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Quantum Mechanics and General Relativity Identify Standard Model Particles as Black Holes

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Abstract

The Standard Model of particle physics does not account for charged fermion mass values and neutrino mass, or explain why only three particles are in each charge state 0, $-e/3$, $2e/3$, and $-e$. These issues are addressed by treating Standard Model particles with mass m as spheres with diameter equal to their Compton wavelength $l = \hbar / mc$, where $\hbar$ is Planck's constant and c the speed of light, and any charge in diametrically opposed pairs $\pm ne/6$ with n = 1, 2, or 3 at the axis of rotation on the sphere surface. Particles are ground state solutions of quantized Friedmann equations from general relativity, with differing internal gravitational constants. Energy distribution within particles identifies Standard Model particles with spheres containing central black holes with mass m, and particle spin resulting from black hole angular momentum. In each charge state, energy distribution within particles satisfies a cubic equation in l, allowing only three particles in the charge state and requiring neutrino mass. Cosmic vacuum energy density is a lower limit on energy density of systems in the universe, and setting electron neutrino average energy density equal to cosmic vacuum energy density predicts neutrino masses consistent with experiment. Relations between charged fermion wavelength solutions to cubic equations in different charge states determine charged fermion masses relative to electron mass as a consequence of charge neutrality of the universe. An appendix shows assigning charge $\pm e/6$ to bits of information on the event horizon available for holographic description of physics in the observable universe accounts for dominance of matter over anti-matter. The analysis explains why only three Standard Models are in each charge state and predicts neutrino masses based on cosmic vacuum energy density as a lower bound on neutrino energy density.

Keywords

Standard Model Particles, Black Holes From Internal Gravity, Neutrino Mass Prediction

1. Introduction

Neutrinos oscillate between three different mass states, so neutrinos cannot be massless and the Standard Model must consider twelve fermions with mass m_i, spin angular momentum $\hbar/2$, and charge 0, $-e/3$, $2e/3$, or $-e$.

The Standard Model treats particles as structureless points. Heisenberg's uncertainty principle specifies the minimum *measurable* scale for structure within particles of mass m_i as the Compton wavelength $l_i = \hbar/m_i c$, but does not mean there is *no* structure with scale smaller than the Compton wavelength. The Standard Model can be extended by treating particles as spheres with diameter equal to their Compton wavelength and any charge in diametrically opposed pairs $\pm ne/6$ with n = 1, 2, or 3 at the axis of rotation on the sphere surface. The uncertainty principle guarantees that spherical particles with diameter l_i are experimentally indistinguishable from point particles with the same charge and mass. Describing Standard Model particles as spheres does not conflict with mathematics underlying the Standard Model and has important observable consequences of requiring neutrino mass and only three particles in each charge state. The appendix shows assigning charge $\pm e/6$ to bits of information on the event horizon available for holographic description [1] of physics in the observable universe accounts for dominance of matter over anti-matter.

An outline of the steps in this analysis is presented in **Table 1**.

2. Particles as Spherical Bound States of Quantized Friedmann Equations

Friedmann equations with gravitational constants G_p, relating curvature of gravitationally bound spheres to their mass density ρ, are $\left(\frac{\mathrm{d}R}{\mathrm{d}t}\right)^2 - \frac{8\pi}{3} G_p \rho R^2 = -c^2$. Schrodinger equations for corresponding Elbaz-Novello quantized [2] [3] Friedmann equations are $-\frac{\hbar^2}{2\mu}\frac{\mathrm{d}^2\psi}{\mathrm{d}R^2} - \frac{\mu G_p m}{R}\psi = -\frac{\mu}{2}c^2\psi$ with effective mass μ.

Table 1. Outline of the analysis.

1. Identify Standard Model particles as spherical bound states of Elbaz-Novello quantized Friedmann equations involving particle internal gravitational constants $G_p \gg G$
2. Identify Standard Model surface and volume mass distributions surrounding central Kerr black holes with black hole mass equal Standard Model particle mass
3. Solve cubic equations allowing only three Standard Model particle Compton wavelengths in each charge state
4. Predict neutrino masses with cosmic vacuum energy density as lower bound on neutrino energy density
5. Determine charged fermion masses in relation to electron mass, based on charge neutrality of the universe
6. In an Appendix, assign charge $\pm e/6$ to holographic bits of information on the cosmic particle horizon to explain matter dominance over anti-matter

Ground state binding energies of quantized Friedmann equations with $\frac{1}{R}$ potentials are $E_b = -\frac{\mu}{2\hbar^2}\left(\mu G_p m\right)^2$. With effective mass $\mu = m$, those gravitationally bound states are spheres with mass m and diameter equal to their Compton wavelength $l = \frac{\hbar c}{mc^2}$. Sphere diameter l equals the Planck length $l_{G_p} = \sqrt{\frac{\hbar G_p}{c^3}}$ for gravitational constant G_p when $G_p = \left(\frac{l}{l_P}\right)^2 G = \left(\frac{m_P}{m}\right)^2 G$, where $l_P = \sqrt{\frac{\hbar G}{c^3}}$ and $m_P = \sqrt{\frac{\hbar c}{G}}$ are Planck length and mass for Newton's gravitational constant G.

