Space Generation Model of Gravitation and the Large Numbers Coincidences

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The basis for a new model of gravitation is presented, as are its basic cosmological consequences. Gravity is conceived as a process of outward movement of matter and space whose cumulative effect is the exponential expansion of the Universe. In the cosmological extreme the model thus resembles Masreliez's Expanding Spacetime Theory. [1] Unlike the latter theory, the new model predicts novel effects that can be revealed in a modest laboratory. The next most noteworthy feature of the model is that it gives new meaning to the well-known "large numbers coincidences." This new approach encompasses a broader range of physical reality than usual, including now the cosmic background radiation and the density of atomic nuclei.

Keywords: Gravitation, cosmology, fundamental constants, large numbers coincidences, cosmic background radiation

1. Introduction

It has sometimes been suggested that the mechanism of gravity involves the expansion of matter. The purpose of the present paper is primarily to show how this idea might arise in the first place, provide a minimum of justification and then delve into the cosmological consequences. Common objections to the idea of “expanding matter” are summarily addressed in another paper. [2] The possibility of testing the model with a laboratory experiment and indirect support from astrophysical observations are also discussed in that other paper.

In §2 I argue that regarding gravity as a process of outward movement stems from a literal interpretation of the readings of accelerometers and clocks. The Space Generation Model’s (SGM’s) redshift-distance relation is derived in §3. This leads to a prediction for the average cosmic matter density—assumed to be a *bona fide constant*—expressed as a particular value of the density parameter Ω_0. §4 is concerned with the COBE satellite’s measurement of the absolute temperature of the Cosmic Background Radiation (CBR). In §5 the value of the SGM’s Hubble constant, another bona fide constant, is predicted. We begin generating the SGM-based “large numbers” in §6. More large numbers arise in §7 by including the density of nuclear matter. Finally, in §8 we discuss implications and leave a few questions unanswered.

2. Accelerometers and clocks

In our everyday experience, acceleration arises for three distinct reasons: 1) forces directed linearly, such as from a motorized vehicle or bodily muscles; 2) rotation; and 3) gravitation. The case of rotation is of particular interest because it is curiously analogous to the case of gravitation. It is well-known that Einstein used this analogy in the course of building his General Theory of Relativity (GR). [3, 4] Imagine a body such as a large, wheel-like space station uniformly rotating in outer space. Accelerometers and clocks are fixed to various locations throughout the body. Upon inspecting their readings and comparing their rates (in the case of the clocks) we would find, 1) negative (centripetal) accelerations varying directly as the distance *r*, from the rotation axis, and 2) clock rates varying as

$$f(r) = f_0\sqrt{1-\frac{r^2\omega^2}{c^2}}, \qquad (1)$$

where ω is the angular velocity, c is the speed of light and f_0 is the rate of a clock at rest with respect to the rotation axis. Since the accelerations and velocities of a uniformly rotating body are constant in time, such systems are often referred to as being *stationary* [5, 6, 7].

On a spherically symmetric gravitating body we also find non-zero accelerometer readings and clocks ticking at reduced rates. The range of acceleration and time dilation would become more evident by having numerous accelerometers and clocks fixed to extremely tall rigid poles firmly planted on the body. We'd then find that the acceleration varies as $1/r^2$ and that clock rates vary as

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

where G is Newton's constant and M is the mass of the body.

Having the idea that such a body and its field are utterly static things, Einstein took this to mean that rotating observers are entitled to regard themselves as being *at rest*. This approach is tantamount to a *denial* that accelerometer readings and clock rates are reliable indicators of motion. This seems to have happened somewhat subconsciously, even prior to Einstein. The Newtonian concept of force and its relation to acceleration is unambiguous if it is applied to rotation or to non-gravitational forces. In these cases the *direction* of the acceleration indicated by an accelerometer is the same as the direction of the force. But in the case of gravity, thought of as a "body force," a positive accelerometer reading is now interpreted as the *negative* of the acceleration a body *would* experience if it were allowed to fall. And a zero reading means a falling body is accelerating with the local value of the force (divided by the body's mass).

