FQXi Essay Contest 2018: What is Fundamental?

The Fundamentality of Gravity

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Abstract After the physicality of existence, gravity's role in the Universe is the most fundamental thing. This role has various manifestations which, it is argued, have been largely misinterpreted by modern physics. An alternative conception of gravity—one that agrees with firmly established empirical evidence—is most compactly characterized by its definition of Newton's constant in terms of other fundamental constants. This expression and supporting arguments largely fulfill the long-standing goal of *unifying* gravity with the other forces. Phenomena spanning atomic nuclei to the large-scale cosmos and the basic physical elements, mass, space, and time, are thereby seen as comprising an *interdependent* (unified) whole. Meanwhile, a virtual industry of fanciful, far-from-fundamental mathematical distractions clog up the literature of what is still called fundamental physics. By contrast with this dubious activity—most importantly—the new conception is empirically testable. The test would involve probing gravity where it has not yet been probed: inside (through the center) of every body of matter.

1. Introduction

> *How far into the foundations, when it comes, must the revolution penetrate?* [1]
>
> — Thomas E. Phipps, Jr.

Many things are fundamental, each in its own context. Even asking what is the *most* fundamental thing evokes a wide range of answers, depending on one's experience and area of focus. In our opening quote, Phipps anticipates the need to disrupt something fundamental in the foundations of *physics* to spark what he sees as an inevitable and overdue revolution.

In the latter decades of his life, the recently deceased Phipps—a Harvard-trained physicist—grew suspicious of *relativism*, especially Einstein's theory of Special Relativity (SR). Insofar as it is based on SR, General Relativity (GR) similarly earned Phipps' mistrust. I disagree with many of Phipps' conclusions, but applaud his poignant, witty iconoclasm, mostly because it unceasingly emphasized the importance of empirical evidence.

One of the current essay contestants, Edwin Klingman, echoes some of Phipps' ideas by suggesting that the course of physics would benefit by rethinking the foundations back to Hertz and Maxwell. [2] Valuable as such probing may be, my hunch is that it is insufficiently fundamental and, like the work of Phipps himself, unlikely to yield any lasting or consequential influence on our understanding of the physical world. I think we need to dig deeper, prior to Newton, to reconsider some assumptions upon which his system of mechanics was built. Contemplating the implications of this pre-Newtonian investigation with regard to Einstein's theories logically follows. Before pursuing this route in a constructive way, some background context will be presented in the form of a summary and brief critique of the status quo. In the end our experience and our understanding of the nature of gravity will be crucially questioned.

The most fundamental thing is the physicality of existence. With physicality comes empirical evidence: an ingredient too often missing—or included only in the stingiest or lip-serviced quantities—in many of physics and cosmology's "frontier skirmishings," as Phipps wryly called them.

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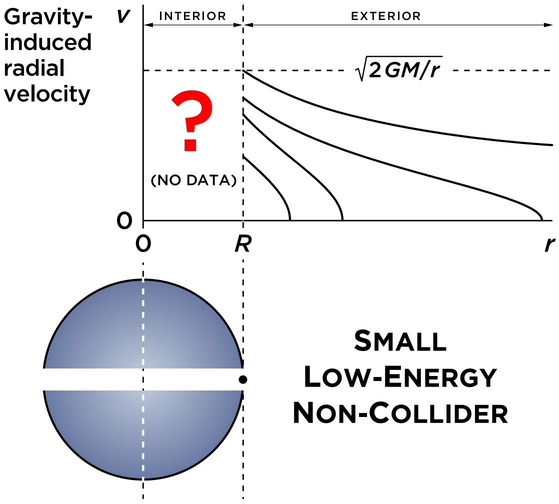

Fig. 1 Huge gap in gravitational data. Almost all published evidence in support of Newton's and Einstein's theories of gravity is based on observations made over the surface of large massive bodies such as the Earth or Sun. Though discussions of the interior falling experiment that would replace the question mark with data are common in physics classrooms and in the literature, it has never been done. The results are therefore unknown, as indicated.

Contrary to common opinion, our understanding of gravity suffers for exhibiting a large and fundamental, yet accessible, gap in empirical data. (See Figure 1.) A simple, feasible experiment would fill this gap. The fundamental significance of the foundation-questioning arguments to be presented here hinges on the result of this as yet undone experiment.

