expansion (i.e., tangent to the radius). The purported "spacetime curvature" associated with Einstein's theory of gravity is based on the assumption embodied by the Schwarzschild metric of "too much radius for the circumference" in the context of Euclidean geometry. However, according to first principles, a "curvature" of space in this particular sense of the word cannot and does not exist in reality. Einstein was a great genius, but imperfect. All of the blather about his mathematically complicated and difficult to understand idea of "spacetime curvature", particularly over the last half-century, is a classic example of *The Emperor's New Clothes* writ large. Like the emperor's special clothes, this kind of "curvature" does not actually exist. It is ironic that while analysis of the rotating system of coordinates led Einstein to his theory, the noted relativistic effect tangent to the acceleration gradient was not incorporated in general relativity, while the *overlooked* relativistic radial dilation was. The Equivalence Principle requires that what is true for one must also be true for the other.

Using a suitable instrument such as a gyroscope over some interval of time, an accelerated rotating observer can determine that the acceleration experienced is an inertial acceleration. However, if measurement is restricted to a single moment in time, then this measurement cannot distinguish between inertial and gravitational acceleration. Accordingly, although in fact moving as perceived by inertial observers and by a local instrument over time, the rotating observer is entitled to the opinion that no such motion exists and to interpret the measured acceleration as the effect of a kind of "gravitational field". Thus, the Einstein Equivalence Principle allows a rotating frame of reference with its associated system of coordinates (K') to function as an accurate analog to a real gravitational field. In the words of Einstein,

> But, according to the principle of equivalence, K' may also be considered as a system at rest, with respect to which there is a gravitational field… We therefore arrive at the result: the gravitational field influences and even determines the metrical laws of the spacetime continuum.[105]

Willem de Sitter had more to say on the matter. [106]

> In Einstein's theory of general relativity, there is no essential difference between gravitation and inertia. The combined effect of the two is described by the fundamental tensor $g_{\mu\nu}$, and how much of it is to be called inertia and how much gravitation is entirely arbitrary. We might abolish one of the two words, and call the whole by one name only. Nevertheless, it is convenient to continue to make a difference. Part of the $g_{\mu\nu}$ can be directly traced to the effect of known material bodies, and the common usage is to call this part "gravitation" and the rest "inertia."[107]

Nearly a century after the Ehrenfest-Einstein blunder, is has been made clear that both the radius *and* the direction tangent to the radius of a rotating frame of reference are dilated due to relativistic effects. Due to the acceleration that is incurred, an observer in the reference frame experiences an expansion of space. For a rotating frame of reference, this means that for a given *coordinate* radius there is a greater measurable square area of a rotating "disk" associated with an accelerated frame than for the same "disk" at rest. Moreover, greater acceleration causes a greater "excess area" to be created. The Equivalence Principle implies that the same phenomenon must also occur for a gravitational field, but in all three dimensions of space. Thus, rather than creating a spatial geometry around a material body having an "excess radius" as modeled by Einstein's theory, a gravitational field creates a geometry with an *excess volume* as compared to normal Euclidean geometric calculations. A gravitational field "stretches" space in every direction; relativistic effects dilate the radius and all directions tangent to it. Although *radial* relativistic effects of the gravitational field were correctly modeled by Einstein's version of GR, complementary tangential effects remained unmodeled. These effects have been readily observed, yet were not properly interpreted, because interpretations were made to fit the established theoretical paradigm. Similarly, retrograde motion of the planets was for centuries interpreted in the context of an established and officially authorized Earth-centered Universe rather than the obvious implication of concentric planetary orbits around the Sun. — If a relativistic effect causes a dilation of space transverse to the gravitational gradient of a material body, then there must also be a complimentary relativistic temporal effect, which implies an associated energy effect.

Einstein's Equivalence Principle is one of the most powerful ideas in the history of science and one of the simplest. There is something to be learned in this. Employing this principle to its full utility, the centripetal acceleration of a rotating reference frame can be used as an almost perfect analogue to a real gravitational field in order to understand the relativistic effects of gravity. Arguably the most import aspect of a rotating system of coordinates in this regard is brought to light by a simple energy analysis. This approach was completely overlooked in the past.

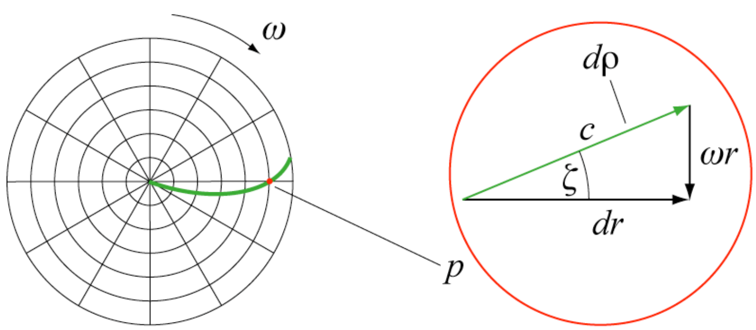
A rotating observer who, according to the Equivalence Principle, is entitled to interpret the experience of inertial acceleration as a kind of "gravitational field", is equally entitled to identify the locally measured "gravitational acceleration" at an eccentric point p with a characteristic "escape velocity" energy value associated with that point. The concept of escape velocity simply refers to a kinetic energy equivalent to the local gravitational potential energy. In the case of a rotating frame of reference, conservation of energy implies that this characteristic velocity, which is essentially *an abstract mathematical property* associated with a coordinate radius *r*, is identical in magnitude to the real physical tangential velocity at radius *r* measured by an inertial observer. If this is not immediately clear, then it can be shown explicitly by integrating the centripetal acceleration over an arbitrary coordinate radius *r*. The work done on a particle of arbitrary mass *m* ideally translated from the disk center to radial coordinate *r* must always equal the particle's kinetic energy of rotation due to its tangential velocity *v* at *r*. In the non-relativistic regime, where *m* is taken to be a constant

$$\int F \cdot dr = m\int \frac{(\omega r)^2}{r} dr = m\omega^2 \int r\, dr = \frac{1}{2} m\omega^2 r^2 = \frac{1}{2} mv^2 \qquad 54$$

The idea embodied by this simple formula is of *utmost importance* in the context of the Equivalence Principle. What it reveals is the following. —

From the point of view of an *inertial* observer, relativistic effects associated with a rotating system of coordinates are incurred due to its motion relative to the inertial frame. Moreover, these effects are specifically quantified according to the measured tangential velocity of a point *p*. For instance, one may wish to determine the magnitude of the local curvature of a radial light beam at point *p* relative to the rotating Euclidean coordinate system fixed to the source of the beam. In deriving this value, we are determining to what extent space as defined in the accelerated frame by a light beam is distorted relative to space as defined in the inertial frame. A simple vector diagram provides the answer. Due to the relative rotation of the coordinate system, the path of a radial photon cannot be parallel to the coordinate radius. In a very simple way, the ratio of the local tangential velocity to the speed of light establishes the local curvature of the beam.

Figure 44 – Differential vector diagram of a radial light beam relative to rotating coordinates



$$\zeta = \sin^{-1}\beta \qquad \left[\beta = \frac{v}{c} = \frac{\omega r}{c}\right] \qquad 55$$

Note that Eq. (55) is identical to Eq. (3). So the "time angle" and the "space angle", which embody the *real* concept of what we may refer to as "space-time curvature", have one and the same value (i.e., for a free-falling observer in a gravitational field, even such "freefall" imagined in the simulated "gravity" of a rotating frame, time and space must remain *orthogonal*). Let the geodesic path of the light beam be denoted by the variable ρ. Then for a constant angular velocity ω, the *curvature* κ of ρ relative to the rotating coordinates (i.e., the coordinate radius *r*) is

$$\kappa = \frac{r^2 + 2r_\theta^2 - rr_{\theta\theta}}{(r^2 + r_\theta^2)^{3/2}} \qquad r_\theta \equiv \frac{\partial r}{\partial \theta} = \frac{c}{\omega} \qquad r_{\theta\theta} = \frac{\partial^2 r}{\partial \theta^2} = 0 \qquad 56$$

Consider that *nothing* that Einstein says in the following passage is actually incorrect.

> Imagine a circle drawn about the origin in the *x'y'* plane of *K'*, and a diameter of this circle. Imagine, further, that we have given a large number of rigid rods, all equal to each other. We suppose these laid in series along the periphery and the diameter of the circle, at rest relatively to *K'*. If *U* is the number of these rods along the periphery, *D* the number along the diameter, then, if *K'* does not rotate relatively to *K*, we shall have $U/D = \pi$. But if *K'* rotates we get a different result. Suppose that at definite time *t*, of *K* we determine the ends of all the rods. With respect to *K* all the rods upon the periphery experience the Lorentz contraction, but the rods upon the diameter do not experience the contraction (along their lengths!). It therefore follows that $U/D > \pi$.[108]

What *is* incorrect (and the greatest blunder ever in scientific history) is the *unstated assumption* that the diameter of *K'* as defined continues to represent the physical radius of *K'* when it rotates. The common obsequious drivel about the "beauty" of Einstein's theory of gravity is ironic, to say the least. In fact, his theory incorporated a momentous error that created an artificially convoluted monstrous tangle of tensor equations that do not accurately reflect physical reality. The entire disaster is fixed by one simple observation: Due to the fact that light does not propagate from one point to another *instantaneously*, the physical radial geodesic of a rotating reference frame, which is defined by the path of a co-rotating radial light beam, *curves* relative to its naturally Euclidean system of rotating polar *reference* coordinates. This truly beautiful simple fact, together with Einstein's Equivalence Principle and special relativity, are all one really needs to know in order to eventually understand everything important about gravity in the context of relativity.

> The pursuit of beauty and elegance has always been a driving force in the development of scientific theories. To its most radical proponents, this bias is based on a firm, axiomatic belief that, at its core, nature simply must be beautiful.[109] – Howard Burton

While an inertial observer experiences relativistic effects in a rotating reference frame in the context of special relativity, a co-rotating observer in the reference frame attributes the identical effects exclusively to the acceleration that is experienced. Moreover, the measured acceleration at any point *p* corresponds to a measurable energy potential relative to the center of the reference frame (i.e., its rotational axis and origin of its coordinate system). This potential is characterized by an "escape velocity" that according to Eq. (54) is identical to the tangential velocity of point *p* as determined by an inertial observer. Therefore, the velocity that appears in Eq. (55) is from the point of view of an accelerated observer the local "escape velocity" of the "gravitational field" at point *p*. According to the Equivalence Principle, an observer in a real gravitational field must have the identical perspective on the matter. The local "time angle" and "space angle", which establish the geometric relationship of local space and time in the gravitational field to an imagined system of reference coordinates in which the Minkowski metric holds, is defined by

$$\zeta = \sin^{-1}\frac{v_{esc}}{c} \qquad \zeta = \sqrt{\frac{2GM}{rc^2}} \quad \left[\frac{v_{esc}}{c} << 1\right] \qquad 57$$

Observers at different radial coordinates of a gravitational field will measure different local accelerations, whether they are at rest or in freefall within the field. Each such observer with a unique radial coordinate is then in a preferred reference frame that is uniquely identifiable from the others. For this reason, relativistic effects associated with changes in coordinate radius are absolute, rather than being symmetric. As was illustrated in Fig. (38), ideal clocks at a higher potential record the passage of time at a faster absolute rate than similar clocks at a lower potential. Ergo, the greater the local gravitational escape velocity, the slower time is recorded relative to an inertial ideal clock and there can be no ideal clock found to record time faster than an inertial ideal clock. It follows that Eq. (57) establishes an *absolute* gravitational time angle relative to the zero reference time angle corresponding to an observer at rest at arbitrary distance.

$$\zeta_{r \to \infty} = 0 \tag{58}$$

Any time coordinate associated with a finite coordinate radius *r* within a gravitational field will have a time angle ζ greater than zero and thus will not be parallel to the reference coordinate. The determination of the absolute rate of an ideal clock in a gravitational field ($d\tau$) relative to the rate of an inertial ideal reference clock (*dt*) is again a matter of a simple geometric projection. However, in this case, no symmetry as was depicted in Fig. (1) exists; the projection of the local time coordinate vector on the reference coordinate vector is distinctly unilateral.

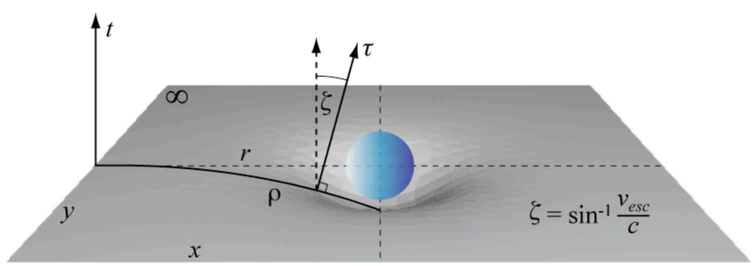
$$\frac{dt}{d\tau} = \sec\zeta = \frac{1}{\sqrt{1-\sin^2\zeta}} = \left(1 - \frac{2GM}{rc^2}\right)^{-\frac{1}{2}} \tag{59}$$

If we appropriately consider the reference time *dt* as *coordinate time*, then the relationship between local proper time $d\tau$ as recorded by an ideal clock at coordinate radius *r* and *dt* is

$$d\tau = \left(1 - \frac{2GM}{rc^2}\right)^{\frac{1}{2}} dt \tag{60}$$

It should come as no surprise that the square of Eq. (60) is the first term of the Schwarzschild metric (52), which models the empirically verified phenomenon of *radial* gravitational redshift (*RGR*) with precise accuracy.

Figure 45 – Conceptual model of geometric time for a gravitational field



19. The effect of geometric time on global timekeeping

In part due to the high speed of electromagnetic radiation (traveling about 30 *cm* in 10^{-9} *s*), the precise measurement of time and the synchronization of time at increasingly high resolution became a global technological priority in the latter part of the 20th century. For centuries, the apparent solar day, sourced from increasingly precise astronomical observations of the Earth's inertial rotation, served as the time calibration unit of reference. The development of precise mechanical clocks in the late 18th century led to the adoption of the mean solar day, whereby significant seasonal variations in the apparent solar day are averaged out. The time measurement resolution afforded by the development of atomic frequency standards made it apparent that the inherent variability in Earth's inertial rotation, which was now measurable, made the mean solar day unsuitable as the source of a stable definition of time.[110] Over a four-year period, from initial recommendation in 1956 to ratification in 1960, a transition took place whereby Ephemeris Time, based on Earth's orbital motion around the Sun was adopted as the new international time calibration reference standard. This stopgap measure was to last less than a decade. The duration of one second of time is currently defined by international convention as "the duration of 9,192,631,770 periods of the radiation corresponding to the transition between the two hyperfine levels of the ground state of the caesium 133 atom".[111] Adopted in 1967, this far more stable realization of time attempted to match as closely as was then possible the duration of one second defined previously according to Ephemeris Time.

Historical events and international politics have played a visible role in international timekeeping. The international time standard, "Coordinated Universal Time", is in the French, "Temps Universal Coordonné". So that the international agreement would not unjustly favor the French language abbreviation (TUC), nor the English (CUT), it was apparently decided that "UTC" would be the moniker of the common globally referenced time standard. On the other hand, International Atomic Time, which is the basis for UTC and which, like UTC, is officially maintained by the Bureau International de Poids et Mesures (BIPM) located in the Parc de Saint-Cloud near Paris, is abbreviated "TAI" for the French phrase "Temps Atomique International" not the ambivalent "ATI". That it is the French working at a location near Paris who are currently appointed to be the world's international timekeepers dates back to a historic event in June 1799, when two platinum standards representing the meter and the kilogram were deposited in the Archives de la République de Paris.[112] That legacy lives on with the BIPM and more specifically concerning time keeping, with the "Bureau National de Métrologie – Systèmes de Référence Temps-Espace" (BNM-SYRTE) at the Paris Observatory.

Time and frequency metrology, more simply known as "official time keeping" is intrinsically dependent on statistics and probability. Partly in jest, but also based on practice, *Segal's Law* states, "A man with one watch always knows what time it is, but a man with two is never sure." The measurement of time is based on process, and the assumption that a particular process used as a reference definition for time measurement, when repeated, will always exhibit the identical quality of what we measure as time. Experience shows that two clocks that might appear to agree on the time, never agree perfectly to some deeper level of time measurement resolution. The spinning Earth is a repeating process that made a good reference clock for many centuries and the rotation of the Earth around the Sun is another repeating process that in consideration of fewer perturbing dynamical forces made an even better clock. When atomic frequency standards were developed and a significant number of them built, there was now a new type of clock with which to measure and compare time. If ten atomic clocks, initially synchronized and syntonized, all read the identical time (to some fraction of a second) but the measurement of time according to observation of Earth's solar orbit is noticed to differ from that shared measurement at that resolution, then it is highly unlikely that the "orbital clock" of Earth moving through space reads the right time while all ten atomic clocks read the wrong identical time (to some resolution). It is far more likely the case that the natural process used by the atomic clocks intrinsically measures time more accurately and that it can therefore resolve inherent variations in the velocity of the Earth in its solar orbit that are larger than the inherent variations in the dynamical behavior of the ten corroborating atomic clocks.

Let us assume that we have a number of atomic clocks in approximately the same controlled location so that the difference in environmental effects among the clocks approaches zero. Now, to a very small part of a measured second, and some period after being initially synchronized and syntonized, the atomic clocks themselves will not all agree on the time. So, which one of the clocks, which generally all read slightly different times, reads the "correct" time? There is really no way to tell. We can best define the time scale to be the computed average of a *well-behaved* clock set and we identify the best individual clocks as those clocks that consistently show the smallest deviation in reference to this statistical "paper clock". Individual clocks can only be judged in reference to their conformity or lack thereof to a well behaved set of other clocks. By "well behaved", we mean clocks that generally conform with other clocks in the set, therefore not exhibiting undue deviation from the average behavior. Modern timing centers all use ensembles of atomic clocks and weighting algorithms that make each additional clock in the set improve the overall performance of the ensemble, which is output in the form of a paper clock. One may then carefully "steer" a real physical clock to mimic the time scale as realized by the clock ensemble so as to have a real-time electronic reference to this time scale, which will greatly exceed the performance of any individual clock.

As described earlier, it is well understood that differential acceleration, gravitational or otherwise, will cause a clock bias due to an absolute distinction in the rate of local proper time. Thus, it is known that an ideal clock at high elevation in Boulder, Colorado will record time at a somewhat faster rate than an ideal clock on the geoid (i.e., at sea level). In addition to distinctions in local gravitational measurements, the relativistic effects due to the axial rotation of the Earth must be taken into account when comparing clocks. The following text has been taken from *Agilent Application Note AN 1289*:

> For a clock fixed on Earth at distance r from Earth's center and at geocentric latitude θ, the fractional frequency shift is
>
> $$\Delta\nu/\nu = \frac{1}{c^2}\left[V(r,\theta) - \frac{1}{2}\Omega_E^2 r^2 \cos^2\theta - \left(V(a_1,0) - \frac{1}{2}\Omega_E^2 a_1^2 \cos^2\theta\right)\right]$$
>
> where $V(r,\theta)$ is the earth's gravitational potential including quadropole and perhaps multipole moment contributions, Ω_E is Earth's angular velocity and a_1 is Earth's equatorial radius. … Clocks being compared at different longitudes on Earth's surface have to include the relativistic Sagnac effect due to the rotation of the Earth. The size of the effect is given by
>
> $$\frac{2\Omega_E A_p}{c^2} = A_p \times 1.6227 \quad ns\,/\,Mm^2$$
>
> nanoseconds per megameter (Mm^2) where A_p is the total area, projected on Earth's equatorial plane, mapped out by the radius vector from the center of the Earth to the electromagnetic signal carrying the time. The correction is positive going eastward.[113]

What has not been included in conventional timekeeping theory is the idea of geometric time, which implies that the time vectors at various distinct points over a circular path of constant coordinate radius r around a typical gravitational field are almost, *but not quite* parallel to one another. Just as each differential region on the geoid is associated with a unique local vertical, each such region is also associated with a unique local time coordinate vector, *none* of which are parallel. Think of it as follows: To an observer who is unaffected by Earth's gravitational field, it is clear that an observer on the surface of the Earth may state: "My time is a *mixture* of your time and your space." This is reflected by the absolute clock rate difference between their respective clocks as quantified by Eq. (60). Two distinct observers at two different locations on the geoid may make exactly the same statement, noting the identical fractional frequency shift of their clock relative to the clock of the observer who is far away from Earth's surface. The distinction between the two observers on the geoid is that the respective "space" that is mixed in with the time in reference to the distant observer's physical space-time coordinates is not the same because the direction of the Earth's gravitational acceleration on each is not parallel.

No observer on the geoid has a "preferred" direction of local gravitational acceleration in space. The only distinction is a relative one, reflected by the angle of the great arc between them. Therefore, any relativistic effect caused by this distinction must be symmetric rather than absolute. So, while according to conventional GR, ideal clocks at rest on the geoid of the rotating Earth all beat at the same rate, this assumption does not hold when geometric time is taken into consideration. One must instead anticipate that, all other effects being accounted for, every ideal clock at rest on the geoid whose frequency is directly compared to a similar distant clock is found to be somewhat faster than the distant clock in some proportion to the physical distance between the clocks. Therefore, the luckless task of trying to synchronize a globally distributed set of atomic clocks to nanosecond resolution is like trying to herd cats; *it is impossible to accomplish. A spatially distributed clock ensemble in a gravitational field is fundamentally unstable.*

Assume that two localized atomic clock ensembles *W* (Washington, D.C.) and *P* (Paris) are independently maintained at distant locations on the globe, each of whose statistically averaged mean time scale very accurately measures time according to the definition of the SI second as realized on the geoid. However, when the two clocks are directly compared, each will perceive the other clock to be somewhat slower than the local clock. If a special "universal" clock at *P* is artificially steered to more closely match the perceived lower frequency of the distant *W* clock ensemble, then from the point of view of those maintaining *W*, the correction applied to *P* will be of the wrong polarity. The *W* team will have expected the *P* team to increase the steered frequency of their clock rather than decrease it. Many people today are trying to keep all of the world's national timing centers synchronized, but to no avail; time is a strictly local geometric property of the Universe, even on the scale of our planet's surface. Nature makes it impossible to maintain a clock on Earth that faithfully adheres to the definition of the SI second and which also synchronizes to nanosecond resolution with one or more *distant* clocks. Because an artificial global time scale (e.g., UTC) that attempts to coordinate various distant clocks incorporates intrinsically slower clocks in the statistical calculation of that time scale, this artificial time scale must record time slower than a local *ideal* reference clock.

The largest and most sophisticated timing center in the world is managed by the *Time Services Department* of the United States Naval Observatory (USNO) in Washington D.C., which works in conjunction with other remote Department of Defense (DoD) timing facilities and also the *Time and Frequency Division* of the National Institute of Standards and Technology (NIST) in Boulder, Colorado.[114,115] The USNO is the official source of time for the Department of Defense, the Global Positioning System and the standard of time for the United States. The USNO unsteered internal mean time scale designated A.1 is currently derived from an ensemble of 63 atomic clocks including 47 Agilent 5071A cesium beam clocks and 16 Symmetricom MHM 2010 hydrogen masers.[116,117,118] The USNO masers have shown drifts of less than 1 part in 10^{16} per day over a 500-day period. The USNO clocks are kept in underground environmentally controlled vaults linked by a fiber optic communications network. The clock vaults are geographically dispersed with a maximum separation of about 300 meters.

The physical realization of the USNO clock ensemble is a distinct hydrogen maser designated Master Clock 2 (MC #2) which is steered to the computed mean timescale UTC(USNO) by an auxiliary output generator designed to extend the maser's intrinsic frequency range.[119] As a matter of *policy*, and according to international *legal agreement*, the UTC(USNO) timescale is itself *steered* to be as close as possible to UTC(BIPM). Fig. (46) and (47) show graphs published in real time by the USNO concerning their clock rates.

Figure 46 – Results of the attempt to synchronize UTC(USNO) with UTC(BIPM)

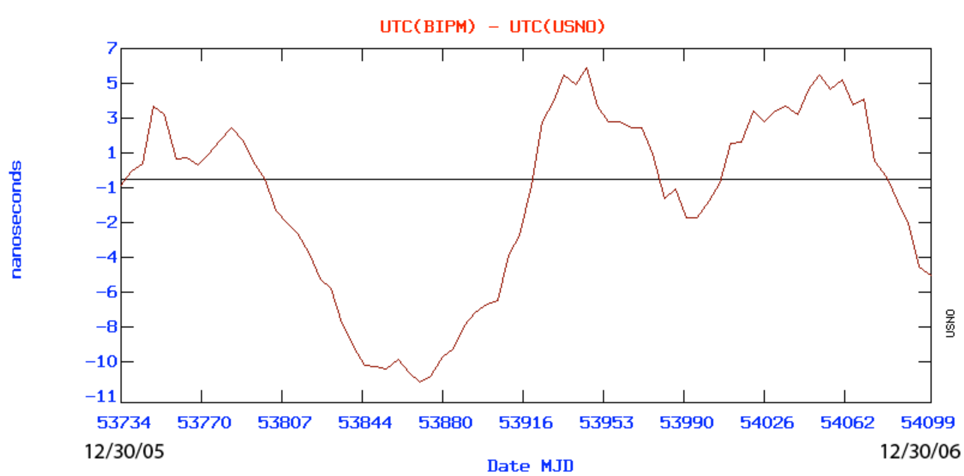
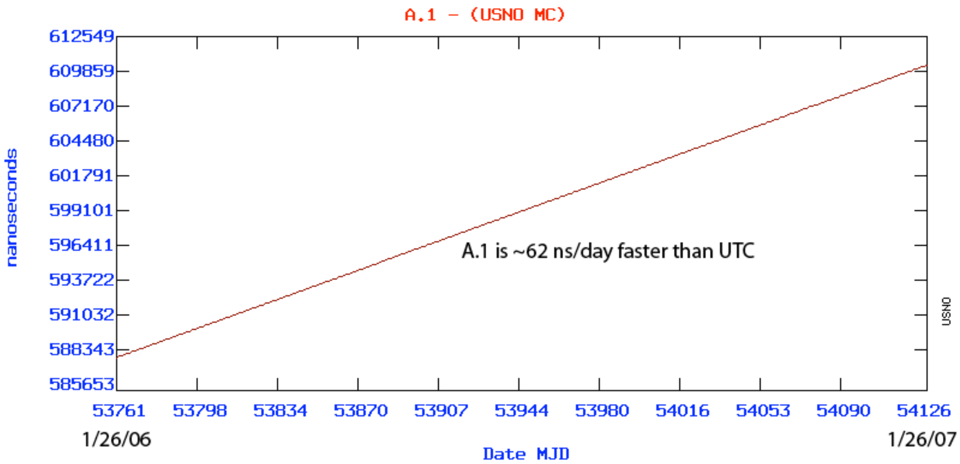


Figure 47 – The unsteered USNO clock A.1 is consistently faster than UTC(USNO, MC)



The first of the two graphs shows that the USNO time keepers do a very good job of steering the official USNO master clock to UTC(BIPM) according to international agreement; over an entire year, the two time scales deviate by no more than about 10^{-8} second. The second graph implies something quite extraordinary. Unsteered and left to record local time as precisely as possible according to the definition of the SI second, the super-accurate phalanx of USNO clocks at the observatory in Washington is quite notably faster than the clock that is steered to follow the international time as established by the French.

Table 2 – Excerpt of BIPM Circular T 228, 2007 January

CIRCULAR T 228 ISSN 1143-1393
2007 JANUARY 11, 17h UTC

BUREAU INTERNATIONAL DES POIDS ET MESURES
ORGANISATION INTERGOUVERNEMENTALE DE LA CONVENTION DU METRE
PAVILLON DE BRETEUIL F-92312 SEVRES CEDEX TEL. +33 1 45 07 70 70 FAX. +33 1 45 34 20 21 tai@bipm.org

...

2 - International Atomic Time TAI and Local atomic time scales TA(k). Computed values of [TAI-TA(k)].

Date 2006 0h UTC	NOV 30	DEC 5	DEC 10	DEC 15	DEC 20	DEC 25	DEC 30	
MJD	54069	54074	54079	54084	54089	54094	54099	
Laboratory k				[TAI-TA(k)]/ns				
CH (Bern)	53702.2	53714.1	53731.5	53739.5	53743.0	53742.5	53748.0	
F (Paris)	168335.7	168333.1	168332.8	168332.5	168331.9	168330.9	168332.1	
IT (Torino)	58489.7	58619.5	58747.5	58878.8	59009.7	59138.1	59270.8	
JATC (Lintong)	-41116.9	-41152.8	-41187.8	-41219.4	-41252.8	-41287.4	-41322.1	
KRIS (Daejeon)	14648.7	14729.9	14797.7	14869.4	14944.3	15011.2	15087.7	
NICT (Tokyo)	-0.2	0.8	-1.0	-3.1	-2.1	-2.9	-2.4	
NIST (Boulder)	-45300253.5	-45300446.7	-45300638.6	-45300830.9	-45301024.1	-45301217.5	-45301408.7	
NRC (Ottawa)	30227.6	30236.1	30243.5	30250.5	30259.9	30262.3	30280.0	
NTSC (Lintong)	3737.0	3760.5	3782.6	3808.0	3831.8	3854.6	3875.1	
ONRJ (Rio de Janeiro)	-1048.8	-1062.1	-1077.2	-1093.3	-1103.4	-1118.4	-1133.7	
PL (Warszawa)	-4002.7	-4010.2	-4022.3	-4029.1	-4039.9	-4048.3	-4054.1	
PTB (Braunschweig)	-357970.4	-357963.4	-357956.8	-357948.5	-357944.3	-357940.5	-357935.8	
SU (Moskva)	27242961.2	27242984.7	27243007.2	27243033.3	27243054.9	27243079.9	27243104.7	(1)
TL (Chung-Li)	535.9	540.4	541.0	543.5	546.5	547.2	552.0	
USNO (Washington DC)	-34988561.0	-34988869.3	-34989173.1	-34989477.6	-34989781.4	-34990087.8	-34990392.0	

- Note on section 2:

(1) SU : Listed values are TAI-TA(SU) - 2.80 seconds

On the principle that a larger clock ensemble will statistically outperform a smaller clock ensemble, and also in keeping with the historic international spirit of global time keeping, the BIPM calculates TAI from the reading of more than two-hundred atomic clocks located in metrology institutes and observatories in more than thirty countries around the world.[120] TAI is made available every month in a publication called the *BIPM Circular T*. In determining the global time scale, the BIPM is mandated to insure that this time scale rigorously subscribes to the definition of the SI second. In concert with this requirement, French teams from BNM-SYRTE have built what are considered to be among the very best and most robust atomic frequency standards in the world,[121] equaling or surpassing the U.S. NIST-F1 laser-cooled cesium fountain atomic clock,[122] which has a frequency uncertainty on the order of 10^{-15}. Table (2) is an excerpt from *Circular T 228* for January 2007 showing *Section 2*, which tabulates the distinction between TAI and the readings of local atomic time scales TA(k).[123] In consideration of the accuracy of modern atomic frequency standards such as the Agilent 5071A and its HP predecessor, which make up the majority of the over two hundred clocks in the BIPM global set, one might expect this list to reflect a more "well behaved" clock set.

Dr. Judah Levine of NIST's *Time and Frequency Division* discusses how we currently make our super-accurate atomic clocks conform to our less than accurate 20th century model of time, which does not take into account the geometric nature of time (emphasis added):

> Stimulated by the acquisition of five hydrogen masers over the last decade and the development of a more accurate primary frequency standard, NIST-F1, we investigated other steering algorithms. Using old clock data, we found that improved time-offset performance could be achieved by increasing the number of steers to two each month and by modifying the objectives of the steering. *The philosophy for steering was changed from an emphasis on frequency stability only to one in which frequency stability could be degraded slightly to achieve smaller time offsets.*[124]

So, we find that we have to constantly adjust our clocks in order to subscribe to *legal convention*. The frequency stability of modern atomic clocks we have built is quite clearly too good for that international convention and the understanding of time and gravitational physics upon which that convention was based. Degrading the inherent frequency stability of an atomic clock is a lot like degrading the resolution of *pi* to 22/7; you can do it, but you had better know that you are not dealing with reality when you reference that number or the time on that clock.

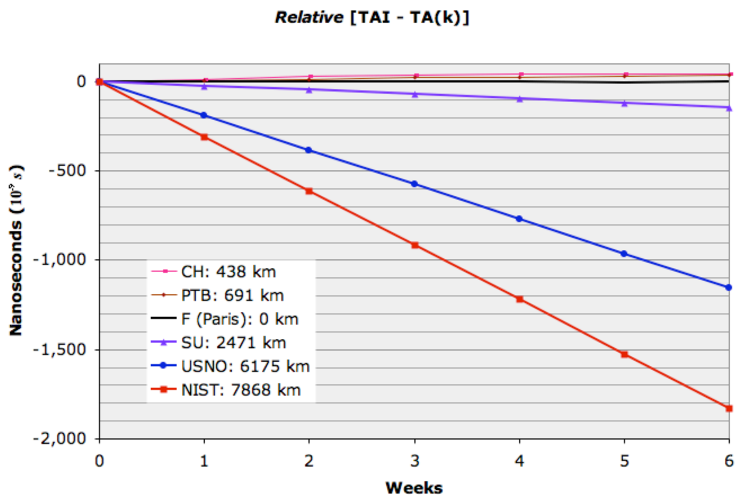
The effect of geometric time on global timekeeping was first observed and discussed in the literature in an article entitled "The Effect of Mass on Frequency" [*Science* **161**, 567 (1968)] by scientists at the U.S. Naval Research Laboratory. However, the observations of a frequency drop associated with distance between points on the globe was inconsistent with general relativity, peers were apparently disparaging of the work, and further inquiry was abandoned. This and other incidents like it suggest that science is sometimes like a religion, where an established belief system overrules empirical evidence to the contrary of that belief system. What sets science apart is that its belief systems are based on testable hypotheses that can be reproduced, once a superior belief system (i.e., theory) presents itself that explains anomalous empirical observations.

> In the second experiment, the frequency of a portable cesium clock was compared with the frequency of a similar clock that transmits its signals from Cape Fear, North Carolina. A decrease of frequency of the received signals as a function of the distance between the two clocks was apparent.[125]

Any subscriber to *Science* or any university student may conveniently download this article for review. Given the many time dissemination radio stations (e.g., WWVB, USA and MSF60, UK) around the world and vast improvements and cost reductions in timekeeping technology, this experiment may be easily repeated today by numerous independent teams at minimal cost and with off-the-shelf technology. A major difference between now and forty years ago for this experiment, other than the tremendous improvement in related technologies, is the expected results of the clock comparisons and the qualitative understanding of them, based on this book.

The BIPM *Circular T* clearly reveals that relative to the European TAI reference clocks in Switzerland (CH), Germany (PTB) and France (F), the more distant clocks in Moscow (SU), Washington, D.C. (USNO) and Colorado (NIST) appear to run slower in proportion to their distance from Europe. The BIPM has no clock of its own; so it is clear that the SI second is established by a statistical average of reliable nearby clocks in Paris, Bern and Braunschweig. The three remote clocks shown in the graph from Russia and the United States have been selected from other clocks appearing in the *Circular T* for the fact that their time scales are linked to strategic navigation capability (GLONASS and GPS). To a significantly greater degree than the others, this precludes these time scales from subjective manipulation by national time metrology management teams who can be expected to have strong motivations to show conformance of the local national time scale to the collective global standard established by the leaders in the field.

Figure 48 – Relative rates of the most precise clocks on Earth, Western Europe perspective



Calculating *geometric time* for a particular location on the planet Earth involves the complex motions of the time vector in spacetime that requires software modeling. It is only by using this method that global timekeeping can be advanced to new levels of accuracy in the 21st century so that the BIPM *Circular T* does not look a mess. In 1898, Henri Poincaré posed the question of whether a second today is equal to a second tomorrow.[126] Due in particular to the motion of the Earth around the Sun, the answer is "no". In addition to including the static effect of altitude and the dynamic effect of Earth's diurnal rotation, the annual rotation of the Earth around the Sun cannot be ignored. At Earth perigee, the local Solar System escape velocity time angle is

$$\zeta_p = 1.417 \times 10^{-4}\ rad \qquad 61$$

Six months later at Earth apogee, this angle reduces to

$$\zeta_a = 1.394 \times 10^{-4}\ rad \qquad 62$$

Over a period of one day, the Earth rotates nearly one degree around the Sun, which causes a relative change in the direction of all time vectors on Earth that must be accounted for. The geoid escape velocity time angle on the surface of the Earth's is

$$\zeta_g = 1.180 \times 10^{-6}\ rad \qquad 63$$

One may think of the local time vector for a typical timing center on the Earth having an inclination of about 1.4×10^{-4} *rad* and rotating over a complete circle once per year relative to a galactic reference time coordinate. In addition, this vector is inclined about 1.2×10^{-6} *rad* relative to the *local* solar reference time coordinate and makes a 2π revolution once per sidereal day.

20. An unmodeled gravitational phenomenon

Referring back to Fig. (7), just as photons dissipate energy (i.e., redshift) in translating over a cosmological path in which the direction of time is changing in spacetime, any translation of energy (mass or radiation) in the direction transverse to a local gravitational gradient must similarly involve energy dissipation. This occurs because time is constantly changing direction in spacetime over such a path. Among other observables, this phenomenon will result in the secular decay of orbits, which may be counteracted by stellar tidal dissipation in some cases, creating an oscillation in the orbital period. Empirical evidence supporting this idea is found in precision ephemeris measurements of eclipsing binary star systems. The observations reveal oscillations of the mean orbital radius driven by a heretofore-inexplicable energy loss mechanism in dynamical gravitational systems.

> The careful timing of [binary star] eclipses can reveal orbital period changes of order a part in 10^5–10^6 because deviations from an assumed ephemeris can build up over many orbits, and many systems have observational records spanning decades or more. These observational records reveal a surprising result: systems that show period changes of alternating sign (orbital period modulations) are common.[127]

The readily observable behavior of these systems due to their rapid time evolution is identical to that implied by far more subtle observations of Solar System planets due to their very slow time evolution. The phenomenon can be expected to drive dominant large-amplitude cycles in planetary climate change with a period of many millions of years.

Careful observation of natural and artificial satellites in the Solar System reveals a ubiquitous anomalous phenomenon. Orbits decay relative to the dominant gravitational field, which may be the host planet or the Sun. In the case of terrestrial geodetic satellites, it is clear that chaotic dynamical behavior with apparent seasonal variations manifests due to the combined effects of both fields. In the context of conventional orbital mechanics, conservation of energy implies that what is observed is "impossible", so in the past, these empirical observations were either considered suspect, conveniently ignored, explained by inventing a possible cause based on known physics, or left to open speculation. The following is from an article by a respected team in the September 2004 issue of the esteemed, peer-reviewed *Astronomical Journal.*

> We show that the peculiar eccentricity distribution of the Hilda asteroids, objects that librate at the 3:2 mean motion resonance with Jupiter, as well as their distribution about the resonance itself, can be nicely reproduced from captured field asteroids if Jupiter has migrated sunward by about 0.45 AU over a time greater than 100,000 years. The latter is a lower limit and longer times are more likely, while the former quantity depends to some degree on the initial eccentricity distribution, but a fit to the observations fails unless it lies in the range of 0.4 to about 0.5 AU, where the lower value is particularly well established.[128]

Three papers in the 26 May 2005 issue of *Nature* by an international team argue that a number of independent observations imply planetary migration.[129,130,131] Specifically, distinct empirical evidence in addition to the Hilda asteroids indicates that Jupiter is indeed now orbiting the Sun considerably faster relative to Saturn's orbital speed than it did in the past.

> …H. F. Levison and colleagues contend that the orbits of Jupiter, Saturn, Uranus and Neptune have been disturbed in a small but significant way. They argue that the giant planets' eccentricities (the deviation of their orbits from a true circle) and inclinations (the tilt of their orbital planes) are much larger than those predicted by theories of planet formation — which implies that some process has disturbed the orbits of the giant planets since the time of their formation.
>
> …the authors show that the passage of Jupiter and Saturn through a 1:2 mean-motion resonance (MMR) can account for the orbital spacings, eccentricities and inclinations of all four giant planets. … The authors' find that the passage of Jupiter and Saturn through

this resonance can excite their eccentricities and inclinations to current levels. However, Jupiter and Saturn are currently rather far from the 1:2 resonance — the ratio of their current orbital periods is near 1:2.5 — so the implication here is that these planets have since migrated through 2:1 to their present positions. This is a remarkable concept, because we usually think of the planets' orbits as being rather static and changing little over time.

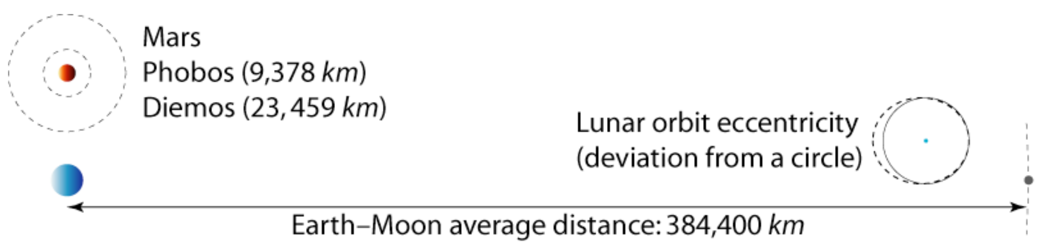
Another interesting finding is described in the second paper, which shows that this planet migration scheme can also account for the existence of Jupiter's Trojan asteroids. …

The third paper shows that the 1:2 MMR can also be implicated in the Late Heavy Bombardment, which was a brief but intense series of impacts known to have occurred early in the Moon's history. In the authors' models, Neptune's orbit is destabilized when Jupiter and Saturn pass through the 1:2 MMR.[132]

Enterprising attempts to explain the migration of the Jovian planets in the context of ancient conventional processes are not incisive and fail to integrate the phenomenon with related empirical observations.[133,134,135]

Judging by their size, shape and composition, Phobos and Deimos, which orbit Mars, are perhaps best categorized as captured carbonaceous asteroids rather than moons. Phobos has an average diameter of only 11.2 *km* while that of Deimos is just 6.1 *km*. Phobos has a mass of only ~10^{16} *kg* (some 7 orders of magnitude less than the Moon) while that of Deimos is smaller still by about a factor of four. With a mean orbital radius of 9,378 *km*, Phobos orbits about 6,000 *km* above the surface of Mars inclined about 1 degree to the Martian equator. Diemos is well over three times farther out from the surface of Mars, having a mean orbital radius of 23,459 *km*. Both orbits are nearly perfectly circular with respective eccentricities of $e = 0.0151$ and $e = 0.0005$.[136]

Figure 49 – Orbits of Phobos and Deimos to scale compared to Earth–Moon System



With a sidereal orbital period of just 7.66 hours as compared to Mars' sidereal rotation period of 24.62 hours, Phobos zooms over the Martian landscape as compared to the Moon's leisurely orbit. The orbital radius of Phobos is observed to *decrease* on the order of 4 centimeters per year, corresponding to a secular increase in its orbital angular velocity as it loses energy and spirals down toward the surface of Mars.[137,138,139] Contrariwise, Deimos exhibits a very small annual decrease in its orbital angular velocity corresponding to a non-Keplerian retardation in longitude of ~7 $mas\ yr^{-2}$ (~7×10^{-3} $arcsec/yr^2$) in contrast to an advance of ~5,328 $mas\ yr^{-2}$ for Phobos.[140] The observed opposite anomalous behavior defies conventional explanation. These satellites are far too small to consider tidal dissipation as the cause of their secular accelerations, although this has been the currently accepted explanation for prior lack of another. The idea of atmospheric drag on Phobos at its altitude is out of the question. Regardless, one must explain why Phobos is descending, while Deimos is ascending in the context of energy conservation. The major distinction between these two satellites is that Mars has a dominant quantitative gravitational effect on Phobos, while the Sun has a dominant quantitative gravitational effect on Deimos.

The mass of Jupiter at ~1.9×10^{27} *kg* is some 318 times greater than Earth. Jupiter's radius at ~142,984 *km* is over eleven times that of the Earth, yet its rotation period is just 9.9 hours, implying a much faster equatorial tangential velocity than that of Earth. Io is the innermost of the four Galilean moons of Jupiter with a mass of ~8.9×10^{22} *kg*, and an orbital radius of less than six

Jovian radii. For comparison, Earth's Moon with a similar mass of ~7.3×10^{22} *kg* has a mean orbital radius of ~384,000 *km* or more than sixty Earth radii. Moreover, Io's orbit with an inclination of 0.04º and eccentricity $e = 0.004$ is almost perfectly aligned with the Jovian equator, while Earth's Moon has an eccentric ($e = 0.0549$) orbit that is closely aligned with the Ecliptic such that its inclination to the terrestrial equator varies between 18.28º and 28.58º.[141] As a serendipitous and convenient reference model, the typical size of a basketball and a tennis ball over their respective small range of official size (having ~24 *cm* and ~6.5 *cm* diameters) may perfectly represent the relative spherical sizes of the Earth and the Moon. At this scale, the distance between the center of the Earth and the Moon over the eccentric lunar orbit varies between about 6.8 and 7.6 meters. In contrast, if we use the size of a basketball to represent Jupiter, then Io is the size of a pea (6 *mm* in diameter) and the pea has a nearly perfectly circular equatorial orbit around the basketball about 59 *cm* from the surface of the ball.

If there is a perfect candidate in the Solar System to demonstrate tidal dissipation it is the Jovian moon Io. According to prevailing wisdom, Io should be seen to be quite rapidly receding from Jupiter. Theoretical astrophysicist Dr. Yanquin Wu, in a recent scholarly treatment of tidal dissipation theory as it has been understood for over a century introduces the analysis thus:

> As Jupiter spins faster than the orbital motion of its nearest satellite (Io), Io raises a time dependent tide on Jupiter. The dissipation of this tide in Jupiter transfers angular momentum to Io and spins down Jupiter.[142]

Yet, in 1928, based primarily on analysis of eclipses of the Galilean satellites by Jupiter, Willem de Sitter, then director of the Observatory at Leiden, first published the baffling result that Io was not observed to be receding from Jupiter as expected. On the contrary, it was apparently spiraling in *toward* Jupiter such that it exhibited a secular *decrease* in its total energy and orbital period consistent with the observed anomalous advance in longitude.[143]

The mean motion n of an astronomical body in an elliptical orbit is equal to the average angular frequency, which is inversely proportional to the orbital period T. When n has a subscript, it denotes the satellite number, starting with the innermost satellite (e.g., 1 denotes Io).

$$n \equiv \frac{2\pi}{T} \tag{64}$$

The observation published by de Sitter was

$$\frac{\dot{n}_1}{n_1} = 3.3 \pm 0.5 \times 10^{-10} yr^{-1} \quad \left[\dot{n}_1 \equiv \frac{dn_1}{dt} \right] \tag{65}$$

The complete abstract from a 1995 paper by Goldstein and Jacobs follows:

> From reanalysis of 17^{th} century and 20^{th} century eclipse observations, with three different models for the Earth's rotation, and from the use of both longitude comparison and mean motion comparison, we find that Io has a fractional acceleration of $(4.54\pm0.95)\times10^{-10}$ yr^{-1}. If Io can be considered a Keplerian oscillator, its orbital semi-major axis *decreases* by 13 *cm/yr*.[144]

An excerpt from the abstract of a 2001 paper by Aksnes and Franklin follows:

> Our determination of [see far left side of Eq. (65)] is in reasonable agreement with the values 3.3±0.5 (from de Sitter, published in 1928) and 4.54±0.95 (from Goldstein & Jacobs, published in 1995), both of which were derived from analyses of eclipses of the satellites by Jupiter and some photographic observations. However, it conflicts with the value -0.074±0.087 found by Lieske (published in 1987) from Jovian eclipse timings. Our results imply that Io is now spiraling slowly inward, losing more orbital energy from internal dissipation than it gains from Jupiter's tidal torque.[145]

Dr. Jay Lieske of the California Institute of Technology's Jet Propulsion Laboratory (JPL) in Pasadena is the author of *Galilean satellite ephemerides E5* (1997) which was used in support of the Galileo mission to Jupiter.[146,147] The behavior of Io observed and reported earlier by Goldstein, de Sitter and others is essentially "impossible" according to understood physical principles and associated mathematical models. By definition, excellence in *engineering* does not involve guesswork or ambiguous anomalies. Dr. Lieske's responsibilities at JPL precluded inclusion of anything but well-understood physical processes in E5. Exhibiting professional scientific conduct for his position, Lieske has been properly skeptical of Io's reported behavior that contradicts the E5 ephemerides. Even so, he collaborated in a 1999 paper that conceded the following in its abstract.

