Strong Field Gravity in the Space Generation Model

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Abstract. —

The standard conception of gravity purports that spacetime curvature *causes inward* motion. The Space Generation Model purports instead that spacetime curvature is a *manifestation* of *outward* motion. It is shown that the latter conception results in magnitudes of curvature that are nearly identical to those predicted by General Relativity for most weak field circumstances. Testable differences are duly pointed out. The most feasible experiment to distinguish General Relativity from the present model would be a test of the interior solution, where the difference in predictions is especially stark. The strong field consequences of the Space Generation Model are not so readily tested, but a comparison with General Relativity is worthwhile because in the new model there are no horizons and no singularities. The heuristic methods used to demonstrate these results motivate a fresh look at the concepts of *mass* and *energy*.

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1. – Introduction

The most celebrated solution of Einstein's gravitational field equations—Schwarzschild's exterior solution—represents a region of physical space such as that surrounding a planet, as an utterly static thing. Somehow the planet's mass causes its neighborhood of space and time to curve, and this curvature determines the trajectories of other objects (e.g., falling apples, orbiting satellites, or light waves) placed in the field. Curiously, objects that are typically regarded as being *at rest* in this static field, manifest signs that they are actually in motion. Specifically, accelerometers placed on or above the planet's surface give positive readings in the outward radial direction. And clocks placed on or above the planet's surface tick slower than clocks placed at greater distances.

The Space Generation Model of gravitation (SGM) is based on the idea that these motion sensing devices—accelerometers and clocks—consistently tell the truth about their state of motion. This means that gravitational fields, the material bodies that generate them and their surrounding space, are not static. Everything moves. That's what the motion sensing devices are saying—whether we believe them or not.

By characterizing gravitational fields as static things, General Relativists clearly do not take the readings of motion sensing devices at face value. According to General Relativity (GR) it's the geometry of spacetime that causes these effects; *geometry* is regarded as the cause of motion. It is important to realize, however, that the only way we know how to produce these effects ourselves—without gravity—is by motion. The present idea is simply to assume that gravity also uses motion to produce these effects. In a certain sense, we are thus *inverting* the relativistic conception of gravity. It's not that spacetime curvature causes inward motion; spacetime curvature is the *manifestation of outward motion*.

New ideas are clearly needed because in the context of standard physics nobody knows what matter must *do* to make spacetime curve. In the context of GR the readings of motion sensing devices are geometric effects whose underlying cause is wholly mysterious and rarely questioned. Since the observed readings are predicted by the theory, physicists assume that the physical space that Schwarzschild's static field is supposed to represent is indeed static. But this assumption could be totally wrong. If it can be proven that the readings of accelerometers and the rates of clocks are accurate indicators of motion—i.e., that gravitational spacetime curvature is caused by motion—this would require revisions to our conceptions of space, time and matter more radical than ever before. The context of physics would need to be dramatically widened. Though in some ways more complicated than GR, the basis for the SGM's "inverted" approach is extremely simple: believe the accelerometers. By denying the truthfulness of motion sensing devices, GR necessitates its own set of complications which, in the end may prove to conflict with empirical evidence.

Clearly then, the SGM is not just a change in perspective. Most importantly, the idea is testable with a variety of experiments. Our highest priority is to have the simplest of these experiments carried out. Additional facts and ideas supporting the SGM and ways to test it have been presented in previous papers. [1-3] Many of the same facts and ideas will be discussed again in what follows, with a new emphasis on extremely strong manifestations of gravity. Since the simplest experiment that would test the model is the highest priority, before going further into the ideas behind it, in §2 I briefly describe this experiment. I should also mention that I have expended considerable effort to conduct the experiment myself. Due to various limitations of my makeshift laboratory, this effort has failed. So I have subsequently tried to generate interest in having the experiment performed by others in a more suitable laboratory.

This latter effort has exposed a sort of "communication gap." Unfortunately, my experience suggests that the foundations of physics are generally *presumed* to be so well understood that the desire to test them any further has been largely squelched. In §3 I argue that this view is based on prejudice. To expose the prejudice as such and to establish the viability of the SGM, a thought experiment is proposed in which we imagine ourselves as being totally ignorant of gravity and then discovering it for the first time. The appeal of this thought experiment lies in its negation of assumed knowledge. The first step is to wipe our minds clean of anything we may have learned about gravity. We go back to square one. To facilitate this difficult proposition, imagine that we have evolved in a world far from any stars or planets. Instead, our civilization has evolved in a self-sustaining rotating cylinder in the far reaches of space. All our lives we have lived very far from any masses whose gravitational effects would be easy to perceive. From the experience of exploring the space beyond our cylindrical world, and then encountering and landing on a planet-sized spherical mass for the first time, we would be unlikely to conceive of gravity as a force of attraction. We would more likely conceive it, I argue, as a process of the generation of space. Hence the name, Space Generation Model. From this experience—in our imagined rotating cylinder and then, for the first time, near a large gravitating body—we conceive of gravity not as something that causes inward motion, but rather as a manifestation of outward motion.

In §4 we reconsider certain theoretical and astronomical facts from the point of view established in §3. Specifically, we regard the limiting speed, c, arising in Special Relativity (SR) as applicable to the outward motion (generation) of space. It is suggested that the SR equation for uniform acceleration, $v = at/\sqrt{1+(at/c)^2}$, has an analog in gravitational physics and that the limiting speed prevents "dim compact massive objects" from developing any horizons or singularities.

We begin to explore the geometric consequences and physical implications of such a limiting gravitational speed in §5. The SGM "curvature coefficient" following from the results of §4, is compared to the "metric coefficient" of the Schwarzschild solution. In GR the "throat" of the spatial curvature embedding diagram (Flamm paraboloid) has a minimum radius, $r = 2GM/c^2$. The vertex of the cross-sectional parabola is at $r = 2GM/c^2$. Whereas the throat of the corresponding SGM paraboloid can be arbitrarily small. The vertex of the cross-sectional parabola is at $r = 0$.

In §6 these geometrical consequences for exterior solutions are extended to the interior. In particular, we compare certain features of Schwarzschild's *interior* solution for a sphere of uniform density with the corresponding features for the same sphere according to the SGM. A key difference is that, according to GR, the coefficients for time and space no longer have the same (or inverse) magnitudes inside matter. Instead they diverge so that the inverse temporal coefficient increases and reaches a maximum at the body's center. Whereas the spatial coefficient begins to decrease at the surface and goes back to unity at the center. By contrast, in the SGM the curvature coefficients for both space and time are always of the same magnitude. To illustrate, consider an array of stationary clocks attached to a uniformly dense sphere, going all the way to the center. According to GR, the slowest one is at $r = 0$; the temporal coefficient manifests a maximum deviation from unity, even as the spatial coefficient returns to equal unity. Whereas, according to the SGM the magnitude of both spatial and temporal coefficients is unity at the center. The maximum (and equal) deviations for both time and space are found at the surface. This difference in temporal coefficients inside matter corresponds to a drastic deviation even from Newtonian gravity, according to the SGM. It is the basis for the experiment that I have tried and have proposed for others to try. In §6 it is also pointed out that, for real astronomical bodies, uniform density is a poor approximation. Other idealized density distributions are presented along with their geometrical consequences.

Although the densities of realistic astronomical bodies increase steeply toward their centers, our discussion of uniform density spheres is continued in §7, as it facilitates clarification of the difference between proper mass and coordinate mass. Spatial curvature causes coordinate *size* (volume) to decrease. To a "coordinate observer" the spatial proportions of a body depend on the degree of curvature of the gravitational field it is in. Coordinate *mass* decreases in the same proportion (mass defect). This is an important relationship to understand, since coordinate mass is essentially the same thing as *active gravitational mass*. This is true in both GR and in the SGM. Unlike GR, however, in the SGM there is no limit on the mass-to-radius ratio and no limit to the mass defect.

In GR the Schwarzschild radius, $r = 2GM/c^2$, acts as a "horizon" when all of M is contained within r. This has caused lots of mathematical complications, the most troublesome one being within the horizon at $r = 0$ ("physical singularity"). The horizon at the Schwarzschild radius is sometimes referred to as a "light front" [4] because with respect to it the speed of light equals zero. This never happens in the SGM, whose possible speeds for matter and light are always well-behaved.

Unlike both Newtonian gravity and GR, the SGM also exhibits an acceleration limit, which is discussed in §8. The limit is not a fixed absolute value, but depends inversely on mass. This circumstance leads to a (very large) *force* limit that *is* absolute.

In §9 we consider the extreme case of an object falling radially from infinity. In the SGM the trajectory of such an object has special significance and is given the name, *maximal geodesic*. The SGM description of this special case is compared with the corresponding descriptions in both GR and Newtonian gravity.

In §10 it is pointed out that spacetime curvature in the Solar System is extremely small and that its magnitude is nearly the same, whether described in terms of Schwarzschild's metric coefficients or the SGM's "curvature coefficients." ($\Delta_{GR-SGM} = 4G^2M^2/r^2c^4(1-\frac{2GM}{rc^2})$.) The differing interpretations as to the cause of curvature nevertheless yield testable differences in predictions for the behavior of light and clocks. Specifically, the SGM's predictions for the *radial* motion of light and clocks differ measurably from the predictions of GR. Experiments that have already been done (e.g., the Shapiro time-delay test and the Vessot-Levine falling clock experiment) are equivocal as between the competing models. Results from the proposed OPTIS satellite experiment would have clearly distinguished between them. Unfortunately, this mission has been canceled due to lack of funds.

In §11 we begin to look more closely at how the concepts of *mass* and *energy* relate to gravitation. In particular, we consider the idea—implied by all preceding sections—that the energy of gravitation is positive rather than negative. This new way of conceiving gravitational energy is coupled with an equally profound new conception: the distinction between (linear) movement *through* space and the (gravitational, omnidirectional) movement *of* space. From these ideas it follows that active gravitational mass is not equal to inertial mass. Examples are given to establish the plausibility of these new SGM-based conceptions, which conflict so dramatically with standard physics.

The difference between proper mass and coordinate mass, as mentioned in earlier sections, implies a consequence that is discussed in more detail in §12. This difference is sometimes referred to as a *mass defect*. Although the idea of a mass defect appears in both GR and the SGM, details as to its cause and magnitude differ. In GR the mass defect can be regarded as a consequence of (negative) gravitational binding energy. This is not the case in the SGM, according to which gravitational energy is positive. In GR the mass defect has a maximum magnitude, whereas in the SGM there is no maximum. The mass defect in the SGM can become arbitrarily large—a property that may help to explain the formation of the enormous dim compact massive objects residing in the centers of many galaxies. Simple examples are given to illustrate the SGM's plausibility.

In §13 the key ideas concerning matter, energy, space and time according to the SGM are shown to imply novel cosmological consequences.

Finally, an Appendix has been added to comment on the methodology used in this paper. Simple analogies and heuristic arguments have been given to suggest extremely drastic changes in the prevailing world view. It is clearly desirable to bolster these arguments with a more rigorous mathematical theory. Though work is proceeding in this direction, it remains more expedient to seek the experimental results that could *immediately* determine the value of any such theoretical efforts.

2. – Importance of Empirical Test

Four of the most important features of the SGM are:

1. For domains that have been empirically explored, the magnitude of spacetime curvature arising in the model is nearly identical to that of General Relativity (GR). To my knowledge, the SGM does not conflict with any observational evidence gathered so far.
2. Gravity is described, not as a force of attraction, but as a process of the "generation of space."
3. Energy is not conserved. And,
4. It would be a relatively easy matter to test the model by experiment.

The violation of energy conservation and other novel consequences of the concept of space generation would be unequivocally demonstrated or refuted by testing an elementary textbook thought problem. Considering a uniformly dense spherical mass with a hole drilled through a diameter, if a test object is released from the surface into the hole, standard theory predicts that the object will harmonically oscillate from one side of the sphere to the other. If this prediction were confirmed, gravity would be rightly conceived as an attraction, energy would be conserved and the SGM would be duly laid to rest. On the other hand, if the test object does not pass the center, the SGM would prevail and our standard ideas about energy and gravity would be duly laid to rest.

Using a modified Cavendish balance, I have made efforts to conduct the experiment whose conceptual basis is described above. But my laboratory has proven to be inadequate for the task. I have therefore made several efforts in writing to draw attention to the fact that we have no empirical data supporting the standard oscillation prediction, that an experiment designed to gather this data is quite feasible, and that the effort would be worthwhile. The intent of these latter efforts is naturally to generate interest in having the experiment conducted in a more suitable laboratory.