2. What's Not Fundamental About Modern Physics and Cosmology?

2.1 Beginnings?

The Universe is supposed to have started about 14 billion years ago with a Big Bang. Among the various cosmological solutions to Einstein's field equations, one has been chosen as the best candidate for corresponding with observations. Insofar as the mass-to-radius ratio M/R near the beginning was enormous (if not infinite, especially at time $T = 0$) one wonders why such a "primordial egg" should expand at all. Wouldn't gravity have been infinitely strong? Even in today's expanded state of the Universe, estimates of M/R suggest that we live in a "black hole." The common response to such ideas is that some quantum theory-based reasoning rescues theorists from the inadequacy of GR to explain the singularities it predicts. [3–5] Some unknown circumstance is supposed to have kickstarted the Universe to defy its own gravity; to accelerate everything toward its cold and inevitable death.

According to A. Zee:

> Extrapolating the curve backward ... [space] must vanish at some point in the past. ... No space! This spacetime singularity at which space disappears is known as the Big Bang. ... The Big Bang is actually the creation of space: from no space to space, stretched by the factor $a(t)$ ever since. [6]

For various questionable reasons the earliest period of the Universe is supposed to have been dominated by a mysterious quantum theory-inspired *inflaton field*, resulting in an overall growth curve that looks like a condom. [7] See Figure 2.

For various questionable reasons the quantum properties of this early phase have sometimes been interpreted to mean that our Universe is but one of a possibly infinite number in the overarching *multiverse*. Some authors have ventured to suppose the multiversal implications are consistent with the independently derived (decades earlier) and arguably just as dubious *Many Worlds* interpretation of quantum theory.

Be that as it may, our bubble of a Universe is supposed to cool as it expands. In its early stages the four forces of Nature (strong, electromagnetic, weak and gravitational) with their corresponding *force-carrying quanta*, the other fundamental particles, and hypothetical exotic dark matter particles, are supposed to have *frozen out* of the soup.

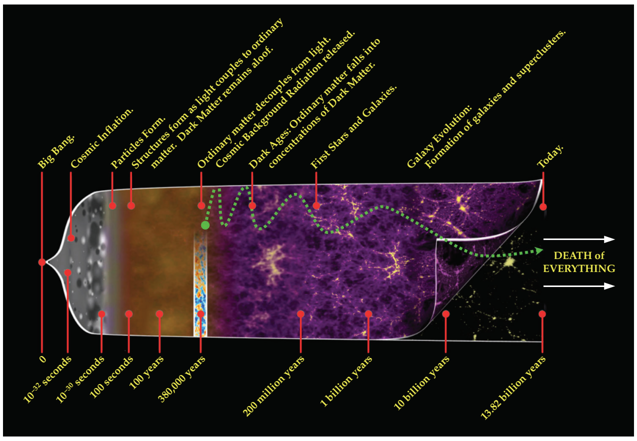

Fig. 2 Condom Cosmology: Starting from a point of infinite density, in the first 10^{-32} seconds the Universe is supposed to have rapidly come into existence thanks to the primordial "inflaton field." Pretty ugly universe, isn't it?

Fast forwarding to the present, we now find thousands of theorists cranking out thousands of theories in hopes of explaining the early times in more detail, of mathematically unfreezing, i.e., *unifying* the four forces, of (more modestly) quantizing gravity as a separate thing, or of explaining how various puzzling objects and structures deduced from observations could have formed in the time allowed since the beginning.

Formation problems facing modern astrophysics and cosmology include many levels of size: planets, stars, star clusters, galaxies, galaxy-clusters, super-clusters, and cosmic "walls" and filaments. The larger structures depend on the existence of exotic dark matter—a hypothetical substance that has been intensively looked for, but never found. Without exotic dark matter, the structures might have been able to form, but only in a Universe much older than ours is believed to be. The problem is sometimes cutely summarized by the fact that *you can't be older than your mother.*

For example, the so-called *super-massive black holes* found in the centers of most galaxies have been found to exist inexplicably near the beginning of time. A recent *Scientific American* article reports that the visible evidence of an enormously concentrated mass, a quasar, indicates a redshift $z \approx 8$, which corresponds to a time less than 700 million years after the Big Bang. The author comments:

> Conventional theories of black hole formation and growth suggest that a black hole big enough to power these quasars could not have formed in less than a billion years. . . . Yet it is unclear how black holes this large could have formed so quickly after the big bang. [8]

The pattern, quite consistently adhered to, is that when time constraints encroach on observations, astrophysicists and cosmologists will pile on more dark matter, speed up their simulations, and invent new mathematical models, way before they will begin to question whether perhaps there really is no time constraint because the Universe doesn't really have a beginning. For example, ca 1990, it was common to think no galaxies would be found with redshifts greater than $z \approx 5$.

