DETECTING COSMIC NEUTRINO BACKGROUND

Weiler, T. (1982). Resonant Absorption of Cosmic-Ray Neutrinos by the Relic-Neutrino Background. Physical Review Letters, 49(3), 234–237. doi:10.1103/PhysRevLett.49.234

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OUTLINE

- Background
- Cosmic Neutrino Background
- Scattering of Cosmic Rays
- Resonant Scattering of Cosmic Rays
- Summary

CNB

Neutrinos decoupled from matter 2s after big bang.

Why CNB?

Detect early universe.

- CMB: 379,000 years, MeV
- CNB: 2 seconds, eV

CNB

Fermi Distribution

$$f_{\nu_i}(E, T) = \frac{1}{e^{(E-\mu_i)/kT} + 1}$$

Relativistic or Not?

Estimation using biologist's scale 300K $\sim \frac{1}{40}\mathrm{eV}$ and the fact that $T_\nu = 1.94$K.

Number Density

$$n_\nu \sim 10^2 \mathrm{cm}^{-3}$$

CMB photons $n_\gamma \sim 10^2 \mathrm{cm}^{-3}$. Hard to observe directly.

Mean Free Path and Hubble Radius

$$\lambda \sim 1/n_\nu \sigma + \sigma \sim G_F^2 s + \lambda < H_0^{-1}$$

$$\Rightarrow E > \frac{\pi}{2G_F^2 \rho_0 H_0^{-1}} \gtrsim 10^{14} \mathrm{GeV}.$$

Opaque universe at this energy

Resonant Scattering

CNB neutrinos are in a distribution of states.
Breit-Wigner form

$$\bar{\sigma} = \int ds \frac{\sigma(s)}{M_R^2} = \frac{16\pi^2 S\Gamma(R \to l\nu)}{M_R^3},$$

We can use

- $\nu\bar{\nu}$ annihilation on Z boson resonance;
- neutrino and electron interaction through resonant charged $W^{\pm}$. (Universe is opaque for charged electron at this energy.)

Transmission Probability

$\bar{\nu}$ is scattered by CNB ν through resonant Z,

$$P \propto e^{-\tau}$$

where

$$\tau = \int_{t}^{t_0} dt \int \frac{d^3p}{(2\pi)^3} f_\nu(p)\sigma_z \left(1 - \frac{p\cos\theta}{\sqrt{p^2 + m^2}}\right).$$

θ: incident angle of collision.

- Smaller $\theta \rightarrow$ larger transmission;
- Larger cross section $\rightarrow$ smaller transmission;
- Larger f_ν $\rightarrow$ larger neutrino density $\rightarrow$ smaller transmission.

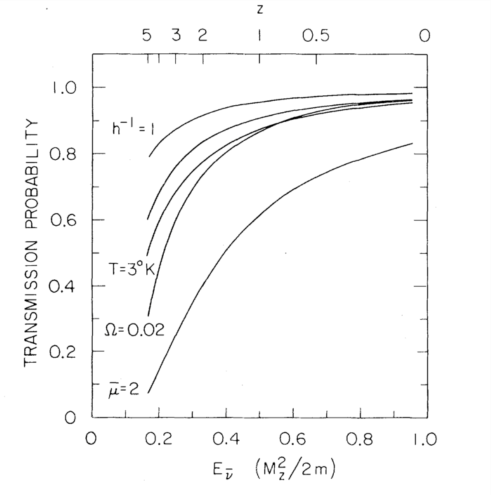

Figure: Transmission Probability for Different Energies. Default values $h^{-1} = 2$, $\Omega = 1$, $\bar{\mu} = \mu/kT = 0$, $T = 2.7K$. 15% to 50% dip for $z = 3.5$

Absorption Dip Energy

The (anti)neutrino flux of any source with (anti)neutrino energy $10^{11\pm1}\mathrm{GeV}$ is in theory reduced. The further away, the larger the dip.

But

We need to know well about the neutrino production of the source.

REFERENCES

1. Weiler, T. (1982). Resonant Absorption of Cosmic-Ray Neutrinos by the Relic-Neutrino Background. Physical Review Letters, 49(3), 234–237. doi:10.1103/PhysRevLett.49.234

Backups

NUMBER DENSITY OF CNB NEUTRINOS

$$n_{\nu_i}(\bar{\mu}_i) = \frac{1}{(2\pi)^3}\int d^3p f_{\nu_i}(p(a))$$

$$u_{\nu_i} = \frac{1}{(2\pi)^3}\int d^3p \sqrt{p^2 + m_i^2}\,(f_{\nu_i}(p(a)) + f_{\bar{\nu}_i}(p(a)))\,.$$