Most of these efforts made no appeal to "new physics" because a common reaction to new ideas is resistance. The positive response I've gotten to this approach [5] suggests that it's an effective way to get people to at least start thinking about doing the experiment. The strategy of the present paper, by contrast, is "full disclosure." The overt idea is to demonstrate that our particular brand of new physics is also very *reasonable* physics. As we await results of the crucial experiment we are free to conceive the possible outcomes by reasoning based on well established facts of experience. To that end, the purpose of the next section is to establish the plausibility of the SGM by building it up from scratch.

3. – Beginner's Mind

> *It is important to realize that in physics today we have no knowledge of what energy* **is**... *We do not understand the conservation of energy.* —
>
> *Richard Feynman* [6]

Mass, one of the three foundational elements of physics, remains in many ways quite puzzling. The highly respected historian of science, Max Jammer, begins and ends his recent book on the subject, writing: "In spite of the strenuous efforts of physicists and philosophers, the notion of mass, although fundamental to physics, ...is still shrouded in mystery." [7] Among the more philosophically minded physicists (and physically minded philosophers) one finds similar assessments of our understanding of the other two foundational elements, time and space. Many volumes have been filled with discussions about the ultimate nature of time and the perennial question as to its evident one-way direction. So too, the meaning and structure of space or "vacuum," are subjects of lively debate.

It is not surprising, therefore, that *energy*, which is arguably the most important combination of these elements ($E = ML^2/T^2$: $M=$ mass, $L =$ spatial length, $T =$ time) is also poorly understood. It has sometimes been suggested [8] that our problem is just that we are missing a simple twist in perspective whose discovery would illuminate an underlying coherent picture that has so far been obscured by our confusion. In this state, we are well advised to try wiping our slates clean, to start over with a beginner's mind.

It is certainly true that observations concerning gravity in the Solar System appear to support the energy conservation law. But these observations all involve phenomena *outside* the surfaces of the bodies under consideration. In particular, we have never followed the trajectory of a falling object *inside* a gravitating body to its center. How do we know that this is not a profoundly consequential oversight? We can't know until we've looked. Furthermore, it is inevitable that our world view has been deeply colored by the fact that humanity's entire evolution has unfolded from a cosmically rare perspective: on the warm moist surface of a very large massive sphere. Since we are starting from scratch and we are already familiar—perhaps *too* familiar—with the Earthian perspective, let's now imagine what it might be like to discover gravity for the first time from an entirely different perspective. This is not easy to do. To facilitate the needed innocence (shall we say) for the remainder of this section let's pretend that we are not from Earth.

Suppose we are members of a civilization that has evolved in a huge self-sustaining rotating cylinder far away from any bodies large enough to produce an appreciable gravitational effect. *We are totally ignorant of gravity.* But we know well how light propagates inside and outside our cylinder. We know well the effect of velocity on measuring rods and clocks. We have highly evolved mathematical knowledge, including deep insights into non-Euclidean and hyper-dimensional geometries. And for spatial and navigational reckoning (inertial guidance) we make good use of our gyroscopes, measuring rods, radar systems, clocks and accelerometers. We have fine-tuned the technology behind these instruments and have developed the deepest trust in their reliability. With their aid we never fail to determine whether or not we are moving, and by what magnitude and direction, with respect to the axis of our home, our unanimously "preferred" rest frame. The idea of a theory of *relativity* purporting to explicate the "relativity of motion" seems to us very strange and unnecessary. For us motion is absolute; it is indicated absolutely by its effect on accelerometers and clocks (the two motion sensing devices whose importance we will emphasize in what follows).

Now suppose we have an advanced space program. The moment comes for us to journey far and long to explore parts unknown. Eventually we come upon a huge spherical mass. With a harrowing feat of rocketry we manage to land softly on its surface. What a bewildering experience! How does the surface of this sphere keep accelerating? Not only near the landing site but all the way around this enormous round mass, accelerometers give constant positive readings. Based on what we know about how accelerometers work, we tentatively take this to mean that matter is a source of perpetual propulsion. We hadn't noticed this before because never before had we any experience with such a huge chunk of it.

Being way too early to draw any firm conclusions, we are nevertheless intent on solving the puzzle. We need more data. So part of our strategy is to set up a system of extremely tall instrument towers on the surface. Accelerometers and clocks are placed at regular intervals, all the way to the very distant top. The accelerometer readings and clock rates provide crucial clues. Together they confirm a pattern that had emerged prior to the firing of our landing rockets. This is important because it reinforces our initial assessment that the sphere approached and overtook us—not the other way around. In a way this is obvious. From the moment when we stabilized our position with respect to the sphere, when it appeared as only a tiny speck in the far distance, our rockets had been turned off. From that moment onward, at first very very slowly, but increasingly, the sphere clearly *accelerated toward us*. Our on board telescope revealed an image of the sphere whose size steadily increased. This size increase correlated exactly with our radar sounding measurements of the rate with which the sphere's distance decreased. One possibility that only the craziest among us might have dreamed up is that *we accelerated* toward the sphere. To the rest of us this idea makes no sense because we have learned from experience to always *believe our accelerometers*, whose readings remain zero.

The tower instruments have confirmed the evidence gathered during the sphere's approach: The body's acceleration varies as the inverse-square of the distance and its velocity varies accordingly (as the inverse square root of the distance). The closest thing we know of to a set of facts like this is the pattern of clock rates and accelerometer readings given by the array of instruments we have mounted on the huge radial spokes of our rotating cylindrical home. The pattern clearly involves motion—but it's a kind of *motion that persists unchanged*. In our cylinder we referred to this as *stationary tangential velocity* and *stationary inward acceleration*, both of whose magnitudes vary directly as the radial distance from the axis. Having conducted many sophisticated experiments designed to reveal the effects of this motion, we discovered that among them is the shortening of measuring rods in the direction of the velocity. Living in a stationary system whose length and time relationships vary with distance inspired the possibility of describing this pattern in terms of non-Euclidean geometry.

Now, on this huge massive sphere, we can't escape the analogy. Stationary motion is the prominent common feature. But differences between the circumstances indicate noteworthy possibilities where the analogy breaks down. If we continue to regard our accelerometers and clocks as faithfully indicating our state of motion, then the manifest stationary *outward* velocity and stationary *outward* acceleration on and around the sphere would require not only that *spacetime is curved*, but that it comprises *more than three spatial dimensions*. In our cylinder the cause of clock slowing and rod-contraction is motion *through* space, which conception requires only three space dimensions. Whereas the cause of clock-slowing and rod contraction on and around the massive sphere is evidently the outward motion *of* space. Matter appears not only as a source of self-propulsion, but as a *generator of space*. This is implied by the acceleration varying according to an inverse-square law. The most (or perhaps the only) logically consistent way to accommodate these facts is to conceive the *generation* of space as a manifestation of another *dimension* of space. Spacetime is evidently $(4 + 1)$-dimensional. Matter is evidently an utterly inexhaustible *source* of space, as it endlessly projects itself from three to four dimensions. (See Figure 1.)

It is important to point out that an alternative explanation might have occurred to us, or at least it might have occurred to the craziest one in our ranks. It is clearly a radical step to invoke a fourth space dimension. So the loon could justifiably ask whether all we need to explain our experience is curved spacetime without the extra dimension?

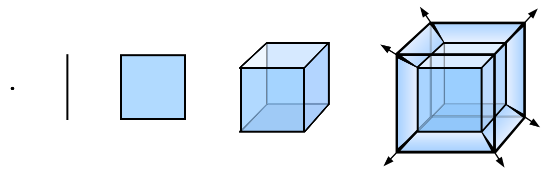

Fig. 1. – Hierarchy of spatial dimensions: height, width, depth, gravity.

Maybe. After all, this is claimed to be the most natural explanation by the natives of the sphere. To them, positive accelerometer readings might indicate a state of motion or they might indicate a state of rest. Their conception of motion is really mixed up. Amazingly, the natives think of their sphere as a *static* thing. Amongst ourselves we have at least one free-thinker who has also ventured to look at things from that perspective.

Since our heritage is to regard accelerometer readings as always indicating how fast the accelerometers accelerate, it is much less radical to invoke a fourth space dimension than it is to suppose accelerometers could lie (or could *mean* something other than what they *say*). Nevertheless, our heritage, our theories and speculations are clearly insufficient to *prove* what we can only learn from Nature. Evidence we have gathered so far is inadequate to clinch it either way. But our experience of being overtaken by the sphere suggests a crucial test. Suppose there had been a hole through the sphere aligned with its direction of approach—a hole large enough to engulf our rocket ship. If then we had never fired our landing rockets but instead we let the sphere swallow us, how much of it would have accelerated past us? If the sphere were a static thing and we accelerated toward it (in contradiction with our accelerometer readings) then we would have acquired a maximum speed upon reaching the center. We'd then continue on up and exit the other side. But if the massive sphere is in a state of stationary outward motion, if it propels itself outwardly and generates the space that accelerates past us, then the motion must, by symmetry, go to zero at the center. Our rocket would not pass the center.

To resolve the question, we would naturally seek an experimental test of a similar circumstance in a laboratory with massive spheres of a more convenient size. It all comes down to this experiment. Note that Figure 2 depicts the "setup" in the ideal location: outer space. The laboratory version, in order to minimize the effect of the huge base-sphere, would have to be done on a horizontal plane. The natives have suggested that a modified Cavendish balance would work as a suitable apparatus. (For details, see *Interior Solution Gravity Experiment* [5].)

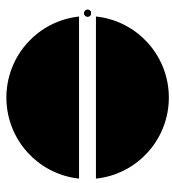

Fig. 2. – What happens? Though Newton's and Einstein's theories of gravity give predictions that are commonly presented in elementary books and articles, as yet we lack the only answer that really matters: Nature's answer.

OK, now let's revert to our Earthian perspective. The purpose of our hypothetical scenario should be clear: If we had only just recently discovered the accelerative effects of huge massive bodies, or if we have succeeded in imagining what discovering gravity for the first time might be like, then the result of the interior solution experiment will have become a burning curiosity. In what follows we will be intermittently reminded of this as we continue to investigate other implications of our explorer's preferred hypothesis.

4. – Speed Limit

> *A theory that involves singularities and involves them unavoidably, moreover, carries wihin itself the seeds of its own destruction. —*
>
> *Peter G. Bergmann* [9]

The experience of our fictional explorers is similar to our own experience insofar as it involves only relatively "weak" gravitational fields. Rather than consider further consequences of our new model in this weak field regime, for the moment, let us jump to the extreme regime of strong gravitational fields. This is an area of lively theoretical research—mostly within the context of GR—which is beginning to also include empirical astronomical data

Astronomical observations provide convincing evidence for the existence of Dim Compact Massive Objects (DCMOs). Contrary to the implied prophesy of Bergmann's remark quoted above, GR lives on even after Hawking and Penrose proved that the theory carries within itself the inevitability of singularity-laden "black holes." [10] DCMO's such as the one at our Galaxy's center are widely regarded as physical examples of black holes. As we shall presently see, in the SGM real physical objects never satisfy the definition of what a black hole is supposed to be; clocks on DCMOs do not stop and light does not get trapped below their horizons because there are no horizons and there are no singularities.

To see this, consider the following analogy from Special Relativity. Material objects cannot be accelerated to the speed of light. An especially simple consequence of light speed being an unreachable limit is the equation which expresses the velocity, v, due to constant proper acceleration, a:

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

where t is coordinate time and c is the light speed constant. In §3 we referred to a *stationary outward velocity* as being the speed that caused the tower clocks to run slow. This speed has the same magnitude as what an object falling radially from infinity would appear to have at any height alongside the tower. In Newton's theory of gravity this speed is called the escape velocity,

$$V_{\text{ESC}} = \sqrt{\frac{2GM}{r}}\,, \tag{2}$$

where G is Newton's constant, M is the mass of the sphere and r is the distance to the sphere's center. We'll come back to this equation momentarily.