Next, we have the "Earliest Ancient Dead Galaxy":

> This huge galaxy formed like a firecracker in less than 100 million years, right at the start of cosmic history. . . . It quickly made itself into a monstrous object, then just as suddenly, it quenched and turned itself off. As to how it did this, we can only speculate. This fast life and death so early in the Universe is not predicted by our modern galaxy formation theories. [9]

The last example is the recently found evidence of spiral structure in high-redshift galaxies, a feature that had previously been thought to take more time to kick in. Dr. Renske Smit, lead author in the original research, was quoted in an on-line magazine, saying:

> We expected that young galaxies would be dynamically "messy," due to the havoc caused by exploding young stars, but these mini-galaxies show the ability to retain order and appear well regulated. [10]

2.2 Particles?

All of this research clearly hinges on our understanding of gravity. As it stands, this understanding is, at best, schizoid. On one hand we have the clichéd Wheelerian pseudo explanation: *Matter tells spacetime how to curve; and spacetime tells matter how to move.* No academic physicist that I know of bothers to point out that we have no idea how these orders are carried out. What exactly is hiding behind the word, *tells*? What does matter *DO* to make spacetime curve? Only if we were able to correctly answer this question could we justifiably claim an understanding of gravity. Experts like S. Hossenfelder nevertheless smugly push the myth that "We understand gravity just fine, thank you." [11] To those who believe the myth, of course, it's not a myth. Sadly, understanding a *theory* about gravity (i.e., GR) is often confused for understanding the physical phenomenon of gravity itself.

On the other hand (or other side of the brain) we find the ever elusive particlized, quantum version of gravity. Theorists dream of finding a way to "marry" the so far only half-baked theories of quantum gravity with GR. But if we don't really understand *why* GR appears to work so well, it may turn out that the dream is a nightmare. Or it might be a nightmare because the quantum side of the coupling is unphysical.

We thus come to one of the key components of many of these pursuits: the *graviton*, alleged "mediator" of the force of gravity. A reasonable question is: How could a particulate thing (bundle of energy and momentum—however "virtual" it may be) cause two massive bodies to be *attracted* toward each other? As far as I can tell, physicists don't like questions like this. After many years of research, I've found only one instance of an attempt at an honest answer. In 1992 Roy Britten presents, as "the primary unexplained assumption," that

> After emission from one mass a graviton may be scattered multiple times and nevertheless when

> it is absorbed by a second mass the momentum transfer is in the correct direction to cause an attractive force on the absorbing mass toward the emitting mass. The underlying mechanism is not easy to visualize, but the problem arises for any model that includes gravitons. [12]

Note that the "underlying mechanism" is actually very easy to visualize. Just as Tinkerbell does fly (and Dumbo, too) a video animation could be drawn to show proper transfer of the momentum. Cartoon gravity *tugs* massive bodies toward one another by the Loonyversal force of *yankage*. The problem is not visualization. The problem is that the idea makes no sense. For all their popularity, *gravitons make no physical sense.*

But the show must go on. Rather than seek empirical evidence from accessible but as yet unexplored places where gravity might exhibit itself as having nothing to do with attraction, the base of modern theorists venture in the opposite direction, where they have reduced gravitons to even tinier, more magical *vibrating strings.* Veering more loftily than Einstein could have imagined "up to the regions of highest abstraction," [13] base members have churned out a cacophony of theories featuring a wide assortment of mental debris, such as amplituhedrons, massive gravitons, galileons, multiversally emergent fuzzballs, glueballs, isotropic Gauss-Bonnets, entangled anti deSitter/conformal field theoretical holograms, *and more.*

Happily, some critiques of this state of affairs can be found [14–18]. Sadly, the critics rarely, if ever, provide convincingly viable alternatives. One of the more gentle, tersely stated critiques is that of Elias Okon. In a paper discussing the possible incompatibilities between one of the foundations of GR (the Equivalence Principle) and quantum gravity theories, Okon concedes

> It is the opinion of at least a sector of the fundamental theoretical physics community that such field is going through a period of profound confusion. The claim is that we are living in an era characterized by disagreement about the meaning and nature of basic concepts like time, space, matter and causality, resulting in the absence of a general coherent picture of the physical world. [19]

2.3 Singularities?

Though Okon is a well respected veteran of the field, since he offers no concrete remedy, the parade of incoherence continues. Among the problems, one that used to be more commonly acknowledged as such is that GR predicts unphysical singularities.