3. Internal Particle Mass Distribution and Spin from Black Holes

For integer n, radial wavefunctions $\left[\sin\left(\frac{2\pi r}{l}\right)\right]^n$ for mass distribution within particles, relative to particle rotation axis, have zero mass at $r = 0$ and $r = l/2$ and peak mass at $r = l/4$, consistent with particles as spherical shells with radius $l/2$ surrounding central Kerr black holes with radius $r_H = l/4$, resulting from internal gravitational constants $G_p \gg G$. General relativity is not reliable at distances less than $l_{G_p} = \sqrt{\frac{\hbar G_p}{c^3}}$ in systems with gravitational constant G_p, so with surface shell thickness l_{G_p} and wavefunctions $\cos\left(\frac{\pi z}{l_{G_p}}\right)$ for mass distribution between polar axis coordinates $z = -\frac{l_{G_p}}{2}$ and $z = \frac{l_{G_p}}{2}$, wavefunctions $\cos\left(\frac{\pi z}{l_{G_p}}\right)\sin\left(\frac{2\pi r}{l}\right)$ and internal mass distributions $\cos^2\left(\frac{\pi z}{l_{G_p}}\right)\sin^2\left(\frac{2\pi r}{l}\right)$ describe torii with minor diameter l_{G_p} approximated by Kerr ring singularities at $r_H = l/4$ and no infinite energy densities.

4. Cubic Equations for Particle Wavelengths

In each charge state, one-dimensional, surface, and volume energy distribution for particle spheres in terms of particle Compton wavelengths l is

$$\frac{4}{3}\pi\rho\left(\frac{l}{2}\right)^3 = \frac{4}{3}\pi\rho_V\left[\left(\frac{l}{2}\right)^3 - \left(\frac{l}{4}\right)^3\right] + 4\pi\rho_S\left(\frac{l}{2}\right)^2 + 2\pi\rho_l l$$

where ρ is particle energy density, ρ_V is energy density in space between the surface and central black hole, ρ_S is surface energy density, and ρ_l is energy density of the torus approximated by the Kerr ring singularity. Energy density between the surface and central black hole in charged particles results from repulsive potential energy of diametrically opposed pairs $\pm ne/6$ with n = 1, 2, or 3 at the axis of rotation on the sphere surface. Using the fine structure constant $\frac{e^2}{\hbar c}=\frac{1}{137}$, $\rho_V=\left(\frac{ne}{6}\right)^2\frac{1}{l}\Big/\left(\frac{7}{48}\pi l^3\right)=\left(\frac{n^2mc^2}{4932}\right)\Big/\left(\frac{7}{48}\pi l^3\right)$. For neutral particles, ρ_V equals cosmic vacuum energy density ρ_{vac}, the lower limit on energy density in the universe. The energy density equation written as $f(l)=(\rho-\rho_V)l^3-6\rho_s l^2-\frac{3}{2}\rho_l l=\boldsymbol{v}l^3-\boldsymbol{s}l^2-\boldsymbol{t}l=0$, has positive discriminant $\Delta=\boldsymbol{s}^2\boldsymbol{t}^2+4\boldsymbol{v}\boldsymbol{t}^3$ and Compton wavelengths l_1, l_2, and l_3 as its three real roots. The wavelengths are projections [4] on the l axis of vertices of an equilateral triangle in the (y,l) plane centered at $\frac{\boldsymbol{s}}{3\boldsymbol{v}}=-(l_1+l_2+l_3)$, so negative energy density at the surface is necessary for wavelengths greater than zero. Mass equivalent energy density in space around the central black hole is offset by negative shell mass equivalent energy density so central black hole mass equals total particle mass. Treating particles as spheres with cubic equations for their wavelengths requires neutrino mass and allows only three fermions in each charge state and three vector bosons with zero average charge.

