Light and Clock Behavior in the Space Generation Model of Gravitation

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General Relativity's Schwarzschild solution describes a spherically symmetric gravitational field as an utterly static thing. The Space Generation Model describes it as an absolutely moving thing. The light propagation time-delay experiment of Shapiro-Reasenberg [i] and the falling atomic clock experiment of Vessot-Levine [ii] provide the ideal context for illustrating how, though the respective world views implied by these models are radically different, they make nearly the same predictions for the results of these experiments.

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1. Introduction

A local gravitational field and the massive body serving as its source are well characterized by the readings of accelerometers and the rates of clocks fixed to the body. The field could be mapped by having numerous accelerometers and clocks attached at various heights to extremely tall rigid vertical poles that are firmly planted on the body. The Space Generation Model (SGM) agrees with General Relativity (GR) concerning the readings given by these accelerometers and the varying rates of these clocks. These models sharply diverge, however, for two different extensions of this picture: 1) If a diameter length hole is dug through the body so as to extend the array of instruments to the center, the SGM agrees with GR concerning the accelerometer readings, but predicts (contrary to GR) that *clock rates will increase toward the center*. And 2) According to GR, in the neighborhood of a given point, the radial motion of clocks and the radial propagation of light is essentially symmetrical with regard to the effect on the clock's rate and the speed of the light's propagation. According to the SGM, by contrast, both of these circumstances involve gross asymmetries: *moving upward is much different from moving downward*.

These predictions arise in the SGM because the model is based on a literal interpretation of the readings of accelerometers and the rates of clocks. We adopt the simple and consistent approach of regarding these instruments as indicating not the *potential to cause* motion, but the *existence* of motion. Gravitating bodies are thus analogous to uniformly rotating bodies. In both cases motion sensing devices (accelerometers and clocks) indicate the magnitude of the motion. Objections that might be raised against this interpretation have been addressed in an earlier paper [iii] and will be mentioned again near the end of this one. Also discussed in [3] is astronomical evidence that tends to support the SGM and a proposed laboratory experiment whose result would unequivocally support either the SGM or the objections to it.

In §2 a few details are added to the picture sketched above. In the Shapiro-Reasenberg experiment the only clocks essentially involved were those fixed on Earth. There was no need to compare clock rates, so the experiment bears only on light propagation, as discussed in §3.

The Vessot-Levine experiment involves a combination of these effects, as discussed in §4. The fact that models that differ so radically in their description of the world give nearly identical predictions for such tests clearly indicates the need to perform tests that are not so equivocal. Such is the conclusion drawn in §5.

2. Stationary outward motion vs static refraction

At least two contexts in physics involve a distinction between that which is *static* and that which is *stationary*. deSitter's cosmological solution, which predicts an exponential expansion of the Universe, has been described by Robertson and Noonan [iv] as "the only non-static stationary model." A deSitter-like expansion takes place without the appearance of the Universe changing over time. The much less well known cosmological models of Masreliez [v] and the present author [vi] also have this non-static stationary character. The second context, discussed by various authors, [vii, viii, ix] is that of uniform rotation. A uniformly rotating body such as a large wheel-like space station manifests a range of magnitudes of both acceleration and velocity extending across its seemingly rigid parts, while also maintaining the same appearance over time (especially to observers who are attached to the body).

Much has been written about the case of rotation largely because the resulting mathematical description resembles the Schwarzschild solution. However similar these descriptions may be otherwise, a sharp distinction is drawn by most authors with regard to motion. The gravitational field is static. Whereas, the *unchanging movement* of the rotating body warrants the designation, *stationary*. Light propagation in the two systems serves well to illustrate the difference. The Schwarzschild field is a near perfect analogy to a static medium with varying refractive index. [x] Therefore, variation in the speed of light is due only to its *location* within the medium. Whereas, in the rotating system, the speed of light depends also on *direction*. With respect to the rotating body light propagates at a speed less than c in the direction of rotation and at a speed greater than c against the direction of rotation (Sagnac effect).

