The Mathematical Universe

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Abstract: We Humans, a curious beings developed from the Darwin's principle of natural selection, are accustomed into an inquisition. The question is not 'do we know everything from the triumph of the Higgs boson to the underlying discomfort of ultimate question of life, the universe, and everything?' or it is 'do we know enough?' But how the creative principle resides in mathematics? There's something very mathematical about our gigantic Cosmos, and that the more carefully we look, the more equations are built into nature: our universe isn't just described by math, but that universe is a "grand book" written in the language of mathematics. We find it very appropriate that mathematics has played a striking role in our growing understanding of the events around us, and of our own existence.

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"But the creative principle resides in mathematics. In a certain sense, therefore, I hold it true that pure thought can grasp reality, as the ancients dreamed." -- Albert Einstein

Before the Beginning of the World there was nothing but an gigantic homogeneous isotropic universe which obeyed the first law of thermodynamics: $0 = dQ = dU + PdV$ (where: Q denoted the total heat which was assumed to be constant, U was the internal energy of the matter and radiation in the universe, P was the pressure and V the volume) and whose space was simply the lowest energy state of the universe. It was neither empty nor uninteresting, and its energy was not necessarily zero [Energy of the empty space was > ($E_{Matter} + E_{Photons}$)]. A specific solution of the field equations that described that Universe was the metric tensor called the Friedmann–Lemaître–Robertson–Walker metric: $ds^2 = -c^2dt^2 + R(t)^2 (\{dr^2 / [1- kr^2]\} + r^2\theta^2 + r^2 \sin^2\theta\, d\phi^2$, where ($r$, θ, φ) corresponded to a spherical coordinate system and curvature index k described the geometry of the universe. The cosmological principle implied that the metric of the universe took the form: $ds^2 = a(t)^2 ds_3^{\ 2} - c^2dt^2$, where: s_3 denoted the three-dimensional metric, t the time and a the scale factor of the universe. Because $E = mc^2$ (the equation that represented the correlation of energy to matter: essentially, energy and matter were but two different forms of the same thing) and due to the fuzziness of quantum theory (that implied: photon {whose volume was proportional to λ^3, where: λ denoted the photon wavelength -- whose density was proportional to λ^{-4}} carried mass proportional to its frequency i.e., $h\upsilon = mc^2$), some of the most incredible mysteries of the quantum realm (a jitter in the amorphous haze of the subatomic world) got far less attention than Schrödinger's famous cat. Virtual particle-antiparticle pairs of mass ($\Delta m = h\Delta\upsilon/c^2$) were continually created out of energy ΔE of the empty space consistent with the Heisenberg's uncertainty principle of quantum mechanics (which implied:

$\Delta mc^2 \times h\Delta\upsilon \times \Delta t_{life}^{\ 2} = \hbar^2$

where: Δt_{life} stood for time during which virtual particle-antiparticle pairs of energy ($\Delta mc^2 = h\Delta\upsilon$) appeared together, moved apart, then came together and annihilated each other giving energy back to the space without violating the law of energy conservation (which stated that energy can neither be created nor destroyed; rather, it can only be transformed from one form to another).

$\Delta t_{life} = c^{3/2} (\mu\Delta\omega)^{-1/2}$

where: Δω stood for angular wave frequency of virtual particle-antiparticle pairs, c denoted the speed of light in vacuum and μ implied standard gravitational parameter for virtual particle-antiparticle pairs). Spontaneous births and deaths of roiling frenzy of particles so called virtual matter – antimatter pairs (whose energy 'E' was < pc: energy and momentum were not proportional) momentarily occurred everywhere, all the time -- violated the Energy-momentum relationship: $E^2 = m_0^2c^4 + p^2c^2$ -- was the conclusion that mass and energy were interconvertible; they were two different forms of the same thing. However, spontaneous births and deaths of so called virtual particles (whose wavelength was = h / Δmc, where: h denoted the Planck constant and was = 6.625×10^{-34} Js. Since the Planck's constant was almost infinitesimally small, quantum mechanics was for little things) could have produced some remarkable problem, because an infinite number of virtual particle-antiparticle pairs of energy ($M_{Planck} (\mu\Delta\omega c)^{1/2}$, where: M_{Planck} → Planck Mass) were spontaneously created out of energy ΔE of the empty space, therefore, by Einstein's famous equation $\Delta E = \Delta mc^2$, infinite number of virtual particle-antiparticle pairs bared an infinite amount of mass and according to general relativity, the infinite amount of mass could have curved up the universe to infinitely small size. But which obviously had not happened. The word virtual particles literally meant that these particles were not observed directly, but their indirect effects were measured to a remarkable degree of accuracy. Their properties and consequences were well established and well understood consequences of quantum mechanics. The gravitational potential energy of the universe was proportional to $(- GM^2/a)$ and its kinetic energy was proportional to MH^2a^2 (where: M denoted the mass of the universe, G the gravitational constant, H the Hubble parameter (where H was = $d\ln a/dt$ and was inversely proportional to the age of the universe) and a the scale factor of the universe {which was proportional to $1 / [1 + z]$, where z denoted the cosmological red shift}). Total energy of matter and of gravity (related to the shape and the volume of the universe) was conserved, but this conservation was somewhat unusual: The sum of the energy of matter and of the gravitational energy was equal to zero (and zero took the value of $e^{\pi i} + 1$ i.e., $e^{\pi i} + 1$ was = 0). Space had three dimensions, I mean that it took three numbers − length, breadth and height − to specify a point. And adding time to its description, then space became space-time with 4 dimensions (t, x, y, z). For n spatial dimensions: The gravitational force between two massive particles was given by: $F_G = Gm_1m_2 / (r^{n-1})$ where G was the gravitational constant, m_1 and m_2 denoted the masses of the two particles and r was the distance between them. The electrostatic force between two point charges was given by: $F_E = q_1q_2/ 4\pi\varepsilon_0 (r^{n-1})$ where ε_0 was the absolute permittivity of free space, q_1 and q_2 denoted the charges and r was the distance between them.

