Predictions of Experimental Results from a Gravity Theory

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A brief overview is given of a Planck scale theory that mimics GR in certain ways, but diverges enough to make testable predictions. A conceptual basis at the Planck scale has large-scale consequences, and leads to a description of the gravitational field, including an equation for the motion of an object in freefall. Some elements of the theory lead to predictions for experimental results.

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The Planck scale may be a limit beyond which physical quantities such as length cease to have meaning, but instead it may only be a limit to the scope of present theories. Planck scale gravity (PSG) is a flat space theory, without curvature as in GR. The conceptual basis cannot be described in full here, a further paper follows, but a small group of assumptions about the Planck scale lead to a very simple theory that mimics GR in certain ways.

In the conceptual basis, a mass at the Planck scale causes a disturbance in the small-scale dimensions, which move slightly in relation to each other, vibrating locally. As a result, waves in the small-scale dimensions radiate outwards from the mass, dissipating as they move away into space. This radiation travels at the local speed of light, and gravity waves are patterns in it at a larger scale, moving outwards at the same speed. Space has a transmission velocity and a refractive index, behaving analogously to the behaviour of large-scale materials that transmit light. Further from the mass, the refractive index of space decreases, as the vibration that causes the effect weakens. Matter responds to this refractive medium at the Planck scale as light does. The result is a scalar field, in which both light and matter are slowed by

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

This closely mimics GR on radial paths. In the non-radial direction the post-Newtonian corrections from GR have comparatively little effect, leaving Newton's circular orbital speed equation unchanged (apart from corrections such as time rate differences from SR and GR). In PSG however, the slowing of light and matter is the same in all directions. The circular orbital speed is

$$v=\sqrt{\frac{GM}{r}-2\left(\frac{GM}{rc}\right)^2}\ , \tag{2}$$

and the central mass from a given circular orbit (where m << M) is well approximated by

$$M\approx\frac{1}{\left(G/r\mathrm{v}^2\right)-\left(2G/rc^2\right)}\ . \tag{3}$$

Similar adjustments are made for all orbits. This leads to very slight differences, for example across the solar system, to mass values, orbits, and distances. It gives a value for the Earth's GM of $3.98600441788 \times 10^{14}$ m^3/sec^2, larger than the estimate from the orbit of the Lageos satellite [1] by a factor of $1+(7.23\times 10^{-10})$. For circular orbits, PSG with a slightly larger central mass is essentially indistinguishable from standard gravity, but the more an orbit includes radial motion the more the differences tend to become noticeable. This provides potential explanations for the Pioneer anomaly [2] and flyby anomaly [3], both of which are unexplained discrepancies in the tracking data for space probes on hyperbolic orbits. Radio signal velocities also require corrections - a detailed analysis of solar system anomalies in this context is being prepared.

Part of the description of the motion of matter in the field involves the speed of an object in freefall, at a given point on its trajectory. In PSG a direct expression for this arises - if an object at a point r in a spherical field falls at a speed v, its speed v' at another point r' anywhere on its trajectory is:

$$v' = \sqrt{c^2 - \left(\frac{2GM}{r'}\right) - \frac{c^2\left[1-\left(\frac{v}{c}\right)^2 - \frac{2GM}{rc^2}\right]\left[1-\frac{2GM}{r'c^2}\right]^2}{\left[1-\frac{2GM}{rc^2}\right]^2}}\ . \qquad (4)$$

The theory predicts a null result for the curvature component of the geodetic effect in gyroscope measurements from Gravity Probe B, the results of which are to be announced April 14th 2007. Gravity Probe B [4] has been in polar orbit since 2004 to test the geodetic effect and frame dragging. In the geodetic effect, according to GR a rotating body in orbit precesses, partly due to the curvature of the space it moves through [5]. There is no space curvature in PSG, so it should not mimic GR to the extent of causing a straight line parallel transported through a gravitational field to change its orientation. This removes the curvature component, which is two thirds of the predicted geodetic effect from GR, 4.4096 arcsecs/yr of a total of 6.6144 arcsecs/yr. The other third has different equivalent interpretations, and might be measured, with a value of 2.2048 arcsecs/yr. But because an orbiting object undergoes an acceleration in PSG, a Thomas precession [6] in the opposite direction, with a value one third of the GR prediction, can cancel the remaining third. A null result for the curvature component is the main prediction, and this cancellation gives a null result for the whole geodetic effect.

Frame dragging [7] arises in GR because space is carried around with a rotating mass. The equivalent in PSG is the Planck scale medium being carried around, which gives the same effect and result as in GR, 0.0409 arc sec/yr. The predicted precession for Gravity Probe B is at right angles to the geodetic precession, and ~160 times smaller, so the result for each will be unambiguous.

PSG can be tested with interferometer experiments, for example with one arm vertical in the field, the other horizontal. A faster average speed of the light along the radial arm, travelling further from the mass than the light on the horizontal arm, will lead to the equivalent of a slight shortening of the radial arm, giving a different prediction from that of GR. If the interferometer can be rotated, different positions in the field for the arms can be compared. As it happens, interferometers capable of doing this exist. The two LIGO interferometers, with an arm length of 4 km., although built for a different purpose, are constantly being rotated in the Sun's field by the motion of the Earth, and are sensitive enough to test PSG. The difference between the two most extreme relative positions for a LIGO interferometer in the Sun's field - the first with both arms horizontal, the second with one arm moved to vertical - is equivalent to a difference in armlength on the vertical arm of $\sim 10^{-12}$ m, if one allows for differences to both the space and time components.

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