The potential for confusion only increases when GR is brought into the picture. For here a positive accelerometer reading is thought of as indicating an acceleration with respect to a nearby *geodesic* (free-fall trajectory). Hence, in standard texts one sometimes finds expressions as "acceleration of a particle at rest" [8, 9]. Of course this expression has a degree of consistency within GR's mathematical scheme; but with regard to the common meaning of the word, *acceleration*, it is contradictory. This becomes especially evident when we note that the "resting" particle is referred to as such because it is at rest with respect to a *static* Schwarzschild field. According to GR everything "at rest" in a static gravitational field is also accelerating. According to Newton a positive accelerometer reading means "trying" (but failing) to accelerate in the negative direction. Is this the best we can do?

One of the core motivations of the SGM is to explore the consequences of eliminating this confused state of affairs by maintaining a simple and consistent interpretation of the meaning of motion sensing devices. We now assume that *accelerometer readings and clock rates are utterly reliable indicators of motion*. It follows that, *since a body undergoing uniform rotation is a manifestation of absolute stationary motion, so too, is a gravitating body*. In the case of gravitation both the velocity and the acceleration are positive, being directed radially outward.

This implies that both matter and space are involved in a perpetual process of self-projection and regeneration. Space generation proceeds according to an inverse-square law; but due to the resulting local inhomogeneities, it is impossible to consistently model or visualize in three-dimensional space. If this interpretation is correct, it would thus require another space dimension to accommodate and to maintain the integrity of the inhomogeneous expansive motion. A natural consequence of regarding gravitation as a perpetual *manifestation* of motion instead of as a static *cause* of motion, is the apparent spacetime curvature of our seemingly three-dimensional world.

However radical the SGM may seem to be, it is simply based on the assumption that the readings of accelerometers and the rates of clocks are *telling the truth* about their state of acceleration and velocity. In principle, the model can be easily tested. An important consequence is that a clock located at the center of a large gravitating body will have the same maximum rate as a clock "at infinity." Unlike GR's interior and exterior Schwarzschild solutions, clock rates in the SGM do not indicate the *potential* for motion, they indicate the *existence* of motion. The centrally located clock has a maximum rate because, just as the acceleration diminishes "by symmetry" and goes to zero at the body's center, so too, does the velocity. It follows that inside a gravitating body a radially falling test object would not pass the center and oscillate through it. Rather, after reaching a maximum apparent downward speed, the object would only asymptotically approach the center. An experiment designed to test this prediction and astrophysical evidence tending to support it are discussed in another paper [2]. Novel predictions also arise in the SGM for the behavior of light and clocks near and beyond the surfaces of large gravitating bodies. These predictions deviate strongly from those of GR for *one-way* light signals and for rates compared between ascending and descending clocks. Due to the *two-way* nature of experiments designed to detect these effects, the SGM actually agrees with their results. This is demonstrated for the Shapiro-Reasenberg time delay test and the Vessot-Levine falling clock experiment in a third paper [10]. Presently, we assume that the model has not been refuted by empirical evidence and move on to explore the cosmological implications.

3. Cosmic redshift and average matter density

Newton's constant, G, can be thought of as representing an "acceleration of volume per mass." The idea that gravity is an attractive force means the *energy* of gravity is a *negative* quantity. In the context of standard cosmology an obvious consequence is that the global effect of gravity is to *eliminate space*. Gravity's negative energy acceleratively reduces the amount of space in the Universe. If the density of the cosmos were sufficient (and there were no "dark energy" having the opposite effect) gravity would negate the Big Bang's expansive effect and eliminate all space (Big Crunch).

In the present scheme, by contrast, the energy of gravity is a *positive* quantity, as it represents not only the generation of space but of the massive bodies themselves that space is ultimately continuous with. This continuousness suggests that space is not a passive background that can be sucked out of existence or be disproportionately increased by any means. In other words, it implies that the average density in the universe should be a fundamental constant. This assumption plays a pivotal role in what follows.

