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Origin of the Universe, Dark Energy, Dark Matter, and Visible Matter

T. R. Mongan

Sausalito, CA, USA
Email: tmongan@gmail.com

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Abstract

This concise *alternative* approach to cosmology is based on holographic analysis and Hamiltonian quantization of Friedmann's equation. It is consistent with PDG 2025 data and involves no singularities or infinities. Holographic analysis (based on quantum mechanics, general relativity, black hole thermodynamics, and Shannon information theory) allows only the finite number of bits of information on the event horizon to describe everything in our three space dimensions. That implies that our expanding universe is a closed system. This analysis then explains the origin of the universe and its contents, using uncomplicated mathematics. Treating the universe as a product space (described by a quantized Friedmann equation and a quantized equation for a closed compact space) allows for origin of the universe by a quantum fluctuation from nothing. Collapse of the compact space to radius of the Planck length inflated the three spatial dimensions we inhabit. Dark energy maintains the size of the compact dimension and accelerates the continuing expansion of our three dimensions. Dark matter particles, produced immediately after inflation by a force 10^{12} times stronger than gravity, have an estimated mass of 38 MeV/c^2. The holographic analysis requires matter dominance. Elementary particles treated as spheres require three fundamental fermions per charge state. Visible matter particles (up quarks, down quarks, and electrons) are shown to have masses specified by fundamental constants $\alpha, \hbar, c, \Lambda$ and Ω_Λ. Quantum fluctuations extending into the past and future indicate no beginning of time or "problem of time".

Keywords

Universe Origin, Quantum Cosmology, Dark Energy, Dark Matter, Matter Dominance, Visible Matter from Fundamental Particles

1. Introduction

This analysis provides a straightforward explanation for the origin of the universe and its contents. It accounts for key PDG 2025 data [1] without introducing mathematical singularities or infinities. If simpler explanations are developed in the future, this analysis will be superseded.

The analysis has three important implications:

1) Continuum mathematics, with its associated infinities and singularities, only approximates an underlying finite and discrete mathematics describing the universe;

2) Classical general relativity is not the best way to account for origin of the universe; and

3) The Standard Model of particle physics can be extended by abandoning the point particle approximation.

2. Holographic Analyses in a Closed Universe

Strong evidence shows the universe began 13.8 billion years ago as a small, closed space at high temperature that expanded and cooled since then. At a fundamental level, information specifies the distribution of matter within the universe, and a tremendous amount of information is required to describe structures, ranging from atoms to clusters of galaxies, in our three spatial dimensions.

Holographic analyses [2] (based on quantum mechanics, general relativity, black hole thermodynamics, and Shannon information theory) show that only a finite number of bits of information on the event horizon will ever be available to describe the universe and its contents. That implies the universe is a closed system described by discrete mathematics.

The event horizon at distance $R_H = \sqrt{\frac{3}{\Lambda}} = 1.661 \times 10^{28}\ \text{cm}$ from any observer's location is the farthest distance observers can ever see out into our vacuum-dominated universe with cosmological constant $\Lambda = 1.088 \times 10^{-56}\ \text{cm}^{-2}$. Using PDG 2025 data, mass of the observable universe inside the event horizon

$$M_H = \frac{4}{3}\pi\left(1-\Omega_\Lambda\right)\rho_{crit} R_H^3 = 5.16 \times 10^{55}\ \text{g} = \left(\frac{0.187\ \text{g}}{\text{cm}^2}\right) R_H^2$$

with Hubble constant $H_0 = 67.4\ \text{km}\cdot\text{sec}^{-1}\cdot\text{Mpc}^{-1}$, critical energy density $\rho_{crit} = \frac{3H_0^2}{8\pi G}\ \text{g/cm}^3 = 8.533 \times 10^{-30}\ \text{g/cm}^3$, gravitational constant $G = 6.67430 \times 10^{-8}\ \text{cm}^3 \cdot \text{g}^{-1} \cdot \text{sec}^{-2}$, and vacuum energy fraction $\Omega_\Lambda = 0.685$. Holographic analysis indicates the bits of information describing systems with definite mass m within the universe are available on spherical surfaces surrounding the system with radius $r = \sqrt{\frac{m}{M_H}} R_H$, so holographic radii of objects with definite mass m are $r = \sqrt{\frac{m}{0.187\ \text{g/cm}^2}}$.