First let's reiterate and elaborate on the significance of SR's speed limit: Material bodies cannot be accelerated to the speed of light and anything that does move at the speed of light is not matter, but energy. One of the key distinctions between the two is that matter is "clock-like." A clock (e.g., a fundamental particle) traveling slower than light keeps time. Whereas "photons" or light waves do not; they are, in this sense, "timeless." This conclusion follows from the Special Relativistic time dilation equation, which shows that increasing speed corresponds to decreasing clock rate, such that a speed equal to c corresponds to a clock that no longer ticks at all; i.e., what is no longer a clock. Since the SGM agrees with these consequences borne of Special Relativity, it is reasonable to postulate that the SGM involves a similar limit, applicable to masses as the source of gravity. We therefore exchange the kinematic quantity, (at) with the stationary gravitational quantity $\sqrt{2GM/r}$:

$$V_{\text{S}} = \frac{\sqrt{\frac{2GM}{r}}}{\sqrt{1 + \frac{2GM}{rc^2}}} = \sqrt{\frac{2GM}{r + \frac{2GM}{c^2}}} \,. \tag{3}$$

This equation resembles Newton's [Eq (2)], except that it does not represent the speed of an object that "escapes" gravity; rather, the stationary outward velocity, V_{S}, represents the motion of the gravitating system itself, which can never attain the speed of light, c. In Eq (1) the speed limit is approached in the course of *time*. Whereas in Eq (3) the speed limit can be approached by increasing the mass-to-radius ratio. Another crucial difference between Eqs (1) and (3) is that Eq (1) refers to a linear velocity *through* space. Whereas Eq (3) refers to an outward velocity *of* space. This distinction—motion *through* space vs. motion *of* space—is a fundamental concept of the SGM and will be a recurring theme in this paper. Presently, the idea is that whether it's motion through space or motion of space, the speed of light cannot be reached by matter.

5. – Radial Coordinates

5˙1. *Schwarzschild Exterior Solution.* – Eq (3) leads to some interesting geometrical consequences. We begin by showing how it compares with key features of GR's Schwarzschild solution. This is the equation from which the consequences of gravity concerning a single dominant spherical mass are commonly derived:

$$ds^2 = c^2dt^2\left[1 - \frac{2GM}{rc^2}\right] - dr^2\left[1 - \frac{2GM}{rc^2}\right]^{-1} - r^2(d\theta^2 - sin^2\theta d\phi^2) \,. \tag{4}$$

Our concern will not be to discuss or derive the various solutions to this equation, but to simply note the quantities in square brackets. They are the *metric coefficients*, which represent the magnitude of spacetime curvature, i.e., the effect matter has on the rates of clocks and the lengths of radially oriented measuring rods. These coefficients would be unity at infinity; they would be unity at any distance if $M = 0$. In any case, the entire field is regarded as a static thing; the Schwarzschild field does not move.

By squaring the velocity given by Eq (3) we can derive an analogous coefficient which similarly represents the effects on measuring rods and clocks:

$$V_{\text{S}}^2 = \frac{2GM}{r(1 + \frac{2GM}{rc^2})} = \frac{2GM}{r + \frac{2GM}{c^2}} \,. \tag{5}$$

Let's call the sum in the denominator on the right side, r-gamma:

$$r_\gamma = r + \frac{2GM}{c^2}\,. \tag{6}$$

The r in Eqs (5) and (6) has a similar meaning to the r appearing in the Schwarzschild solution. The distance, $2GM/c^2$ is commonly referred to as the Schwarzschild radius, r_{S}. But GR does not regard their sum, $r + r_{\mathrm{S}} = r + 2GM/c^2$, as having the significance that it has in the SGM. The role of this quantity in the SGM analog to the Schwarzschild coefficients comes to light by appealing to another analogy that is sometimes discussed in the context of GR.

5·2. *Rotation Analogy.* – The similarity between uniform rotation and gravitational fields is well known. As Einstein and many followers have presented it, the rotation analogy serves as a kind of "link" between Special Relativity and General Relativity [11]. The motion of rotation produces absolute effects that do not go away as they do in cases involving only linear velocities, by a simple coordinate transformation. In other words, with respect to the flat background Minkowski space of SR, rotational motion is *absolute*, not relative. Einstein sought to make any kind of motion as "relative" as possible. He argued that the *principle of relativity* could indeed be retained if the effects of rotation were ascribed not to motion, but to non-Euclidean geometry. To Einstein this supposedly justified thinking of oneself as being *at rest* even if one were rotating. [12, 13] The similarity of the experience of being "at rest" on a uniformly rotating body and being "at rest" on a large gravitating body was seen by Einstein as further motivation for this approach. But Einstein's approach is not the only logical possibility. Maybe he had it backwards. If we simply accept that rotation is a manifestation of absolute motion, the similarity of the effects implies that this is also true of gravitating bodies and everything attached to them.

Uniform rotation may be thought of as a combination of stationary *tangential* velocity and stationary *inward* acceleration, which both vary directly as the radius. The frequency (ticking rate) of clocks and the lengths of rods in the direction of their velocity are both reduced by the stationary tangential velocity. This is often expressed by the equations,

$$f_{\mathrm{r}} = f_0\sqrt{1-\frac{r^2\omega^2}{c^2}} \qquad \text{and} \qquad l_{\mathrm{r}} = l_0\sqrt{1-\frac{r^2\omega^2}{c^2}}\,, \tag{7}$$

where f_0 and l_0 are the frequency and the length of a clock and rod at the axis, r is the radial distance and ω is the angular velocity. Now let's consider gravity using analogous terms. In this case f_0 is the rate of a clock at infinity and Δr_0 is the radial length of a measuring rod at infinity. The rates and sizes of identical clocks and measuring rods at *finite* distances would then be given by

$$f_{\mathrm{r}} = f_0\sqrt{1-\frac{V_{\mathrm{S}}^2}{c^2}} = f_0\sqrt{1-\frac{2GM}{r_\gamma c^2}} = \frac{f_0}{\sqrt{1+2GM/rc^2}} \tag{8}$$

and

$$\Delta r = \Delta r_0\sqrt{1-\frac{V_{\mathrm{S}}^2}{c^2}} = \Delta r_0\sqrt{1-\frac{2GM}{r_\gamma c^2}} = \frac{\Delta r_0}{\sqrt{1+2GM/rc^2}}\,. \tag{9}$$

The expressions under the middle radicals in Eqs (8) and (9) will be recognized as square roots of the analogous expression appearing as a metric coefficient in the Schwarzschild solution:

$$1 - \frac{2GM}{rc^2}\,. \tag{10}$$

The crucial difference, of course, is that in the SGM the radial coordinate is not simply r, but $r + 2GM/c^2$ $(= r_\gamma)$.

5˙3. *Flamm Paraboloid.* – Now both r and r_γ are physically meaningful lengths; but neither one is straightforwardly measurable (e.g., with a long tape measure) as they would be if space were flat. (If space were flat we'd have $2GM/c^2 = 0$ and $r = r_\gamma$; i.e., $M = 0$.) In the Schwarzschild solution r is defined as

$$r = \sqrt{A/4\pi}\,, \tag{11}$$

where A is the surface area of a sphere centered on $r = 0$. This is also true in the SGM. Note that one may also think of r in terms of circumference, C, of the sphere

$$r = C/2\pi\,. \tag{12}$$

In either case the idea is that circumferentially oriented measuring rods are not contracted; they have the same length as identical rods at infinity, and so serve as a meaningful basis for comparison.

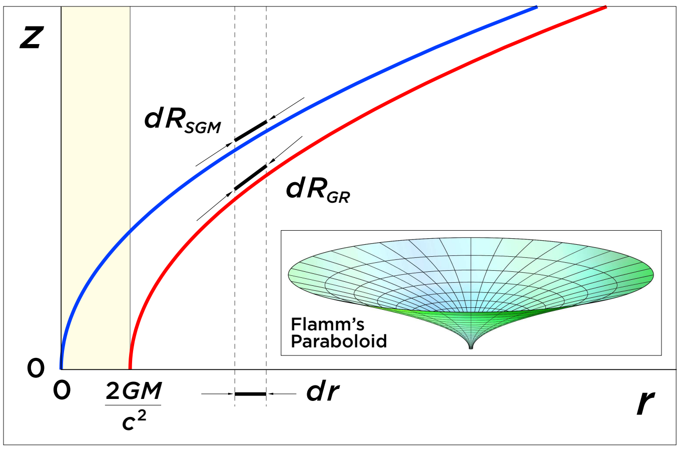

Fig. 3. – Cross-section of $\frac{1}{2}$ of GR's Flamm paraboloid embedding diagram (red); and corresponding cross-section for the Space Generation Model (blue). The curves are identical except for the r-axis offset. Projections of the length elements, dR onto the r-axis indicate the difference between proper length (dR) and coordinate length (dr). Inset: Rotation of red parabola with respect to z-axis produces Flamm's paraboloid, whose throat has a horizon radius, $r = 2GM/c^2$. The corresponding SGM paraboloid is the same except that its throat radius, $r = 0$, and there is no horizon.

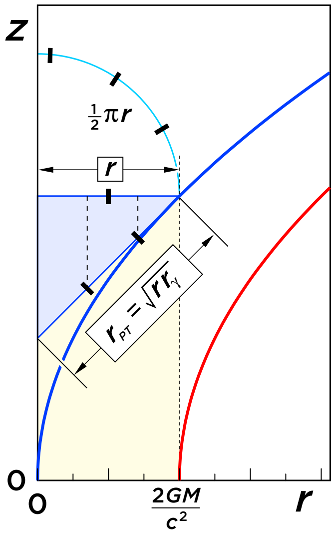

Fig. 4. – Circumferentially oriented measuring rods have the same length as rods imagined as existing along the coordinate r-scale. Radially oriented rods at the surface are shortened so that the number of them it would take to span the distance r is in the ratio $r_{\mathrm{PT}} : r$.

It will be useful to compare the embedding diagrams for both models. For GR this is one half of a cross-section of Flamm's paraboloid. For the SGM this is the cross-section of a similar paraboloid, translated along the r-axis. (See Figures 3 and 4.) The full three-dimensional embedding paraboloid is often depicted as a depression in a rubber sheet, similar to the inset in Figure 3. The vertex of the parabolic profile in GR is at the Schwarzschild radius, defined by $r = 2GM/c^2$. The equation is

$$r_{\mathrm{GR}} = \frac{c^2 z^2}{8GM} + \frac{2GM}{c^2} \qquad \text{or} \qquad z_{\mathrm{GR}} = \sqrt{\frac{8GM}{c^2}\left[r - \frac{2GM}{c^2}\right]}. \tag{13}$$

The Schwarzschild radius is supposed to define the *horizon* of a black hole, where clocks are supposed to stop and within which even light is supposed to be trapped. These characteristics are inevitable consequences of the metric coefficient, $(1 - 2GM/rc^2)$ going to zero.

5˙4. *SGM Paraboloid.* – In the SGM the comparable "curvature coefficent," $(1 + 2GM/rc^2)^{-1}$ never goes to zero and the corresponding parabola contains no added $2GM/c^2$ term. Thus

$$r_{\mathrm{SGM}} = \frac{c^2 z^2}{8GM} \qquad \text{or} \qquad z_{\mathrm{SGM}} = \sqrt{\frac{8GMr}{c^2}}. \tag{14}$$

The main idea of Figure 3 is to represent the difference in length scales, as between radially oriented rods attached to the massive body, i.e., proper length, dR and the coordinate length, r-scale, dr. The SGM parabola is more prominent in Figure 4, where the significance of the tangent to the parabola is also pointed out. Lines extending from any tangent point to the z-axis have the length

$$r_{\text{Parabola Tangent}} = r_{\text{PT}} = \sqrt{r r_\gamma} = r\sqrt{1 + \frac{2GM}{rc^2}}\,. \tag{15}$$

The meaning of these relationships will be further clarified after we consider how the exterior solution curve joins up with the interior for four particular density distributions.

6. – Mass, Density and More Parabolas

6·1. *GR: Spherical Cap and Space/Time Divergence.* – Schwarzschild's interior solution for an incompressible fluid of uniform density, ρ_0 (which will not be presented here) yields a "spherical cap" (circular arc) to Flamm's paraboloid (parabola) [14]. (See Figure 5.) Since the spherical cap joins smoothly with the paraboloid, we may get the impression of a nice continuity of spacetime curvature from the outside to the center of a spherical mass. As is often pointed out, however, the cap applies only to the curvature of *space*. Though time and space are both curved with an equal magnitude *outside* matter, moving inward from the surface, GR says the respective metric coefficients diverge. Time is supposed to be maximally affected at the sphere's *center*. Whereas space is maximally affected at the *surface*; at the center the spatial curvature goes to zero. This is represented graphically by the horizontal "bottom" extremity of the spherical cap.

