Gravity as a Consequence of Mass Variation: A Reinterpretation via the Hubble Constant and Quantum Viscosity

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Abstract

We propose a reinterpretation of Newtonian gravity where the gravitational source is not the static mass M, but the rate of change of mass $Q = dM/dt$. By assuming that mass varies at a fractional rate proportional to the Hubble constant H_0, we derive a modified gravitational coupling constant $\nu = H_0/G$. We demonstrate that this constant can be expressed in terms of a dynamic viscosity η and the speed of light c, such that $\nu = \eta/c^2$. Furthermore, by identifying the viscosity with the quantum volume of a nucleon, we recover the Weinberg relation $m_p^3 = \hbar^2 H_0/(Gc)$, suggesting a deep connection between microscopic particle physics and cosmological expansion.

1 Introduction

The standard model of cosmology relies on the Hubble constant H_0 to describe the expansion of the universe Collaboration (2020). However, the origin of this constant and its relationship to fundamental particle physics remains an open question. Notably, Steven Weinberg observed a remarkable numerical coincidence involving the proton mass m_p, the Hubble constant, and fundamental constants:

$$m_p^3 \approx \frac{\hbar^2 H_0}{Gc}. \tag{1}$$

This relation suggests that the scale of the universe is linked to the scale of elementary particles Chitre and Nariai (1978); Weinberg (1972).

In this paper, we explore a physical mechanism that could underlie this relation. We hypothesize that gravity is not a direct property of static mass, but rather a consequence of a slow, continuous variation of mass over time, a concept explored in varying constant theories Dirac (1937). We show that if the source of gravity is the mass variation rate $Q = dM/dt$, and if this variation is proportional to the Hubble constant, we can derive a new coupling constant that naturally incorporates H_0/G.

2 The Hypothesis: Gravity from Mass Variation

Let us assume that the gravitational acceleration g produced by a body is proportional to the rate of change of its mass, rather than its static mass. Let Q be the source term:

$$Q = \frac{dM}{dt}. \tag{2}$$

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We postulate that the mass of any object varies at a fractional rate Ω:

$$\frac{1}{M}\frac{dM}{dt} = \Omega \quad \Rightarrow \quad \frac{dM}{dt} = \Omega M. \tag{3}$$

We further hypothesize that this rate Ω is proportional to the Hubble constant H_0:

$$\Omega = H_0. \tag{4}$$

Thus, the source of gravity becomes:

$$Q = H_0 M. \tag{5}$$

3 Motivation for $\Omega = H_0$

The hypothesis that the fractional rate of mass variation Ω is proportional to the Hubble constant H_0 is motivated by the concept of cosmological coupling. In General Relativity, matter and spacetime are dynamically coupled. If the mass of a particle is not an intrinsic constant but is generated by its interaction with the vacuum energy, then the mass must evolve as the vacuum evolves.

The vacuum energy density ρ_{vac} is related to the Hubble constant by $H_0^2 \propto \rho_{vac}$. If the mass M is coupled to the vacuum energy such that $M \propto \rho_{vac}^{1/2}$, then $M \propto H_0$. However, since H_0 is approximately constant in the current epoch, this suggests a different coupling. Consider instead that the mass is coupled to the scale factor $a(t)$ of the universe. If the mass scales with the volume of the observable universe, we might have $M \propto a(t)$. Then:

$$\frac{1}{M}\frac{dM}{dt} = \frac{1}{a}\frac{da}{dt} = H(t). \tag{6}$$

At the present epoch, $H(t) = H_0$, leading to $\Omega = H_0$.

Furthermore, from a dimensional perspective, H_0 is the only cosmological parameter with units of inverse time. If there is a fundamental process that generates mass over time, its rate must be proportional to a time scale. The Hubble constant is the only natural time scale that links the microscopic (mass) to the macroscopic (cosmology) in a way that produces the Weinberg relation. If Ω were proportional to some other constant, the dimensions would not match, or the effect would be negligible. Thus, $\Omega = H_0$ is the only cosmologically significant choice for the fractional rate of mass variation.