With Planck length $l_P = \sqrt{\frac{\hbar G}{c^3}} = 1.61625 \times 10^{-33}\ \text{cm}$, holographic analysis finds only $N=\left(\frac{\pi}{\ln(2)}\right)\left(\frac{R_H}{l_P}\right)^2=4.741\times10^{122}$ bits of information encoded on areas of l_P^2 *on* the event horizon will ever be available to describe the observable universe *within* the event horizon. Half the bits on the horizon provide information associated with bits of *matter* within the horizon and the other half provide information associated with bits of *anti-matter* within the horizon. Mass of bits of *matter* within the universe is $m_{bit}=\frac{M_H}{2.371\times10^{122}}=2.17\times10^{-67}\text{ g}$.

3. ΛCDM Cosmology

ΛCDM cosmology, the current standard model of cosmology, is the simplest general relativistic theory providing a good account of the universe. Radius R of our closed, homogeneous, and isotropic three-dimensional space is specified by Friedmann's equation

$$\left(\frac{\mathrm{d}R}{\mathrm{d}t}\right)^2-\left(\frac{8\pi G}{3}\right)\left(\rho_{r0}\left(\frac{R_H}{R}\right)^4+\rho_{m0}\left(\frac{R_H}{R}\right)^3+\rho_V\right)\left(\frac{R}{c}\right)^2=-c^2$$

with today's radiation energy density ρ_{r0} and matter energy density ρ_{m0}, including cold (slow-moving) dark matter. Vacuum energy (dark energy) density ρ_V constitutes 68.5% of total energy density in our three dimensions. Negative pressure associated with vacuum energy density accelerates the observed expansion of our three dimensions. Invisible cold dark matter, constituting 26.5% of total energy density and 98.1% of matter density in our three dimensions, interacts only by gravitation and binds visible matter in stars into galaxies and galaxy clusters.

General relativity is not reliable at distances less than l_P, where quantum mechanical effects become important, so general relativity cannot explain our universe originating as a state with radius $R<l_P$ or a "singularity" with radius $R=0$. In contrast, this quantum cosmology explains the universe as originating with $R>l_P$.

4. Quantized Friedmann Equation

Friedmann's equation multiplied by 1/2

$$\frac{1}{2}\left(\frac{\mathrm{d}R}{\mathrm{d}t}\right)^2-\left(\frac{4\pi G}{3c^2}\right)\left(\rho_{r0}\left(\frac{R_H}{R}\right)^4+\rho_{m0}\left(\frac{R_H}{R}\right)^3+\rho_V\right)R^2=-\frac{1}{2}c^2$$

describes a unit mass particle at coordinate R moving in one dimension in potential

$$V(R)=-\left(\frac{4\pi G}{3c^2}\right)\left(\rho_{r0}\left(\frac{R_H}{R}\right)^4+\rho_{m0}\left(\frac{R_H}{R}\right)^3+\rho_V\right)R^2+\frac{1}{2}c^2$$

with zero total energy. Hamiltonian quantization of Friedmann's equation [3] results in the Schrodinger equation

$$-\frac{\hbar^2}{2}\frac{\mathrm{d}^2}{\mathrm{d}R^2}\psi(R)-\left(\frac{4\pi G}{3c^2}\right)\left(\rho_{r0}\frac{R_H^4}{R^2}+\rho_{m0}\frac{R_H^3}{R}+\rho_V R^2+\frac{1}{2}c^2\right)\psi(R)=E\psi(R)$$

for wavefunction $\psi(R)$ specifying radius R of our closed three-dimensional space, with total energy E.