Since n was = 3:

Both of these forces were proportional to $1/ r^2$

And the ratio of these forces (F_G / F_E) was independent of the distance 'r'. The total energy ($E= Mc^2$) of the universe remained the same; no energy was being created or destroyed. The entire universe was getting more disordered and chaotic with time i.e., the entropy of the universe was increasing toward greater disorder (i.e., (dS/dt) was > 0 and entropic energy of the universe was never less than or greater than TS but = TS). And this observation was elevated to the status of a law; the so called Second law of thermodynamics i.e., the universe (whose energy density u was proportional to Ta^{-3}, where: T stood for the temperature of the universe and a the scale factor of the universe) was tending toward a state of maximum entropy, such as a uniform gas near absolute zero ($T \rightarrow 0$). Since the universe was matter dominated: a (t) was proportional to $t^{2/3}$. The rest mass energy of each particle in that universe was given by: $m_0c^2 = k_BT_{particle}$, where: $T_{particle}$ implied the threshold temperature below which that particle was effectively removed from the universe. All particles had an intrinsic real internal vibration in their rest frame, $\upsilon_0 = m_0c^2 /h$.

$E_0^2 = h\upsilon_0 \times m_0c^2$

$E_0 = M_{Planck} (\mu\omega_0c)^{1/2}$

$T_{particle} = T_{planck} c^{3/2} (\mu\omega_0)^{1/2}$

(where: T_{planck} denoted the maximum temperature and at temperatures above it, the laws of physics was just cease to exist). And Compton wavelength of each particle was given by:

$\lambda_{Compton} = h/m_0c$

$m_0c^2 = hc/ \lambda_{Compton}$

$\lambda_{Compton} = c/ \upsilon_0$

Planck force was the highest possible force and half of this force was responsible for confining the energy ($E_{BH} = M_{BH}c^2$) of the black hole (whose area was proportional to its entropy and a non-decreasing function of time: $dA/dt \geq 0$) to a distance ($R_s = 2GM_{BH}/c^2$)

$E_{BH} = (F_{Planck}/2) R_s$

And 1/4th of this force was responsible for confining the entropic energy "E_s" (which was proportional to k (where: k denoted the surface gravity of the black hole) and was = $T_{BH} \times S_{BH}$) of the black hole to a distance ($R_s = 2GM/c^2$)

$M_{BH}c^2 = 2\, T_{BH} \times S_{BH}$

$E_s = (F_{Planck}/4) R_s$

A photon (whose wave number depended only on its wavelength: $\bar{\upsilon} = 1/\lambda$) was the quantum of electromagnetic radiation that described the particle properties of an electromagnetic wave. The energy of a photon was given by:

$E_{photon} = h\upsilon$

(which implied the energy a photon was proportional to its frequency: larger frequency (shorter wavelength) implied larger photon energy and smaller frequency (longer wavelength) implied smaller photon energy) – Because h was constant, energy and frequency of the photon were equivalent and were different forms of the same thing. And since h -- which was one of the most fundamental numbers in physics, ranking alongside the speed of light c and confined most of these radical departures from life-as-usual to the microscopic realm − was incredibly small (i.e., 6 × 10 to the power of ⁻34 -- a decimal point followed by 33 zeros and a 6 -- of a joule second), the frequency of the photon (whose energy "$h\upsilon$" was proportional to $P_p V_p$, where: P_p denoted the photon pressure ($P_p \rightarrow \rho c^2$) and V_p the photon volume) was always greater than its energy, so it did not took many quanta to radiate even ten thousand megawatts.

$E_{photon} = M_{Planck}^2 \mu_{Planck} \bar{\upsilon}$

where: μ_{Planck} → standard gravitational parameter for Planck mass. Taking into account the particle nature, the energy of a photon was given by:

$E_{photon} = mc^2$

$E_{photon}^2 = mc^2 \times h\upsilon$

$E_{photon} = P_{Planck} (\bar{\upsilon}\mu)^{1/2}$

(where: P_{Planck}→ Planck momentum, υ → angular wave number of photon, μ → standard gravitational parameter for photon). And its wavelength 'λ' was related to its momentum 'p' by the equation:

$\lambda = h/mc = h/p$

$d\lambda = (-dp/p^2)\, h$

$F = p^2/h\,(-d\lambda/dt)$

which implied: force which moved the photon mass ("m" which was = $\hbar\, \boldsymbol{k}/c$, where: $\boldsymbol{k}$ denoted the wave vector) was proportional to the rate of decrease of its wavelength. And the photon power was given by the equation:

$P_{photon} = F \times c$

which implied: the rate of work done in moving the photon mass was proportional to the force which moved the photon mass. Since the photon entropy (S_{photon}) was > k_B: the energy of the photon ($h\upsilon$) was greater than its entropic energy ($T \times S_{photon}$). The photon impulse was = $-(p^2/h)\, d\lambda$. Absolute zero (−273.15° on the Celsius scale and − 459.67° on the Fahrenheit scale) was impossible to reach -- it was the temperature at which entropy reached minimum value. All the known subatomic particles (whose kinetic energy "[$E_{total} - E_{intrinsic}$]" was proportional to k_BT) in the universe belonged to one of two groups, Fermions or bosons. Fermions were particles with integer spin ½ and they made up ordinary matter. Their ground state energies were negative. Bosons were particles (whose ground state energies were positive) with integer spin 0, 1, 2 and they acted as the force carriers between fermions (For example: The electromagnetic force of attraction between electron and a proton was pictured as being caused by the exchange of large numbers of virtual massless bosons of spin 1, called photons {of energy $E = 2.5M_{planck} (\mu a)^{1/2}$ where: a denoted the acceleration of the photon mass, M_{planck} the Planck mass, and μ the gravitational parameter for photon}).

Positive ground state energy of bosons plus negative ground state energy of fermions was = 0

Because $m = m_0 / (1 - v^2/c^2)^{1/2}$ (where c was not just the constant namely the maximum distance a light can travel in one second in vacuum but rather a fundamental feature of the way space and time were married to form space-time), the energy which a particle possessed due to its motion added to its rest mass "m_0". This effect was only really significant for particles moving at speeds close to the speed of light. For example, at 10 percent of the speed of light a particle's mass m was only 0.5 percent more than its rest mass m_0 while at 90 percent of the speed of light it was more than twice its rest mass. And as a particle approached the speed of light, its mass raised ever more quickly, it acquired infinite mass and since an infinite mass cannot be accelerated any faster by any force, the issue of infinite mass remained an intractable problem. For this reason all the particles in that universe were forever confined by relativity to move at speeds slower than the speed of light. Only tiny packets / particles of light (dubbed "photons") that had no intrinsic mass moved at the speed of light. Tachyons the putative class of hypothetical particles (with negative mass: m < 0) was believed to travel faster than the speed of light. But, the existence of tachyons was in question. The equation "$m = m_0 / (1 - v^2/c^2)^{1/2}$" implied: the mass of a particle was not constant; it varied with changes in its velocity. The curvature of the space-time was related to the distribution of energy and momentum in that Universe by the equation:

$R_{\mu\nu} - (Rg_{\mu\nu}/2) + \Lambda g_{\mu\nu} = (8\pi G/c^4)\, T_{\mu\nu}$

where $R_{\mu\nu}$ denoted the Ricci curvature tensor, R the scalar curvature, $g_{\mu\nu}$ the metric tensor, Λ the cosmological constant, G the Newton's gravitational constant, c the speed of light in vacuum, and $T_{\mu\nu}$ the stress–energy tensor. The distribution of matter and energy determined the geometry of spacetime, which in turn described the acceleration of matter.