> This paper derives astrometric data for the Galilean satellites from 213 light curves of 86 mutual eclipses and occultations that occurred in 1990–1992. Comparisons of these data with predictions based on the most precise modern ephemeris (E5) generally show good agreement, although it is rather poorer in the case of J1 (Io).[148]

At face value, the observed *contraction* of Io's orbit as it spirals slowly *inward* towards the surface of Jupiter is inconsistent with the theory of tidal dissipation. Due to the gravitational interaction between Io and Jupiter, some kind of tidal bulge just as described by Yanquin Wu must result and Jupiter's rapid axial spin rate should give this tidal bulge a significant lead on Io. Jupiter's powerful self-gravitation can be expected to quickly smooth the bulge, but even so, tidal dissipation must cause a significant tangential torque on Io tending to *increase* its semimajor axis. The observed recalcitrant behavior of Io is indicative of a *counteracting* phenomenon that is powerful enough to overcome the effect of tidal dissipation for the Jupiter-Io interaction.

Additional independent empirical evidence is required to help resolve the discrepancy between Lieske's tentative report of conventional behavior for Io and the three corroborating reports of unconventional behavior. This already exists. — It is well known that the Io (n_1) Europa (n_2) and Ganymede (n_3) exhibit a Laplace Resonance whereby

$$n_1 - 3n_2 + 2n_3 = 0.0000° day^{-1} \qquad 66$$

For the observed configuration of a stable point of conjunction to evolve, it is certainly the case that a differential migration of these satellites from their random primordial configuration was required; however, no satisfactory theory exists that describes how this evolution came about while avoiding higher order resonances.[149,150]

> On the assumption that the resonance was formed by the action of tidal forces, we describe what the evolution of the system must have been like before and after the formation of the resonance. However, no satisfactory explanation of the capture into the resonance is found. It seems possible that the system could have been captured into a large amplitude libration, but it is then difficult to explain the present very small amplitude.[151]

The implication of the Galilean satellite's orbital resonance is that secular inbound migrations of Io, Europa and Ganymede at differential rates were required. It is clearly the case that such migrations allow for an initial capture into resonance of two bodies followed by a second capture of the third body. The clearly indicated inbound migration of the Galilean satellites relative to Jupiter is identical to that implied for the Jovian planets relative to the Sun and correlates with the observed secular decrease in the semimajor axis of Phobos. It is clear from observations that orbits decay in the direction of the dominant gravitational field and that the conventional post-Newtonian model of gravitation does not model this behavior. If the Jovian planets have migrated towards the Sun, then both Earth and Mars have been influenced by the same phenomenon. However, it can be expected that Earth exists in a special oscillation region where the effect of solar tidal dissipation counteracts the orbit decay phenomenon. The resulting oscillations in the orbital periods of these two planets must drive regular oscillations of planetary climate change.

> With surprising and mysterious regularity, life on Earth has flourished and vanished in cycles of mass extinction every 62 million years, say two UC Berkeley scientists who discovered the pattern after a painstaking computer study of fossil records going back for more than 500 million years…
>
> "We've tried everything we can think of to find an explanation for these weird cycles of biodiversity and extinction," Muller said, "and so far, we've failed." …
>
> But the cycles are so clear that the evidence "simply jumps out of the data," said James Kirchner, a professor of earth and planetary sciences on the Berkeley campus who was not involved in the research but who has written a commentary on the report that is also appearing in *Nature* today. …
>
> Said Muller: "We're getting frustrated and we need help. All I can say is that we're confident the cycles exist, and I cannot come up with any possible explanation that won't turn out to be fascinating. There's something going on in the fossil record, and we just don't know what it is."[152]

As of 1 January 1998, the International Celestial Reference System (ICRS) based on the observed locations of distant quasars, which exhibit no proper motion, replaced the Fifth Fundamental Catalogue (FK5) which had briefly superseded FK4.[153,154] Required corrections in right ascension imply that the Earth is increasingly father along in its orbit around the Sun than it should be according to previous measurements and the assumption of a constant orbital period. What has ironically been called the "fictitious motion of the equinox", implying disbelief in what is definitively observed due to its discord with conventional wisdom, is consistent with a small but indirectly measurable secular decrease in the Earth's mean orbital radius with a corresponding increase in its mean orbital angular velocity.

With the advent of new technologies and techniques in the latter half of the 20th century, space astrometry has attained unprecedented precision. A definite, heretofore inexplicable secular trend in the mean longitudes of planets is observed;[155] for Earth, this trend currently manifests as a heretofore-inexplicable measurable drift in the location of the equinox.[156,157]

> From an analysis of the FK4 proper motions Fricke (1967, 1977) found that all proper motions in right ascension require the correction
>
> $$\Delta \mathrm{e} = \Delta\mu_\alpha = +1.''23 \pm 0.''16 \text{ (m.e.) per century}$$
>
> in addition to the precessional corrections which have been adopted in the IAU (1976) value of general precession. The quantity Δe indicates that the FK4 right ascensions αFK4 are decreasing with time, while they should remain constant if reckoned from the dynamical equinox (true vernal equinox).[158]

The observed drift in the location of the Equinox suggests that the Earth is completing its orbit slightly faster each year and thus very slowly migrating towards the Sun in the current epoch. It seems unlikely that this slow migration has been influential concerning the current trend in global warming as compared to greenhouse gas emissions arising from human industrial activity.

21. The secular acceleration of the Moon

The Moon cannot be classified as a satellite of Earth in the same way as other moons in the Solar System. It is gravitationally bound to the Sun with a force about double that with which it is bound to the Earth, so in effect, the Earth-Moon system is a co-orbiting double-planet system. Prior to the advent of atomic time scales, contributions by various investigators established the secular acceleration of the Moon to have a "dynamical" component of +7.14"/cy^2 attributed to well-understood Newtonian gravitational effects of the Sun and planets and an anomalous component of -11.22"/cy^2 that was ascribed to tidal friction.[159,160,161,162] Modern measurement of lunar orbital parameters using atomic clocks and lunar laser ranging (LLR) yield a significantly larger "tidal acceleration of the lunar longitude: Gamma = -25.858±0.003 "/cy^2."[163] LLR data accumulated since 1969 indicate a current recession rate of the Moon from Earth of 3.8 *cm*/*yr* corresponding to the observed secular deceleration in the Moon's orbital motion.[164]

It is clearly the case that the Moon raises a tidal bulge on the Earth when it is overhead, both in the oceans and in the solid earth. One can then argue that the Earth's axial rotation underneath the Moon, in conjunction with the friction between particles that make up this bulge, cause the bulge to lead the Moon in its orbit by a few degrees. The resulting tangential component of the gravitational acceleration may then cause a torque that tangentially accelerates the Moon. This acceleration will then boost the Moon farther away from the Earth, thus increasing its orbital period, causing a secular *deceleration* of the Moon's orbital velocity around the Earth. The energy equation must balance, so the secular addition of gravitational potential energy to the Moon caused by this phenomenon must be reflected by an equal and opposite secular loss of energy for the Earth, which must manifest in a dissipation of frictional energy, primarily in the oceans, and complementary spin-down of the globe.

The current recession rate held constant, over 4.5 billion years corresponds to 170,000 *km*, or about 45% of the current mean lunar orbital radius. However, if we ascribe the magnitude of the currently observed lunar recession entirely to a tidal interaction between the Earth and the Moon, then a combination of a more rapidly rotating Earth and a smaller separation distance between the two bodies in the past has obvious consequences. The recession rate will have been much greater in previous epochs, putting the Moon very close to the Earth in the past, which for a number of reasons, including the *TGR* effect itself, is an implausible initial configuration. It is obvious that something other than tidal dissipation is the major contributor to the observed lunar recession rate in the current epoch. *The same phenomenon that is causing Deimos to slowly recede from Mars is causing the Moon to recede from Earth and it is definitely not tidal dissipation.*

> The results and methods of determining the secular acceleration of the Moon's orbital motions and the Earth's rotation from astronomical observations are critically reviewed. … General relationships are deduced between these accelerations, the rate of dissipation of energy in the Earth and the fractional change in the rate of rotation of the Earth. It is shown that the theory of tidal torques alone does not completely account for any of the wide range of results for the retardation of the Earth deduced from astronomical observations.[165]

One may quite easily calculate the annual energy requirement to boost the Moon in its orbit by 3.8 *cm* and thus the average power purported to be continuously transferred from the Earth to the Moon through tidal dissipation.

$$E = F \cdot d = \frac{GM_M M_E}{R_{EM}^2} \cdot 0.038 \approx 7.54 \times 10^{18}\, J \qquad 67$$

$$P = \frac{E}{T} = \frac{7.54 \times 10^{18}\, J\ yr^{-1}}{3.16 \times 10^{7}\, s\ yr^{-1}} = 2.39 \times 10^{11}\, J/s \approx 0.24\ Terawatt \qquad 68$$

The kinetic energy of a rotating body is defined as

$$K_\omega = \frac{1}{2} I \omega^2 \qquad 69$$

According NASA's Earth Fact Sheet,[166] the Earth's moment of inertia is approximately

$$I = 0.3308\left(5.9736 \times 10^{24}\, kg\right)\left(6.371 \times 10^{6}\, m\right)^2 = 8.0208 \times 10^{37}\ kg\ m^2 \qquad 70$$

Given a current epoch sidereal rotation period of ~23.9345 hrs (23 hrs 56 m 4.1 s) the angular velocity of the Earth in radians/sec (extending the significant digits to false accuracy) is then

$$\omega_0 = \frac{2\pi}{86{,}164.1\ s} = 7.2921150539 \times 10^{-5}\ s^{-1} \qquad 71$$

From astronomical records dating back several millennia, the long-term increase in the mean length-of-day has been established to be about $2.3\times10^{-3} s\ cy^{-1}$.[167] Then, averaged over an epoch, in one year's time, the angular velocity of the Earth will decrease relative to this initial value to

$$\omega_1 = \frac{2\pi}{86{,}164.1 + 2.3\times10^{-5}\ s} = 7.2921150520 \times 10^{-5}\ s^{-1} \qquad 72$$

Thus, the kinetic energy *lost* by the Earth each year due to spin-down in the current epoch when averaged over several millennia is about

$$\Delta K_\omega = \frac{1}{2} I\left(\omega_0^2 - \omega_1^2\right) = 1.22 \times 10^{20} J\ yr^{-1} \qquad 73$$

The power dissipation this represents is

$$P = \frac{E}{T} = \frac{1.22\times10^{20} J\ yr^{-1}}{3.156\times10^{7} s\ yr^{-1}} = 3.9\times10^{12} J/s = 3.9\ Terawatts \qquad 74$$

This is about eight milliwatts per square meter of the Earth's geoid. It is also over sixteen times more energy than that purported to be transferred to the Moon by tidal dissipation. In what form is this rotational kinetic energy being dissipated? It is certainly not by any kind of mechanical friction. This non-trivial question demands an answer and yet defies conventional explanation. As concerns the observed orbital decay of Phobos and Io, we must ask the same question. How is the total energy of these moons being slowly dissipated? It is also certainly not by any kind of friction. Given the secular decrease in the semimajor axis of these moons, where is their dissipated energy going? We can be virtually certain that the phenomenon that causes unmodeled orbital decay also causes unmodeled secular spin-down. This is not an inconsequential issue. It is perhaps among *the most important scientific questions of our time* and it has been ignored for lack of any prior approach to a rational answer using conventional 20th-century physics.

What is implied by the above discussion is that the observed recession rate of the Moon from the Earth in the current epoch involves a kind of an illusion. Although it is naïvely correct, the interpretation of the observed effect as a secular increase in the Moon's energy relative to the Earth is in fact the differential dynamic energy relationship of both bodies relative to the Sun rather than to each other. Rather than the Earth boosting the Moon's orbit, what is actually happening is that the Earth and the Moon are both losing energy relative to the Sun at different rates. The Moon orbits the Earth very near to the plane of the Ecliptic at a mean distance of about 385,000 *km*. When the Moon is closer to the Sun, it will lose energy and fall towards the Sun a little faster than the Earth and when the Earth is closer to the Sun than the Moon, it will lose energy and fall towards the Sun a little faster than the Moon. This results in a secular increase in the distance between the two bodies, observed as a small annual increase in the Moon's terrestrial orbital radius. Therefore, when we accurately measure the very surprising fact that the Moon is apparently increasing its orbital radius by about four centimeters per year, what we are actually measuring is the *differential decay* of two solar orbits. In the case of the Martian moon Phobos, whose orbital radius is less than 3% of the Moon's orbital radius, we not surprisingly calculate that the planet Mars has a far stronger gravitational pull on Phobos that does the Sun. So, contrary to our Moon's outbound migration, Phobos falls in towards Mars.

It is evident that the total observed effect of the secular acceleration of the Moon, which corresponds to an increase in the Moon's energy relative to the Earth, is a reflection of both tidal dissipation and a differential energy loss between the two bodies relative to the Sun. These two distinct effects have opposite behavior as concerns the time evolution of their respective magnitudes; the differential *TGR* energy loss will have been less in the past, when the Moon's mean orbital radius was less and perhaps more inclined to the Ecliptic, while the effects of tidal dissipation will have been greater. Conversely, with the progress of time, the differential energy loss due to *TGR* will have dominated and tidal dissipation will have been systematically reduced as a component of the observed anomalous acceleration. This being the case, the evolution of the Moon's orbit makes sense over four billion years because we can expect the rate of its recession from Earth to have been generally increasing over time in the past rather than decreasing; the greater the orbital radius in the Ecliptic, the greater the differential energy loss that effectively boosts the Moon's orbit. We can expect, for the distance range involved, that the acceleration component due to tidal dissipation has been consistently a rather smaller component of the two complementary effects. The differential decay of the terrestrial and lunar orbits relative to the Sun also explains the lunar orbit's eccentricity and its skew to the Equator. LLR measurements may be able to confirm that it exhibits time evolution in accord with the differential decay hypothesis.

The idea that the secular acceleration of the Moon is caused by tidal dissipation is inexorably linked to the secular spin-down of the Earth. The observation that this spin-down is inexplicably rapid so that the energy budget is far from being balanced is concerning, for conservation of energy is among the most fundamental of physical laws. One is perhaps inclined to disbelieve the estimated rate of terrestrial spin-down rather than considering the possibility of an unidentified exotic energy dissipation method effecting spin-down. However, the terrestrial secular spin-down rate is well established by historical eclipse events and independent observation of unexplained excess spin-down rate corroborates the terrestrial anomaly. A spinning body is a self-gravitating system whereby its own mass is constantly moving transverse to its own gravitational gradient. If this transverse motion causes an energy dissipation leading to the secular decay of orbits, it must also cause energy dissipation leading to secular spin-down.

> Pulsars associated with supernova remnants (SNRs) are valuable because they provide constraints on the mechanism(s) of pulsar spin-down. Here we discuss two SNR/pulsar associations in which the SNR age is much greater than the age of the pulsar obtained by assuming pure magnetic dipole radiation (MDR) spin-down. The PSR B1757-24/SNR G5.4-1.2 association has a minimum age of ~40 kyr from proper motion upper limits, yet the MDR timing age of the pulsar is only 16 kyr, and the newly discovered pulsar PSR J1846-0258 in the >2 kyr old SNR Kes 75 has an MDR timing age of just 0.7 kyr. These and other pulsar/SNR age discrepancies imply that the pulsar spin-down torque is not due to pure MDR, and we discuss a model for the spin-down of the pulsars similar to the ones recently proposed to explain the spin-down of soft gamma-ray repeaters and anomalous x-ray pulsars.[168]

22. Understanding the orbital dynamics of geodetic satellites

LAGEOS-1 (Laser GEOdynamics Satellite) is a 407 *kg*, 60 *cm* diameter passive spherical satellite that was launched on 4 May 1976 into a circular ($e = 0.0045$) high inclination orbit ($i = 109.8°$) with perigee altitude of 5860 *km*. The obtuse angle of inclination implies a retrograde motion at an angle of (180-109.8) = 70.2° in relation to the Earth's equatorial plane. A beautiful example of balancing competing requirements in the systems engineering process, the satellite was designed by the National Aeronautics and Space Administration (NASA) with a mass high enough to minimize the effects of non-gravitational forces yet low enough to achieve its orbital trajectory using the Delta 2913 launch vehicle. Also, it is large enough to support its many reflectors, yet not so large as to incur undue effects of solar pressure. It is covered with 426 3.8 *cm* diameter cube-corner laser retroreflectors. A cylindrical beryllium copper core (often mistakenly identified in the literature as brass) and aluminum spherical shell were chosen specifically to reduce the effects of the Earth's magnetic field on the satellite's orbit. There is no instrumentation or stabilization mechanism on board; The LAGEOS is very much like a tiny "silver moon".[169,170]

The satellite is designed to reflect precisely timed laser pulses from ground stations for the purpose of determining the relative location of the satellite and the ground station. With an accurately modeled and measured trajectory at a high altitude specifically intended so that its motion would be affected exclusively by gravity, the satellite was intended to provide a stable reference frame uniquely suited to geodesy and particularly the study of crustal dynamics.

Prior to launch, the intended LAGEOS-1 orbit was precisely modeled according to all of the known laws of physics and the environmental conditions understood to exist at its considerable orbital altitude. That altitude, of almost 6,000 *km*, was specifically chosen with the idea that no atmospheric drag whatsoever would act on the satellite. However, after launch, LAGEOS-1 exhibited nothing less than completely inexplicable anomalous behavior. It was losing on average about one centimeter of altitude per week, a rate *at least* an order of magnitude greater than attributable to any known physical phenomena anticipated to act on the satellite.[171,172] Moreover, the anomalous apparent acceleration on the satellite exhibited peculiar variations over time with an obvious repetitive but incomprehensible pattern. Hundreds of papers have been written about the perplexing unmodeled behavior of the LAGEOS satellites over the past three decades suggesting many theories, with the majority of the unmodeled drag being ascribed to Yarkovsky-Schach thermal drag (photon thrust due to anisotropic thermal emission). Yet, it is generally accepted that no proposed explanation has been satisfying, let alone definitive.[173]

> LAGEOS' orbit is the most accurately modeled of any satellite [*Cohen* and *Smith*, 1985]. However, after subtracting out most of the known forces acting on the satellite, such as the gravitational attraction of the sun and the moon, direct solar radiation pressure, etc. there is still a residual along-track acceleration which remains to be explained…
>
> The residual is given as a function of time in Figure 1. Figure 1 shows the average monthly values of *S*, the unexplained along-track acceleration. It clearly acts like a drag and has a mean value of -3.33×10^{-12} m s^{-2}. It brings LAGEOS closer to the earth by 1.2 mm d^{-1}. Moreover, there are fluctuations in the acceleration which can be as large as the mean value. At times, *S* drops almost to zero, as in March 1983. Most of the fluctuations are obviously correlated with the sun-orbit geometry: the largest ones occur when LAGEOS spends time in the earth's shadow.[174]
>
> ——
>
> The semimajor axis of Lageos's orbit exhibits a secular decrease upon which periodic variations are superimposed. This secular decrease cannot be explained by gravitational effects, radiation pressure, the Poynting-Robertson effect, and various electromagnetic effects. On the other hand, charge drag appears to be a possible cause. However, the problem is not definitely settled.[175]

In part to try to understand the peculiar unmodeled behavior of LAGEOS-1, the Italian Space Agency (ISA) built a second satellite, LAGEOS-2, which is almost an identical twin to the original. It was launched on 22 October 1992 by shuttle mission STS 52 and put into a substantially less inclined ($i = 52.6°$) slightly more eccentric ($e = 0.0135$) and lower-altitude orbit, with perigee altitude 5,620 *km*.[176] As the second satellite exhibits a marked difference in time evolution of the unmodeled acceleration from the first, this indicates that the orbit inclination is a significant factor in the manifestation of the effect.[177] In 1989, the former Soviet Union launched Etalon 1 and 2, two larger (1.3 *m* dia., 1415 *kg*) spherical geodetic satellites with perigee altitude 19,129 *km* placed in identical orbits ($i \approx 65°$, $e \approx 0.0006$) ~121° out of phase with one another.[178] France's Centre National d'Etudes Spatiales (CNES) launched the first geodetic satellite, Starlette, in February 1975 followed by Stella in September 1993. These smaller geodetic satellites are 24 *cm* in diameter, having 60 cube-corner reflectors and weighing less than 50 *kg*. They are in circular orbits at about 800 *km* altitude with the former at an inclination of 49.83° and the latter at 98.6°.[179] The Japanese Ajisai satellite, weighing 685 *kg*, was launched into a 1,500 *km* orbit at 50° inclination in August 1986.[180]

In its circular orbit, a geodetic satellite represents mass-energy in constant rapid motion transverse to the terrestrial gravitational field. In order to understand the peculiar seasonal variability of the observed anomalous acceleration on the LAGEOS satellites, one must also consider the motion of the satellite relative to the gravitational gradient of the Sun. The transverse component of its velocity vector relative to the solar gravitational gradient is not constant. While the motion of an artificial Earth satellite in a circular orbit is consistently transverse to the terrestrial gravitational gradient, the rotation of the Earth around the Sun will cause a time-varying geometric relationship between the velocity vector of the satellite and the local direction of the Sun's gravitational gradient. In addition, the well-understood Newtonian precession of the orbit in inertial space due to the oblate shape of the spinning Earth combined with the gravitational effects of the Sun and the Moon will affect the periodicity of this relationship.

Referring to the orbital elements of an artificial Earth satellite such as LAGEOS, the right ascension of the ascending node is the angle between the intersection of the orbit with the terrestrial equatorial plane and the true vernal equinox (the zero longitude reference meridian of the celestial sphere). This coordinate for LAGEOS-1 at orbit insertion was $\Omega = 28.56^{\circ}$. David Rubincam of the NASA Goddard Space Flight Center Laboratory for Terrestrial Physics reports this precession to be $d\Omega/dt = 0.3425^{\circ}\ d^{-1}$, implying an orbital plane rotation relative to the fixed stars of 2π radians in 150 weeks or about 35 months.[181] Therefore, in the time that the Earth has revolved around the Sun 180º in six months, the satellite orbit plane has precessed about 63º about the Earth's axis. Note that as the satellite's orbit precesses around the Earth's spin axis, its geometrical orientation relative to the Ecliptic plane and therefore the solar gravitational gradient changes over time. The orientation of the orbit plane relative to the solar gravitational gradient will depend on the fixed inclination of the satellite relative to the terrestrial equator, the dynamic right ascension of the satellite orbit and the Earth's dynamic heliocentric ecliptic longitude.

Fig. (50) shows why the dynamic orientation of the satellite angular momentum vector to the solar gravitational gradient is significant. In the temporary condition that the two are parallel (A) the satellite's trajectory will be consistently transverse to the solar gravitational gradient. This configuration can only occur for satellites between 66.55º and 113.45º inclination. When it does, it results in maximum loss of *total* energy for the satellite with respect to both the Earth and the Sun. More generally, the two vectors will intersect at an acute angle. Fig. (50-B) shows two particular cases when the two vectors are orthogonal. Note that in these and similar cases, the satellite must coincidentally spend time in Earth's shadow for some portion of its orbit and that this condition will generally be more significant for satellites with lower inclination orbits than those with higher inclination orbits.

Figure 50 – Variability of orbit plane relative to the solar gravitational gradient

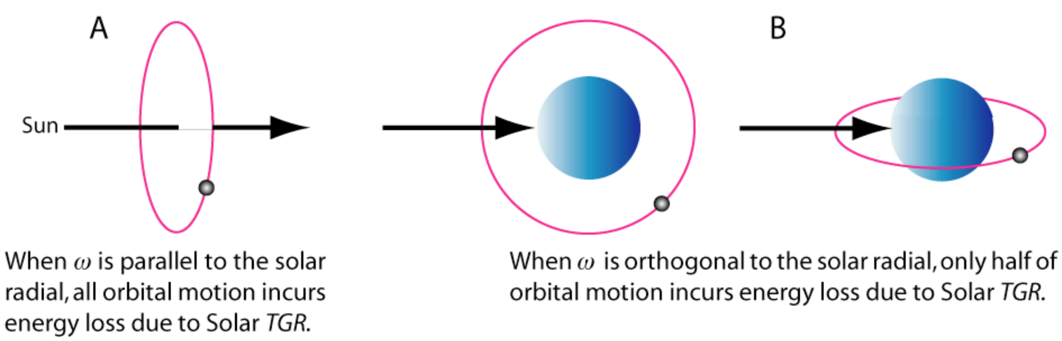
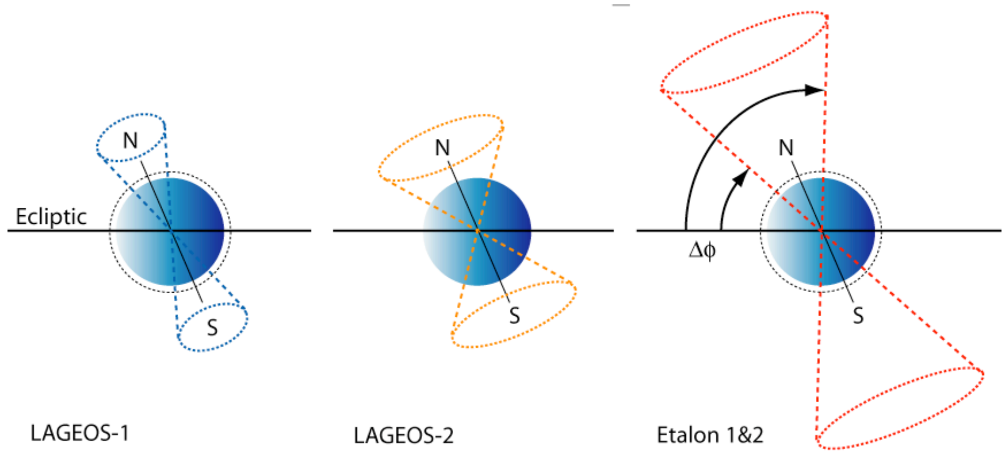


Fig. (51) illustrates satellite precession. Their respective orbital inclinations and their altitudes relative to the radius of the Earth are shown. The Etalons have identical inclinations but are out of phase by about 1/3rd of the precession circle. The precessing plane of the satellite orbit, which results in a dynamic range of inclination to the Ecliptic (ϕ) demonstrated only in the third diagram for clarity, is tangent to the slant-height of the opposing cones in the diagrams. The orbit altitudes represented by the dashed straight lines are drawn to scale relative to the Earth. The dashed black circles represent the orbits of Starlet and Stella for altitude comparison only.

Figure 51 – Precession of the LAGEOS and Etalon satellite orbits



The LAGEOS and other geodetic satellites are falling towards Earth for exactly the same reason that Phobos is falling towards Mars and Io is falling towards Jupiter. Variations in the observed anomalous acceleration can be correlated to the relationship between the angular momentum vector of the satellites and the solar gravitational gradient, which is affected both by the orbit of the Earth and by the precession of the satellite around the Earth's spin axis. If the observed variations in anomalous acceleration were strongly correlated to the satellite spending time in the Earth's shadow, then one would expect the observed variations to peak just prior to reemergence into sunlight. However, the observed variations tend to peak midway through the shadowed periods, corresponding to a maximum angle between the satellite angular momentum vector and the solar gravitational gradient vector. The observed distinct behavior of the respective Etalon satellites cannot be correlated to inclination, because they have identical inclination. However, because they are out of phase by about 121º, the geometry of their orbits relative to the solar gravitational gradient is markedly different, hence the Sun's effect on each is distinct.

> Satellite Laser Ranging (SLR) data to retroreflector-carrying satellites allow the derivation of the details of their orbital evolution and behavioral characteristics. The semi-major axis monitors the effect of non-conservative forces, and the eccentricity is particularly affected by solar radiation pressure… The major difference between the evolution of the LAGEOS satellites' orbits is caused by the difference in inclinations between LAGEOS I and LAGEOS II. There is no such contrast in the orbits of ETALON I and II and the observed dissimilarity in their response to direct solar radiation pressure must be caused by satellite area, mass or reflectivity differences.[182]

Yet, the ETALON satellites were specifically designed to be virtually *identical*, so this last speculation is specious. —Because the French Stella satellite orbits at high inclination close to the poles and at a relatively low altitude of 800 km with an orbital period of 101 minutes, the unmodeled dynamical effects can be expected to be even more marked than for the other satellites due to the stronger gravitational field and greater orbital velocity.

> In this paper we present the two years long analysis of SLR data from the seven available geodetic satellites (Lageos I–II, Stella, Starlette, Ajisai, Etalon I–II) to recover monthly estimates of low degree geopotential coefficients; the results are obtained analysing the satellites separately and in proper combination… Huge residual seasonal signals in the orbit of Stella indicate a strong model deficiency related to the Sun's influence on the environment.[183]

23. Gravity Probe B

Within a year of Einstein's 1915 publication of his gravitation theory, Dutch mathematician and astronomer Willem de Sitter added a new empirical prediction to the few that exist for the theory based exclusively on mathematical analysis of the Einstein field equations; this is a small precession of the Moon's spin vector amounting to about two arc-seconds per century.[184,185] This "geodetic effect" is a theoretical general phenomenon applicable to any gyroscope moving through a curved spacetime for which the spin vector is not perpendicular to the orbital plane. The axial rotation of the Moon effectively makes it an immense orbiting gyroscope subject to this effect. The dynamical analysis of the Moon's spin vector is quite complex as it is tilted ~6.7º from the lunar orbital plane and the lunar orbit is both eccentric ($e = 0.0549$) and inclined ~5.1º to the Ecliptic. Also, the orbit and spin vector are perturbed by Earth's ocean and solid earth tides in a dynamic that is complicated due to Earth's axial tilt of ~23.5º.[186] Furthermore, the Moon has a gravitational tie to the Sun about twice as strong as that to the Earth, whose orbit around the Sun is also eccentric ($e = 0.0167$). In attempting to observe an effect as small as the predicted de Sitter precession, it is difficult to distinguish between this effect and other dynamical gravitational effects. In 2002, analyzing lunar laser-ranging data, Williams *et. al.* claimed to have confirmed the de Sitter precession of the Moon with an accuracy of ~0.35%, besting a previous claim of a measurement of the effect with error bars of ±2%.[187,188]

In 1918, Austrian physicists Joseph Lense and Hans Thirring contributed yet another and far more subtle effect to the body of empirical tests of general relativity.[189] The Lense-Thirring Effect also known as "gravitomagnetism" or "inertial frame dragging" involves a coupling between spin and orbital angular momentum. In October 2004, this effect was reported to be 99% of the predicted value with a ±10% uncertainty by laser ranging measurements of the LAGEOS-1 and LAGEOS-2 satellites.[190]

The respective vector equations governing these two predicted relativistic effects are

$$\dot{S}_G = \Omega_G \times \mathbf{S} \qquad \Omega_G = \left(\frac{\alpha + 2\gamma}{2}\right)\nabla U \times \mathbf{v} \tag{75}$$

$$\dot{S}_{LT} = \Omega_{LT} \times \mathbf{S} \qquad \Omega_{LT} = \left(\frac{\alpha + \gamma}{4}\right)\nabla \times \mathbf{h} \tag{76}$$

In these equations, **S** is the gyroscope spin vector with the standard dot notation implying differential time rate of change, **v** is the velocity of the gyroscope, U is the scalar gravitational potential and **h** is the vector gravitational potential. If general relativity is correct, the values of the Eddington parameters γ and α are both equal to 1, but these are in effect experimentally derived parameters. Taking into account the quadrupole moment of the non-spherical (oblate) rotating Earth, somewhat more specific and complex equations are actually used to compute the predicted behavior of an orbiting gyroscope.[191]

When these two empirical effects were originally proposed, there was no hope that they might be detected by any experiment or observation; the technology to detect such small effects, let alone with good accuracy, seemed at the time not even in the realm of a remote possibility. However, in 1959, the interdisciplinary team of Leonard Schiff (theoretical physics), William Fairbank (low-temperature physics) and Robert Cannon (guidance and control systems) met informally at what was then the Stanford University Men's Swimming Pool and discussed how the problem might be solved.[192] In 1960, Schiff first published articles discussing the possibility of testing these two effects by observing the precession of an orbiting gyroscope relative to a distant star.[193,194,195] George Pugh at the Pentagon had proposed the same idea just a few months prior in a classified document that only became public in 2003.[196] While Schiff and Pugh in their time could at least conceive of a possible means of conducting a meaningful experiment to test the predicted phenomena, still the ability to actually do so was in the far distant future. This is an indication of the great technical difficulty of what they proposed.

Based on the original ideas proposed by Schiff, and over four decades in the making with over \$700 million USD spent on a collaborative effort between Stanford University, NASA and Lockheed Martin Corporation, Gravity Probe B (GP-B) was successfully launched into a nearly circular polar orbit of approximately 650 *km* altitude on 20 April 2004. On board the GP-B spacecraft are the most precise instruments ever crafted by mankind in the form of four precision gyroscopes made of 3.8 *cm* diameter fused quartz spheres. These gyroscopes and their integrated spacecraft support system were designed to yield an angular displacement measurement precision of better than 0.5 milliarcseconds (1.4×10^{-7} degrees) per year. The satellite is intended to measure the predicted 6,614.4 *mas* annual precession (~18 *mas* per day) of its gyroscopes due to the geodetic effect to a precision of 0.01% or better and the predicted 40.9 *mas* annual gyroscopic precession due to inertial frame-dragging to a precision of 1% or better. These predictions are based on more comprehensive and detailed calculations adapted from the fundamental but overly simplified forms of Eqs. (75) and (76). The former test is the most precise empirical verification of an effect predicted by general relativity ever conducted.[197,198] Different teams separately acquired and guarded the experimental data and the calibration data, which are combined to yield meaningful analysis. Initial "successful" experimental results were announced in April 2007. See the Wikipedia GP-B article for a succinct but comprehensive discussion of the experiment.[199]

After four decades of work and nearly a billion dollars spent, there is huge pressure on the team to announce the mission a success, however the original anticipated goals could not possibly have been achieved as they were based on a patently incorrect theoretical foundation. In short, Einstein was wrong and GP-B will likely prove not particularly useful. This and similar upheavals due to emergent reality in physics are likely to elicit a political response similar to the well-known historical reaction of *academia* to Copernicus' new ideas. It is not possible for Gravity Probe B to have measured the geodetic and frame-dragging effects as originally anticipated because of the unanticipated error in general relativity formerly discussed. The predictions of the experiment are essentially derived from the Schwarzschild metric (52), which does not account for the transverse relativistic dilation that must occur according to first principles. Unlike the LAGEOS and other geodetic satellites, GP-B incorporated microthrusters to "fly the spacecraft in drag-free mode". The GP-B satellite will have been subject to the same unmodeled perturbing effect as observed for all geodetic satellites. There is good reason to treat initially announced GP-B measurements and their interpretation with skepticism, which we shall find is also true for other missions…

24. Observations of anomalous redshift associated with near occultation

The previous sections have discussed numerous distinct corroborating empirical observations concerning energy loss of material bodies due to orbital motion in a gravitational field. The relativistic expansion of space tangent to the gravitational gradient implies that energy dissipation must also occur for electromagnetic radiation propagating transverse to the gravitational gradient. There are also numerous distinct corroborating empirical observations of this phenomenon.

The following historical claims warrant reevaluation and the evidence presented in this section must be weighed together with the considerable body of additional evidence presented in this and additional sections. These historical claims of a transverse gravitational redshift were met with trepidation in their time, which is understandable given the context of no realistic theoretical description of the observations and the implication that Einstein's revered theory was somehow lacking. The same 1968 article in *Science* that discussed "The Effect of Mass on Frequency" also reported the following observation:

> The 21-centimeter absorption line from the direction of Taurus *A* was used for detection of a shift in frequency when the source passed near Sun. A possible decrease in frequency of 150 cycles per second was detected, which cannot be caused by general relativity or by the plasma around Sun. …

> In conclusion, a possible decrease in frequency of the 21-cm line was observed, with an indicated dependence of $1/r^2$. This decrease could be of great significance, as it indicates a red shift for waves passing near a mass, but a higher degree of statistical confirmation is needed.[200]

Peers with a stake in the status quo regarded this observation as being less than accurate and significant, rather than indicative of a possible insufficiency in their understanding of relativistic gravitational phenomena.[201] In the early 1970s, there were additional corroborating observational claims of a transverse gravitational redshift phenomenon.

In, May 1974 Chastel and Heyvaerts of the Observatoire de Paris reported the following in *Nature* in reference to an unexplained anomalous observation of a redshift of Pioneer-6 telemetry discussed five years earlier in *Science*.[202]

> ATTENTION has been drawn recently to unexplained perturbations in the telemetry signal of Pioneer 6 (2,300 MHz) during solar occultation. The results shown in Fig. 1 present the following odd features:
>
> (1) An anomalous redshift is added to a normal linear redshift due to the spacecraft oscillator. This residual redshift which is symmetrical with respect to the centre of the Sun is on the order of $z = 5.18^{-8}$ at four solar radii.
>
> (2) The bandwidth increases sharply when the telemetry signal grazes the Sun.
>
> (3) There are some extremely sharp pulses in the bandwidth. In Fig. 2 we show that these pulses are clearly associated with a sharp increase of the redshift…
>
> The existence of the redshift is particularly puzzling because it cannot be attributed to gravitational effects nor to the usual Doppler effect.[203]

Following are excerpts from a related 1974 paper by Merat *et al*. of the Laboratoire de Physique Théorique at Institut Henri Poincaré and Institut d'Astrophysique de Paris.

> An analysis of Goldstein's observations shows an anomalous redshift of the central frequency of the 2292 MHz band emitted by Pioneer-6 during its occultation by the sun. This shift, symmetrical with respect to the sun's center, does not correspond to any presently known physical effect. …
>
> In recent years an increasing number of observations (e.g. Arp, 1971; Pecker et al., 1972; Burbidge, 1973; de Vaucouleurs, 1972; Jaakkola, 1971; Tifft, 1972 and 1973; and others) suggest the existence of a new source of redshift distinct from Doppler-shift and the gravitational shift predicted by Einstein. To observe it, it is tempting to utilize the occultation of distant sources by the sun. Indeed, (neglecting, as we shall see, a small relativistic correction) associated shifts depend theoretically only upon the difference of gravitational potential between the source and the observer and upon their relative motion and can be computed accurately. Any supplemental shift (if definitely established) can thus be considered as evidence for a new effect.[204]

Why were these and other empirical indications of an error in gravitational theory essentially ignored? Historically, significant investment in a particular paradigm by succeeding generations of academics has caused a resistance to change, even in the face of convincing empirical evidence supported by rational theory. The Copernican revolution was primarily fought between Galileo and academic peers invested in Aristotelian cosmology. Galileo's famous letter to the Grand Duchess Christina of Tuscany, written in 1615, reveals that Church authorities were a political weapon successfully used by resentful *academics*.[205] Children routinely and spontaneously point out that Africa and South America "fit together", yet when Alfred Wegener proposed the theory of continental drift in 1912, it took the academic world over half a century to accept the new idea.[206] In an exposition written in a 2002 paper describing observed anomalies in the telemetry of the Pioneer-10 and 11 spacecraft, the Pioneer Navigation Team admonished potential critics:

> Procedures have been developed which attempt to excise corrupted data on the basis of objective criteria. There is always a temptation to eliminate data that is not well explained by existing models, to thereby "improve" the agreement between theory and experiment. Such an approach may, of course, eliminate the very data that would indicate deficiencies in the *a priori* model. This would preclude the discovery of improved models.[207]

Relativistic dilation tangent to the gravitational gradient implies that an electromagnetic signal must exhibit a loss of energy, thus a drop in frequency (redshift) over a transverse path through a gravitational field. This effect will be most prominent just prior to occultation of the source. Additionally, electromagnetic signals propagating transverse to the gravitational gradient must incur a time delay. This time delay we rationally attribute to a length increase in the transverse signal path reflected by the metric (77) rather than a change in the speed of light near a gravitating body. The latter explanation is a historical interpretation of this known and measured signal time delay phenomenon, but one that runs counter to the Equivalence Principle; the speed of light in any freely falling reference frame is always measured to be the same or the entire theory of relativity loses its foundation. In the following textbook formula, **R** and **x** are vectors from the observer to the point of radiation emission and the perturbing gravitating mass.

$$c\Delta t = \frac{2GM}{rc^2}\ln\left(1-\mathbf{R}\cdot\mathbf{x}\right) \qquad 77$$

The Shapiro Delay is named after Irwin I. Shapiro who put forward this fourth test of general relativity in 1964 while working at Lincoln Laboratory at MIT following a 1955 PhD in physics at Harvard.[208,209] He is currently a professor in the Department of Astronomy at Harvard and Senior Scientist of the Smithsonian Institution, having authored a large multifaceted volume of work that contributed significantly to progress in astronomy and astrophysics. In the early 1960s, Shapiro was involved in radar ranging of the planets, but had little knowledge of relativity. A chance attendance of a lecture on general relativity, in which the variable speed of light interpretation was discussed, gave him the idea that the gravitational field of the Sun must cause a predictable time delay for radar signals bounced from a distant planet and returned to Earth.[210] Advances in radar technology within the decade allowed measurement of the effect with reasonable accuracy. Additional tests over the following decades have reduced experimental error. In a September 2003 article in *Nature*, a group of investigators from the Italian Space Agency reported confirming the predicted magnitude of the Shapiro Delay to high accuracy using radio signals from the Cassini spacecraft that passed close to the Sun.[211]

The NASA/JPL Galileo spacecraft was launched on 18 October 1989, destined for Jupiter, the fifth and largest of the Solar System's planets, on what was to become a 14-year mission.[212,213] The mission was a remarkable success in spite of the unfortunate deployment failure of the spacecraft's high-gain antenna.[214] In addition to radio occultation by Jupiter, similar experiments were conducted during flybys of the Galilean moons: Io, Europa, Ganymede and Calisto. In hindsight, the results of these experiments and additional earlier experiments in 1979 involving the Voyager-2 spacecraft clearly reveal the *TGR* effect.[215] However, conventional explanations were attributed to the common observed phenomenon.

Ganymede is the largest satellite in the Solar System, having a 5,262 *km* diameter, which is about 380 *km* greater than that of our innermost planet, Mercury. Therefore, its considerable gravitational mass can be expected to cause a significant *TGR* effect. In a Galileo flyby of this large moon, a transponded signal referencing an Earth-based hydrogen maser frequency standard rather than the onboard USO showed pronounced Doppler velocity residuals commensurate with the *TGR* effect: an anomalous redshift at approach and a similar blueshift at departure. The conventional interpretation appearing in the literature of so-called "mass anomalies" causing the unexpected data is not unreasonable but unlikely. Independent corroborating data from additional experiments show that this interpretation of the observed signal anomaly is incorrect.

> We present the discovery of mass anomalies on Ganymede, Jupiter's third and largest Galilean satellite. This discovery is surprising for such a large icy satellite. We used the radio Doppler data generated with the Galileo spacecraft during its second encounter with Ganymede on 6 September 1996 to model the mass anomalies. Two surface mass anomalies, one positive mass at high latitude and the other a negative mass at low latitude, can explain the data. There are no obvious geological features that can be identified with the anomalies…[216]

Able readers are encouraged to download and review the full article [*Science* **305**, 989 (2004)]. There is actually nothing new about the foregoing report of an anomaly in a Galileo radio occultation experiment, other than the fact that Anderson *et al*. creatively identified the observation as a "gravitational anomaly". Two other teams who independently observed a similar anomalous modulation of Galileo telemetry simply removed the inexplicable offending data. — "There is always a temptation to eliminate data that is not well explained by existing models…" The emphasis and underling has been added to the following excerpts.

> On December 8, 1995, the Galileo spacecraft disappeared behind Jupiter for 3.7 hours. During the 6.2 hours centered on the occultation, the spacecraft LGA [low-gain antenna] radiated a coherent signal at a frequency of 2.3 GHz derived from an ultrastable quartz oscillator (USO) on board. This signal was tracked by the 70-m diameter antenna of NASA's Deep Space Network near Madrid, Spain. …
>
> We extracted the time history of signal frequency through Fourier analysis of these data. We then obtained residual frequencies by subtracting the frequency variation that would have been observed in the absence of an atmosphere/ionosphere on Jupiter. These residual frequencies exhibit a small long-term drift, of order 10^{-4} Hz sec^{-1}, *presumably* from instability of the USO and refraction in the interplanetary plasma and Earth's ionosphere. We removed this drift through use of a simple function fitted to the frequency residuals over a baseline interval well above Jupiter's ionosphere. Separate corrections were applied at ingress and egress.[217]
>
> ——
>
> A search for an atmosphere on Europa was carried out when Galileo was occulted by Europa three times. … For a few minutes before and after the occultations, the S band (2.295 GHz, or about 13 cm wavelength) radio signal from Galileo traversed regions above Europa's surface in which one could observe the effects of refraction by an atmosphere, or more precisely, an ionosphere (a layer of ions and electrons produced in tenuous regions of the atmosphere by photoionization and magnetospheric particle impact), should one exist on Europa. …
>
> Ideally, these residuals should have a zero baseline, which is the portion of the data that is away from the influence of possible ionospheric refraction effects. In reality, because of drift in the USO, effects of the long propagation path through the interplanetary medium, and imperfect knowledge of the frequency transmitted by Galileo and the spacecraft trajectory, this baseline has not only a non-zero mean but also a slope, which over periods of ten minutes can be approximated by linear frequency drift. The bias and linear drift in the residuals were removed by fitting of a straight line to the baseline data…[218]

25. More observations of anomalous redshift associated with near occultation

Stellar occultation by the Moon has been used to identify binary stars since Antares was identified as such in 1819 by Burg of Vienna and the specific application of Fresnel diffraction to astrophysical investigation was first discussed in the literature by Major P. A. MacMahon in 1908.[219,220] Electromagnetic radiation from a point source such as a distant star that is occulted by the Moon will be observed to exhibit Fresnel diffraction with the shape of the diffraction curve being dependent on the apparent angular size of the stellar disk and the wavelength of the light being observed.[221] If a phenomenon of transverse gravitational redshift (*TGR*) occurs, photons that graze the surface of the Moon on a path to telescopes on Earth must be observed to redshift, if only by a very small amount. This implies that, just prior to occultation (immersion), photons will exhibit a heretofore-unmodeled increase in wavelength and just after emerging from lunar occultation, the initially observed unmodeled excess photon redshift will blueshift back to the intrinsic wavelength of the stellar source (the observed wavelength unperturbed by *TGR*).

