Email: priyank.du94@gmail.com

Inflation models in the light of Self Interacting Sterile Neutrinos

Priyank Parashari[1,2], Arindam Mazumdar[3]& Subhendra Mohanty[1]

[1] Physical Research Laboratory, Ahmedabad, India

[2] Indian Institute of Technology, Gandhinagar, India

[3] Indian Institute of Technology, Kharagpur, India

Summary

SBL neutrino experiments, like LSND and MiniBooNE experiments, indicates towards the existence of eV mass sterile neutrinos. But eV mass sterile neutrinos are in tension with the cosmological observations. To accommodate sterile neutrinos in cosmology self interaction between sterile neutrinos has been studied. We analyzed Planck CMB data with self-interacting sterile neutrino (SIν) and studied their impact on inflation models. We found that the fit to the CMB data in SI model is as good as that to ΛCDM model and the spectral index values shift to 0.9375 ± 0.0058 in SIν model. We found that the Starobinsky and quartic hilltop model, which were allowed within CDM cosmology, are ruled out. Whereas some models like natural and Coleman-Weinberg inflation are now favored. Therefore, the existence of self interacting sterile neutrinos with eV order of mass will play an important role in the selection of correct inflation model. [1]

Self interacting sterile neutrinos

- Short-baselines experiments, like LSND and MiniBooNE, observed an as excess in electron like events of $\nu_\mu \to \nu_e$ oscillations.
- In order to explain this data by oscillation, $\Delta m^2 \sim \mathcal{O}(\mathrm{eV}^2)$ and mixing angle $\theta \sim 0.1$ are needed. Therefore, one light sterile neutrino specie is required to explain these events.
- In a cosmological model with one light sterile neutrino, number of relativistic degrees of freedom $N_{\rm eff}$ at the time BBN and CMB will be 4, which will be in tension with BBN and CMB observations.
- Self interaction between sterile neutrino was proposed to resolve this problem.

$$\mathcal{L}_{\rm int} = g_X \bar{\nu}_s \gamma_\mu \frac{1}{2}(1-\gamma_5)\nu_s X^\mu\,.$$

- Self interaction delays the mixing of sterile neutrinos with active neutrinos till sub-MeV temperatures, hence, alleviating the tension with BBN and CMB observation.

Quantum Kinetic equations and perturbation equations in SIν

- The flavor evolution of the 3+1 neutrino ensemble is governed by the QKEs

$$\mathrm{i}\frac{d\varrho}{dt} = [\Omega, \varrho] + C[\varrho]$$

where

$$\Omega = \frac{1}{2p}U^\dagger M^2 U + \sqrt{2}G_F\left[-\frac{8p}{3}\left(\frac{\mathcal{E}_l}{M_W^2}+\frac{\mathcal{E}_\nu}{M_Z^2}\right)\right] + \sqrt{2}G_X\left[-\frac{8p}{3}\frac{\mathcal{E}_s}{M_X^2}\right].$$

- Effective number of relativistic degree of freedom

$$N_{eff} = \mathrm{Tr}\rho(T) = \sum_{\alpha=1}^{4}\rho_{\alpha\alpha}.$$

Mass (m_i)	0.001	0.009	0.05	0.2
Degeneracy(ρ_i)	0.69	0.84	0.90	0.56

Table 1: Values of degeneracy obtained from QKE for different mass eigenstates in SIν model

- Neutrino Boltzmann equation can be written as

$$\frac{\partial\Psi_i}{\partial\tau} + i\frac{q}{\epsilon}(\vec{k}\cdot\hat{n})\Psi_i + \frac{d\ln f_0}{d\ln q}\left[\dot{\eta} - \frac{\dot{h}+6\dot{\eta}}{2}(\vec{k}\cdot\hat{n})^2\right] = -\Gamma_{ij}\Psi_j\frac{3\zeta(3)}{2\pi^2}aG_X^2T_\nu^5\rho_{ss}\,,$$

where $\Gamma_{ij} = \mathrm{U}\,\mathrm{diag}(0,0,0,1)\mathrm{U}^\dagger$.

