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Holographic Analysis Determines Proton and Neutron Masses from Electron Mass

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Abstract

The Standard Model of particle physics assumes that fundamental fermions are point particles with zero radius, no spatial dimensions, and infinite matter density. This alternative model treats the nine charged fundamental fermions (three leptons and nine quarks) as spheres with non-zero holographic radius. Holographic analysis (based on quantum mechanics, general relativity, thermodynamics, and Shannon information theory) specifies electron mass by five fundamental constants: Planck's constant $\hbar$, gravitational constant G, fine structure constant α, cosmological constant Λ, and vacuum energy fraction Ω_Λ. Protons and neutrons are composite systems of up and down quarks. Describing forces between quark constituents confined within nucleons as inverse square attractive forces, this alternative model identifies composition factors C_p and C_n to relate proton and neutron masses to electron mass and thus to fundamental constants. An appendix summarizes holographic analyses characterizing astronomical masses at the opposite end of the mass scale for objects in the universe.

Keywords

Nucleon Masses, Electron Mass, Fundamental Constants

1. Introduction

Everything visible in our universe is composed of electrons, protons, and neutrons. Protons and neutrons are composed of up quarks and down quarks. The Standard Model of particle physics assumes that electrons, up quarks, and down quarks are point particles (with infinite matter density). In contrast, this holographic model treats charged fundamental fermions as spheres with non-zero holographic radius, to determine proton and neutron masses from electron mass and thus from fundamental constants.

2. Holographic Analysis

The radius of the event horizon of any observer in our vacuum dominated universe, with cosmological constant $\Lambda = 1.088\times10^{-56}\ \text{cm}^2$, is $R_H = \sqrt{3/\Lambda} = 1.661\times10^{28}\ \text{cm}$. Using PDG 2024 data [1] with Hubble constant $H_0 = 67.4\ \text{km}/(\text{sec}\cdot\text{Mpc})$, critical energy density $\rho_{crit} = \frac{3H_0^2}{8\pi G} = 8.533\times10^{-30}\ \text{g/cm}^3$, gravitational constant $G = 6.67430\times10^{-8}\ \text{cm}^3/(\text{g}\cdot\text{sec}^2)$, and vacuum energy fraction $\Omega_\Lambda = 0.685$, mass of the observable universe within the event horizon is $M_H = \frac{4}{3}\pi(1-\Omega_\Lambda)\rho_{crit}R_H^3 = 5.155\times10^{55}\ \text{g} = (0.187\ \text{g/cm}^2)R_H^2$.

Based on quantum mechanics, general relativity, thermodynamics, and Shannon information theory, holographic analysis [2] with Planck length $l_P = \sqrt{\frac{\hbar G}{c^3}} = 1.616\times10^{-33}\ \text{cm}$ finds only $N = \frac{\pi}{\ln(2)}\left(\frac{R_H}{l_P}\right)^2 = 4.741\times10^{122}$ bits of information on the event horizon will ever be available to describe the observable universe within the event horizon, and the mass associated with a bit of information on the event horizon is $m_{bit} = M_H/N = 1.078\times10^{-67}\ \text{g}$. This holographic analysis assumes the bits of information describing systems with definite mass m within the universe are available on spherical surfaces around the systems with radius $r = \sqrt{\frac{m}{M_H}}R_H$, therefore holographic radii of particles with definite mass m are $r = \sqrt{\frac{m}{0.187}}\ \text{cm}$.

This model, with electron holographic radius r_e, specifies holographic radii of the three lowest mass Standard Model fermions as r_e, $r_u = 2r_e$ and $r_d = 3r_e$, to predict up quark mass $m_u = 4m_e$ and down quark mass $m_d = 9m_e$. These up and down quark masses are within quark mass estimate ranges, based on intricate lattice quantum chromodynamic calculations, shown in "ideograms" on pages 2 and 4 of PDG 2024 "Particle Listings, Light Quarks."

