

Solution for Cosmological Constant Puzzle & Dark Energy in The Generalized Theory of Gravitational Aether

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Outline

- 1 Where Will Einstein Fail?**
- 2 The Cosmological Constant Puzzle
- 3 Gravitational Aether As Solution for C.C Problem
- 4 Black Hole Formation & Cosmic Acceleration
- 5 Theoretical Predictions & Observational Facts
- 6 General Conclusion & Future Perspectives



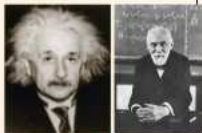
Figure : Richard Feynman

” You see, one thing is, I can live with doubt and uncertainty and not knowing. I think it’s much more interesting to live not knowing than to have answers which might be wrong” Richard Feynman.

WHICH PRINCIPLES TO KEEP?

- Lorentz symmetry

- Locality



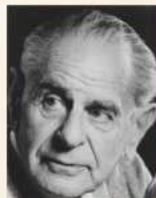
- Action principle

- Unitarity



- Falsifiability

- Predictivity



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Einstein in 1917 introduced the cosmological constant Λ to satisfy that his Equations of gravitational fields must describe the dynamics of a static universe.

$$G_{\mu\nu} \equiv R_{\mu\nu} + \frac{1}{2}g_{\mu\nu}R = 8\pi GT_{\mu\nu} - \Lambda g_{\mu\nu} \quad (1)$$

1929: Hubble discovered that the universe is expanding (Universe not static).

Physical Interpretation of Λ : if $T_{\mu\nu} = 0$ (no source of matter: the Vacuum), and $\Lambda \neq 0$, the space-time still curves, so Λ is the vacuum energy density.

- Theoretical value using QFT: $\Lambda \approx 10^{110}(\text{eV})^4$.
- Theoretical value using SUSY: $\Lambda \approx 10^{46}(\text{eV})^4$.
- Observed Value: $\Lambda \approx 10^{-12}(\text{eV})^4$. The fine-tuning between theoretical and observed value is called: **The cosmological constant puzzle.**

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$$(8\pi G')^{-1} G_{\mu\nu}[g_{\mu\nu}] = T_{\mu\nu} - \frac{1}{4} T g_{\mu\nu} + \dots, \quad (2)$$

where:

$$T_{\mu\nu} = \rho_0 g_{\mu\nu} + \text{Excitations}. \quad (3)$$

So, now the space-time metric $g_{\mu\nu}$ blind to the vacuum energy density (decoupling C.C from gravity) by introducing the above incompressible fluid.

We inspired the expression of ... term from the renormalizability of the emergent Horava-Lifshitz's quantum gravity at low energy:

$$S_{Horava-Lifshitz} = S_{Einstein-Hilbert} + \frac{1-\lambda}{16\pi G_N} \int d^4X \sqrt{-g} K^2, \quad (4)$$

$S_{Horava-Lifshitz} = S_{Einstein-Hilbert} +$ term behaves as incompressible fluid (with velocity $C_s^2 = \infty$, ie, **no new propagating degrees of freedom**).

So, the expression of $T'_{\mu\nu}$ is an incompressible fluid:

$$T'_{\mu\nu} = P'[(1 + \omega'^{-1})u_\mu u_\nu - g_{\mu\nu}] \quad (5)$$

For satisfying the Bianchi's identities:

$$T'^{\nu}_{\mu;\nu} = \frac{1}{4} T_{,\nu} \quad (6)$$

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- understanding of the static equilibrium description of the interior of the aether.
- The gravitational collapse of the interior of the aether: Black hole.

So, we need solution of Tolmann-Oppenheimer-Volkov Equations:

$$\frac{dm(r)}{dr} = 4\pi\rho' r^2; \quad (7)$$

$$\frac{dP'}{dr} = -(P' + \rho')\frac{d\phi}{dr}; \quad (8)$$

$$\frac{d\phi(r)}{dr} = \frac{m(r) + 4\pi r^3 P'}{r(r - 2m(r))}. \quad (9)$$

Spherically Symmetric Vacuum Solutions:

The solution of the pressure equation give us **hydrostatic equilibrium condition**:

$$p = p_0 e^{-\phi(r)} - \rho', \quad (10)$$

By substituting this expression to the metric ODE Equation and solving it, we find:

$$e^{\phi(r)} = \left(1 - \frac{2m}{r}\right)^{\frac{1}{2}} [4\pi P_0 f(r) + 1], \quad (11)$$