The first step in exploring the cosmological consequences of these assumptions is to define the scale of gravity's domain, i.e., to identify a characteristic linear "size" of the Universe. We assume the most reasonable possibility to be

$$R_c = \frac{GM_c}{c^2}, \tag{3}$$

where M_c is the mass within a sphere of cosmic radius R_c. Before using this definition of R_c to predict the average cosmic matter density, it will be useful to first establish our redshift-distance law.

Although the local effects of gravity are complicated by the inhomogeneities of the expansion, our assumption of constant cosmic mass density justifies regarding these inhomogeneities as being smoothed out on a cosmic scale. The cumulative effect would thus be an exponential expansion whose effect on a given length is

$$r = r_0 \exp(\beta \Delta t), \tag{4}$$

where r_0 is some initial cosmic distance, r is r_0's expanded length (the change of which could only be directly perceived by an imaginary being who is unaffected by the global expansion), Δt is a time interval and β is a constant, to be determined below.

Another assumption of SGM cosmology upon which the redshift-distance law depends, involves the distinction between *what is and what is not a clock*. In the SGM, that which travels slower than light, i.e., matter, is clock-like; that which travels at the speed of light is not. (This is, of course, consistent with Special Relativity, according to which "time stands still for the photon," but ticks along at one rate or another for everything else.) The importance of this distinction arises in the SGM because the energy of matter increases with time. Whereas, energy in the form of light maintains only the energy it had at the moment it was emitted. A useful comparison would be with the Steady State models of Hoyle, Bondi and Gold, [11] in which the cosmic density is held constant by the perpetual creation of new particles of matter. The newer Steady State models of Hoyle, Burbidge, Narlikar and others, [12] posit "creation events" on a larger scale, which involve expansive effects that keep the average cosmic density at least approximately constant. In the SGM, the density remains exactly constant, because the matter increase is not due to the discontinuous appearance of new particles, but to the continuous increase in mass of all particles that already exist.

Light's non-clock status in this scheme results in a kind of source-and-sink relationship: it's not that anything really goes down the drain, but that, as the sink's "basin" fills up, so does the material of which it is made; the basin (matter) expands to exactly accommodate what is filling it (radiation), so the level remains constant. In other words, what makes the timeless things appear to get smaller (lose energy) is all the clock-like things getting larger (gaining energy) around them.

Since lengths change as $\exp(\beta\Delta t)$ and the density of our cosmos is constant, volumes and therefore masses change as $\exp(3\beta\Delta t)$. The deBroglie relation in Quantum Theory gives the frequency of a "matter wave" (clock) as

$$f = \frac{mc^2}{h}, \tag{5}$$

where m is the mass (typically, of an elementary particle) and h is Planck's constant. Being proportional to mass, the frequency of distant clocks is given by

$$f_{SGM} = \frac{f_0}{\exp(3\beta\Delta t)} = \frac{f_0}{\exp(3r_0/R_{SGM})}, \tag{6}$$

where we have now identified β as c/R_{SGM} and Δt as the time for a light signal to travel the distance r_0. The rates of clocks increase with cosmic time. Similar to the "deSitter effect" arising in deSitter's GR-based cosmological solution, this means distant clocks would be observed to be running slow. [13] The redshift law that follows is:

$$z = \exp(3r_0/R_{SGM}) - 1. \tag{7}$$

Note that for small z (relatively nearby galaxies) we then have $z \approx 3r_0 / R_{SGM}$. Whereas in standard cosmology, the corresponding equation is $z \approx H_0 r_0 / c = r_0 / R_H$, where $R_H = c / H_0$ is the Hubble radius and H_0 is the Hubble constant. The characteristic length, R_{SGM} is thus three times larger than the characteristic length in standard cosmology.