Undisturbed space + rigid mass was = distorted space

The geometry of spacetime produced by a given distribution of mass and energy was determined by the equation:

$G_{\alpha\beta} = (8\pi G/c^4)\, T_{\alpha\beta}$

where: $G_{\alpha\beta}$ denoted the curvature of space, $T_{\alpha\beta}$ the distribution of mass or energy and $(8\pi G/c^4)$ the constant.

$r_s \times \lambda_{Compton}$ was > Planck area

(where: r_s denoted the gravitational radius of the electron and $\lambda_{Compton}$ the Compton wavelength of the electron)

i.e., $r_s \times \lambda_{Compton}$ was = $4\pi L_{Planck}^2$

The known forces of the universe were divided into four classes:

Gravity: This was the weakest of the four; it acted on everything in the universe as an attraction. And if not for this force, everything would have gone zinging off into outer space and the life sustaining star would have detonated like trillions upon trillions of hydrogen bombs.

Electromagnetism: This was much stronger than gravity; it acted only on particles with an electric charge, being repulsive between charges of the same sign and attractive between charges of the opposite sign.

Weak nuclear force: This caused radioactivity and played a vital role in the formation of the elements in stars (whose stellar luminosity was = $4\pi\sigma T^4R^2$, where: T denoted the surface temperature of the star, R the radius of the star and σ the constant).

Strong nuclear force: This force held together the protons and neutrons inside the nucleus of an atom. And it was this same force that held together the quarks to form protons and neutrons.

If these forces were unified, the protons -- which constituted up much of the mass of ordinary matter -- would have been unstable, and eventually decayed into lighter particles such as antielectrons. However, the probability of a proton in the universe gaining sufficient energy to decay was so small that one has to wait at least a million million million million million years. Any reversible reaction (A + B ↔ AB) occurring in that universe obeyed the relation: $v_1 = v_2\, e^{-\Delta G / RT}$ where: v_1 denoted the rate of forward reaction (A + B → AB), v_2 the rate of backward reaction (AB → A + B), ΔG the change in the Gibbs free energy of the reaction, T the temperature and R the universal gas constant. The entire universe was governed by a set of physical constants:

Planck's constant: $h = 6.625 \times 10^{-34}$ *Js*

Planck hbar: $\hbar = 6.5821 \times 10^{-16}$ *eV s*

Newton's gravitational constant: $G = 6.6743 \times 10^{-8}\ cm^3\ g^{-1}\ s^{-2}$

Speed of light (in vacuum): $c = 3 \times 10^{8}$ *m/s*

Mass of electron: $m_{electron} = 9.1 \times 10^{-31}$ *kg*

Mass of proton: $m_{proton} = 1.672 \times 10^{-27}$ *kg*

Mass of neutron: $m_{neutron} = 1.675 \times 10^{-27}$ *kg*

Electron charge (magnitude): $e = 1.602 \times 10^{-19}$ *C*

Boltzmann's constant: $k_B = 1.3807 \times 10^{-16}\ cm^2\ g\ s^{-2}\ K^{-1}$

Stefan-Boltzmann constant: $\sigma = 5.6704 \times 10^{-5}\ g\ s^{-3}\ K^{-4}$

Fine structure constant: $\alpha = e^2/\hbar c = 1/137.036$

Classical electron radius: $r_{electron} = e^2/m_{electron}c^2 = 2.81 \times 10^{-15}$ *m*

Bohr radius: $a = \hbar / m_{electron}e^2 = 5.29 \times 10^{-11} m$

Bohr energies: $E_n = -\, m_{electron}e^4/2\, \hbar\, n^2$

$E_n = -\,(13.6/n^2)\ eV$

QED coupling constant: $g_e = (4\pi/\ \hbar\ c)^{1/2} = 0.302822$

Weak coupling constants: $g_w = g_e /sin\theta_w = 0.6295$; $g_z = g_w /cos\theta_w = 0.7180$

Weak mixing angle: $\theta_w = 28.76^o$

Strong coupling constant: $G = 1.214$

And out of which three constants (G, c, ħ) framed the existence of Planck units such as:

Planck length: $L_{Planck} = (\hbar\ c/G)^{1/2} = 1.6 \times 10^{-35}$ m (about 10^{-20} times the size of a proton)

Planck time: $t_{Planck} = (\hbar\ G/c^5)^{1/2} = 10^{-43}$ seconds (the time it took for light to travel 1 Planck length, or 1.6×10^{-35} m).

Planck temperature: $T_{Planck} = M_{Planck}c^2/k_B = 1.416808(33) \times 10^{32}$ K

Planck force: $F_{Planck} = c^4/G = 1.210295 \times 10^{44}$ N

Since the condition $F_{photon} \geq F_G$ (where: $F_{photon} \rightarrow \{ p^2/ h\ (-\, d\lambda/dt)\}$ denoted the force of the photon and $F_G \rightarrow \{GMm/r^2\}$ denoted the force of gravitation experienced by the photon} was satisfied, the photon detached the star surface -- its energy shifted from hυ to hυ'. The change in photon energy was equivalent = gravitational potential energy of the photon i.e.,

$\Delta E = -\ GMm/r$

Since $m = h\upsilon/c^2$:

$\Delta E / h\upsilon = -\ GM/rc^2$

Since the gravitational binding energy of a star "U" was $= -3GM^2/5r$:

$\Delta E / h\upsilon = -\ GM/rc^2 \rightarrow z = 1.66U / Mc^2$

where: z denoted the gravitational red shift. Since z was < than 1, Mc^2 was > 1.66U -- which implied: $Mc^2 > 1.66U$ was the condition that must be satisfied for a star to allow the photon of energy "hυ" to escape from its surface.

$F_{photon} = F_G$

$p^2/ h\ (-\, d\lambda/dt) = GMm/r^2$

$(-\, d\lambda/dt) = (GM/r^2c)\ \lambda \rightarrow \lambda' = \lambda \exp\left(-\, [GM/r^2c]\ t\right)$

When an electron and a positron approached each other, they annihilated i.e., destroyed each other. During the process their masses were converted into energy in accordance with $E = mc^2$. The energy thus released manifested as γ photons. A positron had the same mass as an electron but an opposite charge equal to +*e*. The energy released in the form of 2γ photons during the annihilation of a positron and an electron was therefore $E = 2h\upsilon = 2m_0c^2$ where m_0 was the rest mass of the electron or positron.