Because the characteristic interference pattern caused by Fresnel diffraction is dependent on the wavelength, practical requirements imply that observations are conducted using bandpass filters at specific designated wavelengths. From red to violet, the visible spectrum or "V-band" spans wavelengths from about 7000Å down to 4000Å as frequency increases. The predicted occurrence of a redshift for photons grazing the lunar limb (the edge of the Moon's disk) can be expected to manifest as a consistent unmodeled phase shift and/or a momentary change in flux within a band. Repeated observation of the phenomenon, particularly if it is observed over a large range of frequencies, implies that it is associated with the gravitational field, rather than any other imagined explanation.

From March 1979 through January 1980, a team of investigators from MIT and the Harvard-Smithsonian Center for Astrophysics (CfA) conducted observations of lunar occultation of Hyades cluster members. Other than the Ursa Major cluster, the Hyades is the closest open cluster of stars to the Sun with a distance of about 150 light years.[222] Following are excerpts from two resulting papers in the *Astronomical Journal* concerning data that were taken at the Agassiz (Harvard), Wallace (MIT) and Mt. Hopkins (Harvard) Observatories by Deane M. Peterson *et al.*

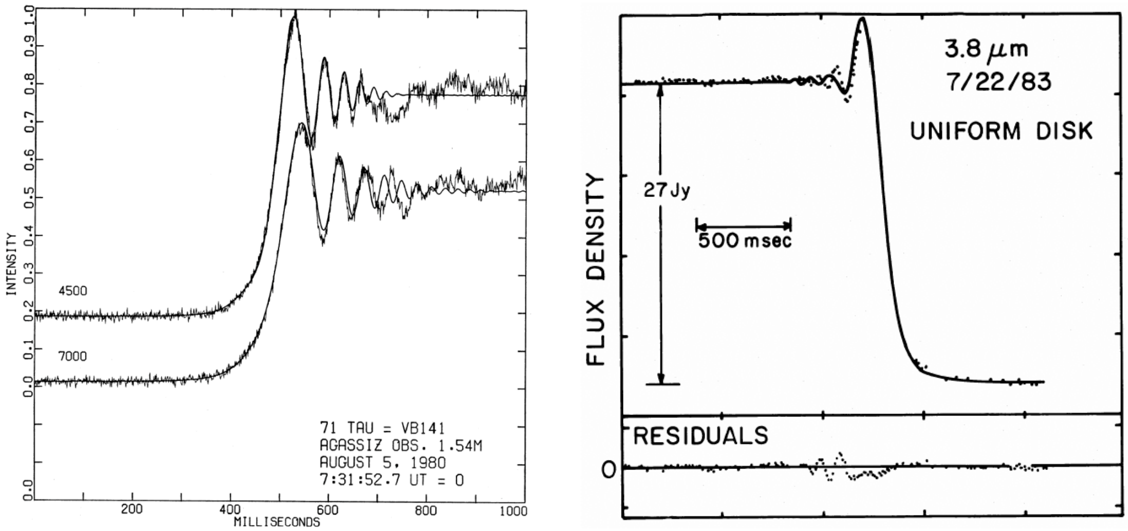
> The most frustrating aspect of these data are the bad points in the red Agassiz channel. It is this channel in particular with its potentially high signal-to-noise ratio that should have provided the definitive detection. To have three glitches at just that point in the data record was extremely unfortunate.[223]

——

> Even here, the detection is not without some complications. …there is a strong distortion in the fringe pattern some 250 ms after the geometrical reappearance of the primary. We suggest that this is due to a limb distortion, since scintillation will produce deviations from the predicted signal, such as seen later in the tracings, that are strongly correlated in different wavelengths. … A boulder 10-20 m high could cause such a distortion. Note, particularly in the red channel, that the original fringe rate is recovered 50 ms further on.[224]

Peterson's team must be complemented on the precision of their observations and their attention to detail in the analysis. Their interpretation of the observed unmodeled effect as being due to a boulder on the horizon of just the right size and in just the right location is creative, however, if the same effect is observed repeatedly and for a radically different wavelength, then the idea of "the perfect obstruction" causing the observed anomaly must be abandoned. On the left side of Fig. (52) is one of the Peterson graphs showing the observed marked deviation from modeled behavior (smooth solid line) occurring for wavelengths (filters) of 4,500 and 7,000 angstroms respectively. This records an event in which a star, initially occulted by the Moon, emerges from occultation. On the right side we have a graph of an entirely distinct lunar occultation event from a 1985 paper in the *Astrophysical Journal* by Michal Simon *et al*.[225] The unmodeled residuals from this immersion event also show a marked deviation from modeled behavior but at a wavelength ($3.8\mu m$) which is an order of magnitude greater than that observed by Peterson's group. These are just two examples among many, demonstrating that lunar occultation of stars are characterized by an unmodeled phenomenon that is consistent with a measurable change in the wavelength of radiation that is localized in the vicinity immediately adjacent to the lunar limb. It is clear that the distinct observations demonstrate the identical unmodeled anomaly; there is no possibility that the cause of the consistently observable residuals is a physical obstruction.

Figure 52 – Observed residuals in Fresnel diffractions of stellar lunar occultations



Left: Figure 1a, Deane M. Peterson *et al.*, “Lunar Occultations of the Hyades. II. August 1980”, *Astronomical Journal*, **Volume 86**, Number 7, July 1981, p. 1092. Copyright 1981, The American Astronomical Society.

Right: Figure 3a, Michal Simon *et. al.*, “Lunar Occultation Observations of M8E-IR”, *Astrophysical Journal*, **Volume 298**, pp 328-339, 1 November 1985, p. 332. Copyright 1985, The American Astronomical Society.

It is certainly remarkable to find strong evidence of just what one goes in search of in the exact place that it is anticipated to be according to theory. The proposed new interpretation of the observable may be rapidly confirmed by multiple additional lunar occultation observations that are specifically designed to investigate the predicted *TGR* effect. Given the unusual sophistication of equipment and knowledge currently in the realm of amateur astronomy, relatively low-budget experiments to observe lunar *TGR* might be designed and conducted by graduate students and amateurs worldwide. One may anticipate that such experiments will become a common part of an astrophysics curriculum in the future.

When a physical phenomenon that is unknown and unsuspected is observed, the most probable known alternative explanation will be attributed to the observation. However, once the true nature of such a phenomenon is at least suspected for observations, its unique distinguishing characteristics will become self-evident. The phenomenon of transverse gravitational redshift in the context of occultation events will be particularly large as concerns observation of eclipsing binary stars, particularly those with strong gravitational fields. An unmodeled redshift will have been unknowingly superimposed on the modeled Doppler velocity shifts in spectroscopy and interferometry studies. These effects must typically be interpreted to imply significantly different orbital parameters than is actually the case for the system. In some instances, observations may suggest the presence of a third perturbing body that does not actually exist and which has suspiciously unlikely properties.

Radio pulsars, first discovered in 1968, are weak radio sources typically measured as having a flux density between 0.1 to 5,000 *mJy* at ~400 MHz that are associated with a synchrotron radiation beaming phenomenon of rapidly rotating neutron stars.[226] A neutron star is theorized to be an ultra-dense compact (~10 *km* radius) remnant of a supernovae explosion and pulsars have been correlated with some supernovae aftermaths such as the ~30 Hz pulsar in the Crab Nebula, which resulted from a supernova in the Milky Way Galaxy documented by Chinese Sung Dynasty astronomers in 1054. Pulsars classified as “normal” have a pulse period on the order of one second but there also exists a class of so-called “millisecond pulsars” with measured pulse frequencies that may be in excess of 600 Hz; the overwhelming majority of these are found in binary systems. Over 1,300 pulsars are currently cataloged in the Milky Way and Megalanic

Clouds but in no other extragalactic objects, such as M31, the Andromeda Galaxy. Only some 3% of known pulsars are members of binary systems with a special subclass of these being eclipsing systems due to fortuitous orbital configuration of the two stars in relation to the Sun.[227]

Radio pulsars and particularly those in binary systems are ideal natural laboratories for the study of relativistic gravitational effects. Fig. (53) is a simple schematic depicting various distinct regions in the ephemeris of a binary eclipsing pulsar with the six o'clock position representing the line-of-sight to an observer on Earth. Rather than showing an accurate ephemeris relative to the barycenter (the system center of mass), the intent of this diagram is only to show the relative geometric configurations of the two stars to the observer during distinct phases in the orbit. The pulsar's relative motion is counterclockwise. Table (3) provides a description of each phase in the context of the *TGR* effect.

Figure 53 – Distinct orbital phases (relative locations) of binary eclipsing pulsar

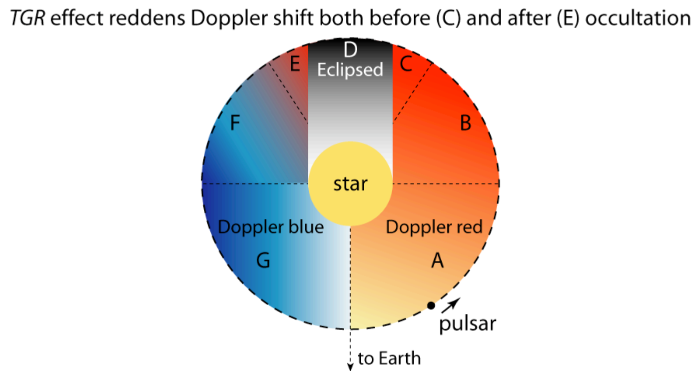


Table 3 – Description of the binary pulsar orbital phases distinguished in Fig. (53)

Phase	Pulsar Relative Doppler Shift	Superimposed *TGR* Effect	Predicted Observation
A	Zero to maximum red	Zero to possible small red	Normal Doppler redshift
B	Maximum red to small red	Zero/small red to large red	Redshift increasingly too high
C	Minimal red	Maximum red	Obvious redshift anomaly
D	No signal (eclipsed)	No signal (eclipsed)	No signal (eclipsed)
E	Minimal blue	Maximum red	Obvious redshift anomaly
F	Minimal blue to maximum blue	Large red to zero/small red	Transition from redshift to blue
G	Maximum blue to zero	Possible small red to zero	Normal Doppler blueshift

At inferior conjunction, when the pulsar is 180° out of phase with the midpoint of eclipse, no *TGR* is in effect; the intrinsic pulsar frequency is observed inclusive of applicable conventional gravitational redshift effects on the signal. As the pulsar approaches eclipse, the unmodeled *TGR* effect increasingly superimposes an anomalous redshift on the modeled behavior. The effect is non-linear with a sharp spike occurring in region C, just prior to immersion, and in region E, just after emersion. After emersion, only at some point in region F or G, when the signal path is sufficiently distant from the limb of the companion, is the pulsar signal observed to be unperturbed by *TGR*. The emphasis has been added to the following quotation.

> A remarkable pulsar with period 1.6 ms, moving in a nearly circular 9.17 hr orbit around a low-mass companion star, has been discovered. At an observing frequency of 430 MHz, the pulsar, PSR1957+20, is eclipsed once each orbit for about 50 minutes. *For a few minutes before an eclipse becomes complete, and for more than 20 minutes after the signal reappears, the pulses are delayed by as much as several hundred microseconds* – presumably as a result of propagation through plasma surrounding the companion. The pulsar's orbit about the system barycenter has a radius of 0.089 light seconds projected onto the line of sight. The observed orbital period and size, together with the fact that eclipses occur, imply a surprisingly low companion mass, only a few percent of the mass of the sun.[228]

One must consider that the immersion and emersion events are geometrically symmetrical with respect to the limb of the eclipsing star. Why is it then that there is a marked *asymmetry* in the observed frequency of the pulsar as concerns the respective observations immediately prior to immersion and immediately following emersion? Specifically, why should it be that the observed period of anomalous pulsar frequency is significantly greater *after* the eclipse as compared to before the eclipse? Is there more "plasma" on one side of the pulsar's companion star than on the other side? The likelihood of this is practically impossible. *TGR* mandates that the observed extended delay occurs exclusively *after* the eclipse because the transverse gravitational redshift dominates and masks the expected relative Doppler *blueshift*. If the observed effect were due to some kind of asymmetrical plasma wind, then the unique characteristic signature of the *TGR* effect as outlined in Table (3) would not be ubiquitous; "plasma delays" would occur at random locations in the orbits of the pulsars in binary systems. If all eclipsing binary pulsars exhibit a similar pattern to PSR1957+20, then it is certain that the *TGR* phenomenon is the cause.

Another germane feature of transverse gravitational redshift concerns the modification in the observable as the orbital period decreases. The closer the pulsar is to its companion and also the stronger the gravitational field of that companion, the greater the percentage of the orbital period in which a transverse redshift will be observed. In such a case, a rather more significant portion of regions B and F in Fig. (53) will be associated with marked observable manifestations of *TGR* and regions A and G will be associated with transitions to and from non-Doppler *TGR* signal modulation. Two distinct regions of "slow" pulses corresponding to pre-eclipse and post-eclipse *TGR* phases are indicative of a tight orbit in a strong gravitational field. Because pulsars are so exceedingly rare ($\sim 10^3$ currently observed instances among $\sim 3\times 10^{11}$ Milky Way Galaxy stars) the chances of finding two co-orbiting pulsars seems exceedingly unlikely. It is reasonable to suspect that interpretation of the apparent observation of a strangely "intermittent" 2.8-second pulsar J0737-3039B as the companion to the 23-millisecond pulsar J0737-3039A with a 2.4-hour eccentric orbit may change in light of confirmation and awareness of the *TGR* effect.[229]

26. Observed anomalous redshifts of stars

The majority of a visible star's photons come from a region that is off-center from the radial line of site to its center point. Close to the source star, the path taken by these photons will have a component transverse to the star's gravitational gradient. The transverse gravitational redshift incurred by these photons, superimposed on the radial gravitational redshift (*RGR*) modeled by Einstein, will generally manifest as an unmodeled excess redshift of starlight. The magnitude of the observed excess redshift will be associated with the gravitational field strength of the star. Therefore, larger stars and compact objects, which have higher escape velocities, can be expected to exhibit larger anomalous redshifts. For the Sun, the TGR effect will cause photons sourced near its limb to have a slightly higher redshift than those sourced from the center of its disk.

Due to their very significantly increased density and stronger gravitational field as compared to main sequence stars, this phenomenon of a radial differential in redshift must be particularly pronounced for white dwarf stars. The observed excess redshift of the point source of light will be misinterpreted as a familiar Einstein gravitational redshift; however, the relativistic mass commensurate with this interpretation of the observed redshift will imply a mass that is far too large for such a star according to astrophysical considerations.

> It is remarkable that the "relativistic" masses of the white dwarf stars, which one obtains by reduction of the observed redshifts, are (on the average, with large scatter) significantly larger than the "astrophysical" ones… Various attempts to explain this discrepancy have been made in the past, e.g., by asymmetry-induced shifts due to slope of the continuum (Schulz 1977) but this problem still is not solved (see also the review by Weidemann 1979). In velocity units the systematic excess of the observed redshift amounts to 10–15$km\ s^{-1}$ (Shipman and Sass 1980; Shipman 1986) above "residual" redshift (i.e., redshift free of all kinematic effects).[230]

In 1911, W.W. Campbell at the Lick Observatory published the observation that brighter Class B stars (larger stars such as Rigel in Orion) typically exhibited an apparent excess redshift of $K \approx +4$ *km/s*. This "K-Effect" was arguably the first historic observation of the *TGR* effect, although it was not identified as such.[231] Interpreted as a Doppler shift, the K-Effect makes the inference that larger, hotter stars have the improbable singular quality of a higher recession velocity from the Sun than smaller, cooler stars.

While being a more subtle observation than the more obvious heretofore-unexplained excess redshift for white dwarfs and massive stars, a similar anomalous radial redshift differential across the diameter of the Sun due to the transverse gravitational redshift effect should be quite readily measurable.[232,233] Measurements that are not restricted to points along the solar diameter will simply reveal a general anomalous redshift.

> A wavelength shift between the Fraunhofer spectrum observed in two quiet areas of the sun and the superimposed telluric absorption spectrum of the Schuman-Runge bands due to O_2 has been measured in the wavelength region 1950-2000 Å. The results deduced from high resolution spectra taken on board a balloon experiment at an altitude of 39 km are presented. They show a systematic redshift of the solar lines relative to the reference telluric spectrum. After correction for the gravitational redshift and for all the known relative motions between sun and observer, the average residual redshift is 7 mÅ and could be from 5 to 12 mÅ for some individual reference lines. This corresponds in terms of velocity to an equivalent Doppler-Fizeau shift on the whole spectrum of about 1 km s^{-1} away from the observer.[234]

The simple fact that the observed excess redshift of starlight is proportional to the strength of the source gravitational field (being greatest for white dwarfs, somewhat less for large massive stars and lesser still for our modest-sized Sun) implies that the effect is a gravitational phenomenon. Furthermore, it is clear that the anomaly must arise because of a modeling error in the spacetime metric.

27. Ubiquitous redshifts of galactic companions

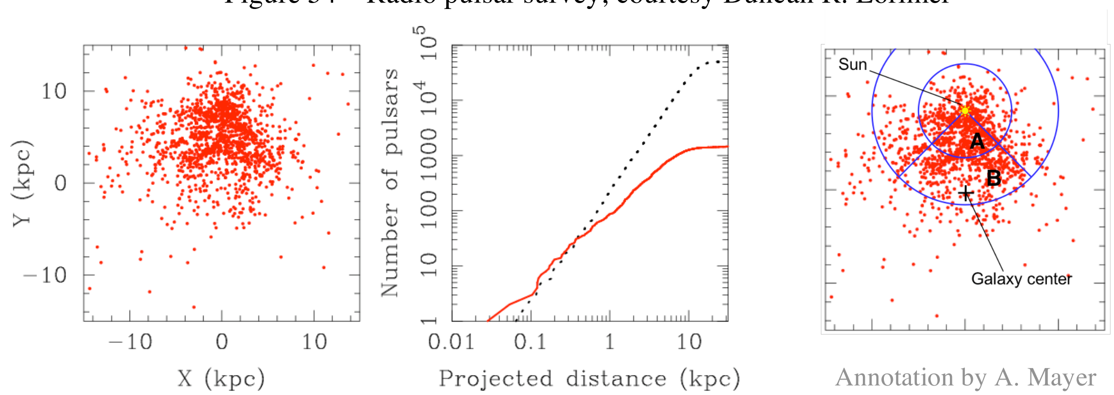
The closest galaxy to the Milky Way is M31 (Messier Catalog #31) familiarly known as Andromeda. According to its observed blueshift, M31 and the Milky Way are closing at on the order of 100 $km\, s^{-1}$. Four small satellite galaxies (M32, M33, NGC 205 and NGC 185) have been identified surrounding it. It has been a mystery why all four companion galaxies are observed to be redshifted relative to Andromeda's blueshift. As they are in random orbits around M31, at least one can be expected to exhibit a blueshift relative to Andromeda, rather than having all simultaneously moving away. While this particular observation could reasonably be attributed to an improbable coincidence, *the identical phenomenon is observed for all 22 of the major companion galaxies of the Local Group and the M81 Group*.[235] It is virtually impossible that all of these companions are all coincidentally simultaneously moving away from the Milky Way.

The observed redshifts for these companion galaxies strongly suggests the *TGR* effect; none of the companions has enough of a velocity component towards the Milky Way relative to their host galaxy to overcome the significant transverse redshift effect caused by the host galaxy's gravitational field, which masks any actual relative Doppler blueshift. Clearly, the same effect observed for these galaxies must affect all other companion objects for any observed pair or group of objects, whether or not they are in actual physical proximity or not. The light from such a background or adjacent object, which passes transverse to its "companion", will exhibit an anomalous additional redshift due to *TGR* giving the false impression that the cosmological redshift of the object is greater than it actually is. While there may be other phenomena at work in specific cases, the *TGR* effect that is apparently observed in the Local Group must also be observed in similar remote configurations.

28. The effect of galactic location on pulsar population statistics

For the same reason that galactic companions all exhibit a redshift, the observed average pulse rate of a population of pulsars that share a particular region of the Milky Way galaxy will exhibit a marked decrease as the distance to that region increases across the plane of the galactic disk. The collective mass of the galaxy results in a significant transverse gravitational redshift effect for radiation traversing it. For observers on Earth, this galactic *TGR* effect must be particularly prominent as concerns observations of pulsar population statistics as a function of distance. While individual pulsar properties vary widely, the *TGR* effect implies that a more distant population of pulsars will exhibit the *frequency-independent* effects of the relativistic time dilation that is caused by the intervening mass of the galaxy. Referencing the Fig. (54) annotation, a population of more distant pulsars (*B*) should exhibit statistically averaged slower pulse rates than a nearby population (*A*). A scatter plot relating observed pulsar pulse rates to independently determined distance estimates should reveal the *TGR* effect of the galactic disk. The relativistic time dilation reflected by the perceived pulse rates of pulsars will also be reflected in a corresponding general redshift in their broadcast spectrum. The galactic bulge will induce a large step function TGR effect, so pulsars beyond the bulge will tend to have unexpectedly different observational properties than those on the Sun's side of the bulge. Radio astronomy software designed to find the latter will almost certainly filter out most of the former. Arguably, the reason why the number of pulsars found in modern surveys at a distance greater than 10 *kpc* is noted to be at least an order of magnitude *less* than the expected distribution based on the nearby population is likely to be that selection criteria will not have previously accounted for the galactic *TGR* effect.[236]

Figure 54 – Radio pulsar survey, courtesy Duncan R. Lorimer



Left panel: The current sample of all known radio pulsars projected onto the Galactic plane. The Galactic centre is at the origin and the Sun is at (0, 8.5) kpc. Middle panel: Cumulative number of pulsars as a function of projected distance from the Sun. The solid line shows the observed sample while the dotted line shows a model population free from selection effects. Right panel: Annotation of leftmost panel by A. Mayer.

Fig. 11 of Duncan R. Lorimer, "Binary and Millisecond Pulsars at the New Millennium" , (Living Reviews in Relativity, Max-Planck-Institut für Gravitationphysik, Potsdam, 2005); http://relativity.livingreviews.org/Articles/lrr-2005-7/

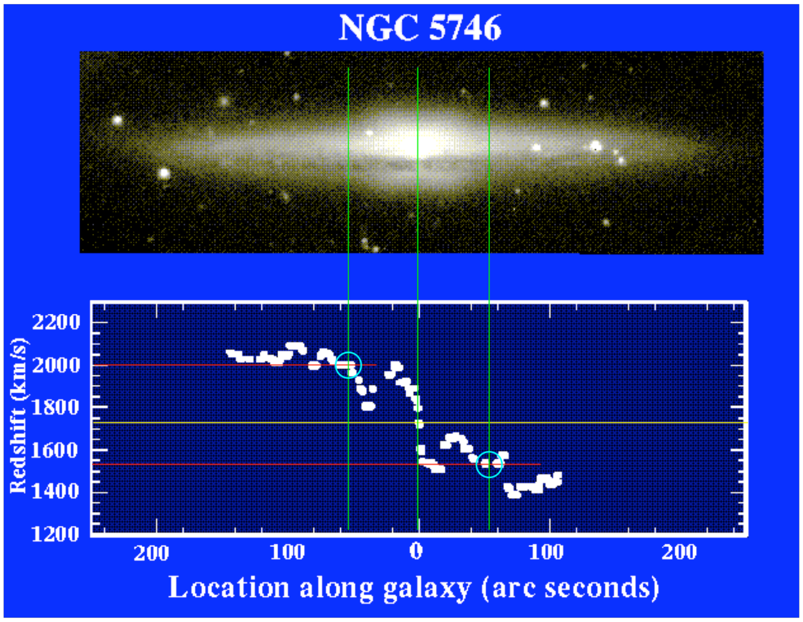
29. Asymmetry of spiral galaxy rotation curves

Vesto Slipher, who is credited with first discovering the cosmological redshift, also first discovered that the nebulae were rotating in 1915.[237] Spectroscopic analysis clearly shows that spiral galaxies rotate in the plane of their disk. Bisected through their center, half of the disk will exhibit a blueshift and the other half a redshift. One must expect an approximately symmetric self-gravitating object to exhibit highly symmetric rotation, particularly as the orbits of stars and clusters of stars in the disk are well understood to be elliptical with an aggregate circular motion. However, it is well known that these rotations curves exhibit a puzzling asymmetry and our Milky Way galaxy is no exception. Even from the perspective of our position within the disk itself, the northern observation exhibits a rough radial symmetry with the southern observation but the former is measured to be typically about 5 $km\ s^{-1}$ faster than the latter.[238] While a number of radically different theories have been put forward to account for this anomaly, none are even remotely satisfying; they simply do not explain the observation.

> Asymmetry is often observed in rotation curves of spiral galaxies. Like the rotation curve, asymmetries indicate the forces and dynamics in a galaxy. Small deviations in the rotation curves of a few $km\ s^{-1}$ are well known (Shane and Bieger-Smith 1966). Large deviations are less appreciated (Jog 2002) because the observational data are generally averaged. Hence, only highly asymmetric cases such as NGC 4321 (Knapen et al. 1993) and NGC 3031 (Rots 1975) are recognized. The rotation curves of all the nearby galaxies where the kinematics are studied have asymmetry such as NGC 0224 (Simien et al. 1978) and NGC 0598 (Colin and Athanassoula 1981). Asymmetry has also been reported in the inner parts of the optical disk (Sofue 1988). Rotation curve asymmetry appears to be the norm rather than the exception (Jog 2002). Weinberg (1995) and Jog (1997) proposed the implied mass asymmetry is due to a galaxy interaction. In this Paper, the rotation curve asymmetry from our viewpoint is related to the strength of the forces from neighboring galaxies.[239]

Due to the gravitating mass in the galaxy disk, *TGR* must cause an unmodeled increase in the redshift and a decrease in the blueshift, causing an asymmetry in the two distinct curves. Thus, *it must always be the blueshift that is observed to be asymmetrically less than the redshift*, in particular for the region adjacent to the central bulge. It is then obvious that a phenomenon that causes a general redshift is superimposed on a nearly radially symmetric relative velocity Doppler shift due to the circular rotation. None of the literature on the subject of observed rotation curve asymmetry seems to have made note of this observational detail. *TGR* implies that, with the exception of obvious external influences such as some unique external gravitational disturbance or an actual unusual internal mass asymmetry, the redshifted side will always be observed to exhibit a "Doppler shift" relative to center that on average has a greater magnitude than the shift relative to center on the blueshifted side. This is unequivocal empirical evidence for *TGR*.

Figure 55 – Spiral galaxy rotation curve asymmetry favors the redshift adjacent to the bulge



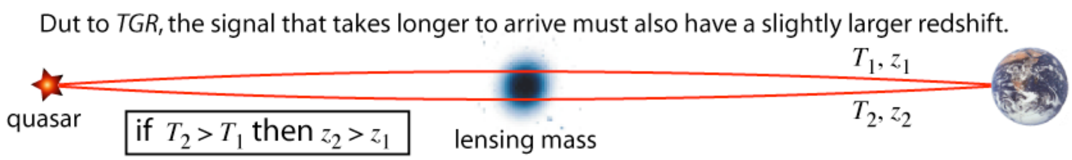
The image is a red-light CCD frame taken by William C. Keel, University of Alabama, at the 42-inch Hall telescope of Lowell Observatory. The rotation curve was measured using the GoldCam CCD spectrometer at the 84-inch telescope of Kitt Peak National Observatory. Reproduced with permission.

30. Predicted surplus redshift of delayed lensed quasar image

The double quasar *Q* 0957+561, discovered in 1979, was the first identification of gravitational lensing of a distant quasar.[240,241] A number of other examples, such as the famous quadruple-image "Einstein Cross", *Q* 2237+0305 have been identified since then.[242] The phenomenon occurs when a massive object, typically a galaxy or group of galaxies is in the line of sight to the distant quasar. Two or more images of the identical astronomical object are observed due to alternate paths taken by the light. A lensed photon, which takes a longer path from source to observer than a direct photon, will be subject to a time-delay. When multiple images of a lensed object are observed, only a relative time-delay can be observed, since the source is never visible, having been obscured by the intervening lensing object. Characteristic photometric variations in the source quasar allow for definitive matching of distinct light curves to determine which observed image took a longer time to arrive and thus pursued a longer path to the observer.[243]

Conventional wisdom would have it that a photon that descends and subsequently reemerges from a gravitational well will suffer no net energy loss. However, *TGR* implies that transverse travel through a gravitational field must cause a net loss in energy. It follows that rather than exhibiting identical spectrums, multiple images of lensed quasars that are subsequently time-synchronized according to their characteristic light curves will exhibit differential redshifts; a slightly greater redshift will be observed for light that pursues the more indirect path with a more significant gravitational interaction and thus arrives later. Unlike most of the other evidence presented, this is a prediction of the *TGR* effect rather than an existing documented observation.

Figure 56 – Independent paths of each image from a lensed quasar



31. The solution to the Pioneer mystery

The Pioneer-10 and 11 spacecraft, launched in the early 1970s, were the first space probes sent to the outer planets, each destined to follow hyperbolic escape trajectories in approximately opposite directions tangential to the galactic gravitational gradient, taking them out of the Solar System.[244] Pioneer-10's present calculated heliocentric range is over 92 AU at about 3° Ecliptic latitude.[245] (An AU or "Astronomical Unit" is equal to the mean Earth orbit radius or about 1.5×10^8 *km*.) For comparison, Pluto's present heliocentric range is about 31 AU, which varies in its eccentric orbit from about 29 AU to 50 AU. Pioneer-10 now has a nearly constant outbound velocity relative to the Sun of 12.1 km/s or about $4\times10^{-5}c$ in the direction of the star "Alpha Tau" some sixty-eight light years distant, which forms the eye of the Constellation Taurus. Pioneer-10 lived well beyond its expected lifetime and generated useful data into the late 1990s. Its last, very faint contact occurred on 23 January 2003.[246] Its extended data set for the purpose of precise measurements in celestial mechanics experiments spans 3 Jan. 1987 to 22 July 1998 over which its heliocentric ecliptic coordinates changed from ~(40 AU, 71° lon, 3° lat) to ~(70 AU, 76° lon, 3° lat). Following a radio switch failure, Pioneer-11 ceased generating useful data on 1 Oct. 1990 at a range of about 32 AU at 16° Ecliptic latitude. Its data set spans 5 Jan. 1987 to 1 Oct. 1990. Single-axis spin stabilization and their great distance from the Sun, which allowed for a minimum number of external disturbances in the form of maneuvers to reorient the spacecraft antenna towards the Earth, allowed for precision acceleration estimates from Doppler data on the order of 10^{-7} cm/s^2. This is about one part in ten billion of the acceleration experienced on the surface of the Earth; the Pioneer spacecraft were unprecedented in their sensitivity as detectors of Solar System modeling errors and remain unsurpassed in this achievement.

The Pioneer Navigation Team and their extended support infrastructure at the NASA Ames Research Center, the Jet Propulsion Laboratory (JPL), the Aerospace Corporation in Los Angeles, Astrodynamic Sciences also in L.A., Los Alamos National Laboratory in New Mexico and other facilities have had decades to devote to the data acquisition and analysis of Pioneer-10 and other spacecraft telemetry. All sources of systematic error have been exhaustively ruled out. While the phenomenon they report is apparent for both Pioneer spacecraft, focusing attention on the best and most extended data set, they report an *apparent* unmodeled constant acceleration of the Pioneer-10 spacecraft *towards* the Sun, thus in the direction *opposite* to the outbound radial velocity of the spacecraft, that cannot be explained by any known physical phenomenon.[247]

$$a_P = (8.74 \pm 1.33) \times 10^{-8} cm / s^2 \qquad 78$$

The Pioneer team, headed by Dr. John D. Anderson of JPL, allows that the experimental observable (an anomalous component of a Doppler frequency shift of a transponded signal) may have an interpretation other than acceleration on the spacecraft. They report that the average frequency drift of the signal over an 8-year period is -6×10^{-9} Hz/*s*, using the singular JPL DSN (Deep Space Network) convention of a *positive* frequency shift for a spacecraft *receding* from the tracking station. Thus, according to the Doppler data, the spacecraft appears to be receding from the Sun at a rate that is very slightly less than modeled by exceedingly precise and comprehensive calculations. The possibility of a systematic drift in referenced atomic clocks has been ruled out. The observed frequency drift is "clear, definite, and cannot be removed" within the context of known physical processes. This apparent long-term effect, which has yet to be explained let alone modeled quantitatively, is accompanied by even more intriguing phenomena.[248]

The Doppler frequency data exhibits an annual periodicity approximated by a damped sinusoid with a systematic variation on a time scale of approximately three months. The period of the sinusoid is approximately one year, and it exhibits rough symmetry in both the time and amplitude axes.[249] At conjunction, when the Sun is between the Earth and the spacecraft, the apparent anomalous acceleration of the isolated annual term is at its peak *local* positive value and initiates a decline in magnitude. Approximately six months after conjunction, when the Sun and the spacecraft are in opposition or opposite sides of the Earth, the annual effect attains its local minimum negative value. The effect then initiates a return to a new peak value at conjunction six months later and repeats the cycle, exhibiting an apparent monotonic decline in amplitude from year to year, as the range of the spacecraft steadily increases. The median value of the effect occurs about three months before and after conjunction.

This peculiar annual periodicity in the Doppler residuals is superimposed on an even more peculiar "high-frequency" sinusoidal effect with a period approximately equal to the Earth's inertial sidereal rotation period of $23^h56^m04.1^s$ relative to the fixed stars. Because the angular velocity ω is some 365 times greater for a diurnal oscillation as compared to an annual oscillation, although the associated Doppler frequency shift is smaller, the daily variation in *apparent* acceleration of the spacecraft is correspondingly greater than the annual variation. The amplitude of the diurnal effect at about 1×10^{-6} cm/s^2 is about two orders of magnitude greater than the long term effect.[250,251] So, the observed anomaly in the Doppler velocity data is essentially a "low resolution" sinusoid with an annual period of a "high resolution" sinusoid with a diurnal period superimposed on a secular linear Doppler blueshift.

Both of these observed sinusoidal effects are indeed "troubling modeling errors". Accepting the data at face value, these observed anomalies in the Doppler frequency shift of the spacecraft telemetry cannot be attributed to any known conventional forces as alleged by a number of critical skeptics.[252,253,254,255] Because they are unexplainable within the context of know physical models, Anderson *et al.* (hereafter "Anderson") assume that these observed annual and diurnal sinusoidal effects are "different manifestations of the same modeling problem", attributing them to systematic error. In summation, what Anderson reports is as follows.

There are three geographically dispersed NASA/JPL DSN locations worldwide: Goldstone, USA in Southern California; Tidbinbilla, Australia near Canberra; and Robledo, Spain near Madrid. At scheduled periods, DSN radio antennas on Earth transmitted a precisely tuned *S*-band (2.113 GHz) signal to the Pioneer spacecraft, which was coherently transponded by the spacecraft back to Earth at 2.295 GHz (a 240/221 ratio). All the known laws of 20th-century physics have been fastidiously applied to a model of how the returned coherent Doppler signal should behave. The actual measured behavior differs from the model and no known phenomenon can explain the discrepancy. As the Earth moves in its orbit away from the point of opposition and toward the point of conjunction, the telemetry suggests that the spacecraft is somehow increasing its outbound radial velocity. The peak of this effect occurs just at the point of conjunction, when the Sun is between the Earth and the spacecraft. When the Earth passes conjunction and begins moving toward the spacecraft and the point of opposition, the telemetry now suggests that the spacecraft is somehow decreasing its outbound radial velocity. Upon again reaching the point of opposition, the cycle repeats. It would appear that the spacecraft is speeding up and slowing down in a coordinated "dance" with the orbital motion of the Earth around the Sun. Because the spacecraft is so far from the Earth, there can be no gravitational interaction between the two, so this is clearly impossible. The Fig. (58) graph shows that over a period of about seven years in which it has traveled, the precisely measured velocity of the Pioneer-10 spacecraft is inexplicably about 20 *cm*/*s* slower than the velocity conventional physics says it should have based on the forces acting on it and the spacetime metric employed.

Table 4 – Pioneer-10 ephemeris December 1992 to December 1994

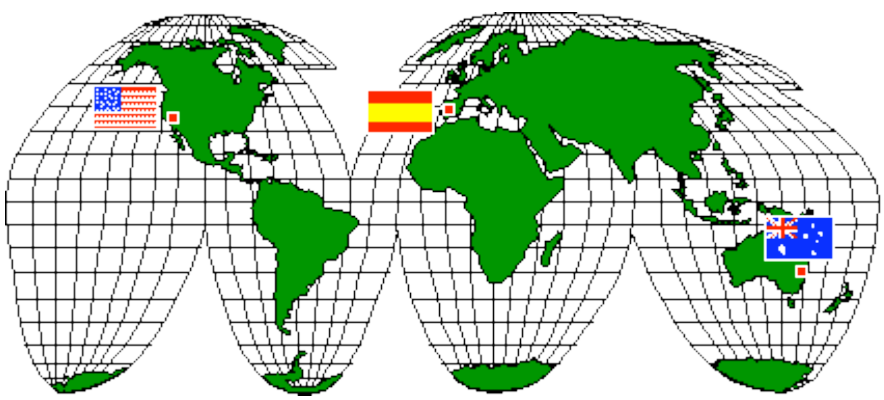
```
JPL HORIZONS Generated Ephemeris
Ephemeris Settings
      Target Body: Pioneer-10 Spacecraft
Observer Location: 0°00'00.0''E, 0°00'00.0''N
 (Puts the "observer" is at the center of the Earth)

Computed values
r       : heliocentric range in AU
delta   : range to observer in AU
deldot  : time rate of change of delta
S-T-O   : Sun-Target-Observer angle
Day count is from 1 January 1987 09:00 UT
*****************************************************
```

Date__(UT)__HR:MN	r	delta	deldot	S-T-O
+2,167 DAYS - OPPOSITION				
1992-Dec-06 09:00	55.82	54.84	13.02638	0.0553
1992-Dec-06 15:00	**55.82**	**54.84**	**12.57266**	**0.0550**
1992-Dec-06 21:00	55.83	54.84	12.73652	0.0552
+2,348 DAYS - CONJUNCTION				
1993-Jun-05 09:00	57.13	58.14	12.38016	0.0536
1993-Jun-05 15:00	**57.13**	**58.14**	**12.84151**	**0.0534**
1993-Jun-05 21:00	57.13	58.14	12.70790	0.0535
+2,532 DAYS - OPPOSITION				
1993-Dec-07 03:00	58.45	57.47	13.03982	0.0526
1993-Dec-07 09:00	**58.46**	**57.47**	**13.14482**	**0.0525**
1993-Dec-07 15:00	58.46	57.47	12.68880	0.0527
+2,713 DAYS - CONJUNCTION				
1994-Jun-06 03:00	59.75	60.77	12.29169	0.0512
1994-Jun-06 09:00	**59.76**	**60.77**	**12.17912**	**0.0511**
1994-Jun-06 15:00	59.76	60.77	12.64369	0.0512
+2,898 DAYS - OPPOSITION				
1994-Dec-07 15:00	61.08	60.09	12.34437	0.0504
1994-Dec-07 21:00	**61.08**	**60.09**	**12.50594**	**0.0501**
1994-Dec-08 03:00	61.08	60.10	13.22745	0.0502

Figure 57 – 70-meter JPL Deep Space Network dish antenna and global DSN facilities map [256]

The diameter of the dish at 70 m is comparable to the width of a football pitch at 45–90 m.



Courtesy NASA/JPL-Caltech

Note that the dates of opposition and conjunction established from the ephemeris in Table (4) are events associated with a switch in polarity of the *time rate of change* of the range to the spacecraft from Earth and the angle between the Sun, the spacecraft and the Earth.

Figure 58 – Unmodeled Pioneer-10 Doppler velocity residuals

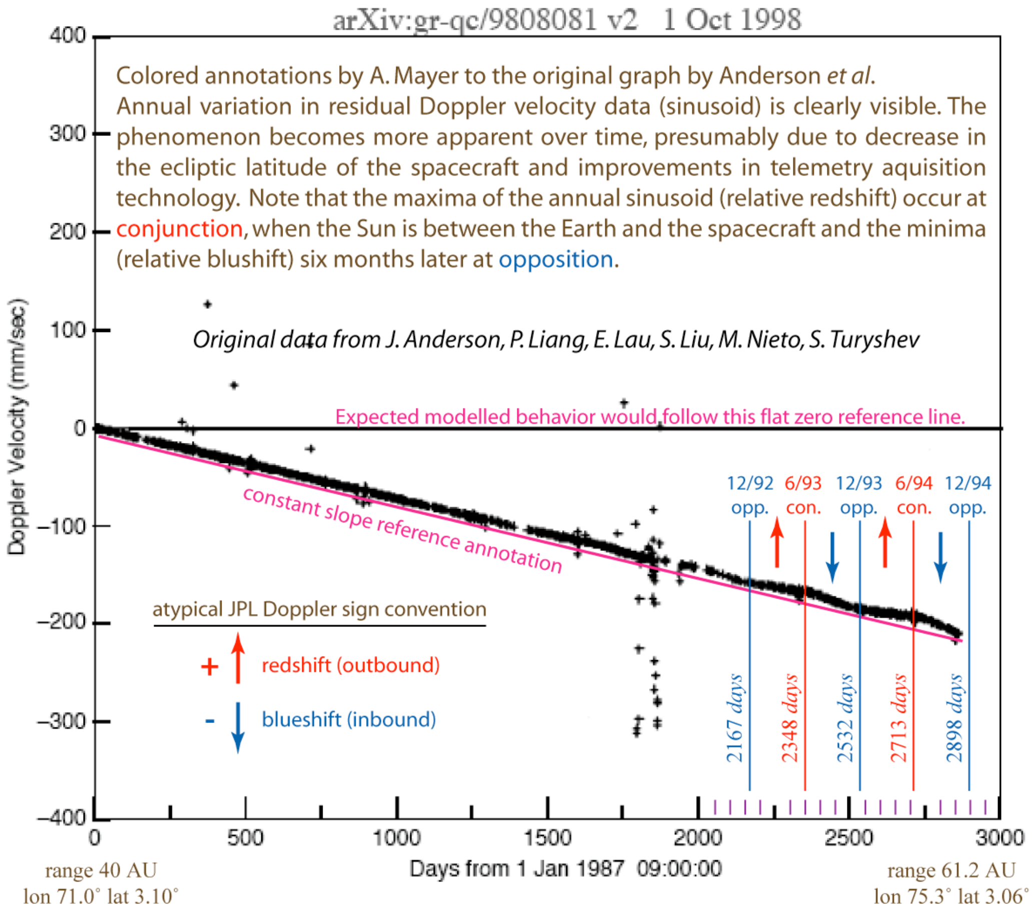
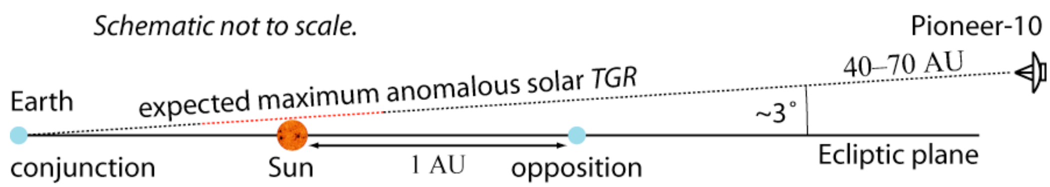


Figure 59 – Pioneer-10 signal path at conjunction



The following passage is footnote #38 of Anderson's 2002 *Physical Review D* paper concerning the observed apparent anomalous acceleration of the Pioneer spacecraft. It emphasizes an important fact about Doppler sign convention. The underlined emphasis has been added.

> The JPL and DSN convention for Doppler frequency shift is $(\Delta\nu)_{DSN} = \nu_0 - \nu$, where ν is the measured frequency and ν_0 is the reference frequency. It is positive for a spacecraft receding from the tracking station (red shift), and negative for a spacecraft approaching the station (blue shift), just the opposite of the usual convention, $(\Delta\nu)_{usual} = \nu - \nu_0$. In consequence, the velocity shift, $\Delta v = v - v_0$, has the same sign as $(\Delta\nu)_{DSN}$ but the opposite sign to $(\Delta\nu)_{usual}$. Unless otherwise stated, we will use the DSN frequency shift convention in this paper.[257]

Because JPL is predominantly concerned with tracking exploratory spacecraft that are generally moving *away* from the Earth, it makes sense that the routine velocity vector pointed away from Earth is associated with a Doppler shift recorded as an unsigned positive number. Then the less prevalent velocity vector pointed back toward the tracking stations on Earth is associated with Doppler shift having an appended negative sign.

Fig. (58) plots Doppler velocity so the Doppler *residual* is the absolute difference between the zero reference and the plotted data. It follows that the maximum Doppler residual occurs at opposition in December (at the local minima of the evident annual sinusoid) while the minimum residual occurs at conjunction in June (the local maxima of the sinusoid). After normalizing the secular blueshift, Fig. (60) provides a magnified view of the Doppler residuals that reveals a diurnal triangle waveform superimposed on the annual sinusoid. The "annual term maximum" for the Doppler *residual* occurring in December corresponds to the trough in the Doppler *velocity* graph that occurs at opposition. This graph, which appears as "FIG. 18" in the original Pioneer-10 telemetry analysis paper by Anderson, clearly shows the *TGR* effect as individually manifested by the gravitational fields of both the Sun and the Earth. The behavior of the Pioneer-10 telemetry is consistent with all of the other empirical observations of the effect previously discussed.

In Fig. (60), showing data from the CHASMP software package, there is a clear distinction between the majority of data runs, which have a negative slope annotated in red, and the five data runs with a positive slope annotated in blue. As time progresses to the right, the red lines reflect a decreasing Doppler residual and the blue runs represent an increasing Doppler residual. Referencing Fig. (57), it is clear that an increasing *residual* (a larger negative Doppler velocity) implies an anomalous blueshifting of the Doppler signal while a decreasing residual implies an anomalous redshifting of the Doppler signal. The "annual term maximum" in the Doppler residual concurrent with the December 1996 opposition, which is very apparent in Fig. (60), then corresponds to the minima in Fig. (57) that are likewise concurrent with opposition.

Figure 60 –Pioneer-10 Doppler residuals: diurnal sinusoid superimposed on annual sinusoid

ANDERSON, LAING, LAU, LIU, NIETO AND TURYSHEV

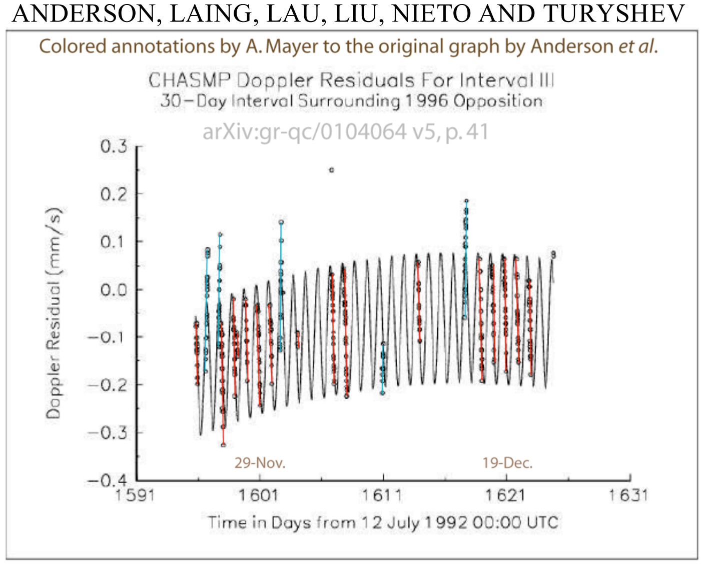


FIG. 18: CHASMP acceleration residuals from 23 November 1996 to 23 December 1996. A clear modeling error is represented by the solid diurnal curve. (An annual term maximum is also seen as a background.)