Note: In the Schwarzschild exterior metric the coefficient for time is the inverse of the coefficient for space. Since they both represent effects of the same relative *magnitude*, in our discussion we are concerned primarily with that magnitude and not with the fact that separately, one's value is expressed as being between zero and unity and the other's value is expressed as as being between unity and infinity. With that in mind, we see in Figure 6 how these magnitudes change going from the exterior metric to the interior. Outside the body, the coefficient for both space and time is $(1 - 2GM/rc^2)^{-1}$. Inside

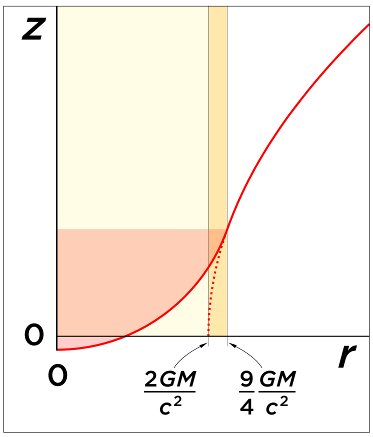

Fig. 5. – Cross-section of Flamm paraboloid at strong field limit with corresponding spherical cap. Not shown is what happens to the *temporal* coefficient when $r \leq 9GM/4c^2$. Time stops, which is why no smaller spherical caps are allowed. Notice how the cap dips below $z = 0$.

the body the effect on space begins to shrink, while the effect on time is supposed to continue increasing to a maximum at the center.

6˙2. *GR: Limiting Radius, Limiting Mass.* – The spatial coefficient presented in Figure 6 includes a term with a variable radius in the numerator, $\sqrt{1-2GMr^2/c^2R^3}$, reflecting the fact that the coefficient still has a value of unity after subtracting the term for $r = 0$. This indicates that space is flat at the center; it is reasonable and poses no problems. But the *time* coefficient includes a term, $(\frac{3}{2}\sqrt{1-2GM/Rc^2})$ that does not have this property. Instead, it refers to the mass of the whole body and its surface radius. For certain M/R ratios the temporal coefficient as a whole therefore becomes "pathological" (singular or imaginary). The accepted interpretation of this is that it indicates a limiting radius, for any given mass, or mass for a given radius, to avoid this "bad behavior":

$$r_{\text{GR Uniform Density Limit}} = \frac{9}{4}\frac{GM}{c^2}\,. \tag{16}$$

If all the matter in a body lies within this distance, then even before a horizon develops at the Schwarzschild radius, a singularity develops at the body's center. This is usually

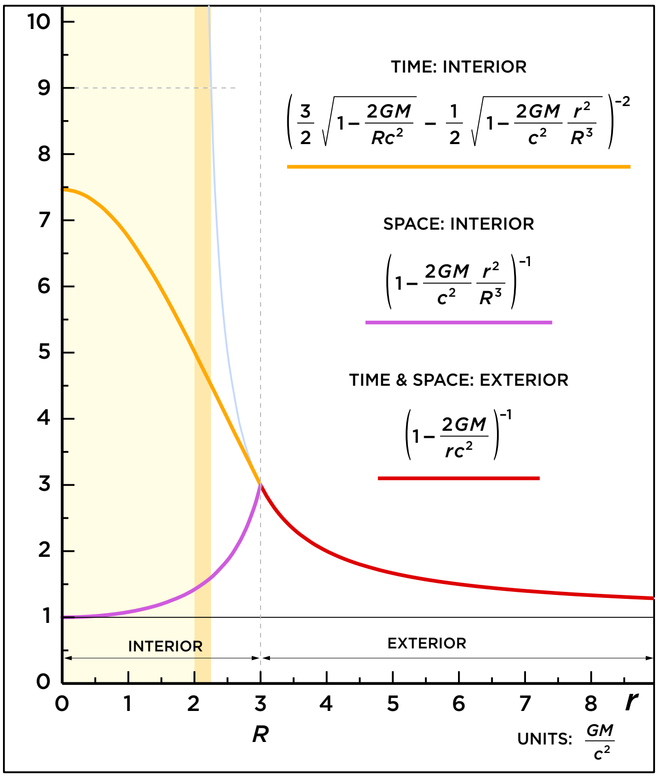

Fig. 6. – Schwarzschild interior and exterior metric coefficients. From the surface inward, clocks get slower, while space gets flatter. The chosen surface radius is close to, but beyond the limiting radius, $r = 9GM/4c^2$. The upper-most curve branching from the surface point crosses the limiting radius at 9.0 and goes to infinity if all the body's mass lies within the limit.

discussed in terms of the central "pressure." But the circumstance clearly arises because a continuous extension of the temporal metric from $9GM/4c^2$ to the center leads to infinite time dilation at $r = 0$ (physical singularity). It should be mentioned that it's not just for uniform density that GR is so fragile; the limit persists (or gets worse) for more realistic density distributions.

The idea that clocks should continue getting slower below the surface and have a minimum rate at the center is GR's way of remaining analogous to the Newtonian gravitational "potential well." In the course of building his gravity theory, Einstein was careful to make sure it agreed with Newton for such "weak field" circumstances. But this clock slowing effect at the center, i.e., the prediction that there should even *be* a gravitational potential well with a central bottom, *has never been demonstrated empirically.* No one knows if the central clock is really the slowest one in the system. A way to test the prediction is to do the experiment discussed in §2 and §3.

6˙3. *SGM: Parabolic Cap.* – The SGM's prediction that the central clock actually has a *maximum* rate follows from the rotation analogy. If gravity is best characterized not as the *potential to cause* external objects to move, but as the *motion of the gravitating body itself*, then clearly such motion cancels by symmetry at the center (analogous to a rotation axis). It follows that the time dilation at any point between the center and the surface is due to only the mass within the given radial distance. Curiously, even in GR the *spatial* curvature is simiarly determined only by the effect of mass within a given distance. But the SGM stands apart from GR by having the magnitude of temporal curvature everywhere equal to the magnitude of spatial curvature. As is true for rotation, the effects on space and time are both attributed, and in equal amounts, to *motion*, which means the time and space coefficients do not diverge. Thus we expect the interior extensions of the SGM parabolas of Figures 3 and 4 to be a single curve which represents the gravitational effect on both time and space. For the case of uniform density, we find that the curve from center to surface is not a circular arc, but an upwardly opening parabola:

$$z = \frac{1}{4} r^2 \sqrt{\frac{32\pi}{3}\frac{G\rho_0}{c^2}} + \frac{3}{4} R^2 \sqrt{\frac{32\pi}{3}\frac{G\rho_0}{c^2}}\,. \tag{17}$$

The far right term in Eq (17) is a constant (for a sphere of given density ρ_0 and radius, R) which defines the vertex of the parabola on the z-axis. Where $r = R$ the interior and exterior parabolas merge. (See Figure 7.) As is also indicated in the Figure, the z-height where $r = R$ will be called Z. In Figure 8 we have drawn a *series* of interior parabolas. In these cases the single exterior parabola serves as a kind of envelope for all of them, which means the mass in each case is the same. Keeping the mass constant also means the z-height for the interior parabolas is entirely determined by the surface radius, or the density, which is uniform in each case and decreases as the interior widens.

6˙4. *SGM: Idealized Density Distributions.* – In Figure 9 the lines emanating from (R, Z) toward the z-axis each represent a particular density distribution. Two of them are extremes and the two middle ones are simple ideals. The case we've just been discussing, the upwardly opening parabola, uniform density case is one of the ideals (Case 2). The horizontal line (Case 1) corresponds to the interior of a massive *shell* of negligible thickness. The curvature of space and time caused by such an extreme

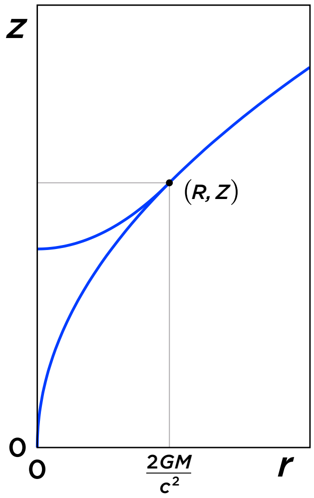

Fig. 7. – For a massive sphere of uniform density, the Space Generation Model extension to the exterior parabola is another parabola, which opens upwardly and joins smoothly at the surface radius.

structure would be, according to the SGM, entirely *external* to its surface. *Within* the cavity of the shell, clocks have *maximum* rates and space is flat. This is another point of disagreement between GR and the SGM. Both models predict that space is flat inside the cavity. But GR predicts that clocks within the cavity will have *minimum* rates. What could cause clocks inside the shell to tick slower? From the General Relativistic perspective, as far as I can tell, the answer is *geometry*. Geometry causes the clocks

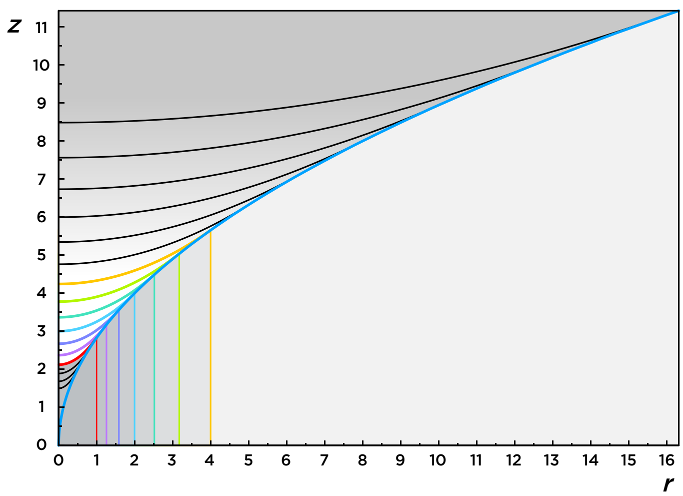

Fig. 8. – Series of nested interior parabolas, merged with the exterior envelope parabola. Being solitary, the exterior parabola indicates that each interior instance involves the same mass. (I.e., the same *coordinate* mass; the *proper* mass is actually greater for smaller, denser spheres.) Wider interior parabolas, higher up the z-axis correspond to larger surface radii and lower density.

to tick slower. Maybe we should check Nature herself to see if they really do (interior solution experiment).

Consider next the opposite extreme (Case 4). Here too, let us imagine that at R we have the surface of a shell. But in this case its *mass* is negligible. Let us also suppose the shell is opaque. Nearly all of the mass within R is concentrated into a tiny kernel near the center. Since we cannot see inside, we would not be able to tell by experiments conducted outside the shell whether this is so or whether the interior is totally empty, with all its mass contained in the material of the shell (Case 1), or indeed, whether the mass is distributed in any spherically concentric manner whatsoever.

The final case is the ideal one corresponding to the tangent to the parabola (Case 3). Since the curvature is caused by stationary outward velocity, V_S, this straight line profile means $2GM/r_\gamma$ is constant from $0 < r \leq R$. Although this could never be strictly true in reality, it is at least approximately true over that domain where the density varies according to an inverse square law ($\rho \propto 1/r^2$). Rough approximations of such density profiles are not uncommon in astronomical cluster systems. Near the center, of course, the density must settle to some finite value.

Though the uniform density case is simpler in some ways, it clearly becomes less and less realistic as the mass is increased. The density of planets, stars, cluster systems and virtually all astronomical bodies increases—usually rather steeply—from the outer zone to the center. Concern for physical realism is never to be forgotten. Yet it is worthwhile to further consider these ideal cases (2 and 3).

6˙5. *Proper Radius and Parabolic Tangent Length.* – In GR the mass, M, in the Schwarzschild solution, which represents the strength of the gravitational field (also known as the *active gravitational mass*) is smaller than the *proper mass*, as would be measured by local observers. In the SGM this is also true. The difference is related to the radial size of the body and, in the case of GR, to the idea of *binding energy*—about which more later (§11 - §13). In both GR and the SGM proper measurements made by local observers reveal the body to be *larger* than the corresponding coordinate radius, r.

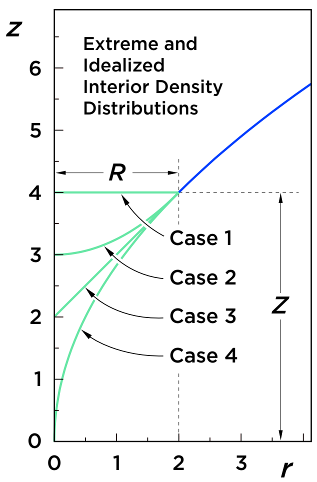

Fig. 9. – Interior extensions of embedding parabola for a wide range of density distributions, including two extreme cases and two more or less physically realistic cases.

This is due to the difference in length scales, $dR/dr > 1$, as indicated in Figures 3 and 4 (as applied, in the present case, to measurements through the body's interior).

Now let's bear in mind that the proper size could conceivably have different values, depending on the density distribution (Cases 1 - 4). In Case (1) measuring rods inside the whole interior of the shell are a maximum size (spatial curvature = 0). And the shell thickness has been specified as "negligible." So the numerical value of the total proper radius would be a *minimum.* Opposite to this, in Case (4) we'd get a *maximum* proper length because measuring rods spanning across the opaque shell will everywhere be "maximally shortened" – increasingly so as the center is approached.