$2h\upsilon = 2m_0c^2$

Since $\upsilon = c/\lambda$. Therefore:

$\lambda = h/\ m_0c$

$\lambda = \lambda_{Compton} = c / \upsilon_0$

which implied: wavelength of the resulted gamma photon was = Compton wavelength of the annihilated electron or positron. Like the formation of bubbles of steam in boiling water – many tiny bubbles of radius r were created out of the empty space, started expanding {because F_B (the gravitational binding force proportional to GM^2/r^2, where M denoted the mass of the bubble and r the radius of the bubble) was < F_E (the force of expansion proportional to MH^2r)} at a rate

$v = dr/dt = Hr$ (where: H denoted the Hubble parameter)

simply because of an uncaused accident called spontaneous creation. Since the area 'A' of the bubble was proportional to r^2 and volume 'V' of the bubble was proportional to r^3:

$v = dr/dt = Hr \rightarrow dV/dt = 3HV$

Since the bubble was expanding adiabatically -- it satisfied the first law of thermodynamics:

$0 = dQ = dU + PdV$

$-dU = 3HPV$

$-dU = 3HF (V/A)$

$-dU = 3Fv$

which implied: the decrease in the internal energy of the bubble was > Fv (where: F implied the Force of expansion, v the rate of expansion of the bubble). The total energy of the bubble was = $E_B + E_C$ where: E_B denoted the gravitational binding energy of the bubble and E_C the energy of its constituents. The gravitational binding energy of a star was = $-3GM^2/5r$ and the gravitational binding force that confined the mass M of the star to the radius R was proportional to $-GM^2/r^2$. Since GM^2/r was = $-5U/3$ (where U denoted the gravitational binding energy of a star): the stars of radius

$r = 2GM/c^2$

$Mc^2 = 2GM^2/r$

$Mc^2 = -3.33U$

i.e., stars of rest mass energy = 3.33 times their negative gravitational binding energy further collapsed to produce dark or frozen stars (i.e., the mass of a star was concentrated in a small enough spherical region, so that its mass divided by its radius exceeded a particular critical value, the resulting space-time warp was so radical that anything, including light, that got too close to the star was unable to escape its gravitational grip). And these dark stars were sufficiently massive and compact and possessed a strong gravitational field that prevented even light from escaping out its influence: any light emitted from the surface of the star was dragged back by the star's gravitational attraction before it could get very far. Such stars become black voids in space and were coined "the black holes" (i.e., black because they cannot emit light and holes because anything getting too close falls into them, never to return). Classically, the gravitational field of the black holes (which seemed to be among the most ordered and organized objects in the whole universe) was so strong that they prevented any information including light from escaping out of their influence i.e., any information was sent down the throat of a black hole or swallowed by a black hole was forever hidden from the outside universe. Anything which fell through the black hole soon reached the region of infinite density and the end of time. However, the laws of classical general relativity did not allowed anything (not even light) to escape the gravitational grip of the black hole but the inclusion of quantum mechanics modified this conclusion− quantum field scattered of a black hole. Because of quantum mechanical effects, the pair of short-lived virtual particles (one with positive energy and the other with negative energy) appeared close to the event horizon of a black hole. The gravitational might of the black hole injected energy into a pair of virtual particles... that teared them just far enough apart so that one with negative energy was sucked into the hole even before it can annihilate its partner... its forsaken partner with positive energy... escaped outward to infinity with an energy boost from the gravitational force of the black hole... where it appeared as a real particle (and to an observer at a distance, it appeared to have been emitted from the black hole {whose density was proportional to $1/M_{BH}^2$}). Because $E = mc^2$ (i.e., energy was equivalent to mass), a fall of negative energy particle into the black hole therefore reduced its mass with its horizon shrinking in size. As the black hole lost mass, the temperature of the black hole "T_{BH}"(which was = $\hbar c^3/8\pi GM_{BH} k_B$) raised and its rate of emission of particle (of energy "$E = k_B T_{BH}$" where: k_B stood for Boltzmann constant) increased, so it lost energy more and more quickly at a rate proportional to ($-dE_s / dt$).

$P = -c^2 (dM_{BH} / dt)$

$P = 2 \times (-dE_s / dt)$

The black hole (whose energy "$M_{BH} c^2$" was = $3Pt_{ev}$, where: t_{ev} denoted the evaporation time of the black hole) ought to emit particles and radiation (whose peak wavelength was nearly 16 times the radius of the black hole) as if it were a hot body with a temperature that depended only on the black hole's mass: the higher the mass, the lower the temperature. The time that the black hole took to dissipate was proportional to M_{BH}^3. The total electric charge "Q" and total angular momentum "J" of charged rotating black holes (whose energy change "dE" was related to change of its area "dA" { dA was ≥ 0}, angular momentum "dJ", and total electric charge "dQ" by the equation: $dE = (\kappa/8\pi)\, dA + \Omega dJ + \Phi dQ$ {which implied the size and shape of the black hole depended only on its mass, charge and rate of rotation, and not on the nature of the star that had collapsed to form it} where: κ denoted the surface gravity, Ω the angular velocity and Φ the electrostatic potential) were constrained by their mass "M" and were expected to satisfy the relation: $Q^2 + (J / M_{BH})^2 \leq M_{BH}$. Every particle was nothing but a vibrating, oscillating, dancing filament named a string (whose mass "m" was proportional to its mode of vibration). A string did something aside from moving – it oscillated in different ways. Each way represented a particular mode of vibration. Different modes of vibration made the string appear as a dark energy or a cosmic ray, since different modes of vibration were seen as different masses or spins. A new field called the Higgs field which was analogous to the familiar electromagnetic field but with new kinds of properties permitted all over the space. More the strength of interaction of the string with the Higgs field, more the mass of the particle. The masses of the particles were due to (the different modes of vibration of the string plus the different strengths of interaction of the string with the Higgs field). The ratio of the electric to magnetic fields in an electromagnetic wave in free space was always equal to the speed of light i.e., c was = (E / B). The efficiency with which a photochemical reaction occurred was given by its Quantum Yield (Φ) = v / I_{ab} (where: I_{ab} denoted the absorbed intensity of light and v the rate of photochemical reaction). The strength of the electromagnetic force was measured by the dimensionless parameter $\alpha = e^2/4\pi\varepsilon_0\hbar c$ (where: e denoted the charge = 1.602×10^{-19} Coulombs, ε_0 the absolute permittivity of free space = 8.8×10^{-12} F / m, c the speed of light in vacuum and $\hbar$ the reduced Planck's constant), called the fine structure constant, which actually varied with the energy of particles. The massive bodies that were accelerated caused the emission of gravity waves, ripples in the curvature of 4 dimensional fabric of space-time that travelled away in all directions like waves in a lake at a specific speed, the speed of light. These were similar to light waves, which were ripples of the electromagnetic field. Like light, gravity waves (whose speed, wavelength, and frequency were related by the equation: $c = \lambda \upsilon$, just like the equation for a light wave) carried energy away from the bodies that emit them and, in the case of orbiting bodies, this was associated with an inspiral or decrease in orbit.