5. The Universe Described as a Product Space

The universe can be described as a product space composed of our three closed space dimensions with radius R and a compact space with radius r. The equation

$$\left(\frac{\mathrm{d}r}{\mathrm{d}t}\right)^2+K_r(r-l_P)^2+c^2=E$$

describes a unit mass particle at coordinate r moving in one dimension in potential

$$V(r)=K_r(r-l_P)^2+c^2$$

with total energy E. The corresponding Schrodinger equation

$$-\frac{\hbar^2}{2}\frac{\mathrm{d}^2}{\mathrm{d}r^2}\psi(r)+\left(K_r(r-l_P)^2+c^2\right)\psi(r)=E\psi(r)$$

determines wavefunction $\psi(r)$ specifying radius r of the compact closed space. Describing the universe as a product space with wavefunction $\psi(R)\psi(r)$ allows origin of the universe by a quantum fluctuation from nothing, with expectation value $\langle R\rangle\langle r\rangle$.

6. Origin of the Universe from Nothing

The universe, a product space with wavefunction $\psi(R)\psi(r)$, probably originated by quantum fluctuation from nothing. Nothing (the absence of any thing, or any information) is a homogenous, isotropic state of indefinite size with zero energy and zero angular momentum. The quantum fluctuation producing the universe created an unstable initial state, resulting in the inflationary three-dimensional space we inhabit today and all of its contents.

In order of decreasing strength, forces acting today in the universe are the strong force, the electromagnetic force, the weak force, and gravity. Long-range forces are gravity, important at macroscopic scales, and electromagnetic force important at atomic scales. Planck mass $M_P=\sqrt{\frac{\hbar c}{G}}=2.176\times10^{-5}\ \mathrm{g}$, characteristic of gravity, has quantum mechanical Compton wavelength $l_P=\frac{\hbar}{M_P c}=\sqrt{\frac{\hbar G}{c^3}}$. Electromagnetic force is characterized by electron mass $m_e=9.109\times10^{-28}\ \mathrm{g}$, the lowest stable mass in the universe, and electron Compton wavelength is $l_e=\frac{\hbar}{m_e c}$. If those forces were unified when the universe originated, Planck mass equaled electron mass, and quantum wavelength of the universe's initial state was

$$l_e = \frac{\hbar}{m_e c} = \frac{M_P}{m_e} l_P = \frac{2.176\times10^{-5}\ \text{g}}{9.109\times10^{-28}\ \text{g}} l_P = 2.389\times10^{22} l_P = 3.861\times10^{-11}\ \text{cm}.$$

Origin of the universe by quantum fluctuation from nothing 13.8 billion years ago might seem unlikely, but it only had to occur once. If other universes originated in the same way at other times, they are profoundly elsewhere. We could never have contact with such universes, so they are scientifically irrelevant.

This description of the universe identifies time with quantum mechanical time, classical time, and cosmic time in a Friedmann universe. It allows for quantum fluctuations extending indefinitely into the past with no beginning of time and no "problem of time". In contrast, general relativity describes the relative *duration* of events observed in different systems moving relative to each other *within* the universe.

7. Initial State of the Universe

In the initial state of the universe, $\psi(R)$ specified radius R of a closed three-dimensional space filled with electromagnetic radiation, with $\rho_r = \rho_{r0}\left(\frac{R_H^4}{l_e^2}\right)$. Since $\psi(R)$ is zero at $R=0$ [4], the universe could not begin as a point singularity with zero radius. The quantum mechanical equation

$$\left[-\frac{\hbar^2}{2}\frac{\mathrm{d}^2}{\mathrm{d}R^2}\psi(R) - \left(\frac{4\pi G}{3c^2}\right)\rho_{r0}\left(\frac{R_H^4}{l_e^2}\right)\psi(R) - E\psi(R)\right]$$
$$\times\left[-\frac{\hbar^2}{2}\frac{\mathrm{d}^2}{\mathrm{d}r^2}\psi(r) + V_r\psi(r) + E\psi(r)\right] = 0$$

with $E=0$ allows origin of the universe by a quantum fluctuation from nothing into a product space with wavefunction $\psi(R)\psi(r)$, radius l_e, energy $E=0$ and $\frac{\mathrm{d}R}{\mathrm{d}t} = \frac{\mathrm{d}r}{\mathrm{d}t} = 0$.