5. Neutrino Mass Predictions

With average energy density of electron neutrinos equal to ρ_{vac} (the lower limit on energy density in the universe) and $\rho_{vac}=\Omega_\Lambda\rho_{crit}=5.93\times10^{-30}\ \text{g}\cdot\text{cm}^{-3}$, from [5] $\Omega_\Lambda=0.689$ and critical energy density $\rho_{crit}=\frac{3H^2}{8\pi G}=8.60\times10^{-30}\ \text{g}\cdot\text{cm}^{-3}$, electron neutrino Compton wavelength is $l_1=\sqrt[4]{\frac{6\hbar}{\pi c\rho_{vac}}}$ and electron neutrino mass is $m_1=0.0014\ \text{eV}$. Neutrino oscillation data [6] then predict $m_2=0.0088\ \text{eV}$ and $m_3=0.051\ \text{eV}$, resulting in neutrino mass sum 0.062 eV, 51% of Vaganozzi's [7] 0.12 eV upper bound on the sum of neutrino masses.

6. Charged Fermion Masses from Charge Neutrality of the Universe

Solutions of the cubic equation [4] for wavelengths in a charge state, in descending order, are $l_1=l_{avg}+R\cos\theta$, $l_2=l_{avg}+R\cos(\theta+4\pi/3)$, and $l_3=l_{avg}+R\cos(\theta+2\pi/3)$. They specify vertices of an equilateral Nickalls triangle in the l plane, centered on $l_{avg}=\frac{1}{3}(l_1+l_2+l_3)$, with triangle offset angle $\theta=\tan^{-1}\left[\frac{l_2-l_3}{\sqrt{3}(l_1-l_{avg})}\right]$ between the l axis and a line from triangle center to the vertex corresponding to l_1, $R=\frac{l_1-l_{avg}}{\cos\theta}$ the radius of a circle centered at the triangle center and passing through the vertices, and Nickalls triangle offset distance $d=(l_1-l_{avg})\tan\theta$ along the perpendicular from the vertex corresponding to l_1. Nickalls triangle offset distance $d(q)$ for fermions in charge state q is determined by difference between lowest mass fermion wavelength and average fermion wavelength in that charge state. Vector bosons have zero average charge and wavelengths related by a Nickalls triangle with $\theta = 0$ and $d(0) = 0$.

Electrons and protons, containing two down quarks and an up quark, are stable charged particles in the universe. A charge neutral universe requires equal numbers of electrons and protons, so symmetry breaking resulting in charged fermion masses requires charged fermion Nickalls triangles with offset distances $d(e) + 2d(2e/3) - d(-e/3) = 0$. Particle Data Group [8] charged fermion masses in Table 2, with bold values (within PDG error bars) for up quark mass four times the electron mass, down quark mass nine times the electron mass, and strange quark mass increased by about 0.5% to 93.4215 GeV/c^2, result in $d(e) + 2d(2e/3) - d(-e/3) = 0.00000$.

7. Discussion

Gravitational repulsion by central black holes of surface shell negative effective mass (modified by pressure from energy density in space between the shell and black hole) maintains particle radius, and positive pressure from negative energy density within the shell maintains shell thickness.

Unlike astrophysical black holes, rotating Kerr black holes within fermions and vector bosons are isolated by surrounding spherical shells, so conservation of angular momentum forbids central black hole gain or loss of energy between particle creation and annihilation. In contrast, with Boltzmann constant $k_B = 1.38 \times 10^{-17}\ \text{g} \cdot \text{cm}^2 \cdot \text{sec}^{-2} \cdot \text{K}^{-1}$, Hawking temperature for Schwarzschild black holes identified with spinless Higgs bosons is $T_H = \frac{\hbar c^3}{8\pi k_B G_p m} = \frac{mc^2}{8\pi k_B}$, on the order of 10^{12} K, consistent with black hole evaporation and short lifetime, on the order of 10^{-24} sec, of Higgs bosons.

Closed time-like curves associated with Kerr black holes are not problems since fundamental particles do not change between creation and annihilation.

Lacking point particles and infinite energy densities, this approach could help reconcile quantum field theory and general relativity with the holographic principle. The holographic principle (1), based on thermodynamics, quantum mechanics, general relativity, and Shannon information theory, indicates only about 10^{122} bits of information will ever be available to describe our universe. A discontinuous universe negates difficulties associated with Cantor's proof of the

Table 2. Charged fermion masses in MeV/c^2.

Charge	m_1	m_2	m_3
e	0.510999	105.658	1776.86
$2e/3$	**2.04400**	1270	172,760
$-e/3$	**4.59899**	**93.4215**	4180

uncountable infinity of points on continuous line segments and Godel's incompleteness theorem in continuum mathematics. Continuum mathematics can be seen as a successful, and probably necessary, approximation to an underlying 10^{122} dimensional discrete mathematical representation of the universe.

