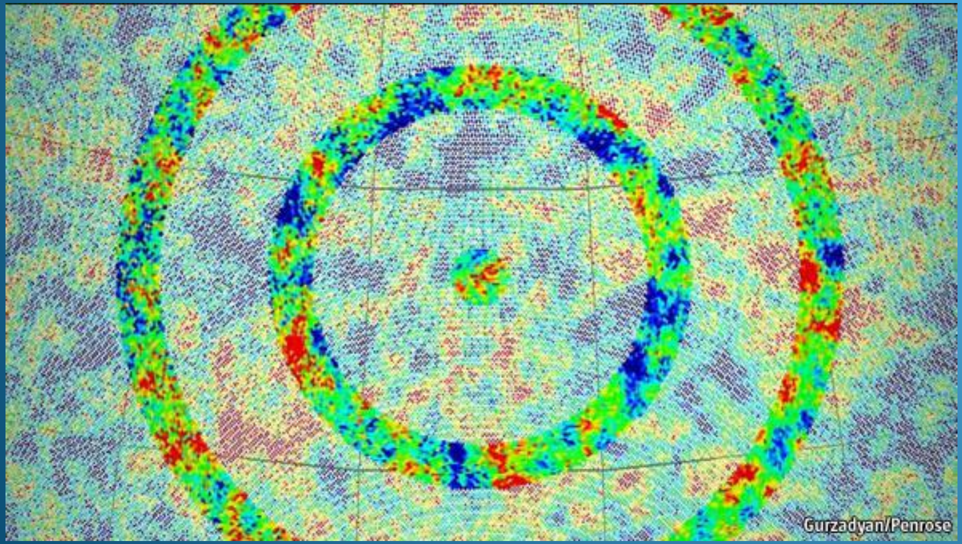
Varying constants and Cyclic Multiverses



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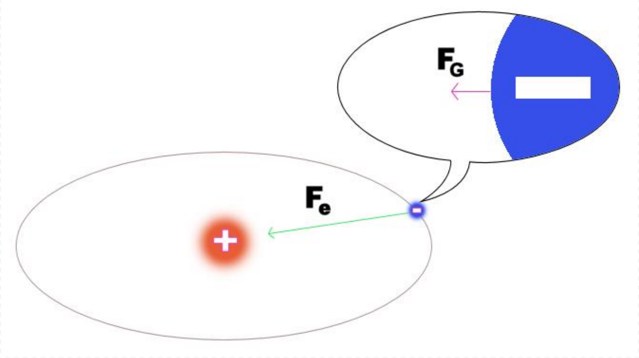
Large Numbers Hypothesis

Dirac noticed that the ratio of the **electromagnetic to gravitational** interaction between a proton and an electron is **roughly the same** as the ratio of the size of the observable universe to the classical radius of the electron.

$$\frac{F_e}{F_G} = \frac{e^2/(4\pi\varepsilon_0)}{G m_p m_e} \approx 10^{40} \quad \frac{R_u}{r_e} = \frac{c/H_0}{e^2/(m_e c^2)} \approx 10^{40}$$



Hubble parameter is inversely proportional to the age of the universe, so that to keep all ratios with Hubble parameter constant one needs:

$$G \propto 1/t$$

$$e^2/m_e \propto 1/t$$

Some limits for variation of fundamental constants

The Oklo phenomenom

Oklo is the name of a region in **Gabon** where an open-pit uranium mine is situated.

$$|\Delta\alpha/\alpha| < 5 \times 10^{-10}$$

Quasars

Quasar absorption lines provide a powerful probe of the variation of fundamental constants.

$$\frac{\Delta\alpha}{\alpha} = (-0.5 \pm 1.3) \times 10^{-5} \qquad 2.33 < z < 3.08$$

$$\frac{\Delta\alpha}{\alpha} = (-0.15 \pm 0.43) \times 10^{-5} \qquad 1.59 < z < 2.92$$