At an Institute for Advanced Study symposium that took place a few years after the famous black hole papers of Hawking and Penrose were published (attended by Hawking) Einstein's devoted assistant, Peter G. Bergmann voiced his reservations about the cherished theory that had long been the focus of his research:

> A singular region represents a breakdown of the postulated laws of nature. . . . A theory that involves singularities and involves them unavoidably, moreover, carries within itself the seeds of its own destruction. [20]

Bergmann obviously did not like the idea of attaching undue physical significance to a theory that would require dividing by zero.

Willingness to accept singularities appears to be an acquired taste that modern theorists (and Hollywood) have turned into a lucrative pork barrel. Cogent, sensible arguments by Britten and Bergmann nevertheless remain on the books to inspire serious misgivings about gravitons and black holes (and even Big Bangs?) no matter how popular they have become in the meanwhile.

Phipps' critique was harsher than Okon's, but perhaps more accurate. He likened modern theoretical physics to a scientific community that "has suffered its own invasion by barbarians . . . hordes of pseudo-mathematicians . . . [wielding their] . . . bottomless kitbag of fields." [21]

Contemplating the possibility that at least some of the barbarians know their own work is useless, and likening them to the con-artist haruspices of old, Phipps wondered how it goes (wink, nod, and chuckle-wise) as they pass one another in the streets and halls of Princeton. As I see it, fundamental physics and cosmology have largely devolved into an entertainment industry, where *points for boldness* is a prime motivator; and "closeness to experience" (as Einstein disparagingly called it) hardly matters anymore. [22]

3. Testable Alternative

Crackpot amateurs inclined to trash the status quo are, of course, a dime a dozen. In my (exceptional?) case, I'm eager to back up my criticism by putting my ideas on the chopping block of Nature, the only authority that matters.

As indicated in Figure 1, the empirical gap mentioned above resides inside every body of matter. Proposals to fill the gap, at least in thought, go back to

1632, when Galileo proposed dropping a cannonball into a hole through the center of Earth. Though proposals for experiments that could actually be done (in an orbiting satellite or Earthbased laboratory) have been made, none of them have as yet been carried out. [23, 24]

In my 2011 paper *The Direction of Gravity*, it is argued that the first (most fundamental?) thing we might want to know about gravity is what happens to bodies that fall *inside* other bodies (near $r = 0$). I.e., what happens when a radially falling body is prevented from suffering a material collision on its path all the way to (or past) the center?

By performing this experiment we will be enabled to at long last conclusively answer the even more fundamental question: *What is the* ***direction*** *of gravity?* If the test mass oscillates back and forth along the length of the hole, the direction of gravity is inward, as has been *assumed* for centuries—even preceding Newton. A potent clue suggesting that we should expect a wholly different result, is that accelerometer readings perpetually indicate that the direction of gravity is not inward, it is pronouncedly *outward*. Prior to the invention of modern accelerometers we had, of course, the crude but equally indicative fact of the *flattening of our undersides*. If accelerometers tell the truth about their actual state of motion, then the test object in Galileo's experiment will not pass the center. If this prediction is supported, a deep and wide array of fundamental assumptions will promptly get the axe. (See Figure 3.)

Foremost among them would be: The *energy conservation law*; the assumption that gravity is an attractive force; and that spacetime is $(3+1)$-dimensional. While extra-dimensionality has become a fair sport in modern physics (for reasons quite unlike mine; see below) the sanctity of the energy conservation law and assumed attractive nature of gravity are out of bounds. That I would question these seemingly unquestionable things

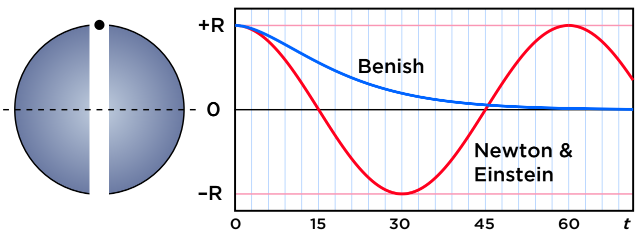

Fig. 3 Schematic showing competing predictions: Simple harmonic motion (red curve) vs. asymtotic approach to the center. The 60-minute oscillation period corresponds to a spherical source mass made of lead.

may partly explain why physicists have for so long ignored my urgent pleas to perform Galileo's experiment.

