Extragalactic high energy neutrinos

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Cosmic Ray Bound on Extragalactic Neutrino Flux

• $\gamma + p \rightarrow \pi^+ + n$

• Protons observed as cosmic rays

• $\pi^+ \rightarrow \nu_\mu, \bar{\nu}_\mu$

• Proton flux sets limit on neutrino flux

• Assume protons escape: optically thin at $10^{19}$ eV
Effects included

- Energy loss via interaction with CMB
- Energy loss via redshift
- Redshift evolution: like quasars, star formation
WB Bound (with evolution)

\[ E_{\nu}^2 \phi_\nu = 5 \times 10^{-8} \text{ GeV/cm}^2\text{s sr} \]
GRBs?

by Eli Waxman

$E^2 \phi_{\nu} \text{ [GeV/cm}^2 \text{s sr]}$

AMANDA($\nu_{\mu}$); Baikal($\nu_{e}$) Bound

Waxman-Bahcall Bound

No evolution

Atmospheric $\rightarrow$

GRBs?

$E_{\nu} \text{ [GeV]}$

by Eli Waxman

$0.1 \text{ km}^2$

$1 \text{ km}^2$

$GZK$
Little known facts about WB limit

Applies also: $p + p \rightarrow p + n + \pi^+$

$p + n \rightarrow n + n + \pi^+$

$n + n \rightarrow p + n + \pi^-$

“The Waxman Bahcall bound overestimates the most likely neutrino flux by a factor $\sim 5/\tau$, for small optical depths $\tau$.” B&W: hep-ph/9902383
Lower energies

Max. protons $\propto E^{-2}[1 + 0.1(10^{17}\text{ eV} / \text{E})]$
Ways out

- Decays of supermassive dark matter
- Topological defects
- Superheavy relic neutrinos
- Ultrahigh-energy photons
Predicted Characteristics of GRB ν’s

1) \( E^2 \Phi_\nu (E) = 3 \times 10^{-9} \text{ GeV cm}^{-2} \text{s}^{-1} \text{sr}^{-1} g(E) \)

\[ E_c = 10^{+2} \text{ TeV} \]

\[ g(E) = \begin{cases} 1, & E > E_c \\ (E / E_c), & E < E_c \end{cases} \]

2) \( t(\nu) = t(\gamma)(\sim 1 \text{ sec}) \)

\[ g(E) = \begin{cases} 1, & E > E_c \\ (E / E_c), & E < E_c \end{cases} \]

3) Direction(\nu) = Direction(\gamma)
Detection signatures

*) Direction of GRB

*) $t_\nu = t_\gamma$ (~10 sec)

*) Flux $\sim 10 \text{ km}^2 / \text{yr}$