Varying Constants Theory

Field equation with varying „G” and „c”

$$\varrho(t) = \frac{3}{8\pi G(t)}\left(\frac{\dot{a}^2}{a^2} + \frac{kc^2(t)}{a^2}\right) ,$$

$$p(t) = -\frac{c^2(t)}{8\pi G(t)}\left(2\frac{\ddot{a}}{a} + \frac{\dot{a}^2}{a^2} + \frac{kc^2(t)}{a^2}\right)$$

And conservation equation:

$$\dot{\varrho}(t) + 3\frac{\dot{a}}{a}\left(\varrho(t) + \frac{p(t)}{c^2(t)}\right) = -\varrho(t)\frac{\dot{G}(t)}{G(t)} + 3\frac{kc(t)\dot{c}(t)}{4\pi G a^2}$$

Action in Brans-Dicke Theory:

$$S = \int d^4x\sqrt{-g}\,\left(\frac{\phi R - \omega\frac{\partial_a\phi\partial^a\phi}{\phi}}{16\pi} + \mathcal{L}_{\mathrm{M}}\right)$$

Conservation equation:

$$\Box\phi \quad = \quad \frac{8\pi}{3+2\omega}T,$$

Multiverse in varying G

First thermodynamics law:

$$d\rho + \frac{dV}{V}\left(\rho + \frac{p}{c^2}\right) - \frac{T}{Vc^2}dS = 0$$

And conservation equation:

$$d\rho + \frac{dV}{V}\left(\rho + \frac{p}{c^2}\right) = -\rho\frac{dG}{G}$$

If we combine this equations we will get:

$$-\frac{T}{Vc^2}dS = \rho\frac{dG}{G}$$

Which give:

$$dS = -\frac{\rho V c^2}{T}\frac{dG}{G}$$

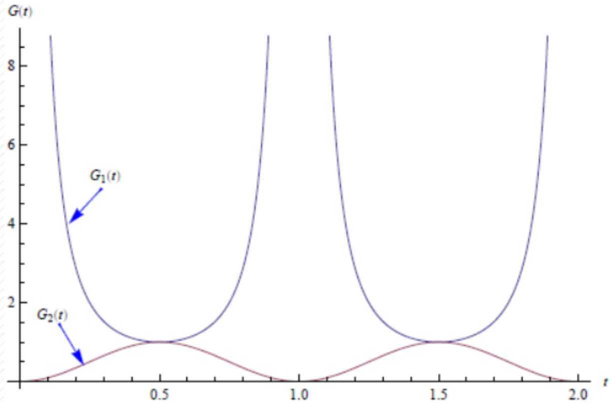
We can express entropy density by:

$$S(t) = N k_B \ln\left[\frac{A_0}{G(t)}\right],$$

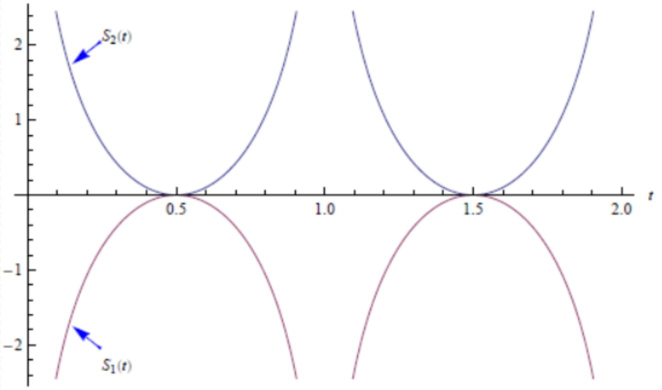
Multiverse with constant entropy

To avoid the problem of decreasing entropy in cyclic universe (2nd law of thermodynamics) we may assume that the entropy of the multiverse being a sum of entropies of individual universes is constant:

$$S = S_1 + S_2 + S_3 + ... + S_n = const.$$



Gravitational in both universes.



Entropy in both universes.

Thank You For Your Atention

The End