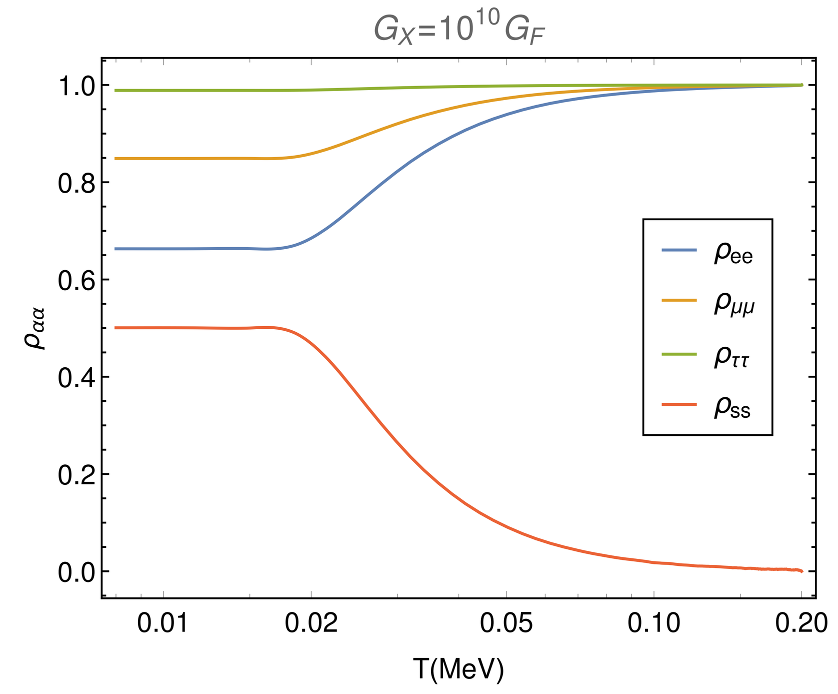

Figure 1: Self interaction delays the thermal mixing of neutrinos.

Results

- We analyze the effect of self-interacting sterile neutrinos on cosmological parameters using Planck CMB observations.
- Self-interaction helps to grow the perturbations on small scales and therefore the peaks of the CMB grows up due to that.

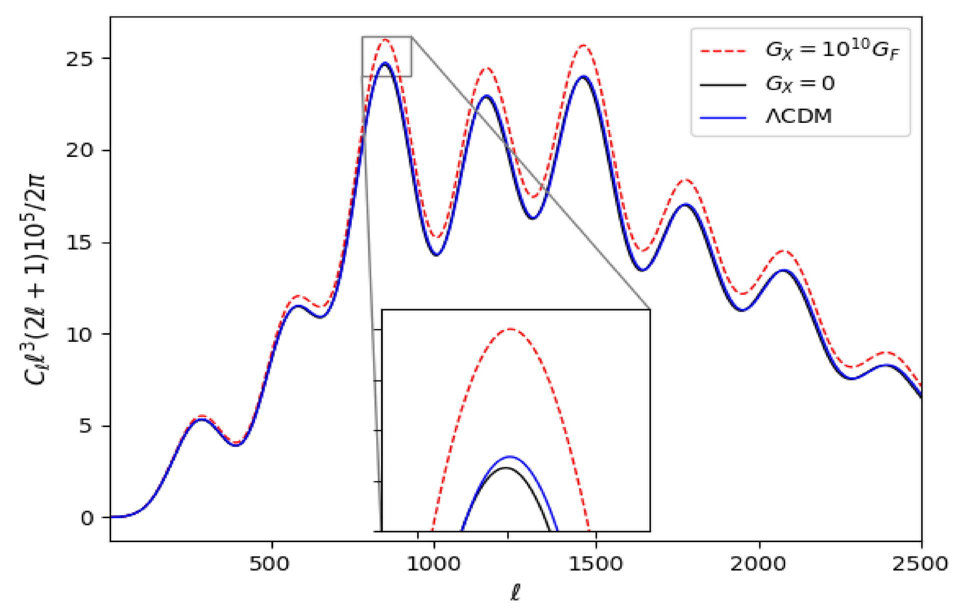

Figure 2: Effect of self interacting sterile neutrinos on the CMB temperature anisotropy power spectrum.