The first two (sacred) assumptions mentioned above serve as the fundamental principles upon which the oscillation prediction rests. Physicists thus effectively say: "We don't have to do the experiment because we already 'know' what happens. We already know because the energy conservation law says it must be so." Instead of seeing Galileo's experiment as a welcome opportunity, as an invitation to once again *test* these assumptions, virtually all physicists are inclined instead to *reject* the invitation as a *test of faith*. We already know the result. Our holy theory tells us what we'd find if we looked, so why bother? Nature schmature. We already know. *Amen*.

4. Dimensions, Curvature, and an Always Positive, Always Finite Coefficient

4.1 Stationary Motion

Early civilizations—up until, perhaps, the early 20th century—had little reason to suspect that flattened undersides could mean that falling things don't fall "down," but instead, its members were perpetually moving upward. In modern times, however—at least since the inception of Einstein's *Equivalence Principle*—the latter possibility had become a thinkable idea, and more recently, even a testable one. For it to be true some radical auxiliary assumptions concerning the nature of space, matter and time must also come into play. Arguably the most important of these ideas has to do with the dimensionality of space.

Consistent with the ancient idea that matter is composed of tiny static chunks of stuff is the notion that there are only three spatial dimensions. Including time, spacetime is supposed to be $(3+1)$-dimensional, where the $+1$ represents time as a dimension. These concepts are also consistent with the symmetry of *block time*, and with the idea of gravity as a force of attraction.

But then Einstein proposed that the attractive nature of gravity could be described as the *curvature of spacetime*. Neither Einstein nor his followers care about *how* the curvature is produced. But they do care that the staticness of matter and the blockiness of time (as in the static Schwarzschild solution) are maintained. Everyone is happy that, when motion takes place in this otherwise static picture, it is accounted for even more accurately than in Newton's theory. This has been shown to be the case for Schwarzschild's *exterior* solution, but Schwarzschild's corresponding *interior* solution has never been tested.

A curious stepping stone that Einstein used to get from SR to GR, is the analogy between uniform rotation and gravitational fields. [25] Einstein thought of the analogy as meaning that we have the right to think of rotating bodies as static things. The more logical interpretation is that *gravitating bodies perpetually move.* Curved spacetime indicates not only the perpetual stationary motion of gravitating matter, but the perpetual *generation of space* by matter. For this to be true requires—in order to maintain the coherence of physical systems—that there be more than three dimensions of space.

To see the logic of this in relation to the spacetime curvature of GR, let's begin with a *line.* When a 1-dimensional line begins to *curve*, it enters a *second* spatial dimension. When a 2-dimensional surface begins to *curve*, it enters a *third* spatial dimension. Evidence abounds that *the geometry of our seemingly* $(3+1)$-*dimensional world is curved.* Consistent with the pattern illustrated above, this simple fact is also an indication that the world possesses at least *four* spatial dimensions. By virtue of its manifest curvature, seemingly $(3+1)$-dimensional spacetime requires a fourth spatial dimension *to curve into.*

Would it be possible for a *static* thing to cause the curvature of spacetime? No. Especially in the absence of any other explanation, an obvious possibility is that spacetime curvature is a consequence of an unfolding *process*; something *happening.* In other words, something must be *moving*; lots of things must be *moving in concert*—to make it so.