GR, the SGM and empirical evidence all agree that the rate of a clock fixed at a point in an external gravitational field is given by

$$f(r) = f_0\sqrt{1-\frac{2GM}{rc^2}}, \tag{1}$$

where G is Newton's constant, M is the mass, r is a radial distance and f_0 is the rate of a clock "at infinity." In GR the metric coefficient, $(1-2GM/rc^2)$ is the analog for the static Newtonian potential GM/r. In the SGM, on the other hand, the speed contained in this coefficient, $\sqrt{2GM/r}$ is the analog for the tangential speed in the case of rotation. The frequency given by (1) is the rate a clock would have if it were moving at the speed $\sqrt{2GM/r}$ relative to a clock at infinity because in a physically real sense that is what is actually happening. At least, that is what our motion detecting instruments seem to be telling us.

To clarify this, suppose one of our tall poles extends to, let's say, *just this side of* infinity. From the top we drop a clock alongside the pole. Our "literal interpretation" thus means we expect the dropped clock to maintain the same rate even as it falls. Nothing has ever caused it to accelerate. This assertion is backed by the fact that a co-moving accelerometer would read zero all the way down. In a strict sense, its speed therefore does not increase, so its rate should not decrease as it falls. With regard to its rate, this clock remains a faithful representative of all clocks at infinity. The velocity that accrues as between this dropped clock and the pole we ascribe absolutely *to the* *pole* — because this is where we know the accelerometers have non-zero readings and the clock's rates are slowed. By this reasoning, it follows that the speed of light is isotropically equal to c only with respect to the clock falling radially from infinity. I call these special trajectories of objects falling radially from infinity, *maximal geodesics*. In the SGM there is no *single* global preferred ether frame. The preferred frames are the maximal geodesics determined by locally dominant gravitating bodies.

3. Shapiro-Reasenberg experiment

By the above reasoning the radial speed of light at Earth's surface or anywhere along one of our tall poles is

$$c_{\uparrow\downarrow} = c \mp \sqrt{\frac{2GM}{r}}, \tag{2}$$

where the upper sign refers to the upward speed and vice versa. In a plane that passes through the center, we have the more general equation:

$$c* = \sqrt{c^2 - \frac{2GM}{r}\sin^2\theta} + \sqrt{\frac{2GM}{r}}\cos\theta. \tag{3}$$

The Shapiro-Reasenberg tests began in the mid 1960's with a probe orbiting Venus. They culminated in the 1970's with a transponder that the Viking Mission had landed on the surface of Mars. The key measurements were of the time delay of signals transmitted between Earth and the planetary probe as the planets approached and passed through superior conjunction, which means, when the planets were on the far side of a line from Earth that passes very near the surface of the Sun. The idea is to compare the time taken for signals to make the out and back trip with the time that would have elapsed for the same trip without the spacetime curvature caused by the Sun's gravity. The curvature increases the effective distance, so especially during superior conjunction the signals take longer to return.

The Schwarzschild solution (in standard coordinates) gives a maximum delay for the Mars lander signal [xi]

$$\Delta t_{GR} = 227.4584\ \mu\text{sec}. \tag{4}$$

Numerical integration of an equation based on (3) corresponding to the same superior conjunction path gives

$$\Delta t_{SGM} = 227.4589\ \mu\text{sec}. \tag{5}$$

The observational error was given as 0.2 μsec, so the SGM is in excellent agreement with the observations.

4. Vessot-Levine experiment

In 1976 Vessot, Levine, et al launched a hydrogen maser clock on a nearly vertical trajectory whose peak was ≈ 1.6 Earth radii (≈ 10,000 km) over Earth's surface. The rate of the clock was monitored by a three-link system, two links of which had the purpose of cancelling the first order Doppler shifts. The results were in agreement with the GR prediction to about $\Delta f / f \approx 10^{-4}$.