8. Cosmic Inflation

Immediately after the universe originated as an unstable product space, radius of the compact space collapsed from radius l_e to l_P, inflating our three space dimensions by a factor of 2.389×10^{22} from radius l_e to $R_I = 9.223\times10^{11}$ cm. When the universe originated, energy of our three dimensions was $-\left(\frac{4\pi G}{3c^2}\right)\rho_{r0}\left(\frac{R_H^4}{l_e^2}\right)$ and energy of the compact space was $\left(\frac{4\pi G}{3c^2}\right)\rho_{r0}\left(\frac{R_H^4}{l_e^2}\right)$. Inflation duration T_I is determined by $\left(\frac{\mathrm{d}r}{\mathrm{d}t}\right)^2 + K_r\left(r - l_P\right)^2 + c^2 = E$. At universe origin, $\left(\frac{\mathrm{d}r}{\mathrm{d}t}\right) = 0$, $r = l_e = 3.861\times10^{-11}$ cm, $E = \left(\frac{4\pi G}{3c^2}\right)\rho_{r0}\left(\frac{R_H^4}{l_e^2}\right)$, $K_r = \left[\left(\frac{4\pi G}{3c^2}\right)\rho_{r0}\left(\frac{R_H^4}{l_e^2}\right) - c^2\right]\Big/\left(l_e - l_P\right)^2$, so

$$\begin{aligned} T_I &= \int_{l_e}^{l_P} \frac{\mathrm{d}r}{\sqrt{K_r\left(r-l_P\right)^2 + c^2}} \\ &= \frac{1}{\sqrt{K_r}} \ln\left(\left[\frac{c}{\sqrt{K_r}}\right] \Big/ \left[l_e - l_P + \sqrt{\left(l_e - l_P\right)^2 + \frac{c}{\sqrt{K_r}}}\right]\right). \\ &= 6.70\times 10^{-68}\ \text{sec} \end{aligned}$$

T_I is *much* less than Planck time 5.39×10^{-44} sec identified by Heisenberg's uncertainty principle as the shortest *measurable* time interval, so inflation happened almost instantly after the universe began.

Energy in the compact space after inflation, maintaining compact space radius at l_P, is now the constant dark energy accelerating today's expansion of our three space dimensions. Collapse of the compact space injected energy into our three dimensions that became matter. If bits of matter have slightly lower energy than bits of anti-matter, many more bits of matter than anti-matter were produced when energy was injected into our three space dimensions by compact space collapse. When almost all of the tremendous number of matter and anti-matter bits annihilated to two photons, only matter was left.

9. Dark Matter

Rigid spheres of dark matter with mass M and radius r have self-interaction cross-section $\sigma = 4\pi r^2$. Observations of eight galaxy clusters [5] find $\frac{\sigma}{M} = 0.082\frac{\text{cm}^2}{\text{g}}$, so $r = \sqrt{\frac{0.082M}{4\pi}}$ and dark matter particle density $\rho = \frac{M}{\frac{4}{3}\pi r^3} = \frac{45}{\sqrt{M}}\ \text{g/cm}^3$. Rigid spheres of dark matter with density equaling matter density $1.4\times 10^{19}\ \text{g/cm}^3$ in our three space dimensions immediately after inflation have mass $M = 6.7\times 10^{-26}\ \text{g} = 74 m_e = 38\ \text{MeV/c}^2$.