From (3) we get the mass contained within the cosmic radius, $M_{SGM} = R_{SGM} c^2 / G$. Dividing this mass by the volume $4\pi R_{SGM}^3 / 3$ gives the equation for the average matter density,

$$\rho_{SGM} = \frac{3c^2}{4\pi G R_{SGM}^2}. \tag{8}$$

In standard cosmology the parameter Ω_0 represents a density ratio which, for a *flat* Universe (such as those required by *inflation*) equals unity. The denominator in this ratio, known as the *critical density*, is given by

$$\rho_{CRIT} = \frac{3H^2}{8\pi G} = \frac{3c^2}{8\pi G R_H^2}. \tag{9}$$

If (3) is used to get a corresponding density ratio, using R_H would give

$$\Omega = \frac{\rho}{\rho_{CRIT}} = 2.0. \tag{10}$$

On the other hand, since $R_{SGM} = 3R_H$, the SGM density parameter is

$$\Omega_{SGM} = \frac{\rho_{SGM}}{\rho_{CRIT}} = \frac{2}{9} = 0.2222. \tag{11}$$

Most every measurement of Ω_M within the last 10–15 years has error margins within which Ω_{SGM} comfortably fits [14, 15, 16]. This is still one of the least well-known parameters (or constants, as the case may be) however. So let's now turn to the next one.

4. Cosmic background temperature

> *The exact temperature of the CMBR is not important for cosmology, since every other cosmological constant is more poorly determined.* [17]

In standard cosmology the background temperature is actually not a constant. Nor is the Hubble "constant," nor the scale length, nor the matter density, etc. These parameters all change with time, so that, although there may be some meaningful relationships among them, this meaningfulness is hardly profound due to how very adjustable the whole scheme is. The above quotation clearly makes sense if one accepts the assumption that the temperature started extremely high and is on its way to zero. For then its exact value at any given epoch would be more incidental than fundamental. By contrast, in the SGM there is no adjustability; the temperature is a *bona fide* constant whose exact value is *very* important for cosmology. Therefore, the purpose of this section is to establish how well we actually know the value of T_{CBR}.

The most accurate measurements we presently have of T_{CBR} are those of the Cosmic Background Explorer (COBE) satellite. In Kelvins, the initial (1990) report gave: [18]

$$T_{COBE} = 2.735 \pm 0.060. \tag{12}$$

With further analyses of the data over the next 12 years the values determined for both T_{COBE} and its error margin had undergone some changes. The satellite's assortment of instruments provided three, more or less independent methods for measuring the temperature. The most useful tool for this purpose was FIRAS (Far Infrared Absolute

Spectrophotometer). Of the three methods, the one that used the *dipole* signal of the background was more independent than the other two, which measured the *monopole* signal. This is largely because in the dipole method the sky itself served as the calibrator, whereas the monopole methods depended on the onboard instrumental calibrators. The dipole method also had a wider error margin and tended to be more discrepant. Or so the impression is given. It's actually possible that, even with its lower precision, this method is the most accurate of the three. Four years after the initial report, using the "entire FIRAS data set," Mather, et al gave [19]

$$T_{COBE} = 2.726 \pm 0.010. \quad (13)$$

Whereas, in a companion paper published at the same time, using the dipole method Fixsen, et al found [20]

$$T_{COBE} = 2.714 \pm 0.022. \quad (14)$$

In 1996 another update [21] yielded for the combined data (which was essentially the same as that measured by the monopole method):

$$T_{COBE} = 2.728 \pm 0.004, \quad (15)$$

and the temperature measured by the dipole method yielded:

$$T_{COBE} = 2.717 \pm 0.007. \quad (16)$$

In 1999 [17] a step was taken to nudge the persistently "low" dipole-derived temperature closer to the others (even though this had the effect of substantially increasing its error margin). With a new combined figure as well, the results became (combined/monopole):

$$T_{COBE} = 2.725 \pm 0.002, \quad (17)$$

and dipole:

$$T_{COBE} = 2.722 \pm 0.012. \quad (18)$$

The *final* COBE data, reported in 2002 [22] left the 1999 temperatures intact, but cut the error of the combined result in half, giving

$$T_{COBEFINAL} = 2.725 \pm 0.001. \tag{19}$$

This error margin is extremely impressive. The authors themselves have pointed out that "there is reason to be cautious." In fact, there are at least two reasons for caution: 1) Kolb and Turner give an idea what we're up against as follows:

> *While measuring a temperature difference of order tens of microKelvins is in itself a technical challenge, even more daunting is shielding against sunshine, earthshine, and moonshine, and discriminating against foreground sources including synchrotron, bremsstrahlung and thermal dust emission from the Milky Way, as well as discrete sources between here and the last-scattering surface.* [23]

Plenty of caveats to this effect can be found in the literature.