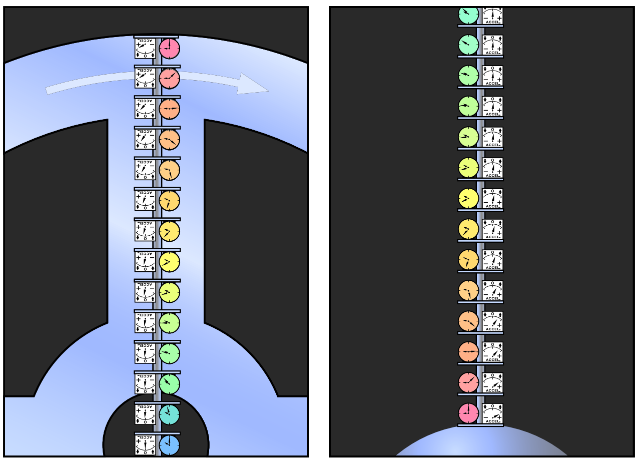

Fig. 4 The range of constant non-zero accelerometer readings combined with the range of constant clock rates indicates that both of these systems—rotational and gravitational—are undergoing *stationary motion.* Stationary motion of the rotating system is *through* space. Whereas stationary motion of the gravitating system is evidently *motion OF space.* Spacetime *curvature* caused by this motion implies a *fourth spatial dimension.*

Accelerometers are motion-sensing devices that indicate our gravity-induced *acceleration.* Clocks are also motion sensing devices, ones that indicate our state of gravity-induced *speed.* With regard to a large massive body like Earth, we thus conceive, as indicated by an array of motion-sensing devices, a range of stationary speeds and stationary accelerations undergone by seemingly rigid gravitating bodies. (See Figure 4.) As per Einstein's rotation analogy, we see this pattern as being analogous to that found on seemingly rigid rotating systems. In the present case (gravity) the motion is not *through* space, it is motion (generation) *OF* space. Its *curvature* indicates that it is $(4+1)$-dimensional.

In the vast academic literature about the possibility of spatial dimensions greater than three, we sometimes find snippets of discussions that perhaps vaguely echo the picture sketched above. But it never quite comes together. Many convoluted, unphysical, and observationally inconsequential ideas about extra dimensions are in the books, but the simplest and most physically plausible possibility appears to have been overlooked.

4.2 Well-Behaved Spacetime Curvature Coefficient

As suggested by Figures 1 and 4, the rates of clocks attached to Earth depend on the gravity-induced speed $\sqrt{2GM/r}$. For the surface radius $r = R$ this is the speed that the surface would have with respect to an object falling radially from (just this side of) infinity. As suggested by the rotation analogy, the state of motion of points attached to the gravitating body are seen as a combination of *stationary outward velocity* (clocks) and *stationary outward acceleration* (accelerometers).

Acknowledging the need to accommodate the limiting speed of light in all cases involving motion, how are we to apply this limit in the case of gravity? It is intuitively sensible to appeal to the many accounts in the literature about how the limiting speed relates to motion under constant acceleration. The limit is expressed as the speed $v(t)$, acquired by a rocket that is propelled for a long coordinate time t, under constant acceleration a, as measured by an onboard accelerometer:

$$v(t) = \frac{at}{\sqrt{1 + a^2t^2/c^2}} \,. \tag{1}$$

Replacing the kinematic (*through* space) quantity at with the gravitational (*of* space) quantity $\sqrt{2GM/r}$ yields a variety of interesting results:

$$V_{\mathrm{S}} = \frac{\sqrt{2GM/r}}{\sqrt{1 + 2GM/rc^2}} = \sqrt{\frac{2GM}{r + 2GM/c^2}}\,. \qquad (2)$$

This speed approaches c, not with increasing time, but with increasing M/r ratio. A deeply fundamental consequence follows from this simple analysis. Since the implied curvature coefficient $(1 + 2GM/rc^2)$ and its inverse remain positive and finite, singularities are never encountered, which means there are no black hole singularities (nor horizons). [26,27] Clocks do not stop, time does not turn to space, space does not turn to time, matter does not pop out of the Universe (or become infinitely dense). Rather, all of spacetime is well-behaved (singularity-free) and continuous.

To establish that our intuitively deduced and well-behaved coefficient and its inverse are empirically viable, let's compare the standard Schwarzschild metric coefficient with its possible replacement, as implied here. Squaring V_{S}, in Eq (2) yields the second term:

$$\left(1 - \frac{2GM}{rc^2}\right)^{-1} - \left(1 + \frac{2GM}{rc^2}\right) = \frac{4G^2M^2}{r^2c^4(1 - \frac{2GM}{rc^2})}\,. \qquad (3)$$

The difference is immeasurably small for all weak-field cases. The significant difference for strong-field cases motivates a prediction that conflicts with a flurry of recent accounts of gravitational waves supposed to have been caused by colliding black holes or neutron stars. This will be discussed in the next two sections.

