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An Exceptionally Simple Experiment Testing Quantum Theory

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Abstract:

A simple equation $GM = tc^3$ explains many puzzles about the Universe, and may provide a link between Relativity and Quantum Mechanics. The quantities h and c could provide a first link. Conversion to the Planck units of time, length, and mass indicates that these units are fundamental. A simple experiment tests whether the Planck mass is part of a quantized gravity. This experiment may also be conducted in the microgravity environment of Space. Applications extend from the large Universe to the microscopic world, including the scale of living cells.

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1. INTRODUCTION:

Cosmology seeks to link the large Universe with the small. Theories of quantum mechanics aid in describing the tiny atomic world, where energies are described by multiples of the Planck value *h*. The large-scale Universe may be described by General Relativity, in which Space/time is curved by the presence of mass, related to the speed of light *c*. Expanding both these theories helps to understand origins of the Universe.

Previously we have tested a Universe that is spherical in 4 dimensions, with radius *R* given by:

$$R = ct \tag{1}$$

Where *c* is speed of light, *t* is age of the Universe.

This spherical Universe is predicted to expand as *t* increases. It cannot expand at the same rate forever, for gravity causes expansion to slow. Speed of light *c* must then be related to time. This results from a joining of Special Relativity, which does not allow for gravity, with the orders of General Relativity.

In Special Relativity, the separation between two points may be given by:

$$ds^2 = -dx_1{}^2 - dx_2{}^2 - dx_3{}^2 - dx_4{}^2 = -\delta_{\mu\nu} dx_\mu dx_\nu \tag{2}$$

By Einstein's notation, $x_4 = ict$, where $i = \sqrt{-1}$.

In General Relativity, the separation is given by: (Einstein, 1923)

$$ds^2 = g_{\mu\nu} dx_\mu dx_\nu \tag{3}$$

The metric $g_{\mu\nu}$ can be challenging to calculate, until we consider the Universe as a spherical mass distribution. Gravitational influence is the same as if all mass were at a central point.

For a field-producing mass *M* at the origin of coordinates, we have: (Einstein, 1915)

$$g_{\mu\nu} = -\delta_{\mu\nu} - a\frac{x_\mu x_\nu}{r^3} \quad \mu,\nu = 1,2,3$$

$$g_{\mu 4} = g_{4\nu} = 0$$

$$g_{44} = 1 - \frac{a}{r} \quad a = \frac{2GM}{c^2} \tag{4}$$

In matrix form:

$$g_{\mu\nu} = \begin{pmatrix} -1 - a\frac{x_1^2}{r^3} & -a\frac{x_1x_2}{r^3} & -a\frac{x_1x_3}{r^3} & 0 \\ -a\frac{x_2x_1}{r^3} & -1 - a\frac{x_2^2}{r^3} & -a\frac{x_2x_3}{r^3} & 0 \\ -a\frac{x_3x_1}{r^3} & -a\frac{x_3x_2}{r^3} & -1 - a\frac{x_3^2}{r^3} & 0 \\ 0 & 0 & 0 & 1 - \frac{a}{r} \end{pmatrix}$$

We can simplify this further by measuring from an origin of coordinates where $x_1=x_2=x_3=0$:

$$g_{\mu\nu} = \begin{pmatrix} -1 & 0 & 0 & 0 \\ 0 & -1 & 0 & 0 \\ 0 & 0 & -1 & 0 \\ 0 & 0 & 0 & 1 - \frac{2GM}{c^2 r} \end{pmatrix}$$

If we set *M=0*, we have the metric of Minkowski Space-time, which does not allow for gravity and contains no mass. To recover the metric of Special Relativity, we need $g_{\mu\nu} = -\delta_{\mu\nu}$.

$$1 - \frac{2GM}{c^2 r} = -1 \tag{5}$$

$$r = \frac{GM}{c^2} \tag{6}$$

If *G, M* and *r* are fixed, we have an Einstein spherical space. (Einstein, 1921) This universe would collapse due to self-gravity unless it expands or is supported by a repulsive force.

Here we add the simple *R=ct*:

$$R = \frac{GM}{c^2} = ct \tag{7}$$

$$GM = tc^3 \tag{8}$$

Where *G* is Newton's gravitational constant, *M* is mass of the Universe.

By this equation when *t* was tiny, *c* was very fast, causing the early Universe to expand in a "big bang". As age *t* increases, *c* slows and is slowing today at a very small rate. Prediction of *c* decreasing at a rate of *-0.72 cm/secyr* has been precisely shown in comparison of Lunar Laser Ranging Experiment data with independent experiments. (Riofrio, 2012) A changing *c* will be further tested as a goal of the Atomic Clock Ensemble in Space aboard our International Space Station.

Equation (8) simply explains conditions of the origin of the Universe, and why the cosmic microwave background has a nearly uniform temperature across large portions of the sky. It also explains the redshifts of distant Type Ia supernovae, prematurely thought to show the Universe accelerating. (Riofrio, 2004) Finally it explains the tension between measurements of the Hubble-Lemaitre value from the early and late Universe. This 'crisis' in cosmology may be simply explained by a changing speed of light.