3. Electron Mass from $G, \hbar, \alpha, \Lambda$ and Ω_Λ

Electron holographic radius $r_e = \sqrt{\frac{m_e}{0.187}}\ \text{cm}$ is the radius of a spherical holographic screen accommodating $N_e = \frac{\pi}{\ln(2)}\left(\frac{r_e}{l_P}\right)^2$ bits of information. Electrostatic potential energy of electron charge e and positron charge $-e$ separated by distance $2r_e$ is $V = -\frac{e^2}{2r_e} = -\frac{\alpha\hbar c}{2r_e}$ where $\alpha = \frac{e^2}{\hbar c}$ is the fine structure constant. Two adjacent spheres with holographic radius r_e, a precursor for electron-positron pair production, have total energy $E = 2m_ec^2 - \frac{\alpha\hbar c}{2r_e} = 0$ when

$r_e = \frac{\alpha \hbar c}{4 m_e c^2}$. Two equations for r_e result in $\frac{\alpha \hbar c}{4 m_e c^2} = \sqrt{\frac{m_e}{M_H}} R_H$ and the equation for electron mass $m_e = \left[\frac{(\alpha \hbar)^2}{32} \left(\frac{1-\Omega_\Lambda}{G \Omega_\Lambda} \sqrt{\frac{\Lambda}{3}} \right) \right]^{1/3}$ g.

PDG 2024 values predict electron mass 0.5% higher than actual electron mass to three significant figures. Setting $\Lambda = 1.08800 \times 10^{-56}\ \text{cm}^{-2}$ and increasing Ω_Λ by 0.5% to 0.6883855, within PDG 2024 error bars, specifies electron mass to six significant figures. Since gravitational constant G is only known to six significant figures, the calculation cannot be extended to greater precision until G is measured more precisely.

4. Proton and Neutron Masses from Electron Mass

The model considered in this paper describes protons and neutrons as an up or down quark bound to a diquark (composed of an up and down quark). Forces between quarks and diquarks are specified as attractive forces $-K_p (e/r)^2$ within protons and $-K_n (e/r)^2$ within neutrons.

Schrodinger equations for two particles bound by $-K(e/r)^2$ forces have the same form as the hydrogen atom Schrodinger equation, so two particles bound by a $-K(e/r)^2$ force have Bohr radius $a = \frac{\hbar^2}{\mu K e^2} = \left(\frac{\hbar c}{\mu c^2} \right) \left(\frac{\hbar c}{K e^2} \right) = \frac{\hbar c}{\alpha K \mu c^2}$, where μ is reduced mass of the two particles.

If quarks within protons were unbound, their masses would be $4U_p m_e$ and $9U_p m_e$. Corresponding unbound quark masses for quarks within neutrons would be $U_n 4 m_e$ and $U_n 9 m_e$.

Then reduced mass for the proton bound system is $\mu_p = \frac{(4U_p m_e + 9U_p m_e) 4U_p m_e}{4U_p m_e + 4U_p m_e + 4U_p m_e} = \frac{52}{17} U_p m_e$ and reduced mass for the neutron bound system is $\mu_n = \frac{(4U_n m_e + 9U_n m_e) 9U_n m_e}{9U_n m_e + 9U_n m_e + 4U_n m_e} = \frac{117}{22} U_n m_e$.

Hydrogen atom van der Waals radius is radius of the sphere surrounding all mass of a hydrogen atom. Free hydrogen atom van der Waals radius [3] is 3.16 times hydrogen atom Bohr radius. So, this model treats nucleon holographic radii r_p and r_n as 3.16 times Bohr radii a_p and a_n, resulting in $r_p = 3.16 a_p = \frac{3.16 \hbar c}{\alpha K_p U_p m_e c^2} = \frac{3.16 \hbar c}{\alpha C_p m_e c^2}$ and $r_n = 3.16 a_n = \frac{3.16 \hbar c}{\alpha K_n U_n m_e c^2} = \frac{3.16 \hbar c}{\alpha C_n m_e c^2}$, with composition factors $C_p = K_p U_p$ and $C_n = K_n U_n$. Thus $C_p = 5591$, $C_n = 5570$, proton mass $m_p = 1.87 \left(\frac{\hbar}{\alpha c C_p} \right)^2 \left(\frac{1}{m_e^2} \right) = \frac{0.986}{m_e^2} = 0.986 \left[\frac{(\alpha \hbar)^2}{32} \left(\frac{1-\Omega_\Lambda}{G \Omega_\Lambda} \sqrt{\frac{\Lambda}{3}} \right) \right]^{-2/3}$, and neutron mass $m_n = 1.87\left(\frac{\hbar}{\alpha c C_n}\right)^2\left(\frac{1}{m_e^2}\right) = \frac{0.979}{m_e^2} = 0.979\left[\frac{(\alpha\hbar)^2}{32}\left(\frac{1-\Omega_\Lambda}{G\Omega_\Lambda}\sqrt{\frac{\Lambda}{3}}\right)\right]^{-2/3}$.