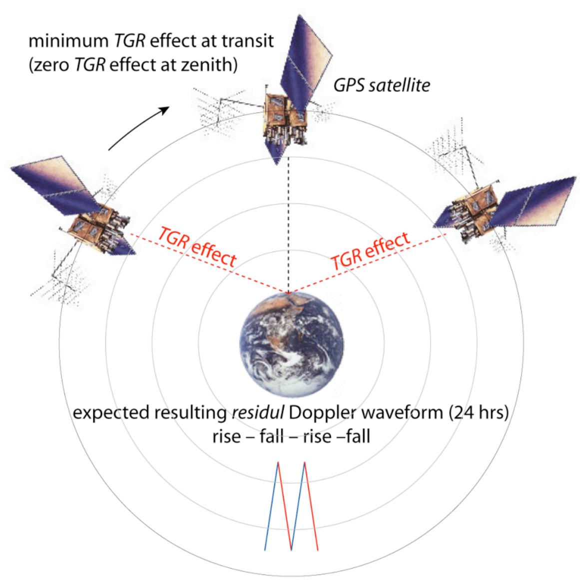
As the Earth turns on its axis, the Pioneer-10 spacecraft must rise and fall in the sky once per day relative to a DSN tracking station. At transit (the spacecraft's highest point in the sky), the transverse gravitational redshift effect on the telemetry due to the Earth's gravitational field will be at a minimum. As the spacecraft falls in the sky, the terrestrial *TGR* effect will increase towards its maximum, just prior to when the spacecraft dips below the horizon. For a distant spacecraft that is near the Ecliptic, the *TGR* effect is consistent with observation of a diurnal triangle waveform in the Doppler velocity data caused by the Earth's gravitational field superimposed on a larger annual sinusoid caused by the Sun's gravitational field. This is exactly what is seen in the mysterious unmodeled Doppler residuals of the Pioneer-10 spacecraft.

Over about eleven years, Pioneer-10 changed its heliocentric ecliptic longitude from 71.0° to 76.4° over heliocentric range 40.0–70.5 AU and over about four years Pioneer-11 changed its ecliptic longitude from 256° to 265.7° over range 22.4–31.7 AU. In doing so, the spacecraft had distinct velocity components transverse to the solar gravitational gradient at different heliocentric ranges. One would expect this to yield a higher anomalous apparent solar acceleration on P-11 than P-10. Although not initially reported, additional analysis of the data may reveal this distinction. For precisely the same reason that geodetic satellites are observed to be inexplicably falling towards Earth, that Io is observed to be inexplicably falling towards Jupiter, that Phobos is observed to be inexplicably falling towards Mars, etc., the *apparent* gravitational acceleration of the Sun on the Pioneer spacecraft is observed to be slightly greater than is modeled by the post Newtonian gravitational model. This phenomenon manifested as an almost imperceptible residual blueshift in the Doppler signal (negative Doppler by JPL DSN convention). The so-called "Pioneer Mystery" has been definitively solved; only quantitative details remain.

32. Observed GPS anomalies

It could possibly be argued that the unmodeled annual and diurnal Doppler signal modulations for the Pioneer-10 spacecraft shown in Fig. (60) are artifacts unique to the spacecraft, the telemetry system or the data analysis process rather than being a product of the solar and terrestrial gravitational fields. However, if the Earth's gravitational field causes the observed diurnal variation, then one can expect the identical triangle waveform to have show up as a residual in GPS satellite signal analyses. As GPS is a practical system with a specific mission, over time efforts will have been made to "engineer" the unmodeled effect out of the system to improve accuracy. However, there can be no substitute for an accurate spacetime metric.

Figure 61 – *TGR* effect of a GPS satellite relative to a ground control station

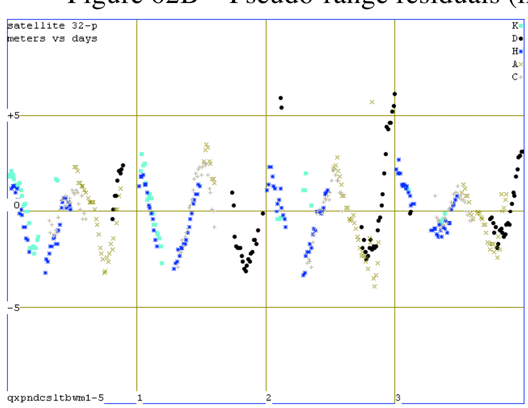


A constellation of 24 operational GPS satellites managed by the United States Department of Defense orbit the Earth in approximately circular orbits (eccentricity typically less than 1%) at an altitude of about 20,350 *km*. There are six orbital planes spaced about 60º apart around the Equator and inclined between about 55º–65º from the equatorial plane. The orbital period of one half of a sidereal day (~11^h58^m) allows a satellite to very nearly repeat the identical ground track every two orbital revolutions. Each GPS satellite or "space vehicle" (SV) carries four atomic time references (two cesium beam clocks and two rubidium clocks) and continuously transmits its time and location on two distinct frequencies. Only one of the clocks is referenced during operation. Air Force ground control segment monitoring stations can typically attain signal when an SV attains an altitude of about 6º above the local horizon.[258]

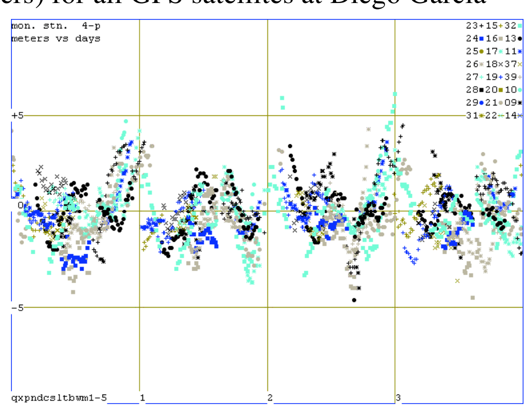
The observed pseudo-range (PR) between a control segment monitoring station on Earth and an SV, measured in meters, corresponds to the light travel time of the measured time delay between signal transmission and reception ($c\Delta t$). Based on orbital and other data, the actual physical location and velocity (state vector) of any satellite may be simultaneously independently determined. The calculated PR of a satellite incorporates the known locations of the satellite and monitoring station and all known physical phenomena that may affect the signal time delay. These include corrections for propagation through the ionosphere and troposphere, dynamic values of both gravitational and relativistic time dilation due to velocity and altitude changes associated with orbital eccentricity, Earth deformations under the stress of solar and lunar tides, satellite antenna offset, and demodulator cable lengths. The difference between observed and calculated PR values is called a residual. If the JPL satellite state vector is accurate and if all phenomena effecting signal propagation have been accurately modeled, then the residuals should resemble Gaussian noise intrinsic to the observed PR.[259]

A systematic error in the residuals implies either a systematic error in the data, an improperly modeled correction, an unmodeled correction or an unmodeled phenomenon. Analysis conducted in 2002 of about six million raw PR measurements from 19 GPS satellites accumulated at 1.5 second intervals over a period of four days in August 1993 for all monitoring stations revealed an unmodeled "saw-tooth effect" [sic] with an amplitude of about one to two meters ~($c \cdot 5\times10^{-9}$ *sec*) superimposed on the data with a roughly 12-hour periodicity matching the orbital period of the satellites. This particular 1993 data set was free of the influence of selective availability, which is no longer in use. Lacking another explanation, investigators attributed the anomaly to the JPL procedure to overlap fits of orbits for each GPS satellite to minimize discontinuities in position.[260] Fig. (62-A) shows PR residuals gathered by all monitoring stations for one SV and Fig. (62-B) shows PR residuals gathered by one monitoring station for all SVs, over a period of four days.

Figure 62A – Pseudo-range residuals (in meters) for all monitor stations for SV 32
Figure 62B – Pseudo-range residuals (in meters) for all GPS satellites at Diego Garcia



(**A**) Days (4 x 24 hours shown)



(**B**) Days (4 x 24 hours shown)

Courtesy Meta Research, Chevy Chase, MD.

Because a GPS satellite has an orbital period of about 12 hours, then it rises and falls *twice* per 24-hour period relative to a ground station as compared to a distant spacecraft like Pioneer-10, which rises and falls only once per day. The diurnal residuals that appear in both Fig. (60) and (62), which are both correlated to the distinct period of the rise and fall of the signal source, one of which is in orbit around Earth and one which is billions of kilometers away, is unlikely to be a coincidence. The spacecraft and their respective signal analyses had nothing in common. It is virtually certain that both graphs reveal the transverse gravitational redshift effect. The annual variation in the Pioneer-10 Doppler residuals correlated with the identical effect associated with the Sun corroborates this conclusion and indeed "triangulates to the truth".

33. Geodesy measurement peculiarities

Satellite geodesy has its beginnings in a 1955 proposal by the U.S. Naval Research Laboratory authored by Martin Hotine, first director of the Britain's Directorate of Overseas Surveys established after World War II, and author of the groundbreaking work *Mathematical Geodesy*, published in 1969 by the U.S. Environmental Science Services Administration.[261] Early space-based photographic processes gave way to the Navy Navigation Satellite System (NAVSAT) called TRANSIT, which evolved from an original constellation of five operational OSCAR satellites providing navigational service into three operational NOVA-2 satellites in low polar orbit (~1,175 *km*) with orbital periods of 109 minutes. The first successful tests of the system were conducted in 1960 and the system was continuously upgraded through the last satellite launch in June 1988. TRANSIT was retired in 1996, having been replaced by the NAVSTAR Global Positioning System, which met the requirements for Full Operational Capability in April 1995. The primary mission of TRANSIT was to obtain accurate coordinates to support ballistic missile submarines, although it was also used more generally for navigation and surveying. The TRANSIT satellites broadcast a continuous dual-frequency signal (150 MHz and 400 MHz) in order to calculate ionospheric delays with a two-minute period that included the time and ephemeris. The system employed the Doppler effect, whereby the apparent dynamic frequency shift of a satellite signal combined with knowledge of its location at transmission yielded a latitude/longitude fix for the location of the receiver. No altitude measurements were possible.[262]

The various successive versions of the U.S. Department of Defense World Geodetic Systems (WGS) were heavily influenced by Doppler satellite geodesy. In the development of the World Geodetic System 1972 (WGS72) and later the current WGS84, which was developed as the improved coordinate reference frame for the nascent Global Positioning System, most major datum parameters were influenced by Doppler satellite measurements.[263] The following is taken from *The Global Positioning System Geodesy Odyssey*, a definitive historical and technical review of GPS by Alan Evans *et al.* (2002).

> The preliminary WGS84 coordinates of the USAF [United States Air Force] and DMA [Defense Mapping Agency] GPS tracking stations were obtained by transformation from their WGS 72 coordinates. During 1985 and 1986, the WGS84 coordinates were directly derived using Doppler TRANSIT point positioning by DMA. This positioning technique used the recently calibrated WGS84 Doppler station coordinates, Doppler observations collected from TRANSIT satellites, and the WGS84 gravity model. The WGS84 positions of the GPS tracking stations were defined by transferring WGS84 positions of nearby collocated Doppler stations using terrestrial survey differences.
>
> Uncertainties in these Doppler-derived WGS84 station coordinates were attributed principally to uncompensated ionospheric effects on signal propagation and, to a smaller extent, the determination of the electrical phase center of the antennas. TRANSIT, like GPS, used dual-frequency observations to correct for ionospheric effects. This correction's residual errors are inversely proportional to the satellite transmitted frequencies. Ionospheric corrections for the TRANSIT low-frequency

> observations contained relatively large residual errors; these errors primarily corrupted the height of Doppler-derived coordinates. Smaller errors in the GPS station coordinates were introduced by inaccurate definitions of the electrical phase center of both the TRANSIT and GPS antennas used in the coordinate transfers. The combination of these and other errors made the initial GPS station coordinates internally inconsistent and biased with respect to the BTS [Bureau International de l'Heure Terrestrial System]. The largest bias, which was in the GPS station heights, was estimated to be at the meter level.[264,265]

The transverse gravitational redshift effect that is not modeled by general relativity will have had a considerable unmodeled influence on the Doppler signals from the TRANSIT satellites, seriously degrading their expected performance. Estimates of TRANSIT's accuracy will have been erroneous, implying far more accurate coordinate values than was actually the case. The effect will have been particularly insidious in introducing errors because it is dependent on the variable relative elevation of the satellite at transit.

In addition to the Master Control Station (MCS), which is a part of Schriever Air Force Base[266] just outside of Colorado Springs in the United States, there are four remote unmanned GPS Operation Control Segment (OCS) Monitoring Stations worldwide. Because these stations collect ranging data and timing from each GPS constellation satellite and transmit this information back to the MCS, it is imperative that their geographic locations are precisely known. The accuracy of each station coordinate component is currently estimated to be on the order of "1 *cm*, 1 sigma".[267] Relative to the International GPS Service (IGS) antenna at Schriever AFB, we are here concerned with a particular pair of the remote stations due to their conveniently similar geographic features.

The IGS antenna at Diego Garcia is on an island atoll that is part of the Chagos Archipelago in the British Indian Ocean Territory just south of the Equator.[268] As is common to virtually all such island atolls, the terrain has an average elevation of about 1–2 meters above local sea level and a maximum elevation not exceeding ten meters. The IGS antenna at Kwajalein is on a very similar island atoll that is part of the Marshall Island Group in the North Pacific Ocean, about half way between Hawaii and Australia just north of the Equator.[269] The terrain there is essentially identical to that of Diego Garcia. Fig. (63) shows the geographic locations of these two remarkably similar islands, both of which are surrounded by vast expanses of open ocean near the Equator. New Guinea, north of Australia, appears in both maps, so it is easy to get a sense of their relative global positions. Fig. (64) shows aerial photographs of the two islands so that one may appreciate their virtually identical completely flat topographies at sea level.

Figure 63 – Geographic locations of Kwajalein and Diego Garcia

Map of Kwajalein courtesy of Jeff Winter, National Air Traffic Controllers Association

Intuitively, the surface of an undisturbed body of water such as a placid swimming pool or any such container of water represents a plane perfectly orthogonal to the local gravitational gradient. Disturbances may cause temporary deviation from the mean water surface, but the nature of a fluid in a gravitational field implies that its surface will constantly self-equalize. In spite of their size and the fact that the applicable gravitational field is spherical rather than planar, the world's oceans clearly must subscribe to this principle. The Permanent Service for Mean Sea Level (PSMSL) is the global data bank for sea level change information established in 1933 in the

United Kingdom. According to the PSMSL, Mean Sea Level (MSL) is the local height of the global Mean Sea Surface above a "level" reference surface, or datum, called the geoid. There is a sea level difference of about 20 centimeters across the Panama Canal, which has been accurately measured by geodetic leveling from one side to another. The Atlantic Ocean surface as a whole is considered about 40 centimeters lower than the surface of the Pacific due to differences in density and prevailing weather conditions. An apparent notably large variation in mean sea level results from the southerly Gulf Stream current in conjunction with the Earth's rotation, which is *reported* to cause about a one meter difference in sea level height between New York and Bermuda.[270]

Figure 64 – Aerial photographs of Kwajalein and Diego Garcia Atolls

Aerial Photo of Kwajalein

~ 167º43' E, 8º43' N

Aerial Photo of Diego Garcia

~ 72º22' E, 7º16' S

Photos courtesy Unites States Department of Defense

The Earth's geoid as defined by the United States National Geodetic Survey is

> "The equipotential surface of the Earth's gravity field which best fits, in a least squares sense, global mean sea level."[271]

Then the geoid is that smooth surface that closely approximates the mean sea surface and is everywhere perpendicular to a local plumb line defining the direction of the local gravitational gradient. One should be aware in this discussion that the Jason-1 and TOPEX/Poseidon satellites, which map ocean surface topography, actively reference GPS in real time; *these two systems are not independent of GPS, so their data will incorporate any GPS error*.[272,273] In a publication entitled "Vertical Datums, Elevations and Heights", the U.S. National Imagery and Mapping Agency (NIMA) states (emphasis in the original):

> It turns out that MSL is a close approximation to another surface, defined by gravity, called the **geoid**, which is the *true zero surface for measuring elevations*. Because we cannot directly see the geoid surface, we cannot actually measure the heights above or below the geoid surface. We must infer where this surface is by making gravity measurements and by modeling it mathematically. For practical purposes, we assume that at the coastline the geoid and the MSL surfaces are essentially the same. Nevertheless, as we move inland we measure heights relative to the zero height at the coast, which in effect means relative to MSL.[274]

Armed with the foregoing, one might reasonably estimate that the maximum mean sea level differential between Kwajalein and Diego Garcia is less than one meter. The topography of the two islands and the fact that both antennas are mounted in nearly identical fashion within a few meters of the ground then imply that the two respective antennas are at nearly identical elevations relative to the geoid. (See "IGS Station Logs" in the Appendices.)

The Global Positioning System measures elevation not relative to the geoid *per se*, but relative to a theoretical equipotential ellipsoid of revolution specified by the World Geodetic System 1984 (WGS84) which was designed for use as the reference system for GPS. The relationship between the ellipsoid height h that is specified by GPS, the height H of the topographic surface of the Earth above the geoid and the geoid height N relative to the ellipsoid is

$$h = H + N \tag{79}$$

At mean sea level, by definition the value of H is zero, so here the ellipsoid height reported by GPS is then equal to the geoid height relative to the ellipsoid, which at sea level should also be close to zero.

Although the equivalent of mean sea level over the entire Earth's surface does not describe a perfect ellipsoid, the perfectly smooth and well-defined mathematical surface of the equipotential ellipsoid furnishes a simple, consistent and uniform reference system for geodesy (surveying) and geophysics (study of the Earth's interior).[275] The parameters of the reference ellipsoid, the semimajor axis a, and the flattening f have been chosen so that the ellipsoid might very closely follow the geoid. The geoid height N or "undulation of the geoid" relative to the ellipsoid should represent to good approximation the effects of gravitational anomalies due to density variations in the Earth's interior. These density variations can be tested to an accuracy of about 2μGal[a] using an *absolute* gravimeter such as the Micro-*g* Solutions *FG*5 Absolute Gravimeter or, even better, a "triumvirate" of these very accurate instruments whose local independent redundant readings by distinct teams can be compared for error detection.[276,277]

With all of the foregoing in mind, consider now that the published GPS reference height of the Kwajalein IGS antenna is 38.27 meters *above* the ellipsoid and the published GPS reference height of the Diego Garcia IGS antenna, mounted atop a low one-story building, is 64.75 meters *below* the ellipsoid. This is a stunning discrepancy of over 100 meters in their relative ellipsoid heights, which have been specified to an accuracy of 10^{-4} meter![278] When its full capacities are used by authorized personnel in *differential* mode, as verified by a laser rangefinder, GPS has been advertised to be very accurate in discriminating between two distinct locations that are within line of sight from one another. Accuracy in specifying the distance between two points that is better than one part in a million has been demonstrated. It is then easy to assume that all coordinates generated by GPS reflect empirical reality to very high accuracy. However, from a geodetic and geophysical perspective, these ellipsoid elevation discrepancies simply do not make sense. They must be considered just as troubling as the purported anomalous acceleration of the Pioneer spacecraft. Are we to believe that "a geoid which undulates wildly across the landscape" reflects empirical reality?[279] Perhaps the considerable distance (~10,700 *km*) between Kwajalein and Diego Garcia may give one the false impression that such a large ellipsoid height differential for locations in the open ocean near the Equator could be reasonable. The following should erase any doubt that something is indeed seriously amiss.

Malé International Airport on Hulhule Island in the Maldives is located a mere 1,270 *km* north of Diego Garcia in the Indian Ocean. This unique airport, built on an island atoll has an official runway elevation of four feet (~1 meter) ASL.[280] Fig. (65) includes an aerial photo of the airport and a map of its location relative to Diego Garcia. The Malé Airport IGS Station is located at 73º31'35" E, 4º11'19" N with an antenna fixed to a post approximately 2.3 meters high.[281] However, its reported GPS reference ellipsoid height is *minus* 92 meters, using the same WGS84 coordinates as for Diego Garcia and all other IGS stations.[282] This is a discrepancy of 27.25 meters over only 1,280 kilometers. According to the GLOSS handbook, tide levels at Hulhule Island are similar to those at Diego Garcia and Kwajalein.[283]

[a] 1 galileo (Gal) ≡ 1 $cm\,s^{-2}$ ∴ 1 μGal ≡ $10^{-8}\,m\,s^{-2}$

Figure 65 – Aerial photograph and geographic location of Malé Airport, Maldives

Aerial Photo of Malé Airport, Maldives

Location of Malé Airport

Photo courtesy John S. Goulet, (ebushpilot.com). Map by *Google Earth*, annotated by A. Mayer.

It is by rigorous definition that the ellipsoid very nearly follows the ocean surface of the oblate Earth, particularly for the open ocean near to the Equator.

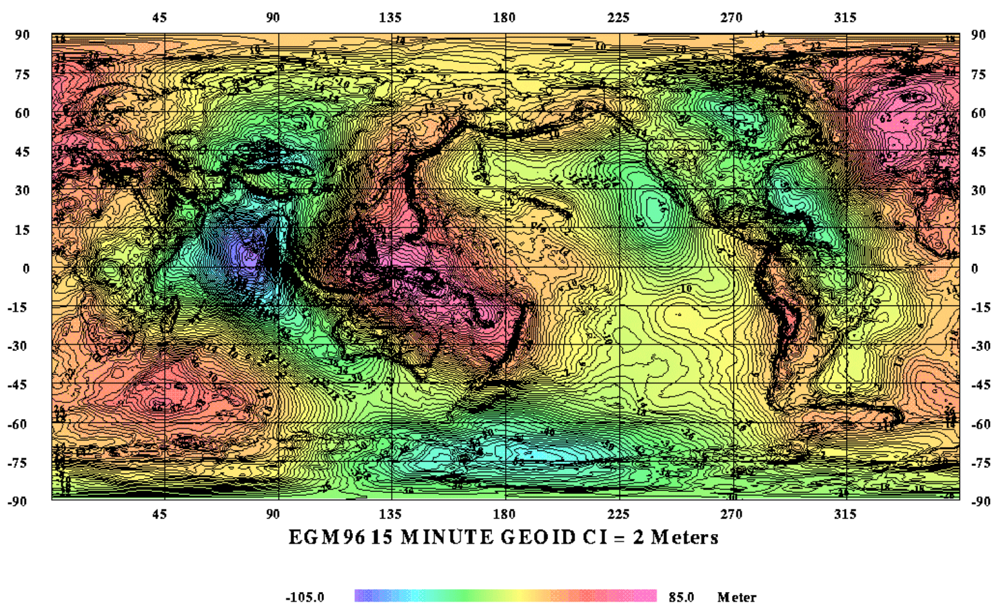
> The geoid is an equipotential surface of the Earth's gravity field that is closely associated with the mean ocean surface. "Closely associated" can be defined in a number of ways [*Rapp*, 1995]. A working concept is that the mean difference between a geoid and the mean ocean surface should be zero. Deviations between the mean ocean surface and the geoid represent (primarily) mean Dynamic Ocean Topography (DOT). The standard deviation of the DOT is approximately ± 62 cm, with extreme values from about 80 cm to about –213 cm, the latter in the Antarctic Circumpolar Regions (e.g., 66°S, 356°E).[284,285]

However, it is quite clear that Malé Airport is not 92 meters (over 300 feet) under water, so how do we justify the GPS ellipsoid height of 92 meters *below* the ellipsoid with the fact that Malé Airport is a place for airplanes and not submarines? In the absence of any theoretical model that might otherwise explain GPS results, which have been accepted as very accurate empirical data, geodesists have had no choice but to arbitrarily invent something called a "gravity disturbance" to model the anomalies that appropriately shocked geodesy experts who had realistically expected to measure a far smoother terrestrial geoid.[286]

> The NASA Goddard Space Flight Center (GSFC), the National Imagery and Mapping Agency (NIMA), and the Ohio State University (OSU) have collaborated to develop an improved spherical harmonic model of the Earth's gravitational potential to degree 360. The new model, Earth Gravitational Model 1996 (EGM96) incorporates improved surface gravity data, altimeter-derived anomalies from ERS-1 and from the GEOSAT Geodetic Mission (GM), extensive satellite tracking data – including new data from Satellite laser ranging (SLR), the Global Positioning System (GPS), NASA's Tracking and Data Relay Satellite System (TDRSS), the French DORIS system, and the US Navy TRANET Doppler tracking system – as well as direct altimeter ranges from TOPEX/POSEIDON (T/P), ERS-1, and GEOSAT. The final solution blends a low-degree combination model to degree 70, a block-diagonal solution from degree 71 to 359, and a quadrature solution at degree 360. The model was used to compute geoid undulations accurate to better than one meter (with the exception of areas void of dense and accurate surface gravity data) and realize WGS84 as a true three-dimensional reference system. Additional results from the EGM96 solution include models of the dynamic ocean topography to degree 20 from T/P and ERS-1 together, and GEOSAT separately, and improved orbit determination for Earth-orbiting satellites.[287]

Using a spectrum of colors to represent various geoid heights relative to the zero reference point, Fig. (66) and (67) show mean values of geoid undulations computed from EGM96 to degree and order 360. The values refer to the WGS84 (G873) system of constants, which provide a realization of the geometry and the normal gravity potential of a mean-Earth ellipsoid. The permanent tide system is "non-tidal", and the units are meters.[288] In the vicinity of the GPS Operational Control Station Monitoring Station at Diego Garcia, we see a huge purple splotch about 2,500 *km* in diameter in the middle of the ocean on the EGM96 Geoid. Notice that the giant *minus one-hundred meters* (-100 *m*) purple splotch in the EGM96 Geoid is "coincidentally" surrounding Diego Garcia, the *farthest* GPS OCS Monitoring Station from *the USNO Alternate Master Clock in Colorado Springs* on the opposite side of the globe. Does it represent what it purports to be on these maps or is it something else? To find out we need to make absolute gravity measurements specifically on Malé and also on Diego Garcia and Kwajalein and compare them, but there seems to be no evidence in the literature of such measurements. Moreover, there is an indication that when the satellite data disagrees with extremely precise and reliable surface gravimetry data, it is surprisingly the latter data that has been generally "downweighted" to one degree or another rather than identifying the problem causing the *dissimilar information*.

Figure 66 – EGM96 15' x 15' geoid undulation plot

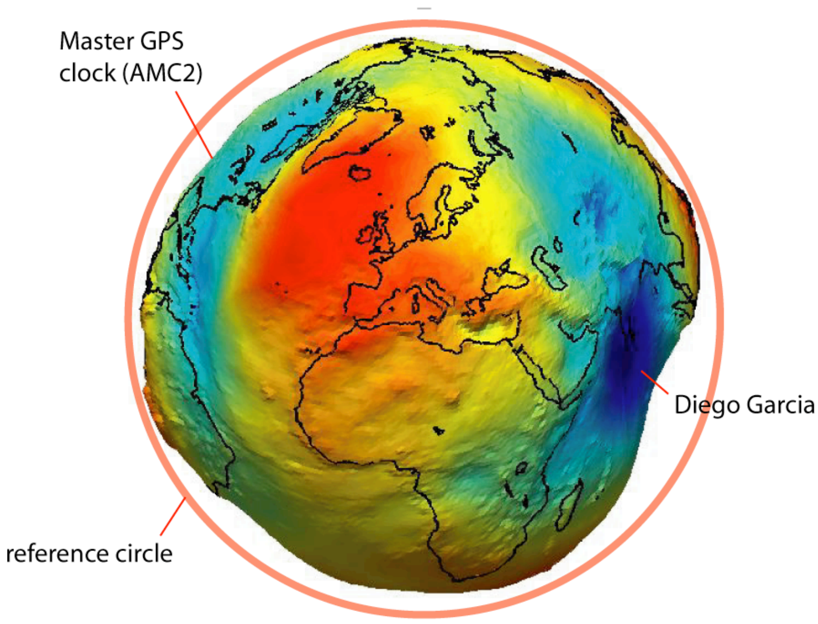


Courtesy National Geospatial-Intelligence Agency[289]

The emphasis has been added to the following quotation.

> EGM96, through its incorporation of newly available surface gravimetry has significantly improved continental geoid modeling. The new data include contributions over most of Asia and the former Soviet Union, airborne gravity surveys over polar regions including Greenland, surveyed data from South America, Africa, and North America, as well as improvements to the data sets provided by many countries. These data enhancements have all increased the short wavelength global geoid accuracy of the resulting model. Of importance is the progress which was achieved in eliminating a significant level of *inconsistency between the geopotential signal sensed by satellite tracking versus terrestrial anomaly data*. Earlier combination solutions "required" (given model design considerations) the strong downweighting of surface gravimetry (for example in JGM-2 and JGM-3). EGM96 gave much higher weight to the surface information, yet still performs well on orbital and ocean geoid modeling applications.[290]

Figure 67 – Annotated amplified 3-D model of the EGM96 Geoid



Geoid model courtesy European Space Agency

Recall that the anomalous results of the Galileo-Ganymede flyby mission were classified as "mass anomalies" or "gravity anomalies". This is just an invented term, conveniently used to describe observed unmodeled variations in data that would otherwise be inexplicable. It is not a coincidence that the giant "bite" out of the Geoid is associated with Monitoring Station (MS) Diego Garcia, at the approximate antipode to the master GPS atomic clock (AMC2) in Colorado. Here we see Earth's "gravity anomalies", which do not actually exist, at least at this magnitude. In order for the Earth's spin to be free of significant non-precessional wobbling, the Geoid must be remarkably smooth. Since the Earth is free of such wobbling, we know that the Geoid is free of the "wild undulations" that are now incorrectly modeled.

People implicitly trust their $10 calculator to always give the right answer. — The GPS system is a $15 billion "calculator", but because it incorporates an incorrect space-time metric, it is essentially slightly "broken" and so effectively implies that Malé Airport is ninety meters under water. Because this is obviously not true, we have a huge "mass anomaly" and a Geoid that looks like a worn dog toy. There is no possibility that the Earth's Geoid is anything like this model. Rather, the Earth's observed dynamical behavior implies that the Geoid is remarkably smooth. Application of a corrected relativistic gravitational model to satellite geodesy measurements and analysis will result in an appropriately smooth Geoid reflecting empirical reality.

Looking for clues, the most obvious distinction between the two very similar OCS locations under consideration is that the atomic clock at Kwajalein is approximately 9,200 *km* distant over a great arc from the USNO Alternate Master Clock at the GPS Master Control Station in Colorado, while the atomic clock at Diego Garcia is about 16,500 *km* distant over a great arc from the same MCS atomic clock. Because Diego Garcia is almost twice as far away from the MCS as Kwajalein, the *TGR* effect as measured over a great arc between clocks is considerably greater for Diego Garcia than it is for Kwajalein. Additionally, because the GPS is a product of people and facilities located in the United States, it would make sense that any free parameters that might be manipulated to reduce positional accuracy degradation of GPS due to an unmodeled relativistic gravitational effect would have been adjusted due to predominantly local testing so as to make those inaccuracies a minimum in and around the continental United States. The implication is that inherent errors in the system would tend to increase with distance from the United States. Due to the complexity of the system, there is no convenient single simple explanation; there are many interrelated factors leading to subtle errors in GPS and its data products from the current real-time effects of TGR to inevitable historical inaccuracies related to datum coordinates in WGS84.

In short, without accounting for the *TGR* effect, the assumed "accuracy" of currently published geodetic measurements is a fantasy. The big purple "hole" in the Indian Ocean around Diego Garcia obviously *does not exist* in reality. — If your calculator says that the square root of 324 is 16 you should immediately know that your calculator is broken. Apparently due to some internal damage, the LCD display fails to light the top rightmost digit of an 8 and so displays it as a 6. You know this because it should immediately occur to you that 16-squared (2^8) is 256. Therefore, the square root of 324 has to be larger (it is 18). If you write down 16, blindly trusting your calculator, there was obviously something lacking in your education and training. Likewise, if your GPS system says that your planet's (amplified) geoid looks something like Fig. (67), you should immediately suspect that something is wrong with your GPS system or the physics behind it, not the mass distribution of your smoothly spinning planet!

> The accuracy for dynamic geodesy and—to a large extent—all space geodesy, is dependent on accurate positioning of the satellite. In turn, satellite orbit computation accuracy (and satellite ephemeris accuracy) is dependent on the accuracy of the space geodesy. Satellite observations made from the ground can be used accurately only if the ground station locations are known accurately, while the orbit itself can be computed accurately only if all of the forces governing the satellite motion are known. The early dynamic geodesists observed satellite prediction errors and made bootstrap corrections to the gravity models. GPS benefited greatly from the existing WGS gravity model. Techniques that eliminate common-mode errors among ground locations provide improved accuracy over limited distances, but they still depend on satellite position accuracy. GPS geodesy, like GPS navigation, relies on the accuracy, quality, and timeliness of the orbit computation and prediction.[291]

34. The black drop effect

Earth is the third planet from the Sun after Mercury and Venus. Therefore, on occasion and from the right location on Earth, these two inner planets can be observed to transit the solar disk, appearing as a dark round shadow moving across the background of the Sun. Transits of Venus last only about six hours, occurring at regular intervals of 121.5 and 105.5 years in pairs that are separated by about eight years. The last transit of Venus occurred on 8 June 2004; the second of the pair in this century will occur on 6 June 2012. As some kind of telescope is required to view these rare events, only five Venus transits have been seen previously — in 1639, 1761, 1769, 1874 and 1882. Transits do not occur each time Venus overtakes Earth, as its orbital plane is about 3.4 degrees out of the Ecliptic. The orbital period of Mercury is less than 40% that of Venus, so its transits occur more frequently with an average of thirteen events per century. A French astronomer, and Catholic priest named Pierre Gassendi made the first observation of a transit, which was that of Mercury in November 1631.[292,293]

Edmund Halley first proposed the idea that simultaneous accurate timing of transit events across two distinct chords as observed from different latitudes on Earth could be used as a means to measure the astronomical unit (the Earth's orbital radius).[294] Historically, Mercury has been too small and far from Earth as compared to Venus for the purposes of such measurements. Efforts to make the necessary very accurate timing measurements for the transit of Venus in the 18th and 19th century were thwarted by a peculiar phenomenon which became commonly known as the "black drop" effect. This is an observed meniscus between the respective limbs of the Sun and Venus that distorts the anticipated sharp circular outline of the planet when its limb is internally tangent to that of the Sun at both ingress (Contact II) and egress (Contact III). This distortion of the background light streaming past the planet's limb made it frustratingly impossible to accurately time the moments that the transit began and when it ended.

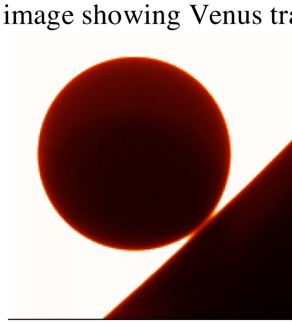
Historically, a number of possible explanations were posited for this puzzling observation. These included a simple optical illusion, light diffraction around the planetary disk, refraction by the atmosphere of Venus, or terrestrial atmospheric "seeing" effects whereby the Earth's atmosphere smears the light, which is typically the case for telescopic observations of stars. Photographic images revealed the effect, so it was clearly not an optical illusion and the calculated magnitude of possible diffraction effects is entirely negligible. Throughout the 20th century, it seemed inevitable then that one or both of the other two remaining purported causes was correct. However, in both 1999 and 2003, the NASA Transition Region and Coronal Explorer (TRACE) spacecraft was used to make high spatial resolution optical images of the transit of Mercury. The effect was clearly observed, by the spacecraft cameras, eliminating the possibility of either of these explanations.[295,296] Mercury has no appreciable atmosphere and space-based observation eliminates seeing effects as a possible cause. Schneider *et al*. came to the following conclusion (emphasis added).

> The principal cause of the Black Drop effect, which has historically impeded ground-based planetary transit measurements, is *optical broadening* resulting from the convolution of the systemic PSF [Point Spread Function] with the planetary and limb-darkened solar disks. TRACE observations are free from PSF instabilities caused by "seeing" in the terrestrial atmosphere and allow mitigation of the Black Drop effect from the intrinsic disk images. Such stable, critically sampled, near diffraction-limited images may be further enhanced by PSF deconvolution, enabling very high-precision differential astrometric position measures.[297]

Limb darkening is presumably the result of temperature differences within the solar photosphere. While TRACE observations of the black drop effect for Mercury eliminate the idea that the observed phenomenon is attributable to an atmosphere (Earth or Venus) the idea that the phenomenon must then be due to an instrumental point-spread function (PSF) is far from unequivocal. It is unlikely that the phenomenon observed by TRACE and the identical phenomenon observed for centuries using telescopes have two entirely distinct causes. Rather, we can reasonably assume that the TRACE observations and Captain Cook's observations of the same effect in 1771 share an identical phenomenological cause.[298] The "logical" conclusion that the TRACE observations must be due to an artifact of the instrumentation fails to consider that the list of all possible causes previously ruled out was not an exhaustive list.

Due to the transverse gravitational redshift effect, the background sunlight streaming past the transiting planet will incur a radial frequency shift differential with a pronounced redshift at the limb. This will clearly cause an asymmetric line broadening, a phenomenon which can be easily verified during observations of the June 2012 transit of Venus, and perhaps even from archive data from previous transits. It is virtually certain that the following TRACE satellite image, and what has similarly been seen for centuries, is additional empirical evidence of the *TGR* effect.

Figure 68 – TRACE image showing Venus transit black drop effect



Courtesy NASA

In the above image, the dark lower right corner is space, the white area is the disk of the Sun, and the dark disk is the planet Venus. The observed phenomenon occurs at both ingress and egress.

35. Dynamic stability of galaxy clusters, spiral galaxies, and globular clusters

At the conclusion of *Section 15*, it was claimed that the production of the cosmic microwave background radiation is fed by a real-time phenomenon in which microwave radiation is emitted in a ubiquitous process of energy transformation and that this process has been definitively identified. The apparent fundamental error in the general theory of relativity was then discussed and the concept of transverse gravitational redshift (*TGR*) was introduced. Subsequently, many existing empirical observations supporting the claimed existence of this effect have been pointed out. In addition, the TGR phenomenon solves the longstanding astrophysical puzzle of accretion disk angular momentum transfer (e.g., whereby disks of rotating matter collapse to form stars). Prior to discussion of the source of the CMBR, the relevance of the *TGR* effect concerning the observed stability of galaxy clusters, globular star clusters and spiral galaxies is warranted. —

Following observational studies of the Coma cluster of galaxies in the 1930s, Fritz Zwicky noted that there was a significant discrepancy (two orders of magnitude) between the estimated mass of the cluster based on the luminosity of its constituent galaxies and its estimated virial mass based on its observed dynamical properties according to Newtonian physics.[299] In 1964, Zwicky and Milton Humason of the Mt. Wilson Observatory published the last paper of a series in the *Astrophysical Journal*. In the abstract's last sentence, we find the first definitive claim for what is now commonly known as (otherwise undetected) "dark matter".

> An observational and theoretical analysis of the medium compact cluster of galaxies around NGC 541 has been initiated. … From the spatial distribution of the values of the velocity distribution, it may be concluded that the cluster is not expanding. The fact that the fainter galaxies have a greater velocity dispersion than the brighter galaxies indicates a tendency toward the establishment of equipartition of energy among at least the brighter cluster galaxies. … The indicative distance of the cluster, the indicative absolute photographic magnitude of its brightest member galaxy and the relative indicative mass-luminosity ratio, as determined from the Virial theorem, are respectively, D^* = 53.2 million pc, M^* = -20.2 and $\mathfrak{R} \sim 100$. This value of $\mathfrak{R}$ lies midway between those found for individual bright galaxies and those of very richly populated compact clusters of galaxies. Suggestions are discussed of how $\mathfrak{R}$ might be found to be drastically reduced because of the presence of various types of as yet undetected types of intergalactic matter.[300]

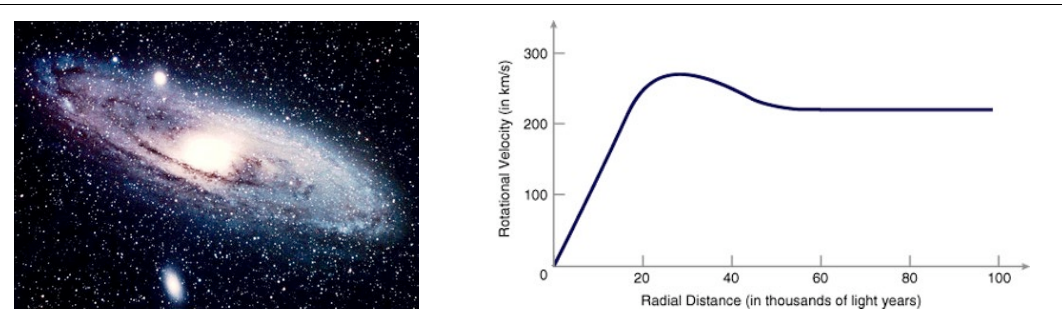
In spite of many decades searching for the mysterious stuff called "dark matter", there is no independent evidence of its existence beyond its apparent gravitational effects. Thus, the alleged ubiquitous "dark matter" would have the improbable properties of being wholly unaffected by electromagnetic forces and emitting no radiation whatsoever. Moreover, while the Milky Way Galaxy is supposedly made up mostly of "dark matter" there is no evidence for its existence in the Solar System; it is readily apparent that the only gravity acting in the Solar System is sourced from the Sun, the planets and other minor material bodies. The fanciful (i.e., unscientific) ideas for particles that have put forward as possible candidates for "dark matter" have been categorized by an anonymous pundit as "Fabricated Ad hoc Inventions Repeatedly Invoked in Efforts to Defend Untenable Scientific Theories" (FAIRIE DUST). At face value, like the "phlogiston" of the 19th century, "dark matter" simply does not exist and it is therefore unproductive to continue looking for it. Yet, how does one otherwise explain the observed *apparent* gravitational effects of the "missing matter"?

If galaxies were indeed embedded in halos of normally gravitating but otherwise essentially inert "dark matter" there is no compelling reason why the subset of visible luminous material would cluster together to form the distinct observed shapes of galaxies. If "dark matter" and normal matter gravitate identically, why would there be a distinct spiral disk of conventional matter inside a halo of "dark matter"? The only possible configuration of a mixed matter galaxy would be a random distribution of normal matter and "dark matter". However, showing utter disregard for the most elementary scientific logic, proponents of "dark matter" have implicitly suggested that a disk of normal matter made of atoms can somehow gravitationally differentiate itself from “dark matter”. Because the idea of “dark matter” is so immediately and obviously invalidated by the most elementary scientific analysis, it is among the most irrational ideas in the history of science. The initial premise of an investigation has to be that *no “dark matter” exists*. In science, one must not stray from first principles and one cannot simply invent radical arbitrarily concepts and properties in an attempt to explain empirical phenomena.

The transverse gravitational redshift effect implies that galaxies interacting in a cluster must constantly dissipate energy due to their tangential motion relative to the other members of the cluster. No mysterious invisible mass with impossible physical properties is required. Note that the question still remains as to what form the energy takes that is apparently “lost” from the gravitational system due to *TGR*. Whatever form the energy takes, it would clearly have to exhibit *anisotropies* with a stronger signature occurring where there are large concentrations of mass and a weaker signature where less gravitational interaction takes place. The astute reader likely has an answer in mind at this point, but that discussion is reserved for the next section.

Vera Rubin graduated from Vassar College in 1948 with an undergraduate degree in astronomy, later completing her doctorate at Georgetown in 1954. Her early ideas and research suggested *inconsistencies* with the Big Bang, which were not well received, yet she persevered in her career while also raising a family of four children and is now a staff astronomer at the Carnegie Institution. Rubin made a major contribution to astronomy in the 1970s when her observational work first revealed that the velocity profiles of spiral galaxies are generally flat beyond the inner core.[301] This was a startling revelation, for at the time it was assumed that the velocity profiles must naturally exhibit exponential decay consistent with the apparent mass distribution according to the observed luminosity profile and Newtonian physics. It has since been shown by radio astronomy observations that this property extends to orbiting clouds of hydrogen gas that exist far beyond the edge of the optical disk.

Figure 69 – Andromeda Galaxy (M31) and its approximate Doppler rotational velocity curve



Courtesy National Center for Supercomputing Applications[302]

According to celestial mechanics based on Newtonian physics, the proportionately thin disks of spiral galaxies should be unstable in a number of ways, yet clearly they are not. Most obviously, dynamic stability of an orbiting body requires a balance of forces; one expects the gravitational acceleration and the centripetal acceleration to be equivalent.

$$\frac{GM}{R^2} = \frac{v_r^2}{R} \quad \rightarrow \quad v_r = \sqrt{\frac{GM}{R}} \tag{80}$$

The conspicuous central bulge of spiral galaxies implies a significant associated mass concentration. Then a Newtonian point mass approximation governing disk orbits is not an unreasonable assumption, although one must also account for the radial increase in enclosed mass from the disk. The application of the virial theorem to the galactic system also implies that orbital velocities should decline with the radius.

$$v_c^2 \propto \frac{M}{R} \quad \rightarrow \quad v_c \sim \frac{1}{\sqrt{R}} \qquad 81$$

So, without some counteracting phenomenon, according to the graph in Fig. (69), Newton's inverse square law implies that the stars and gas in the outer regions of typical spiral galaxies should rapidly spin out and away from the galaxy like mud spinning off of a rotating tire. This is because the centrifugal force corresponding to their rotational motion is far greater than the counteracting gravitational force. Therefore, following Rubin's groundbreaking astronomical observations, *astrophysicists* jumped to the conclusion that spiral galaxies must be embedded in a vast halo of "dark matter", which would presumably provide the additional gravitational attraction to prevent this from happening. However, the observation that the gravitational clustering of luminous matter would somehow have to be distinct from the identical clustering of "dark matter" immediately precludes such a naïve proposed solution.

Upon sober consideration, it is quite clear that there are essentially no *significant* drag forces operating on orbiting bodies, so according to Newton they should have stable orbits, but they do not; all orbits are observed to decay. If no "dark matter" envelops spiral galaxies, then according to Newton the observed rotational velocities of galactic disks should rip them apart, yet they are stable. If it is not already clear, the orbiting stars in spiral disks are dissipating energy and "falling" towards the galactic core, thus counteracting their excess orbital velocity, for precisely the same reason that stars, planets, moons, spacecraft and satellites are all observed to dissipate energy and "fall" in towards the center of the dominant local gravitational field. Moreover, the effect tends to keep the shape of the galaxy disk stable as it is vectored in the plane of the disk.

No discussion of spiral galaxy disks is complete without mention of the Tully-Fisher relation. In 1922, an Estonian astrophysicist named Ernest Oepik (aka Öpik) who spent the latter part of his career at Armagh Observatory in Ireland published an article in the *Astrophysical Journal*. Following is the first sentence of the abstract.