In what follows we idealize the experiment by assuming a perfectly radial trajectory. The GR prediction is

$$\frac{\Delta f_{GR}}{f_G} = \frac{f_P - f_G}{f_G} = \frac{\sqrt{1 - \dfrac{2GM}{r_P c^2} - \dfrac{v^2}{c^2}}}{\sqrt{1 - \dfrac{2GM}{r_G c^2}}} - 1, \tag{6}$$

where *G* and *P* denote ground and probe, and *v* is the probe's speed. Standard theorists implicitly assume that it's possible to ascertain from a distance whether the actual rate of a clock on such a trajectory agrees with (6) by implementing a first order Doppler cancellation system such as that used by Vessot-Levine. Including terms that represent the two-link cancellation system, (6) becomes

$$\frac{\Delta f_{GR}}{f_G} = \frac{1}{1 \pm \frac{v}{c}} \left(\frac{\sqrt{1 - \frac{2GM}{r_P c^2} - \frac{v^2}{c^2}}}{\sqrt{1 - \frac{2GM}{r_G c^2}}} - 1 \right) - \frac{1}{2} \left(\frac{1 \mp \frac{v}{c}}{1 \pm \frac{v}{c}} - 1 \right), \qquad (7)$$

where the upper sign represents the ascent phase of the trajectory and vice versa. After correlating the time and velocity values from the Newtonian equation for radial free fall, the frequency prediction and observational data yield the curve in Figure 1.

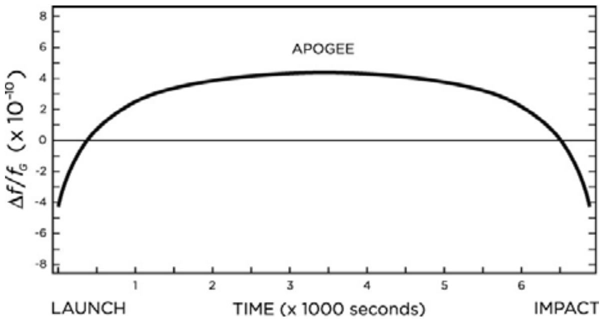

Figure 1. GR prediction for actual rate of probe clock and observational data. Observations match predictions so well that, to the scale of this figure, one curve describes both.

On the face if it, the SGM is in stark disagreement with this result. The SGM prediction for the actual rate of the probe clock is

$$\frac{\Delta f_{SGM}}{f_G} = \frac{f_P - f_G}{f_G} = \frac{\sqrt{1 - \frac{\left(\sqrt{2GM/r_P} \pm v\right)^2}{c^2}}}{\sqrt{1 - \frac{2GM}{r_G c^2}}} - 1, \tag{8}$$

There is no "gravitational potential" here. In its place we have what I call the *stationary outward velocity* of the ground, $\sqrt{2GM/r_G}$ and the *stationary outward velocity* at the height where the probe is momentarily located, $\sqrt{2GM/r_P}$. The rate of the probe clock is gotten by adding the latter velocity to the probe's velocity with respect to the ground, *v*, before squaring. Since this term depends strongly on whether the probe is going up or down, we get the asymmetrical curve of Figure 2.

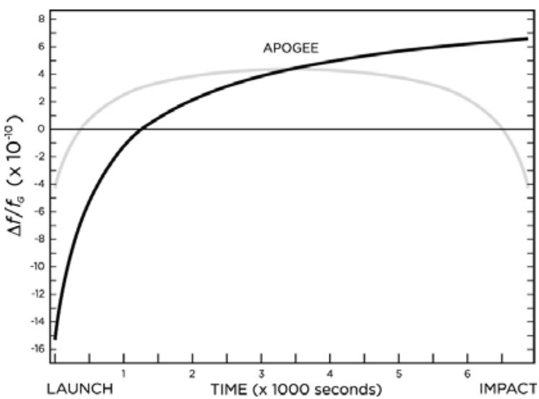

Figure 2. SGM prediction for actual rate of probe clock (black) and prediction for results of experiment (gray). Observations match predictions so well that, to the scale of this figure, the gray curve describes both. The black curve is not directly deducible using the methods of the Vessot-Levine experiment.