Reason 2) is that the dipole measurement was never entirely reconciled with the monopole measurement. Concerning the persistence of the discrepancy and the manner in which it was dealt with by the COBE team, P. M. Robitaille has commented:

> *It is inappropriate to make so many adjustments for "systematic errors," and thereby remove a highly significant difference between two numbers, long after completion of an experiment.* [24]

This is not to detract from the COBE team's amazing accomplishment. It is rather simply to emphasize the possibility that there may be a bit more slack in their final measurement than they have stated. Specifically, there may be reason to suspect the dipole measurement method to have come closer than the monopole method to the actual temperature of the cosmic background radiation.

5. Hubble constant

> *The likelihood of coincidences between numbers of the order of 10^{39} arising for no reason is so small that it is difficult to resist the conclusion that they represent the expression of a deep relation between the cosmos and microphysics, a relation the nature of which is not understood…In any case it is clear that the atomic structure of matter is a most important and significant characteristic of the physical world which any comprehensive theory of cosmology must ultimately explain.—Herman Bondi* [25]

The "large numbers coincidences" we are about to examine fall more neatly into line when we adopt a value for T_{CBR} that is nearly the same as that given by the pre-nudged dipole method. Before making that small adjustment, it will be useful to see what we get by taking the value from (19) ($T_{CBR} = 2.725$).

Let's begin by converting T_{COBE} to an energy density (in Joules meter^{-3}):

$$\mu_{COBE} = aT_{COBE}^4 = 4.1718 \times 10^{-14}, \tag{20}$$

where a is the radiation density constant. Dividing by c^2 then gives us an "equivalent" mass density (in kg meter^{-3}):

$$\frac{\mu_{COBE}}{c^2} = \rho_{\mu COBE} = 4.6417 \times 10^{-31}. \tag{21}$$

The idea at this point is to relate this equivalent-mass density to the average matter density, so that we can (by 8) determine the value of the scale length R_{SGM}. Since we expect both the radiation density and the matter density to be fundamental constants, we should expect the relationship between them to also be a fundamental constant, and so be expressible in terms of other known constants. The most likely candidate, it seems, would be the electron mass-to-proton mass ratio, where we suspect the electron to correspond to the more ethereal, cosmic radiation density; and the proton to correspond to the more firmly anchored matter density. Accordingly, let us assume

$$\frac{\rho_{\mu COBE}}{\rho_{mCOBE}} = \frac{1}{2}\frac{m_e}{m_p}, \tag{22}$$

where ρ_{mCOBE} is the matter density following from the above assumptions, and m_e and m_p are the electron and proton masses, respectively. This gives

$$\rho_{mCOBE} = \frac{3c^2}{4\pi G R_{COBE}^2} = 1.7046 \times 10^{-27}. \tag{23}$$

Rearranging (23) yields a cosmic length (in meters),

$$R_{COBE} = \sqrt{\frac{3c^2}{4\pi G \rho_{mCOBE}}} = 4.3428 \times 10^{26}. \tag{24}$$

Recalling that $R_{SGM} = 3R_H$, the Hubble constant following from (24) is (in km sec^{-1} Mpc^{-1}):

$$H_{COBE} = \frac{3c}{R_{COBE}} = 63.66. \tag{25}$$

Although many measurements of H_0 have come close to the value given by (25) it is not yet clear which of these are the most reliable. A large faction of astronomers still favor a value closer to $H_0 \approx 72$.

And yet some recent studies give values as low as $H_0 = 52$ [26]. Figure 1, adapted from Tammann and Reindl 2005 [27], charts the recent history of H_0 measurements. Clearly, it would not be too surprising to see a future convergence to $H_0 = 64$. Since the density parameter ($\Omega_{SGM} = 0.2222$) arising from our model is similarly consistent with observations, we may be on the right track.