> *Andromeda Nebula*.—Assuming the centripetal acceleration at a distance *r* from the center is equal to the gravitational acceleration due to the mass inside the sphere of radius *r*, an expression is derived for the absolute distance in terms of the linear speed v_0 at an angular distance ρ from the center, the apparent luminosity *i*, and *E*, the energy radiated per unit mass.[303]

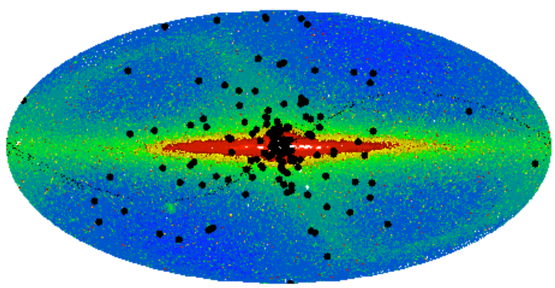
Oepik's original idea, applied locally to Andromeda, was later expanded upon and made practical for great distances by R. Tully at the Observatoire de Marseille in France and J. Richard Fisher of the National Radio Astronomy Observatory (NRAO) in West Virginia. From their 1977 paper:

> We propose that for spiral galaxies there is a good correlation between the global neutral hydrogen line profile width, a distance-independent observable, and the absolute magnitude (or diameter). It is well known that the intrinsic luminosity of a galaxy is correlated with total mass, which is a derivative of the global profile width and is linearly dependent and that comparison of the total mass with such parameters as hydrogen mass, luminosity, and neutral hydrogen surface density can be used as a distance tool.[304]

The Tully-Fisher relation, which recognizes that to close approximation the intrinsic luminosity of spiral galaxies is proportional to the 4th power of the circular velocity ($L \propto V_c^4$) is presently considered one of the more accurate astrophysical secondary distance indicators. Although it is an empirical fact that this relationship holds true (more luminous galaxies spin faster) the theoretical derivation of the relationship is not sensible in that the assumptions do not correlate with the observation that the rotation curves are flat. In particular, the fundamental assumption in the theoretical derivation of the Tully-Fisher relation is that the centripetal acceleration of the *observable luminous matter* and the gravitational acceleration holding the galaxy together are in balance. In other words, the assumption is that the luminous matter dominates the mass of spiral galaxies. However, without the *TGR* effect, the observed flat rotation curves imply that this is impossible. The existence of the transverse gravitational redshift effect, which can be empirically verified by numerous rigorous and repeatable terrestrial experiments, implies that the improbably invisible “dark matter” does not actually exist in any form. Searching for “dark matter” is like searching for heffalumps. The flat velocity profiles of spiral galaxies as well as the observed relationship between luminosity and circular velocity are yet additional quite clear empirical manifestations of the *TGR* phenomenon.

Globular star clusters are observed to be dense generally spherical clusters of up to about one million stars with a diameter typically less than 150 light years, which are apparently bound together by their mutual gravitation. There are over two hundred extended objects identified as globular clusters that orbit the center of the Milky Way Galaxy within a roughly spherical region called the halo. Globular clusters are generally associated with metal-poor Population II stars of roughly similar age that are understood to be an older population of coevolved stars certainly not less than 10 billion (10^{10}) years old.[305] The common old ages of the majority of stars in a globular cluster implies that these stars have all been together from the ancient birth of the cluster, rather than having aggregated over a period of time.

Figure 70 – Distribution of Milky Way globular clusters (black dots) [306]



Courtesy Brian Chaboyer

It is obvious that globular clusters do not “hover” in their presently observed locations; rather, they must orbit the galactic core and have been doing so for billions of years. The majority of them, which can be found near the galactic center, have a calculated galactic orbital period in the tens of millions of years, which means they must routinely pass through a dense ~2,000 light-year thick region of the galactic disk. It follows that a typical globular cluster will have passed through the galactic disk many times over its lifetime. The question arises as to how these clusters remain dynamically stable. Without some mechanism augmenting gravitational attraction, it would be impossible for globular clusters to have remained dynamically stable over time. According to conventional celestial mechanics, repeated passage through the galactic disk would eventually tear a cluster apart by imparting significant gravitational tidal forces and perturbing velocities on its stellar members, yet it is quite clear that this does not happen; globular clusters clearly have retained their generally symmetric shape and star population over any number of galactic orbits.

It is evident that something other than Newtonian gravitation is necessary to keep the constituent stars of globular clusters bound to one another over the lifetime of the cluster. Recall that the transverse gravitational redshift effect is a function of the gravitational field strength and the relative tangential velocity of constituent bodies. Therefore, an increase in velocity will increase the effect, producing a natural trend toward stability, which will tend to bind any potentially errant star to the host cluster. The actual escape velocity of the cluster will be considerably greater than that computed according to conventional Newtonian physics. Celestial mechanics implies that it is impossible for globular clusters to exhibit their apparent long-term dynamic stability without the stability-inducing energy-dissipation effect of *TGR*. It can therefore be inferred that the existence of globular clusters implies the existence of *TGR*.

36. The source of the cosmic microwave background radiation

Transverse gravitational redshift is a clearly observed phenomenon that operates on dynamical gravitational systems. If these systems experience a secular loss of gravitational potential energy, in what other form does this energy manifest? Conservation of energy implies that these systems must radiate significant amounts of energy. Because galaxies are maelstroms of trillions of dynamical gravitational interactions, they must be the source of copious amounts of radiated energy as a consequence of the *TGR* effect. They should be "lit up like Christmas trees" with a radiation that cannot be attributed to stellar emission produced by thermonuclear fusion. As it turns out, nobody can explain the "excess microwave emission" observed to be pouring out of the Milky Way without resorting to outlandish speculation. According to Douglas Finkbeiner, a Hubble Fellow at Princeton and an assistant professor at Harvard's Center for Astrophysics,

> The cause of observed inner galaxy excess microwave emission is assumed to be synchrotron emission from highly relativistic electron-positron pairs produced by dark matter particle annihilation as more conventional sources have been ruled out.[307,308]

If Finkbeiner says, "conventional sources have been ruled out", one can be reasonably certain that they indeed do not exist. However, one still needs to explain where the microwave energy is coming from, so the creative idea of "dark matter particle annihilation" was invented ex nihilo in order to create an ad hoc explanation for the inexplicable "excess microwave radiation".

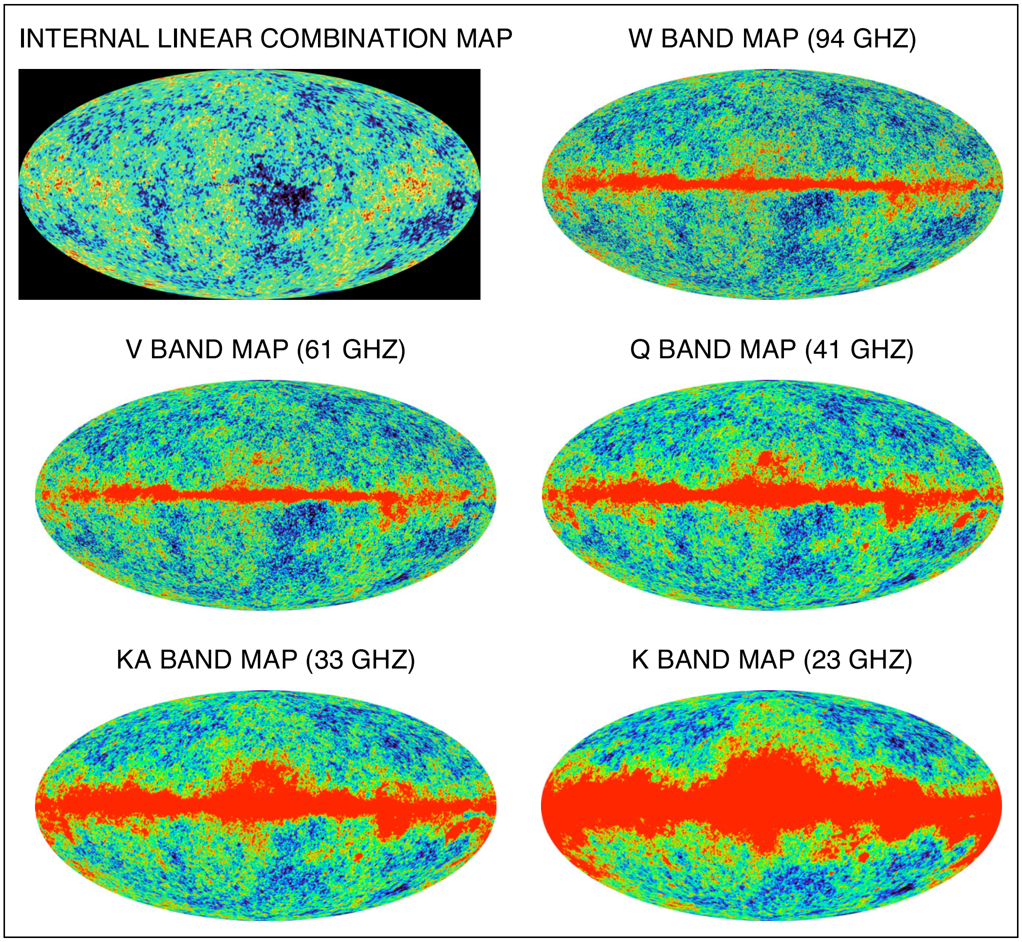
The touted results of the WMAP mission (review *Section 15*) were summarized for the popular press in a single processed digital image described thus (emphasis added).

> The Internal Linear Combination Map is a weighted linear combination of the five WMAP frequency maps. The weights are computed using criteria which *minimize the Galactic foreground contribution* to the sky signal. The resultant map provides a *low-contamination* image of the CMB anisotropy.[309]

The label of "contamination" for empirical data is very likely to be a *subjective* assessment. Removal of empirical data that inconveniently does not fit the theory one is trying to prove is bad science at best. Fig. (71) shows this internal linear combination map framed in black, which has been touted to be the "echo of the Big Bang". The far less well-known individual source maps over five distinct frequencies extending down to the K band are also shown. Each map is an equal-area Mollweide projection that depicts the entire celestial sphere as an oval with the central meridian corresponding to the plane of the Milky Way. The maps exhibit the same linear temperature scale from -200 to 200 μK ($\pm 2\times 10^{-4} K$). The red color represents the "warmer" regions while the blue color represents the "cooler" regions as compared to the median CMBR temperature in green. There is an obvious trend in the data as the frequency is decreased; the galactic foreground contribution (microwave photons sourced from the Milky Way Galaxy itself) exhibits rapid growth toward the cut-off at the midpoint of the microwave band.

Why is there only on the order of 10^{-4} of a degree Kelvin difference in temperature between foreground microwave photons clearly coming from our own galaxy right now and photons imagined to have been sourced as ultra high-energy photons in the purported Big Bang that have suffered extreme redshift into the microwave band? What property of a photon can one examine to definitively identify that it is a "Big Bang photon"? Other than an idea handed down by a series of academic authorities, what observable and testable property today makes a "Big Bang photon" fundamentally different and special from other photons in the all-spectrum background radiation sky? *Nothing*. The only thing that distinguishes such a photon from another is unwarranted *faith* in what has always been a tenuous scientific theory. That theory is based on the assumption that the observed progressive redshift of distant galaxies implies a general expansion and that no possible alternate phenomenon of nature might be found to explain it. That assumption has been debunked. Moreover, observation of ubiquitous energy dissipation in dynamical gravitational systems (*TGR*) suggests a real-time source for the observed CMBR.

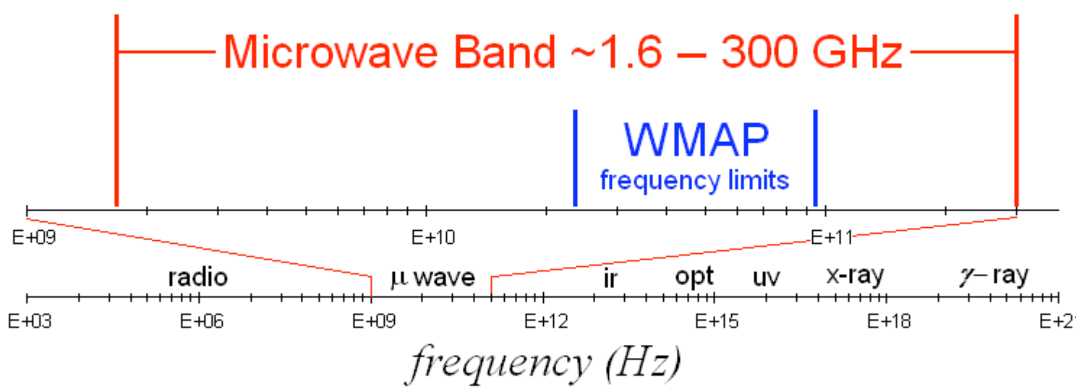
Figure 71 – WMAP full-sky temperature maps (linear scale from -200 to 200 μK)



Courtesy WMAP Science Team[310]

While the microwave radiation spectrum shown in Fig. (72) comprises only a small part of the total spectrum of background radiation in terms of frequency range, having a measured intensity of ~10^{-6} $W/m^2/sr$, ("*sr*" denotes a steradian) it is responsible for the vast majority of the total energy flux of the full spectrum background radiation.[311] In comparison, the total flux of the IR backgrounds determined by COBE add up to less than 10% of this intensity and the flux of the observed diffuse gamma-ray background found by EGRET is about 10^{-6} of the CMB.[312,313,314]

Figure 72 – Truncated WMAP window in the electromagnetic frequency spectrum

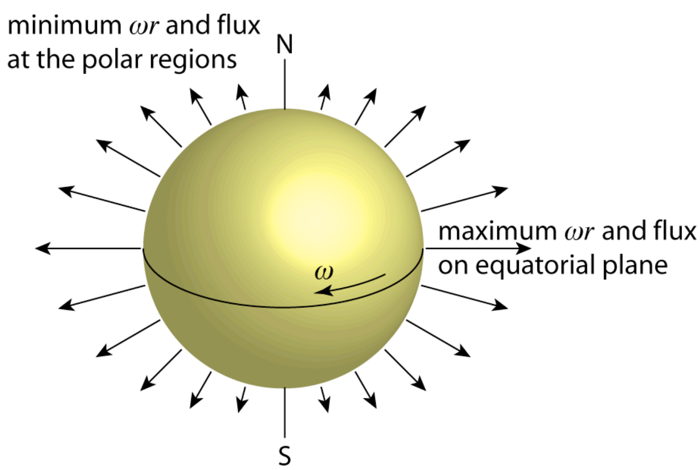


How does one prove scientifically, *beyond reasonable doubt*, that the microwave background radiation, claimed to be "proof" of the Big Bang, has nothing to do with this purported event, which in fact never occurred because "Early Universe" has no meaning?[315]

> – astrophysicists have found that the plane of the solar system threads itself through hot and cold spots in the cosmic microwave background, suggesting that some of the variations in the latter are not caused by events that took place in the early universe.[316,317]

The major *Solar System* source of *TGR* microwave radiation is from the spin-down of the Sun. A secondary source that may be locally detected by an instrument such as WMAP is the radiation produced by Earth's spin-down. As mentioned previously, when a material body spins around an internal axis, this represents mass-energy moving transverse to the gravitational field of the body. Clearly, the maximum velocity will be at the equator and so the maximum *TGR* effect will also occur at the equator. It follows that the maximum correlated microwave radiation flux, which balances the energy budget associated with spin-down, will also occur in the plane of the equator.

Figure 73 – *TGR* microwave radiation flux for a spinning body is a maximum at the equator



Motion of a microwave detector relative to the equatorial plane of a spinning body will lead to predicted *dynamical variations* in the detected flux density of radiation as a function of the detector's latitude. A detector such as WMAP located at L2 will spend six months on each side of the solar equatorial plane. The solar equatorial plane is inclined 7.25º to the Ecliptic and the longitude of the ascending node of the solar equator on the Ecliptic is (75.76º +0.014T) where T is the time in years since J2000.0 (1 Jan. 2000).[318] Note that these are heliocentric ecliptic coordinates and are not to be confused with declination and right ascension. It follows that Earth descends "below" the solar equatorial plane when it passes through $\lambda \approx 76º$ in December and rises "above" the solar equatorial plane six months later in June. In the former case, the solar equatorial plane will be in the north ecliptic hemisphere and in the latter case it will be in the south ecliptic hemisphere. Fig. (74) provides a detailed schematic of the ephemeris.

> Also, in 2003 Hans Kristian Eriksen of the University of Oslo and his co-workers presented more results that hinted at alignments. They divided the sky into all possible pairs of hemispheres and looked at the relative intensity of the fluctuations on the opposite halves of the sky. What they found contradicted the standard inflationary cosmology—the hemispheres often had very different amounts of power. But what was most surprising was that the pair of hemispheres that were the most different were the ones lying above and below the ecliptic, the plane of the earth's orbit around the sun. This result was the first sign that the CMB fluctuations, which were supposed to be cosmological in origin, with some contamination by emission in our own galaxy, have a solar system signal in them—that is, a type of observational artifact.[319]

Figure 74 – South latitudes μ-wave temperature variation calendar at L2 due to solar spin-down

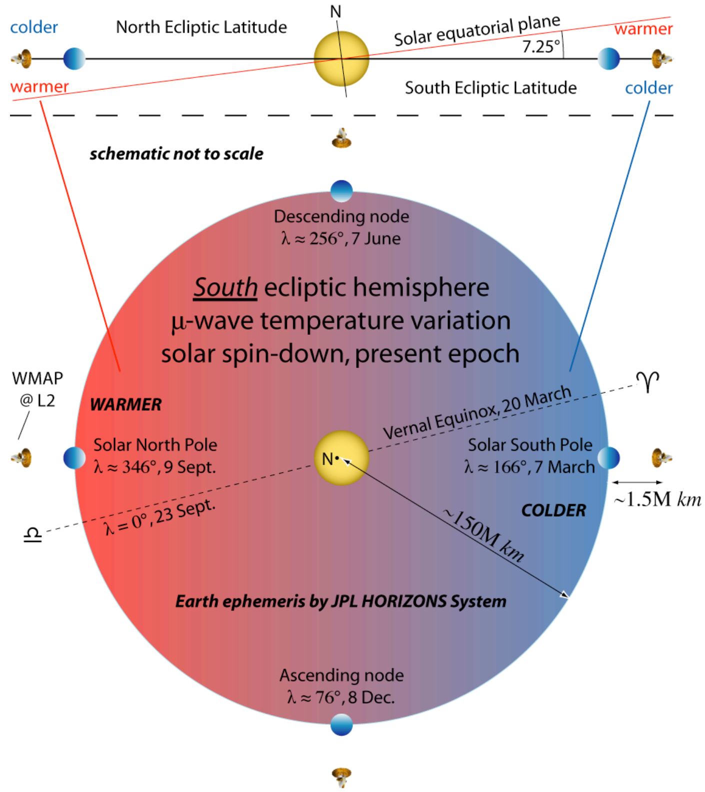
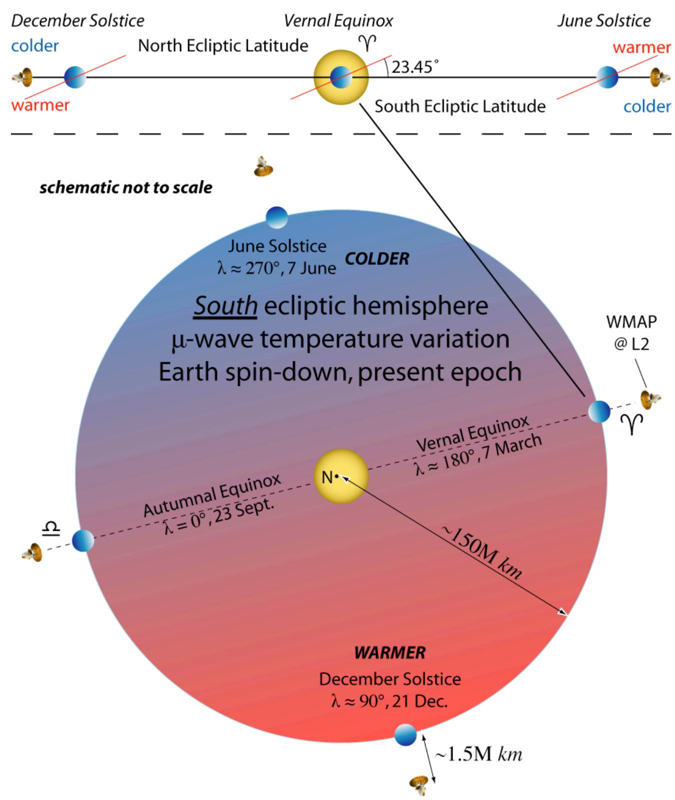


Figure 75 – South latitudes μ-wave temperature variation calendar at L2 due to Earth spin-down



Note that Fig. (74) and (75) refer exclusively to the South ecliptic hemisphere. However, it should be clear that similar temperature variation calendars for the North ecliptic hemisphere are simply polar opposite (i.e., warmer region shown replaced by colder region and vise versa). Also note that in Fig. (74), the 9-o'clock and 3-o'clock positions of the Earth on the Ecliptic disk shown in the lower half of the figure correspond to the left and right sides of the upper half of the figure where the Ecliptic is shown edge-on. In Fig. (75), the orientation of the equinoxes for the disk as shown in the previous figure is preserved, so that that there is no such correspondence.

The following continues extensive quotation of a critical article in the August 2005 issue of *Scientific American* by Starkman and Schwarz entitled, "Is the Universe Out of Tune?" While this journal has a wider target audience than peer-reviewed journals aimed at professional scientists, it offers an important forum for new ideas communicated in a style that facilitates understanding by an interdisciplinary audience. This particular article first revealed to a broader audience that evidence of unconventional origins of the microwave background radiation existed. The entire article can be conveniently downloaded from sciam.com for a nominal fee for non-subscribers. Readers who may not now be among the over half million subscribers to this journal may wish to consider it. Where it appears, the emphasis has been added to the following.

> Meanwhile one of us (Starkman), together with Craig Copi and Dragan Huterer, then both at Case Western Reserve University, had developed a new way to represent the CMB fluctuations in terms of vectors (a mathematical term for arrows). This alternative allowed us (Schwarz, Starkman, Copi and Huterer) to test the expectation that the fluctuations in the CMB will not single out special directions in the universe. In addition to confirming the results of de Oliveira-Costa and company, we revealed some unexpected correlations in 2004. <u>Several of the vectors lie surprisingly close to the ecliptic plane. Within that plane, they sit unexpectedly close to the equinoxes—the two points on the sky where the projection of the earth's equator onto the sky crosses the ecliptic</u>. These same vectors also happen to be suspiciously close to the direction of the sun's motion through the universe. Another vector lies very near the plane defined by the local supercluster of galaxies, termed the supergalactic plane.
>
> Each of these correlations has less than a one in 300 chance of happening by accident, even using conservative statistical estimates. Although they are not completely independent of one another, their combined chance probability is certainly less than one in 10,000, and that reckoning does not include all the <u>odd properties of the low multipoles</u>.[320]
>
> …
>
> At first glance, <u>the discovery of a solar system contaminant in the CMB data</u> might appear to solve the conundrum of weak large-scale fluctuations. Actually, however, it makes the problem even worse. When we remove the part that comes from the hypothetical foreground, the remaining cosmological contribution is likely to be even smaller than previously believed. (Any other conclusion would require an accidental cancellation between the cosmic contribution and our supposed foreground source.) It would then be harder to claim that the absence of low *l* power is just a statistical accident. It looks like inflation is getting into a major jam.
>
> A statistically robust conclusion that less power than expected exists on large scales could send us back to the drawing board about the early universe. The current alternatives to generic inflation are not terribly attractive: a carefully designed inflationary model could produce a glitch in the power spectrum at just the right scale to give us the observed absence of large-scale power, but <u>this "designer inflation" stretches the limits of what we look for in a compelling scientific theory— an exercise akin to Ptolemy's addition of hypothetical epicycles to the orbits of heavenly bodies so that they would conform to an Earth-centered cosmology</u>.[321]

Exhibiting judicious choice of language, the Nobel Committee awarded the 2006 Physics Prize to George Smoot of the University of California at Berkeley and John Mather of the NASA Goddard Space Flight Center specifically "for their discovery of the blackbody form and anisotropy of the cosmic microwave background radiation". Very appropriately, there was no specific mention of how they *interpreted* the data gathered by the COBE and various supporting balloon-borne missions. While this interpretation may be incorrect, none of the discussion in this section would have been possible without the pioneering observational work that was carried out under the leadership of these two Nobel laureates.

Excerpt from *John Mather's Nobel Lecture*:

> [nobelprize.org – video time code of *John Mather Nobel Lecture*; 20:07/34:17] [322]
> So this was the thing [the CMBR blackbody radiation curve] that people recognized as so important. And why was it so important to us? Well, I think the number one thing is that people had been a little worried that the Big Bang was not the right story. There were so many measurements that were a little fuzzy about what the right brightness was that not very long before, there had been measurements including measurements by our group that showed there was a little bit too much radiation out here. And if that were true then the whole deal was off; the Big Bang could not have been the whole story. So, I'll show you a little bit more about what this meant and how we got it.
>
> Just to tell you how we made this processing, we had to sort all the tremendous amount of data out and we had to take out something that has turned out to be a useful effect for other people. Cosmic rays hit the detector and make little bumps of temperature and though you have to find all those and take them out, then we had to make a simultaneous least squares fit, which is basically a model of the sky and a model of the instrument and adjust it all to fit the data. And Dale Fixsen led that team and, uh, it was a huge effort. Anyway, we make the maps. [sic]
>
> Then we take out our understanding of everything else that is going on. The sky is full of dust in between the stars and atoms and molecules between the stars, dust in the space between the planets. Um, there is some kind of far infrared background radiation from other galaxies and there is a small effect of the motion of the Earth through the Universe and all of these things we have to understand and remove and see if there is anything left, um, that would worry us about the Big Bang. And the answer is, uh, nothing was wrong.

Given the assumed origins of the CMBR based on the Big Bang paradigm, it would never have occurred to prior investigators to design an instrument that would be particularly sensitive to measuring a *dynamic* anisotropy of the microwave background relative to the ecliptic plane. Even so, the analyses of the WMAP data conducted by various researchers as summarized by Starkman and Schwarz in *Scientific American* shows that WMAP could still provide the necessary clues as to the true origins of the observed microwave background.

Excerpt from *George Smoot's Nobel Lecture*:

> [nobelprize.org – video time code of *George Smoot Nobel Lecture*; 10:44/44:41][323]
> OK, so, what's the issue for the cosmic microwave background? Basically, you are looking for a very small signal in a very large background plus the noise, that is that noise that comes from your own instrument plus the noise from, from [sic] the environment.
>
> [11:21/44:41]
> ...that meant that the signal was going to be at about a part in ten to the minus six compared to the background radiation that is coming in and so this is the beach party that is going on and you are trying to hear a whisper back of the hall here. And so we had to come up with techniques in order to do that and so the technique is to compare the signal with signals of the same level and what the improvements in the field had been is how to do that and how to improve on that and FIRAS was an extreme example of that. And so you either look at something that is the same temperature as the microwave background or you do what we did, compare one part of the microwave background with another.

> And the other thing you have to do is exclude, reject, average out other signals and sources and that is why the data analysis is so complicated and why it took so long, took such a good team. So if it's easy, try to read it now.
> [George points to an image of the WMAP Internal Linear Combination Map and laughs.]
>
> [30:05/44:41]
> Title of slide shown: *COBE Spectrum of the Universe, First 9 minutes of data*
>
> And this is sort of the spectrum, you'll notice with four hundred times error bars. This we presented results from COBE at the 1990 AAS meeting. John got up and talked before me, and at the end he presented the spectrum. At the end he got a standing ovation, which is one of the few things I've ever, I've ever time, I've ever seen that [sic]. Everybody appreciated how, um, impressive it was.
>
> [31:00/44:41]
> Here is the intensity plot. You can still see the FIRAS curve on here and it just looks like a straight line until you get to the very highest frequency and you see a slight distortion and you see the UBC measurement and see how both of them were very good, but the FIRAS measurement is extraordinary. I mean it really just tied things down, uh, in a very good way and you know, now I'm sort of embarrassed because these points don't exactly line up, but, they, they're within errors, I guess... And so we turn to COBE and talk about the differential microwave radiometer.
>
> [35:56/44:41]
> Eventually we made these maps. I believe these are the two-year or four-year. I forgot the color scheme. You see the dipole, now in galactic coordinates. Here is the galactic plane, looking down the spiral arm one way, the other spiral arm the other way, and then blown up with the dipole removed. You see the variations off the plane, the galaxy showing very dominant, the galaxy masked off.
>
> These are the things we believe are the original, uhh, intrinsic perturbations of the Universe that are reflected in the light coming from the distant Universe. And, we continued on, at the same time we are taking more data with COBE we are doing balloon flights. Here are some pictures from Maxima and BOOMERang of what the sky looked like, and if you looked at the COBE, original COBE map, you will see that you see variations where a bunch of cool areas are collected together and a bunch of warm areas are collected together and that's what you get if you have long waves with small waves superposed on it. If you have a dip and you have wherever there is a dip below it you see a bunch of cool spots and when it goes back warm, you don't see the variations. But likewise on a warm spot, and you have variations, you see the little peaks on it. So you, if you really were good and can do transforms with your eyes, you'd recognize this is a scale invariant spectrum, but when you go and look at the Maxima and the, uh the, BOOMERang max you see a particular scale is picked out. And this is the beginning of not only seeing that there was a primordial perturbations but that there were process, some in the early Universe. [sic]
>
> Beginning to understand what is going on in the Universe.

Actually, there is no possibility of anyone having had an accurate idea about what is going on in the Universe without understanding geometric cosmic time. The COBE and WMAP teams were focused on proving their assumption that the Big Bang did indeed occur. They clearly did not consider that there was even a possibility that the Big Bang theory was incorrect, so they consciously discarded some of the most important information about the cosmic microwave radiation gathered by their instruments as being irrelevant to cosmology. I reiterate the Pioneer Navigation Team's admonition:

> There is always a temptation to eliminate data that is not well explained by existing models, to thereby "improve" the agreement between theory and experiment.

One is inclined to believe that the COBE and WMAP teams presented their colleagues and the world with what they truly believed to be objective scientific data. Because this data, as it was presented, perfectly fit the theoretical predictions, which is what good physics is all about, it seemed that the Big Bang was an empirically proven theory. However, the objectivity of the data was an *illusion*, just like a convincing magic trick that seems real. The observations of the cosmic microwave radiation were so subjectively manipulated in the lengthy data analysis process, that most of the relevant data required to discover the true source of the CMBR was removed. That data analysis process was clearly designed to align the data with the *a priori* concept of what investigators thought was the certain origins of the CMBR. That it could actually be something else was inconceivable to them. Even so, it is virtually impossible to completely remove evidence of the local Solar System contribution to the CMBR, so other teams pouring over the data were able to determine that something was wrong.

Consider that when we look at the Hubble Ultra Deep Field, we are clearly looking exclusively at light with origins long ago and far away. This is because virtually all of the foreground light sources have been purposefully removed, in this case by looking at a tiny region of the sky. This does not mean that the light we see is fundamentally any different from the light that is emitted by our Sun or even a light bulb we observe from a distance of one meter. It has been made very clear that the faint all-sky microwave *background* must be painstakingly extracted using subjective criteria from various much brighter sources of the microwave *foreground*. The idea that these background microwave photons have a unique singular source (i.e., the purported Big Bang) and that there is therefore no connection whatsoever between the microwave background and significant portions of the microwave foreground is an *assumption*. It may be readily proven by various empirical observations that this assumption is patently incorrect.

Fig. (74) is clear as concerns anticipated *dynamical variations* in measurements of cosmic microwave radiation from an instrument located in Antarctica. If the spin-down of the Sun produces a maximum microwave radiation flux in the solar equatorial plane as predicted, then such an instrument will record seasonal variations in the microwave temperature of the southern ecliptic hemisphere with transitions occurring in the first part of June and December. The microwave temperature of the southern sky will be somewhat colder in the first half of the year and somewhat warmer in the latter half. The Center for Astrophysical Research in Antarctica (CARA) currently maintains three complementary microwave observatories, Viper, DASI and ACBAR. A fourth observatory to study the CMBR (the South Pole Telescope) achieved first light in February 2007.[324] Data from one or more of these observatories should be able to verify or disprove the unambiguous prediction of seasonal variations in the microwave brightness of the southern sky. It would never have occurred to anyone in the past to look for dynamical variations in cosmic microwave radiation when it was assumed that there could be no possible connection between the CMBR and real-time processes occurring locally and in the current epoch.

The stable L2 Lagrange point where WMAP orbits is located 1.5 million kilometers beyond the Earth, an increase of about 1% as compared to Earth's solar orbital radius. As shown in Fig. (75), this means that WMAP spends six months of the year in the northern half of the celestial sphere, "above" Earth's equatorial plane and six months in the southern half, "below" the equatorial plane. Given that the spin-down of the Earth generates a microwave radiation flux that is a maximum in its equatorial plane, measurement of microwave radiation brightness of the *southern* ecliptic hemisphere will be warmer during the half of the year centered about the December solstice and colder during the other half of the year centered about the June solstice. Contrariwise, the microwave radiation brightness of the *northern* ecliptic hemisphere will be warmer during the half of the year centered around the June solstice and colder during the other half of the year. This predicted measurement will, of course, be superimposed on the similar effect due to solar spin-down [Fig. (74)], which is 104° of Earth's annual solar orbit out of phase with the effect due to Earth spin-down. The predicted dynamic anisotropy measurements relative to the Ecliptic plane shown in Fig. (74) and (75) are unambiguous. This signature can be attributed to no other possible phenomenon than the *TGR* spin-down of the Sun and the Earth.

From study of Fig. (74) and (75), it should be clear that observations of the CMBR over a period of one year that are analyzed for previously unanticipated *dynamic* variation will reveal two superimposed smooth sinusoidal temperature variations of either choice of north or south ecliptic hemispheres of the sky that are approximately 104º out of phase with one another. The two annual local maxima of the CMBR for the *South* ecliptic hemisphere of the sky will occur around the dates of 9 September and 21 December. The complimentary corresponding local minima will occur around the dates of 7 March and 7 June.

A suitable microwave detector in a polar or high inclination orbit can independently verify the *TGR* phenomenon, which results in peak microwave radiation brightness in the equatorial plane of a rotating astrophysical body. Three such suitable detectors that exist include the Defense Meteorological Satellite Program (DMSP) Special Sensor Microwave/Imager (SSM/I) in polar orbit around the Earth, the Advanced Earth Microwave Scanning Radiometer (AMSR) on-board Japan's Midori-II satellite and the RADAR instrument aboard Cassini, when the spacecraft it is put in a high inclination orbit around Saturn. It may also be possible to verify from ground-based observations, perhaps even by amateur radio astronomers, that the equatorial plane of the Moon has measurably greater microwave brightness than its polar regions. However, due to the low mass and slow rotation of the Moon, the expected flux gradient may be difficult to observe.

It should be clear that in addition to spin-down, secular decay of all orbits due to *TGR* also results in emission of electromagnetic radiation. It is for this reason that our galaxy is observed to be a source of unexplained microwave radiation and why galaxy clusters are associated with *high-energy* "holes" in the CMB. The field of view of the *Hubble Ultra Deep Field* (HUDF) image is about 10^{-10} (1 ten millionth) of the total sky. Within this image, about 10,000 discrete objects (i.e., galaxies) have been counted, though most of them are said to be many orders of magnitude smaller than the Milky Way. Yet, the HUDF still suggests that there are on the order of 100 *billion* distinct galaxies in the observable Universe. The grey circle in Fig. (28), which represents the total observable Universe within the Milky Way's cosmological redshift horizon has an area of 6,567 square millimeters as it is printed on the page. In order for this circle to represent a total galaxy population of 100 billion, at this scale there must be a uniform density of about 15.2 million galaxies per square *millimeter* within the circle. Recall that for the Minkowski cosmology, there is no intrinsic difference between the nearby Universe and the high-redshift Universe. Each galaxy and also each cluster is a source of copious radiation just as is observed for the Milky Way in Fig. (71). It is not difficult to visualize that the cosmic microwave background radiation has nothing whatsoever to do with the purported Big Bang, which never occurred; the CMB is continuously produced. Both the Sachs-Wolfe Effect (uneven CMB spectrum attributed to gravitational redshift) and the Sunyaev-Zeldovich Effect (galaxy clusters exhibit a higher energy "hole" in the microwave background) are misinterpretations of the observables based on the *a priori* assumption of the origins of the CMB.

It should come as no great surprise that the observed cosmic microwave background radiation is the actual manifestation of the so-called "gravitational radiation" that has been long sought by astrophysicists. Misguided by assumptions of general relativity's infallibility as it was posed and interpreted in the past, it was never suspected that energy transfer inherent to dynamical gravitational systems manifests in the form of readily perceptible ubiquitous *electromagnetic* radiation that manifests primarily in the microwave region. This phenomenon is the empirical manifestation of an intimate connection between electromagnetism and gravity.

The various observatories around the world built to detect the assumed perturbing effects of "gravitational waves" using interferometry techniques are unfortunately white elephants that have never detected these waves and will certainly never detect them as they are designed to measure an imagined phenomenon that does not actually exist. Although it will be a hard blow for some, it will soon be clear to the scientific community that allocation of capital and human resources for these projects should be terminated at the earliest possible opportunity. In particular, the plan to upgrade LIGO to "Advanced LIGO" must be understood by all concerned, including taxpayers, to be a useless exercise. The National Science Foundation (NSF) has already spent more than $365 million (in 2002 USD) on the project.[325] There is nothing wrong with making a mistake in science, even a big mistake. However, backing bad science due to the inability to comprehend important new developments or for political reasons is a "career-limiting move" for a young investigator. Ultimately, the scientific profession has nothing to do with the politics of human relationships or claims of authoritative expertise; it is about what is empirically correct.

The prediction of peak microwave brightness in the equatorial plane of the Sun, the Earth and other rotating Solar System bodies can be rapidly verified. The development of a thorough theoretical model of electromagnetic radiation associated with the *TGR* phenomenon, beyond the informal qualitative understanding initially discussed here, will be one of the foremost problems of our time in theoretical physics. When achieved, it will provide understanding of a *connection* with electromagnetism and gravity, though arguably no *unification* between them.

37. Abundance of the light elements

Upon initial formation by gravitational collapse of a large mass of interstellar gas, all stars begin to generate energy by a process of nuclear fusion whereby hydrogen is converted into helium. It is currently understood that stars that are less than about 1.4 times the size of the Sun with lower core temperatures employ a slower fusion chain reaction while larger stars with higher core temperatures employ a much faster chain reaction. Larger stars, though they may have a much bigger fuel supply, consume their hydrogen fuel much faster and are much shorted lived than smaller stars.[326] The solar wind has been measured by count to be approximately 95% protons (H^+), 4% alpha particles (He^{++}) and 1% minor ions, of which carbon, nitrogen, oxygen, neon, magnesium, silicon and iron are the most abundant.[327] In contrast, spectroscopy of the Sun indicates a relative abundance by weight of ~70.6% hydrogen, ~27.5% helium, ~1.0% oxygen, ~0.3% Carbon, ~0.2% Neon ~0.1% Iron, with the remaining ~0.3% composed of about sixty additional trace elements.[328] Looking out at the Universe, we see in the most general terms that it is made up mostly of hydrogen (H) atoms with a single proton in the nucleus and for about every ten of these there is one helium (He) atom with two protons and two neutrons in the nucleus. Depending on where we choose to look, the Universe seems to be generally somewhere in the neighborhood of 70-75% H and 23-28% He by weight with only 2% attributable to all of the other elements combined.

If we presuppose that the Universe is only on the order of about fifteen billion years old according to 20^{th}-century ideas, then there is not enough time for the observed amount of helium to have been synthesized in the stars. However, this so-called "helium problem" is of lesser concern if this age constraint is removed. Although it has been argued otherwise, a remaining problem that arguably cannot be elegantly removed by allowing for more time is the observation of trace amounts of naturally occurring deuterium or "heavy hydrogen" (^2H) and other light element isotopes including helium-3 and lithium-7 (^3He, ^7Li).[329] A very high temperature plasma (~10^9 K or ~0.1 Mev) of free protons and neutrons ($p + n$) that cools rapidly is understood to be one process that will lead to the nucleosynthesis of the light elements.[330] The high temperatures required for the following reaction sequence to take place are not found in stars and in any case, deuterium production apparently requires an environment of high energy coupled with low density.[331] The observed existence of the light elements cannot be due to normal processes in stellar evolution particularly because typical stellar evolution involves destruction of deuterium. In the following nuclear reaction equations, the symbol γ represents a high-energy *gamma* ray, which generally exceeds ~100 keV.

$$p + n \rightarrow {}^{2}H + \gamma \qquad 82$$

$${}^{2}H + {}^{2}H \rightarrow {}^{3}He + n \quad \& \quad {}^{3}H + p \qquad 83$$

$${}^{2}H + \left(p,\ {}^{3}H,\ {}^{3}He\right) \rightarrow \left({}^{3}He + \gamma,\ {}^{4}He + n,\ {}^{4}He + p\right) \qquad 84$$

$${}^{3}He + {}^{3}He \rightarrow {}^{4}He + 2p \qquad 85$$

Note that deuterium (^{2}H) and 3-helium (^{3}He) are primarily destroyed with the main effect of building up neutral helium (^{4}He). In this reaction sequence, tritium (^{3}H) is an essential ingredient in the creation of lithium-7, which in turn is used to create helium.[332]

$${}^{4}He + {}^{3}H \rightarrow {}^{7}Li + \gamma \qquad 86$$

$${}^{4}He + {}^{3}He \rightarrow {}^{7}Be + \gamma \qquad 87$$

$${}^{7}Be + n \rightarrow {}^{7}Li + p \qquad 88$$

$${}^{7}Li + p \rightarrow 2\,{}^{4}He \qquad 89$$

With the basic idea that stars create energy by thermonuclear fusion having already been worked out starting with the early pioneering investigations of Arthur Eddington, George Gamow was primarily concerned in the late 1940s with the problem of nucleosynthesis.[333] A 1948 article in *Nature* summarized ideas presented in three previous papers that year in *Physical Review*.[334] The important work of creating the modern view of primordial nucleosynthesis was developed by a number of contributors as described by Schramm and Wagoner (1977).[335] Even if the actual cause of the physical environment required to effect the processes described by theoretical investigators is different from what they imagined (a primordial "Big Bang") their contribution to fundamental scientific understanding is of immense value. It became immediately apparent that in their nuclear reactions, stars typically consume rather than produce deuterium, so where did the deuterium that we observe come from? The idea that a very high temperature is needed that is simply not available in any stars combined with the idea that the galaxies seemed to be expanding from a common point in space and time implied that the only natural occurrence of the necessary plasma temperatures was a very dense and hot "primeval fireball" that started the Universe. While the nuclear reactions of very high temperature plasmas are relatively well understood, over half a century after George Gamow initiated the investigation of Big Bang nucleosynthesis, there is still considerable ongoing debate as to how the observed abundances were created.

> A significant discrepancy between the calculated ^{7}Li abundance deduced from WMAP and the Spite plateau is clearly revealed. To explain this discrepancy, three possibilities are invoked: systematic uncertainties on the Li abundance, surface alteration of Li in the course of stellar evolution, or poor knowledge of the reaction rates related to ^{7}Be destruction. In particular, the possible role of the up to now neglected ^{7}Be $(d, p)\ 2\alpha$ and ^{7}Be (d, α) ^{5}Li reactions is considered. Another way to reconcile these results coming from different horizons consists of invoking new, speculative primordial physics that could modify the nucleosynthesis emerging from the big bang and perhaps the CMB physics itself.[336]
>
> ——
>
> Other than the blackbody spectrum of the microwave background, there is very little evidence in support of the nearly universally accepted hot Big Bang model of cosmology– the "standard" model. Primordial nucleosynthesis provides a unique opportunity to test the assumptions of the standard model, serving as it does, as a probe of the physical conditions during epochs in the early evolution of the Universe that would otherwise be completely hidden from our scrutiny.[337]

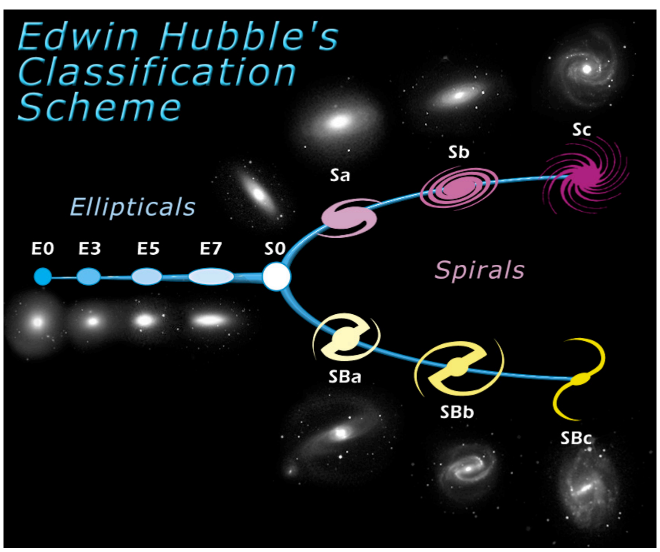
We consider inhomogeneous big bang nucleosynthesis in light of the present observational situation. Different observations of ^4He and D disagree with each other, and depending on which set of observations one uses, the estimated primordial ^4He corresponds to a lower baryon density in standard big bang nucleosynthesis than what one gets from deuterium. Recent Kamiokande results rule out a favorite particle physics solution to this tension between ^4He and D.[338]

Currently, it is generally held that there is no alternative to Gamow's hot primeval fireball for synthesizing deuterium, but we shall find that this is not the case according to observational evidence. George Gamow's ideas concerning the source of the temperature requirements of nucleosynthesis germinated more than a decade before Thomas Matthews and Alan Sandage discovered "radio stars", now called quasi-stellar objects (QSO) or more familiarly "quasars", which are currently understood to be a subset of active galactic nuclei (AGN).[339] In 1962, Martin Schmidt obtained a spectrum of object 3C 273 (object #273 in the 3rd Cambridge Catalogue) and found it to have a $z = 0.158$ redshift. Given its observed linear flux of about 29×10^{-14} *ergs cm*$^{-2}$, this implied an intrinsic luminosity far greater that of the entire Milky Way Galaxy.[340,341] Even if the distance to this object is somewhat less than estimated, its intrinsic luminosity would still be inexplicable. AGN, some of which are associated with enormous relativistic mass outflows from a small volume of space, typically in the form of long thin jets, are quite obviously natural sources of temperatures high enough to meet Gamow's nucleosynthesis needs, but in 1948 he knew nothing about them. The proposed correction of the general theory of relativity must change our ideas concerning the nature of active galactic nuclei. This will be discussed in the following section together with the most recent observational evidence, which indicates that some AGN are associated with deuterium production.

38. Galaxy evolution and mophology

Speculation on the lifecycle of galaxies began in 1926 when Edwin Hubble put forward his famous "tuning fork" diagram including the explicit proposition that galaxy evolution takes place starting from "early types" on the left of the diagram and evolving to "late types" on the right. A clear distinction was drawn between two apparent evolutionary paths in the creation of spirals, those exhibiting a bar through their center (SB-type) and those that do not (S-type).

Figure 76 – Hubble "tuning fork" diagram



Courtesy NASA & STScI[342]

Modern observational evidence implies that Hubble's idea that "late-type" spiral galaxies evolve from "early-type" ellipticals is precisely the opposite of the actual evolutionary sequence. It is now well known that spiral galaxies exhibit profuse amounts of gas and dust with the characteristic arms harboring stellar "nurseries" of active new star formation. In contrast, elliptical galaxies have a characteristic paucity of gas and dust and spectroscopic studies indicate a more mature system with minimal new star formation. Giant cluster-dominating (cD) elliptical galaxies, which may exhibit multiple galactic nuclei, are typically found at the centroid of rich galaxy clusters, surrounded by smaller ellipticals and a halo of outlying spiral galaxies. Size, morphology and stellar velocity profiles strongly suggest that elliptical galaxies have typically formed over a long time from the merger of other galaxies, generally spirals.