Curiously, when the effect of the first order Doppler cancellation system is included in the calculation, the asymmetry almost entirely disappears. The various additional velocity terms make the equation more complicated than the corresponding GR equation (7). To make it a little less unwieldy, we make the following substitutions: $\sqrt{2GM/r_G} = W$ and $\sqrt{2GM/r_P} = V$. The three links then add up to

$$\frac{\Delta f_{SGM}}{f_G} = \frac{c+V}{c+V \pm v}\left(\frac{\sqrt{1-\frac{(V\pm v)^2}{c^2}}}{\sqrt{1-\frac{W^2}{c^2}}} - 1\right) - \frac{1}{2}\left(\frac{c-V\mp v}{c-v}\cdot\frac{c+V}{c+V\pm v} - 1\right). \tag{9}$$

The difference between (9) and the GR prediction (6) is

$$\frac{\Delta F}{f_G} = \left[\frac{\pm v}{2c}\left(\frac{V-W+v}{c}\right)^2\right]. \tag{10}$$

The difference appears only at O $(v/c)^3$. Figure 3 shows the residuals, which are consistent with the empirical data.

Vessot and Levine claimed not only that their experiment would "measure directly the effect of the gravitational potential on the frequency of a proper clock." They also claimed that their experiment was "the first direct, high-accuracy test of the symmetry of the propagation of light." (They concluded that the asymmetry of light speed is less than $\Delta c/c \approx 6\times 10^{-8}$.) Their use of the word, "direct" was obviously misguided. For in making these claims they tacitly and unwittingly excluded models that equally well account for the data by predicting gross light speed anisotropy that is tightly correlated with an equally gross direction-dependence on clock rate. Their first statement quoted above (concerning clock rate) may well be true for that moment when the probe was at apogee. But in light of the SGM, the second statement (concerning light speed) may not be true at all.

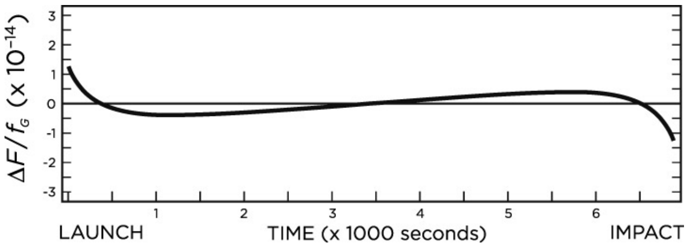

Figure 3. SGM – GR residuals. An order of magnitude improvement in sensitivity would suffice to test between these models.

Note that, although the agreement with the Shapiro-Reasenberg test was within the experimental error by at least three orders of magnitude, in the Vessot-Levine experiment the envelope is narrower. Near launch and impact the residuals go slightly beyond the 10^{-4} margin.

This suggests that if the same experiment were done with another order of magnitude sensitivity, the difference between the GR and SGM predictions could be revealed. Another possibility, at least in principle, is to compare *elapsed times* given by a clock on its ascent phase vs. its descent phase. For a trajectory such as that of the Vessot-Levine experiment, GR says these times should be equal; whereas the SGM says more time ($\approx 10^{-6}$ sec) should elapse on the descent phase.

5. Conclusions

I'm not sure how a General Relativist would assess the SGM's agreement with these tests. Turning the question around, on the other hand, under the assumption that the SGM turns out to be essentially correct, I'd say that the Schwarzschild solution evidently represents a sort of "staticalized" approximation of what is actually a most "unstatic" phenomenon. I would argue further that the SGM approach of literally interpreting the indications of motion sensing devices follows a more natural order of cause and effect. The warped spacetime of GR is, geometrically speaking, a very small effect because the quantities representing the curvature are to second order of a ratio which is already small at first order, $\sqrt{2GM/r}/c$. The unnatural thing about GR, it seems to me, is that first order effects such as velocity and acceleration are supposed to be *caused* by the much smaller second order quantities that are *devoid of all motion*. Surely it would be more natural to have second order effects arising as *consequences* of first order effects. Regarding motion as the cause of curvature makes more sense than regarding static curvature as the cause of motion.