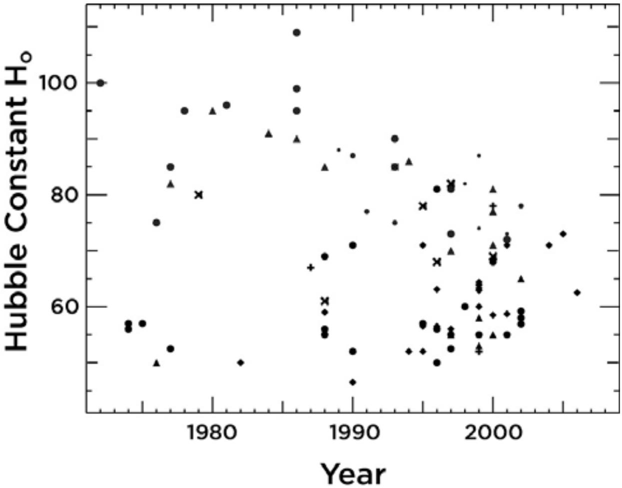

Figure 1. Thirty years of H_0 measurements. Adapted from Tammann and Reindl 2005. [27]

6. Fine structure constant and smaller numbers

The famous large numbers might just as well have been called *small* numbers since their reciprocals are equally important. One of the most famous of the small numbers is the gravitational-to-electrostatic force ratio in a hydrogen atom:

$$\frac{F_G}{F_E} = \frac{Gm_p m_e}{e^2/4\pi\varepsilon_0} = 4.4068\times10^{-40}. \tag{26}$$

This is not too far from the ratio between the Bohr radius, a_0 and R_{COBE}

$$\frac{\mathrm{a}_0}{R_{COBE}} = 1.2185\times10^{-37}. \tag{27}$$

In previous large numbers explorations, the cosmic length is usually taken as $\approx R_H$ and the atomic length is often the classical electron radius or the electron's Compton wavelength. Being multiples of the fine structure constant, α, either of these latter lengths would suffice to expose the pattern of the present scheme. However, starting with a_0 makes it more obvious that we are not slipping α into the mix beforehand.

Comparing the ratios (26) and (27) we get

$$\frac{\mathrm{a}_0/R_{COBE}}{F_G/F_E} = 276.4451. \tag{28}$$

Comparing this with $2/\alpha$ yields

$$\frac{\mathrm{a}_0/R_{COBE}}{F_G/F_E} = \frac{2}{\alpha}(0.9914). \tag{29}$$

Under the assumption that (28) and (29) should equal $2/\alpha$ exactly, we adjust R to fit (and change the subscript). The adjustment gives an average matter density

$$\rho_{SGM} = \frac{3c^2}{4\pi G R_{SGM}^2} = 1.6754\times10^{-27}. \tag{30}$$

Making the corresponding mass-equivalent radiation density, $\rho_{\mu COBE}$ in the ratio of one half the electron-to-proton mass, as per (22), we get the cosmic background temperature:

$$T_{SGM} = \left(\frac{\rho_{\mu SGM} c^2}{a} \right)^{1/4} = \left(\frac{\mu_{SGM}}{a} \right)^{1/4} = 2.7133. \tag{31}$$

Comparing this to the final COBE value, we get

$$\frac{T_{COBE}}{T_{SGM}} = \frac{2.725}{2.7133} = 1.0043. \tag{32}$$

Note that T_{SGM} is within the error margins of the temperature measured by the dipole method, especially the 1994 and 1996 reports (Eqs 14 and 16). Substituting the 1996 value in (32) for example, gives

$$\frac{T_{COBE}}{T_{SGM}} = \frac{2.717}{2.7133} = 1.0014. \tag{33}$$

We next extend our scheme to the density regime at the opposite extreme in size: the atomic nucleus.