dE / dr was proportional to $F_{Gravitation}$

where: dE denoted the change in energy of the orbiting bodies, dr the change in orbital distance and $F_{Gravitation}$ the gravitational force of attraction between the orbiting bodies. The speed "c" of an electromagnetic wave was determined by the constants of electricity and magnetism: $c = 1/(\varepsilon_0\mu_0)^{1/2}$ where: ε_0 denoted the absolute permittivity of free space and μ_0 the absolute permeability of free space. Radioactivity (a property exhibited by certain types of matter of emitting energy and subatomic particles spontaneously) was governed by the equation: (dM / dN) = (t_2 / t_1) m (where: $M \rightarrow M_0 \exp(0.693t / t_1)$ denoted the mass of radioactive matter, $N \rightarrow N_0 \exp(0.693t / t_2)$ the number of radioactive atoms, m the average mass of radioactive atom, t_2 the time required for the mass of radioactive matter to reduce to half its initial value and t_1 the time required for the number of radioactive atoms to reduce to half its initial value). The energy densities for matter, radiation (whose energy density "u" was = 3P and its pressure "P" was proportional to T^4 where T denoted the temperature) and vacuum energy varied with the size of space (the scale factor "*a*" of the universe which was inversely proportional to the wavelength of radiation):

$\rho_{Matter} \approx a^{-3}$

$\rho_{Radiation} \approx a^{-4}$

$\rho_{Vacuum} \approx 1$

So as the Universe was getting bigger {the photon wavelength decreased as λ proportional to *a* and its frequency decreased as υ proportional to 1/*a*}, the energy density from matter and radiation was getting smaller, but vacuum energy density (which was = $\Lambda c^2/8\pi G$, where Λ denoted the cosmological constant {which appeared from a form of energy which had negative pressure, proportional to its (positive) energy density: P proportional to $-\rho c^2$}. Since $c^2/8\pi G$ was constant, ρ_{Vacuum} and Λ were in fact equivalent and interchangeable. And since c^2 was > 8πG, therefore Λ was < ρ_{Vacuum} which meant: a very large amount of dark energy attributed to a fairly small vacuum energy density) remained the same. The Equation: $k_r = \kappa (k_B T / h) (v_2 / v_1) \exp(-\Delta G^*/ RT)$ {where: k_r denoted the rate constant, κ the transmission coefficient {"fraction of activated complex crossing forward to form products"}, ΔG* the standard Gibbs free energy of activation, R the universal gas constant, T the temperature, v_2 the rate of deactivation and v_1 the rate of activation (which was = [(dC*/dt) + v_3] / [$e^{-\Delta G/ RT}$ – 1] where: v_3 denoted the rate of formation of the product, (dC*/dt) the net change in the concentration of the activated complex and ΔG the Gibbs free energy of activation)} gave a more accurate calculation of rate constants and provided insight into how a reaction progresses at the molecular level. The density of the universe was = $3H^2\Omega / 8\pi G$ (where: Ω denoted the density parameter, which was = (ρ / ρ_c) – "the equation that described how close the current density in the Universe to the critical value") and the ultimate fate of that universe was determined by a parameter called critical density ($\rho_c = 3H^2/8\pi G$):

- Density of the universe > critical density implied: force of gravity > force of expansion → the universe will eventually stop expanding then collapse.
- Density of the universe < critical density implied: force of expansion > force of gravity → the universe will expand forever.

The equation: $H^2 = (8\pi G/3) \rho - (Kc^2/a)$ {where: K denoted the curvature of the universe, *a* the scale factor and ρ the total energy density of the universe} defined how the energy in the universe compiled its expansion. As the universe (of density proportional to $H^2\Omega$, where H denoted the Hubble parameter and Ω the density parameter of the universe) was expanding:

- Like raisins in expanding dough, galaxies that were further apart were increasing their separation more than nearer ones. And as a result, the light emitted from distant galaxies and stars was shifted towards the red end of the spectrum. Observations of galaxies indicated that the universe was expanding: the distance D between almost any pair of galaxies was increasing at a rate:

$v = dD/dt = HD$

Beyond a certain distance, known as the Hubble distance or the Hubble radius (c / H), it exceeded the velocity greater than the speed of light in vacuum. But, this was not a violation of relativity, because recession velocity was caused not by motion through space but by the expansion of space. Since D was proportional to the wavelength 'λ' of the light emitted from distant galaxies: ν was = dλ/dt = Hλ

$z = H \times dt$

where: z denoted the cosmological red shift. The universe was very rapidly expanding and cooling in a way consistent with Einstein field equations. As the universe was expanding, the temperature was decreasing. The expansion of the universe was actually accelerating or speeding up. The acceleration of the expansion of the universe was given by:

$a = dv/dt = (dH/dt) D + (dD/dt) H$

$a = - H^2 (1+q) D + (dD/dt) H$

$a = - Hqv$

where: q denoted the deceleration parameter (which was a dimensionless measure of the cosmic acceleration of the expansion of space).