8. Conclusion

Using quantum mechanics and general relativity, and treating Standard Model particles as spheres with internal gravitational constants $G_p \gg G$, this analysis shows there can only be three particles in each Standard Model charge state. Setting the cosmic vacuum energy density as a lower bound on neutrino energy density then enables a prediction of neutrino masses.

Conflicts of Interest

The author declares no conflicts of interest regarding the publication of this paper.

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Appendix. Matter Dominance from Charge ±*e*/6 on Holographic Bits of Information

The holographic principle [1] says physics at any point within the universe at time t_{bf} of baryon formation is described by the finite number of bits of information on the particle horizon at the greatest distance *d* from which light signals could reach the point since the end of inflation. The number of bits of information on the horizon, specified by one quarter of the horizon area in Planck units [1], is $\pi d^2 / \left(l_P^2 \ln 2\right)$. In any physical system, energy must be transferred to change information in a bit from one state to another. A charge neutral universe, such as one beginning by a quantum fluctuation from nothing [9], has equal numbers of *e*/6 and −*e*/6 charges, ensuring charge conservation as a precondition for gauge invariance and Maxwell's equations.

Protons have charge *e* and anti-protons have charge −*e*, so regardless how bits of information on the horizon specify protons or anti-protons, protons must differ in 6 bits from the configuration specifying anti-protons. Because *e*/6 bits and −*e*/6 bits do not have the same energy, the number of protons and anti-protons created in the early universe must be slightly different and, if *e*/6 bits have lower energy than −*e*/6 bits, there will be more matter than anti-matter in the universe. A small difference in energy of the bits on the horizon specifying protons or anti-protons is not inconsistent with protons and anti-protons having almost identical mass.

Temperature at baryon formation was $T_{bf} = 2m_p c^2 / k_B = 2.18 \times 10^{13}\ \text{K}$, where proton mass $m_p = 1.67 \times 10^{-24}\ \text{g}$. Radius of the universe at baryon formation was [10] $R_{bf} = R_0 \left(\frac{2.726}{T_{bf}}\right) \approx 10^{15}\ \text{cm}$, where 2.726 K is today's cosmic microwave background temperature and today's radius of the universe is $R_0 \approx 10^{28}\ \text{cm}$. Time t_{bf} of baryon formation, in seconds after the end of inflation, is determined from the Friedmann equation $\left(\frac{\mathrm{d}R}{\mathrm{d}t}\right)^2 - \left(\frac{8\pi G}{3}\right)\varepsilon\left(\frac{R}{c}\right)^2 = -\kappa c^2$. After inflation, the universe is so large it is almost flat, and curvature parameter $\kappa \approx 0$. Energy density is $\varepsilon(R) = \varepsilon_r \left(\frac{R_0}{R}\right)^4 + \varepsilon_m \left(\frac{R_0}{R}\right)^3 + \varepsilon_V$, where ε_r, ε_m, and ε_V are today's radiation, matter and vacuum energy densities. Radiation energy density $\varepsilon_r = 4 \times 10^{-13}\ \text{g} \cdot \text{cm} \cdot \text{sec}^{-2}$, matter energy density $\varepsilon_m \approx 2 \times 10^{-9}\ \text{g} \cdot \text{cm} \cdot \text{sec}^{-2}$, and vacuum energy density was negligible in the early post-inflationary universe, so radiation dominated when $R \ll 10^{-5} R_0$, before radiation/matter equality. Integrating $\left(\frac{\mathrm{d}R}{\mathrm{d}t}\right)^2 - \left(\frac{8\pi G}{3c^2}\right)\frac{\varepsilon_r R_0^4}{R^2} = \left(\frac{\mathrm{d}R}{\mathrm{d}t}\right)^2 - \frac{A^2}{R^2} = 0$, where $A = \sqrt{\frac{8\pi G \varepsilon_r R_0^4}{3c^2}}$, from the end of inflation at $t = 0$ to t results in $R(t) = \sqrt{R_i^2 + 2At}$, where R_i is radius of the universe at the end of inflation.