7. Nuclear connection

The density of nuclear matter is not as well measured as the background temperature. At least three sources [28, 29, 30] I've found express the density as 0.17 nucleons per cubic fermi, or give a nearly equivalent value in kg meter^{-3}:

$$\rho_N = \frac{0.17 m_p}{10^{-45}} = 2.8435 \times 10^{17}. \tag{34}$$

Although it is well known that this density is nearly the same from one nucleus to the next, there is some variation (a few percent). So this is clearly not as "tight" a number as most of the others. Nevertheless, if we compare (34) to the cosmic matter density and the hydrogen atom force ratio (and take the square root) we get:

$$\sqrt{\frac{F_G/F_E}{\rho_{SGM}/\rho_N}} = \frac{\alpha}{2}(1.0021). \tag{35}$$

Especially as the nuclear density admits of some slack, it is not unreasonable to assume that (35) should be exactly $\alpha/2$ so as to give us a *fiducial* nuclear density that relates exactly to our cosmic matter density. This assumption yields

$$\rho_N = \rho_{SGM}\left(\frac{4}{\alpha^2}\cdot\frac{F_E}{F_G}\right) = 2.8552\times 10^{17}. \tag{36}$$

It is interesting that the nuclear density is at least approximately related (within ≈ 2%) to the mass-equivalent of the CBR independent of any model:

$$\rho_N = \rho_{\mu CBR}\left(\frac{8}{\alpha^2}\cdot\frac{F_E}{F_G}\cdot\frac{m_p}{m_e}\right) = 8\rho_{\mu CBR}\left(\frac{c^2 \mathrm{a}_0}{Gm_e}\right). \tag{37}$$

From the standard point of view, this would have to be a mere coincidence.

To the empirical measurements of the nuclear density we should add a theoretical method of calculating it. The calculation is actually concerned with an estimation of a characteristic nuclear "volume in which equilibrium is established." After E. Fermi, E. Segre [31] has shown that this volume is defined by the Compton wavelength of a charged pion. Multiplying the inverse of this volume by the mass of two protons (since it is obviously a *plurality* of nucleons between which the interactions take place) we get a nuclear density

$$\rho_{NSegre} = \frac{2m_p}{V_{NSegre}} = 2.8259 \times 10^{17}. \quad (38)$$

A curious fact concerning the above calculation is that if the pion mass were *exactly* equal to $2m_e / \alpha$ (instead of being slightly smaller) then the presented densities (Eqs 36 and 38) would also be exactly equal.

Although there is some evidence that matter densities can exceed ρ_N (approaching "quark matter") such circumstances are rare. From (37) we see that the common, normal extremes appear to be connected to one another by gravity:

$$G = 8\left(\frac{\rho_{\mu CBR}}{\rho_N} \cdot \frac{c^2 a_0}{m_e}\right) = 8\left(\frac{\mu_{CBR}}{\rho_N} \cdot \frac{a_0}{m_e}\right). \quad (39)$$

We thus have a simple definition of G arising from atomic nuclei and the CBR that is at least approximately true independent of any model. Coincidence? If the Universe has had an infinite time to organize itself, then we should really expect something like this.

The various density regimes relate to one another as:

$$\rho_N = \frac{12m_p}{\pi\alpha^6 a_0^3} = \rho_{SGM}\left(\frac{4}{\alpha^2} \cdot \frac{F_E}{F_G}\right) = \rho_{\mu CBR}\left(\frac{8}{G} \cdot \frac{c^2 a_0}{m_e}\right). \quad (40)$$

(Note that the regime of "planetary" density, whose range is comparatively wide, falls between ρ_N and ρ_{SGM}, having a magnitude roughly given by $\rho_{PLANET} \approx \rho_N \alpha^6 / 16 = 3m_p / 4\pi a_0^3 \approx$ 2700 kg m^{-3}). Rearranging (40), Newton's constant is also simply defined as:

$$G = 4\left(\frac{\rho_{SGM}}{\rho_N} \cdot \frac{c^2 a_0}{m_p}\right) = \frac{1}{2}\alpha^3\left(\frac{c^2}{m_p} \cdot \frac{a_0^2}{R_{SGM}}\right). \quad (41)$$