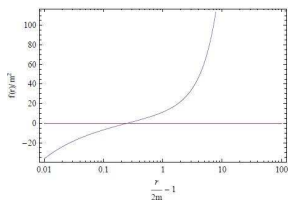


Figure : The asymptotic behaviour of $f(r)$, near, and far from the black hole

that implies that the BH metric for large r ie, $r \gg m_0$, or far from BH is described by:

$$ds^2 = - \left[1 + 2\pi \left(p_0 - \frac{2}{3}\rho' \right) r^2 - 2\pi \left(\frac{4}{3}m_0\rho' - 32\pi m_0^3 p_0 \rho' \right) r - \frac{32\rho' m_0^3 \pi}{r} \right]^2 dt^2 + \left(1 - \frac{8}{3}\pi\rho' r^2 \right)^{-1} dr^2 + r^2 d\Omega^2. \quad (12)$$

For small ρ this modified Schwarzschild BH's metric will be the same as de-sitter space's metric for $P_0 = -\frac{2\rho\Lambda}{3}$

So, the formation of the black hole trigger the cosmic acceleration, and we interpret the minus sign, as slow-moving observers accelerate through $\rho\Lambda$ away from the event horizon of BH.

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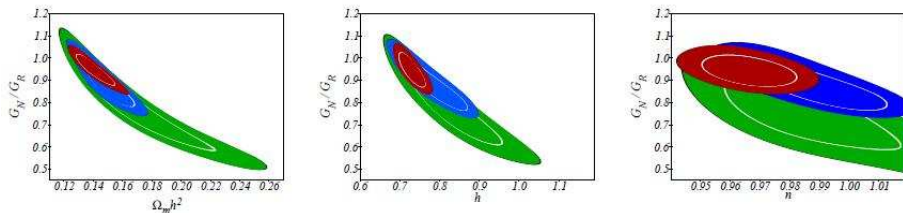


Figure : Some cosmological observations in, with confidence levels of the ratio $\frac{G_N}{G_R}$, 95% (for blue and red), and 68% (for white). On the other hand, in our GA theory, the estimated ratio is 75% which matches nicely these cosmological tests comparing with GR, when $G_N = G_R$.

- The Red-Shift: By Adopting the Transplanckian-Ansatz:

$$1 + Z_{max} = -\frac{1}{32\pi P_0 m^2} = \frac{T_{max}}{T_H} = 8\pi\theta_P m, \quad (13)$$

which implies:

$$P_0 = -\frac{1}{256\pi^2\theta_P m^3}, \quad (14)$$

So, the correction of the previous modified BH solutions is, in order of the Planck scale length in GA theory,

- **Theoretical value of the dark energy density is the same as the observed one when $m = 75M_\odot$!!**

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- We constructed a thermodynamical description of Einstein Equations by modifying the matter side.
- Decoupling the vacuum Energy density for Einstein's Equation → Solution for the C.C Puzzle.
- Corrections of BH's Solutions are in order of Planck Scale → Quantum Version of GA's Theory.
- UV and IR BH'solutions are coupled by the integration constant P_0 and Formation of BH trigger the cosmic acceleration (dark Energy).
- Recent Observational facts matches perfectly with Observational facts.

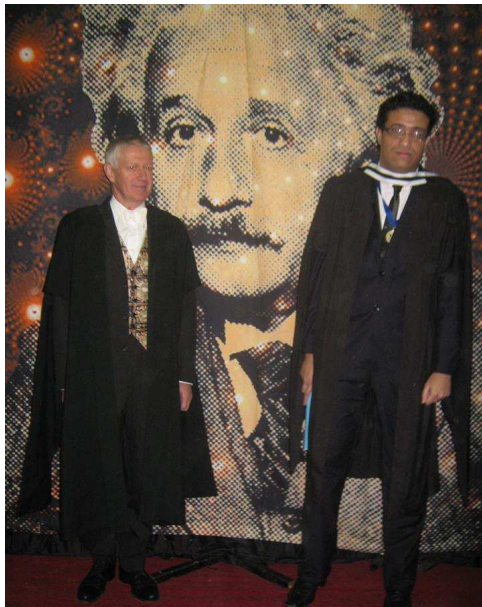




Figure : Me & Neil Turok

”Newton refused to be next Galileo, and Einstein refused to be next Newton, and the same for us, we refused to be next Einstein, but next African leader, who will draw next boundaries of Human Knowledge by revolutionary falsifiable Theories which will reveal the mystery of Nature and will change the face of history.” Mohammed Akram Fellah.