So, $t_{bf}=\frac{R_{bf}^2-R_i^2}{2A}\approx\frac{R_{bf}^2}{2A}\approx 10^{-7}\text{ sec}$, if $R_{bf}\gg R_i$. Distance $d(t)$ from any point in the universe to the particle horizon for that point [11] is $d(t)=cR(t)\int_0^t\frac{\mathrm{d}t'}{R(t')}$ $=\left[\frac{R(t)}{A}\sqrt{R_i^2+2At}\right]_0^t$, so $d_{bf}=\frac{cR_{bf}}{A}\left[\sqrt{R_i^2+2At_{bf}}-R_i\right]$ Since $R_{bf}\gg R_i$, $d_{bf}\approx$ $cR_{bf}\sqrt{\frac{2t_{bf}}{A}}\approx 10^4\text{ cm}$. Surface gravity on the particle horizon at baryon formation is $g_{Hbf}=G\frac{4\pi}{3}\frac{\varepsilon(R_{bf})}{c^2}d_{bf}\approx\frac{4\pi G}{3c}\varepsilon_r\frac{R_0^4}{AR_{bf}^2}$ and associated horizon temperature is $T_{Hbf}=\frac{\hbar}{2\pi ck_b}g_{Hbf}\approx 6\times10^{-7}\text{ K}$. Temperature at any epoch is uniform throughout a post-inflationary homogeneous isotropic Friedman universe, and the causal horizon at baryon formation is at distance d_{bf} from every point in the universe. Temperature at every point on the causal horizon for every point in the universe is the same because surface gravity of the uniform sphere within the horizon is the same at every point on every horizon. Bits on all causal horizons are in thermal equilibrium, and only two quantum states are available for those bits. So, equilibrium statistical mechanics can be used, and occupation probabilities of bit states in thermal equilibrium at horizon temperature T_{Hbf} are proportional to their corresponding Boltzmann factors. If energy of *e*/6 bits on the horizon at the time of baryon formation is $E_{bit}-E_\Delta$ and energy of −*e*/6 bits is $E_{bit}+E_\Delta$, proton/antiproton ratio at baryon formation $\left(\frac{\mathrm{e}^{-\frac{E_{bit}-E_\Delta}{k_BT_{Hbf}}}}{\mathrm{e}^{-\frac{E_{bit}+E_\Delta}{k_BT_{Hbf}}}}\right)^6=\mathrm{e}^{\frac{12E_\Delta}{k_BT_{Hbf}}}$.

Since $\mathrm{e}^{\frac{12E_\Delta}{k_BT_{Hbf}}}\approx 1+\frac{12E_\Delta}{k_BT_{Hbf}}$, the proton excess is $\frac{12E_\Delta}{k_BT_{Hbf}}$. Any holographic model must link bits of information on the horizon to bits of information specifying the location of particles within the universe. The wavefunction specifying the probability distribution for location of a particular bit of information within the universe has only two energy levels. Energy released when a bit in the universe drops from the (1) to the (0) state raises another bit from the (0) to the (1) state, and that is the mechanism for charge conservation. Energy must be transferred by massless quanta with wavelength related to the size of the universe. This analysis applies only to closed Friedmann universes, because a reliable definition of size (as opposed to scale factor) of flat or open universes is lacking. The only macroscopic length characteristic of the size of a closed Friedmann universe with radius $R(t)$ is the circumference $2\pi R(t)$. If energy $2E_\Delta$ to change the state of a bit associated with a particle within the universe (and the corresponding bit on the horizon) at baryon formation equals the energy of massless quanta with wavelength characteristic of the size of a closed Friedmann universe with radius R_{bf}, $2E_{\Delta} = \frac{\hbar c}{R_{bf}}$. Substituting from above, proton excess at baryon formation is $\frac{12E_{\Delta}}{k_B T_{Hbf}} = \left(\frac{24\pi c^2}{R_0}\right)\left(\frac{2.726}{T_{bf}}\right)\sqrt{\frac{3}{8\pi G \varepsilon_r}}$.

Dependence on R_0 arises because R_{bf}, the radius of the universe at baryon formation, depends on R_0, today's cosmic microwave background temperature 2.726 K, and temperature T_{bf} at baryon formation. For $R_0 \approx 10^{28}$ cm, proton excess is $\frac{12E_{\Delta}}{k_B T_{Hbf}} \approx 1.8 \times 10^{-9}$. WMAP estimated [12] ratio of baryon density to cosmic microwave background photon density as 6.1×10^{-10}. At the time of baryon formation, the number of protons with six $e/6$ bits, the number of anti-protons with six $-e/6$ bits, and the number of photon states with one $e/6$ and one $-e/6$ bit are approximately equal. When almost all protons and anti-protons annihilate to two photons, the ratio of baryon to photon states is $\frac{1}{3}\left(1.8 \times 10^{-9}\right) = 6 \times 10^{-10}$, in agreement with WMAP results.