Formation of rigid impenetrable spheres of dark matter involves Friedmann's equation

$$\left(\frac{\mathrm{d}R}{\mathrm{d}t}\right)^2 - \left(\frac{8\pi sG}{3c^2}\right)\rho R^2 = -c^2$$

defining radius R of closed systems bound by effective gravity with gravitational constant sG, and its Hamiltonian quantization to Schrodinger's equation

$$-\frac{\hbar^2}{2}\frac{\mathrm{d}^2}{\mathrm{d}R^2}\psi(R) - \left(\frac{4\pi sG}{3c^2}\right)\left(\rho R^2 + \frac{1}{2}c^2\right)\psi(R) = E\psi(R)$$

for wavefunction $\psi(R)$ with total energy E. Schrodinger's equation with gravitational constant sG, has the mathematical form of Schrodinger's equation for hydrogen atoms and solving it results in $\langle R\rangle = \frac{sGM}{\pi c^2}$,

$\rho = M\Big/\left[\frac{4\pi}{3}\left(\frac{sGM}{\pi c^2}\right)^3\right]$, and $s = \frac{c^2}{G}\left[\frac{3}{\rho}\left(\frac{\pi}{M}\right)^2\right]^{\frac{1}{3}} = 1.8\times 10^{12}$.

Schwarzschild black holes with mass M have radius $r_S = \frac{2GM}{c^2}$, density $\rho_S = \frac{3c^6}{32\pi G^3 M^2}$, and Hawking temperature $T = \frac{\hbar c^3}{8\pi GMk}$, so rigid impenetrable spheres of dark matter result in a minimum black hole mass in today's universe. An aggregate of close-packed impenetrable spheres, each with density 1.4×10^{19} g/cm^3, has density $0.74\left(1.4\times10^{19}\ \text{g/cm}^3\right) = 1.0\times10^{19}\ \text{g/cm}^3$. In today's universe, the minimum mass of black holes composed only of rigid impenetrable spheres with mass $M = 6.7\times10^{-26}\ \text{g}$ is $0.15M_\odot$, about 15% of the mass of V723 Mon, the smallest black hole found to date. Hawking temperature of minimum mass black holes is $4.0\times10^{-7}\ \text{K}$, far below today's 2.7255 K CMB temperature.

10. Matter Dominance

Energy of bits of matter $(1-f)m_{bit}c^2$ and energy of bits of anti-matter $(1+f)m_{bit}c^2$ with $f = 5.079\times10^{-10}$ resulted in more matter than anti-matter in the universe. Radiation temperature after inflation was $T_I = \frac{2.7255\ \text{K}}{R_I/R_H} = 4.908\times10^{16}\ \text{K}$, with today's cosmic microwave background (CMB) temperature 2.7255 K. Ratio of nucleons to anti-nucleons, resulting from energy difference between matter and anti-matter bits, is the ratio of Boltzmann factors

$$\frac{m_N}{m_{\bar{N}}} = \mathrm{e}^{-\frac{(1-f)m_N c^2}{kT_I}} \Big/ \mathrm{e}^{-\frac{(1+f)m_N c^2}{kT_I}} \approx 1 + \frac{2fm_N c^2}{kT_I}$$

so nucleon excess is 6.04×10^{-10}. Nucleons are baryon constituents of all atomic nuclei, so nucleon excess 6.04×10^{-10} results in PDG 2025 baryon to photon ratio 6.04×10^{-10}.

11. Elementary Particles as Spheres

Standard Model particle physics treats elementary particles as point particles with angular momentum $\pm\hbar/2$, but point particles have zero volume, infinite energy density, and cannot rotate or have angular momentum. The Standard Model involves nine particles with charge qe (electrons, muons and tauons with $q = -1$, three quarks with $q = 2/3$, and three quarks with $q = -1/3$), but does not explain why only three particles are in each charge state.

