Space Generation Model of Gravity, Cosmic Numbers, and Dark Energy

R. Benish([1])

([1]) *Eugene, Oregon, USA, rjbenish@comcast.net*

Abstract. —
This is an updated and augmented version of the previously published paper, *Space Generation Model of Gravitation and the Large Numbers Coincidences.* [1] The basis of the gravity model is that motion sensing devices—most notably accelerometers and clocks—consistently tell the truth about their state of motion. When the devices are attached to a uniformly rotating body this is undoubtedly true. Uniform rotation is sometimes referred to as an example of *stationary motion.* It is proposed here, by analogy, that gravitation is also an example of stationary motion. Einstein used the rotation analogy to deduce spacetime curvature. Similar logic suggests that *in both cases* the effects of curvature are caused by *motion.* A key distinction is that, unlike rotation, gravitational motion is not motion *through* space, but rather motion *of* space. Extending the analogy further, gravitation is conceived as a process involving movement into a fourth space dimension. Space and matter are dynamic, continuous extensions of each other, which implies that the average cosmic density is a universal constant. Assuming this to be the case leads to a cosmological model according to which ratios such as the gravitational to electrostatic force, electron mass to proton mass, Bohr radius to cosmic radius, and constants such as the fine structure constant, Hubble constant, the saturation density of nuclear matter and the energy density of the cosmic background radiation are all very simply related to one another. Measured values of these numbers are discussed in sufficient detail to facilitate judging whether or not the found and predicted relationships are due to chance. The notorious "cosmological constant" (dark energy) problem is also addressed in light of the new gravity model. Finally, it is emphasized that the model lends itself to a relatively easy laboratory test.

PACS 04. – General relativity and gravitation.; 98.80.-k – Cosmology; 04.80.Cc – Experimental tests of gravitational theories; 04.50.-h – Higher-dimensional gravity and other theories of gravity

1. – Introduction

Almost everyone believes that gravity is a force of attraction. In the context of General Relativity (GR) the word, *force* is usually eschewed. Instead, gravity is conceived as a geometrical thing—the curvature of spacetime which, in any case, is still believed to cause bodies of matter to be *attracted* toward one another. Be it a force or spacetime curvature, common to both conceptions is the underlying assumption that bodies of matter and the fields (or spacetime) they reside in are essentially *static* things. The most common examples of gravitational phenomena are routinely conceived in terms of the static Schwarzschild solution (GR) or the static Newtonian field caused by large spherical bodies such as the Sun or Earth. Presently, we question the underlying assumption of staticness, and along with it, the assumption of the attractive nature of gravitation. Perhaps bodies of matter and their surrounding fields (or spacetime) are perpetually moving, moving outwardly. Absurd though it may at first seem, in what follows we will find reasons to take this idea seriously. The first concern of this paper will be to establish the logical basis of conceiving gravity to be a process of outward, rather than inward motion. We provide evidence and analogies indicating that the idea is viable, and then delve into the cosmological consequences.

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. These instruments are motion sensing devices whose readings tell us that we (residing on Earth's surface) are perpetually moving. This motion refers not to motion *through* space, but to the motion and the generation *of* space. Unlike GR, which posits a static spacetime curvature as the cause of inward motion, we now regard outward motion as the cause of spacetime curvature. In §3 it is argued that this explanation for spacetime curvature only makes sense if there are four, rather than just three, dimensions of space. Gravitational motion *of* space means the *active extension* of seemingly three-dimensional bodies into another dimension.

Jumping then, to cosmological considerations, the Space Generation Model's (SGM's) redshift-distance relation is derived in §4. This leads to a prediction for the average cosmic matter density—assumed to be a *bona fide constant*, which is expressed as a particular value of the density parameter, Ω_0. The absolute temperature of the Cosmic Background Radiation, $T_{\rm CBR}$, measured by the COBE satellite is the concern of §5. In §6 the value of the Hubble constant, another bona fide constant, is predicted. We begin generating the SGM-based Cosmic Numbers in §7. In §8 we present some background details concerning measurements of the density of nuclear matter, $\rho_{\rm N}$. This is to provide an assessment as to how accurately this density is known. §8 thus parallels §5, which does the same thing for $T_{\rm CBR}$. In §9 we then extend our Cosmic Numbers explorations by including the nuclear density. §10 focusses on a chosen few Cosmic Number relationships that seem especially meaningful.

The question of "vacuum energy"—which has attracted so much attention lately—is the subject of §11. In order to assess whether the SGM Cosmic Numbers scheme is related to the 10^{120} discrepancy in the standard model of particles, we appeal to the SGM's prediction of a *maximum force* in physics. Though a similar maximum force can also be derived from the "Planck units," the standard vs. SGM trains of thought here are shown to be entirely different. In §12 our results are summarized and it is emphasized that the model can be readily tested by a laboratory experiment.

2. – Accelerometers and Clocks

2˙1. *Assessing our State of Motion.* – In our everyday experience, acceleration arises for three distinct reasons: 1) forces directed linearly, such as from motorized vehicles 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

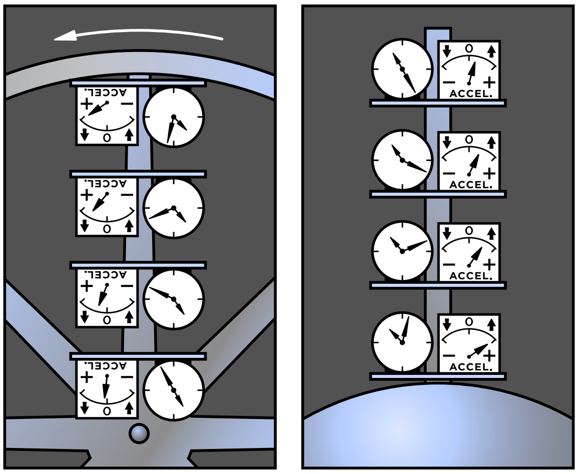

Fig. 1. – Stationary Motion. Left: A uniformly rotating body causes accelerometer readings to vary directly as the distance (stationary inward acceleration); and causes clock rates to vary according to Equation 1 (stationary tangential velocity). Right: A gravitating body causes accelerometer readings to vary as the inverse square of the distance (stationary outward acceleration); and causes clocks to vary according to Equation 2 (stationary outward velocity). It is easy to visualize rotational motion as motion *through* pre-existing space. Gravitational motion, on the other hand, is motion *of* space, which is more difficult to visualize because it requires a fourth dimension of space. According to the Space Generation Model, gravity is the process whereby matter generates the fourth dimension of space. (See also Figure 2.)

(GR) [2,3]. 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

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

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.* [4-6] Thus, a system whose motion persists unchanged is stationary; whereas a system that lacks all motion is static.

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. (See Figure 1.) We'd then find that the acceleration varies as $1/r^2$ and that clock rates vary as

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

where G is Newton's constant and M is the mass of the body. In these two distinctly different circumstances—a rotating body and a gravitating body—motion sensing devices behave in a similar, distance-dependent way.

2˙2. *Historical Assessments of Motion.* – When Einstein began to contemplate these relationships he already had in mind the preconceived idea that the gravitating body and its field are static things. He believed that observers attached to the body may rightly regard themselves as being *at rest.* Since the effects on a rotating body are similar to the effects on a gravitating body, Einstein drew the analogy that rotating observers are therefore also entitled to regard themselves as being at rest. Thus he wrote,

> An accelerated coordinate system represent[s] a special case of the gravitational field. It is the same in the case of the rotation of the coordinate system: there is *de facto* no reason to trace centrigugal effects back to a 'real' rotation. [7]

This approach is tantamount to a *denial* that accelerometer readings and clock rates are reliable indicators of motion. To Einstein, what is more fundamental than motion is the concept of a "gravitational field," described in terms of non-Euclidean geometry. The idea that bodies of matter and their gravitational fields were static things was a view that Einstein inherited from antiquity.

Based on our visual impressions, it has been generally assumed throughout all human history that material bodies are static things, that we are entirely justified to conceive that the Earth does not move. The Copernican revolution began to chip away at this persistent illusion. But there is much yet to do. Building on the work of Kepler, Galileo and others, Newton invented the astonishingly useful concept of *gravitational force.* Before explicitly considering Newton's force of gravity, let's first exclude gravity from the more general notion of force in Newtonian mechanics. The idea is to clarify the relationship between *force* and *acceleration.* This relationship is quite unambiguous, for example, in the cases of rotation or linear propulsion. What makes the relationship unambiguous in these cases is that *the direction of the acceleration indicated by accelerometers is the same as the direction of the force.* But in the case of gravity this is no longer true. In the case of gravity, 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). A positive reading means rest; a zero reading means negative acceleration. How strange! In this respect gravity is a real oddball in Newton's mechanical scheme; no other force is treated so backwardly with respect to the *direction* indicated by accelerometer readings.