The uniform density option (Case 2) would give an intermediate value which would, however, rarely be realized in astronomical bodies. Case 3 comes closer to what would be found in many astronomical mass systems. But a simpler, and usually more meaningful radial length arises as follows. Whatever the interior density distribution may actually be, the given total amount of mass causes global space to "bulge" due to exactly that curvature existing *at the surface.* Therefore, since circumferentially oriented rods do not contract, multiplying $C/2\pi$ by the radial surface length ratio, $dR/dr = \sqrt{1 + 2GM/rc^2}$ provides the physically meaningful length,

$$R_{\text{PT}} = R\sqrt{1 + 2GM/rc^2}\,. \tag{18}$$

This will be further clarified in connection with Figure 10.

6˙6. *Multiple Mass Parabolas.* – Let's consider another series of related cases. (See Figure 10.) Suppose we build up a sphere by successively adding shells of matter of uniform density. Let's choose our shell thicknesses so that at each step the added mass increases the coordinate radius by a factor $\sqrt{2}$. Thus two steps doubles the radius and increases the active gravitational mass by a factor of 8. Since the coordinate volume the mass occupies has shrunk relative to its size "at infinity," a factor *greater than 8* in *proper mass* is needed to reach this factor in *active gravitational mass* (i.e., coordinate mass). This difference in masses—known as *gravitational mass defect*—is a feature of both GR and the SGM and will be discussed in more detail later. (See §12.) For now it suffices to point out that the masses, M, discussed here, as in Fig 10, if broken up into smaller pieces and widely separated, would add up to a greater total *coordinate* mass, even as the *proper* mass would not change.

Each of the parabolas in Figure 10, as we recall (Eq 14) is given by the equation:

$$r_{\text{SGM}} = \frac{c^2z^2}{8GM} \qquad \text{or} \qquad z_{\text{SGM}} = \sqrt{\frac{8GMr}{c^2}}\,. \tag{19}$$

The seven right-opening parabolas in the figure range in mass from $1/64 \le M \le 8$ (in units $G = c = 1$). According to GR the case ($M = 1,\ R = 2$) would be a black hole (as would the cases with larger M/R ratios) because $(1 - 2GM/rc^2 \le 0)$. In the SGM this simply corresponds to $(1 + 2GM/rc^2)^{-1} = \frac{1}{2}$. The distance $2GM/c^2 = r$ is not crucial, and by having the particular value of unity, simply makes the ratio $R_{\text{PT}}/R = \sqrt{2}$.

An interesting consequence of laying out the series of tangent lengths, R_{PT}, as in Figure 10 is how they line up to define a *hyper*bola whose asymptote (slope = 2) is shown. The ratio $M/R \to \infty$ as $z/R_{\text{PT}} \to 2$. It is often mentioned that constant proper acceleration, as given by Eq (1), can be thought of as "hyperbolic motion" because of its representation on a spacetime diagram. Since the present scheme has adopted Eq (1)

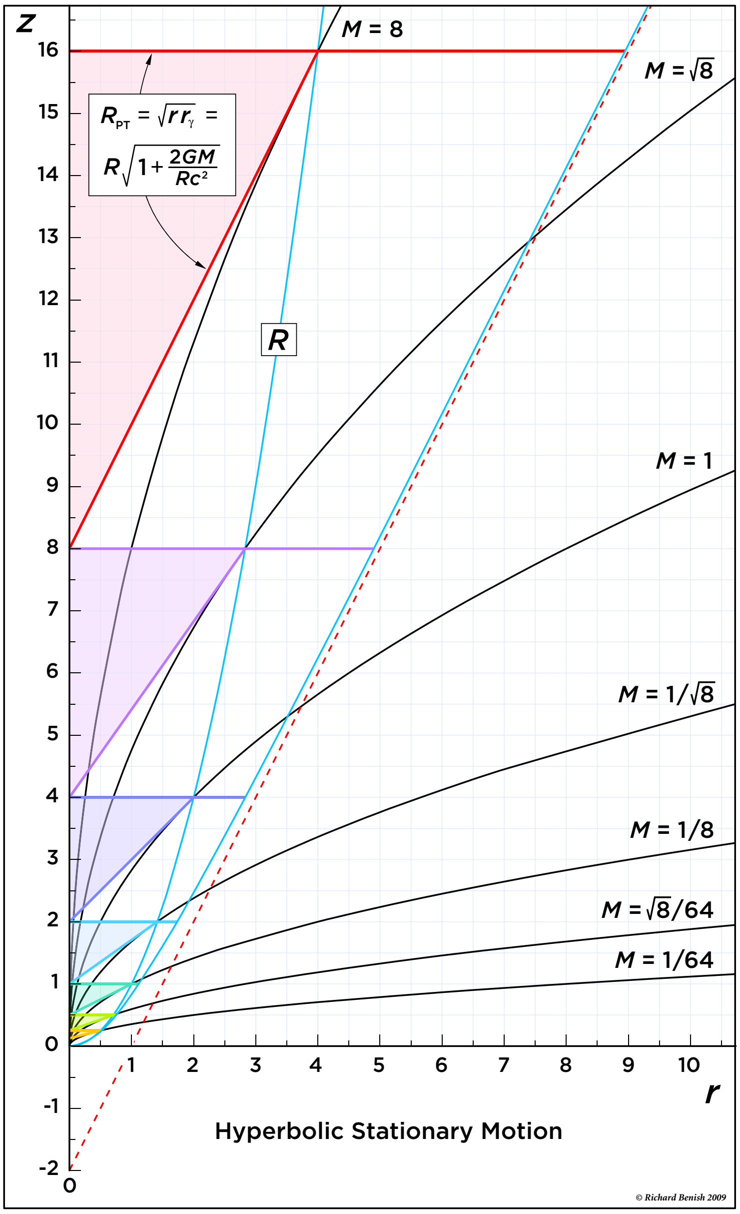

Fig. 10. – Series of embedding parabolas corresponding to spheres of constant density, in steps of increasing mass, M ($\times\sqrt{8}$). The surfaces of these masses correspond to coordinate radii, R (in steps $\times\sqrt{2}$). The latter points lie on the upwardly opening parabola as shown. The tangents from these points to the z-axis have lengths, $R_{\rm PT}$, that are equal to the horizontal lengths whose end points lie on the upwardly opening hyperbola. Note that the case ($R = 2,\ M = 1,\ z = 4$) corresponds to that of a Schwarzschild black hole. In the SGM, it is just one unexceptional case in a continuous series.

as an analogy, it was to be expected that we'd find a hyperbolic relationship for some physical circumstance. Thus, instead of hyperbolic linear motion *through* space with increasing time, we have hyperbolic stationary motion *of* space due to increasing M/R.

7. – Density Assessment and Velocity Limit

When the mass of a body is increased by adding layers of uniform density ρ_0, local (proper) measurements of mass and volume will always yield a ratio equal to ρ_0. Coordinate observers who assess the mass and volume of the body from a distance would also keep finding the same constant ratio. But as M/R keeps increasing, proper observers would increasingly disagree with coordinate observers about the (separately considered) mass or volume of the body. The discrepancy is revealed graphically in Figure 11. The middle curve (horizontal line) represents constant density. The other two curves serve to compare the calculable changes in density when proper masses are mixed with coordinate volumes, and vice versa.

Both volumes and masses depend to the same degree on what may be called the radial "compaction" of space. This is a direct consequence of spatial curvature, i.e., the shortening of radially oriented measuring rods. The flip side of the idea of compacted measuring rods is that they represent a "bulge" in space, because if used to measure a given radial extent, they indicate a longer distance, i.e., *more space* than the corresponding coordinate distance. Inside a uniformly dense body the effect varies with distance, so calculating the volume and mass requires integrating from $r = 0$ to the surface:

$$M = 4\pi \int \rho_0 r^2 \sqrt{1 + \frac{8\pi}{3}\frac{G\rho_0 r^2}{c^2}}\, dr\,. \tag{20}$$

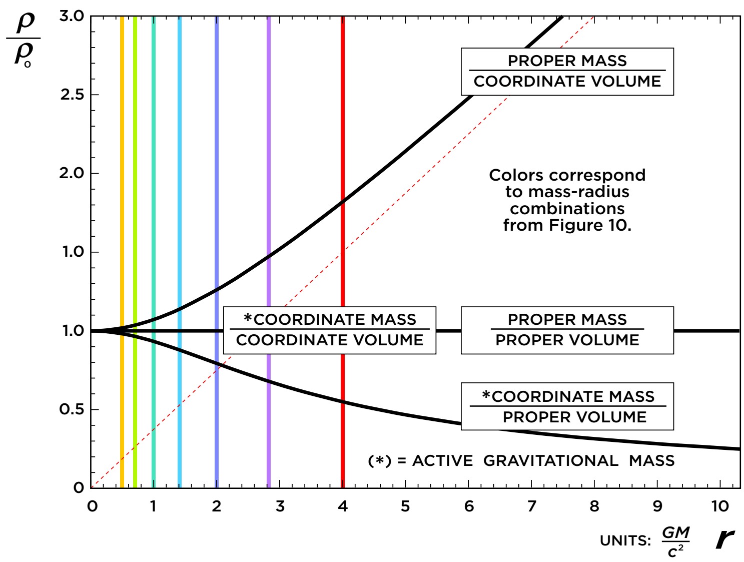

Fig. 11. – Space curvature causes the "compaction" of mass in the same proportion as the compaction of space (volume). This keeps the *proper* density constant, but yields varying densities when comparing masses and volumes from mixed coordinates.

This is the integral which gives the mass. A similar integral, without the ρ factor, gives the volume. The curves in Figure 11 follow from comparing the resulting compacted volumes and masses with volumes and masses calculated by assuming the validity of Euclidean geometry.

Relating the *proper mass* to the *coordinate volume*, yields the increasing density shown by the upper curve. Whereas relating the coordinate (active gravitational) masses to the proper volumes calculated from the integral yields the lower descending curve. The cases from Figure 10 are indicated on the resulting curve by the colored vertical bars. The upper curve is a hyperbola whose asymptote has a slope 3/8. As $2GM/rc^2$ grows large compared to unity, the lower curve approaches the abscissa as $1/r$.

In Figure 12, using the same radial coordinates as in Figure 11, we show the increasing stationary outward velocity, $V_{\rm S}$, as the mass of the body is increased. In connection with the multiple mass embedding diagram (Figure 10), moving left to right across these graphs corresponds to rising up the z-axis and, always less so, along the r-axis, so that even as the parabolas grow ever larger, we get *proportionally closer* to the vertex. Physically, this means we have a sphere of ever increasing mass, whose proper density remains constant and whose proper radius grows ever faster than the coordinate radius. Observers hopping up to the new surface at each step would find that light from distant sources becomes ever more *blue-shifted*, as proper clocks slow down ever more and the the stationary outward velocity approaches c.

To conclude, then, provided only that mass is distributed with spherical symmetry, no matter how its density varies below the surface, the gravitational effect on measuring rods at the surface is the same; i.e., it depends only on the amount of mass within the surface. Mass creates a *bulge* in space; we get an "excess" amount of space over the massless flat background. This bulge doesn't get there by mere "geometry." Matter can't just sit around *telling* spacetime how to curve (to borrow a common expression from GR). Nothing would happen. Rather, matter has to *do* something to create the curvature; matter has to *do* something to make it happen. According to the SGM matter and space move; according to GR matter and space just sit there. How can something that does not itself move cause other things to move? Invoking geometry as an answer will not satisfy those who yearn to understand gravity's *physical* mechanism. According to the present scheme the essence of matter is to perpetually *generate* the bulge. The *motion* of this process causes spacetime to curve. (Cosmological space is the cumulative effect of the bulges produced by material objects scattered throughout the Universe.) We may thus begin to see *why* Schwarzschild's *exterior* solution has

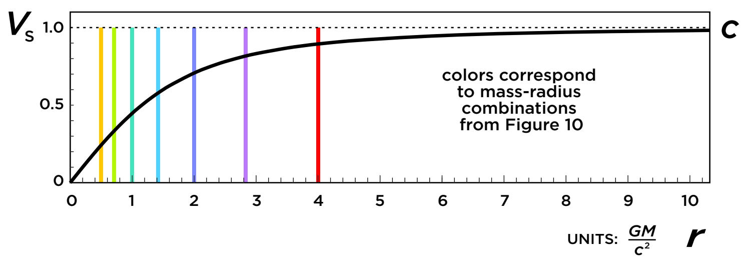

Fig. 12. – Stationary outward velocity, $V_{\rm S}$, at the surface of the bodies represented in Figures 8, 10 and 11, and in general, as $2GM/c^2$ increases in proportion to the coordinate radius, r.

seemed to work so well. It describes a kind of *staticalized average* of what is actually a most *un*static phenomenon. It predicts orbital motion and many other phenomena much more accurately than Newton's theory. If this new explanation for the *cause* of spacetime curvature is correct, then Schwarzschild's *interior* solution, by contrast, would be completely wrong. A test of the interior solution would be the most effective way to decide between GR and the SGM.