$dv = -zqv$

- The density of the universe was decreasing with time

and at a certain point of expansion, the density of the universe was greater than critical density. The universe stopped expansion and started contracting with time. At a certain point of contraction: all the forces were unified into a single force and this force was > Planck force and this force was attractive enough to cause further contraction. The nature of the force was similar to intermolecular force – attractive up to certain distance (i.e., x A^0) and repulsive < x A^0. At certain point of contraction, the distance was < x A^0 -- the contraction turned to explosion. This was not any ordinary explosion as might occur today, which would have a point of origin (center) and would spread out from that point. The explosion occurred simultaneously everywhere, filling all space with infinite heat and energy. At this time, order and structure were just beginning to emerge − the newly born universe was hotter and denser than anything we can imagine (at such temperatures and densities (of about a trillion trillion trillion trillion trillion trillion (1 with 72 zeros after it) tons per cubic inch) gravity and quantum mechanics were no longer treated as two separate entities as they were in point-particle quantum field theory, the four known forces were unified as one unified super force) and was very rapidly expanding. The quantum black holes (with mass < mass of the electron) were created, they were extremely difficult to spot - and they were the large emitters of radiation (because $T = \hbar c^3/ 8\pi GMk_B$) and they shrinked and dissipated faster even before they were observed. As the universe was expanding, the temperature was decreasing. Since the temperature was decreasing, the universe was cooling and its curvature energy was converted into matter like a formless water vapor freezes into snowflakes whose unique patterns arise from a combination of symmetry and randomness. Approximately 10^{-37} seconds into the expansion, a phase transition caused a cosmic inflation, during which the universe underwent an incredible amount of superliminal expansion and grew exponentially by a factor e^{3Ht} (where H was a constant called Hubble parameter and t was the time) – just as the prices grew by a factor of ten million in a period of 18 months in Germany after the First World War and it doubled in size every tiny fraction of a second – just as prices double every year in certain countries. After inflation stopped, the universe was not in a de Sitter phase and its rate of expansion was no longer proportional to its volume since H was no longer constant. At that time, the entire universe had grown by an unimaginable factor of 10^{50} and consisted of a hot plasma "soup" of high energetic quarks as well as leptons (a group of particles which interacted with each other by exchanging new particles called the W and Z bosons as well as photons). And quarks and gluons were "deconfined" and free to move over distances much larger than the hadron size (>>1 fm) in a soup called quark gluon plasma (QGP). There were a number of different varieties of quarks: there were six "flavors," which we now call up, down, strange, charmed, bottom, and top. And among the leptons the electron (whose charge "*e*" was related to its mass "m_e" by the equation: $e = [2\mu_B/\hbar]m_e$, where: μ_B denoted the physical constant for expressing the magnetic moment of an electron) was a stable object and muon (that had mass 207 times larger than electron and now belongs to the second redundant generation of particles found in the Standard Model) and the tauon (that had mass 3,490 times the mass of the electron) were allowed to decay into other particles. And associated to each charged lepton, there were three distinct kinds of ghostly particles called neutrinos (the most mysterious of subatomic particles, were difficult to detect because they rarely interacted with other forms of matter. Evidence of neutrino oscillations proved that neutrinos were not massless but instead had a mass less than one-hundred-thousandth that of an electron):

- the electron neutrino (a subatomic lepton elementary particle which had no net electric charge. Together with the electron it formed the first generation of leptons).

- the muon neutrino (a lepton, an elementary subatomic particle which had no net electric charge. Together with the muon it formed the second generation of leptons).
- the tauon neutrino (a heavier cousin of the electron neutrino which had no net electric charge. Together with the tau, it formed the third generation of leptons).

Temperatures were so high that these quarks and leptons were moving around so fast that they escaped any attraction toward each other due to nuclear or electromagnetic forces. However, they possessed so much energy that whenever they collided, particle – antiparticle pairs of all kinds were being continuously created and destroyed in collisions. And the uncertainty in the position of the particle times the uncertainty in its velocity times the mass of the particle was never smaller than a certain quantity, which was known as Planck's constant. Similarly, $\Delta E \times \Delta t$ was $\leq h/4\pi$ (where h was a quantity called Planck's constant and $\pi = 3.14159...$ was the familiar ratio of the circumference of a circle to its diameter). Hence the Heisenberg's uncertainty principle was a fundamental, inescapable property of the universe. At some point an unknown reaction led to a very small excess of quarks and leptons over antiquarks and antileptons — of the order of one part in 30 million. This resulted in the predominance of matter over antimatter in the universe. The universe continued to decrease in density and fall in temperature, hence the typical energy of each particle was decreased in inverse proportion to the size of the universe (since the average energy of the particles was simply a measure of the temperature of the universe and speed of the particles was proportional to k_BT). The symmetry however, was unstable and, as the universe cooled, a process called spontaneous symmetry breaking phase transitions placed the fundamental forces of physics and the parameters of elementary particles into their present form. After about 10^{-11} seconds, the picture became less speculative, since particle energies dropped to values that can be attained in particle physics experiments. At about 10^{-6} seconds, there was a continuous exchange of smallest constituents of the strong force called gluons between the quarks and this resulted in a force that pulled the quarks to form little wisps of matter which obeyed the strong interactions and framed up only a tiny fraction of the matter in the universe and was dwarfed by dark matter called the baryons (protons – a positively charged particles very similar to the neutrons, which accounted for roughly half the particles in the nucleus of most atoms − and neutrons – a neutral subatomic particles which, along with the protons, framed up the nuclei of atoms – belonged to the class baryons) as well as other particles. The small excess of quarks over antiquarks led to a small excess of baryons over antibaryons. The proton was composed of two up quarks and one down quark and the neutron was composed of two down quarks and one up quark. And other particles contained other quarks (strange, charmed, bottom, and top), but these all had a much greater mass and decayed very rapidly into protons and neutrons. The charge on the up quark was = + 2/3 e and the charge on the down quark was = – 1/3 e. The other quarks possessed charges of + 2/3 e or – 1/3 e. The charges of the quarks added up in the combination that composed the proton but cancelled out in the combination that composed the neutron i.e.,