4 Derivation of the Modified Gravitational Law

We seek a gravitational law of the form:

$$g = -k\frac{Q}{r^2} = -k\frac{H_0 M}{r^2}, \tag{7}$$

where k is a new coupling constant with dimensions to be determined. We require this law to reproduce the observed Newtonian acceleration $g = -GM/r^2$ for a given mass M. Equating the two expressions:

$$-k\frac{H_0 M}{r^2} = -\frac{GM}{r^2}. \tag{8}$$

Solving for k, we find:

$$k = \frac{G}{H_0}. \tag{9}$$

Let us define a new constant ν as the inverse of this coupling:

$$\nu = \frac{1}{k} = \frac{H_0}{G}. \tag{10}$$

The dimensions of ν are:

$$[\nu] = \frac{[H_0]}{[G]} = \frac{T^{-1}}{L^3 M^{-1} T^{-2}} = ML^{-3}T. \tag{11}$$

This dimension matches that of mass density multiplied by time, or equivalently, dynamic viscosity divided by the square of the speed of light.

5 Connection to Dynamic Viscosity

We propose that ν can be expressed in terms of a dynamic viscosity η and the speed of light c, inspired by the idea that spacetime may have fluid-like properties Kovtun et al. (2005):

$$\nu = \frac{\eta}{c^2}. \tag{12}$$

The dimensions of dynamic viscosity are $[\eta] = ML^{-1}T^{-1}$. Dividing by c^2 (L^2T^{-2}) yields:

$$\left[\frac{\eta}{c^2}\right] = \frac{ML^{-1}T^{-1}}{L^2T^{-2}} = ML^{-3}T, \tag{13}$$

which is consistent with Eq. (11).

We now introduce a quantum volume V_n associated with a fundamental particle (such as a proton or neutron). Let us define the viscosity as Planck's constant divided by this volume:

$$\eta = \frac{\hbar}{V_n}. \tag{14}$$

The dimensions of $\hbar/V_n$ are:

$$\left[\frac{\hbar}{V_n}\right] = \frac{ML^2T^{-1}}{L^3} = ML^{-1}T^{-1}, \tag{15}$$

which correctly matches the dimensions of viscosity.

Substituting Eq. (14) into Eq. (12), we get:

$$\nu = \frac{\hbar}{V_n c^2}. \tag{16}$$

6 Recovering the Weinberg Relation

We now equate the two expressions for ν: Eq. (10) and Eq. (16):

$$\frac{H_0}{G} = \frac{\hbar}{V_n c^2}. \tag{17}$$

Rearranging for V_n:

$$V_n = \frac{G\hbar}{H_0 c^2}. \tag{18}$$

We assume that the quantum volume V_n is related to the Compton wavelength of a particle of mass m. The reduced Compton wavelength is $\lambda_c = \hbar/(mc)$ Griffiths (1987). We define the volume as the cube of this length:

$$V_n = \left(\frac{\hbar}{mc}\right)^3 = \frac{\hbar^3}{m^3c^3}. \tag{19}$$

Substituting Eq. (19) into Eq. (17):

$$\frac{H_0}{G} = \frac{\hbar}{\left(\frac{\hbar^3}{m^3c^3}\right)c^2} = \frac{m^3c^3}{\hbar^2c^2} = \frac{m^3c}{\hbar^2}. \tag{20}$$

Solving for m^3:

$$m^3 = \frac{\hbar^2 H_0}{Gc}. \tag{21}$$

This is precisely the Weinberg relation (1). Thus, if we identify the mass m with the proton mass m_p, the hypothesis that gravity arises from mass variation at a rate H_0 naturally leads to the observed connection between particle physics and cosmology.

7 Conclusion

We have presented a theoretical framework where gravity is sourced by the time derivative of mass, $Q = dM/dt$. By assuming that mass varies at a rate proportional to the Hubble constant, we derived a new gravitational coupling constant $\nu = H_0/G$. We showed that this constant can be interpreted as a viscosity term η/c^2, where $\eta = \hbar/V_n$. By identifying the quantum volume V_n with the cube of the Compton wavelength of a nucleon, we recovered the Weinberg relation $m_p^3 = \hbar^2 H_0/(Gc)$.

This suggests that the Hubble constant may not be an independent cosmological parameter, but rather a consequence of the quantum properties of matter and the dynamic nature of mass. Future work should explore the implications of this mass variation on orbital dynamics and the equivalence principle.

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