8. – Acceleration Limit

One of gravity's most well known characteristics is that it obeys an inverse square law. The Newtonian equation is: $g = GM/r^2$. For most purposes, this is an excellent approximation, just as the stationary outward velocity, $V_{\rm S}$, is well approximated by $\sqrt{2GM/r}$. Owing to the curvature of spacetime, we should expect that a more accurate law might look a little different. The question is, which radial distance should be used in this law? Our analogy with Eq (1) implies that we should replace r with r_γ. Therefore, we assume that the r in the acceleration equation should also be replaced with r_γ. Our stationary outward acceleration then becomes

$$g_{\rm S} = \frac{GM}{r_\gamma^2} = \frac{GM}{(r + 2GM/c^2)^2} = \frac{GM}{r^2 + \frac{4rGM}{c^2} + \frac{4G^2M^2}{c^4}} \,. \tag{21}$$

Comparison with Newton's theory and GR is clearly in order. (See Figure 13.) For a given mass, whose radius we suppose to be arbitrarily small, the Newtonian acceleration ranges between $0 < g < \infty$ For the same mass GR [15] gives

$$g_{\rm GR} = \frac{GM}{r^2\sqrt{1 - 2GM/rc^2}} \,, \tag{22}$$

which approaches infinity even faster, as $2GM/rc^2$ approaches unity.

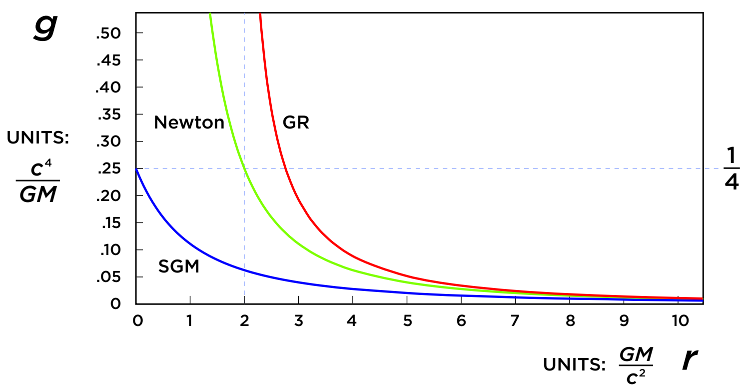

Fig. 13. – Acceleration due to gravity: Newton, GR and the SGM. At large distances the three models become almost indistinguishable (inverse-square law). Though the SGM exhibits a limit at $g = 1/4$, it is essential to note that this limit is inversely proportional to the mass of the gravitating body. See discussion in text.

Now consider a noteworthy feature of the acceleration given by Eq (21). In the limit $r \to 0$ we get

$$g_{r\to 0} = \frac{GM}{(2GM/c^2)^2} = \frac{GM}{4G^2M^2/c^4} = \frac{1}{4}\frac{c^4}{GM}\,. \tag{23}$$

We find a limiting acceleration that depends inversely on M. In Figure 14 masses covering a cosmic range are plotted against their corresponding maximum accelerations. Referring to the figure, the product of the acceleration and the mass of the body giving rise to it yields a constant maximum force

$$F_{\text{MAX}} = Mg_{\text{S}} = 3.0256 \times 10^{43}\ \text{kg}\cdot\text{m}\cdot\text{sec}^{-2}\,. \tag{24}$$

This is an unreachable maximum which traces back to our kinematic equation reflecting the analogous unreachable maximum, the speed of light, c. The force given by (24) is huge; it is many orders of magnitude greater than any known force at any scale.

A more rigorous calculation of the maximum involving two separate massive bodies, M_1 and M_2, is actually smaller by 1/4—and then only for the special case of $M_1 = M_2$. This follows from the equation

$$F_{\text{M}\times 2} = \frac{GM_1M_2}{\left[r + \frac{2G(M_1+M_2)}{c^2}\right]^2}\,. \tag{25}$$

In the limiting case, $r_1 \to 0$, $r_2 \to 0$, deviation from the simple product $g_{\text{S}}M$ is due to the ratio

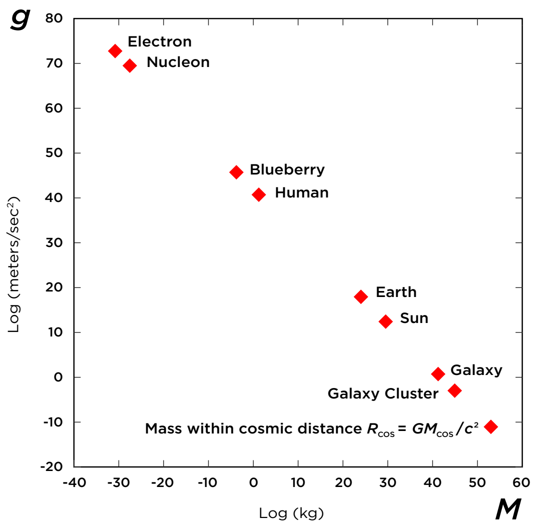

Fig. 14. – Maximum accelerations of bodies over a cosmically wide range of masses.

$$\epsilon = \frac{M_1 M_2}{[2(M_1 + M_2)]^2} \,. \tag{26}$$

When $M_1 = M_2$, $\epsilon = 1/16$, which results in a force 1/4 of (24), as stated above. For any given mass sum, the larger the disparity between M_1 and M_2, the smaller the force becomes. It must be borne in mind that we are here discussing a very extreme regime, where it makes sense to regard the coordinate radius, r, as being negligible compared to the gravitational radius, $2GM/c^2$. It's not likely that we'll be able to ascertain with empirical evidence a factor of four difference in force in this regime any time soon.

9. – Maximal Geodesics

In §7 we presented a graph (Figure 12) showing how the SGM's stationary outward velocity increases with increasing mass, by building up a spherical body from the inside out. Here we consider the case, represented in Figure 15, of constant mass and distances beyond the surface (exterior solution), supposing that the radius is arbitrarily small. Newtonian gravity poses no limit at all; an object falling radially from infinity reaches the speed of light at the radius $r = 2GM/c^2$, and goes to infinity as r approaches zero.

According to GR we find a limit, again imposed by the Schwarzschild radius. In the $(t,\, r,)$ coordinate plane the falling object reaches a maximum speed ($v = 2\sqrt{3}c/9$) at $r = 6GM/c^2$. As judged by a coordinate observer, the trajectory slows down and asymptotically approaches the horizon at $2GM/c^2$.

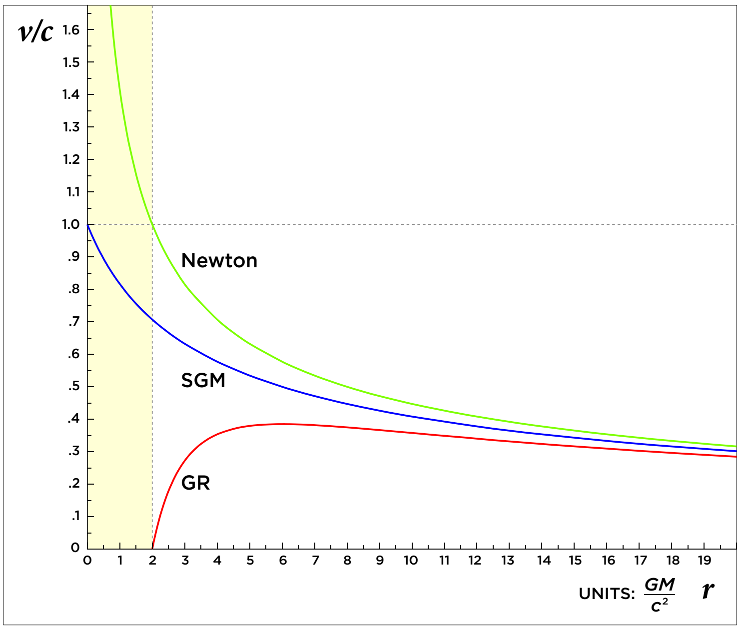

Fig. 15. – Velocities as per Newton, GR and the SGM. The trajectory is that of an object falling radially from infinity (maximal geodesic).

The trajectory we are considering is an extreme case—the extreme of an object which, in effect, has never suffered any acceleration due to the gravitating body. Suppose the falling object is a ganged pair of instruments: an accelerometer and a clock. The accelerometer reading is zero as it begins to fall, strictly speaking, from *just this side of* infinity. During its entire "descent," it suffers no acceleration; the reading remains at zero. Therefore, according to the SGM, an object on such a trajectory *remains* a faithful representative of accelerometers and clocks that remain at infinity. As it falls, the *clock* maintains its maximum rate. It also maintains its maximum *size*. It's speed hasn't changed, so its spacetime proportions do not change. I call these special trajectories *maximal geodesics*.

With respect to a test mass on a maximal geodesic and the larger body which makes it appear to fall, all of the space which moves past the test body is due to the perpetual generation of space of the larger body. In other words, the distance which initially separated the two objects diminishes as that *space moves past the falling object.* We thus again come to the distinction between moving through space and the movement of space. According to the SGM the apparent downward acceleration of a falling body is an illusion; in spite of appearances, the body is not moving downward through space; *space is moving upwardly past the body.* If we imagine one of our huge instrument towers to extend all the way to just this side of infinity, the velocity that accrues as between the maximal geodesic and the tower is ascribed entirely *to the tower.* It's the tower accelerometers that give positive readings. It's the tower clocks that run slow. The *tower* instruments give readings indicating evidence of motion, the maximal geodesic instruments do not.

The object falling from infinity cannot reach the speed of light because its speed doesn't increase at all. Maximal geodesics thus define a family of rest frames. It is useful to compare the gravitational circumstance again with our analogy from Special Relativity. Imagine that you are an inertial observer watching an extremely long rocket pass by with an acceleration that propels it to near the speed of light. Similarly, if you were an observer on a maximal geodesic you might measure the speed of the instrument tower moving past as it approaches the speed of light. The rocket is accelerating itself *through* space; the large body is a manifestation of the acceleration *of* space. As long as you are not too close to its path, you can ignore the rocket. Its path is a very *linear* thing, so it is easy to avoid and to remain unaffected by it. The space through which the rocket travels is hardly *its* space any more than it is *your* space. The rocket is traveling in one particular direction, but there is nothing special about it; all directions are about the same. Though this may at first seem to be true with regard to the tower accelerating past, eventually you'd come to realize something very special about its direction. Its energy, its source of propulsion is something very huge at its base; the direction of its base is very special. Sooner or later you'd have to hop on the tower to be carried by it or you'd need a considerable amount of your own energy to escape it (and its base) altogether. You are literally *in its space.* The tower delineates only a special case of a general pattern of motion that is not linear; it is volumetric and omnidirectional. (Hence the inverse square law variation.) It is the same from any angle around the base. And it is absolutely unavoidable. You are permeated by it and it extends to extremely huge distances. You ignore stationary outward motion at your peril.

10. – Geometric Coefficients and Physical Evidence

According to GR the magnitude of the effects of gravity on and around a spherically symmetrical body all derive from the magnitude of the metric coefficients appearing in the Schwarzschild solution. The quantity $(1 - 2GM/rc^2)$ applies to the time coordinate; and its inverse,

$$\left[1 - \frac{2GM}{rc^2}\right]^{-1} \tag{27}$$

applies to the radial space coordinate. The analogous coefficient in the SGM is:

$$\left[1 - \frac{2GM}{r_\gamma c^2}\right]^{-1} = \left[1 - \frac{2GM}{rc^2 + 2GM}\right]^{-1} = \left[1 + \frac{2GM}{rc^2}\right] . \tag{28}$$

As is also true of the parabolic embedding diagrams (Flamm paraboloid and its SGM analog) the above coefficients also differ from each other by a simple r-axis translation.