2˙3. *The Modern View and an Alternative.* – 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). Thus, 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. The "resting" particle is referred to as such because it is at rest with respect to a *static* Schwarzschild field. In GR the word, acceleration, which usually indicates motion, is scrambled up with words indicating lack of motion (rest, static) so that any consistent, intuitive way of distinguishing one from the other is lost. Summarizing then, according to Einstein's theory it is routine, yet clearly somewhat schizoid, to regard that which is "at rest" in a static gravitational field as also accelerating. According to Newton's theory 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 eliminate 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.* Gravitating bodies produce the effects of motion, such as the readings on accelerometers, *by moving.* We are simply abiding by one of the basic principles of scientific reasoning, to attribute to the same effect, the same cause. [10] Our motion sensing devices tell us that everything moves all the time. Thus we come to contemplate these issues unencumbered by Einstein's preconceptions about rest and staticness. By disbelieving his accelerometers, Einstein may have built a theory that perpetuates the illusion of self-rest.

3. – Fourth Dimension of Space

3·1. *Analogy for Spacetime Curvature, Hyperdimensionality, Inertial Mass, and Asymmetrical Time*. – Motion sensing devices tell us that, 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. To clarify this, let's again appeal to the rotation analogy.

Consider the following differences between the two key types of stationary motion. Rotational stationary motion is clearly conceivable as motion *through* space, through

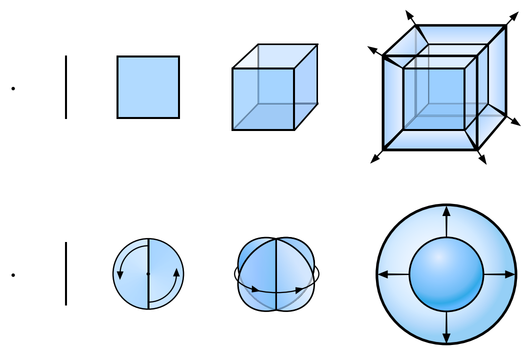

Fig. 2. – Dimensional Hierarchy. Each step, i.e., each new direction, each new dimension, arises from the perpendicular projection of the preceding step. The process culminates here when the first three dimensions all project themselves together into (or outfrom) the fourth spatial dimension. Note that isolating one step, i.e., one direction from the others is only an abstraction. In the real physical world the "higher" dimension subsumes all the "lower" dimensions by the process of actively perpetuating extensions simultaneously in every direction. Without this process there would be no space at all. This process is gravitation, whose "agent" is matter.

pre-existing three-dimensional space. The SGM requires one more dimension of space because the stationary motion manifest by gravitating bodies is not motion through pre-existing space; it is the motion *of* space, the motion of newly generated space. (See Figure 2.) This is essential. But now bear in mind that for Einstein, the purpose of the rotation analogy was to establish that the geometrical relationships on a rotating body could be conceived as non-Euclidean. The physical manifestations of these non-Euclidean properties are changes in rod-lengths and clock rates. These effects are clearly caused by the rotating body's *motion*. It is therefore logical to surmise that the rod-length and clock rate distortions (spacetime curvature) pertaining to a *gravitating* body are caused by *its* motion.

The jump in dimensions may be seen as part of the same analogy. Rotational stationary motion manifests circular or cylindrical—essentially two-dimensional—symmetry. Whereas gravitational stationary motion manifests spherical, three-dimensional symmetry. For gravity one more dimension is needed. Rotation is a way for extended bodies to coherently project themselves into another dimension (a line sweeps out a plane; a plane sweeps out a volume). Gravitation is the way that extended, seemingly three-dimensional bodies coherently project themselves into the next higher dimension (a volume sweeps out a hypervolume).

It is important to emphasize that the "projections" conceived here are *extensions* in the *active* sense. The progression up the hierarchy of dimensions occurs by *moving* the lower dimensional state at right angles to itself (as by turning) so as to generate the next higher dimensional state. Each of the seemingly separate dimensions owes its existence to the process whereby the *whole system* moves, whereby the whole system is perpetually extending itself. Without gravity there would be no physical dimension at all. Though gravity may be identifiable as the "fourth" dimension of space (as implied by Figure 2) if true, then it is ultimately much more than that because the higher dimension subsumes the lower ones. For example, this conception would begin to explain the origin of inertial mass. A body's resistance to being accelerated in any *one* direction is essentially proportional to the amount of space that the body generates in *every* direction. It would also explain the irreversibility of time. Time only increases because space and matter also only increase.

Invoking an extra dimension of space is thus not an ad hoc fix, making an ostensibly implausible scheme even more so. A straightforward interpretation of the accelerometer readings on the right side of Figure 1 is that matter and space accelerate inhomogeneously, yet coherently, at the same time. If this straightforward interpretation is a fact, then it *requires* the existence of more than three dimensions to explain it. To deny that it is a fact, to deny the truthfulness of the accelerometer readings, allows avoiding complications engendered by a fourth space dimension, it allows clinging to the ancient notion of self-rest. But then we are left with the puzzle of inertia, the puzzle of time's arrow, the puzzle of gravity. More important than arguing the logic of the situation, however, is that the question can be settled without a single word by observing what Nature does in response to a suitably arranged physical experiment.

3˙2. *Perspective and Empirical Testability.* – However radical the SGM may seem, 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. Fortunately, it would not be too difficult to test the model by experiment. To see the principle behind such an experiment, note that an important consequence of the SGM is that a clock located at the *center* of a large gravitating body will have the same maximum rate as

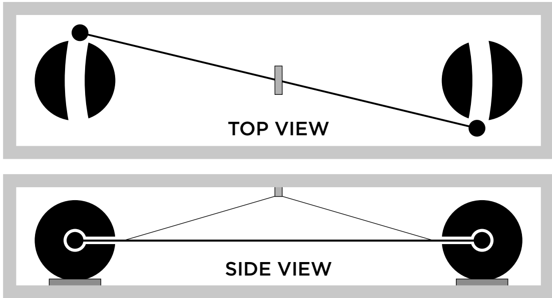

Fig. 3. – Schematic of modified Cavendish balance for testing interior field motion predictions. If the gravity of the large masses causes the balance arm to oscillate back and forth from one side of the hole to the other, then Newton and Einstein are right and the SGM is wrong. Whereas, if the balance arm begins to move inward , but then slows down and does not pass the center, Newton and Einstein are wrong and the SGM is right.

a clock "at infinity." Imagine a set of clocks arrayed at various radial distances along a tunnel that spans the diameter of a massive sphere. 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 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 more detail in another paper. [11] With regard to the experiment, suffice it here to point out that the most suitable apparatus is likely to be a modified Cavendish balance, as shown in Figure 3. The trajectory of the test object would have a slight arc. But it would be a close enough approximation to the ideally straight path to answer the crucial question: to oscillate or not to oscillate?

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 from those of GR for *one-way* light signals and for frequencies 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 has been demonstrated (in yet another paper [12]) for the Shapiro-Reasenberg time delay test and the Vessot-Levine falling clock experiment.

3˙3. *Summary and Course of Action.* – Putting these things in perspective then, Einstein gave us curved spacetime without telling us what matter has to *do* to make spacetime curve. If the curvature is caused by motion into another dimension, this would clearly add a level of complexity to our conception of gravity—even as the logical and factual basis is extremely simple. On this logical basis, one may well build up the model into a rigorous mathematical theory. A reason not to jump onto that project, however, is that nobody has ever tested the interior field predictions mentioned above. The most expedient course of action would be to do the experiment first. Its result would, first of all, fill a long-standing gap in our empirical knowledge of gravity. And secondly, depending on what that result is, it would tell us either that the hyperdimensional mathematics of the SGM should indeed be enthusiastically pursued, or that there is no compelling reason to do so because the model is entirely wrong. Presently, we assume that the model has not been refuted by empirical evidence and move on to explore the cosmological implications.

4. – 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 changed 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

$$R_{\rm C} = \frac{GM_{\rm C}}{c^2}\,, \tag{3}$$

where $M_{\rm C}$ is the mass within a sphere of cosmic radius $R_{\rm C}$. Note that this expression has been suggested as a basis, or at least as a key relation in several cosmological hypotheses. Most commonly it has been presented in the context of cosmological ideas motivated by "Mach's Principle." (See, for example, Dicke [13], Sciama [14], and Bondi [15].) For various reasons these models are no longer popular. Leaving Machian ideas out of the discussion, we nevertheless retain the expression (3) for its scale-setting implications.

Before using this definition of $R_{\rm C}$ 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 matter 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, [16] 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, [17] 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. The proportions of matter-to-radiation and matter-to-space remain constant. From this point of view, the cosmic redshift is evidence of the energy increase of all material bodies. 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. Due to the finite propagation speed of light, the farther away a massive body (e.g., a galaxy) is, the older is the light we see from it. The light we see was emitted when the mass of the body that emitted it was smaller than it is now—smaller than an identical body that is nearby. Since mass changes as $\exp(3\beta\Delta t)$, and [by (5)] frequency is proportional to mass, the observable frequency of distant clocks is given by

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

where we have now identified β as c/R_{C} 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. [18] The redshift law that follows is:

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

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

Even without knowing the absolute value of $R_{\rm C}$, seeing how it compares with $R_{\rm H}$ enables us to compare the key mass densities arising in the respective models. The relation for the cosmic mass density in the SGM is gotten by appealing to (3), which can be rearranged to give the mass contained within the cosmic radius, $M_{\rm C} = R_{\rm C}\, c^2/G$. Dividing this mass by the volume $(4/3)\pi R_{\rm C}^3$ gives the equation for the average cosmic matter density,

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

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

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

If (3) were used to get a corresponding density ratio, using $R_{\rm H}$ would give

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

On the other hand, since $R_{\rm C} = 3R_{\rm H}$, the SGM density parameter is

$$\Omega_{\rm M} = \frac{\rho_{\rm C}}{\rho_{\rm CRIT}} = 0.2222\,. \tag{11}$$

Most every measurement of $\Omega_{\rm M}$ within the last 20–25 years gives error margins within which (11) comfortably fits [19-24]. 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.

5. – Cosmic Background Temperature

> *The exact temperature of the CMBR is not important for cosmology, since every other cosmological constant is more poorly determined.* — John Mather [25]

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 $T_{\rm CBR}$.

The most accurate measurements we presently have of $T_{\rm CBR}$ are those of the Cosmic Background Explorer (COBE) satellite. The initial (1990) report [26] gave:

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

The values determined for both T_{COBE} and its error margin changed somewhat over the next 12 years due to continued reanalysis of the data. 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 with respect to COBE's other measurements. It's actually possible, however, that even with its lower precision, this method is the most accurate of the three; perhaps the other two methods are the discrepant ones. Four years after the initial report, in 1994, using the "entire FIRAS data set," Mather, et al [27] gave

$$T_{\text{COBE}} = 2.726 \pm 0.010 \text{ K}\,. \tag{13}$$

Whereas, in a companion paper published at the same time, using the dipole method Fixsen, et al [28] found

$$T_{\text{COBE}} = 2.714 \pm 0.022 \text{ K}\,. \tag{14}$$

In 1996 another update [29] yielded for the combined data (which was essentially the same as that measured by the monopole method):

$$T_{\text{COBE}} = 2.728 \pm 0.004 \text{ K}\,, \tag{15}$$

and the temperature measured by the dipole method yielded:

$$T_{\text{COBE}} = 2.717 \pm 0.007 \text{ K}\,. \tag{16}$$

In 1999 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 [25] became (combined/monopole):

$$T_{\text{COBE}} = 2.725 \pm 0.002 \text{ K}\,, \tag{17}$$

and (dipole):

$$T_{\text{COBE}} = 2.722 \pm 0.012 \text{ K}\,. \tag{18}$$

The *final* COBE data, reported in 2002 [30] left the 1999 temperatures intact, but cut the error of the combined result in half, giving

$$T_{\text{COBE}} = 2.725 \pm 0.001 \text{ K} . \tag{19}$$

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. [31]

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. Notice that, especially from 1996 onwards, the error margins are always given so that the two measurements are just barely consistent with each other. One naturally wonders what values would have been gotten in a "blind" analysis, in which there was no knowledge of what the "other" measurement was. 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. [32]

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.

6. – 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 [33]

The Cosmic 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) $T_{\text{COBE}} = 2.725$. Let's begin by converting T_{COBE} to an energy density:

$$\mu_{\text{COBE}} = aT^4_{\text{COBE}} = 4.1718 \times 10^{-14}\ \text{J m}^{-3}\,, \tag{20}$$

where a is the radiation density constant. Dividing by c^2 then gives us an "equivalent" mass density:

$$\frac{\mu_{\text{COBE}}}{c^2} = \rho_{\mu\text{COBE}} = 4.6417 \times 10^{-31}\ \text{kg m}^{-3}\,. \tag{21}$$

[Note: Rather than round down to four significant figures, I will use five (and/or four decimal places) throughout because the last digit sometimes almost matters. Leaving it in gives an idea—only slightly exaggerated—of how closely the SGM Cosmic Numbers line up.] The idea at this point is to relate this equivalent-mass (radiation) density to the average matter density, so that we can [by (8)] determine the value of the scale length R_{C}. 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

$$\frac{\rho_{\mu\text{COBE}}}{\rho_{\text{MCOBE}}} = \frac{1}{2}\frac{m_{\text{e}}}{m_{\text{p}}}\,, \tag{22}$$

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

$$\rho_{\text{MCOBE}} = \frac{3c^2}{4\pi G R^2_{\text{COBE}}} = 1.7046 \times 10^{-27}\ \text{kg m}^{-3}\,. \tag{23}$$

Rearranging (23) yields a cosmic length,

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

Recalling that $R_{\text{C}} = 3R_{\text{H}}$, the Hubble constant following from (24) is (in kilometers per second per megaparcec):

$$H_{\text{COBE}} = \frac{3c}{R_{\text{COBE}}} = 63.904\ \text{km s}^{-1}\,\text{Mpc}^{-1}\,. \tag{25}$$

In discussions of Hubble's constant, it is convenient to introduce the dimensionless expression: h = measurement/100 km sec^{-1} Mpc^{-1}, where h is obviously not to be confused with Planck's constant. Although many measurements of h have come close to the value, $h = 0.6390$, given by (25) it is not yet clear which of these are the most reliable. A large

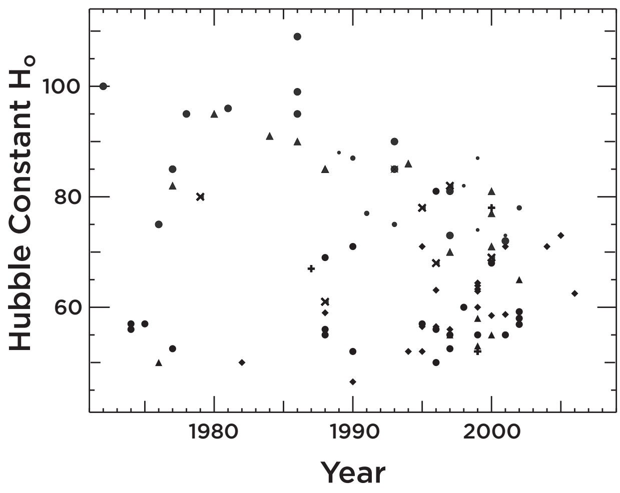

Fig. 4. – Thirty years of H_0 measurements. Adapted from Tammann 2006. [35]

faction of astronomers still favor a value closer to $h \approx 0.72$. And yet some recent studies give values as low as $h = 0.52$. [34] Figure 4, adapted from Tammann, 2006, [35] charts the recent history of h measurements.

Writing the latest revision of this paper in September 2009, I've gotten the impression that in the last few years the $h = 0.72$ contingent has gotten more press than anyone else. But the Sandage, Tammann, Reindl, Saha, Baccheto, and Panagia team persist at making their own measurements and expressing doubts about the higher value. The latest from Tammann, et al is $h = 62.3 \pm 1.3$ [36] (Note also that impartial reports on the status of H_0 can be found. [37,38])

Given the unsettled state of the situation and the numbers that have been given, it is certainly not unreasonable to imagine a future convergence to $h \simeq 0.64$. Since the density parameter ($\Omega_{\rm M} = 0.2222$) arising from our model is similarly consistent with observations, we may be on the right track.

7. – 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. (Thus, *Cosmic* Numbers is a better name!) One of the most famous of the Small Numbers is the gravitational-to-electrostatic force ratio in a hydrogen atom:

$$\frac{F_{\rm G}}{F_{\rm E}} = \frac{G m_{\rm p} m_{\rm e}}{e^2/4\pi\epsilon_0} = 4.4068 \times 10^{-40}\,. \tag{26}$$

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

$$\frac{\mathrm{a}_0}{R_{\rm COBE}} = 1.2185 \times 10^{-37}\,. \tag{27}$$

In previous Large Numbers explorations, the cosmic length is usually taken as $\approx R_{\rm H}$ and the atomic length is often the classical electron radius, $r_{\rm e} = {\rm a}_0\,\alpha^2$, or the electron's Compton wavelength, $\lambda\!\!\!^-_{\rm C} = {\rm a}_0\,\alpha$. 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 $\rm a_0$ makes it more obvious that we are not slipping α into the mix beforehand.

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

$$\frac{{\rm a}_0/R_{\rm COBE}}{F_{\rm G}/F_{\rm E}} = 276.4451\,. \tag{28}$$

Comparing this with $2/\alpha$ yields

$$\frac{{\rm a}_0/R_{\rm COBE}}{F_{\rm G}/F_{\rm E}} = \frac{2}{\alpha}(0.9914)\,. \tag{29}$$

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

$$\rho_{\rm C} = \frac{3c^2}{4\pi G R_{\rm C}^2} = 1.6754\times 10^{-27}\ {\rm kg\ m^{-3}}\,. \tag{30}$$

Making the corresponding mass-equivalent radiation density, ρ_μ in the ratio of one half the electron-to-proton mass, as per (22), we get the cosmic background temperature

$$T_{\rm SGM} = \left[\frac{\rho_\mu\, c^2}{a}\right]^{1/4} = \left[\frac{\mu}{a}\right]^{1/4} = 2.7133\ {\rm K}\,. \tag{31}$$

Comparing this to the final COBE value, we get

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

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

$$\frac{T_{\rm COBE1994}}{T_{\rm SGM}} = \frac{2.714}{2.7133} = 1.0003 \quad \text{and} \quad \frac{T_{\rm COBE1996}}{T_{\rm SGM}} = \frac{2.717}{2.7133} = 1.0014\,. \tag{33}$$

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

8. – Atomic Nuclei

8˙1. *Preliminary*. – Before discussing how the density of nuclear matter connects up with our other Cosmic Numbers, a little background is in order. Just as it was important to consider a few background details concerning the primary measurements of $T_{\rm CBR}$, it will help to consider a few background details concerning $\rho_{\rm N}$, the nuclear saturation density. We will see that $\rho_{\rm N}$ has not been measured to the same precision as $T_{\rm CBR}$. Although a reasonable estimate of $\rho_{\rm N}$ has been known for a few decades, it has proven difficult to get a more exact figure. Nuclear physics is complicated, and we will take only the briefest glimpse of it. Our main concern is simply to get a sense of how well known $\rho_{\rm N}$ actually is, so that we can gauge the reasonableness of supposing it to have one particular value over another.

One of the ways $\rho_{\rm N}$ is similar to $T_{\rm CBR}$ is that it is not an absolute limit. Temperatures below 2.7 K are routinely achieved in laboratories. And densities greater than $\rho_{\rm N}$ are achieved momentarily in high energy collisions and at the centers of neutron stars. But these circumstances are rare and unstable. Generally, Nature seeks a more equilibrious state, and here we have another similarity suggestive of an actual *relationship.* In the context of a cosmological model such as the SGM, which assumes a stationary "ground state" density at one extreme ($T_{\rm CBR}$) it is not unreasonable to expect a relationship with the ground state density at the other extreme ($\rho_{\rm N}$). The possibility of connecting $\rho_{\rm N}$ to the Universe will make more sense after we've briefly considered it in its own context.

8˙2. *Value of* ρ_N. – The density of nuclear matter is not only difficult to measure precisely, it also differs very slightly from one atomic species to the next. (The difference is more extreme for the lightest four or five elements.) The close similarity in density for medium to heavy weight species is understood in terms of the *saturation* of nuclear matter. Nuclear forces are presumed to have both an attractive component and a repulsive component, both of which have a very short range. The repulsive component's range is the shorter of the two and when they are in balance, we get what is known as the *saturation density of nuclear matter*, a kind of *ground state* in which the average separation between nucleons does not change.

A common practice in the theoretical study of this regime is to eliminate the complications of "surface effects" and treat a sea of nucleons as having infinite extent ("infinite nuclei"). The goal is to come up with an *equation of state* that faithfully matches or serves as a basis for comparison for the measured behavior of actual (finite) physical nuclei. Besides the density, this equation includes at least two other parameters (e.g., the Fermi momentum, the Fermi energy and the compressibility of nuclear matter). Different models each have their strengths and weaknesses, but as yet there is no agreement as to any exclusively correct approach.

The point of giving this background is to establish that nuclear physics is not yet well developed enough to give more than a rough theoretical basis to expect any particular density value. Rather, the models are basically built to satisfy the empirical measurements. Curiously, though the approximate value of nuclear matter, $\rho_{\rm N}$, has been known for several decades, during this time the measurements have only gotten a little more precise, if that.

Let's consider a few examples. In 1973 the book, *Fields and Particles* by Bitter and Medicus, [39] gives the average distance between nucleons as 1.8 fm (where one fm = fermi = 10^{-15} m, so that $\rm fm^3 = 10^{-45}\,m^3$). The number density is thus $(1/1.8)^3\,\rm fm^{-3} = 0.1715$. This equates to 2.8680×10^{17} kg m^{-3}. Seventeen years later the value given in an

Encyclopedia of Modern Physics article [40] by George Leung, is $\rho_{\mathrm{N}} = 2.8 \times 10^{17}$ kg m^{-3}. One of the most common values given in more recent literature (e.g., [41]) is

$$\rho_{\mathrm{N}} = 0.17\, m_{\mathrm{p}}\, \mathrm{fm}^{-3} = 2.8435 \times 10^{17}\ \mathrm{kg\ m}^{-3}\,. \tag{34}$$

Another commonly cited number is: $\rho_{\mathrm{N}} = 0.16\, m_{\mathrm{p}}\, \mathrm{fm}^{-3} = 2.6762 \times 10^{17}$ kg m^{-3}. Only rarely—in the earlier citations as well as the later ones—do we find the given value accompanied by an explicit error margin. The error implied by being given these two significant figures is of course about 6%. An exception is a recent paper by Santra and Lombardo, [42] who gave

$$\rho_{\mathrm{N}} = 0.17 \pm 0.02\ m_{\mathrm{p}}\ \mathrm{fm}^{-3}\,. \tag{35}$$

Judging by these examples, in over 30 years the (implicit or explicit) error margin has not diminished, it has doubled! Just as rare as finding explicit error margins, in my experience, is finding explicit references to the original work done to get these values. More common are no references at all or references to work in which ρ_{N} is one among the several parameters being juggled according to one model or another, so as to get an acceptable (equation of state) fit. Clearly, nuclear physics is a complicated, delicate, relatively new business, and one is just not going to find the kind of lucid and direct accounts of measurements of ρ_{N} like one finds, for example, for measurements of Newton's constant, G.

I will mention one more cited value—for two reasons: 1) it is expressed with three significant figures rather than the usual two. And 2) it comes close to the value that we will arrive at by another route. In the 2007 book *Nuclear Physics in a Nutshell*, [43] C. A. Bertulani refers to $\rho_{\mathrm{N}} = 0.172\, m_{\mathrm{p}}\, \mathrm{fm}^{-3}$ as "the approximate density of all nuclei with $A \gtrsim 12$," where A is the number of nucleons in a given atomic species. Bertulani does not cite a source to back up his assertion. We will of course bear in mind the more conservative assessment of Santra and Lombardo ($\rho_{\mathrm{N}} = 0.17 \pm 0.02\, m_{\mathrm{p}}\, \mathrm{fm}^{-3}$).

8·3. *Implied Theoretical Density Prediction.* – In his book, *Nuclei and Particles*, Emilio Segre [44] describes an idea by Enrico Fermi, according to which one can calculate a characteristic nuclear-sized volume. It's the volume "in which equilibrium is established" during an interaction between two nucleons. Equilibrium, I assume, corresponds to the same condition as the saturated or ground state. The calculated volume is:

$$V_{\mathrm{SEGRE}} = \frac{4}{3}\pi \lambda\!\!\!^{-}{}_{\pi+}^{3}\,, \tag{36}$$

where $\lambda\!\!\!^{-}{}_{\pi+}$ is the Compton wavelength of a charged pion. Pions are regarded as being among the *quanta* of the nuclear force. They are conceived as "mediating" the nuclear attraction. The mass of the two interacting nucleons divided by this volume gives:

$$\rho_{\mathrm{NSEGRE}} = \frac{2m_{\mathrm{p}}}{V_{\mathrm{SEGRE}}} = 2.8259 \times 10^{17}\ \mathrm{kg\ m}^{-3} = 0.1690\, m_{\mathrm{p}}\, \mathrm{fm}^{-3}\,. \tag{37}$$

As far as I can tell, neither Fermi nor Segre intended this as an explicit *prediction* for the saturation density. Yet one may certainly infer it as such. We are given two nucleons and an equilibrium volume; an equilibrium density is an obvious consequence.

9. – Micro-macro Connection

9·1. *Density Comparisons.* – To get on with our Cosmic Numbers sleuthing then, let's compare the commonly given value, 0.17 nucleons per cubic fermi ($= 2.8435 \times 10^{17}$ kg m^{-3}) to the average cosmic density ρ_{C}. (Remember that $\Omega_{\mathrm{SGM}} \simeq 0.2222$ is consistent with nearly every measured value of the matter density, so our comparison will be true at least to order of magnitude.) We'll add a subscript, .17 to keep this nuclear density value distinct from others:

$$\rho_{\mathrm{N.17}} \over \rho_{\mathrm{C}} = \frac{2.8435 \times 10^{17}\ \mathrm{kg\ m^{-3}}}{1.6754 \times 10^{-27}\ \mathrm{kg\ m^{-3}}} = 1.6971 \times 10^{44}\,. \tag{38}$$

Once again we are not too far from the prevalent Large Number 10^{40}. It turns out that (38) compares to $F_{\mathrm{E}}/F_{\mathrm{G}}$ as:

$$\frac{F_{\mathrm{E}}/F_{\mathrm{G}}}{\rho_{\mathrm{N.17}}/\rho_{\mathrm{C}}} = \frac{\alpha^2}{4}(1.0041)\,. \tag{39}$$

This is suggestive enough to motivate the assumption that (39) should be exactly $\alpha^2/4$ so as to see what else may come of it. This assumption yields

$$\rho_{\mathrm{NSGM}} = \rho_{\mathrm{C}}\left[\frac{4}{\alpha^2}\cdot\frac{F_{\mathrm{E}}}{F_{\mathrm{G}}}\right] = 2.8552 \times 10^{17}\ \mathrm{kg\ m^{-3}} = 0.1707\ m_{\mathrm{p}}\ \mathrm{fm^{-3}}\ . \tag{40}$$

Recalling the range given by Santra and Lombardo ($0.17 \pm 0.02\, m_{\mathrm{p}}\,\mathrm{fm}^{-3}$) we could conclude that, though our number is easily in the ballpark, the ballpark is so big that the exactitude of our number loses meaning. True as that may be, note that our number also lies between the one given by Bertulani and the one implied by the Fermi-Segre calculation (the latter being the more significant of the two, I suppose). Comparing (40) with (37) yields

$$\frac{\rho_{\mathrm{NSGM}}}{\rho_{\mathrm{NSEGRE}}} = \frac{2.8552 \times 10^{17}\ \mathrm{kg\ m^{-3}}}{2.8259 \times 10^{17}\ \mathrm{kg\ m^{-3}}} = 1.0104\,. \tag{41}$$

9·2. *Pion Compton Wavelength, or Not.* – Let's consider the origin of the 1% discrepancy in (41). It traces back to the mass value of the charged pion, whose Compton wavelength gave us the "equilibrium volume" for two nucleons (36). This distance is $ƛ_{\pi+} = h/2\pi\, c\, m_{\pi+}$ and the pion's mass is $m_{\pi+} = 273.1331\, m_{\mathrm{e}}$. It has sometimes been pointed out that the pion mass to electron mass ratio is nearly twice the inverse fine structure constant, $2/\alpha$. There is no known reason for this. For our purpose, we simply point out that it makes the pion Compton wavelength nearly equal to one half the classical electron radius,

(42) $$ƛ_{\pi+} = h/2\pi\, c\, m_{\pi+} \approx \frac{r_e}{2} = \frac{1}{2}\,\alpha^2\,\mathrm{a}_0\ .$$

Inside the nucleus the pion is supposed to be only a "virtual exchange particle" which "mediates" the strong nuclear attraction. Various other heavier virtual mesons are hypothesized to represent the stronger repulsive force. One of the approaches to finding the correct equation of state for nuclear matter involves adjusting these meson masses, to get just the right attraction-repulsion balance. As alluded to above, this all gets very complicated and goes beyond the present concern. So let's leave aside the exchange particle picture of nuclear interactions and simply acknowledge that empirical measurements and theoretical arguments come very close to a nuclear matter density equal to the one that we got by a very small adjustment to one of our Cosmic Numbers:

(43) $$\rho_{\mathrm{NSGM}} = \frac{2\,m_p}{\frac{4}{3}\,\pi\left[\frac{1}{2}\,\alpha^2\,\mathrm{a}_0\right]^3} = \frac{12\,m_p}{\pi\alpha^6\,\mathrm{a}_0^3} = 2.8552\times10^{17}\ \mathrm{kg\ m^{-3}}\,,$$

where the volume is calculated from the length given by (42). Equation (43) is approximately correct independent of any model. Exactly how close it is to physical reality, of course, needs to be determined by experiment. At the outer range of Santra and Lombardo's error margin, it could be off by 12%. A 1% deviation would put it closer to Bertulani's value or the Fermi-Segre value. Maybe it's a meaningless coincidence; or maybe it's exact, and for a good reason. How close one guesses it to be depends on the reader's assessment of the rest of our scheme, whose validity depends, ultimately, on the results of the interior field experiment. In any case, since α is now part of our expression for the nuclear density (via the volume in the denominator) it becomes, perhaps, an almost trivial task to explore the resulting algebraic relationships arising amongst our other Cosmic Numbers.

10. – Simple, Suggestive Relationships

> *Could the dimensions of Newton's gravitational constant be explained [by] a theory of gravity characterized by a fundamental mass (or length) and a dimensionless strength? Could we then unify* ***all*** *the forces?... Something new is needed.* — I. J. R. Aitchison [45]

As noted in §4, the dimensions of Newton's constant ($\mathrm{L}^3/\mathrm{T}^2\,\mathrm{M}$) suggest the conceptual interpretation: *acceleration of volume per mass*. In physics today nobody has any idea how G connects to the rest of physics. But Aitchison (quoted above) takes a stab at what such a connection might look like. What is potentially the most important consequence of the SGM Cosmic Numbers relationships is the following expression for Newton's constant:

(44) $$G = 8\left[\frac{\rho_\mu}{\rho_{\mathrm{N}}}\cdot\frac{c^2\mathrm{a}_0}{m_e}\right] = 8\left[\frac{\mu}{\rho_{\mathrm{N}}}\cdot\frac{\mathrm{a}_0}{m_e}\right]\,,$$

where we now assume $\rho_{\mathrm{N}} = \rho_{\mathrm{NSGM}}$, μ is the energy density of the CBR and ρ_μ is its mass-equivalent. Acceleration of volume per mass is represented by $c^2\mathrm{a}_0/m_e$—where the fundamental import of each constant is well known. And the dimensionless strength is given by $8(\rho_\mu/\rho_{\rm N})$. We have atomic nuclei, atomic matter and electromagnetism, and the cosmic background energy density. The expression is as all-encompassing as it is simple. Considering the factors in the first bracketed quantity, $c^2 {\rm a}_0/m_{\rm e}$ is a large (Large) Number ($\simeq$ O 10^{36}). But the notorious "smallness" of G comes about because $\rho_\mu/\rho_{\rm N}$ is an even smaller (Small) Number ($\simeq$ O 10^{-48}).

We'll comment further on (44) later. Presently, note that G can also be expressed with the electron mass being replaced by the proton mass:

$$G = 4\left[\frac{\rho_{\rm C}}{\rho_{\rm N}} \cdot \frac{c^2 {\rm a}_0}{m_{\rm p}}\right] = \frac{1}{2}\alpha^3 \left[\frac{c^2}{m_{\rm p}} \cdot \frac{{\rm a}_0^2}{R_{\rm C}}\right] . \tag{45}$$

In (45) both bracketed quantities are model-dependent, as they contain $\rho_{\rm C}$ and $R_{\rm C}$. But their simplicity and suggestiveness perhaps make them worth pondering.

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 cosmic mass, $M_{\rm C} = R_{\rm C}\, c^2/G$. Dividing by the proton mass, $m_{\rm p}$ gives

$$N_{\rm C} = \frac{M_{\rm C}}{m_{\rm p}} = 3.5266 \times 10^{80} . \tag{46}$$

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

$$\alpha = \frac{1}{2}\left[\frac{F_{\rm E}}{F_{\rm G}}\right]^2 \frac{m_{\rm p}}{M_{\rm C}} . \tag{47}$$

The fine structure constant is also given by

$$\alpha^3 = \frac{2\, G\, m_{\rm p}}{c^2} \cdot \frac{R_{\rm C}}{{\rm a}_0^2} = \frac{2\, R_{\rm C}^2}{{\rm a}_0^2} \cdot \frac{m_{\rm p}}{M_{\rm C}} . \tag{48}$$

Before introducing the last major constant to be discussed in this paper, consider the following curious relationship that is at least approximately true independent of any model. The gravitational energy of an electron in a ground state hydrogen atom can be expressed as

$$E_{\rm GH} = \frac{G\, m_{\rm p} m_{\rm e}}{{\rm a}_0} . \tag{49}$$

If we multiply by 2 and divide by the volume within a Bohr radius, we get an energy density that relates to the CBR as

$$\frac{2\, E_{\rm GH}}{V_{\rm H}} = \mu\, \alpha^6 . \tag{50}$$

This is an equality according to the SGM. If the monopole-measured value of μ_{COBE} replaces μ above, (50) is still correct to within 1.8%. If the (1994) dipole-measured value is used, then (50) is correct to within 0.11%. From the standard point of view, this would have to be a mere coincidence.

11. – Vacuum Energy

> *The greatest mystery surrounding the values of the constants of Nature is without doubt the ubiquity of certain huge numbers that seem to appear in a variety of quite unrelated considerations... What are we to make of all these large numbers? Is there something cosmically significant about* 10^{40} *and its squares and cubes?* — J. D. Barrow [46]

11˙1. *Standard Model Enigma.* – We've touched on a few 10^{40} numbers and a 10^{80} number. What about the 10^{120} number that Barrow has alluded to here? He is referring to the notorious "cosmological constant problem." Cosmologists and astronomers claim to have measured a value for this constant, Λ, which represents a distance-proportional repulsive force that appears in Einstein's gravitational field equation. Its magnitude, expressed as a matter density, is supposed to be about the same as that of the average cosmic matter density, $\Omega_\Lambda \approx \Omega_{\text{M}}$; (their sum is supposed to equal unity). The repulsive force that this constant represents is supposed to be utterly independent of matter. So it is often referred to as *vacuum energy*—also known as *dark energy*.

From an entirely different context, the "standard model" of particle physics makes a prediction for the vacuum energy density due to their plethora of quantum fields. The problem is that the value they come up with is infamously 120 orders of magnitude larger than the "measured" (i.e., inferred) value. Commenting on this problem, Frank Wilczek has written, "We do not understand the disparity. In my opinion it is the biggest and worst gap in our current understanding of the physical world." [47]

It must be mentioned that the 10^{120} disparity depends on a key assumption by particle physicists. The vacuum energy density would actually come out *infinite* if they did not cut off their calculations at the "Planck scale." This is the length scale at which a massive body (the Planck mass) would have a Compton wavelength equal to its Schwarzschild radius: $L_{\text{P}} = \sqrt{Gh/2\pi c^3} = 1.6163 \times 10^{-35}\,\text{m}$. This length can be combined with a suitably large *force* to yield an energy density ratio of approximately 10^{120}. We will question the significance of these numbers after deriving the requisite force from our gravity model.

11˙2. *SGM Gravity Digression.* – To assess what a number like 10^{120} may or may not have to do with SGM cosmology, we need to digress briefly to consider a "Planck-like" quantity that the SGM predicts in a purely gravitational context. (For a more detailed treatment, see *Strong Field Gravity in the Space Generation Model*, [48].) We begin by comparing the metric coefficients in the Schwarzschild solution with the corresponding coefficients in the SGM. The magnitude of the curvature of space and time in the Schwarzschild solution are determined by the coefficient, $(1 - 2GM/rc^2)$, and its inverse. Since this quantity can equal zero, horizons and singularities arise.

Since the corresponding coefficient in the SGM cannot equal zero, our model is horizon and singularity-free. This latter coefficient derives from an analogy involving the equation expressing the limiting speed of light due to constant proper acceleration:

$$v = \frac{(at)}{\sqrt{1 + (at)^2/c^2}}\,. \tag{51}$$

This represents linear motion *through* pre-existing space. The SGM gravitational analog represents omnidirectional motion *of* space, so we replace (at) with $\sqrt{2GM/r}$:

$$V_{\rm S} = \frac{\sqrt{\frac{2GM}{r}}}{\sqrt{1 + \frac{2GM}{rc^2}}} = \sqrt{\frac{2GM}{r + \frac{2GM}{c^2}}}\,. \tag{52}$$

A limiting speed relation such as (52) is expected in the SGM because we adopt the reasonable consequence of Special Relativity that matter cannot possibly move as fast as light. $V_{\rm S}$ remains less than c even as $M/r \to \infty$. By squaring both sides and rearranging, we can derive the SGM's curvature coefficient:

$$\left[1 - \frac{2GM}{(r + \frac{2GM}{c^2})c^2}\right] = \left[1 + \frac{2GM}{rc^2}\right]^{-1} \tag{53}$$

and its inverse. Comparing with the GR coefficient, we see that the Schwarzschild r coordinate is thus replaced by $r + 2GM/c^2$, a sum that I call $r_\gamma = r + 2GM/c^2$. This implies that a body of mass, M, has an effective radius greater than the coordinate radius, r. Even as $r \to 0$, the length $2GM/c^2$ remains, so the curvature coefficients cannot equal zero. Just as the inverse square root of r_γ gave us the stationary velocity (52), we expect the inverse square of r_γ to give the stationary acceleration. Thus

$$g_{\rm S} = \frac{GM}{r_\gamma^2} = \frac{GM}{(r + 2GM/c^2)^2} = \frac{GM}{r^2 + \frac{4rGM}{c^2} + \frac{4G^2M^2}{c^4}}\,. \tag{54}$$

In the limit $r \to 0$ this gives a limiting acceleration that is inversely proportional to M:

$$g_{\rm S} = \frac{GM}{(2GM/c^2)^2} = \frac{GM}{4G^2M^2/c^4} = \frac{1}{4}\frac{c^4}{GM}\,. \tag{55}$$

For a cosmic range of different masses, in Figure 5 this acceleration is plotted on a logarithmic scale. The product of any of these masses and the corresponding acceleration is a constant, indicated by the constant slope. Thus we get an unreachable maximum force,

$$F_{\rm MAX} = g_{\rm S} M = \frac{c^4}{4\,G} = 3.0256 \times 10^{43}\ \text{kg m sec}^{-2}\,. \tag{56}$$

Now it so happens that, aside from the factor, 1/4, this is equal to the force gotten by manipulation of Planck units:

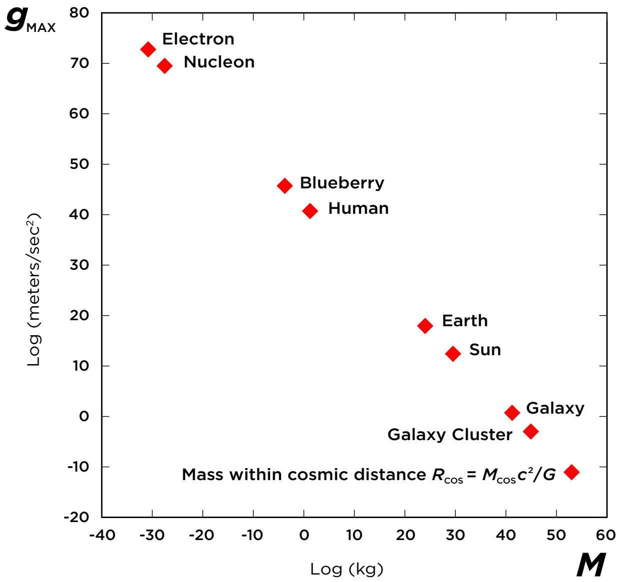

Fig. 5. – Multiplying the maximum acceleration, $c^4/4GM$, by the corresponding mass gives the maximum force, $c^4/4G$.

$$F_P = M_P\left[\frac{L_P}{T_P^2}\right] = \frac{c^4}{G} = 1.2103 \times 10^{44} \text{ kg m sec}^{-2}\,. \tag{57}$$

Since Planck's h drops out, the name "Planck force" is questionable. Be that as it may, putting the fraction $1/4$ back in and dividing this force by the square of the Planck length then gives the huge energy density (or pressure),

$$\frac{F_P}{4L_P^2} = \frac{c^4/4G}{L_P^2} = 1.1583 \times 10^{113} \text{ J m}^{-3}\,. \tag{58}$$

And dividing this by the energy equivalent of the cosmic matter density gives

$$\frac{c^4/4GL_P^2}{\rho_C c^2} = \frac{c^2}{4G\rho_C L_P^2} = 7.6918 \times 10^{122}\,. \tag{59}$$

In (59) I have used the SGM's value for the average matter density. Taking the cube root gives the familiar $\approx 10^{40}$.

On the basis of the SGM we have at least two reasons to doubt the physical significance of this. 1) The Planck mass is about equal to the mass of a grain of sand. Of what fundamental significance is the Compton wavelength of a grain of sand? None, I suppose.

And 2) In the SGM the Schwarzschild radius does not have a deep physical meaning. (This is by contrast with GR, of course, according to which it is hugely meaningful.) In the SGM, $2GM/c^2$ sets the magnitude of the curvature of a massive body, but this curvature does not become singular; nor does it require fancy coordinate transformations to give the appearance of reasonableness. There are no horizons; no stopped clocks and no "light front." To conclude, in both the standard model and the SGM we can find an energy density ratio $\simeq 10^{120}$. In the standard model this is an embarrassing enigma; in the SGM it is inconsequential because there is scarcely any significance to the length L_P.

11·3. *Vacuum Energy Reconsidered.* – So let's return to the vacuum energy predicted by Quantum Theory. Recall that, if we deny the validity of the Planck scale cut-off, as we do, then the predicted energy density is *infinite*. This is *empty space* we're talking about now. Recall that Wilczek declared this to be the biggest puzzle in all of physics. Another renowned field theorist, A. Zee, echoes this sentiment, calling it the "most egregious paradox of present day physics." [49] Much as Wilczek, Zee, and many others have tried for many years, they have still not come to any kind of resolution. Evidently they are not looking at the problem correctly.

Recall then, the essential feature of SGM cosmology: Space and matter are in a state of perpetual exponential expansion. The limits are an infinitesimal past and an infinitely large future, whose overall density and structure, however, never change. Therefore, perhaps it makes sense to *expect* an infinitely energized vacuum. Of course, infinity is a quantity we can never measure. What we observe are *deviations from the uniformity* of the infinitude. Material bodies are as inhomogeneous concentrations and sources of endless (infinite) space and energy. Their cumulative effect is *stationary motion on a cosmic scale.*

This evokes the following suggestion with regard to Einstein's field equation, which may be written as

$$G_{\mu\nu} = T_{\mu\nu}\frac{8\pi G}{c^4} - \Lambda g_{\mu\nu}\,. \tag{60}$$

It is a cliché that Einstein regarded introducing the Λ-term as his biggest blunder. But it has lately been revived as representing the uniform repulsive force ("dark energy") which has everybody scratching their heads. The $T_{\mu\nu}$ term, on the other hand, represents the normal attraction of gravitating matter.

Here's my suggestion. Instead of representing a uniform effect that is utterly independent of matter and varies linearly with distance, suppose the Λ-term, with its space-creating "repulsion" is re-cast as a *non-uniform* effect. Suppose it is modified to represent creation of space according to an inverse square law, with sources corresponding to material bodies. This would necessitate another space dimension to maintain coherence; it would require four space dimensions whose local curvature is produced by their perpetual inhomogeneous outwardness. By thus *modulating* the vacuum energy—by making it non-uniform in proportion to matter and the outpouring of space therefrom—we would have no need for any troublesome gravitational attraction. Perhaps thinking of gravity as an attraction and insisting on the validity of the energy conservation law were Einstein's biggest blunders.

12. – Conclusion

Imagine being assigned the task of mimicking the effects of gravity all over the Universe—without being allowed to use gravity itself. You would need infinite energy. The task of maintaining the positive accelerometer readings on Earth alone would require a fraction of that infinite energy—which fraction would also have to be infinite in order to maintain the readings forever. But it's an impossible task because (among other things) any attempt to keep the accelerometers accelerating would also cause them to fly away from one another—because without a way to keep the motion *stationary*, i.e., without *real gravity*, the result would be only motion *through* pre-existing space. Coherence of material bodies could only be maintained, according to this scheme, if gravitational motion can be identified as a process of the extension of seemingly three-dimensional space into (or outfrom) a higher, fourth dimension of space.

If gravity is the outward motion of four-dimensional space, generated by four-dimensional matter, then we can justifiably believe our accelerometers. If we should get the idea that accelerometers are indeed to be believed, and we have managed to suspend our conservative preconceptions about space, time and matter, then we will be led to a conception of gravity (and space, time and matter) similar to that described above. As scientists, we would be eager to test the idea by conducting the interior field experiment. And we would naturally pursue the cosmological implications. Piecing the puzzle together, another emerging idea would be that space is neither a pre-existing background arena nor a passive container whose size can be disproportionately changed by a big bang, "dark energy" or a mysterious force of attraction.

These latter conceptions reflect the persistent mental dichotomy between matter and space. They reinforce the illusion of discontinuity, according to which space can expand or contract independent of matter. Quantum Theory is as full of implications that matter and space are a continuum as it is full of implications that it makes no sense at all to think of matter or space as static things. As long as physicists accept the representation of gravitational fields as static things (e.g., the Schwarzschild solution) there can be no harmony with Quantum Theory and the Universe.

The continuousness of matter and space and their coordinated, vigorous and perpetual movement suggests that their overall ratio, i.e., density, should be constant. By assuming this to be true, we are led to assume further, that this matter density should be simply and constantly related to the background energy density, i.e., the Cosmic Background Radiation. We are fortunate in having a fairly accurate measurement of the temperature of this background radiation, T_{COBE}, which then allows fixing absolute values for other constants—under the assumption that they are in fact absolutely related to one another.

One more foundational assumption is that the scale of the system is fixed by the relation

$$\frac{G\,M_{\mathrm{C}}}{R_{\mathrm{C}}\,c^2} = 1\,, \tag{61}$$

a signpost that has repeatedly appeared in the cosmology literature over the years, but is presently ignored. With our new territory thus marked out, it becomes a fairly simple matter to find that when the matter and radiation densities are assumed to be related to each other as

$$\frac{\rho_\mu}{\rho_{\mathrm{C}}} = \frac{1}{2}\frac{m_{\mathrm{e}}}{m_{\mathrm{p}}}\,, \tag{62}$$

then not only this assumption, but various other cosmological numbers fall right in line with observations. The matter density in terms of the "critical" density, $\Omega_{\rm M} = 2/9$ and the Hubble parameter $h = 0.63$ are the first step.

Compared to the background temperature, there is more uncertainty in measurements of the nuclear saturation density, $\rho_{\rm N}$. But a reasonable theoretical prediction of this number is either within 1% of our adopted value or is exact—depending on whether the pertinent volume is calculated by the Compton wavelength of the charged pion or by one half the classical electron radius.

The collection of ratios and constants tied together in this scheme includes:

$$\frac{F_{\rm E}}{F_{\rm G}}\,,\ \ \frac{m_{\rm p}}{m_{\rm e}}\,,\ \ \frac{M_{\rm C}}{m_{\rm p}}\,,\ \ \frac{R_{\rm C}}{{\rm a}_0}\,,\ \ G\,,\ \ \alpha\,,\ \ \Omega_{\rm M}\,,\ \ H_0\,,\ \ \rho_{\rm N}\,,\ \ \text{and}\ \ T_{\rm CBR}\,. \tag{63}$$

Absolute values are predicted for the average matter density, $\rho_{\rm C}$, the cosmic radius, $R_{\rm C}$, and mass within that distance, $M_{\rm C}$.

In standard cosmology $T_{\rm CBR}$, H_0, $\Omega_{\rm M}$, $R_{\rm C}$, and $\rho_{\rm C}$ are only a few of the many parameters which, though sometimes related to one another, are not constant. The persistent conundrums involving dark matter and dark energy are but the latest bugaboos in the big bang model, whose growing flexibility reflects its growing implausibility.

By contrast, as one should expect from any model whose properties remain fixed for all time, in the SGM all these numbers are interrelated. This raises a key point as to the comparative plausibility of the scheme. Though no direct empirical evidence is in hand, the close alignment of these numbers clearly suggests that something more than random chance is involved. The breadth of physical domains and the extremes in magnitude are so vast that one would be hard-pressed to artificially arrange a simpler, more natural order.

That these interrelationships amongst the constants are physically meaningful is further suggested by the following. A truism of physics is that Planck's constant, h, is the key to the world of the atom. 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):

$$\alpha = \frac{e^2}{4\pi\epsilon_0\hbar c} = \frac{h}{2\pi m_e c{\rm a}_0}\,. \tag{64}$$

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! I'd guess that the standard practioners' preoccupation with the Planck scale is why they are getting nowhere. It remains to show that any of the Planck numbers are at all relevant for understanding physical reality. 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.

Before closing, let's thus consider once more what is perhaps the most transparently encompassing of the above expressions:

$$G = 8\left[\frac{\rho_\mu}{\rho_{\mathrm{N}}} \cdot \frac{c^2 \mathrm{a}_0}{m_\mathrm{e}}\right] . \tag{65}$$

This reflects the idea that the unalterable fullness, the "saturation" of the Universe comes about because of the vigorous activity within atomic nuclei, then on to atoms, and the ground state cosmic background radiation. Due to the timelessness of light and the temporality of matter, we have an incessant, ever increasing, yet constantly proportional acceleration of volume per mass.

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.

REFERENCES

[1] Benish R., Space Generation Model and the Large Numbers Coincidences. *Apeiron*, **15** (January 2008) 25–48.

[2] Einstein A., *Relativity, the Special and General Theory* (Crown, New York) 1961, pp. 79-82.

[3] Stachel J., *The Rigidly Rotating Disk as the 'Missing Link' in the History of General Relativity*, in *Einstein and the History of General Relativity*, edited by Howard D. and Stachel J. (Birkhäuser, Boston) 1989, pp. 48–62.

[4] Möller C., *Theory of Relativity* (Clarendon Press, Oxford) 1972, p. 284.

[5] Rindler W., *Essential Relativity* (Van Nostrand Reinhold, New York) 1969, p. 152.

[6] Landau L. D. and Lifshitz E. M., *Classical Theory of Fields* (Addison-Wesley, Reading, Massachusetts) 1971, p. 247.

[7] Einstein A., quoted by Norton J., from a letter to a correspondent in, *What was Einstein's Principle of Equivalence?* in *Einstein and the History of General Relativity*, edited by Howard D. and Stachel J. (Birkhäuser, Boston) 1989, pp. 5–47.

[8] Rindler W., op. cit., p. 182.

[9] Möller C., op. cit., pp. 279, 374.

[10] Newton I., *Sir Isaac Newton's Mathematical Principles of Natural Philosophy and His System of the World II* Motte's translation revised by Cajori F. (University of California Press, Berkeley) 1962, p. 398.

[11] Benish R., Laboratory Test of a Class of Gravity Models. *Apeiron*, **14** (October 2007) 362–378.

[12] Benish R., Light and Clock Behavior in the Space Generation Model of Gravitation, *Apeiron*, **15** (July 2008) 222–234.

[13] Dicke R., *The Many Faces of Mach*, in *Gravitation and Relativity*, edited by Chiu H.-Y. and Hoffman W. F. (W. A. Benjamin, New York) 1994, pp. 121–141.

[14] Sciama D., On the Origin of Inertia, *Monthly Notices of the Royal Astronomical Society*, **113** (1953) 34-42.

[15] Bondi H., *Reflections on Mach's Principle*, in *Mach's Principle, from Newton's Bucket to Quantum Gravity*, edited by Barbour J. and Pfister H. (Birkhäuser, Boston) 1995, pp. 474–476.

[16] Bondi H., *Cosmology* (Cambridge, Cambridge) 1952, Chapter XII.

[17] Vishwakarma R. G. and Narlikar J. V., QSSC Re-examined for the Newly Discovered SNe Ia, < arXiv:astro-ph0412048 >.

[18] North J. D., *Measure of the Universe* (Clarendon Press, Oxford) 1965, p. 92.

[19] Bahcall N. A., et al, Where is the Dark Matter?, <astro-ph/9506041> Matter density parameter given as $0.15 < \Omega_{\rm M} < 0.20$ or $0.20 < \Omega_{\rm M} < 0.30$, the latter value depending on "bias."

[20] Peebles P. J. E., Probing General Relativity on the Scales of Cosmology, < arXiv: astro-ph/0410284 > Matter density parameter given as $0.15 < \Omega_{\rm M} < 0.30$.

[21] Carlberg R. G., et al, $\Omega_{\rm M}$ and the CNOC Surveys, < astro-ph/9711272 >. Matter density parameter given as $\Omega_{\rm M} = 0.19 \pm 0.06$.

[22] Hale-Sutton D., Fong R., Metcalfe N. and Shanks T., An extended galaxy redshift survey – II. Virial constrains on $\Omega_{\rm M}$. *Monthly Notices of the Royal Astronomical Society*, **237** (1989) 569–587. Matter density parameter given as $0.09 < \Omega_{\rm M} < 0.27$.

[23] Scarmella R., Vettolani G. and Zamorani G., The distribution of clusters of galaxies within 300 Mpc h^{-1} and the crossover to an isotropic and homogeneous universe. *Astrophysical Journal*, **376** (20 July 1991) L1-L4. Matter density parameter given as $0.2 < \Omega_{\rm M} < 0.4$.

[24] Turner M. S., *Dark Matter Candidates*, in *Astronomy, Cosmology and Fundamental Physics*, edited by Caffo M., Fanti R., Giacomelli G. and Renzini A. (Kluwer, Dordrecht) 1989, pp. 279–286. In this brief review paper, matter density parameter given as inference from many measurements: $0.1 < \Omega_{\rm M} < 0.3$.

[25] Mather J. C., et al, Calibrator Design for the COBE Far Infrared Absolute Spectrophotometer (FIRAS). *Astrophysical Journal*, **512** (20 February 1999) 511–520.

[26] Mather J. C., et al, A Preliminary Measurement of the Cosmic Microwave Background Spectrum by the Cosmic Background Explorer (COBE) Satellite, *Astrophysical Journal*, **354** (10 May 1990) L37–L40.

[27] Mather J. C., et al, Measurement of the Cosmic Microwave Background Spectrum by the COBE FIRAS Instrument, *Astrophysical Journal*, **420** (10 January 1994) 439–444.

[28] Fixsen D. J., et al, Cosmic Microwave Background Dipole Spectrum Measured by the COBE FIRAS Instrument. *Astrophysical Journal*, **420** (10 January 1994) 445–449.

[29] Fixsen D. J., et al, The Cosmic Microwave Background Spectrum from the Full COBE FIRAS Data Set. *Astrophysical Journal*, **473** (20 December 1996) 576–587.

[30] Fixsen D. J. and Mather J. C., The Spectral Results of the Far-Infrared Absolute Spectrophotometer Instrument on COBE. *Astrophysical Journal*, **581** (20 December 2002) 817–822.

[31] Kolb E. W. and Turner M. S., *The Early Universe.* (Addison-Wesley, Reading, Massachusetts) 1990, p. xxi.

[32] Robitaille P. M., On the Origins of the CMB: Insight from the COBE, WMAP and Relikt-1 Satellites. *Progress in Physics*, **1** (January 2007) 19–23.

[33] Bondi H., *Cosmology* (Cambridge, Cambridge) 1952, 61–62.

[34] Vuissoz C., et al COSMOGRAIL: the COSmological MOnitoring of GRAvItational Lenses, V. The time delay in SDSS J1650+4251. <arXiv:astro-ph/0606317>.

[35] Tammann G. A., *The Ups and Downs of the Hubble Constant*, in *Reviews in Modern Astronomy 19: the Many Facets of the Universe—Revelations by New Instruments*, edited by Roeser S. (Wiley-VCH Verlag, Wenheim, Germany) 2006, pp. 1–29.

[36] Tammann G. A., Sandage A. and Reindl B., The expansion field: The value of H_0. *Astronomy and Astrophysics Review*, **15** (2008) 289–331.

[37] Lahav O., Cosmology: Climbing up the cosmic ladder. *Nature*, **459** (4 June 2009) 650–651.

[38] Huchra J., The Extragalactic Distance Scale and the Hubble Constant. < http://www.cfa.harvard.edu/ huchra/ > Though he is part of the team endorsing the higher value of H_0, Huchra points out "the very recent convergence to values near $65 + / - 10$ km/sec/Mpc."

[39] Bitter F. and Medicus H. A., *Fields and Particles* (American Elsevier, New York) 1973, p. 474. Curiously, on widely separated pages, the authors actually give two different values for the average separation between nuclei. Besides the quoted value of 1.8 fm, on p. 475, they also give, on p. 674, 2.4 fm, which would result in a much smaller density. If they would have given a reference as to where these numbers came from, one could perhaps find the source of the discrepancy. But they didn't. So I quoted the value that turned out to be closer to values that are common in more recent literature.

[40] Leung G. Y. C., *Dense Matter Physics*, in *Encyclopedia of Modern Physics*, edited by Meyers R. A. (Academic Press, New York) 1990, pp. 115–148.

[41] Martin B. R., *Nuclear and Particle Physics* (John Wiley & Sons Ltd., Chichester, England) 2006, p. 43.

[42] Santra A. B. and Lombardo U., Nuclear Matter equation of State and σ-Meson Parameters. *Pramana Journal of Physics*, **64** (January 2005) 31–37.

[43] Bertulani C. A., *Nuclear Physics in a Nutshell* (Princeton University Press, Princeton, New Jersey) 2007, p. 126.

[44] Segre E., *Nuclei and Particles, Second Edition* (W. A. Benjamin, Reading, Massachusetts) 1977, p. 895.

[45] Aitcheson I. J. R., *The Vacuum and Unification*, in *The Philosophy of Vacuum*, edited by Saunders S. and Brown H. R. (Clarendon Press, Oxford) 1991, pp. 185-186.

[46] Barrow J. D., *The Constants of Nature* (Pantheon, New York) 2002, pp. 97, 99.

[47] Wilczek F., *Future Summary.* Closing talk delivered at the LEPfest, CERN, October 11, 2000 < arXiv:hep-ph/0101187v1 >.

[48] Benish R., Strong Field Gravity in the Space Generation Model. < http://www.gravitationlab.com/Grav%20Lab%20Links/Strong%20Field%20Gravity%208-9-09.pdf >.

[49] Zee A., *Quantum Field Theory in a Nutshell* (Princeton University Press, Princeton, New Jersey) 2003, p. 434.