- Both ΛCDM and SIν models have equivalent statistical significance of fitting Planck CMB data.
- Introduction of self-interaction in the sterile neutrino sector leads to significant changes in the cosmological parameters allowed from CMB observations. Most importantly, best fit values of $n_s = 0.9643 \pm 0.0057$ in ΛCDM model changes to $n_s = 0.9361 \pm 0.0055$ in SIν model.
- We have considered four inflation models. Out of these models, two models, Starobinsky and quartic hilltop inflation, are disfavored in SIν model and models, natural and Coleman-Weinberg inflation, are favored now.

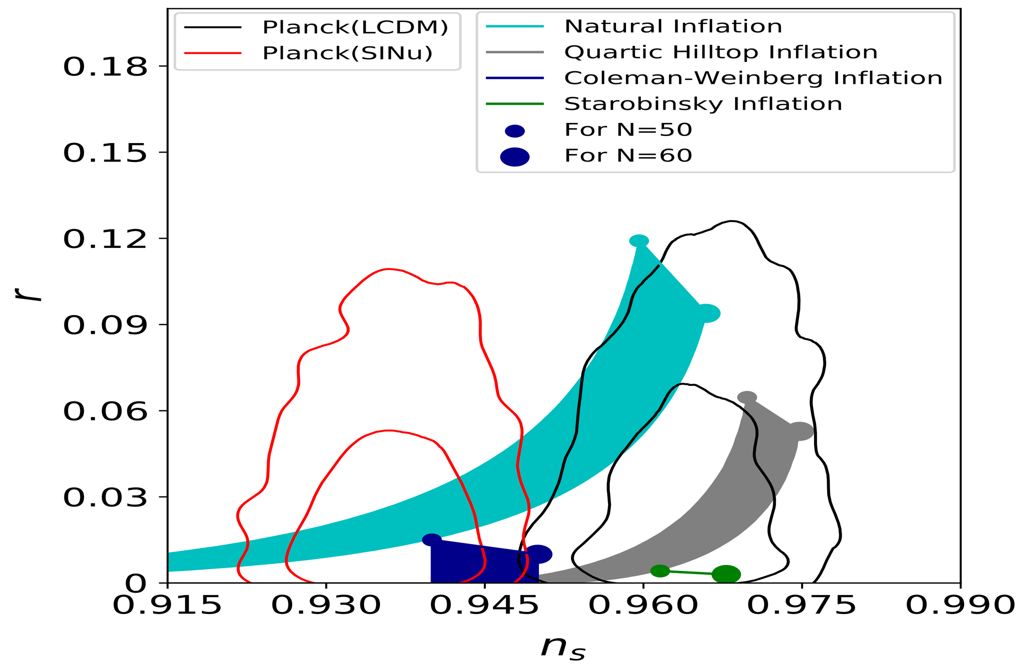

Figure 3: Effect of self interacting sterile neutrinos on $n_s - r$ parameter space.

Conclusions

- SBL oscillation experiments indicates the existence of light sterile neutrinos. Light sterile neutrinos are not favored by cosmological data.
- Self interaction between sterile neutrinos can resolve this problem. Introduction of self interaction makes a significant impact on the validity of different cosmological models.
- Starobinsky model is ruled out and models like quartic hilltop model is disfavored in the SIν cosmology. Whereas, models like natural and Coleman-Weinberg inflation are now favored.

References

[1] Arindam Mazumdar, Subhendra Mohanty, and Priyank Parashari. Inflation models in the light of self-interacting sterile neutrinos. *Phys. Rev. D*, 101(8):083521, 2020.