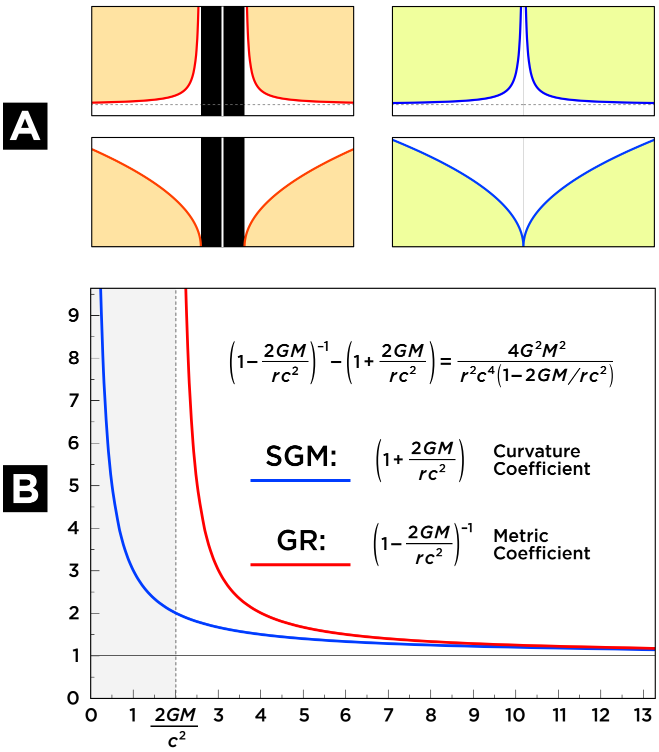

Fig. 16. – **A**: Visually simplified collage of embedding diagrams and metric coefficient graphs. GR is on the left. SGM is on the right. The black zones are where geometry says time becomes space, space becomes time, clocks stop and, at the center, "the laws of physics" break down. **B**: As with the embedding diagram (see Figure 3) the curvature coefficient curves shown here are also identical in shape, but offset horizontally by $2GM/c^2$. The vertical separation is given by the equation. To give an idea of the smallness of the difference, putting in values corresponding to Earth's mass and radius gives $\Delta = 1.93 \times 10^{-18}$.

(See Figure 16.) Though quite large in the strong field regime, the difference between the coefficients becomes quite small when the Schwarzschild radius is very small compared to the physical size of the massive body it refers to. This is almost always the case in our actual experience. Due to the enormity of the speed of light, spacetime is almost everywhere very "flat." The spacetime curvatures in both models are nearly identical when $2GM/rc^2 \ll 1$. The huge differences in the basic assumptions underlying the two models nevertheless involve circumstances in which their predictions diverge even in exterior fields.

These differences primarily involve *radial* motion near large gravitating bodies. Recall the properties that the SGM attributes to *maximal geodesics.* If such extreme radial trajectories are indeed similar to "preferred" frames of reference, then their clocks have maximum rates and the speed of light will equal c with respect to them. This implies, and indeed the SGM predicts, that the radial speed of light with respect to the surface of a gravitating body is

$$c_{\uparrow\downarrow} = c \mp \sqrt{\frac{2GM}{r_\gamma}} \tag{29}$$

(slower upward, faster downward). The propagation of light near gravitating bodies is thus predicted to be *asymmetrical* depending on whether it's going up or down; and the rate of a clock will depend not only on its location and its *speed*, but also on its *direction.* This is in direct conflict with GR, which treats the gravitational field as being analogous to an unmoving *medium of refraction,* in which the speed of light at a given location is the same whether it is going up or down and the rate of a clock moving with a given speed relative to Earth's surface is the same whether it is going up or down. The latter predictions are consequences of the presumed staticness and symmetry of matter and space, as represented by the Schwarzschild solution.

Two experiments whose results had the potential to falsify the SGM are the Shapiro time delay test and the Vessot-Levine falling clock test (Gravity Probe A). Light propagation was involved in both of these tests, and clock rates were crucially involved only in the latter one. Due to the *two-way* signaling used in these experiments, the asymmetries predicted by the SGM were almost entirely cancelled by the equipment, by the back and forth nature of the light paths or a combination of these. In other words, the SGM predictions for these experiments actually agree almost exactly with the predictions of GR. The experiments support GR, so they also support the SGM. (For details, see *Light and Clock Behavior in the Space Generation Model of Gravitation.* [3])

A new experiment has been proposed whose results would have decided between the GR and SGM predictions for the questions discussed above, and more. Unfortunately, this experiment, the OPTIS satellite mission, has been canceled due to lack of funding. It is pertinent to point out that the interior solution experiment could be done in a small Earth-based laboratory for a small fraction of the cost of OPTIS.

One more experiment—or more correctly, experimental *enterprise*—should be mentioned here. Funds on the order of a billion dollars have already been spent on attempts to detect *gravitational waves.* The search has been going on now for over 30 years. The decay of the orbits of binary pulsars is regarded as evidence that these systems are radiating gravitational waves. The energy carried by the waves is supposed to equal that lost by the decay so that the total remains constant.

As we have already seen, the SGM predicts gross violations of energy conservation. Gravity is not an attraction and its energy is not negative. It's positive and increasing all the time. As in the interior solution predictions, where the falling projectile appears to lose energy, it follows that the apparent loss of energy in the case of binary star obits is also due to the increase in energy of the whole system. Gravitational waves are often explained in terms of the finite propagation speed of gravity's influence. Although the SGM would describe what happens differently (in terms of space generation) one can well imagine that there should be a similar delay in one body's responding to the space generated by a nearby body, especially if these bodies are moving rapidly around each other. This delay could explain the decay of the orbit, but in the SGM's case it would not be accompanied by any outgoing gravitational waves. The SGM explicitly denies the existence of the negative energy needed to make a body emit gravitational radiation. Therefore, the SGM predicts that gravitational waves will never be found.

11. – Kinds of Mass and Energy

The concept of *active gravitational mass*, which we have already made use of, is related to and often discussed alongside two other kinds of mass. Having explored a few of the *immediate* consequences of Eq (3), it will be good to consider a few of its deeper implications. We'll begin by discussing how the M in that equation relates to these three masses.

Active gravitational mass, $m_{\rm A}$, is a measure of mass deduced by determining the strength of the gravitational field that a body produces. Passive gravitational mass, $m_{\rm P}$, is a measure of a body's response to a gravitational field; i.e., its *resistance* to being accelerated *specifically by gravity.* And inertial mass, $m_{\rm I}$, is a measure of how difficult it is (i.e., the force needed) to accelerate a body *by any means.*

In GR all three masses are assumed to be equivalent. In the SGM it should be clear that $m_{\rm I} = m_{\rm P}$. The idea that they might be different stems from the assumption that gravity is an attractive force which might not have the same effect on bodies of the same inertial mass, but composed of different chemical elements, for example. Many tests of Einstein's Equivalence Principle, which asserts the equivalence of these masses, have involved comparing the response of gold, aluminum, lead, etc., to an imagined "pull" of gravity. The results are all consistent with the idea that there is no pull; the response is the same as it would be if instead the ground were accelerating upward! To repeat, $m_{\rm I} = m_{\rm P}$ in both GR and the SGM.

The question of what "gives" a body its inertial mass (sometimes expressed as the *origin* of inertial mass) has perplexed philosophers for ages. Einstein, too wrestled with this question, but arrived at no satisfactory answer. Based on the above sections, the reader may have deduced what the SGM would say.

First, to get our nomenclature straight, note that *inertia* is the *property* by which a body resists linear acceleration. Whereas inertial *mass* is a quantitative *measure* of that property. According to the SGM inertial mass is *primarily* the magnitude of omnidirectional acceleration that the body is generating (active gravitational mass). The more a body moves outwardly in *all* directions (the more space it generates) the more difficult it is for an external agent to move the body in any *particular* direction. In other words, the greater the (volumetric) motion *of* space, the more resistance there is to (linear) motion *through* space. The "origin" of mass (inertia) is thus to be found in this fundamental *process* of what matter is *doing.* This is in stark contrast to common attempts to ascribe mass to some hypothetical "scalar field interaction" with distant masses (Mach/Dicke) or some hypothetical particle "field" that magically "gives" other particles their mass (Higgs).

Inertial mass, according to the SGM, is *primarily* the same thing as active gravitational mass. But, unlike GR, the SGM says there's a difference. GR is well known for regarding *all* forms of energy as having gravitational mass. Even light is supposed to attract things toward itself by gravity. It is also well known that this feature of GR causes all kinds of problems, math problems and conceptual problems. It is not important to hash out the many issues because it is well enough to point out the huge contrast with the SGM, which regards light and most forms of energy as *not* producing gravitational fields.

Since the SGM accepts that light and other forms of energy do, however, have inertia, this means we have: $m_{\text{I}} = m_{\text{P}} \neq m_{\text{A}}$. Let's illustrate with some examples. Consider three identical bodies in three different energy states: a body at room temperature, an identical body that is heated to a high temperature, and another identical body that is in a state of rapid uniform rotation. Heating and rotation would increase the *energy* of the bodies and it would increase their *inertial* masses and thus also their passive gravitational masses. They would *weigh* more if placed on a sufficiently sensitive balance. By what means would this also increase their gravitational fields? I don't believe it does.

Heating and rotation involve increasing the velocity of the components of the bodies. It thus increases their motion *through* space. But why should a body's linear motion *through* space increase its omnidirectional motion *of* space; i.e., the amount of space it generates? Although similar in some ways, these are two fundamentally different things. The property of generating space (active gravitational mass) would more naturally be related to the atoms and particles that comprise a body. Ultimately, gravity must be related to quantum theory.

It is worth emphasizing that a body's *inertial* mass is reasonably expected to be a sum of both effects. Both motion *through* space and motion *of* space contribute. By a very wide margin, the main component of inertial mass is the *rest mass*, which I suppose is equal to the active gravitational mass. To be more specific, by rest mass, I certainly don't mean the rest mass of "quarks." I mean the rest mass of whole atoms and nuclei, whose nuclear binding energies have been accounted for before entering into gravity-related questions. (Binding energy should not be counted twice.)

We can see how heating or rotation could contribute to inertial mass, because they both involve an increase in *internal motion*, which would add up as some kind of omnidirectional (random, heat) or cylindrical (orderly, rotation) sum. But it does not follow that that additional internal motion contributes to the body's capacity to generate space.

Another important example is *light*. On one hand, you can think of light as the paragon of that which moves *through* space (or *on* space or as a ripple *in* space). But it is hard to imagine that it would *generate* any *more* space than the space through which it propagates. Which brings us to the other hand: Light could be conceived as *an entirely different kind of motion of space*. That is, different from gravity. It is a propagating vibration. As such, light nicely wiggles (moves) the space that already exists. But wiggling existing space and creating new space are rather different things. Nor does the question get easier to answer if you think of gravity as an attraction. How does light pull things toward itself? Nobody is close to answering this; I think it's because it doesn't happen. Light's unsuitability as a source of gravity may sink in by simply asking, *at what speed relative to itself* does light "communicate" an attraction? The SGM says that since light is timeless, pure energy, it does not gravitate; it does not generate space. Only clock-like particles, atoms and nuclei generate space. Hence the quantum connection appears essential and inevitable. [2] The equivalence between mass and energy proposed by Einstein is irreconcilable with the SGM because the latter model predicts that $m_{\rm I} \neq m_{\rm A}$.

12. – Mass Defect and Energy

In this section, taking a different route, we will reach the same conclusion presented just above. Figure 17 shows how proper mass would increase by the continual addition of shells of uniform density according to Newton (Euclid), GR and the SGM. The "Newtonian" curve ($\propto 1/r^3$) simply assumes the validity of Euclidean geometry. The SGM predicts a slightly steeper curve, based on the considerations discussed in §6 and §7.