However "natural" the SGM approach may be, in its present state, it leaves a major complication unresolved. The "stationary outward motion" that plays such a central role in this scheme cannot be consistently modeled or visualized in three-dimensional space. The lack of a mathematical model corresponding to the conceptual one is, of course, a valid objection. My response echoes that given in an earlier paper. [3] In addition to a literal interpretation of motion sensing devices, the SGM's guiding concepts are the rotation analogy and the geometric consequence that spatial dimensions are generated by the *projection* of one dimension into the next. On this basis, I suggest that it should be possible to devise a mathematical theory in which matter and space are described as a continuum of *four* space dimensions that perpetually regenerates itself. The density contrast manifested by matter vs. space results in a locally inhomogeneous expansive process ($\propto 1/r^2$) whose cumulative effect is an exponential expansion of the Universe ($\propto r$).

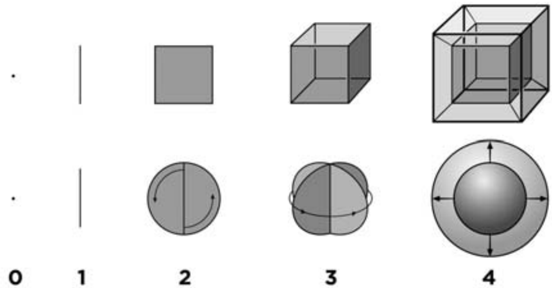

Figure 4. Hierarchy of dimensions: linear, rotational and omnidirectional projection.

A modest laboratory should be all that's needed to find out whether the standard approach or the SGM is richer in truth. Recall that the SGM diverges from GR not only with regard to the radial motion of light and clocks beyond the surface of a gravitating body. The faster clock rate (mentioned in §1) *at the center* of the gravitating body reflects a rather more drastic difference in predictions. GR predicts that a clock at the center is the slowest one, as it resides at the bottom of a "potential well." This corresponds to the prediction that a test object dropped into a hole through the center would oscillate from one end of the hole to the other. Whereas, if the rate of the central clock is as fast as a clock at infinity, which is the SGM prediction, then an object dropped into the hole would not pass the center. A simple experiment designed to test this prediction is discussed in [3].

References

i. R. D. Reasenberg, I. I. Shapiro, et al, "Viking Relativity Experiment: Verification of Signal Retardation by Solar Gravity," *Astrophysical Journal* **234** (15 December 1979) L219-L221.

ii. R. F. C. Vessot and M. W. Levine, "A Test of the Equivalence Principle Using a Space-Borne Clock," *General Relativity and Gravitation*, **10** (1979) 181.

iii. R. Benish, "Laboratory Test of a Class of Gravity Models," *Apeiron* **14** No 4 (October 2007) 362-378. http://www.gravitationlab.com/Grav%20Lab%20Links/Lab-Experiment-2007.pdf

iv. H. P. Robertson and T. W. Noonan, *Relativity and Cosmology* (W. B. Saunders, Philadelphia,1961) 347.

v. C. J. Masreliez, "Scale Expanding Cosmos Theory I — An Introduction," *Apeiron*, **11**, (3 July 2004) 99–133.

vi. R. Benish, "Space Generation Model of Gravitation and the Large Numbers Coincidences," *Apeiron* (Submitted September 2007). http://www.gravitationlab.com/Grav%20Lab%20Links/SGM-and-LNC-Aug-2007.pdf

vii. C. Möller, *Theory of Relativity* (Clarendon Press, Oxford, 1972) 284.

viii. W. Rindler, *Essential Relativity*, (Van Nostrand Reinhold, New York, 1969) 152.

ix. L. D. Landau and E. M. Lifschitz, *Classical Theory of Fields* (Addison-Wesley, Reading, Massachusetts, 1971) 247.

x. C. Möller, *Theory of Relativity* (Clarendon Press, Oxford, 1972) 394.

xi. R. Adler, M. Bazin and M. Schiffer, *Introduction to General Relativity, Second Edition* (McGraw-Hill, New York, 1975) 220.