Proton charge was = (2/3 e) + (2/3 e) + (–1/3 e) = e

Neutron charge was = (2/3 e) + (–1/3 e) + (–1/3 e) = 0

And the force that confined the rest mass energy of the proton or the neutron (i.e., total energy of its constituent particles) to its radius was proportional to its rest mass energy divided by its radius i.e., for the proton of radius $\approx 1.112 \times 10^{-15}$ meter: F was approximately $= 13.52 \times 10^{26}$ Newton. And this force was so strong that it was proved very difficult if not impossible to obtain an isolated quark. As one tried to pull them out of the proton or neutron it got more and more difficult. Even stranger was the suggestion that the harder and harder if one could drag a quark out of a proton this force got bigger and bigger – rather like the force in a spring as it was stretched causing the quark to snap back immediately to its original position. This property of confinement prevented one from observing an isolated quark. Each quark possessed baryon number = 1/3: the total baryon number of the proton or the neutron was the sum of the baryon numbers of the quarks from which it was composed. And the electrons and neutrinos contained no quarks; they were themselves truly fundamental particles. And since there were no electrically charged particles lighter than an electron and a proton, the electrons and protons were prevented from decaying into lighter particles – such as photons (that carried zero mass, zero charge, a definite energy $E_{photon} = pc$ and a momentum "p" = mc) and less massive neutrinos (with very little mass, no electric charge, and no radius — and, adding insult to injury, no strong force acted on it). And a free neutron being heavier than the proton was not prevented from decaying into a proton (plus an electron and an antineutrino). The strength of the gravitational force was described by the dimensionless parameter α_G, which was $= Gm^2/\hbar c$ (where m denoted the mass of the proton or the electron). And the ratio (α_G / α) was $=136.25 \times (m / M_{planck})^2$. And since m was < than Planck mass: α was > than α_G (i.e., the strength of electromagnetic force was > than the strength of gravitational force). The temperature was now no longer high enough to create new proton–antiproton pairs, so a mass annihilation immediately followed, leaving just one in 10^{10} of the original protons and neutrons, and none of their antiparticles (i.e., antiparticle was sort of the reverse of matter particle. The counterparts of electrons were positrons (positively charged), and the counterparts of protons were antiprotons (negatively charged). Even neutrons had an antiparticle: antineutrons). A similar process happened at about 1 second for electrons and positrons (positron: the antiparticle of an electron with exactly the same mass as an electron but its electric charge is +1e). After these annihilations, the remaining protons, neutrons and electrons were no longer moving relativistically and the energy density of the universe was dominated by photons − (what are sometimes referred to as the messenger particles for the electromagnetic force) − with a minor contribution from neutrinos. The density of the universe was about 4×10^{9} times the density of water and much hotter than the center of even the hottest star – no ordinary components of matter as we know them – molecules, atoms, nuclei – could hold together at this temperature. Entropy (a thermodynamic measure of untidiness in a system and a measure of how much information a system contains) was defined as

$S = k_B \ln \{\text{number of states}\}$

which, for N particles of the same type, was

$S = k_B \ln \{(\text{no of one-particle states})\ N\}$

$S = k_B N \ln \{\text{a not-too-big number}\}$

$S = k_B N$

This meant: the more particles, the more disorder. The force which moved the particle mass was $= mac^2 / (c^2 - v^2)$ i.e., F was $= m^3a / m_0^2 = p\,(-d\ln\lambda_p /dt)$ where: a denoted the acceleration of the particle mass, p the momentum (p = mv) and λ_p the wavelength associated with the particle mass (for particles moving at speeds < < c, F was $= m_0 a$). And the total positive charge due to protons plus the total negative charge due to electrons in the universe was = 0 (Just what it was if electromagnetism would not dominate over gravity and for the universe to remain electrically neutral).

$M_{Planck} / m_{electron}$ was $= 2.39\times 10^{22}$

which meant: 2.39×10^{22} electron masses were required to create one Planck mass. And a few minutes into the expansion, when the temperature was about a billion (one thousand million; 10 to the power of 9) Kelvin and the density was about that of air, protons and neutrons no longer had sufficient energy to escape the attraction of the strong nuclear force and they started to combine together to produce the universe's deuterium and helium nuclei in a process called Big Bang nucleosynthesis. And most of the protons remained uncombined as hydrogen nuclei. And inside the tiny core of an atom, consisting of protons and neutrons, which was roughly 10^{-13} cm across or roughly an angstrom, a proton was never permanently a proton and also a neutron was never permanently a neutron. They kept on changing into each other. A neutron emitted a π meson (a particle – composed of a quark and antiquark, which was unstable because the quark and antiquark annihilated each other, producing electrons and other particles) and became proton and a proton absorbed a π meson and became a neutron. That is, the exchange force resulted due to the absorption and emission of π mesons kept the protons and neutrons bound in the nucleus. And the time in which the absorption and emission of π mesons took place was so small that π mesons were not detected. And a property of the strong force called asymptotic freedom caused it to become weaker at short distances. Hence, although quarks were bound in nuclei by the strong force, they moved within nuclei almost as if they felt no force at all. Within only a few hours of the explosion, the Big Bang nucleosynthesis stopped. And after that, for the next million years or so, the universe just continued expanding, without anything much happening. Eventually, once the temperature had dropped to a few thousand degrees, there was a continuous exchange of virtual photons between the nuclei and the electrons. And the exchange was good enough to produce — what else? — A force (proportional to a quantity called their charge and inversely proportional to the square of the distance between them). And that force pulled the electrons towards the nuclei to form neutral atoms (the basic unit of ordinary matter, made up of a tiny nucleus (consisting of protons and neutrons) -- whose radius "r" was proportional to $A^{1/3}$, where: A denoted the atomic mass number -- surrounded by orbiting electrons). The orbiting electrons only existed in certain special states of motion - called stationary states, in which no electromagnetic radiation photons (of energy $h\upsilon$ proportional to PV (where P denoted the photon pressure and V the photon volume) and PV proportional to k_BT) was emitted. In these states, the angular momentum of the electrons "L" took on integer values of Planck's constant divided by 2π, denoted by $\hbar = h/2\pi$ (i.e., ħ, 2ħ, 3ħ... but never non-integer values). For circular orbits, the position vector of the electron "r" was always perpendicular to its linear momentum "p". The angular momentum "L" was = p × r -- had magnitude $L = n\hbar$, where n denoted a positive integer called principal quantum number. And these atoms reflected, absorbed, and scattered light and the resulted light was red shifted by the expansion of the universe towards the microwave region of the electromagnetic spectrum. And there was cosmic microwave background radiation. The irregularities in the universe meant that some regions of the nearly uniformly distributed atoms had slightly higher density than others. The gravitational attraction of the extra density slowed the expansion of the region, and eventually caused the region to collapse to form galaxies and stars. And the nuclear reactions in the stars transformed hydrogen to helium (composed of two protons and two neutrons and symbolized by $_2He^4$, highly stable—as predicted by the rules of quantum mechanics) to carbon (with their self-bonding properties, provide the immense variety for the complex cellular machinery— no other element offers a comparable range of possibilities) with the release of an enormous amount of energy via Einstein's equation $E = mc^2$. This was the energy that lighted up the stars to shine for a lifetime $\approx Mc^2 / L$ (where M stood for mass, L for luminosity and c for the speed of light). And the process continued converting the carbon to oxygen to silicon to iron. And the nuclear reaction ceased at iron. And the star experienced several chemical changes in its innermost core and these changes required huge amount of energy which was supplied by the severe gravitational contraction. And as a result the central region of the star collapsed to form a neutron star (a cold star {whose mass was = $N_n m_n$ where: N_n denoted the number of neutrons and m_n the mass of the neutron}, supported by the exclusion principle repulsion between neutrons – about the size of Manhattan (i.e., ten to 50 times the size of our sun). And the outer region of the star got blown off in a tremendous explosion called a supernova, which outshone an entire galaxy of 100 billion stars {The total energy released approached the luminosity of a whole galaxy which was = (Total energy of the star – its Gravitational binding energy)}, spraying the manufactured elements into space. And these elements provided some of the raw material for the generation of cloud of rotating gas which went to form the sun and a small amount of the heavier elements collected together to form the asteroids, stars, comets, and the bodies that now orbit the sun as planets like the Earth (with velocity $< (2GM/R)^{1/2}$ where: M denoted the mass of the sun and R the radius of the orbit) and their presence caused the fabric of space around them to warp (more massive the bodies, the greater the distortion it caused in the surrounding space). The earth was initially very hot and without an atmosphere. In the course of time the planet earth produced volcanoes and the volcanoes emitted water vapor, carbon dioxide and other gases. And there was an atmosphere. This early atmosphere contained no oxygen, but a lot of other gases and among them some were poisonous, such as hydrogen sulfide (the gas that gives rotten eggs their smell). And the sunlight dissociated water vapor and there was oxygen. And carbon dioxide in excess heated the earth and balance was needed. So carbon dioxide dissolved to form carbonic acid and carbonic acid on rocks produced limestone and subducted limestone fed volcanoes that released more carbon dioxide. And there was high temperature and high temperature meant more evaporation and dissolved more carbon dioxide. And as the carbon dioxide turned into limestone, the temperature began to fall. And a consequence of this was that most of the water vapor condensed and formed the oceans. And the low temperature meant less evaporation and carbon dioxide began to build up in the atmosphere. And the cycle went on for billions of years. And after the few billion years, volcanoes ceased to exist. And the molten earth cooled, forming a hardened, outer crust. And the earth's atmosphere consisted of nitrogen, oxygen, carbon dioxide, plus other miscellaneous gases (hydrogen sulfide, methane, water vapor, and ammonia). And then a continuous electric current through the atmosphere simulated lightning storms. And some of the gases came to be arranged in the form of more complex organic molecules such as simple amino acids (the basic chemical subunit of proteins, when, when linked together, formed proteins) and carbohydrates (which were very simple sugars). And the water vapor in the atmosphere probably caused millions of seconds of torrential rains, during which the organic molecules reached the earth. And it took two and a half billion years for an ooze of organic molecules to react and built earliest cells as a result of chance combinations of atoms into large structures called macromolecules and then advance to a wide variety of one – celled organisms, and another billion years to evolve through a highly sophisticated form of life to primitive mammals endowed with two elements: genes (a set of instructions that tell them how to sustain and multiply themselves), and metabolism (a mechanism to carry out the instructions). But then evolution seemed to have speeded up. It only took about a hundred million years to develop from the early mammals (the highest class of animals, including the ordinary hairy quadrupeds, the whales and Mammoths, and characterized by the production of living young which are nourished after birth by milk from the teats (MAMMAE, MAMMARY GLANDS) of the mother) to Homosapiens.

