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

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Abstract

We discuss the effect of Beyond the Standard Model charged current interactions on the detection of the Cosmic Neutrino Background by neutrino capture on tritium in a PTOLEMY-like detector. We show that the total capture rate can be substantially modified for Dirac neutrinos if scalar or tensor right-chiral currents, with strength consistent with current experimental bounds, are at play.

Cosmic Neutrino Background (CβB)

Neutrinos were maintained in equilibrium due to \( \nu_e \rightarrow \nu_x \) and \( \nu_x \rightarrow \nu_e \).

\begin{align*}
\nu_e \text{ at } t = 0 \quad \text{and} \quad \nu_x \text{ at } t = 0
\end{align*}

When do they decouple?

Direct \( \nu_e \) and \( \nu_x \) capture rates

\begin{align*}
\Gamma_{\nu_e}^{\text{Total}} & = \frac{2}{3} \left( \sigma \nu \frac{1}{10^7} \right) m_{\nu_e} m_{\nu_x} \text{ keV}^{-1}
\end{align*}

Relic neutrinos are non-relativistic today.

\begin{align*}
\text{Temperature and root-mean-square momentum per neutrino species at the present time:} & \\
\text{\( T_e \approx 0.168 \text{ meV} \)}, & \text{\( \langle p_e \rangle \approx 0.064 \text{ meV} \)}
\end{align*}

How would be the detection?

BSM Capture Rate

\begin{align*}
\sigma_{\nu_e}^{\text{BSM}}(0, p_e) & = \frac{G_F^2}{4 \pi} \left( \frac{m_{\nu_e}}{m_{\nu_x}} \right)^2 \left( 1 - \frac{m_{\nu_x}^2}{2 p_e^2} \right) \langle p_e \rangle \text{ keV}^{-1}
\end{align*}

Right-handed couplings are relevant.

\begin{align*}
\mathcal{L}(\nu_e, \nu_x) & \geq 2 \frac{G_F^2}{4 \pi} \left( \frac{m_{\nu_e}}{m_{\nu_x}} \right)^2 \left( 1 - \frac{m_{\nu_x}^2}{2 p_e^2} \right) \langle p_e \rangle \text{ keV}^{-1}
\end{align*}

How would be the detection?

Conclusions

- The detection of the cosmic neutrino background could shed light on the neutrino fermionic nature and the absolute values of the masses.
- We found that BSM physics can hinder the discovery of the neutrino nature, as it can modify the capture rate in a PTOLEMY-like detector.

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References