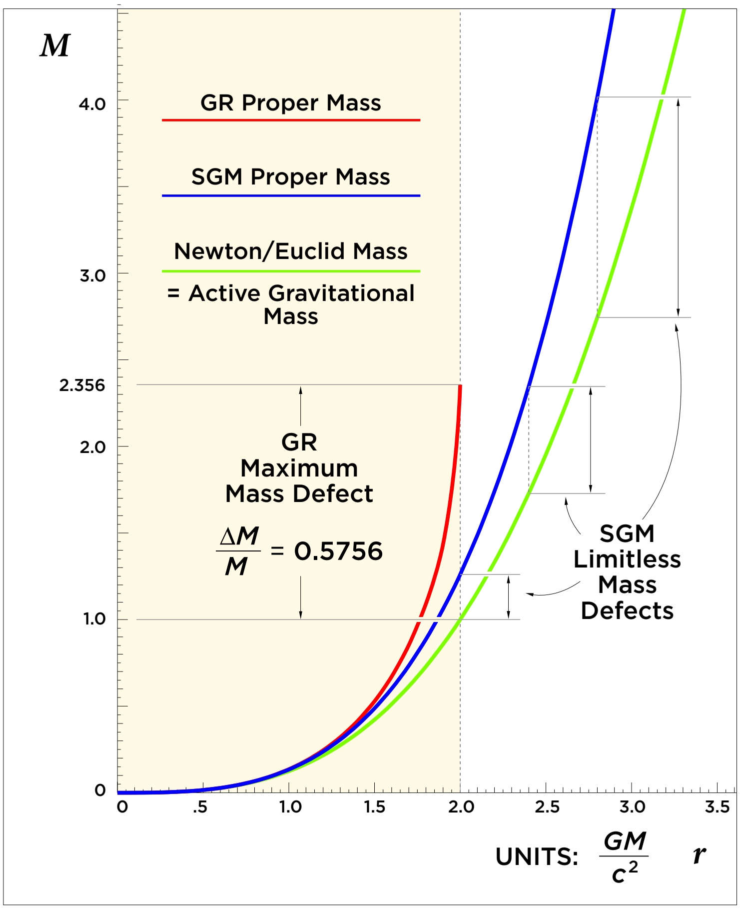

Fig. 17. – For a sphere of uniform density, the Newton/Euclid mass increases as the cube of the radius. Spatial curvature, as occurs in both GR and the SGM, results in a "compaction" of volume as well as of the mass within that volume. The mass defect is the difference between the proper mass (sum of separated component masses) and the mass of the same density that would reside in the shrunken volume. The horizon (black hole) condition in GR occurs when the ratio, $M/r \geq c^2/2G$. As we see on the graph, this happens when the proper mass within $2GM/c^2$ is ≈ 2.356 times the coordinate (active gravitational) mass.

Dividing the mass by the cube of the r-scale of the graph would give the upper curve in Figure 11.

The GR and SGM curves in Figure 17 were both generated by calculating the respective integrals of the mass within a sphere of uniform density. GR gives:

$$M = 4\pi \int \frac{\rho_0 r^2}{\sqrt{1 - \frac{8\pi}{3}\frac{G\rho_0 r^2}{c^2}}}\, dr\,. \tag{30}$$

Whereas the SGM gives:

$$M = 4\pi \int \rho_0 r^2 \sqrt{1 + \frac{8\pi}{3}\frac{G\rho_0 r^2}{c^2}}\, dr\,. \tag{31}$$

Disregarding the fact that the GR answer gets cut off, the meaning of the calculations is similar. Imagine a supply of distantly separated incompressible, uniformly dense component masses scattered in the far reaches of space. The curvature of space where all these masses reside is negligible. Their volumes (sizes) are unaffected, so their active gravitational masses are unaffected. When they are brought together, their coordinate sizes shrink, so their active gravitational masses shrink in the same proportion. Roughly speaking, 100 scattered masses, when brought together, might add up to only 99 on the active gravitational mass scale. Add one more to get the latter to total ≈ 100. The density is not changed by the disparity; *gravitationally*, it still behaves like 100 component masses divided by 100 component mass volumes. (Even as proper observers measure *101* component masses and *101* component mass volumes.) This description is consistent with both GR and the SGM.

But the GR and SGM interpretations conflict when it comes to an alternative derivation given by GR. If gravity is an attractive influence whose energy is negative, then this same curvature (compaction) effect is supposed to be equivalent to the effect of *gravitational binding energy.* (For details, see Adler, Bazin and Schiffer [16], Wald [17] and Ghose and Kumar [18].)

Let's elaborate on an example from §11 to illustrate the SGM's disagreement with the binding energy interpretation. Suppose we've engineered a device to extract and store the energy of falling bodies. Suppose one of these bodies is a "component mass," as mentioned above—one that falls radially from infinity, as a maximal geodesic. The mass is intercepted by a long vertical piston. As the piston is forced closer to Earth's surface by the collision, the energy causing this to happen is shunted into a flywheel, or it heats up a box of gas. For simplicity, assume the system is 100% efficient, so that all the body's gravitational energy gets successfully stored. When the falling body's velocity has been increased to match the surface (stationary outward) velocity, it will suffer compaction so that its mass does not make a full contribution to Earth's active gravitational mass. A mass defect would seemingly apply. All of the *energy* generated by the interaction, however, remains on Earth. According to GR, then, the would-be mass defect of the fallen body is exactly compensated by the energy extracted from the interaction. It's all been stored. In this case there would be no net active gravitational mass defect; the magnitude of Earth's binding energy would increase due to the sum of the rest mass and the converted kinetic energy.

The SGM disagrees. The way I see it, the Earth's *inertial* mass increases by the full amount (rest mass energy + converted kinetic energy). But Earth's active gravitational mass increases only by the fallen body's *compacted* rest mass, only by the contribution from the body's clock-like particles, atoms and nuclei. The spinning flywheel or the box of heated gas weigh more due to their increased inertial mass. Their internal motion has increased. But this is entirely motion through space. Motion through space increases inertia; it does not increase gravitation. According to the SGM, *only matter gravitates*, in proportion to the collective rest masses of its clock-like particles, atoms and nuclei (which total is then reduced in proportion to the degree of spatial curvature, i.e., compaction). The importance of material *particles* for producing gravity suggests that ultimately gravitation is a quantum phenomenon.

It should be mentioned that, unfortunately, the energy differences discussed above are utterly dominated by the rest masses. It would be extremely difficult to detect them by experiment. The way to test the validity of the SGM idea is to do the interior solution experiment, where the model's predicted energy conservation violation is so extreme that, if it should be borne out, anyone could perceive it with the unaided eye.

13. – Ramifications and Conclusions

> *The energy—and therefore the mass—of a gravitational field is a slippery eel indeed, and refuses to be pinned down in any clear location. …Even before we need consider the mysterious effects of quantum theory, our theories of physics tell us that there is something very odd and counter-intuitive about the nature of matter. …We must expect, also, that future theory will provide us with yet further shocks to our cherished intuitions. —*
>
> *Roger Penrose* [19]

The simple idea that accelerometers tell the truth about their state of motion—not as some geometrical word game, but as an absolute physical fact—leads to all of the results presented above. One should naturally want to test the idea by experiment before spinning one's wheels too far or long on further implications. And I do. But since my experimental desires have been thwarted by circumstances beyond my control, a few further implications may just as well be briefly presented.

First, I should say that the remarks of Penrose, quoted above, were motivated by attempts to reconcile the energy "account books" with regard to energy conservation and the assumed *attraction* of gravity, i.e., the idea that gravitational energy is supposed to be entered as a *negative* quantity. Based on this idea, calculations have been made of the total energy of the whole Universe. By some noteworthy accounts, it turns out that the negative gravitational energy exactly offsets whatever positive energy may exist, so as to yield a total energy of the Universe = 0. No kidding! (See Feynman [20] or Hawking [21].) All the positive accelerometer readings on massive bodies all over the Universe are thus casually *neutralized* by the "conservative" accountant's idea of negative energy. Imagine being assigned the task of getting all those accelerometers to give the readings they do *without gravity*. How does one go about mimicking the primary effect of gravity without being allowed to use gravity itself? To get the accelerometers to give positive readings requires that we accelerate them. To do this we'd obviously need an enormous amount of propulsive *positive* energy. Maybe this is also true for gravity itself. In any case *somebody* here is clearly looking at things upside down and backwards. Should we believe the accountants or the accelerometers?

Finally, let's include a few connections to the SGM cosmological model. [2] It is pertinent to do so for at least two reasons: 1) The model's prediction for the cause of the cosmological redshift resembles the local gravitational effects discussed above. And 2) The quantum implications alluded to above are made more plausible.

Suppose a clock moves as a part of a system undergoing uniform rotation. This motion through space causes the clock's rate to slow down. Its size also decreases due to contraction in the direction of its velocity. But its *inertial* mass *increases* in *inverse* proportion to the clock rate and size reductions. We have seen that gravitating bodies exhibit an analogous stationary motion (velocity and acceleration). However, being the motion *of* instead of motion *through* space, the coordinate masses, i.e., the active gravitational masses, change in *like* (not inverse) proportion; i.e., *they decrease along with the size and the clock rate decreases.*

The light we receive from distant galaxies is redshifted, increasingly so the larger the distance. The common conception is that this is due to recessional motion. In the SGM cosmology, galaxies (on average) are not moving apart. In the past they were smaller, less massive and their clocks ticked slower. It's a gravitational effect. Over time the Universe and all bodies in it become less and less "compacted." Their masses, sizes and clock rates all increase, as the average cosmic density stays constant. On a global scale all proportions remain constant: *cosmic stationary motion.* Looking outward in the Universe we are looking backward in time at an ever increasing mass defect.

Now to the quantum connection: Physicists have tried for decades to "unify" gravitation with quantum theory. Also there have been many attempts to understand the relationship between various fundamental constants and parameters occurring both in quantum theory and cosmology. One may argue that any semblance of unification will not be at hand until the *characteristic numbers* of microphysics are connected to the characteristic numbers of large scale phenomena, i.e., gravitation and cosmology. An indication that we have a long way to go is the fact that Newton's constant, G, presently stands apart from the rest of physics. Why should G have the value it does? How does it relate, for example, to the mass ratio between protons and electrons, to the ratio between electromagnetic and gravitational forces, to the fine structure constant and the characteristic size of the Universe? In the SGM cosmology these constants and ratios all fit into a neat pattern that consistently ties together things like the Hubble constant, the average cosmic mass density and the temperature of the microwave background radiation.

Emerging from the model, for example, is a relation giving Newton's constant in terms of the mass-energy density of the background radiation, $\rho_{\mu\mathrm{CBR}}$, the density of nuclear matter, ρ_{N}, the mass of an electron, m_{e}, the Bohr radius, a_0 and the speed of light:

$$G = 8\left[\frac{\rho_{\mu\mathrm{CBR}}}{\rho_{\mathrm{N}}} \cdot \frac{c^2 \mathrm{a}_0}{m_{\mathrm{e}}}\right] . \tag{32}$$

Let's consider one last implication, one that is especially easy to see and to interpret. If gravity is a force of attraction, then the test object depicted in Figure 2 (p. 8) will harmonically oscillate through the large mass. Such a trajectory would be a direct confirmation of the fact that existing laws of mechanics are symmetrical with respect to time translation; the accepted laws of mechanics work just as well forward or backward in time. Therefore a video of the oscillatory motion in the sphere would look exactly the same whether it was played forward or backward. This result would shed no light at all on one of the prevailing conundrums of physics: Why does time seem to go only forward? Why do things only get older and not younger? As noted in the Introduction, many volumes have been filled with speculations on these questions.

The SGM has an unequivocal answer. If the trajectory of the test object in the interior solution experiment abides by the SGM prediction, it would be obvious whether a video recording of it was being played forward or backward. In one direction you see the object getting swallowed by the large mass, where it eventually appears to slowly settle toward the center. This is the forward direction. An object at rest or moving slowly near the center cannot possibly (without an extraneous propulsion device) escape these inner confines. Therefore, if the video showed the object moving upward, we'd know it was being played backward.

What this means is that, according to the SGM, gravity is a "time reversal violator." Gravity is a cogent manifestation of the one-way direction of time. In the simplest terms, *time only increases because mass and space also only increase.* The failure to explain time's direction in terms of standard physics has been due to the failure to perceive that mass and space also have a global one-way direction. All moves onward and outward (what the accelerometers say).

14. – Appendix: Note on Methodology

The SGM is clearly in an embryonic state. Continued development could take one of two directions: 1) Test by experiment. This is the preferred direction because of its obvious expedience; it's the most unequivocal way to demonstrate whether the conceptual / theoretical basis is sound. When the results are in, the SGM would be definitively pronounced either dead or alive (and vice versa for GR).

The other direction is to build the SGM into a more formal and rigorous mathematical theory. If this were successful, it would surely make pleas to do the experiment more convincing. As it stands, the model is based on simple appeals to measuring instruments (accelerometers and clocks) and analogies (e.g., SR acceleration analogy, rotation analogy, hyperdimensional analogy). It is certainly desirable to have this heuristic approach supported by "field equations" (or their equivalent) from which the analogies could be more forcefully justified and from which all manner of predictions could be derived. Therefore, I am working in this direction.

Meanwhile, it is ironic that the fruitfulness of these lofty theoretical efforts could be decided beforehand by a simple experiment. The crucial data could be obtained (in principle) in less than 15 minutes ($\approx 1/4$ oscillation period). I have no interest in expending energy on a dead embryo. To me it looks very much alive. But I am eager to discover the truth. Conceivably, some factual empirical evidence already exists to decide the matter. I try to be as thorough as I can, but I may have missed something. If the reader is aware of any such evidence, please let me know. Thank you very much.

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