Proton and neutron masses are therefore determined by composition factors C_p and C_n Planck's constant $\hbar$, gravitational constant G, fine structure constant α, cosmological constant Λ, and vacuum energy fraction Ω_Λ.

5. Neutrino Masses

Holographic analysis only applies to systems in the universe with definite mass. The three neutrinos in the Standard Model of particle physics oscillate between three mass states when travelling within the universe, so holographic analysis does not apply to neutrinos. The only lengths characteristic of neutrinos are their Compton wavelengths $\lambda = \frac{\hbar}{mc}$. If electron neutrinos are vacuum energy excitations, with radius $r = \frac{1}{4}\frac{\hbar}{mc}$ and the lowest energy density in the universe (cosmic vacuum energy density $\rho_v = 5.83\times10^{-30}\ \mathrm{g/cm^3}$), electron neutrinos have mass $m_1 = \left[\frac{\pi}{6}\rho_v\left(\frac{\hbar}{c}\right)^3\right]^{\frac{1}{4}} = 2.02\times10^{-36}\ \mathrm{g} = 0.0013\ \mathrm{eV}$. Neutrino oscillation data [4] [5] then predict $m_2 = \sqrt{m_1^2 + 7.42\times10^{-5}(\mathrm{eV})^2} = 0.00871\ \mathrm{eV}$ and $m_3 = \sqrt{0.5(m_1+m_2)^2 + 2.517\times10^{-3}(\mathrm{eV})^2} = 0.0507\ \mathrm{eV}$, resulting in neutrino mass sum = 0.0607 eV, consistent with minimum neutrino mass sum [6].

6. Conclusion

Electron, proton, and neutron masses have been considered independent fundamental constants of nature. Electron mass is determined by Planck's constant $\hbar$, gravitational constant G, fine structure constant α, cosmological constant Λ, and vacuum energy fraction Ω_Λ. This analysis specifies proton and neutron masses by composition factors $C_p = 5591$ and $C_n = 5570$ and electron mass. Therefore electron, proton, and neutron masses are *not* fundamental constants.

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Conflicts of Interest

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

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Appendix: Astronomical Masses from Holographic Analysis

Holographic analysis cannot address details of matter accumulation into large scale structures, but can account for masses of large-scale structures at specific times, with the following results:

Massive early galaxies

It was thought galaxies would not be seen at redshifts $z > 10$, because there was not time for them to develop so early in the history of the universe. Therefore, many were surprised when JWST found JADES-GS-z14-0 with mass $10^9 M_\odot$ at redshift $z = 14$. In contrast, holographic analysis [7] predicts *average* galactic mass $\sim 10^9 M_\odot$ for galaxies expected at redshifts z between 10 and 20.

Supermassive black holes in galaxy centers

Holographic analysis [8] predicts central supermassive black holes (SMBH) with mass $M_{SMBH}(z) = \sqrt{M_g(z) M_{sc}(z)}$ in galaxies at redshift z with isothermal matter density distribution within their holographic radii, where $M_g(z)$ is galactic mass and $M_{sc}(z)$ is mass of a star cluster within the galaxy.

Formation of first stars (Population III) at redshift $z = 66$

Holographic analysis [8], updated with PDG 2024 parameters, finds first stars (population III stars with mass $\sim 300 M_\odot$) formed at redshift = 66, consistent with observations.

Upper bound on supercluster, galaxy, and black hole masses

Holographic analysis [8], updated with PDG 2024 parameters, shows:

- Laniakea supercluster with mass $10^{17} M_\odot$, the most massive supercluster known, is consistent with an upper bound on supercluster mass equal to Jeans mass $1.16 \times 10^{17} M_\odot$.
- Galactic level Jeans mass $3.43 \times 10^{11} M_\odot$ is consistent with observations finding all galactic masses below $\sim 5 \times 10^{11} M_\odot$.
- The most massive black hole known, in SDSS J123132.37 + 013814.1, has mass $1.12 \times 10^{11} M_\odot$. That is consistent with an upper bound on SMBH mass (in a supercluster with isothermal matter density distribution and Jeans mass $1.16 \times 10^{17} M_\odot$) of $M_{maxSMBH}(0) = \sqrt{1.16 \times 10^{17} M_\odot M_{maxsc}(0)} = 5.17 \times 10^{11} M_\odot$.