The current state of observational astronomy, which has benefited from late 20th-century advances, implies that galaxy evolution and morphology is radically different and considerably more complex than Hubble imagined. The spiral arms of barred galaxies typically emanate from the ends of the bar and most spiral galaxies exhibit some of the characteristics of the barred variety with the SB-types merely representing the extreme examples, so Hubble's broad distinction between the two morphologies is almost certainly incorrect. Based on Doppler data, the average rotation period for a spiral galaxy is quite short relative to the age of its constituent stars (e.g., the Sun's galactic rotation period is estimated to be about 250 million years) therefore, many rotations must have occurred for a typical spiral galaxy. Then, contrary to intuition, the spiral arms do not wind up commensurately with the observed differential rotation of the inner and the outer regions. The spiral arms are currently understood to manifest due to the systematic radial change in the orientation of elliptical galactic orbits of stars and gas. This creates natural spiral-shaped density waves creating periodic enhancements in the background stellar distribution and regions of enhanced star formation. Galaxies with conspicuous central bulges tend to have more tightly wound spiral arms and the "earlier" the stage according to Hubble's system, the larger the bulge fraction (the fraction of galactic light sourced from its bulge).[343] The spiral arms are trailing, i.e., stellar orbits are counterclockwise in Fig. (77).

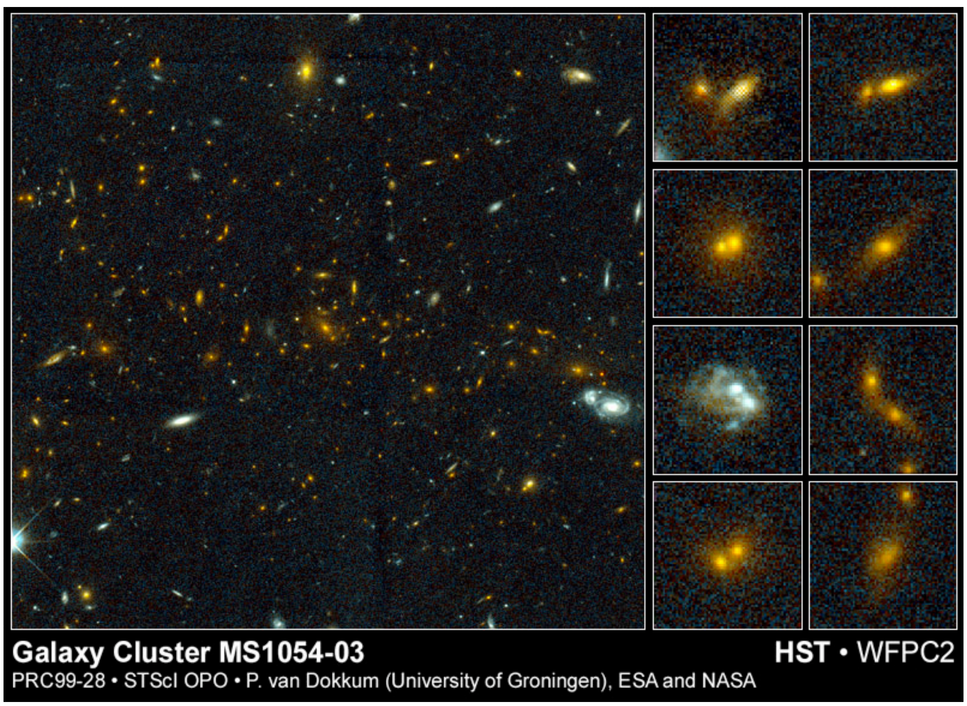
Figure 77 – Spiral Galaxy NGC 5194 (M51)

Courtesy NASA, ESA & STScI[344]

Figure 78 – A merger of two spiral galaxies (NGC 2207 and IC 2163) in progress

Courtesy NASA, ESA & STScI[345]

Figure 79 – Ancient galaxy mergers observed within a large distant cluster



Courtesy P. van Dokkum, NASA, ESA & STScI[346]

The morphological type of a galaxy is clearly associated with the density of the region within which it is found. Galaxies in clusters are far more likely to be ellipticals or of type SO and observations are consistent with their being essentially no spiral galaxies in the cores of regular clusters. A galaxy's radius within a cluster is the primary factor that dictates its morphology. Moreover, there is a correlation between the morphology of the cluster and the morphology of its constituent galaxies. The higher the percentage of ellipticals in a cluster, the more symmetrical the cluster is observed to be. This very strongly suggests that elliptical galaxies are in general intrinsically older than spiral galaxies, that larger ellipticals formed by multiple mergers are older still than smaller ellipticals and that more symmetric galaxy clusters are older than those clusters that have a more haphazard architecture.

The Big Bang paradigm suggested that galaxies originally all formed at approximately the same time from the gravitational collapse of protogalactic masses of hydrogen gas. There are so many confrontations between this idea and empirical observations, as well as basic theoretical considerations, that it is difficult to believe that it was seriously considered for so many decades. Primarily, the idea cannot explain the various structures observed which cover the scale extending from globular clusters of stars in galactic halos to enormous superclusters that tie together numerous smaller clusters of many galaxies. The huge variation in the intrinsic ages of these structures based on dependency relationships is immediately apparent: elliptical galaxies are formed by the merger of old fully-formed spiral galaxies, elliptical galaxies merge to form still more massive ellipticals, jagged clusters become symmetric over eons, etc. However, the social and cultural blinders of the dominant paradigm were so effective during the 20th century that the overwhelming empirical evidence against the Big Bang was essentially disregarded.

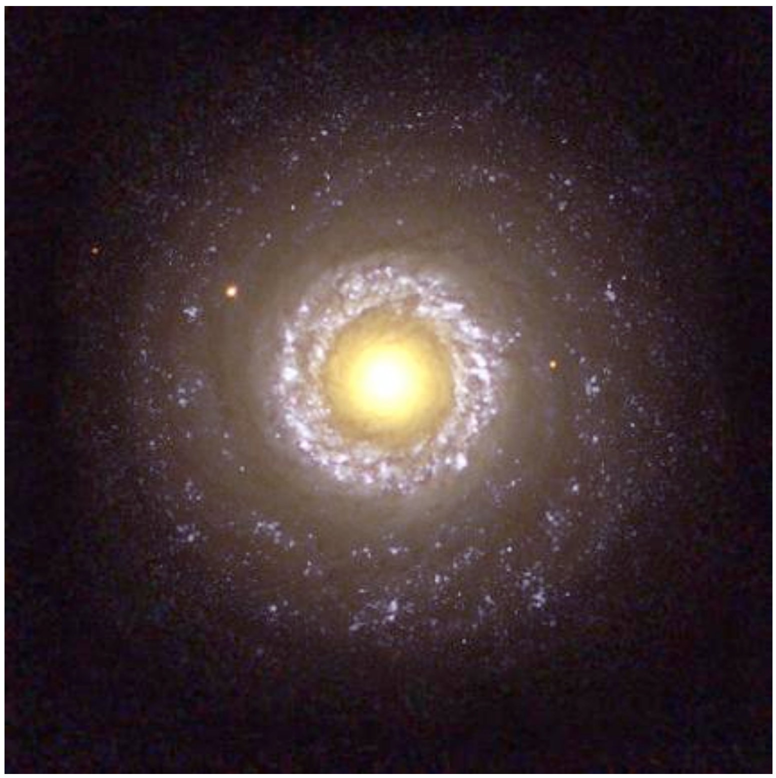
Figure 80 – Dramatic view of the flattened disk of a spiral galaxy (M104)

Courtesy NASA, STScI/AURA[347]

Observational astronomy has made it quite clear at this point that younger galaxies are typically spirals with a characteristic flat disk. How do these disks form? The answer is obvious based on what we see. Similarly, the historical fact of continental drift is rather obvious when one considers that the continents of Africa and South America quite clearly fit together at some time in the past. — It is quite certain that two opposing jets of effluent matter emanating from a typical active galactic nucleus build the plane disks of spiral galaxies from the inside out. As we shall see in the next section, conservation of mass is not an issue *cosmologically* as there is a relationship between large black holes, which "eat" old galaxies and white holes, which create new galaxies. These disks were most certainly not formed by gravitational collapse of a hydrogen gas cloud, first because there never was a Big Bang and second because gravitational collapse tends to create spherically shaped things, not flat disks. However, jets from a central source, will quite *naturally* create a self-gravitating rotating plane disk of matter over time and we know that such effluent jets exist because we see them. New youthful galaxies are observed in the local Universe all the time; they are called Seyfert galaxies, which are generally associated with massive star formation and make up about two to three percent of the local galaxy population.[348,349] Moreover, we see these same nascent galaxies all over the Universe. As was made clear earlier, "quasars" are just distant AGN of the local variety that have been misinterpreted to be a distinct class of object orders of magnitude brighter than they are in reality due to a faulty redshift-distance scale.

> We argue that the narrow-line regions (NLRs) of Seyfert galaxies are powered by the transport of energy and momentum by the radio-emitting jets. This implies that the ratio of the radio power to jet energy flux is much smaller than is usually assumed for radio galaxies. This can be partially attributed to the smaller ages of Seyferts compared to radio galaxies, but one also requires that either the magnetic energy density is more than 1 order of magnitude below the equipartition value or, more likely, that the internal energy densities of Seyfert jets are dominated by thermal plasma, as distinct from the situation in radio galaxy jets where the jet plasma is generally taken to be nonthermally dominated. If one assumes that the internal energy densities of Seyfert jets are initially dominated by relativistic plasma, then an analysis of the data on jets in five Seyfert galaxies shows that all but one of these would have mildly relativistic jet velocities near 100 pc in order to power the respective narrow-line regions. However, observations of jet-cloud interactions in the NLR provide additional information on jet velocities and composition via the momentum budget.[350]

Figure 81 – Seyfert galaxy NGC 7742

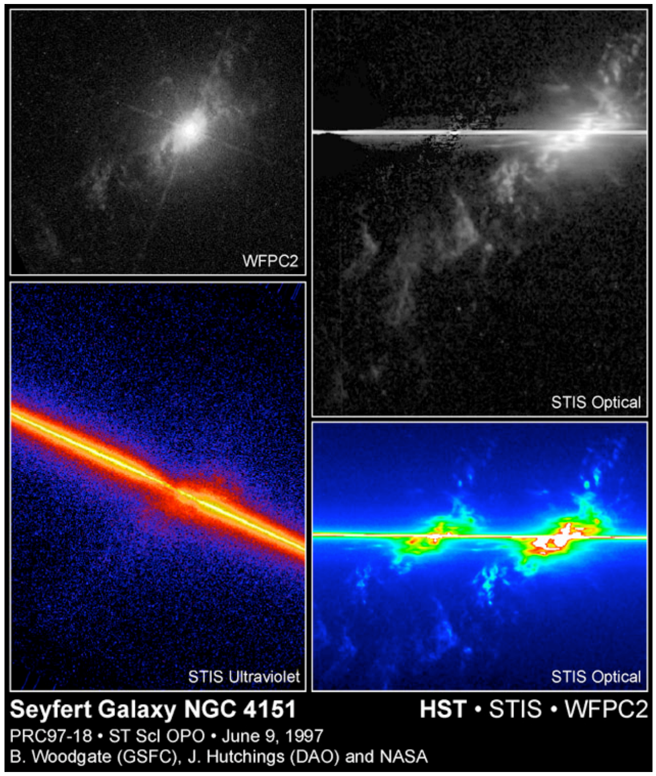


Courtesy NASA, STScI/AURA[351]

The caption to Fig. (82), which follows, appears below.

> The Hubble telescope's imaging spectrograph simultaneously records, in unprecedented detail, the velocities of hundreds of gas knots streaming at hundreds of thousands of miles per hour from the nucleus of NGC 4151, thought to house a super-massive black hole. This is the first time the velocity structure in the heart of this object, or similar objects, has been mapped so vividly this close to its central black hole.
>
> The heart of NGC 4151 was captured in visible light in the upper left picture. In the other images, Hubble's imaging spectrograph has zeroed in on the galaxy's active central region. The Hubble data clearly show that the some material in the galaxy's hub is rapidly moving towards us, while other matter rapidly receding from us. This information is strong evidence for the existence of a black hole, an extremely compact, dense object that feeds on material swirling around it.[352]

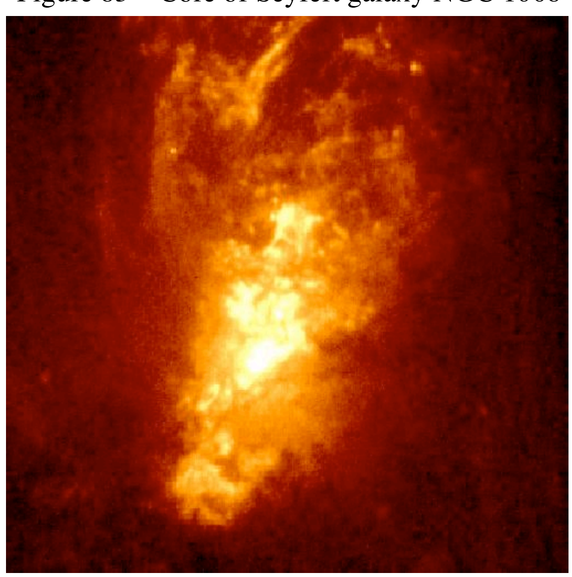
Figure 82 – Core of Seyfert galaxy NGC 4251



Courtesy NASA & STScI[353]

It is not a black hole consuming mass-energy that astronomers are looking at in the heart of Seyfert galaxies, it is a white hole that is ejecting enormous amounts of matter and literally building the young spiral galaxy from the inside out. However, without the required correction of Einstein's gravitational theory, white holes did could not exist in the minds of astrophysicists and astronomers even though they have been observing their rather obvious signature property of massive *efflux* for a number of decades.

Figure 83 – Core of Seyfert galaxy NGC 1068



Courtesy NASA, ESA & STScI[354]

> A representative sample of 12 extended quasars from the 3CR catalog has been imaged at 4.9 GHz using the VLA [Very large Array]. … Jets are detected on at least one side of every source. The jets are well collimated compared with those in less powerful sources, but spreading is detected in most of them. The opening angles of several jets are not constant, but show recollimation after an initial regime of rapid spreading. … The correlations between the prominence and sidedness of the large-scale straight jet segments and of the small-scale central features favor models in which kiloparsec-scale jets initially have bulk relativistic velocities.[355]

As discussed previously, the nucleosynthesis of deuterium and other light elements requires a very high temperature, exceeding that found even at the core of large stars. Moreover, this initially very hot and dense plasma must cool rapidly in a low-density environment. Anyone with even a meager knowledge of thermodynamics knows that rapid free expansion of a high-pressure jet is an excellent way to achieve such cooling. A jet or jets of effluent matter from a central white hole is also a natural means and arguably the only *realistic* means of creating a rotating flat disk of gas and dust in space. The obvious conclusion one may draw from this scenario is that the disk will exhibit an inexplicably high concentration of deuterium and the other light elements including the high percentage of helium. That evidence comes from our own galaxy.

> The Galactic Centre is the most active and heavily processed region of the Milky Way, so it can be used as a stringent test for the abundance of deuterium… As deuterium is destroyed in stellar interiors, chemical evolution models predict that its Galactic Centre abundance relative to hydrogen is $D/H = 5 \times 10^{-12}$, unless there is a continuous source of deuterium from relatively primordial (low-metallicity) gas. Here we report the detection of deuterium (in the molecule DCN) in a molecular cloud only 10 parsecs from the Galactic Centre. Our data, when combined with a model of molecular abundances, indicate that $D/H=(1.7\pm0.3) \times 10^{-6}$, five orders of magnitude larger than the predictions of evolutionary models with no continuous source of deuterium. The most probable explanation is recent infall of relatively unprocessed metal-poor gas into the Galactic Centre (at the rate inferred by Wakker). Our measured D/H is nine times less than the local interstellar value, and the lowest D/H observed in the Galaxy…
>
> The Galactic Centre … has a higher abundance of elements heavier than He (metallicity), faster star formation rate, and steeper initial mass function. Thus the astration (recycling) rate in the Galactic Centre should be considerably larger than elsewhere in the Galaxy, resulting in a reduced D abundance. Chemical models at 12 Gyr of the Galactic bulge and the Galactic Centre predict the almost total destruction of deuterium giving $D/H = 3.2 \times 10^{-11}$ and $D/H = 5 \times 10^{-12}$, respectively. Thus if there were no additional sources of D, the Galactic Centre molecular clouds should be composed primarily of astrated material completely depleted in D, and DCN should not be detectable. Thus the mere detection of D (in DCN) in the Sagittarius A molecular clouds requires a continuous source of deuterium to negate the effects of astration. Alternatively, if D is produced by any stellar or Galactic process, then it should be more abundant in the Galactic Centre and there should be a corresponding gradient in the D abundance.[356]

In contrast to prior conventional explanations for these observations, we may conclude that the original source of the deuterium and other light elements observed in the Milky Way was its historical active galactic nucleus characterized by rapidly expanding and cooling jets of material. This phase of its evolution occurred long ago and significantly higher astration in the region of the core has caused the observed radial gradient. Additional corroborating evidence for this idea is found in observations of quasar (distant Seyfert AGN) radiation. As distance can no longer be associated with "lookback time", these observations take on new meaning. The concept of "primordial" has only local meaning, and certainly has no meaning in a cosmological context. The following is taken from a 1994 article in *Nature* entitled "Deuterium abundance and background radiation temperature in high-redshift primordial clouds".

> We have now finally obtained data of the required quality, using the recently introduced high spectral resolution spectrograph on the Keck 10-m telescope (Mauna Kea, Hawaii), and report here the result of the first measurements, based on one night of data. We find absorption consistent with a detection D/H ≈ (1.9-2.5)x10^{-4} in a chemically unevolved cloud in the line of sight of the quasar Q0014+813; because in any single instance we cannot rule out the possibility of a chance H contamination at exactly the D velocity offset, this result should be considered as an upper limit until further observations of other systems are made.[357]

39. Cosmic dynamical stability

If the Cosmological Principle is "perfect" such that Universe is homogeneous, isotropic and has been in dynamic equilibrium for all time (i.e., eternity) the question arises as to how cosmic gravitational collapse is prevented. The answer is intuitive and beautiful.

For the purposes of investigating basic aspects of the strong field limit (i.e., a black hole), it is not necessary to derive the applicable metric from scratch. We know that the first two terms of the Schwarzschild metric (52) are already correct and that the error in the two transverse terms is that the identical relativistic expansion of these dimensions commensurate with the expansion of the radius was simply left out. That is, the coefficient to these terms should be the physical radius of the idealized point mass, not the coordinate radius. If we denote the physical radius by ρ, and apply the convenient conventions of setting both G and c to unity, then we have

$$d\rho^2 = \left(1 - \frac{2M}{r}\right)^{-1} dr^2 \qquad 90$$

$$d\rho = \left(1 - \frac{2M}{r}\right)^{-\frac{1}{2}} dr \qquad 91$$

Integrating Eq. (91) with Mathematica® and simplifying yields

$$\rho = \frac{1}{\sqrt{r-2M}}\left(\sqrt{r}(r-2M) + 2M\sqrt{2M-r}\left[\tan^{-1}\left(\frac{\sqrt{r}}{\sqrt{2M-r}}\right)\right]\right) \qquad 92$$

$$\rho^2 = r(r-2M) + 4M\sqrt{r}\sqrt{2M-r}\left[\tan^{-1}\left(\frac{\sqrt{r}}{\sqrt{2M-r}}\right)\right] - 4M^2\left[\tan^{-1}\left(\frac{\sqrt{r}}{\sqrt{2M-r}}\right)\right]^2 \qquad 93$$

$$\rho^2 = r(r-2M) + 4M\tan^{-1}\left(\frac{\sqrt{r}}{\sqrt{2M-r}}\right)\left[\sqrt{r}\sqrt{2M-r} - M\tan^{-1}\left(\frac{\sqrt{r}}{\sqrt{2M-r}}\right)\right] \qquad 94$$

Evaluating ρ^2 at the boundary $r = 2M$ yields

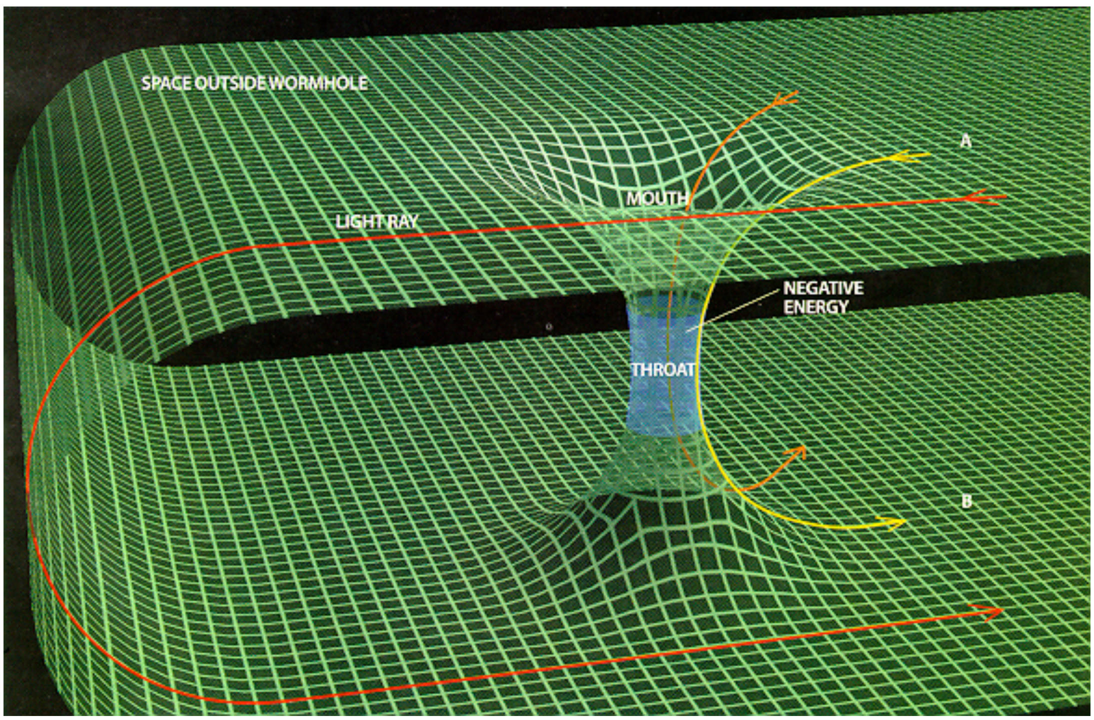
$$\rho^2(2M) = 0 + 4M\frac{\pi}{2}\left[0 - M\frac{\pi}{2}\right] = -M^2\pi^2 \qquad 95$$

$$\to \rho(2M) = iM\pi \qquad 96$$

The imaginary coefficient implies a ninety-degree rotation in spacetime, which effectively converts a space coordinate into a time coordinate. This, of course, is exactly what is needed, because the radius of a black hole's horizon is time-like from the point of view of an observer far away from the hole. That is, the time coordinates at the horizon correspond to what are space coordinates for the observer far away from the hole.

In 1935 Einstein and his long-time collaborator Nathan Rosen published a paper based in large part on the work done by Karl Schwarzschild in which they showed that the Schwarzschild singularity could not exist and that implicit in the general relativity formalism is a curved-space structure that can join two distant regions of spacetime through a tunnel-like curved spatial shortcut.[358] The schematic in Fig. (84) shows the conventional *hypothetical* model of a Schwarzschild wormhole or "Einstein-Rosen Bridge" between two distinct regions of spacetime where there is a black hole (*A*) and a white hole (*B*). However, in a 1962 paper, Robert Fuller and John Wheeler showed that according to the Einstein field equations "The key point in preventing any violation of causality is simple: The (Schwarzschild) throat of the wormhole pinches off in a finite time and traps the signal in a region of infinite curvature."[359] Lacking the simple concept of geometric time, and lacking awareness of Einstein's blunder in developing GR, Einstein and Rosen's intuitive idea of a physical wormhole had to be abandoned.

Figure 84 – Conventional conceptual model of a wormhole [360]

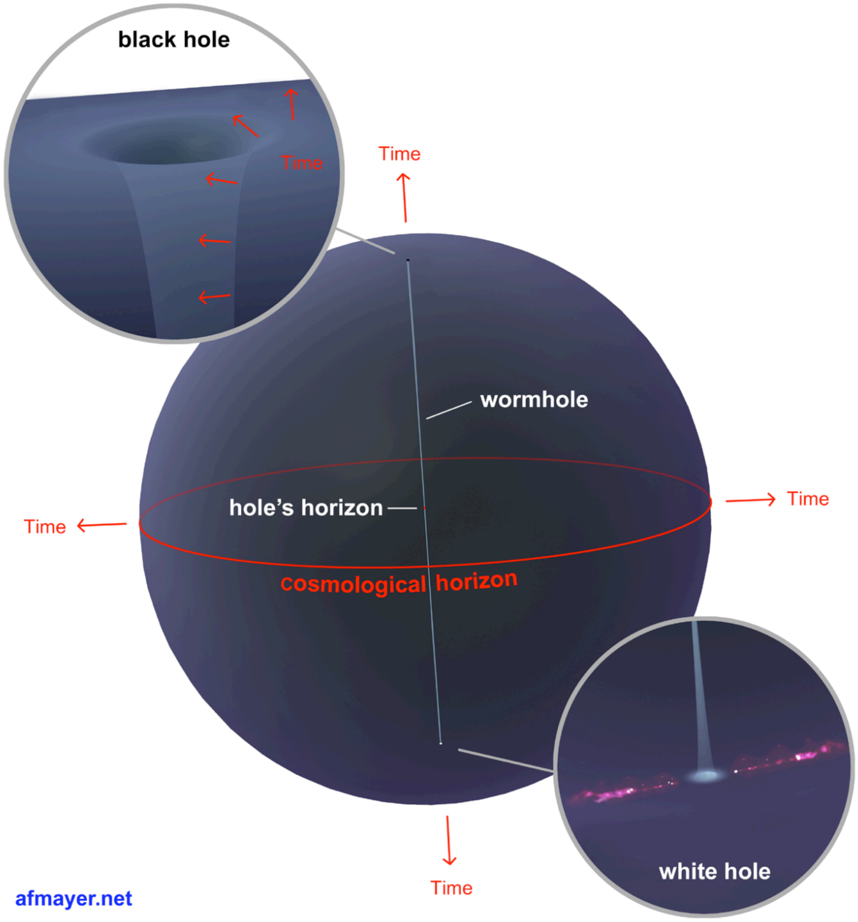


Source: Wikipedia

Minkowski showed that the Lorentz transformation equations require space and time to be orthogonal. It is then an almost trivial step to model the *local* time coordinate as the *local* vertical in this conceptual diagram. It should be clear from previous discussion (review *Sections 2–4*) that regions *A* and *B* are antipodes of a finite boundaryless Universe and that the light ray shown must actually terminate at the half way point due to infinite redshift. The concept of geometric time implies that spacetime is smooth and continuous everywhere. There is no such thing as a physical "singularity" and "infinite curvature" is utterly meaningless.

There is no need for exotic "negative energy" to hold the throat open. A black hole is not an object; it is a *process* caused by catastrophic gravitational collapse, which creates an *unstable* spacetime geometry condition. The hole can only be maintained if it is fed by a *continuous flow* of mass energy and through the hole. The direction of the initially established momentum, which is caused by a local catastrophic gravitational collapse, determines which side of the hole is "black" and which side is "white". If no such external energy source exists, the hole immediately collapses (i.e., vanishes).

Figure 85 – New conceptual model of a wormhole



Traveling through the wormhole, time changes direction in the four-dimensional spacetime "world" from one end to the other, but from the point of view of a particle freefalling through the wormhole, time is always advancing perfectly normally. It should be understood that the actual *passage* of time does not ever "reverse" anywhere; it just changes direction across the hole in reference to a global coordinate system for the four-dimensional spacetime "world", much as a gravitational gradient changes direction from one side of a planet to another. Spacetime is smooth and continuous everywhere over this "shortcut" connecting opposite sides of the spacetime Universe; *no physical singularity exists*. There is no fundamental difference in interpretation between the minimum *diameter* inside the hole at what is called the "horizon" and the local vertical to the sphere outside the hole; both represent local proper time at their respective locations. What is unique about the hole is that a large volume of unrestricted space has funneled down to a rather small volume of restricted space at the "horizon", so that whatever goes through the hole must pass through a region of extreme pressure and temperature. When we imagine mass-energy traveling through the hole shown in Fig. (85), we must restrict it to being on the *surface* of the hole in the diagram, which represents space, not the interior volume of this hole, which does not. This surface abstractly represents a three-dimensional volume in four-dimensional spacetime, so jumping up one dimension we can imagine matter accelerating through an increasingly restricted volume of space like water from a hydrant being forced through a fire hose nozzle. The only exceptionally unusual physical feature of the hole as compared to the normal Universe is the resulting tremendous compression at the throat of the hole, causing uniquely high temperatures there that are not found even at the centers of very large stars.

The idea that time changes direction in spacetime across the hole, which connects cosmic antipodes, might seem peculiar and so warrants some discussion. — Think about where you are on the Earth right now and imagine someone else about 20,000 kilometers away on the opposite side of the Earth. Now drop something, perhaps a set of keys, and imagine that your counterpart has done the same thing. Is it not true that in global coordinates, your "up" is their "down" and your "down" is their "up"? Certainly, but does this imply anything unusual? Does this mean that their "up" somehow represents a *loss* of energy relative to you rather than a gain? No, it implies nothing special or peculiar. Referencing Fig. (84), the same principle applies to the experience of time for observers at points *A* and *B* in the diagram. There is nothing strange about the fact that their respective local time coordinates point in different directions in cosmic global spacetime coordinates. However, the change in direction of time across the hole is fundamentally what makes the wormhole "bridge" through spacetime work. Note that at the throat of the wormhole, which we may also call the hole's horizon, the time and space coordinates are swapped with those just outside the entrance and exit to the hole. It is senseless to think of a material object "falling" off the surface toward the axis of symmetry because the diameter of the hole at the horizon represents a time coordinate, not a space coordinate over which material objects can translate. Motion of mass-energy through the wormhole is restricted to the curved *surface* of the diagram.

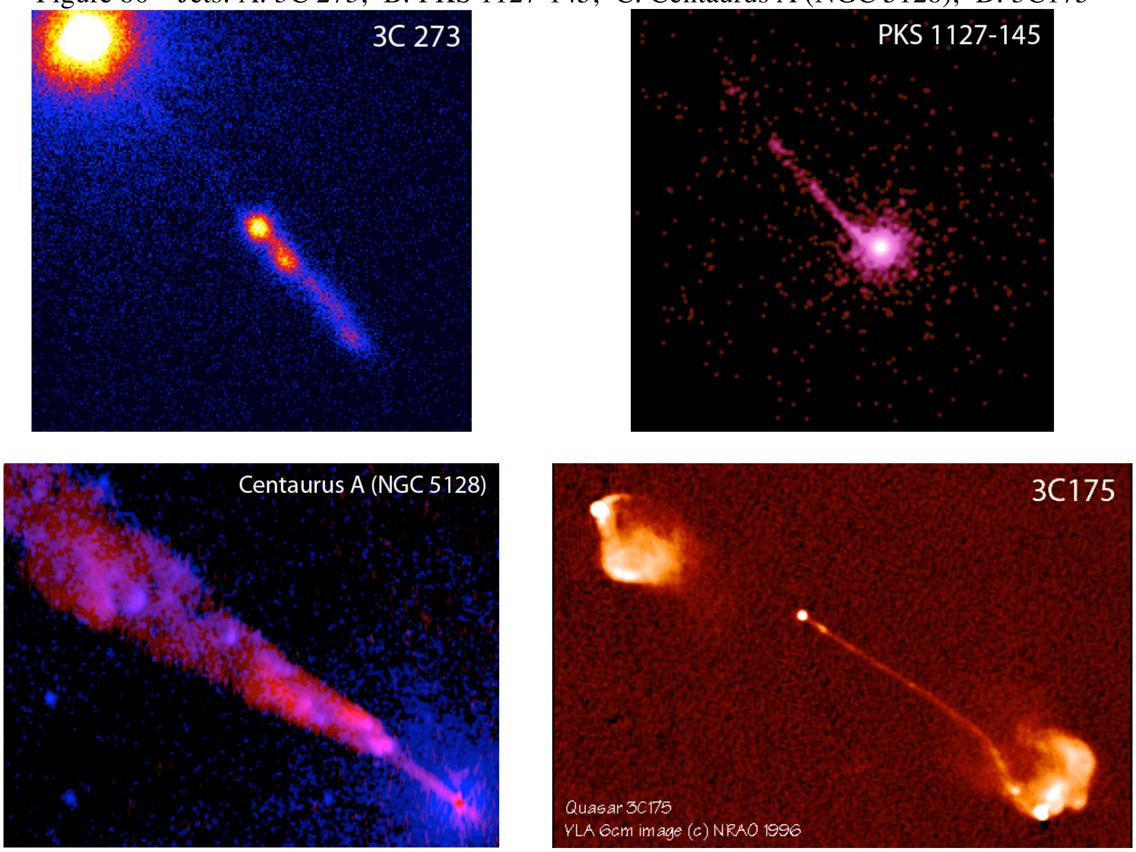
Nature always seeks balance. Heat flows from a hot object to a cold object until both are in thermal equilibrium. An electric field causes electric charge to flow across the potential in an attempt to create charge equilibrium. In this case, we have an imbalance with a natural tendency for mass-energy to flow across the hole from a region of higher mass-energy density to a region of lower mass-energy density. One may quite accurately envision the wormhole as something very much like a combination of an extremely powerful linear accelerator and a jet engine. The efflux typically forms a relativistic jet of material emitted from an active galactic nucleus that is by physical necessity located on the opposite side of the Universe from the maw of the black hole at the core of a large galaxy that feeds it. An important idea is that this spacetime configuration is fundamentally unstable. It takes mass-energy *flow* through the hole to maintain it. Without such an energy flow, spacetime will not maintain this unnatural geometric configuration, but rather will revert to its normal geometry, thus destroying the hole. When a large isolated star goes supernova, it will generally implode into a short-lived wormhole. Some part of the star's mass creates the hole and moves through it. On the star side of the hole, we see the supernova itself. On the backside of the temporary wormhole, a gamma ray burst (GRB) is observed, but the two events take place on opposite sides of the Universe. Wormholes transport mass energy from one side of the Universe to the other side. Energy is conserved on a cosmological scale, but at the location of the black hole, there is a local net decrease in mass energy over time and at the location of the white hole, there is a local net increase in mass energy over time.

There will naturally be variability in the amount of mass-energy feeding a black hole at the center of a galaxy per unit time. Sometimes more energy will enter the hole and sometimes less. This will cause commensurate fluctuations on small timescales in the observed luminosity of the remote corresponding white hole. Thus AGN are observed to fluctuate in brightness over surprisingly short time spans. A black hole and its corresponding white hole cannot be observed simultaneously. Of two such connected objects, one can see either the energy source outflow or the energy sink inflow; it is impossible to see both simultaneously for they are on opposite sides of a cosmological redshift horizon.

The Chandra X-ray Observatory spacecraft was deployed by the Shuttle Columbia on 23 July 1999. Following are three images (A, B, C) of quasar jets that were resolved by Chandra's X-ray telescope. The fourth image (D) is an image in the radio spectrum produced by Alan Bridle of the National Radio Astronomy Observatory (NARO). An accurate and intuitive description of the image appears on NASA's "Astronomy Picture of the Day" Website.

Explanation: 3C175 [image D] is not only a quasar, it is a galaxy-fueled particle cannon. Visible as the central dot is quasar 3C175, the active center of a galaxy so distant that the light we see from it was emitted when the Earth was just forming. The above image was recorded in radio waves by an array of house-sized telescopes called the Very Large Array (VLA). Shooting out from 3C175 is a thin jet of protons and electrons traveling near the speed of light that is over one million light-years long. The jet acts like a particle cannon and bores through gas cloud in its path. How this jet forms and why it is so narrow remain topics of current research.[361]

Figure 86 – Jets: A: 3C 273; B: PKS 1127-145; C: Centaurus A (NGC 5128); D: 3C175



Courtesy NASA (A-D) and NRAO (D) [362,363,364,365]

Readers are encouraged to visit Alan Bridle's "Images of Radio Galaxies and Quasars" Webpage to see additional remarkable images of AGN jets: http://www.cv.nrao.edu/~abridle/images.htm

Gamma-ray bursts (GRB) are isotropically distributed sudden intense flashes of high-energy gamma rays sourced at cosmological distances that are observed to occur regularly about once per day. They were first reported publicly in 1973 based on earlier initial detections that took place by the U.S. Vela military satellites designed to monitor the Nuclear Test Ban Treaty. The Burst and Transient Source Experiment (BATSE) aboard the NASA Compton Gamma Ray Observatory (CGRO) satellite, launched in 1991 provided initial clues of their cosmological origin.[366,367] By localizing and monitoring GRB fading X-ray afterglow, the Italian Space Agency's *Beppo*SAX satellite, launched in 1996, has been able to measure the redshift of GRBs confirming that they are of cosmological origin.[368] Even given an erroneous redshift-distance relationship, which has caused high-redshift GRB intrinsic luminosity to be grossly exaggerated, their energy output is still equivalent to converting a good portion of a star's mass into radiant energy in a few seconds.[369] A link between supernovæ and gamma ray bursts has been suspected for some time but conventional physics has had no ready answers to explain the phenomenon.[370]

When an isolated large star undergoes catastrophic collapse, the wormhole that subsequently forms cannot be stable, because there is no additional mass to feed the hole. Unlike the stable large holes at the cores of galaxies, which are fed with a continuous flow of energy from these rich cores, a wormhole formed by gravitational collapse of a star can have only a brief existence. This phenomenon must initially manifest as a high-energy gamma ray burst (GRB) from the white hole side, which is like a momentary tiny AGN. Note that in contrast to conventional thinking, the location of the supernova and the location of the GRB are distinct, actually occurring at antipodes of the Universe with a cosmological redshift horizon half way between them. One implication of this idea is that the frequency of supernovae and the frequency of gamma ray bursts in the observable Universe should be approximately the same. To test this hypothesis, it is important to accurately determine what percentage of the total population of both types of events are actually being observed and counted.

Because unwarranted faith in the accuracy of the Schwarzschild metric was the foundation of all "black hole research" for the past forty years, the literature concerning black holes during that time does not correlate with empirical reality. According to the foregoing discussion, there are no physical singularities where the laws of physics break down; rather, even in the event of catastrophic gravitational collapse, spacetime is smooth and continuous everywhere. Conservation of mass-energy is one of the most fundamental laws of physics. However, the existence of wormholes implies that this law does not hold *locally* in the region around either wormhole terminus. While mass-energy is never created or destroyed, we may have a white hole region of space where mass-energy increases over time or a black hole region in which mass-energy decreases over time. This has important ramifications for cosmology, specifically concerning the origins and evolution of galaxies.

With the mechanism of wormholes, the Universe is constantly recreating itself in an eternal cycle of death and rebirth of galaxies that prevents general gravitational collapse by redistributing mass-energy across the Universe. Thus, the Universe is eternal according to any particular clock. It will soon become generally apparent to educated people that we do not live in an expanding Universe that exists in a shared "cosmic time", but rather in an eternal dynamic equilibrium Universe that completely transcends our local experientially based concept of time. While it is conceivable that the Universe may have been different in the past, reflecting some kind of cosmic evolutionary process, it seems likely that its current general architecture has remained the about same over an infinite extent of any local measurement of time.

A number of people have been talking about the possibility of wormholes for decades, and now their intuitive ideas are vindicated. Other people, like Steven Weinberg have worked out many important details of how matter behaves in conditions of intense heat and pressure, far surpassing that which can occur in the interior of stars. While it was assumed these conditions existed some moments after a single primordial creation event, it turns out that these conditions exist deep in the bowls of black holes and white holes, which are opposite ends of wormholes through spacetime. Sophisticated and detailed mathematical models of the strong field limit will evolve from a new 21st-century vision of gravitation. However, even the quite simple equations that appear in this mathematically unsophisticated introductory discussion provide deep insight into what these developments will elegantly and precisely define.

> Is something wrong with gravity? Is some unknown force acting on the [Pioneer-10 & 11] probes? This seems another indicator of my own pet theory that science has barely begun to grasp what's going on in the universe, and that in centuries to come, people will chortle regarding what we consider knowledge, in the same way we today chortle about those of past centuries who thought the Earth was flat or the air was full of phlogiston. (Conversation in the year 2105: "Can you believe that in 2005, people at Harvard actually thought the entire universe emerged as an explosion of a point with no dimensions?")[371,372]
>
> – Gregg Easterbrook [373]

One may hope that the erudite Harvard community will absorb the contents of this book and begin to expand on it in far less than a century. Mr. Easterbrook, who is a visiting fellow at the Brookings Institution, could have written instead, “Conversation in the year 2010…”

40. A general model of gravitational lensing

Albert Einstein’s successful prediction that the gravitational field would “bend” light was one of the spectacular early empirical proofs of the theory. In 1919, Arthur Eddington of the Royal Astronomical Society lead an investigative team sent to Principe Island off the West Coast of Africa to observe stars visually aligned near the Sun during a total solar eclipse.[374,375,376] In retrospect, the experimental error of about 20% for these observations was too large to draw rigorous conclusions. However, at the time the results were presented, the prediction was considered confirmed and the news made the front page of most of the international newspapers. Modern techniques that reconfirm the prediction, taking advantage of quasar radio frequency radiation, and Very Long Baseline Interferometry (VLBI) have reduced the experimental error to about 0.2 percent.[377]

Simplicity and elegance of mathematical expressions that describe fundamental physical relationships is often a guide to the truth in theoretical physics. Einstein’s empirically verified equation for the bending of light (change in momentum of incident photons) by a point mass gravitational field meets these criteria.

$$\alpha = \frac{4GM}{bc^2} \tag{97}$$

Therein, α is the angle through which the light bends, G is the gravitational constant, M is the mass of the gravitating body such as the Sun, c is the speed of light and b is the radius of closest approach, also called the “impact parameter”. This odd name for the parameter b is due to the vague similarity of the phenomenon to nuclear scattering under the influence of the Coulomb force. Using the modern value of the solar radius ($b = 6.960\times10^8\ m$), we evaluate the solar photon deflection angle

$$\alpha = 8.487\times10^{-6}\,rad \approx 1.75'' \tag{98}$$

Of note, Einstein’s original published quantification of the phenomenon in a brief 1911 paper was too small by a factor of two.[378] Apparently unbeknownst to Einstein, the identical erroneous value for the phenomenon had been calculated more than a century earlier.

> The first written account of the deflection of light by gravity appeared in the *Berliner Astronomisches Jahrbuch auf das Jahr 1804* in an article entitled: “Ueber die Ablenkung eines Lichtstrals von seiner geradlinigen Bewegung, durch die Attraktion eines Weltkörpers, an welchem er nahe vorbeigeh” (“On the Deflection of a Light Ray from its Straight Motion due to the Attraction of a World Body which it Passes Closely”). Johann Soldner – a German geodesist, mathematician and astronomer then working at the Berlin Observatory – explored this effect and inferred that a light ray close to the solar limb would be deflected by an angle α = 0.84arcsec. It is very interesting to read how carefully and cautiously he investigated this idea and its consequences on practical astronomy.[379]

As its root words imply, celestial mechanics is the study of motion through the heavens, which typically involves the calculation of trajectories for material bodies such as spacecraft or astronomical bodies. A principle of this subject as concerns the typical fundamental two-body problem wherein one body is ponderous (e.g., a star or planet) and the other is of insignificant mass (e.g., a spacecraft) is that the *shape* of the orbit will be one of the four conic sections. Mathematical analysis dating back several centuries leads to the conclusion that the trajectory under an inverse-square central force must necessarily be a conic section with the orbit symmetric about a focus; the particular conic section evident will be based on the energy relationship of the moving body in the rest frame of the gravitational field in question. The assumption as concerns this discussion is that no other forces but gravitation is at work. The convenient general equation of any conic section corresponding to an orbit is

$$r = \frac{p}{1 + e\cos\theta} \qquad 99$$

In this equation, p is the semi-latus rectum (*not* the focal parameter), e is the eccentricity and θ is the polar angle measured about the focus with the origin at the periapsis. For a parabola, the semimajor axis denoted by a is unbounded, so with this exception the value of p is defined. For a hyperbola $(e > 1)$ and $(a < 0)$.

$$p = a\left(1 - e^2\right) \qquad 100$$

Table 5 – Orbital Trajectories and Parameters

shape of orbit	eccentricity	velocity	effect of GTR on a material body
circular	$e = 0$	$v < v_{esc}$	inbound spiral ($r \to 0$)
elliptical	$0 \leq e \leq 1$	$v < v_{esc}$	periapsis precession, $e \to 0$, $r \to 0$
parabolic	$e = 1$	$v = v_{esc}$	will always cause $e<1$ (unstable)
hyperbolic	$e > 1$	$v > v_{esc}$	$e_i \sim 1$ may cause $e_f<1$
semilinear	$e \to \infty$	$v >> v_{esc}$	$dE/dt \neq 0$ (<0)

For an incident particle, as we define its relative velocity through the gravitational field of a typical star to approach the speed of light c, there must be a commensurate increase in the eccentricity of its hyperbolic trajectory such that for or all practical purposes the trajectory will appear to be linear. However, given that the eccentricity, though very large, will be finite, then the asymptotes of the characteristic hyperbola will not be collinear. Their acute angle of intersection ε will be defined by

$$\sin\frac{\varepsilon}{2} = \frac{1}{e} \qquad 101$$

As the linear incident trajectory and the outgoing trajectory of the particle prior to gravitational interaction correspond to the complementary asymptotes of the characteristic hyperbola, it is clear that this very small angle ε represents the tiny deviation or "bend" in what we may appropriately call the "semilinear" trajectory. This is simply a hyperbolic trajectory, but one with such a large eccentricity as to fall under this subjective subcategory.

It is a trivial observation that the photon deflection angle α in Einstein's remarkably elegant and empirically verified equation (97) is completely independent of the energy hf of the photon. This is quite unlike the behavior of a material particle, for we know that as we increase the (kinetic) energy of a material particle in a gravitational field, we must alter its trajectory. We may note that the fundamental *purely geometric* rules of celestial mechanics outlined in Table (5) are mass independent; the only consideration is the velocity of the particle as it compares to the local gravitational escape velocity. It is clearly the case that the deflection of the trajectory of a photon by a gravitational field is a smooth and continuous process over an extended region of space and moreover that the effect is geometrically symmetrical; certainly we are not dealing with an event involving a rapid and discontinuous change in the photon's momentum.