Conclusion:

The physical reality is not merely is described by the language of mathematics — but, instead, is mathematics.

Note:

- If space was 2 dimensional then force of gravitation between two bodies would have been = to GMm/r (i.e., the force of gravitation between two bodies would have been far greater than its present value). And if the force of gravitation between two bodies would have been far greater than its present value, the rate of emission of gravitational radiation would have been sufficiently high enough to cause the earth to spiral onto the Sun even before the sun become a black hole and swallow the earth. While if space was 1 dimensional then force of gravitation between two bodies would have been = GMm (i.e., the force of gravitation between two bodies would have been independent of the distance between them). And if spacial dimensions would have been > than 3, the force of gravitation between two bodies would have been decreased more rapidly with distance than it does in three dimensions. (In three dimensions, the gravitational force drops to 1/4 if one doubles the distance. In four dimensions it would drops to 1/5, in five dimensions to 1/6, and so on.) The significance of this was that the orbits of planets, like the earth, around the sun would have been unstable to allow for the existence of any form of life and there would been no intelligent beings to observe the effectiveness of extra dimensions.
- If c would have been = 3 × 10 to the power of −8 meters per second, then according to the equation E = mc squared: 1 kg of mass would have yielded only 9 × 10 to the power of −16 joules of energy. Hence, thousands and thousands of hydrogen atoms in the sun would have to burn up to release 4 × 10 to the power of 26 joules of energy per second in the form of radiation. Therefore, sun would have ceased to black hole even before an ooze of organic molecules would react and built earliest cells and then advance to a wide variety of one – celled organisms, and evolve through a highly sophisticated form of life to primitive mammals.
- If the value of G would have been far greater than its actual value, then according to the equation $F_{Gravity} = GMm/r^2$: Each star in the universe would have been attracted toward every other star by a force far greater than its present value, so it seemed the stars would have got very near each other, the attractive forces between them would have become stronger and dominate over the repulsive forces so that the stars would have fell together at some point to form a sphere of roughly infinite density.
- If Λ would have been = 0, then according to the equation $\{\rho_{vacuum} = \Lambda c^2 /8\pi G\}$ " ρ_{vacuum}" would have been = 0 i.e., the entire vacuum would have been empty. The empty vacuum though unstable would have ceased to exist.
- If the value of G would have been far greater than its actual value, then according to the equation $U = -3GM^2 /5r$: The gravitational binding energy of a star would have been far greater than its present value, so it seemed the matter inside the star would have been very much compressed and far hotter than it is. And the distance between the constituents of the star would have been decreased beyond the optimum distance (maximum distance below which the gravitational force is no longer attractive it turns to a repulsive force) then all the stars would have exploded spraying the manufactured elements into space. No sun would have existed to support life on the earth.
- If there was no Pauli's exclusion principle: The two quarks would have occupied precisely the same point with the same properties, and then would not have stayed in the same position for long. And quarks would have not formed separate, well-defined protons and neutrons. And nor would these, together with electrons have formed separate, well-defined atoms. And the world would have collapsed before it ever reached its present size.
- If the Boltzmann's constant was a variable then the universal gas constant (which was Boltzmann's constant times the Avogadro number) would have been a variable. And kinetic theory of gases would have been much different if the universal gas constant would have been a variable.
- If any one of the constants (absolute permittivity of free space ε_0 or absolute permeability of free space μ_0) were zero, then c (the speed of light which is = 1 / square root of ($\varepsilon_0 \times \mu_0$)) would have been infinite. And if any one of the constants (ε_0 or μ_0) was a variable, then c would not have remained a fundamental constant.

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