Another ratio often presented in "large numbers" discussions is the number of nucleons contained within a sphere of cosmic radius. Appealing again to (3), we get the mass, $M_{SGM} = R_{SGM} c^2 / G$. Dividing by the proton mass, m_p gives

$$N_{SGM} = \frac{M_{SGM}}{m_p} = 3.5266 \times 10^{80}. \quad (42)$$

This ties back to the fine structure constant and our other ratios:

$$\alpha = \frac{1}{2}\left(\frac{F_E}{F_G}\right)^2 \frac{m_p}{M_{SGM}}. \quad (43)$$

The fine structure constant is also given by

$$\alpha^3 = \frac{2Gm_p}{c^2} \cdot \frac{R_{SGM}}{\mathrm{a}_0^2} = \frac{2R_{SGM}^2}{\mathrm{a}_0^2} \cdot \frac{m_p}{M_{SGM}}. \quad (44)$$

Before commenting on the possible significance of these relationships, I'll present one more that is at least approximately true independent of any model. Consider the gravitational energy of an electron in a ground state hydrogen atom,

$$E_{GH} = \frac{Gm_p m_e}{\mathrm{a}_0}. \quad (45)$$

If we multiply by 2 and divide by the volume within a Bohr radius, $V_H = 4\pi \mathrm{a}_0^3 / 3$ we get an energy density that relates to the CBR as

$$\frac{2E_{GH}}{V_H} = \mu_{SGM} \alpha^6. \quad (46)$$

If the monopole-measured value of μ_{COBE} is used in place of μ_{SGM}, (46) is still correct to within 1.8%. If the dipole-measured value is used, then (46) is correct to within 0.55%.

8. Conclusions, comments, questions

Since no empirical evidence proving otherwise is in hand, the close alignment of these numbers could be a coincidence. It seems to me, however, that it would be a pretty amazing coincidence. That this interrelationship amongst the constants is not just coincidence is suggested by the following. A truism of physics is that Planck's constant, h, is the *key* to the world of the atom:

$$\alpha = \frac{1}{2} \cdot \frac{e^2}{\varepsilon_0 hc} = \frac{h}{2\pi m_e c a_0}. \tag{47}$$

Since h and α are related to each other by various other constants in this domain and α comprises a dimensionless ratio among them, α also has this "key-like" quality: another truism.

Contrast this with the counterpart for h in the realm of gravitational physics, i.e., G. Of what other constants is G comprised? How does G relate to the other constants? Nobody knows! The persistent failure of standard theoretical thinking to incorporate gravity into a "unified" physical theory may be *represented* by the fact that *Newton's G stands isolated from the rest of physics.* It doesn't seem right that the Universe is actually so disjointed. Surely G connects up to the other constants *somehow*. Over the last several decades there have been many attempts to find a connection. As far as I can tell, none of these previous attempts have been as simple as those presented above; none have included such a wide range of physical phenomena with the numerical values agreeing so well with measurements; and none could be so easily tested by experiment.

I'll close with a remark about what is perhaps the most transparently encompassing of the above expressions:

$$G = 8\left(\frac{\rho_{\mu SGM}}{\rho_N} \cdot \frac{c^2 a_0}{m_e}\right). \tag{48}$$

One of the persistent puzzles about gravity is why it is so weak compared to electromagnetism. The answer suggested by (48) is that, although the dimensioned part, $c^2 a_0 / m_e$ ("acceleration of volume per mass") is a fairly large large number (O 10^{36}), the dimensionless part $\rho_{\mu SGM} / \rho_N$, is an even smaller small number (O 10^{-47}). This makes G of the order (O 10^{-11}). Of course this is not intended as a complete or totally satisfactory answer, but as a possibly crucial clue.

The highest priority in determining the ultimate meaning of these relationships is to carry out the experiment described in [2]. If a test object oscillates through a hole spanning opposite sides of a massive sphere in accord with Newton, one could hardly escape the conclusion that the near exactitude of these numerical connections is an unfortunate accident having no physical significance at all.

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