In his doctoral thesis of 1924 entitled *Research on the quantum theory,* Louis de Broglie put forward the remarkable (and rapidly empirically verified) prediction that all material particles, whether or not they carry mass, must exhibit wave behavior that is commensurate with their momentum.[380] In the same spirit, we will suggest here that all particles, whether or not they carry mass, are subject to similar mass-independent *geometric* rules of celestial mechanics. A photon carries energy and momentum but has no mass *per se*. It is clearly the case that the velocity of a photon c will in general be very much greater than the local gravitational escape velocity, typically by several orders of magnitude. It follows from the foregoing proposition that in general the trajectory of a photon through a gravitation field will correspond to a *hyperbolic trajectory* of exceedingly high eccentricity. Foregoing any resort to theoretical considerations or additional independent mathematical derivation, we now make the reasonable assumption that the elegance and weak field empirical verification of Einstein's equation (97) together imply that this equation holds true to nature exactly as formulated. If we understand this to be the deflection of what is fundamentally a hyperbolic trajectory then

$$\varepsilon = \frac{4GM}{bc^2} \qquad 102$$

A rule for the sine function states that the sine of a very small angle is essentially equal to that angle. Clearly, the sine of the solar photon deflection angle ε let alone the sine of half of this angle are indistinguishable from the argument of the function as concerns angular measurement. So, we find that the following relationship has been empirically verified to high accuracy as concerns the observed phenomenon of photon deflection by a gravitational field.

$$\frac{\varepsilon}{2} = \frac{2GM}{bc^2} = \frac{1}{e} \qquad 103$$

We can then make the arguably incontrovertible proposition that a photon must pursue a smooth hyperbolic trajectory through a gravitational field whose eccentricity is defined by the following simple equation.

$$e = \frac{bc^2}{2GM} \qquad 104$$

Simple geometric considerations then imply that the general equation for the hyperbolic deflection of a photon in a point-mass gravitational field is

$$\tilde{\alpha} = 2\sin^{-1}\frac{2GM}{bc^2} \qquad 105$$

Eq. (105) is indistinguishable from Einstein's formula in the weak field, but it is in the strong field that this new formula gains no trivial distinction. The strong field is associated with the limiting velocity c for the escape velocity and the radial coordinate known as the Schwarzschild radius at which the local gravitational escape velocity equals the speed of light.

$$R_S = \frac{2GM}{c^2} \qquad 106$$

While Einstein's formula (97) exhibits elegance in form, his equation loses its applicability over the complete range of gravitational escape velocity from zero to c. When one applies it to the strong field by using the Schwarzschild radius for the impact parameter, the result is universally acknowledged to be meaningless.

$$\alpha = \frac{4GM}{c^2} \cdot \frac{c^2}{2GM} = 2 \ radians \qquad 107$$

We then find the validity of Einstein's formula in the weak field to be disingenuous; if the formula is quite clearly meaningless in the strong field yet is quite obviously accurate in the weak field, then this begs the question, "At what point does it fail in the range of v_{esc}?" The obvious answer from any competent applied mathematician is that it in fact must fail everywhere, but that the deviation of the failure in the weak field is so small as to be zero as concerns measurement. Consider that we must employ an impractical precision to draw a distinction between the results of Eq. (97) and Eq. (105) as calculated for the Sun.

$$\alpha = 8.486788958198 \times 10^{-6} rad \tag{108}$$

$$\tilde{\alpha} = 8.486788958224 \times 10^{-6} rad \tag{109}$$

However, Eq. (105) exhibits a remarkable quality in the strong field limit than can only lead one to believe that our postulate holds true; all particles that carry energy and momentum subscribe to the same general *geometric* rules of celestial mechanics (e.g., that when the velocity of a particle is *equal* to the local escape velocity of the gravitational field, then the shape of the trajectory must be parabolic rather than hyperbolic). While the asymptotes of the hyperbola intersect, those of the parabola are by definition parallel lines. Since one of these lines represents the inbound trajectory and the other the eventual outbound trajectory, then the "deflection angle" corresponding to a parabolic trajectory is exactly π. This is the exact deflection angle calculated at the Schwarzschild radius by Eq. (105).

$$\tilde{\alpha} = 2\sin^{-1}\left(\frac{2GM}{c^2} \cdot \frac{c^2}{2GM}\right) = \pi \tag{110}$$

It is neither unremarkable nor coincidental that Eq. (105) is empirically verified in the weak field and also smoothly transitions to the perfect expected value as concerns the trajectory of a particle having velocity c commensurate with an inverse-square central "force" where the escape velocity is also c. It should be immediately obvious that Eq. (105) is the only possible correct general model of gravitational lensing.

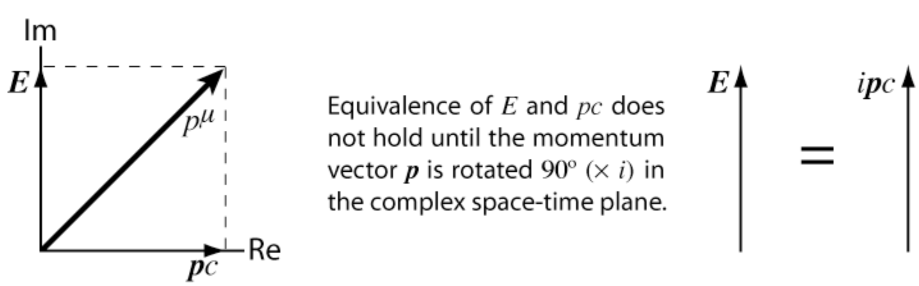
41. Energy

There were arguably three "pillars" of 20th-century physics: the General Theory of Relativity, the idea of the Expanding Universe and the Standard Model of Particle Physics. So far, we have toppled the first two, so toppling the third will make a clean sweep to start the new century.

The real and imaginary components of the four-vector momentum p^μ respectively correspond to the linear momentum **p** and energy **E** of a particle. Employing natural units (c = 1), these two vector components are of identical length for any massless particle (e.g., a photon).

$$|\mathbf{E}| = |\mathbf{p}| \tag{111}$$

Figure 87 – The four-vector momentum of a photon and its two distinct components



Conventional treatment of the relationship between energy and momentum for massless particles appearing in all physics textbooks expresses it as the following immediate equality.

$$E = pc \qquad 112$$

However, Eq. (112) is inconsistent with the principles of special relativity. Although the scalar magnitudes of pc and E are equivalent, establishing the mathematical relationship between them *in the context of special relativity* [Fig. (87)] unequivocally requires an imaginary coefficient.

$$E = ipc \qquad 113$$

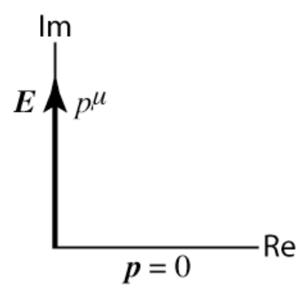
Yet, in common algebraic expressions, total energy E conventionally represents a measurable quantity, which must be real-valued. Therefore, the mathematical expression for the real-valued total energy corresponding to momentum that reflects the subtleties of special relativity with complete and detailed precision is the following complex modulus.

$$E = |ipc| = \sqrt{(0 + ipc)(0 - ipc)} = pc \qquad 114$$

Far from being trivial, this mathematical subtlety is of the utmost importance for developing a physically accurate conceptual model of energy in microphysics. The relationship commonly expressed by the simple form of Eq. (112) is deceptive because it *implicitly* disregards the fact that the four-vector components **p** and **E** of radiation energy (i.e., wave energy) lie along different dimensions in space-time and so are not equivalent although they are equal in magnitude. Critical physical insights associated with this geometric relationship have been obscured by the conventional algebra. Fig. (87) makes it clear that mathematical equivalence of energy and momentum requires the momentum vector to be rotated in the complex plane so that it is collinear with the energy vector. The *explicit* appearance of the imaginary coefficient in Eq. (114) based on the fundamental mathematical relationship expressed by Eq. (113) is essential.

In contrast with the preceding case, consider now the rest frame of a material particle, which has a none-zero rest mass. By definition, the momentum is zero for the rest frame; therefore, the particle's four-vector momentum is collinear with the imaginary axis.

Figure 88 – The four-vector momentum of the rest frame



The energy in this case is simply the rest energy of the material particle.

$$E = m_0 c^2 \qquad 115$$

Accordingly, an elementary mathematical distinction exists between the real-valued intrinsic rest energy of a material particle (115), which is invariant, and the imaginary-valued energy of momentum (113), which is dependent on the reference frame of the observer. The subtle fact that the mathematical descriptions of these two energy manifestations do not coexist on the same number line, which is obscured by the conventional algebraic equations, is made readily apparent by the foregoing intuitive graphical analysis using Fig. (87) and Fig. (88). Clearly, we are not entitled to arbitrarily sum two such energy values together without considering their underlying geometric relationship in the complex plane. It follows that in the general case of a moving material particle having both rest energy and momentum, the total energy of the particle is described most fundamentally by a complex number.

$$E = m_0c^2 + ipc \qquad 116$$

Again, since total energy E is a measurable quantity, its necessarily real-valued magnitude is the complex norm (i.e., the modulus) of what can *only* be correctly described by a complex number.

$$E = \sqrt{\left(m_0c^2 + ipc\right)\left(m_0c^2 - ipc\right)} = \sqrt{m_0^2c^4 + p^2c^2} \qquad 117$$

It is exceedingly clear that the principles of special relativity require the underlying mathematical representation of total energy to employ the complex numbers, yet apparently Einstein never understood this. Conceived several years before Minkowski formalized special relativity using the complex numbers, it was not subsequently immediately realized that Eq. (118) must be updated to reflect this formality. Applying a few elementary algebraic steps to Einstein's famous 1905 energy equation (119) yields the same well-known relationship between energy, momentum and mass (120), however it is not obvious or even discernable from this prior derivation that the roots of E^2 are complex conjugates. The *a priori* assumption was that E and m are a real numbers.

$$E = mc^2 \qquad 118$$

$$E = \frac{m_0c^2}{\sqrt{1 - \frac{v^2}{c^2}}} \quad \rightarrow \quad E^2 - m^2c^2v^2 = m_0^2c^4 \qquad 119$$

$$E^2 = m_0^2c^4 + p^2c^2 \qquad 120$$

In 1908, simultaneously with the introduction of the "world-postulate" in which space and time were unified into an independent reality, Hermann Minkowski also introduced the concept of the momentum four-vector.[381] This vector in the complex plane is defined by

$$p^\mu \equiv m\eta^\mu \qquad 121$$

where η^μ is the velocity four-vector, i.e.,

$$p^\mu = \begin{bmatrix} \gamma m_0 c \\ \gamma m_0 v^1 \\ \gamma m_0 v^2 \\ \gamma m_0 v^3 \end{bmatrix} \qquad 122$$

With Eq. (118) and the definition of relativistic linear momentum, p^μ is succinctly expressed

$$p^\mu = \begin{bmatrix} \frac{E}{c} \\ p^1 \\ p^2 \\ p^3 \end{bmatrix} \qquad 123$$

The Minkowski norm of p^μ (i.e., the rest energy) is Lorentz invariant.

$$p^\mu p_\mu = \frac{E^2}{c^2} - p^2 = m_0^2c^2 \qquad 124$$

Again, but more formally, this is the identical relationship between energy, momentum and rest mass as previously derived algebraically (118–120). Similarly, the equations presented in this approach do not readily reveal that the roots of E^2 are complex conjugates (116, 117). The natural doctrine that energy as a measurable must be real-valued contributed to obscuring the fact that total energy in the context of the special theory of relativity cannot be accurately described by the real numbers, alone.

Define the phase angle α as follows.

$$\alpha \equiv \sin^{-1}\beta \qquad \beta \equiv \frac{v}{c} \tag{125}$$

One may then conveniently define a phasor associated with the relativistic description of energy.

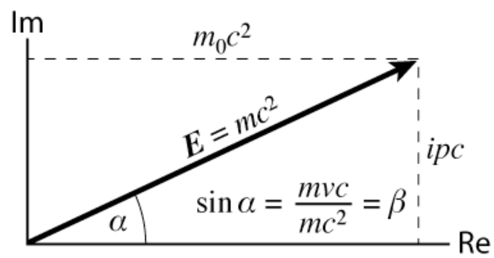
$$e^{i\alpha} = \cos\alpha + i\sin\alpha = \sqrt{1-\beta^2} + i\beta \tag{126}$$

$$\therefore mc^2 e^{i\alpha} = mc^2\gamma^{-1} + imvc = m_0c^2 + ipc \tag{127}$$

Eq. (117) is then more elegantly and succinctly written

$$E = \left| mc^2 e^{i\alpha} \right| \tag{128}$$

Figure 89 – Energy represented as a phasor



In addition to demonstrating mass-energy equivalence, this new energy formula (128), of which Einstein's 1905 equation (118) is a naïve form, explicitly reveals the non-trivial fact that the roots of E^2 are complex conjugates (i.e., that mass energy and momentum energy are mathematically and also physically distinct). *This necessitates profound changes to conventional interpretations of quantum mechanical phenomena, in particular the wave-particle duality.*

42. The energy of matter waves

Some two decades after the photoelectric effect had demonstrated the particle-like behavior of light, Louis de Broglie initially put forward the proposition that material particles must exhibit wave-like behavior. In a 1923 published paper that immediately preceded his celebrated 1924 PhD thesis, de Broglie stated the following.

> …the atom of light should be considered as a moving object of a very small mass ($<10^{-50}$ *g*) that moves with a speed very nearly equal to *c* (although slightly less). We come therefore to the following conclusion: *The atom of light, which is equivalent by reason of its total energy to a radiation of frequency, is the seat of an internal periodic phenomenon that, seen by the fixed observer, has at each point of space the same phase as a wave of frequency propagating in the same direction with a speed very nearly equal (although very slightly greater) to the constant called the speed of light.*[382]

Although this line of thinking concerning the nature of light is erroneous and even nonsensical, it apparently lead de Broglie to correctly predict that the relationship between momentum and wavelength that holds for massless particles (129) also holds for all particles.

$$\lambda = \frac{h}{p} \tag{129}$$

One may judge from de Broglie's statement, quoted above, that although he was successful in making an important quantitative empirical prediction, the genesis of the wave theory of matter was associated with a confused and incorrect understanding of physical principles. Furthermore, these ideas drove the conceptual model of the wave manifestation of material particles as a wave packet moving with group velocity v (the relative velocity of the particle). This model rests on two fundamental *a priori* mathematical assumptions. The first is that the energy of the wave packet hf corresponds to the total energy of the material particle. Here, f represents frequency rather than the Greek ν (*nu*), which is difficult to distinguish from the italic v (v) of the English alphabet used herein to represent velocity.

$$hf = mc^2 \tag{130}$$

The second is that the phase velocity w is superluminal and boundaryless (i.e., "unphysical") according to the idea that the wave packet's group velocity is that of the material particle (v).

$$w = \frac{c^2}{v} \tag{131}$$

The de Broglie wavelength then follows from the definition of the phase velocity $(w = \lambda f)$.

$$\lambda = \frac{c^2}{v} \cdot \frac{h}{mc^2} = \frac{h}{mv} \tag{132}$$

Because a mass term explicitly appears in this equation, it fails to be meaningful for massless particles and so does not represent a generalized solution. Also, although experiment confirms the empirical validity of this relationship for particles of non-zero rest mass, the derivation and associated conceptual model behind the equation leads to a conspicuous logical inconsistency between Eqs. (132) and (130). For the rest frame of a particle, the velocity is zero, which implies an infinite wavelength. An infinite wavelength suggests the model of a string of arbitrary length in which no displacement can be found (i.e., a null wave). It is therefore the case that the string contains no wave energy whatsoever (i.e., the frequency is necessarily zero). However, because de Broglie's model for wavelike behavior of material particles assumes no distinction between a particle and its wave manifestation (i.e., that the energy of the wave hf is equal to the total energy of the particle mc^2) the frequency of the wave associated with the zero momentum condition corresponds to the rest energy. While it is unequivocally true that the measurable manifested wavelength of any particle is inversely proportional to its momentum according to Eq. (129), it is also true that the frequency of these "matter waves", which has not been subject to empirical measurement, cannot possibly correspond to Eq. (130). Something is clearly amiss in the conventional *conceptual* foundations of quantum mechanics that must be addressed.

Unlike Eq. (118), Eq. (128) makes a vivid mathematical distinction between the rest energy of a particle and the energy contribution due to its motion (i.e., momentum). In consideration of a massless particle such as a photon, for which energy manifests exclusively in the form of a wave characterized by a particular frequency, rest mass plays no part in the wave manifestation associated with the momentum carried by the particle. The wave manifestation of energy associated with a frequency is then associated with the imaginary (i.e., time) part of the total energy exclusive of the real (i.e., space) part.

$$hf = \mathrm{Im}\left[mc^2 e^{i\alpha} \right] = pc \qquad 133$$

The logical inconsistency between Eq. (132) and Eq. (130) arising from de Broglie's initial assumption of the latter relationship (130) implies that Eq. (133) is a general physical principle that applies to *all* particles; *the energy of the momentum-driven wave manifestation of any particle is an independent contribution to the total energy that is not inclusive of any rest energy.* — As this was not previously known, the resulting inaccurate understanding of fundamental phenomena underlying quantum mechanics will have caused numerous puzzling theoretical impasses in physics. This correction is certain to yield a number of important breakthroughs.

43. The manifestation of matter waves

Combining Eq. (133) with Eq. (129), the phase velocity of matter waves is determined to be fixed and equal to the speed of light, rather than superluminal and boundaryless.

$$w = \lambda f = \frac{h}{p} \cdot \frac{pc}{h} = c \qquad 134$$

Then the wave manifestation of a material particle on the microphysics scale is a *periodic field* that surrounds the source particle with some similarity to the distinction between a macroscopic material body and its associated gravitational field. The particle produces its momentum-induced wave manifestation, but the particle and the wave it produces are *not* one and the same thing. With the exception of the rest frame and the massless particle, neither of the two forms of energy (wave/radiation or particle/mass) can be identified with total energy; only the *geometric* vector sum of each manifestation's distinct energy component in the complex plane yields total energy. Given that Eq. (133) correctly describes the energy of matter waves, we must abandon the long-held conventional idea that these waves manifest as a wave packet with group velocity v and are formed by the superposition of many waves with different wavelengths. Rather, the newly emergent model required by Eq. (128) is that of a particle surrounded by a spherical standing wave. This wave is characterized by a single well-defined wavelength associated with momentum (129) that has a radially decreasing amplitude, a group velocity of zero, a phase velocity of the speed of light c (134) and an energy pc (133) that is *not* inclusive of rest energy. Like the gravitational field, matter waves are clearly higher-dimensional geometric objects because wave amplitude is a fourth coordinate for points in three-dimensional space. The standing wave model requires both an outbound and an inbound matter wave. While the former is produced by the particle, the latter can be envisioned as a response of spacetime to the presence of mass-energy.

The familiar fundamental interpretation of general relativity, applicable on the macro-scale, is "matter tells spacetime how to warp and warped spacetime tells matter how to move." It is now suggested (i.e., asserted) that on the microphysics scale, the momentum of a particle tells spacetime how to *wave* (i.e., warp in a unique way within the immediate vicinity of the particle). It is also true that this *locally* warped spacetime, typically in the form of interfering waveforms, will constrain the motion of elementary particles, which move through spacetime modified by their own wave manifestation. This quantitative and qualitative re-evaluation of the microphysics scale wave nature of matter provides a new and intuitive interpretation of quantum mechanics, in particular *the measurement problem*.

Before proceeding, it is worth mentioning as an aside that there is an intriguing conceptual analogy between the unified distinction between the rest and momentum energy and the unified distinction between the electric and magnetic fields. The electric field is produced by non-moving charges and likewise rest energy is associated with the static condition. In contrast, the distinct magnetic field is produced exclusively by moving charges and likewise the distinct momentum energy is associated with the dynamic condition. Perhaps there is some illuminating conceptual and mathematical correlation between the electromagnetic (charge) field and the gravitational (mass) field to be discovered by further pondering this similarity.

44. The wave-particle duality

The wavefunction in quantum mechanics described by the Schrödinger equation describes a linear superposition of different states, but actual measurements are always made of a physical system in a definite state. For example, in the two-slit particle diffraction experiment, it is the actual impact locations of whole and indivisible particles (e.g., electrons) that are observed. However, the mathematics describes only the "fuzzy" statistical probability of the lateral distribution of electrons on the screen. The critical question that was not answered satisfactorily by any previous interpretation of quantum mechanics is how the mathematically calculated probabilities are converted into a distinctive measured physical outcome. It is clear that this question cannot possibly have been correctly answered without incorporating the idea that nature makes a sharp distinction between the real-valued rest energy (which may be zero) and the imaginary-valued momentum-driven wave energy in accord with Eq. (128). Because de Broglie failed to make a distinction between a particle and its momentum-driven wave manifestation (i.e., he assumed $hf = mc^2$ rather than $hf = |\, ipc \,|$), the various interpretations of observed and calculated quantum effects that arose from his conceptual model of the wave-particle duality were manifestly flawed. This has led to the general disaffection and vigorous debate concerning these various interpretations persisting to the present day.

An idea is now introduced that transforms our understanding of quantum mechanics in an intuitive way. Indeed, it is arguably the case that this very simple idea is the realization of "Einstein's dream" of a robust semi-classical picture of quantum mechanical effects. Recall that Einstein's equivalence principle simply states that there is no distinction between inertial acceleration and gravitational acceleration for a reference frame of limited size such that tidal effects are negligible and that this single idea forms the foundation of general relativity. In like manner, we shall state *the quantum equivalence principle*. This principle states that $\Psi^*\Psi$ implies an underlying spacetime energy structure correlated to the calculated probability distribution of the particle. In short, matter waves manifest as a metric field through which particles propagate. When we speak of the energy of a matter wave, we must ask, "What is waving?" The answer is clear; *spacetime* is waving. *If spacetime is waving, then this implies a local geometry of spacetime correlated to the amplitude of the linear superposition of matter waves.*

Consider the following intuitive classical picture. A steady wind implying a vector field blows through the ideal barrier in the form of a symmetric "mountain range" shown in Fig. (90). Although this vector field is smooth and predictable on the large scale, there are also intrinsic chaotic processes at play. If we release a neutrally buoyant balloon (i.e., a test particle), far away from the windward side of this barrier, at what lateral location on a plane coordinate boundary near to the leeward side will the "particle" end up? A particular balloon will end up at some definite lateral coordinate, but if we repeat the process many times, the results will clearly be statistical. The most likely location for any particular balloon to be found will be behind the large central valley designated region *A*. Another but far less likely location will be behind either one of the narrower and higher peripheral valleys (*C*). It is very unlikely that the balloon will be found directly behind one of the peripheral peaks (*B*). Assuming appropriately constrained initial conditions, it is intuitively the case that if one releases many such balloons one at a time and then plots their final location on a virtual plane surface just leeward of the barrier, the population distribution of the balloons would essentially be the inverted image of the barrier [Fig. (91)]. With the *a priori* knowledge that a kind of *geometric* barrier was responsible for the observed lateral distribution of balloons shown in Fig. (91), but being privy only to the data and not to the direct observation of this barrier, one would naturally intuit the basic geometry of the barrier.

Figure 90 – An ideal symmetric "mountain range" and central valley

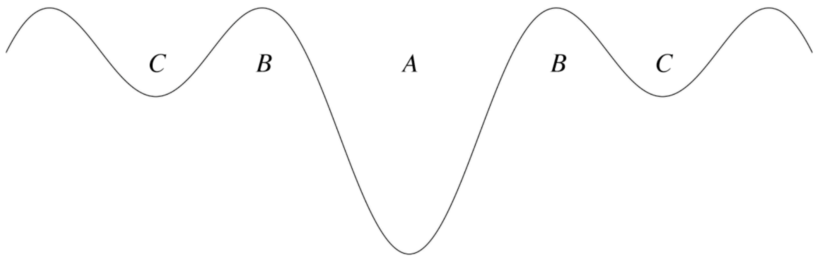
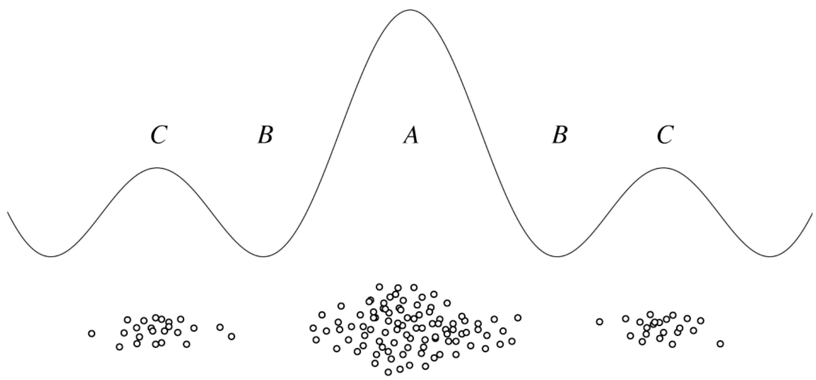
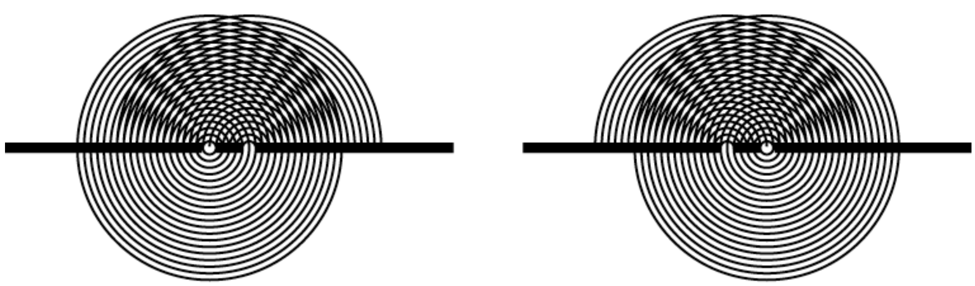


Figure 91 – Plot of lateral balloon location "intensity" on the leeward side



The quantum equivalence principle states that what we see in the data of the single-electron double-slit experiment, which is similar to that shown in Fig. (91), is indicative of a kind of geometric spacetime barrier that exists in the region of space between the diffraction grating and the screen, when both slits are open. The cause of this effective barrier is intuitively obvious; it is the interference and linear superposition of the wave manifestation of each individual electron. Opening the second slit allows the wave energy *ipc* (i.e., the matter wave field) to travel through both slits, clearly preceding and accompanying the particle itself m_0c^2 (i.e., the wave center), which can travel through only one slit or the other. In the case of a photon, there is still a wave center, although the rest mass energy associated with it is zero.

Figure 92 – One distinct particle (wave center) yet two separate wave sources



The indivisible particle always goes through one slit or the other while its wave field always goes through both open slits. Each scenario has an equal likelihood.

Therefore, within the space between the diffraction grating and the target screen, the single indivisible particle travels through a spacetime with a local geometry temporarily modified during its transit by the interference of its own distinct wave manifestation, which emanates from two separate laterally displaced points in space. On the microphysics scale, the situation is similar to the vector field of the balloon analogy. The local microphysics spacetime geometry created by the interference of the two distinct matter wave sources can be envisioned as a peculiar kind of "gravitational field" in which the strongest potential points to the center of the screen and comparatively narrower and weaker symmetric potentials interspersed by barriers are peripherally distributed. In short, the amplitude of the wavefunction (i.e., by how much spacetime is waving) correlates to the strength of the temporary local periodic potential on the microphysics scale. So, there is nothing mysterious about the observed statistical distribution of individual particle impacts on the screen in the single electron double-slit experiment. The observed intensity of these impacts exhibiting "organized chaos" is essentially identical to the observed and intuitive lateral distribution of balloons whose path towards their final plotted semi-random destinations is constrained by the geometry of an idealized vector field.

A convincing classical analogy of this concept can be demonstrated in a very simple way that is suitable even for the high-school physics classroom. — A rectangular shallow tank of water is separated across its width by a two-slit barrier. A floating disk incorporating a vibrating mechanism powered by a watch battery causes concentric water waves to surround it. The disk is made to pass through one of the slits towards the back wall of the tank. The waves it generates have passed through both slits, creating a pattern of waves and troughs on the far side of the slits. When the disk moves through the barrier, it will tend to continue to the back wall of the tank through one of the troughs caused by the interference pattern, thus it will almost never hit a lateral position on the back wall associated with the location of a wave crest. The water represents spacetime, the disk represents an electron, the water waves represent "negative" matter waves and the back wall of the tank represents the target screen in the single-electron double-slit experiment

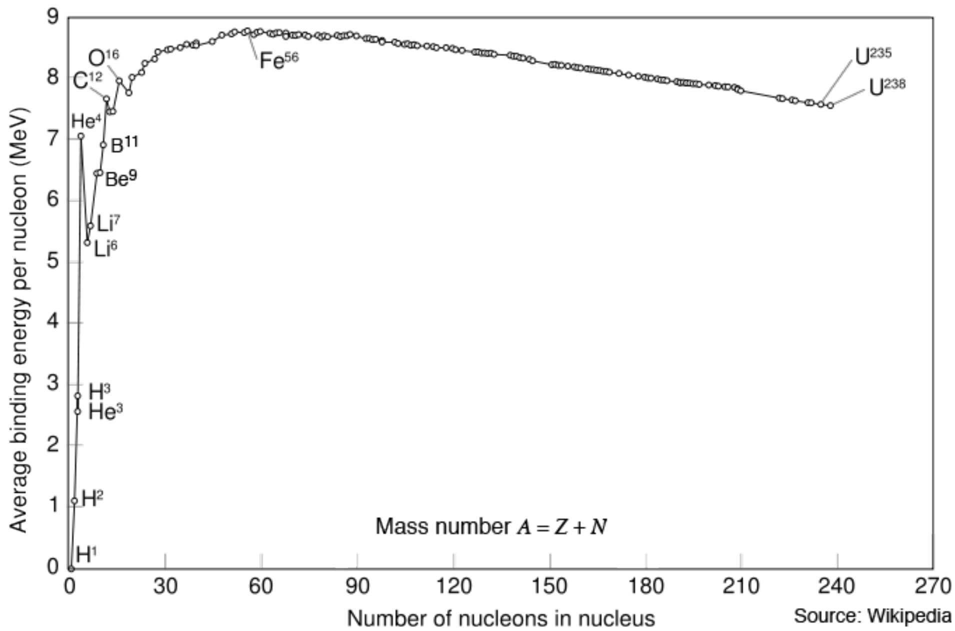
In summary, a new fundamental interpretation of quantum mechanics and in particular the empirical results of the single-electron double-slit experiment arises from the realization that a particle and its wave manifestation are distinct energy manifestations according to Eq. (128). The squared amplitude of the wavefunction is interpreted to correspond to a spacetime geometry that correlates to periodic local potentials. When the statistical probability distribution of a particle (e.g., an electron) is determined, whether in the double-slit experiment or for atomic electron orbits, what is indirectly being measured is the underlying local spacetime geometry caused by the interference of matter waves.

45. The atomic nucleus

There is a well-defined set of observables concerning the atomic nucleus. A successful theoretical model must comprehensively describe all of these observables. They are:

1. The nucleus is made up of protons (*Z*), which strongly repel each other and neutrons (*N*), which are electromagnetically inert and slightly more massive than protons.
2. Nuclear density is constant and is idependent of its nucleon constituency ($A = Z + N$).
3. The binding force between any two nucleons is identical (charge independence).
4. The nuclear core is effectively repulsive, preventing implosion of the nucleus.
5. Nucleus size increases with *A* in close approximation to the Fermi model [Eq. (135)].
6. Evidently, the nucleus cannot grow larger than about 15 *fm* in diameter.
7. There are forbidden nuclear configurations (e.g., ^{2}He, ^{5}Li, ^{8}Be)
8. Increasingly heavier stable nuclei require an increasingly larger proportion of neutrons.
9. Bound nucleons exhibit quantized energy states rather than continuous energy states.
10. Disregarding periodic discontinuities, the average binding energy per nucleon is less for smaller nuclei than for larger nuclei with this trend reversing at about $A = 60$.
11. *Contrary to intuition, collisions do not occur between bound nucleons!*
12. Some nuclei are stable while others are subject to statistical decay.
13. Magic numbers (2, 8, 20, 28, 50, 82, 126) of *Z* and *N* clearly promote nuclear stability.
14. Observations of nuclear spin and parity.
15. Observations of nuclear magnetic dipole moments.
16. Observations of nuclear electric quadrupole moments.

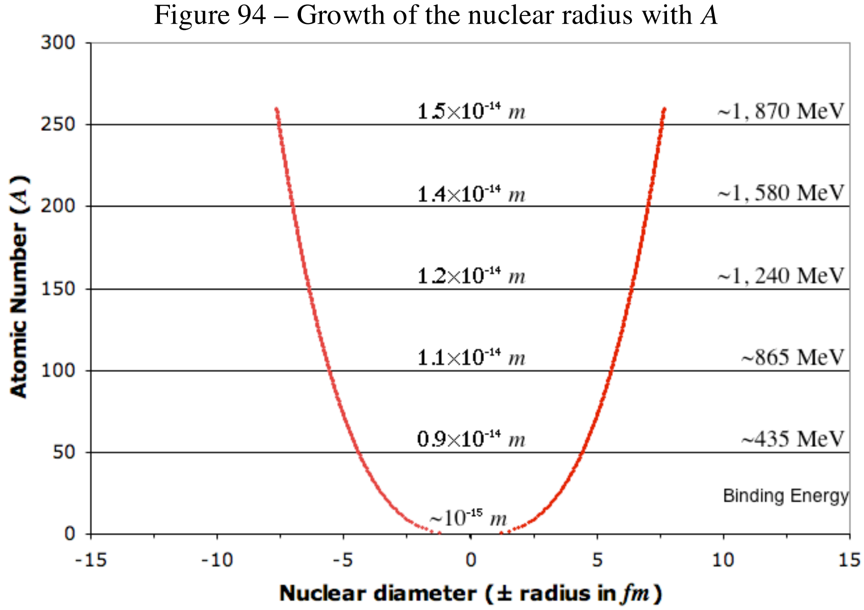
Figure 93 – Nuclear binding energies of common isotopes



The Fermi model for the nuclear radius expressed in units of fermis ($fm \equiv 10^{-15}\ m$) is

$$R = 1.2 \cdot A^{1/3}\ fm \qquad 135$$

Figure 94 – Growth of the nuclear radius with A



Drawing an analogy to quantum electrodynamics, Hideki Yukawa proposed in 1935 that the strong force holding the nucleus together against the Coulomb repulsion of the confined protons was similarly an exchange force between particles.[383] Although there is actually no compelling reason why this should be the case, Yukawa's pioneering ideas established a narrow perspective on the matter that dominated thinking for the next seven decades, leading to the currently popular theory of quantum chromodynamics (QCD).

Ironically, from the perspective of QCD, the foundations of nuclear physics appear distinctly unsound. –Frank Wilczek, *Nature* **445**, 157 (11 Jan. 2007).

Wilczek, who shared the 2004 Nobel Prize in Physics with both Politzer and Gross "for the discovery of asymptotic freedom in the theory of the strong interaction", might have rather more accurately stated that from the perspective of the *observational* foundations of nuclear physics, which are on firm ground, the *theoretical* foundations of QCD appear "distinctly unsound". While quantum electrodynamics very accurately models electromagnetic interaction, this force is associated with polarity of charge, which results in both binding and repulsive force. In contrast, the strong nuclear force is associated exclusively with a binding force in which polarity has no part to play. If there is an analogy to be drawn between distinct fundamental forces, common sense rather aligns the strong nuclear force with the exclusively binding force of gravity. It shall be made clear that they are indeed the same phenomenon (i.e., spacetime geometry) operating in different ways on radically different length scales. Along these lines, Albert Einstein wrote a paper in 1919 entitled *Do gravitational fields play an essential part in the structure of the elementary particles of matter?* Exhibiting his ingenious and characteristically profound insight (though it was consistently incomplete) he stated,

…there are reasons for thinking that the elementary formations which go to make up the atom are held together by gravitational forces.[384]

One may immediately deduce from the facts that the nucleus is a dynamical rather than a static system. That is to say, confined nucleons must be *harmonic oscillators* under the influence of internal nuclear forces. This oscillation may take on one of two modes: an orbital motion akin to electron orbits, or a vibrational mode driven by the opposition of the nuclear binding force and Coulomb repulsion between the protons. It is then clear that nucleons have momentum relative to one another and the rest-frame of the composite nucleus. Therefore, they must exhibit a wave manifestation in accord with Eq. (128).

In the previous section, the obvious idea that matter waves imply a distortion of spacetime was introduced. Indeed, if this is not so, then what other than spacetime is waving? Although such a wave is clearly a four-dimensional structure in spacetime, for illustrative purposes it can be modeled schematically in two dimensions as shown below. In exactly the same way that we think of a gravitational field as being a distortion of spacetime that creates a central binding force in the form of a potential well, the central troughs of matter waves are interpreted in the same manner. Of course, we are no longer thinking of this quantum-scaled "gravitational force" as behaving in accord with an inverse square law; rather we are thinking of it in terms of how the shape of interacting matter waves locally distort spacetime. This is a completely new perspective on "matters of gravity" that synthesizes the quantum concept of *matter wave* with the general relativity concept of *spacetime geometry* producing a central binding force. Drawing any parallel between the strong force and gravity, an immediate concern is how to prevent implosion of the nucleus with an effective repulsive force at the core. This will be addressed in short order.

Figure 95 – Energy interpretation of a matter wave as a spacetime geometry distortion

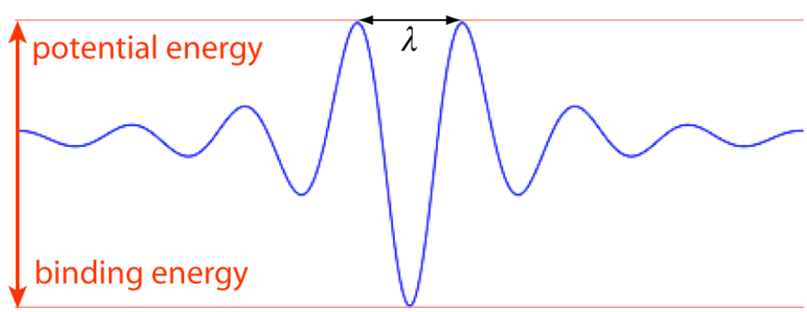
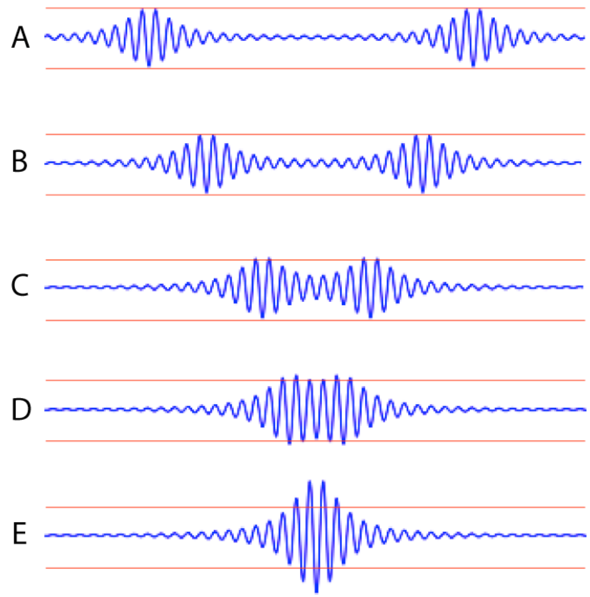


Figure 96 – Two independent waves "fuse" to become a composite waveform

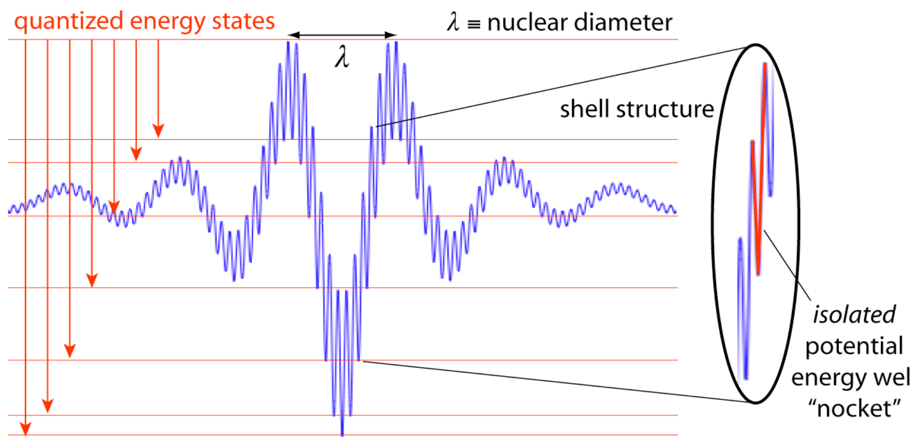


The Fig. (95) model intuitively conveys one of the primary observables related to the atomic nucleus. Inside the central trough of the radially damped matter wave, a binding force operates within a *very sharply defined boundary*, yet no central binding force exists beyond this boundary, which has a diameter of λ. For example, if we create a macroscopic mental model of the wave as an ideally frictionless surface in a gravitational field, a marble representing a nucleon may oscillate indefinitely within the central trough. However, if the marble were given sufficient energy to crest the initial potential barrier, Fig. (95) clearly implies that the marble representing the nucleon would be effectively ejected from the nucleus to arbitrary radius.

In order to visualize the interaction between material particles and spacetime at the quantum scale, we can imagine spacetime to be modeled by a kind of viscous medium. Rather than the 19th century idea of an "aether" permeating space, spacetime is *itself* the "medium" that waves. Relative motion of mass-energy through spacetime creates a local disturbance with wavelength h/p, which is what we call a "matter wave". The amplitude of this wave implies an energy structure as shown in Fig. (95). When particles interact *within one wavelength of each other*, constructive interference of their respective matter wave manifestations occurs. The result is a potential trough that in particular circumstances may be deep enough to *confine* the interacting particles within the local wave-like spacetime energy structure that their mutual interaction creates. This is the fundamental nature of an atomic nucleus. In the context of this idea, Fig. (96) can be envisioned as depicting the fusion of a free neutron and proton to form a deuteron.

In general, the composite wave structure created by the superposition and *interference* of many dynamical interacting wave sources will create a complex wave structure. With no attempt to accurately depict the actual quantized energy relationships in a nucleus, Fig. (97) is intended to be only a conceptual diagram showing the main features of this model that are consistent with numerous seemingly incompatible experimentally observed features of the nucleus. The primary idea is that within the unified energy structure of the nucleus, there is *substructure* that allows nucleons to behave as harmonic oscillators in physical isolation from one another. Each nucleon can be imagined to be individually confined to one of these substructures with the aggregate nucleus confined within the composite energy superstructure of the dominant wave. The term "nocket" (i.e., "nucleon pocket") is coined here to describe the isolated potential energy wells modeled to exist within the composite nuclear strong force spacetime geometry waveform.

Figure 97 – High-resolution conceptual matter-wave model of an atomic nucleus



This nuclear model has the following appealing qualitative features:

1. The boundary of the central potential force is sharply defined at the periphery.
2. The binding force exerted on protons and neutrons is identical (charge independence).
3. The nockets allow for extremely close packing and uniform density of the nucleons.
4. The nockets intrinsically prevent implosion without the need for a distinct repulsive force.
5. The nockets implement a shell structure that can accommodate the magic numbers.
6. The nockets naturally implement quantized energies of the constituent nucleons.
7. The nockets prevent collision between constituent nucleons.
8. The nockets provide for excited energy states.
9. The energy structure allows for quantum tunneling.
10. The size of the nucleus is limited by minimum allowed average nucleon momentum.
11. The dynamical wave structure is consistent with the statistical nature of radioactive decay.
12. The model is consistent with the shape of the binding energy curve shown in Fig. (93).

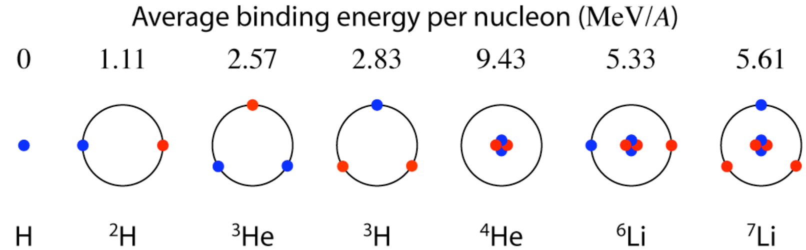
Alpha decay is characterized by mono-energetic particles with a velocity of about ten percent the speed of light. If we take this observation to imply that the internal velocity of bound nucleons is of the same order, then from the de Broglie relation, the calculated nucleon wavelength accurately represents the typical measured diameter of the atomic nucleus [Fig. (94)].

$$\lambda = \frac{6.626\times10^{-34}}{\left(1.673\times10^{-27}\right)\left(3\times10^{7}\right)} = 1.3\times10^{-14}\ m \qquad 136$$

The waveform in Fig. (97) suggests that the binding energy associated with a particular nocket is inversely related to its radial displacement. So, with some similarity to a gravitational field, a particular nucleon is more tightly bound the closer it is to the centroid of the central potential and nucleons closer to the periphery contribute less to the total binding energy of the aggregate, akin to a more peripheral satellite orbiting a dominant gravitational field. This feature is associated with the observed distinct quantized energy states of bound nucleons. Moreover, this also helps to explain several critical features of the Fig. (93) binding energy graph.

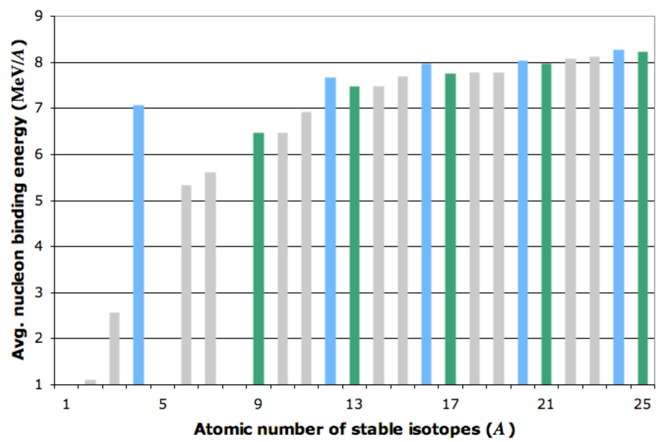
The schematics of the nuclei employed in Fig. (98) reflect the basic idea that the energy with which a particular nucleon is bound is related to its radial position in the nucleus. No attempt at detail is made other than to emphasize the empirical observation that the alpha particle plays a key architectural role in larger nuclei and that ^{4}He apparently forms a tightly bound core *subunit* that is repetitively used in building some larger nuclei. Orbital motion is not implied by the circles, only a peripheral location in the central potential.

Figure 98 – The alpha particle as a core nuclear subunit



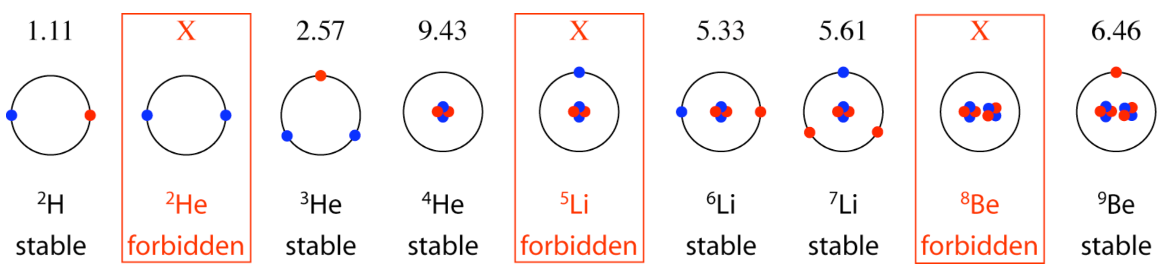
The following graph suggests that when an additional neutron is added to a core consisting of an integer number of alpha particles in these isotopes (^{12}C, ^{16}O, ^{20}Ne, ^{24}Mg) the binding energy contribution of the neutron is considerably less than the core nucleons, thus reducing the average contribution of each. In the context of Fig. (97), the isotopes (^{13}C, ^{17}O, ^{21}Ne, ^{25}Mg) have what we may call a *peripheral* neutron added to a nucleon core existing closer the centroid.

