Impact of Beyond the Standard Model Physics in the Detection of the Cosmic Neutrino Background

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June 26, 2018

arXiv:1708.07841[hep-ph], JHEP09(2017)124

Outline

CMB and CνB

The discovery of the Cosmic Microwave Background radiation, CMB, represents a cornerstone in Cosmology. The CMB anisotropies are and indirect imprint of the CνB.

- CMB: Radiation from the epoch of recombination, photons started to travel freely.
- CνB: Radiation from neutrinos after they decoupled from matter

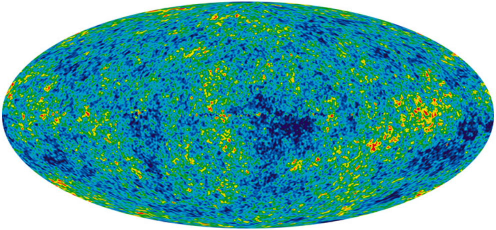


Figure 1: CMB, 13.77 billion year old temperature fluctuations (color differences)[Credit: NASA / WMAP Science Team]

The root mean square momentum of relic neutrinos is

$$\overline{p}_0 \approx 0.6\,\mathrm{meV}$$

and because

$$m_\nu \approx \mathcal{O}(0.1\,eV)$$

$\Rightarrow$ Relic neutrinos are non-relativistic.

Helicity operator, $\widehat{h}$, commutes with the free Hamiltonian

$$\left[\widehat{H}_{\text{free}}, \widehat{h}\right] = 0,$$

so, the helicity is conserved.

The today abundances are:

- Dirac neutrinos:

$$\begin{aligned} n(\nu_-^j) = & \quad n(\overline{\nu}_+^j) & = n_0 \approx 56\, cm^{-3} \\ n(\nu_+^j) \approx & \qquad 0 & \approx n(\overline{\nu}_-^j) \end{aligned}$$

- Majorana neutrinos:

$$n(\nu_+^j) = n(\nu_-^j) = n_0$$
$$n(N_-) = n(N_+) = 0$$

We focus in the capture of these relic neutrinos, through

$$\nu_e + {}^3\mathrm{H} \longrightarrow {}^3\mathrm{He} + e^-.$$

$$\Gamma_{C\nu B} = \sum_{j=1}^{3} \Gamma_{C\nu B}(j) = N_T \sum_{j=1}^{3} \left[\sigma_j(+1) v_j n_{\nu_+^j} + \sigma_j(-1) v_j n_{\nu_-^j} \right]$$

- Capture rate for Majorana Fermions is twice the Dirac ones, considering only SM.

$$\Gamma^M_{C\nu B} = 2\, \Gamma^D_{C\nu B}.$$

What is the effect of turning on BSM interactions?

$$\mathcal{L}_{\text{eff}} = -\frac{G_F}{\sqrt{2}} V_{ud} U_{ej} \left\{ [\overline{e}\gamma^{\mu}\mathbb{P}_L \nu_j][\overline{u}\gamma^{\mu}\mathbb{P}_L d] + \sum_{l,q} \epsilon_{lq} [\overline{e}\gamma^{\mu}\mathcal{O}_l \nu_j][\overline{u}\gamma^{\mu}\mathcal{O}_q d] \right\}$$

Table 1: Dimension 6 Effective operators.

ϵ_{lq}	$\mathcal{O}_l$	$\mathcal{O}_q$
ϵ_{LL}	$\gamma^{\mu}(1-\gamma^5)$	$\gamma^{\mu}(1-\gamma^5)$
ϵ_{LR}	$\gamma^{\mu}(1-\gamma^5)$	$\gamma^{\mu}(1+\gamma^5)$
ϵ_{RL}	$\gamma^{\mu}(1+\gamma^5)$	$\gamma^{\mu}(1-\gamma^5)$
ϵ_{RR}	$\gamma^{\mu}(1+\gamma^5)$	$\gamma^{\mu}(1+\gamma^5)$
ϵ_{LS}	$(1-\gamma^5)$	1
ϵ_{RS}	$(1+\gamma^5)$	1
ϵ_{LP}	$(1-\gamma^5)$	$-\gamma^5$
ϵ_{RP}	$(1+\gamma^5)$	$-\gamma^5$
ϵ_{LT}	$\sigma^{\mu\nu}(1-\gamma^5)$	$\sigma_{\mu\nu}(1-\gamma^5)$
ϵ_{RT}	$\sigma^{\mu\nu}(1+\gamma^5)$	$\sigma_{\mu\nu}(1+\gamma^5)$

PTOLEMY

The background in this experiment is the β-decay, because this process has no threshold. Considering $m_{^3H} \approx m_{^3He} \gg m_e \gg m_\nu$, we have

$$K_e^{C\nu B} \approx K_{end} + 2m_\nu$$

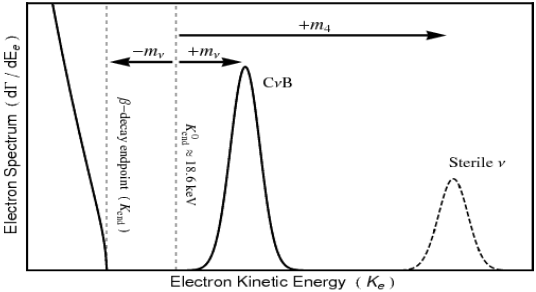


Figure 2: Signal of non-relativistic relic neutrinos captured by Tritium in the background of the β-decay at PTOLEMY.[2]

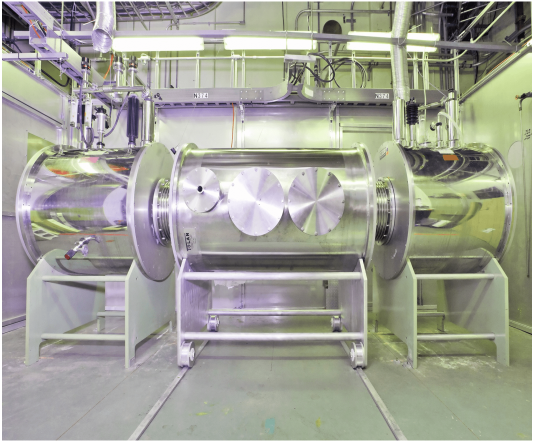
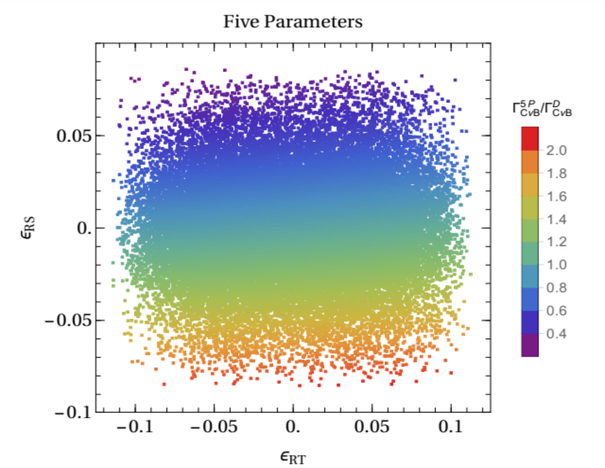


Figure 3: A prototype of PTOLEMY detector at the Princeton Plasma Physics Laboratory (February 2013). [1]



BSM interactions can mimic SM Majorana neutrinos!

$$\Rightarrow \Gamma^{BSM}_{C\nu B} \approx 2\,\Gamma^{D}_{C\nu B} = \Gamma^{M}_{C\nu B}$$

Thank you!

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