In contrast, charged elementary particles treated as spheres rotating around an axis through their center have volume components, surface components, and axial components. Cubic equations for particle holographic radii in each charge state are

$$\frac{4}{3}\pi\rho r^3 = \frac{4}{3}\pi\rho_v r^3 + 4\pi\rho_s r^2 + \frac{3}{2\pi}\rho_a r$$

Rewritten as $Ar^3 + Br^2 + Cr = 0$ with $A = \frac{4}{3}\pi(\rho - \rho_v)$, $B = 4\pi\rho_s$, and

$C = \frac{3}{2\pi}\rho_a$, with average component mass densities ρ_v g/cm³, ρ_s g/cm², and ρ_a g/cm, the equations have positive discriminant and three (and only three) positive solutions corresponding to holographic radii of three particles in a charge state. Angular momentum $\pm\hbar/2$ is determined by clockwise or anti-clockwise rotation about the central axis and charge on the central axis precludes energy loss from accelerated charge.

12. Electron Mass from Fundamental Constants $\alpha, \hbar, c, \Lambda$ and Ω_Λ

Electron mass, the lowest mass particle persisting indefinitely, is specified by holographic analysis involving electron holographic radius r_e. Electrostatic potential energy of electron charge e and positron charge $-e$ separated by $2r_e$, a precursor to electron-positron pair production, is $V = -\frac{e^2}{2r_e} = -\frac{\alpha\hbar c}{2r_e}$ with fine structure constant α. Two adjacent spheres with radii r_e have total energy $E = 2m_e c^2 - \frac{\alpha\hbar c}{2r_e} = 0$ when $r_e = \frac{\alpha\hbar c}{4m_e c^2}$. Two equations for r_e result in

$$\frac{\alpha\hbar c}{4m_e c^2} = \sqrt{\frac{m}{M_H}} R_H \quad \text{and} \quad m_e = \left[\left(\frac{(\alpha\hbar)^2}{32}\right)\left(\frac{1-\Omega_\Lambda}{G\Omega_\Lambda}\sqrt{\frac{\Lambda}{3}}\right)\right]^{\frac{1}{3}}.$$

PDG 2025 parameters predict electron mass 0.5% higher than actual to three significant figures, but setting $\Lambda = 1.08800\times10^{-56}\ \text{cm}^{-2}$ and increasing Ω_Λ by 0.5% to 0.6883855 (within PDG 2025 error bars) specifies electron mass to six significant figures. Since gravitational constant G is known to six significant figures, the calculation cannot be extended to greater precision until G is measured more precisely.

13. Quarks and Neutrinos

Specifying up quark and down quark holographic radii as $r_u = 2r_e$ for up quarks and $r_d = 3r_e$ for down quarks results in up quark mass $m_u = 4m_e$ and down quark mass $m_d = 9m_e$ (within estimated ranges in PDG 2025 Quark Particle Listings).

Mass of electron neutrinos, described as spherical excitations of vacuum energy density $\rho_V = 5.840\times10^{-30}\ \text{g/cm}^3$ with radius one quarter their Compton wavelength, is

$$m_1 = \left[\frac{\pi}{16}\rho_V\left(\frac{\hbar}{c}\right)^3\right]^{\frac{1}{4}} = 2.66\times10^{-36}\ \text{g} = 0.00149\ \text{eV}$$

Neutrino oscillation data [6] predict

$$m_2 = \sqrt{m_1^2 + 7.49\times10^{-5}\,(\text{eV})^2} = 0.00878\ \text{eV}$$

$$m_3 = \sqrt{0.5\left(m_1 + m_2\right)^2 + 2.513\times10^{-5}\left(\text{eV}\right)^2} = 0.0507\ \text{eV}$$

resulting in neutrino mass sum 0.0609 eV, below the lowest upper limit 0.07 eV from terrestrial and astronomical observations.

14. Conclusion

This analysis accounts for key PDG 2025 data regarding our universe and its contents, using simple mathematics with no singularities or infinities.

Conflicts of Interest

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

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