A changing *c* suggests that Planck value *h* is linked. As one example, *h* and *c* appear in the dimensionless fine-structure value:

$$\alpha = ke^2/\hbar c \tag{9}$$

While some quasar data suggests α has changed, most experiments indicate that it is constant.

Quantities h and c also appear together in the photon energy $E = hc/\lambda$ and are part of the Chandrasekhar mass. Since the above quantities appear to be constant over time, as c decreases h must then increase. The increase of $h \sim t^{2/3}$ is similar to the solution of the random-walk problem. This indicates a link between Relativity and Quantum Mechanics. The uncertainties given by h increasing over time may explain the thermodynamic "arrow of time," or why entropy increases over time.

Equations (1) and (8) may be combined using the units introduced by Max Planck. The Planck units are made up of combinations of h, c, and the gravitational constant G:

$$t_{PL} = \sqrt{\frac{\hbar G}{c^5}} = 5.44 \times 10^{-44} sec \tag{10}$$

$$l_{PL} = \sqrt{\frac{\hbar G}{c^3}} = 1.62 \times 10^{-35} m \tag{11}$$

$$m_{PL} = \sqrt{\frac{\hbar c}{G}} = 2.2 \times 10^{-8} kg \tag{12}$$

Where t_{PL} is Planck time, l_{PL} is length, and m_{PL} is mass.

Using Planck units, equations (1) and (8) become:

$$\frac{M}{m_{PL}} = \frac{R}{r_{PL}} = \frac{t}{t_{PL}} = 0.79 \times 10^{61} \tag{13}$$

$$M = R = t \tag{14}$$

This exceptionally simple equation describes the large Universe in tiny Planck units.

The large number 0.79×10^{61} is beyond the scope of this short paper to derive. When hc is constant, the Planck length increases as $l_{PL} \sim t^{2/3}$ in proportion to size R of the Universe. The Planck time t_{PL} increases in proportion to age t of the Universe. The Planck mass is alone fixed over time. This equation does tell that the largest possible measures, size and age of the Universe, are multiples of the Planck units. This suggests that these units are fundamental, and that space and time are discontinuous on the Planck scale.

While the Planck time and length are too small to measure, the Planck mass is a macroscopic quantity. $2.2 \times 10^{-8} kg$ is far from the smallest mass in nature. The proton mass of $1.67 \times 10^{-27} kg$, for instance, is many orders of magnitude smaller. Tiny atomic masses are normally measured using mass spectrometers, but these instruments measure inertial, not gravitational mass.

Inertial mass is experienced as a mass reacts to an accelerating force. An object's gravitational mass, according to General Relativity, causes space/time to be curved affecting both nearby objects and the propagation of light. As shown by Galileo, Earth's gravity causes objects to fall toward it at the same rate. (In 1971 Apollo 15 astronaut Dave Scott performed Galileo's experiment with a hammer and a feather on the surface of the Moon.) Two small particles dropped from Pisa's Leaning Tower both fall toward the Piazza de Miracoli because Earth's mass is large.

The Equivalence Principle assumes that inertial and gravitational mass are always equal. This assumption has not previously been tested for sub-Planck masses. While the Planck time and length are too small to be measured by present means, the Planck mass is observable in nature. It is similar to the mass of a flea egg or a human eyelash hair.

Many people have seen dust fall toward Earth, and dust particles tend to settle uniformly on a flat surface without attracting one another. (The phenomenon of "dust bunnies" gathering in corners is a result of electrostatic and aerodynamic action). Even when suspended for a long time in microgravity, small particles do not attract one another. I have observed the fall of lunar dust particles, and their behaviour in a vacuum is similar. This observation is a clue to a *quantized gravity*.

Equation (14) suggests that the Planck gravitational mass is fundamental. In this hypothesis a mass below the Planck value is too small to cause curvature of space/time. Two tiny particles fall toward Earth because of Earth's large mass, but they may not attract one another. The following procedure tests that hypothesis.

2. PREDICTION

If mass is *quantized*, two sub-Planck masses will not attract each other gravitationally.

3. METHODS

This is an exceptionally simple experiment to test quantized gravity, within the capability of a laboratory or classroom. The heart of the experiment is two sub-Planck masses.

Two spheres of mass less than 2.2×10^{-8} *kg* are prepared. We may select two spherical grains of limestone *0.2 mm* in diameter. With a limestone density of $2{,}500\ kg/m^3$, each sphere has mass of 1.0×10^{-8} *kg*, slightly less than the Planck mass.

The two masses are placed a distance of *1 mm* apart on a low-friction surface such as Teflon. The surface must be kept precisely level to reduce the effect of Earth's gravitational pull. Grounding the masses via the surface prevents them from developing an opposing electric charge. The surface may be placed in a Petri dish and covered to shield from air currents. If possible the experiment should be conducted in a vacuum chamber to reduce the effects of air pressure.

4. RESULTS

According to old theories of gravity, the two spheres should roll toward one another. After long observation no motion can be detected between the two masses. This indicates that their mass is quantized, and sub-Planck masses do not produce gravitational curvature of space/time. Reproduction of the experiment by independent laboratories would be welcome.