Figure 99 – Emphasis of periodic discontinuities in Fig. (93)



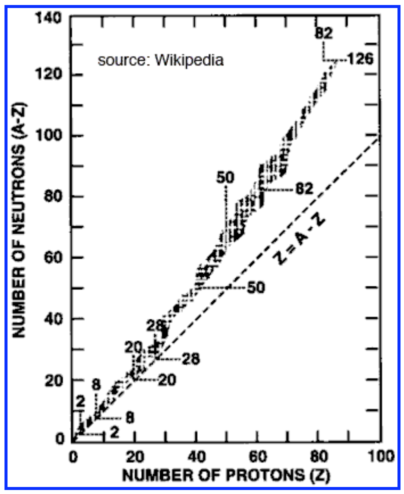
Given the success of the atomic electron shell model at describing chemical phenomena, the conventional shell model of the nucleus borrows heavily from the electron model in its attempt to describe the behavior of nucleons. Although the shell model first put forward by Maria Goeppert-Mayer has had some measure of success, one of its deficiencies is that it cannot explain the existence of forbidden nuclear configurations. For instance, no nucleus exists with an atomic number of five. In addition, a beryllium atom with matched sets of four protons and four neutrons, which one might expect to be one of the abundant alpha-conjugate nuclides, does not exist. Neither of these two nuclear configurations exists, even as an unstable isotope; they are evidently *forbidden*. This empirical fact is inconsistent with a nuclear model imagined to have a strong correlation with the electron shell model. Such a model cannot explain why it is impossible to build a nucleus with the forbidden configurations shown in the Fig. (100) schematics.

Figure 100 – Three forbidden nuclear configurations (binding energies shown in MeV)



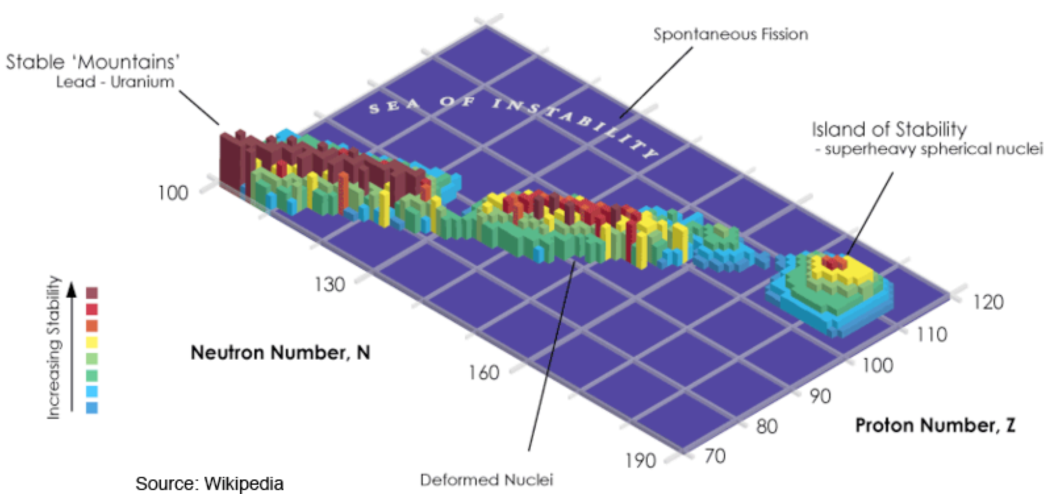
The wave model of the strong force is allied with an intuitive concept of distinct roles for the proton and the neutron in the nucleus; protons are "fuel" while neutrons are "coolant". Only a correct balance of the two can produce a stable nuclear architecture. With too much "fuel" in the form of Coulomb repulsion (e.g., ^{5}Li), *internal momentum is too great* and accordingly the wavelength is too short to bind the nucleons. Adding more "coolant" in the form of a neutron (e.g., ^{6}Li) creates the proper balance. The same situation holds for the forbidden configurations of ^{2}He and ^{8}Be. As the proton count increases with heavier nuclei, there is a clear trend towards an increasing proportion of "coolant" neutrons required for stable nuclei to form.

Figure 101 – Neutron-proton ratio for stable isotopes



> In the period from 1966 to 1972, a number of calculations (2) based on modem theories of nuclear structure showed that in the region of proton number $Z = 114$ and neutron number $N = 184$ the ground states of nuclei were stabilized against fission. This stabilization was due to the complete filling of major proton and neutron shells in this region and is analogous to the stabilization of chemical elements, such as the noble gases by the filling of their electronic shells. Some of these detailed calculations even suggested that the half-lives of some of these superheavy nuclei might be on the order of the age of the universe, and this stimulated a great effort to observe these "missing elements" in nature. The superheavy elements were predicted to form an island of relative stability extending both above and below $Z = 114$ and $N = 184$ and separated from the peninsula of known nuclei by a sea of instability…[385]

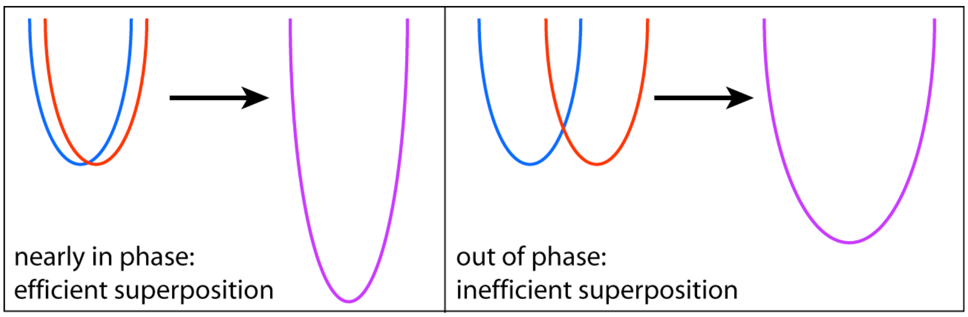
Figure 102 – Predicted "Island of Stability" *has never been found*



Although it has been sought for four decades, the "Island of Stability" predicted by the shell model of the nucleus has never been found. The wave model of the strong force implies that this is so because the predicted island does not exist. — If the attractive force between nucleons is mediated by particle exchange, then there should be no limit to the size of the nucleus. Why does the nucleus apparently get "full" at a diameter of about 15 *fm* rather than not or at some other value? Furthermore, the binding force per nucleon would be expected to always increase with each new nucleon as, regardless of increasing mass number, each additional nucleon experiences nearly equal attraction to the ensemble according to the constant density Fermi model.

The limit on the size of the nucleus and the shape of the binding energy curve are related. The sharp general rise in the binding energy curve from hydrogen to oxygen is due to a rapid rise in wave amplitude resulting from efficient constructive interference of the adjacent initial nucleons.

Figure 103 – Phase effects efficiency of constructive interference



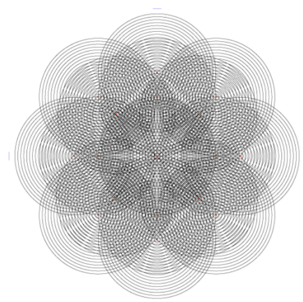
However, after A = 16, we see a steady decline in the slope of the binding energy curve as additional nucleons are added because the matter waves of nucleons added to the periphery of the core are increasingly out of phase with those of the core nucleons. As the core grows larger and newly added nucleons must be located further from the centroid of the nucleus, the efficacy of matter wave superposition declines. At some distance from the core, superposition no longer yields an increase in the overall potential depth of the wave structure to produce a viable nucleus. In effect, the nucleus "spills" at this size and cannot get larger because the wavelength of the confining energy superstructure cannot increase.

It has been made apparent that the nuclear binding force, which is the strongest force in nature operating on the quantum scale, shares essential features with the gravitational force, which is the weakest force in nature operating on the cosmic scale. If the atomic nucleus is bound by a quantum-scale periodic "gravitational field" effected by matter waves, then the superposition of all of these waves emanating from each of the individual atoms of a material body can be expected to effect the macroscopic gravitational field. Recall that Eq. (128) requires these waves to have a phase velocity equal to the speed of light. This implies that the "gravitational signal" from a mass propagates at the speed of light, never directly interacting with other bodies *per se*, but only modifying the spacetime geometry within which they exist. Because these waves must exhibit a spherically symmetric dispersion similar to light emanating from an isotropic source, the locally measured flux of these waves will naturally subscribe to an inverse square relationship. Newton's inverse square law is then understood to arise for much the same reasons that the apparent luminosity of an isotropic light source at double the distance decreases by a factor of four in accord with the growth of the enclosing spherically symmetric surface area. If it is not already clear, gravity and the strong force are identified as the same phenomenon, which we may refer to as the gravi-nuclear force, to join the electro-weak force.

What were at one time considered the four fundamental forces of Nature are now bifurcated into only two distinct types with quite different characteristics. One is a force described by the exchange of particles, while the other is a manifestation of spacetime geometry. In spite of this chasm between them, the *TGR* effect, which causes dynamical gravitational systems to emit ubiquitous electromagnetic radiation, implies a *relationship* between the two fundamental forces. It seems pointless to seek their unification; rather one may appreciate their distinction.

The modeling of the strong force as a dynamical wave structure is the ultimate challenge to be solved by modern scientific supercomputing. It is clear that this model is not something that can be elegantly presented in the form of a single descriptive equation or even a set of equations. To give some vague initial idea of this, Fig. (104) shows the graphical superposition of sixteen static two-dimensional wave structures, all having the identical wavelength. Now imagine that the wavelengths may be different, the source particles are oscillating at relativistic speeds, there are many more interacting particles and the structure is four-dimensional. That is what it will take to model the complex energy structure of an atomic nucleus with wave mechanics.

Figure 104 – The superposition of sixteen radial wave structures



46. Stimulated fusion

Einstein's famous energy equation ushered in the 20th century, bringing with it the threat of nuclear weapons, the inherent dangers of fission nuclear reactors (e.g., Chernobyl) and the vexing problem of how to dispose of radioactive nuclear waste. As it turns out, his equation was naïve, leaving out the most important and revealing part of the mathematical physics, which transforms the foundations of quantum mechanics and with it, much of *practical* modern physics.

The wave model of the nuclear binding force suggests the possibility of engineering an apparatus operating at room temperature in which the probability of a fusion event between a free nucleon and a target nucleus can be increased by many orders of magnitude by employing the concept of harmonics. Another way to put it is that one may artfully "drop" a projected nucleon into the potential well of a target atomic nucleus by "surfing" the nucleon through the protective barrier of waves that surround the nucleus. An appropriate term coined here for such a devise is a "stimulated fusion reactor". It seems reasonably certain that this technology could *not* be used to cause an explosion. This is because relatively few fusion events can be induced within a brief moment of time as occurs for thermonuclear detonation.

Conventional "hot fusion" technology is based on the assumption of a very small statistical probability of a nuclear fusion event at other than extremely high pressure and temperature ($\sim 4\times10^7$ K required for deuterium-tritium fusion). However, the concept of stimulated fusion is based on the idea of creating a fusion event between a nuclear target and single projected incident nucleons, which does not require a high-temperature environment. The wave model of the strong force opens the possibility that if the momentum of the incident nucleon is precisely controlled, thus very accurately "tuning" its wavelength to match the requirements of the target, the nucleon will have a high probability of fusing with the target. The energy cost of the tuning process can be expected to be an insignificant fraction of the energy produced by the fusion, which is not dependent on containment of high-temperature plasma. Given the rising human demand for energy and the specter of global warming due to the excessive use of fossil fuels, every effort should be made to investigate the viability of this concept. Moreover, as concerns global politics, it is important to consider the strategic and economic value of such a technology.

47. Conclusion

Ask someone, "How old is God?" Even if the person thinks of God from a secular perspective, the typical answer, is "God does not have an age; the very *idea* of God transcends finite time." Perhaps within a few years, the same question concerning the Universe, posed to any educated scientist, will result in a similar answer. The Universe is evidently a *process* (not an object) that does not have an age; only in reference to a local ideal clock that records the sequential time coordinates of local events does the human concept of "age" even have significant meaning. Moreover, eternity may be insufficient to describe cosmic time because geometric cosmic time is a concept that apparently transcends an infinite extent of *local* time.

It has very recently been asserted that the age of the Universe is 13.7 billion years with a margin of error of 1%. In a short time, this statement will be regarded as having the same scientific merit as when the celebrated astronomer and astrologer Johannes Kepler (1571-1630) naïvely declared that according to his calculations, the year of the Biblical Six-Day Creation was precisely 3992 years before the birth of Christ.[386] The intrinsic age of the relatively youthful Milky Way Galaxy is probably closer to 100 billion years than 10 billion years, although this is nothing more than a "guestimate" at this point. What is certainly the case is that giant elliptical galaxies are very many times older than the Milky Way and with little doubt their intrinsic age is on the order of many hundreds of billions of years.

Statements in recent years by not a few so-called 'experts' in cosmology have gone far beyond speculative scientific error. — There is a difference between being mistaken about something discussed and being a windbag when knowledge about the topic of conversation is uncertain. Using about 88,000 words, 136 equations over 100 graphics, and nearly 400 scholarly references, this book claims to overturn the apple cart of 20th-century physics. It asserts that

1. There never was a Big Bang; the Universe never existed as a singularity.
2. There is no such thing as the "early Universe" or "the beginning of time".
3. The Milky Way Galaxy is considerably older than was previously thought.
4. The visible Universe is considerably smaller than was previously thought.
5. Einstein misunderstood special relativity because it requires *geometry*, not algebra.
6. Einstein incorporated an obvious mistake in the general theory of relativity.
7. Spacetime does not incur "curvature" in the conventional geometric sense.
8. Einstein's "light bending" equation is a naïve form of a more general geometric equation.
9. Einstein's energy equation is a naïve form of the more general phasor equation.
10. Point 9 implies that the foundation of quantum mechanics must be significantly altered.
11. Point 10 implies that the strong force and gravity can be elegantly unified.
12. Point 11 implies that the QCD model of the strong force is incorrect.

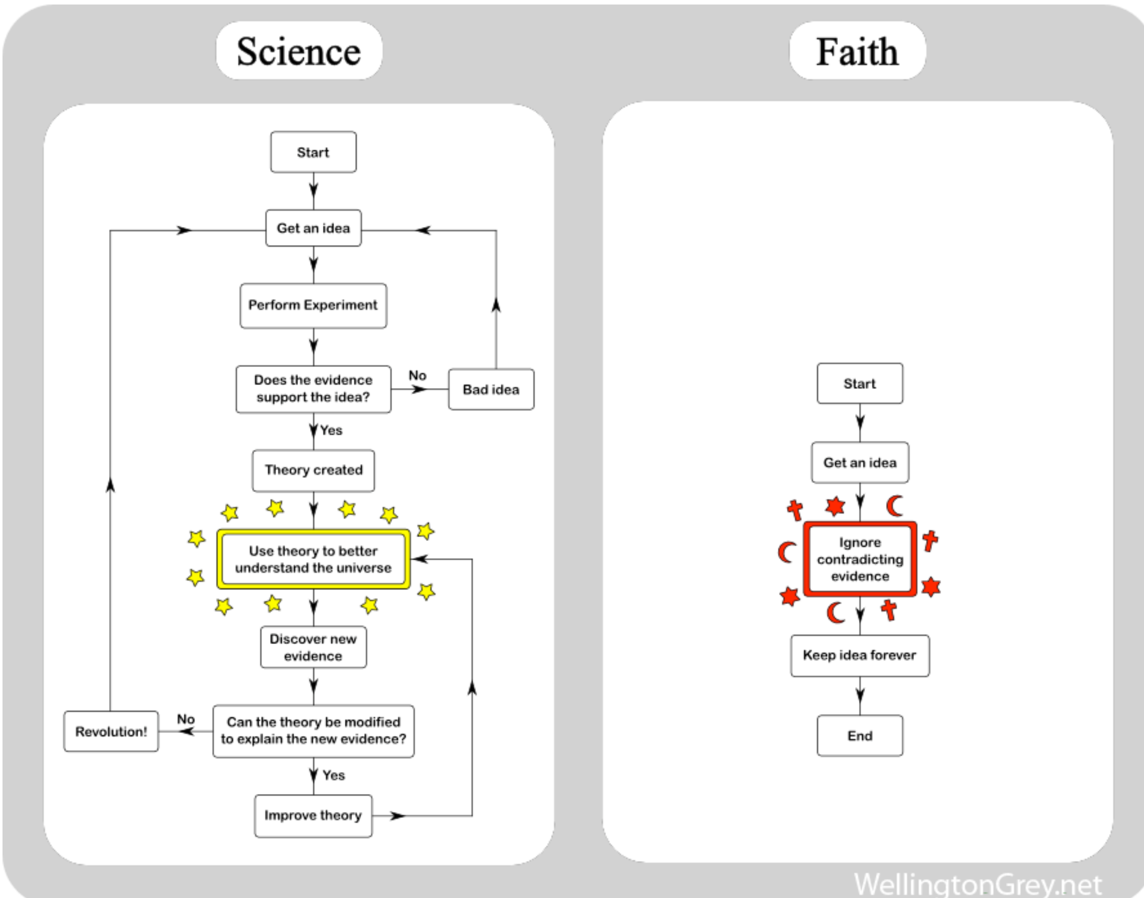
All of the above is based on existing empirical evidence and theoretical ideas based on the logical implications of first principles. Therefore, it can be expected to hold up under scrutiny.

> A new scientific theory does not triumph by convincing its opponents and making them see the light, but rather because its opponents die and a new generation grows up that is familiar with it. – Max Planck [387]

Max Plank implied that the scientific establishment he was familiar with in his time had more in common with the right hand panel of Fig. (105) than the left hand panel. He suggested that for them, ego-driven *beliefs* trumped new ideas and empirical evidence that challenged those beliefs. Times have changed; professionalism, public scrutiny and global competition require modern scientists to rapidly evaluate and develop promising new ideas. This book does not simply present a new scientific theory; it presents an entirely different way of looking at the physical Universe. Adopting a model of geometric versus linear time is as simple, natural and necessary as adopting a model of a round versus a flat Earth. It also requires the same significant shift in thinking away from a false immediate *perception* of reality to a more abstract physical scientific truth.

According to the ideas and evidence presented in this book, a large portion of 20th-century science essentially became a kind of popular ideology (i.e., "consensus science"). Evidence contradicting that ideology was ignored, conveniently advancing personal agendas instead of scientific truth. Indeed, the modern history of the Big Bang theory seems to be far better described by the flow chart in the right panel of Fig. (105) than in the left.

Figure 105 – "Science" vs. "Faith" flow charts



Courtesy Wellington Grey

Rather than something mysterious or questionable to be debated, the concept of God can be seen as something completely natural that is reflected in part by the self-evident beauty in Nature and the human capacity for understanding some part of it through science. The existence of a Creator also seems to be self-evident because mathematical facts and physical principles are *discovered* and not invented. Likewise, ubiquitous technologies such as the wheel or the laser are not invented; they are *discovered* based on underlying principles. Moreover, it seems clear that there exist general principles and precepts for optimal individual and cooperative human behavior that have the same source. Arguably, the self-evident intellectual, emotional and economic flourishing of a peaceful and healthy global society can no more be created by inventing and enforcing arbitrarily rules than a successful mathematical system can be arbitrarily "invented". The source of these self-evident universal facts and principles is one sensible definition of God.

In this light, Wellington Grey's flowcharts do not contrast science vs. religion, *per se*; but rather two fundamentally different ways of thinking. Ironically, the process labeled "Science" suggests a humble attitude toward developing human understanding of the Universe and therefore God [the word "theory" has its roots in the Greek "theos" (God) and ora (to look)] while the process labeled "Faith" here suggests hubris (excessive pride and arrogance). Perhaps a portion of the population lacks the feeling-awareness required to perceive God as the majority of others do. One may imagine this as similar to a blind person who cannot see. There is nothing "wrong" with blindness, and while a handicap, it is known to stimulate the superior development of other abilities. It would clearly be a profound iniquity if the blind were politically persecuted because of their handicap, yet it would be similarly irrational if the blind were to suggest that a preferred course of action was to promote blinding the majority of people whose vision is intact. By analogy, the separation of church and state and the guarantee of religious freedom, including the choice of atheism, are inalienable social principles that must one day be ubiquitous.

Science is an essential tool for human advancement, but it has its limitations and the scientific method is evidently not applicable to all phenomena or experience. Along these lines, I have an interesting story to tell of actual events that took place in July of 2004. — I was visiting a friend, Dr. Michael A. Stewart (PhD. Mathematics), who lives near San Louis Obispo, California.[388] Mike had been injured in a serious accident and I was driving him from his home to a restaurant to have lunch as he had been incapacitated for many weeks and was still unable to drive. At the time, most of the ideas that are presented in this book were nascent with no mathematical detail having yet been developed. As we drove north along Hwy 101, I began a conversation by saying "Michael, I don't think there ever was a Big Bang." I then began to discuss why I though this was the case (i.e., the concept of geometric time). I recall that Michael was dubious but respectful. The main theme of his response was a concerned warning that trying to disprove the Big Bang theory would likely be an unproductive waste of time, because the theory seemed to be a firmly established modern scientific fact. The conversation continued over a span of perhaps ten minutes and we took the Oak Park exit towards Grover Beach. Whilst in the midst of the debate, we cresting the top of a hill and a sign in front of a church suddenly came into view. It is accurate to state that we were both completely flabbergasted. The sign said, "BIG BANG THEORY – YOU'VE GOT TO BE KIDDING! –GOD". I had one of those disposable cameras in my car, so I was able to pull over, run across the street, and take a photograph. As I was visiting from far away, I had never before seen this sign and the local topography made certain that it had never been visible to either of us prior to the moment when we first saw it and I took the photograph.

Clearly, the event of this sign appearing to me when it did has no bearing whatsoever on discussion and evaluation of whether or not the Big Bang theory is incorrect. The only things that matter *in science* are correct empirical predictions supported by repeatable experimental and observational results. Unusual coincidences are not admissible as evidence in support of any scientific theory. However, experiences like this, which Carl Jung called synchronicity, can be interpreted in that context as inexplicable "messages from the Universe".[389] This particular event certainly was an interesting and arguably encouraging coincidence, under the circumstances. However, I cannot say that it was of great significance to me or that it profoundly affected me. What it did do was inform me that not all Christians are necessarily tied to the concept of a single cosmic creation event and that perhaps not a few people outside of professional science suspected that the Big Bang theory was a ludicrous idea, in spite of the ubiquitous "propaganda".

I had included a scan of the photograph I took in the first few iterations of the manuscript, but I was advised against it by a number of people, so I removed it. It is reasonable to believe that many people might make a negative judgment about the book without ever reading a word based only on that one inconsequential photograph. Therefore, it seemed prudent to remove it. I debated for a time whether to include the story of the sign in the book. There were reasons not to do so, particularly in a scientific document. However, in the end, I decided to include it because a major current social issue in the world is the conflict between modern science and religion. In particular, I want to avoid sparking a religious controversy over the scientific claim that the Big Bang never occurred, which might unduly influence objective scientific debate. I imagined atheists claiming that the proposed new cosmology, which lacks a cosmic creation event, was "scientific proof" that God does not exist. This serendipitous happenstance seemed to give me the opportunity to preempt such a groundless and potentially inflammatory claim as, with some good humor, it advances the idea that people of all faiths can abandon the idea of the alleged Big Bang event without concern that one is thereby questioning the existence of God, let alone denying it.

Unfortunately, much of science is posed by the scientific community in such a way that the average person feels as if the pursuit of science and reverence for God are mutually exclusive. It is also true that modern elite academia seems to discourage young students, particularly scientists, from incorporating a religious perspective in their secular studies. This arguably stems from the well-documented historical repression of revolutionary scientific ideas by religious institutions. However, that repression was clearly perpetrated by *individuals* who felt that the new ideas were threatening, both politically and economically. Confronted with the new ideas in this book that challenge their authority, it is likely that at least some members of the 21st-century scientific community will behave no differently from their 16th and 17th-century religious counterparts. The battle has never been between religion and science; it is between individuals who have a personal stake in preserving defunct ideas and those truth seekers who seek to advance better new ideas.

Science and religion can and should go hand in hand; they both concern the study of universal principles and they are each necessary to prevent abuses within the other. A ubiquitous fault with religion is that arbitrary human ideas of questionable purpose and value are invented and then attributed to the authority of God, while science has devastating effects when employed without the guidance of a moral compass. Using mathematical jargon, one might claim that science and religion are each *necessary but insufficient* without the other. In spite of whatever thoroughly convincing evidence is presented, if the scientific community presents its ideas as a *choice* between God and science, science will lose. Regardless of whether one may regard oneself as enlightened and guided by modern scientific principles, it is advisable to hold science as one way that can be used to understand God (e.g., the Jesuits), rather than as a challenge to God.

Dating back to the legacy of Georges Lemaître, many have associated the Big Bang theory with the Biblical *Genesis*. However, judging by its opening paragraph, the King James Version of which was quoted by the Apollo 8 crew orbiting the Moon on 24 December 1968, *Genesis* is clearly an *allegorical* story that relates exclusively to *our planet*, rather than the entire cosmos.

> IN THE BEGINNING GOD created the heaven and the earth. And the earth was without form and void; and the darkness was on the surface of the deep. And the wind from GOD moved over the surface of the waters. And GOD said, Let there be light: and there was light. And GOD saw the light, that it was good: an GOD divided the light from the darkness. And GOD called the light Day and the darkness he called Night. And there was evening and there was morning, one day.[390]

Following is an excerpt from an interview of John Mather and George Smoot by Adam Smith.

> [nobelprize.org – video time code of Mather and Smoot Interview; 30:52/33:25] [391]
> *Mather*: Life is just as mysterious now as it ever would have been.
>
> *Smith*: And moving on to the unexplainable, for the last question Vijaya Krishna Giravaru from California wants to know what you would tell curious kids if they asked you, "What happened before the Big Bang?" [laughter]
>
> *Mather*: I'd say that is a really good question and science has not answered the question. We don't know if it is even a meaningful question because we don't know whether, um, there were any such thing as space and time before the Big Bang. But, on the other hand mathematicians and physicists are working on the question and it's a thing we hope to be able to answer sometime. And George has had lots of interesting things to say about this too.
>
> *Smoot*: Right. It's a problem that I've been interested in because not surprisingly many people have asked this question and one of the hardest things that people– they just can't accept the fact there couldn't be time before the beginning. They– the idea that time doesn't go back forever is alienable and you try to give them examples like, you know, try and go past the North Pole and try to go North of the North Pole or something. You try and give those examples and it's unsatisfying for people even though you can understand that if you keep

> heading north, which is like going back in time, there comes a time when you are going forward in time and you can construct a Universe like that. But in fact there are lots of alternatives out there where going back in time is like a kind of random walk or something. There are a lot of people who are working on various models where there might have been something going on before our particular part of the Universe bubbled into a Big Bang and you don't know what the answer is and you know that the Big Bang is going to confuse. It's– it's like somebody torched the place and set fire to and the clues are very hidden after that but occasionally when you are experts in arson you can figure out whether it was burned by mistake or by accident and that's what scientists are trying to do they are trying to pose the question in the most general way, right. And right, even including making the most general laws in physics and see what kind of Universes you get and some of the things I think are quite successful and some are things like you have in the early days of quantum mechanics and the Copenhagen School. Some of the stuff makes a lot of sense and they are good rules and some of it is just mysterious mumbo jumbo because nobody knows what is going on and it will sort itself out.

When he talks about time here, George Smoot is repeating an ill-conceived idea discussed by Stephen Hawking on pages 137–138 of *A Brief History of Time*, which is predicated on the existence of the Big Bang. Hawking's book has little bearing on reality as it does not discuss geometric cosmic time. What Smoot did get right was the underlined portion of the last sentence. In the same interview, John Mather provided an excellent description of the scientific profession.

> We have to have a combination of confidence and caution. The person who is too confident is dangerous and the person who has no ambition is dangerous, so we have to have a mix of the things that are beyond what we can do but can still be proven, so this is what we do.

Given the theoretical ideas and empirical evidence presented in this book, it is reasonable to now state with some confidence that the Big Bang never happened or could have happened. If this is true, then the scientific purpose of particle accelerators with ever increasing energies must be questioned.[392] Yes, we can build machines to smash subatomic particles together at increasingly greater energies, but does this actually teach us anything essential about how the Universe really operates? With these machines, perhaps we are artificially creating conditions that are not relevant to any natural process, similar to writing a piece of fiction. While the ideas presented in this book offer many new opportunities, they also require many old ideas and projects to be reconsidered and perhaps abandoned. People are going to have to admit that they made mistakes and apply their precious expertise in new directions.

Every scientifically trained mind is of value to our world, for there are too few as compared to the number that are needed. That particular ideas that may have been pursued in the past are overturned has no bearing on the importance of these skills in service to society. While it may be disappointing to abandon particular former ideas, the excitement of applying skills and experience to promising new ideas should far outweigh any temporary discouragement.

> "I am not so unreasonable, sir, as to think you at all responsible for my mistakes and wrong conclusions; but I always supposed it was Miss Havisham."
>
> "As you say, Pip," returned Mr. Jaggers, turning his eyes upon me coolly, and taking a bite at his forefinger, "I am not at all responsible for that."
>
> "And yet it looked so like it, sir," I pleaded with a downcast heart.
>
> "Not a particle of evidence, Pip," said Mr. Jaggers, shaking his head and gathering up his skirts. "Take nothing on its looks; take everything on evidence. There's no better rule."
>
> "I have no more to say," said I, with a sigh, after standing silent for a little while. "I have verified my information, and there's an end."
>
> – Charles Dickens, *Great Expectations*, Chapter 40.[393]

Thank you
If you have read this book in its entirety, then it is clear that your time is particularly valuable and I greatly appreciate that you have invested it in my ideas. If you have enjoyed reading the book, I encourage you to periodically visiting my Website at http://www.afmayer.net. There will be new information and opportunities for visitors as the Website continues to develop.

SDSS recognition
Critical portions of this book have relied on the data acquired by the Sloan Digital Sky Survey (SDSS). — Funding for the SDSS and SDSS-II has been provided by the Alfred P. Sloan Foundation, the Participating Institutions, the National Science Foundation, the U.S. Department of Energy, the National Aeronautics and Space Administration, the Japanese Monbukagakusho, the Max Planck Society, and the Higher Education Funding Council for England. The SDSS Web Site is http://www.sdss.org.

The SDSS is managed by the Astrophysical Research Consortium for the Participating Institutions. The Participating Institutions are the American Museum of Natural History, Astrophysical Institute Potsdam, University of Basel, Cambridge University, Case Western Reserve University, University of Chicago, Drexel University, Fermilab, the Institute for Advanced Study, the Japan Participation Group, Johns Hopkins University, the Joint Institute for Nuclear Astrophysics, the Kavli Institute for Particle Astrophysics and Cosmology, the Korean Scientist Group, the Chinese Academy of Sciences (LAMOST), Los Alamos National Laboratory, the Max-Planck-Institute for Astronomy (MPA), the Max-Planck-Institute for Astrophysics (MPIA), New Mexico State University, Ohio State University, University of Pittsburgh, University of Portsmouth, Princeton University, the United States Naval Observatory, and the University of Washington.

Release history
A draft of this manuscript was initially released to the public on 4 April 2007. While all of the essential content and equations remained the same, the manuscript then underwent a rapid series of edits over the next seven weeks. Subsequent release dates during this time were:

7 April 2007
9 April 2007
11 April 2007
Attended National APS Meeting, Jacksonville (14–17 April)
21 April 2007
1 May 2007
10 May 2007
14 May 2007
16 May 2007
17 May 2007

The 23 May 2007 release should be considered the first "production" version of the manuscript. The introductory chapters and the conclusion were significantly reorganized and rewritten, producing a far superior communication. In addition, the critically important concept of a fractal cosmic architecture was introduced as a means to explain aspects of redshift survey observations.

Acknowledgements
The *Jay Pritzker Fellowship in Theoretical Physics* established by Daniel and Karen Pritzker and named in memory of Daniel's father has contributed to the successful completion of this book. The book exists in large measure due to their financial support of my efforts. Thank you, Daniel and Karen, for helping me to spend nearly an entire year of my life focused on my highest calling.

The work of the Pioneer Navigation Team played a critical historical role in initiating the process of writing this book. At some time in about 2003, when I first saw the subtle annual variations in the Pioneer-10 Doppler data shown in Fig. (58), I immediately suspected that my idea of an unmodeled relativistic transverse gravitational redshift was correct. It took a long time to go from that realization to finally completing this comprehensive new perspective on physics. Special thanks to Slava Turyshev of JPL who I had the good fortune to meet at the 2007 Annual Meeting of the American Physical Society in Jacksonville, Florida.

I would like to extend thanks to the many people who contribute to Google, Adobe Systems, Apple, Microsoft, Mozilla, MySQL AB, Wolfram Research, Design Science, the Calc Team and Scott Fortmann-Roe, author of *Longhand*, for creating the tools that I have used to do my work. Thanks are also due to all the programmers, system administrators, database administrators, and various engineers and technicians whose daily work makes the Internet a reality. Likewise, thanks to the staffs of the scientific journals that I have used in my research and to the many technical specialists, engineers, scientists, astronomers and supporting staff who have contributed to our knowledge of the Universe. I would also like to specifically recognize Carl R. (Rod) Nave of Georgia State University, author of the unparalleled *HyperPhysics* Website as having played an important role in my work. I often consulted this Website, which I found to be a particularly useful and comprehensive academic reference.

I am fortunate to have had the assistance of the talented Ms. Hollin Calloway, who expertly rendered my concepts of the Universe and of a wormhole [Fig. (9) and (85)] in Maya. Thanks and gratitude to my close friends, Louis J. Fabbri of Chugiak, Alaska; Brooks Howard of Portland, Oregon; and both Todd Andersen and Michael Fiske of San Francisco, California, who have followed my work and encouraged me for many years. Thanks also to Mr. John Harwood of Bay Alarm for our enjoyable conversations about physics when I was working in the office during his late night security route. Louis, Brooks, Todd, Michael and John knew about most of these ideas before anyone else and each knows parts of the story of how the ideas developed. There are also not a few people I met while working at cafés, including a fair number of women (pun intended) that may remember talking to me about why "the Big Bang never happened".

.

Closing quotations

Oh, it [the Big Bang] could be wrong, that is one of the interesting things about science, that you never know anything for certain—and when the Big Bang was first proposed it was a maverick, outlandish theory that nobody believed in.[394]

– Simon Singh (2005) author of *Big Bang: The most important scientific discovery of all time and why you need to know about it*

I am driven to try to right a terrible error that pervades the world of science. That wrong is the almost total acceptance of the Big Bang cosmological theory.

– William C. Mitchell, *Bye Bye Big Bang, Hello Reality* (2002)

Creativity is the sudden cessation of stupidity.

– Edwin Land (1909 – 1991)

Some people will never learn anything because they understand everything too soon.

– Alexander Pope (1688 – 1744)

Most people would die sooner than think; in fact, they do.

– Bertrand Russell (1872 – 1970)

No great thing is created suddenly…

– Epictetus (1st century)

Every cluster of galaxies, every star, every atom had a beginning, but the Universe, itself, did not.

– Sir Fred Hoyle (1915 – 2001)

An invasion of armies can be resisted, but not an idea whose time has come.

– Victor Hugo (1802 – 1885)

Care of man and his destiny must always be the principle interest in all technical efforts. Never forget this in the midst of your diagrams and equations.

– Albert Einstein (1879 – 1955)

Addendum (Segal's chronometric theory)

Irving Ezra Segal (1918–1998) was a professor of mathematics at M.I.T. and author of the chronometric theory. Following is the abstract of A. Levichev's review of the theory (1993).

> The main ideas and conclusions of the chronometric theory of I. Segal are surveyed. This theory differs from the special theory of relativity in that it replaces Minkowski space by a model $M = R^1 \times S^3$, but without specifying in the latter a Lorentz metric. In model M a 15-dimensional conformal group acts globally. Some successful applications of the chronometric theory to cosmology are mentioned, and a number of examples are cited to show the prospects for its use in the physics of elementary particles. The chronometric theory is briefly compared with the twistor program of Penrose.[395]

Following is the abstract of another review of Segal's theory by L. Wormald (1984).

> The Segal chronometric theory (1976, 1979, 1980) is examined, with particular attention given to the role of a physical measurement in the theory. A calculation of the redshift in Segal's theory in the geometrical-optics limit yields the result $z = 0$, in contradiction to Segal's result $z = \tan^2(alpha/2)$, and the disagreement is shown to arise from the unphysical nature of Segal's theory of measurement. An argument is also presented to show that the postulates on which Segal's theory is based are inconsistent when massive particles are introduced into the Segal universe.[396]

In his textbook discussing the theory (1976), Segal states the following:

> There exists a cosmos that is locally identical to the Minkowski cosmos, and has certain theoretical universality, in being apparently applicable in a fundamental sense at all distance levels. It may be described as the universal covering space of the conformal compactification of Minkowski space. For these reasons, and by virtue of applications made below to large-distance astronomy, it seems appropriate to designate this model as the universal cosmos. Its essential ideas were summarized in a preliminary account in Segal (1972).
>
> …
>
> More specifically, the redshift z is found to vary with the distance r from the point of emission in accordance with the law: $z = \tan^2(r/2R)$, where R is the "radius of the universe". This is in itself not a relation between observable quantities; but a variety of relations between observed quantities, such as redshifts, apparent luminosities, number counts and apparent angular diameters, are readily deduced from this law. These predictions from the theory have been found to be in much better agreement with actual raw observational data than would a priori have been expected by an astronomical theory.[397]

In the following equations, we replace Segal's use of the variable *r*, per above, with *d*.

$$z = \tan^2\left(\frac{d}{2R}\right) \quad \rightarrow \quad z = \frac{1}{\cos^2\left(\frac{d}{2R}\right)} - 1 \qquad 137$$

$$\cos^2\left(\frac{d}{2R}\right) = \frac{1}{z+1} \qquad 138$$

Note the striking similarity between this equation and Eq. (13). Like Hoyle and others, Segal was convinced that the Big Bang theory was incorrect and his ideas led to a theory having some similarities to the Minkowski cosmology put forward herein. However, Segal's ideas were based more on complicated formal theoretical mathematics than simple visualized physical intuition and so they did not ultimately produce a viable physical or cosmological theory.

Appendices

Portrait of Hermann Minkowski (1864–1909)

Preface to *Raum und Zeit* (Space and Time)

Preface.

The talk on “Space and Time”, which Hermann Minkowski gave at the Convention of German Scientists and Doctors in Cologne, is the last of his ingenious creations. Unfortunately, it was not destined for him to finish the more detailed development of his audacious concept of a mechanics in which time is integrated with the three dimensions of space. Equally esteemed as a person and professional, the author was torn away from his loved ones and friends at the height of his life and creativity by a tragic fate on 12 January.

The understanding and enthusiastic interest that his talk had awakened filled Minkowski with inner content and he desired to make his interpretation available to a wider circle through a special published edition. It is with a painful duty of piety and friendship that the editor’s bookshop von B. G. Teubner and the undersigned do herewith fulfill the last wish of the deceased.

Halle an der Saale, Germany

20 February 1909

A. Gutzmer

– Translated from the German with the kind assistance of Dr. Martin Lades. –

SQL select statements for Fig. (21[left] & 22)

```
-- this query must be performed on the 2dFGRS database
-- it returns 233,251 rows
-- select option "e-mail URL of compressed text file"
SELECT
        z_helio
FROM
        TDFgg
WHERE
AND     extnum = 0
AND     quality >= 3


-- this query must be performed on a local database
-- after importing the above z_helio data
SELECT
ROUND(z_helio, 4)
,       COUNT(1)
FROM
        TDFgg
WHERE
        z_helio <= 0.01 -- Fig. (21)
        -- use "z_helio > 0.001" instead for Fig. (22)
GROUP BY
        ROUND(z_helio, 4)
ORDER BY 1
```

SQL select statement for counts shown in Fig. (21[left])

```
-- this query must be performed on a local database
-- after importing the above z_helio data
SELECT
        COUNT(1)
FROM
        TDFgg
WHERE
        z_helio <= 0  -- blueshift count
        -- use "z_helio <= 0.01 AND z_helio > 0"  -- for low redshift count
```

SQL select statement for Fig. (26)

```
-- this query must be performed on a local database
-- after importing the z_helio data as above
SELECT
        ROUND(z_helio, 2)
,       COUNT(1)
FROM
        TDFgg
WHERE
        z_helio > 0
GROUP BY
        ROUND(z_helio, 2)
ORDER BY 1
```

Sloan Digital Sky Survey / SkyServer v5_20061016_1229
http://cas.sdss.org/astrodr5/en/tools/search/sql.asp

SQL select statement for Fig. (21[right] & 23)

```
SELECT
        ROUND(z, 4) AS z
,       COUNT(1) AS n
FROM
        SpecObj
WHERE
        objType IN (0, 1) --galaxies and QSO only
AND     zStatus IN (3, 4, 6, 7, 9) --good data only
AND     z <= 0.01  -- Fig. (21)
        -- use "z > 0.001" instead for Fig. (23)
GROUP BY
        ROUND(z, 4)
ORDER BY 1
--3 Redshift determined from cross-correlation and emz are consistent.
--4 Redshift determined from x-corr with high confidence.
--6 Redshift from emz plus consistent xcorr redshift measurement.
--7 Redshift determined from em-lines with high confidence.
--9 Redshift determined "by hand" with high confidence.
```

SQL select statement for counts shown in Fig. (21[right])

```
SELECT
        COUNT(1) AS n
FROM
        SpecObj
WHERE
        objType IN (0, 1) --galaxies and QSO only
AND     z <= 0  -- blueshift count
        -- use "z <= 0.01 AND z > 0" instead for low redshift count
AND     zStatus IN (3, 4, 6, 7, 9) --good data only
```

SQL select statements for Fig. (35)

```
CREATE TABLE 2QZN_QA
SELECT
        z1
,       z2
FROM
        2QZN
WHERE
        (W1 = 'QSO' OR W2 = 'QSO')
AND     (z1 > 0 OR z2 > 0)
AND     (Q1 > 0 OR Q2 > 0)


CREATE TABLE 2QZN_Z
SELECT
        CASE 0
                WHEN z1 THEN TRUNCATE(z2, 4)
                WHEN z2 THEN TRUNCATE(z1, 4)
                ELSE TRUNCATE((z1+z2)/2, 4)
        END AS Z
FROM
        2QZN_QA


CREATE TABLE 2QZS_QA
SELECT
        z1
,       z2
FROM
        2QZS
WHERE
        (W1 = 'QSO' OR W2 = 'QSO')
AND     (z1 > 0 OR z2 > 0)
AND     (Q1 > 0 OR Q2 > 0)


CREATE TABLE 2QZS_Z
SELECT
        CASE 0
                WHEN z1 THEN TRUNCATE(z2, 4)
                WHEN z2 THEN TRUNCATE(z1, 4)
                ELSE TRUNCATE((z1+z2)/2, 4)
        END AS Z
FROM
        2QZS_QA

CREATE TABLE 2QZ_Z
SELECT * FROM 2QZS_Z
UNION ALL
SELECT * FROM 2QZS_Z

-- this query must be performed on a local database after importing data
-- from 2QZ (NGP) & (SGP) into a local database and doing the above processing
SELECT
        ROUND(z,1)
,       COUNT(1)
FROM
        2QZ_Z
GROUP BY
        ROUND(z,1)
ORDER BY 1
```

IGS Station Logs

```
International GPS Service
     DGAR Site Information Form
     See Instructions at:
       ftp://igscb.jpl.nasa.gov/pub/station/general/sitelog_instr.txt

0.   Form

     Prepared by (full name)  : Oivind Ruud
     Date Prepared            : 2004-05-18
     Report Type              : UPDATE
     If Update:
      Previous Site Log       : dgar_20021105.log
      Modified/Added Sections : 1, 2, 3.7, 4.4, 11, 13

1.  Site Identification of the GNSS Monument

     Site Name                : Diego Garcia Island
     Four Character ID        : DGAR
     Monument Inscription     : None
     IERS DOMES Number        : 30802M001
     CDP Number               : None
     Monument Description     : STAINLESS STEEL BRACKET/MOUNT
     ...
     Additional Information   : Leveling mount placed over reference
                              : mark in stainless steel bracket.

2.   Site Location Information

     City or Town             : Diego Garcia Island
     State or Province        :
     Country                  : U.K. Territory
     Tectonic Plate           :
     Approximate Position (ITRF)
       X coordinate (m)       : 1916269.5191
       Y coordinate (m)       : 6029977.6090
       Z coordinate (m)       : -801719.9793
       Latitude (N is +)      : -071610.8688
       Longitude (E is +)     : +0722212.8584
       Elevation (m,ellips.)  : -64.7482
     Additional Information   : US-UK Military facility


International GPS Service
     MALD Site Information Form
     See Instructions at:
       ftp://igscb.jpl.nasa.gov/pub/station/general/sitelog_instr.txt

0.   Form

     Prepared by (full name)  : Eric C. Kendrick
     Date Prepared            : 2001-05-22
     Report Type              : NEW
     If Update:
      Previous Site Log       : mald0105.log
      Modified/Added Sections : (n.n,n.n,...)

1.  Site Identification of the GNSS Monument

     Site Name                : Maldives Tide Gauge
     Four Character ID        : MALD
     Monument Inscription     : none
     IERS DOMES Number        : 22901S001
     CDP Number               : (A4)
     Monument Description     : (PILLAR/BRASS PLATE/STEEL MAST/etc)
     Additional Information   : Antenna is fixed to an aluminum post ~ 2.3m
                              : high. Post base has a flange that is bolted
                              : to a concrete dock.
                              : Geodetic reference point is top-center of
                              : aluminum post.
```

```
2.   Site Location Information

     City or Town             : Male Airport
     State or Province        : Hulhule Island
     Country                  : Republic of Maldives
     Tectonic Plate           : Indian Plate
     Approximate Position (ITRF)
       X coordinate (m)       : 1803858.
       Y coordinate (m)       : 6099998.
       Z coordinate (m)       : 462749.
       Latitude (N is +)      : +041119.32
       Longitude (E is +)     : +0733134.68
       Elevation (m,ellips.)  : -92
     Additional Information   : Reference frame used is ITRF97.
                              : Coordinate system used is WGS84.

International GPS Service
     KWJ1 Site Information Form
     See Instructions at:
       ftp://igscb.jpl.nasa.gov/pub/station/general/sitelog_instr.txt

0.   Form

     Prepared by (full name)  : Dave Stowers
     Date Prepared            : 2006-06-12
     Report Type              : UPDATE
     If Update:
      Previous Site Log       : kwj1_20030811.log
      Modified/Added Sections : 0,3

1.  Site Identification of the GNSS Monument

     Site Name                : Kwajalein Atoll
     Four Character ID        : KWJ1
     Monument Inscription     :
     IERS DOMES Number        : 50506M001
     CDP Number               : None
     Monument Description     : PLATE WELDED TO TOP OF ALUMINUM I-BEAM
       Height of the Monument : 1m (from rooftop)
       Monument Foundation    : ROOF, BOLTED TO
       Foundation Depth       : N/A
     Marker Description       : DIVOT
     Date Installed           : 1996-03-05

2.   Site Location Information

     City or Town             : Kwajalein Atoll
     State or Province        :
     Country                  : Marshall Islands
     Tectonic Plate           :
     Approximate Position (ITRF)
       X coordinate (m)       : -6160880.8779
       Y coordinate (m)       : 1339883.3948
       Z coordinate (m)       : 960810.6383
       Latitude (N is +)      : +084319.94
       Longitude (E is +)     : +1674348.87
       Elevation (m,ellips.)  : 38,WGS84
     Additional Information   : position estimate taken from URL
                              : http://sideshow.jpl.nasa.gov/mbh/series.html
```

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