5. Predictions

It bears repeating: Galileo's gentle, non-collider experiment needs to be done out of simple scientific curiosity alone. We do not really know what happens because Nature has not yet been allowed to testify. One can almost hear her saying: *Me too!* Perhaps the oscillation prediction will not withstand the *Ithuriel Spear of experiment*, to use Michael Faraday's expression. [28] My website (gravitationlab.com) and papers linked there spell out the reasoning upon which I make the following predictions:

1. A graph of the result of the Small Low-Energy Non-Collider experiment—when it is at last carried out—will look decidedly more like the blue curve in Figure 3 than the red curve.
2. Observations from the soon-to-be launched James Webb Space Telescope will reveal high redshift galaxies ($z \gtrsim 10$) to be very much like nearby galaxies. Astronomers will either bend and extend their already severely strained formation hypotheses, or they will begin to question the Big Bang theory.
3. Exotic dark matter particles will never be found because they don't exist.
4. Sometimes regarded as "a profound public humiliation of theoretical physicists," [6] the cosmological constant problem will turn out to be no problem at all. Neither the gravitational repulsion emanating from matterless space, as conceived in the context of GR, nor the 10^{120} greater repulsion borne of particle theory make any physical sense. Nor do any other theories that attach significance to the "Planck scale." (See *Rethinking the Universe*, Appendix A3–A6 [29].) Finally,
5. Claims by LIGO and LIGO/Virgo as to the observation of gravitational waves from colliding black hole and neutron star binaries will not hold up over time. (See below.)

6 Gravitational Waves?

6.1 Advice of a Sleuth

The last prediction on the list above is partly inspired by the spirit of the oft-quoted Sherlock Holmes remark: "Once you eliminate the impossible, whatever remains, no matter how improbable, must be the truth." In the present instance, the word *impossible* is perhaps too categorical. Without the evidence to be gained by performing Galileo's experiment, *impossible* should perhaps read: *extremely unlikely.* Or much more unlikely than merely *improbable.*

Specifically, I think it is much more likely that accelerometers tell the truth about their actual state of motion than that gravitons go around yanking at everything or that dividing by zero should be turned into an academic-entertainment industry. Big Bangs, black holes, gravitons, stringbranes, holographic amplituhedrons and such strike me as impossible. Whereas the violation of energy conservation that I think will be revealed by Galileo's experiment, strikes me as reasonable, even as I understand how *impossible* this must sound to the base of academic physicists.

6.2 Bipolar vs. Monopolar

A more direct physical argument bearing on the existence and measurability of gravitational waves concerns their *speed*. Electromagnetic (EM) waves, i.e., light waves, travel at the speed of light because of the electric and magnetic properties of vacuum space. Electromagnetism is a bipolar phenomenon $(+\,,-), (N, S)$.

Gravity, by contrast, is monopolar. So why should gravitational waves travel at the speed c? Why should gravitational radiation ride the same rails as EM radiation when there are no known corresponding base properties of gravity by which we should expect this?

6.3 Authorities Respond

I asked these questions in the Comments section following the October 2017 *Quanta Magazine* announcement of the latest LIGO observations. [30] With some evident coaching from MIT physicist Scott Hughes, the author Katia Moskvitch replied that: "Relativity demands that . . . all massless radiation travels . . . at the speed of light c." Curiously, Moskvitch concludes by quoting Hughes directly: "It is worth checking every time Nature makes a new test possible. 'One never knows where cracks in the edifice will show up,' says Hughes."

To this I replied that accepting the "demands" of a *theory* as physically true is not very scientific. Simply admitting that "we don't know why; we have only just *assumed* the speeds are the same," would have been more truthful. I then echoed Moskvitch and Hughes' suggestion to "check every time Nature makes a new test possible" by pointing out humanity's neglect to build and operate a Small Low-Energy Non-Collider. Alas, my latter response did not pass the *Quanta Magazine* moderator. Nature invites; the authorities pay lip-service, but ultimately decline. It gets old.

6.4 Judging the Evidence

For no known *physical* reason gravitational waves are supposed to have the same speed as EM waves. This equality was claimed to have been proven by the recent results at LIGO/Virgo. In light of this claim, how do I explain my prediction (5)? Without pretending to provide a complete answer (due to space constraints) I will nevertheless make a few key points. First, even the elderly Nobel Prize recipients Kip Thorne and Rainer Weiss have often been quoted (or seen on video) saying that LIGO's initial results were "too good to be true."