5. AN EXPERIMENT IN ORBIT

As with atomic clocks, our International Space Station makes many kinds of science possible. The orbital environment removes the effects of external gravity. Atomic clocks in space can be more accurate than clocks on Earth. A further refinement of this experiment could take place in orbit.

Here the two masses may be enclosed in an evacuated nucleus, centred in a spherical cell of clear material such as polycarbonate, with a cavity diameter of *2 mm* and an outer cell diameter of *16 mm*. The spherical or cylindrical cavity is sealed as a vacuum to remove the effects of air pressure. Because the two masses are encased within a spherical cell, gravity from the cell does not affect their motion. The spherical cell also acts as a magnifier to aid observations.

[Insert Figure 1 here.]

This version of the experiment, no larger than a marble, can be easily carried in an astronaut's personal effects. Aboard a space station the experiment may be left floating in a quiet corner and periodically observed. As a further refinement, the two masses can be monitored with a laser-diffraction instrument to measure small displacements.

The gravitational effect of Planck masses would be small. We have at distance of *1 mm*:

$$a = Gm_{PL}/r^2 = (6.67 \times 10^{-11})(2.2 \times 10^{-8})/(10^{-3})^2$$

$$a = 1.4 \times 10^{-12}\, m/sec^2 \qquad (15)$$

Where *r* is a distance, *a* is acceleration due to gravity.

The time to travel a distance of 100 microns may be approximated by:

$$t = \sqrt{2d/a} = \sqrt{(2 \times 10^{-4})/(1.4 \times 10^{-12})} = 1.2 \times 10^4 \; sec \qquad (16)$$

Where *t* is the time, here *12,000 sec* or 200 minutes to travel 100 microns.

6. OBSERVATIONS OF NATURE

A quantized gravity may be observed in nature, where the fall of small particles toward Earth and not toward one another is but one example. Within the atom, interactions between protons and electrons are guided by the electromagnetic force. The structure of the nucleus is subject to the strong nuclear and weak nuclear forces. Gravity does not play a part in the interactions of atoms.

The behaviour of microscopic life forms is a fascinating study. Small creatures seen in a microscope tumble about and behave as if in microgravity. Without the aid of gravity, they extend pseudopods and simple tentacles to draw food particles toward them. Prokaryotic life forms such as bacteria all have masses significantly less than the Planck mass; they appear to inhabit a microscopic world free of gravity.

Larger eukaryotic forms of life, including all plants and animals, are almost universally divided into cells (Hooke, 1665) of less than the Planck mass. The living cell draws in nutrients, processes them, and stores genetic material to produce new cells. Without a circulatory system, the cell exchanges material through a process of diffusion. The cell's activities are also independent of self-gravity. If a cell were larger than the Planck mass, self-gravity would affect its internal processes.

In the library of microbiology, observations of *Amoeba Proteus* are particularly interesting. (Prescott, 1955) *Amoeba Proteus* grows to just below the Planck mass. As it approaches the Planck mass, the Amoeba's growth slows before division into more *Amoebae*. This tiny amorphous creature demonstrates the effects of quantized gravity on the growth of cells.

The largest cell of the human body is the female egg cell, with a mass just below the Planck mass. Upon fertilization by a male sperm cell, the egg cell must divide and reproduce to grow into an embryo. The chromatids, containing DNA, migrate to opposite ends of a cell to begin the process of mitosis. What limits the size of cells was a longstanding puzzle of biology. (Marshall et al., 2012) Gravity has been found to play a factor in cell size, for a hypothesis that size is limited by difficulty in absorbing food is not backed by experimental evidence. (Feric and Brangwynne, 2013)

Some cells in nature, such as the algae *Caulerpa taxifolia,* grow larger than the Planck mass. These cells have evolved unique processes to accommodate their growth and reproduction. Monothalameans, for instance, have evolved multiple independent nuclei. Though bird eggs are sometimes considered single cells, their genetic material is contained within a germinal disk containing thousands of tiny blastodermal cells. Amphibian eggs are made of multiple cells that originate from a small germ cell. The majority of living cells, including cells of the human body, are limited to below the Planck mass. The size of cells indicates that gravitational mass is quantized.

7. DISCUSSION

A simple equation $GM = tc^3$ explains some big puzzles of the Universe, and also links the large and the small. A slowing speed of light c coupled with a growing Planck value h provides a link between Relativity and Quantum Mechanics, explaining the "Arrow of Time". In Planck units $M = R = t$ indicates that quantum values are fundamental.

The behaviour of small particles indicates that Planck mass is a limit to gravitational effects. This is a clue that the Planck units of time and length may also be indivisible. The mass, size and age of the Universe may be linked as multiples of the Planck units. A simple experiment may show that mass and gravity are quantized.

Applications extend from the large to the small, including the cells in a human body. Size of a living cell, a basic structure of life, may be determined by the Planck mass. This may help solve a longstanding question of biology, why life forms cells. Further investigations of cosmology will be very rewarding for the future.

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Figure 1: