Cosmological Coincidences

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Since the measurement of the Hubble constant made it possible to calculate the age or diameter of the observable universe, theorists have noticed that when the fundamental constants of physics are combined so that their units cancel, the dimensionless numbers created cluster around two values, 10^{40} and 137. Some of these numbers predicted relationships that were later verified but still have no explanation within standard theories. Recently, a simple relationship between 137 and 10^{40} has been found. Another coincidence has been found involving the magnetism of rotating bodies. Furthermore, a new coincidence has been found to occur between a dimensionless constant that is used to describe the redshift quantization of astronomical bodies and the fractal dimension of the universe.
The older coincidences are reviewed and the new ones are surveyed. The author draws no conclusions, he merely presents the puzzle.

Introduction

When physicists describe the natural world they must do so in terms of arbitrary systems of units. When physical laws are written in terms of these units, constants must be inserted to make the quantities come out correctly. These constants are dependent upon the system of units employed. In an effort to free their thinking from these systems of units, scientists in various fields rewrite their equations so that they are independent of the system of units. This is done by combining the constants in such a way that their units cancel out, producing a pure number. When this was done in fundamental physics and cosmology, several coincidences appeared.

Originally there were several numbers that were close to 10^{40} or its cube root, 10^{13}, or its square, 10^{80}. These involved the ratios of the electromagnetic, weak and gravitational forces; the age of the universe; and the number of particles in the universe. While many researchers were stimulated by these phenomena, the scientific establishment quickly dismissed them as mere coincidences.

In the seventies and eighties, two additional numbers were calculated to be very close to the fine structure constant ($\frac{1}{137}$), a nondimensional number from microphysics. These new numbers contained constants from relationships which heretofore were not known to exist. One is that an isolated gravitational body will possess an angular momentum which is proportional to its mass squared. The other is gyromagnetism, the concept that a magnetic field such as the earth's is generated simply by the earth's rotation and nothing more. Also noticed is that the ratio of the earth's magnetic strength to its gravitational attraction is equivalent to the ratio of magnetic strength to coulomb attraction for a charged body with the same rotation rate.

More recently it has been suggested that quantization of quasar and galaxy redshifts could be the result of the electron or proton mass possessing certain discrete values. If this is the case, then the allowable values would be related by a simple ratio. This ratio is identical to the fractal dimension of the universe.

It has also been shown that the fine structure constant and the large numbers can be related by a simple expression.

The Large Number Hypotheses

There are several versions of the Large Number Hypothesis, LNH, depending on how the Hubble law is interpreted. If an expanding universe is assumed, Hubble's constant determines the age of the universe and its radius. If a static universe is assumed, then the constant still sets a limit to the radius of observability. To liberate the coincidences from the models that are used to interpret them, we will use the Hubble constant to determine a distance of about 15 billion light years and not concern ourselves with what is beyond that. If this distance and other fundamental constants are combined to yield dimensionless numbers (see Table 3) several coincidences ensue.

Table 1: Relative Strengths of Fundamental Forces

Name of force	Strength
Strong nuclear force	1
Electromagnetic force	$\frac{1}{137}$
Weak nuclear force	10^{-13}
Gravity	10^{-39}

Immediately obvious is that the dimensionless numbers are not random. Both the ratio of the electromagnetic force to gravity and the radius of the observable universe to the radius of a subatomic particle are approximately 10^{39}. The number of nucleons in the known universe, assuming a uniform distribution, is roughly 10^{78} which is 10^{39} squared. (For a rigorous treatment of dimensionless numbers and the large number hypothesis see Roxbough (1978) or Wesson (1978).)

P.A.M. Dirac (1937, 1938) reasoned that the random chance of such large numbers being so similar was insignificant; therefore, the ratios must be equalities. (Because everyone at least agrees that 10^{39} is a large number, it is called the Large Number Hypothesis, LNH.) If they are equalities and we assume a finite expanding universe, this poses another problem. One of the ratios is not a constant because the universe is expanding. This means that at least one of the constants that make up the other ratios must be a variable. The constant most often chosen to vary is G, the gravitational constant. (For a good summary of attempts to calculate these constants, see Barut 1988.)

Another common version of the LNH is to interpret the recessional velocity of astronomical bodies as an illusion, caused by the increasing masses of fundamental particles. When we look into the distance we are also looking back in time. The lighter particle masses would produce a redshifted spectrum.

The Houtermans-Jordan Hypothesis

The ratio of the strong force to the weak force in the nucleus is approximately 10^{12} or approximately the cube root of 10^{39}. Houtermans and Jordan (1945,1946) theorized that if 10^{39} was proportional to the age of the universe, then the weak force must be decreasing with the cube root of time.

The Fine Structure Constant

The fine structure constant, $e^2/c = \frac{1}{137}$ is a combination of Plank's constant, (which is a quantum of angular momentum); the charge of an electron or proton, e; and the speed of light, c. This nondimensional number occurs repeatedly in quantum mechanics. One example that is easy to visualize is that in the ground state of the Bohr hydrogen atom, the electron is moving with a velocity that is $\frac{1}{137}$ times the speed of light.

Angular Momentum and Mass

Paul Wesson (1979 and 1980) of Berkeley has proposed that a new constant equating angular momentum and mass must exist on purely theoretical grounds. An investigation by Peter Brosche (1980) at the Observatorium Hohner List, Germany has verified its existence.

Wesson postulated the new constant on the following grounds. If the most significant constants in particle physics, , e and c (see Table 2) can be combined into a dimensionless number, e^2/c, the fine structure constant; why could not the gravitational constants be combined to form a gravitational fine structure constant? They cannot because there are only two constants in gravitation, the gravitational constant, G, and the speed of light, c. If the needed third constant existed it would need to have the dimensions of angular momentum divided by mass squared. In other words, the angular momentum of a body would be proportional to its mass squared.

If this relationship exists at all, it should be apparent in large systems where gravity is the only force involved. An analysis of these variables for all bodies ranging from asteroids to galaxy clusters shows a good fit for the entire range. When the new constant is combined with G and c it produces a number which is close to the fine structure constant.

Gyromagnetism

The earth's magnetic field has been the subject of wonder since its discovery. Even today, there is no universally accepted theory of earth magnetism. One theory that keeps reappearing is that a rotating mass, in and of itself, will produce a magnetic field. Of course there is nothing in the traditional laws of physics that could account for this; but there is a great deal of empirical evidence that would support it. The hypothesis was quite popular until the 1950's when a few experiments refuted several versions of it. After a period of disrepute, the theory has been resurrected by a series of observations of celestial bodies ranging from the moon to pulsars (Ahluwalia and Wu 1978 and Sirag 1979). The new data, with the exception of Mars, obeys a linear relationship between angular momentum and the magnetic moment. When the constant of proportionality (see Table 2) is combined with the speed of light and the gravitational constant, we produce a nondimensional number very close to the fine structure constant (See Table 3).

An interesting new interpretation of this phenomena has been given by Barut (1982 and 1985). He points out that if gravitational bodies possessed an electrical charge sufficient to produce a force equal to their gravitational force, then rotating them at their present speeds would produce the measured magnetic field.

Table 2: Fundamental Constants (CGS units)

Constants	Significance
$c = 3 \times 10^{10}$ cm s^{-1}	speed of light.
$= 1.5 \times 10^{-27}$ erg s	Plank's constant, angular momentum exists only in integral multiples of .
$e = 4.8 \times 10^{-10}$ erg$^{1/2}$ cm$^{1/2}$	electric charge on one electron or proton.
$m_p = 1.6 \times 10^{-24}$ g	proton mass.
$m_e = 9.1 \times 10^{-28}$ g	electron mass.
$G = 6.7 \times 10^{-8}$ erg cm g^{-2}	universal gravitational constant.
$T_S \approx 10^{-9}$ s	a typical half-life of an excited state of a hadron.
$T_W \approx 10^{3}$ s	a typical half-life associated with beta decay.
$H = 1.6 \times 10^{-18}$ s^{-1}	Hubble constant.
$\rho_o = 4 \times 10^{-31}$ g cm^{-3}	average density of the universe.
New Constants	
$p = 8 \times 10^{-16}$ g^{-1} s^{-1}	defined by $J = pM^2$ where M is the mass of a body or system of bodies where gravity is the only force acting between them and J is the rotational angular momentum of the system.
$q = 1.3 \times 10^{-15}$ g$^{1/2}$ cm$^{-1/2}$	defined by $S = qU$, where S is the intrinsic angular momentum and U is the strength of the magnetic dipole of a rotating body. This effect has only been observed for bodies of planetary size.

The Fractal Dimension of the Universe

The concept of fractal dimension in regards to distributions of matter is rather simple. If we look at two rods of equal density and equal diameter and compare their respective masses, M_1 and M_2, and their respective lengths, R_1 and R_2, we find that $M_2/M_1 = (R_2/R_1)^1$ or $\ln(M_2/M_1)/\ln(R_2/R_1) = 1$. Therefore, we can say that the dimension of a rod is one.

If we look at two plates of equal density and thickness, we find $\ln(M_2/M_1)/\ln(R_2/R_1) = 2$. Therefore the dimension of a plate is two. For spheres, we have $\ln(M_2/M_1)/\ln(R_2/R_1) = 3$; and the dimension of a sphere is three.

One type of fractal is a distribution of matter that falls between the integer dimensions. If we can assume that the universe consists of a self-similar hierarchy of structure, where clusters of stars form larger clusters which form galaxies which form clusters of galaxies and so on, we can then treat the universe as a fractal. Let M_1 and R_1 be the mass and radius of a smaller structure in the hierarchy (galaxies for example) and let M_2 and R_2 be the mass and radius of the next larger structure (galaxy clusters). Defining the dimension of the fractal in the same way as we did for the simpler structures described above, we have $\ln(M_2/M_1)/\ln(R_2/R_1) = 1.23 \pm 0.04$ (Mandelbrot 1983 and Peebles 1980), where 1.23 is the fractal dimension of the universe. This relationship holds to about 30 million light years (Peebles 1993) and was tested with two dimensional correlation techniques which did not require any assumption about the redshift-distance relationship.

Quasar Redshifts and the Electron Mass

Arp (1987) and Arp et al. (1990) have made a very strong case for quasar redshift to be caused by something other that recessional velocity and for the redshifts to be quantized. They maintain that the quasar redshifts tend to cluster around $z = 0.30$, 0.60, 0.96, 1.41 and 1.96, where z is the change in wavelength per wavelength. ($z = [(c+v)/(c-v)]^{1/2} - 1$, where c is the speed of light and v is the apparent velocity. If the velocity is small we can approximate this formula with $z = v/c$. For small velocities, redshift is quite often expressed in units of velocity.)

One possibility is that the electron mass may vary and it could only exist at certain discrete masses. Kokus and Barut (1993) have shown that if this is the case, then the electron masses would obey a very simple formula. If m_1 is one of the allowable electron masses and m_2 is the next heavier allowable mass, then $m_2/m_1 = 1.23$. Kokus (1994) has derived this formula from the fractal dimension of the universe, the mass angular momentum relationship, and the magnetic dipole-angular momentum relationship.

Galaxy Redshifts and the Proton Mass

Arp (1987) and Tifft (1988) have made the suggestion that differences in galaxy redshifts come in multiples of 72 km s^{-1}. In what is the most comprehensive study of galaxy redshifts, Guthrie and Napier (1991) have calculated that the most common difference between galaxy redshifts is 37.4 km s^{-1}, or roughly half of 72 km s^{-1}.

Kokus and Barut (1993) have suggested that this small quantization could be the result of the hydrogen atom's nucleus, a proton, being lighter. If it were lighter, then the center of mass of the atom would be closer to the electron and the electron would behave as if it were slightly lighter. For it to appear as if it had a redshift of 37.4/72 km s^{-1} the ratio of the heavier proton to the lighter proton would have to be 1.23.

The relationship between the quasar redshifts and galaxy redshifts can be expressed in a slightly different but equivalent way. The ratio of the fundamental quantum of quasar redshift, 0.23, to the quantum of galaxy redshift, 0.000125 (37.5 km s^{-1} divided by the speed of light), is about 1840, which is very close to 1836, the ratio of proton mass to electron mass.

Link between the Large and Small Numbers

Sternglass (1984) has suggested that the relationship between the large numbers and the fine structure constant is simply: $2^{137} = 10^{41}$. A model that would help visualize this is to have a particle that divides into two, and then for each of the new particles to divide into two, and so on. If the division process occurs 274 (2×137) times, then there will be 10^{82} particles; which is a very good approximation for the number of particles in the known universe. In the Sternglass cosmology (which is a revision of the LeMaitre cosmology), we start with a very dense particle which keeps dividing into smaller and smaller particles until we have the present universe.

Landau (1955) suggested a similar relationship for completely different reasons. If gravitation provides the cutoff needed to give finite results in quantum electrodynamics, then the fine structure constant would be proportional to $\ln G$. This is equivalent to the Sternglass expression with an arbitrary multiplicative constant.

Kokus (1994) also notes that $1.23^{137} = 10^{12}$. This equation relates the fine structure constant, the ratio of the strong force to the weak force, and a number used to describe the large scale structure of the universe and fundamental particle masses.

Mass Quantization Directly from the LNH

Markhov (1967) suggested that the masses of elementary particles were equal to the product of a fundamental mass, $M = (c/G)^{1/2}$, and $(10^{-40})^{1/2}$. If the ratio of the electrostatic force to the gravitational force in a hydrogen atom is divided by the fine structure constant, the electrostatic terms cancel and we have,

$$\frac{c}{Gm^2} = \frac{M^2}{m^2} = 137 \cdot 10^{40} = 137 \cdot 2^{137}$$

where m is the electron mass. Rearranging,

$$m = M \cdot (137 \cdot 2^{137})^{-1/2} = M \cdot \left(\frac{1}{1.41^{274}} \right)^{1/2}.$$

If 274 is an integer that denotes epochs, then the ratio of masses between epochs would be

$$\frac{m_2}{m_1} = \left(\frac{1.41^{274}}{1.41^{273}} \right)^{1/2} = 1.19$$

which is within 3% of the semi-empirical ratios given above.

Mass Quantization, Structure of the Universe and Stability of the Cosmos

In the above mentioned studies of the fractal dimension of the universe, the unit of study was the galaxy, with some effort by Mandelbrot to extend the relationship down to the scale of stars. The assumption was made that there was no systematic variation in the mass of the galaxies. But if the mass decreased with distance and did so with the quantization described above, then the fractal dimension with respect to mass would be approximately one (Kokus 1994). This is precisely the mass distribution calculated for many of the steady state models (Hoyle 1953, Mandelbrot 1973). The mass enclosed by a sphere would be proportional to the sphere's radius and the gravitational potential would be inversely proportional to the radius, so the potential would be constant with no net force.

One apparent contradiction in the original formulation of the LNH is that while a uniform density is assumed for the universe in calculating the number of particles, 10^{78}, most of the models

Table 3: Fundamental Dimensionless Numbers

Expression	Significance
$\frac{e^2}{Gm_e m_e} = 4.2 \times 10^{42}$	ratio of electrical to gravitational force between two electrons.
$\frac{e^2}{Gm_p m_e} = 2.3 \times 10^{39}$	ratio of electrical to gravitational force in a hydrogen atom.
$\frac{m_e c^3}{e^2 H} = 10.6 \times 10^{39}$	the radius of the observable universe divided by the radius of a fundamental particle.
$\frac{\rho_o c^3}{m_p H^3} = 1.2 \times 10^{78} = (10^{39})^2$	number of protons and neutrons in the observable universe.
$\frac{T_W}{T_S} \approx 10^{12} \approx (10^{39})^{1/3}$	comparison of weak force to strong force.
$\frac{1}{137} = \alpha = \frac{e^2}{c}$	fine structure constant.
$\frac{1}{360} = \beta = \frac{G}{pc}$	gravitational fine structure constant.
$\frac{1}{130} = \gamma = \frac{c^2}{q^2 G}$	gyro-magnetic fine structure constant.
$2^{137} = 1.7 \times 10^{41}$	this formula equates the above numbers with the large numbers.
$1.23 = \frac{\ln(M_2/M_1)}{\ln(R_2/R_1)}$	the fractal dimension of the universe (Mandelbrot 1983) where the subscripts 1 and 2 refer to the level of the structure in a self-similar hierarchy of structures with 2 pertaining to the larger structure that contains several smaller structures denoted by 1. The M's refer to the masses of these structures and the R's refer to the radii. An alternative way of writing this is $M = R^{1.23}$, where M is the mass enclosed in a sphere of radius R (Peebles 1980).
$1.23 = \frac{e_2}{e_1}$	the ratio of electron masses required to explain quasar redshift quantization in terms of discrete, variable electron masses (Kokus and Barut 1993)
$1.23 = \frac{p_2}{p_1}$	the ratio of proton masses required to explain galaxy redshift quantization in terms of discrete, variable proton masses (Kokus and Barut 1993).
$1.19 = \frac{m_2}{m_1}$	ratio of particle masses from adjacent epochs from Markhov hypothesis.
$1.23^{137} = 2 \times 10^{12}$	equates the above constants, the fine structure constant, and the weak coupling constant.
$1836 = \frac{m_p}{m_e}$	the ratio of the proton mass to the electron mass.
$1840 \approx \frac{0.23}{0.000125}$	the ratio of quasar redshift quantization, 0.23, to galaxy redshift quantization, 0.000125.

formulated from the LNH would produce a hierarchical or fractal distribution of matter which is generally not uniform. If, instead, we assume a fractal dimension, D, which is constant from particle to cosmological scales, then the number of particles would be $(10^{39})^D$.

Perhaps a better way to phrase the coincidence originally implied by Dirac is to say that the local density of the universe (on a scale less than galactic clusters) is approximately one particle per a volume equivalent to 10^{39} hadron volumes.

Summary

The above relationships hint at physical connections between electromagnetism and gravity; between mass and angular momentum; between magnetism, mechanics and gravity; between the large numbers and the small numbers; and between the structure of the universe and particle physics that are not contained within the present laws of physics. They also beg the question: If the fundamental constants are related so simply, why are the attempts at unification so complicated?

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