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From Quarks to Cosmos

Observational constraints on the possibility that Sterile Neutrinos cause Anti-Gravity

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Abstract

The origin of neutrino masses heralds new physics. Some theories that explain small neutrino masses, predict the existence of sterile neutrinos. Observationally, there is no evidence that neutrinos cause attractive gravity. Exploring a new idea, we study constraints posed by data as to what if sterile neutrinos cause repulsive gravity. We use an effective negative gravitational constant for the sterile neutrinos to constrain the extent of anti-gravity sourced by them. The case of an open universe is explored (in accordance with the positive value of H_0), taking into account different combinations of parameters, and collating with observed values.

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Analyzing Repulsive Gravity due to Sterile Neutrinos

Motivation :

- More no. of stars formed late in the cosmic timeline $\Rightarrow$ more supernovae explosions ; stellar neutrinos produced copiously.
- Greater flux of sterile neutrinos ; if they cause repulsive gravity $\Rightarrow$ accelerated expansion in late-time universe.

Modified Einstein Field Equation :

$$R_{\mu\nu} - \frac{1}{2} g_{\mu\nu} R = \frac{8\pi G}{c^4} T_{\mu\nu} - \frac{8\pi G'}{c^4} (T_{\mu\nu})_{s\nu}$$

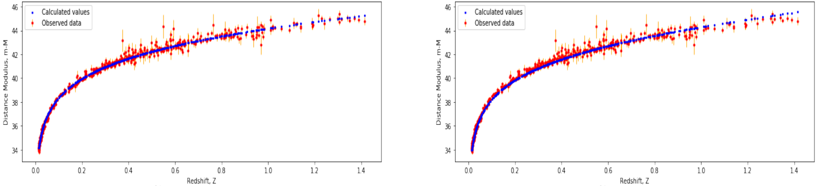
$$\boxed{H^2 = \frac{8\pi G}{3} \rho_m \left[1 - \frac{G'}{G} \frac{\rho_{s\nu}}{\rho_m} \right] - \frac{kc^2}{a^2} > 0} \Longrightarrow \boxed{k = -1}$$

- Replace $\Lambda g_{\mu\nu}$ with $-G'$ and $(T_{\mu\nu})_{s\nu}$. Solve modified FLRW equations.
- Calculate radial distance, $r(z)$, and thus distance modulus values :

$$\left[m - M = 5 \log_{10} \left(\frac{d_L}{10kPc} \right) \right]$$

Results & Conclusions

- Used z from Type Ia Supernovae observed data (Supernova Cosmology Project, Suzuki et al., 2012).
- Plotted and compared calculated & observed values of $(m - M)$ vs. z, according to best fit of the free parameter $\frac{G'}{G}\Omega_{s\nu}$. ($\Omega_{s\nu}$ = density parameter of sterile νs)
- Different combinations of H_0 and $\frac{G'}{G}\Omega_{s\nu}$ studied. Goodness of fit estimated using weighted least-squared minimization.
- Satisfactory fits even with recent findings of $H_0 \sim 73$ (Pesce et al., 2020).



(a) Light Sterile Neutrinos, $H_0 = 67.4, (G'/G)\Omega_{s\nu,0} = 0.1584$

(b) Massive Sterile Neutrinos, $H_0 = 73, (G'/G)\Omega_{s\nu,0} = 0.6904$

H_0	Massive case, $\frac{G'}{G}\Omega_{s\nu}$	Light case, $\frac{G'}{G}\Omega_{s\nu}$
67.4	0.3579	0.1584
69.8	0.5243	0.2199
73	0.6904	0.2685