Second, it may be relevant that the seemingly clinching report of simultaneous electromagnetic and gravitational waves from GW170817–GRB170817A occurred during a one month period when LIGO and Virgo were both on line (just prior to a scheduled extended shutdown of LIGO) which occurred shortly before the Nobel Prize announcement was made. Also of possible significance is the null response of Virgo. The lack of a positive signal was argued to have positional significance, as the source must then have been located on or near the wave-cancellation plane at 45° to Virgo's arms.

Finally, the triumphant announcements made since the first one have all been based on the work of an enormous monolithic establishment that has made (and for decades has been making) a huge investment. The ultimate value of this investment had sometimes been questioned, right up to the 100 year anniversary of GR, when the first observation was reported. The pressure (either real or self-imposed) to at last yield some fruit after decades of intense effort and great expense, must have been substantial. The stakes are extremely high. In my opinion, therefore, we ought to continue to reserve judgment until the evidence becomes even more abundant and convincing.

Based on the successes reported so far, astronomer Edo Berger has recently predicted that 12–24 binary neutron star collisions per year should be observed when LIGO and Virgo go back on line. [30] To reiterate, I predict that this will not happen and that the already reported observations will, upon further investigation and passage of time, prove to have been caused by something other than gravitational waves.

7. Conclusion

Setting aside the dramatic conflicts between established ideas and those presented here, and while we await the testimony of Nature, I am eager to point out consequences of my model that I think have a ring of truth and beauty which justifies some confidence that these pursuits are worthwhile.

The cosmologist George Ellis is among those who have written extensively on the persistently puzzling *Arrow of Time Problem.* [31] Why do things only get older, not younger? Why does time only increase? The answer borne of my model, borne of the truthfulness of accelerometer readings, is simply this: *The arrow of time only increases because the arrows of matter and space also only increase.* Accelerometers all around the globe keep telling us that everything is "going up." Neither time, space nor matter, nor the seemingly distinct forces (nor particles) are separably, independently fundamental. Rather, they are *in*separably, *interdependently fundamental*. The most fundamental thing about them is their *inter*dependence.

Among the cosmological consequences of this new conception of gravity is a deSitter-like exponential global expansion. Unlike the "empty" deSitter model, however, we now regard gravitating matter as the generator of the expansion because the direction of gravity is now seen as being always and only outward.

From the present perspective, the Steady State models of previous decades were misguided because they maintained that gravity is an attraction. Consequently, they needed to invoke *spontaneous generation of matter* by the production of ever more new particles popping out of nowhere. By contrast, we now conceive that matter is generated out of all material bodies that already exist. The process by which this happens is gravity. The process may also be identified as *inertia*. The resistance to *linear* acceleration *through* space is caused by (or is the same thing as) the *volumetric* acceleration *of* space. In colloquial terms: The more space a body generates, the harder it is to push. The harder a body is to push, the more space it must be generating.

By virtue of its constant density, an eternal Universe whose semi-autonomous components are so characterized, must have its global, cosmic, gravitational properties simply related to its particulate, nuclear, quantum properties. We thus come upon a definition of Newton's constant that ties it all together:

$$G = 8\left(\frac{\rho_\mu}{\rho_{\rm N}} \cdot \frac{c^2 \mathrm{a}_0}{m_{\rm e}}\right), \tag{4}$$

where ρ_μ is the mass-equivalent of the CBR energy density, $\rho_{\rm N}$ is the nuclear saturation density, c is the light speed constant, a_0 is the Bohr radius, and $m_{\rm e}$ is the electron mass.

Remarkably, Eq 4 is very nearly true wholly independent of my model, as is also true of the assumption that led to it:

$$\frac{\rho_\mu}{\rho_{\rm M}} = \frac{1}{2}\frac{m_{\rm e}}{m_{\rm p}}, \tag{5}$$

where $\rho_{\rm M}$ is average cosmic density and $m_{\rm p}$ is the proton mass. [32]

After the fact of the physicality of existence, I thus propose that the truthfulness of accelerometer readings and Equations (4) and (5) are right up there as among the next most fundamental things. I stand to be corrected, or not, by the outcome of building and operating humanity's very first Small Low-Energy Non-Collider.

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