End of the Cosmic Neutrino Spectrum?

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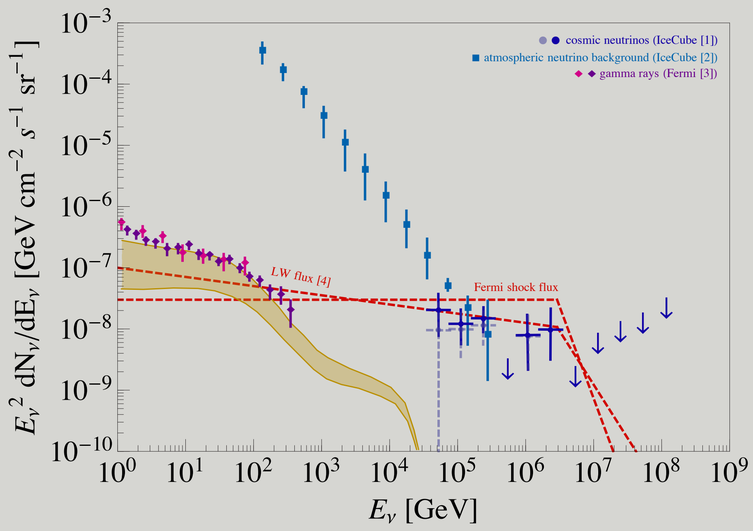
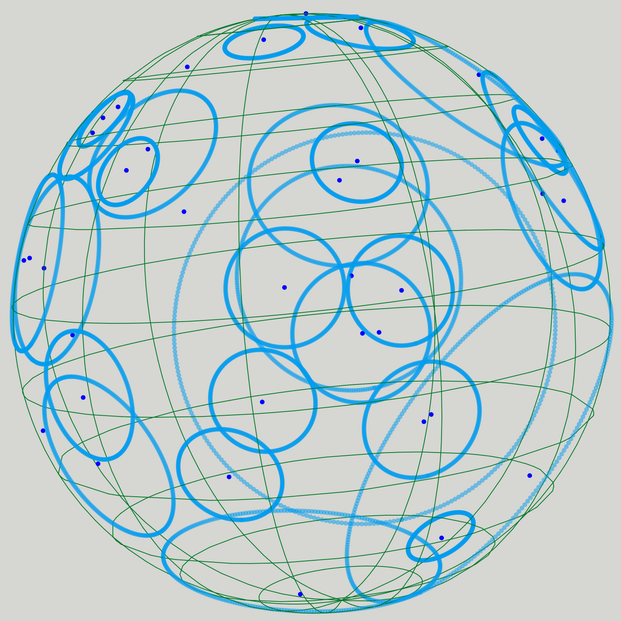
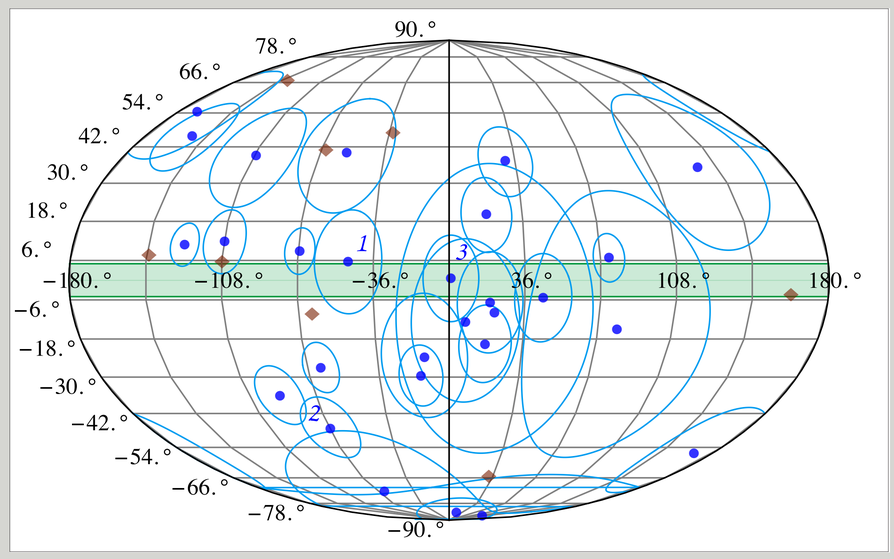
IceCube and *Fermi* Observations







Left: Neutrino and gamma ray spectra compared to flux models
Middle & Right: Arrival direction distribution of IceCube events in Galactic coordinates (circles = showers, diamonds = traks)
Figures taken from Ref. [5]

Source Candidates

- Absence of "Glashow resonance" events $\bar{\nu}_e + e^- \to W^- \to$ shower at $E_{\bar{\nu}_e} = 6.3$ PeV implies strong suppression of neutrino spectrum
- Effective area at resonant energy
  (about 40 times that of off-resonance events at a PeV)
  offsets falling unbroken power law of neutrino spectrum ($\propto E_\nu^{-\alpha}$)
- Expected event number for neutrino flux on-resonance at ~ 6.3 PeV relative to 3 observed events at $\sim$ PeV ☞ $3\times 40\times 6.3^{-\alpha} = 3\times(6.3)^{(2-\alpha)}$
- Earlier statistical study [6] concluded that α was constrained by absence of Glashow events in IceCube data to $\alpha \geq 2.3$
- If sources are extragalactic γ's accompanying ν's saturate Fermi data for $\alpha \approx 2.15$ [7] (left fig.)
  - Arrival directions consistent with isotropy (right fig.)
  - Second highest energy event out of Galactic plane
- Three previous points suggest cutoff
- LW predicted diffuse ν flux from starbursts which gives correct α, normalization, and consistent with cutoff at $E_\nu \sim 3$ PeV (left fig.)
- Cutoff *could* be astrophysical or . . .

Crazy Physics

- The fact that IceCube does not (yet) see neutrinos with $E_\nu \gtrsim$ PeV invites some interesting speculation: Perhaps there are none!
- Herein we impose limiting velocity $v_{\rm max}$ on each lepton flavor
  (as long as each $v_{\rm max} < c$ ☞ causality is preserved)
  new "lightcones" appear inside *the* lightcone
- Postulate equivalence of limiting energy and limiting velocity β_ν

$$E_\nu^{\rm max} \equiv \frac{m_\nu}{\sqrt{1-\beta_\nu^2}} \sim \frac{m_\nu}{\sqrt{2(1-\beta_\nu)}} \quad \text{with} \quad \beta_\nu \equiv \frac{v_\nu}{c}$$

- Accordingly ☞ required $v_{\rm max}$ to suppress ν's above $E_\nu^{\rm max}$ is $\beta_\nu \approx 1-\frac{1}{2\gamma_\nu^2}$ which differs from speed of light by

$$1-\beta_\nu \simeq 0.5\times 10^{-28}\left(\frac{m_\nu}{10\,{\rm meV}}\right)^2\left(\frac{\rm TeV}{E_\nu^{\rm max}}\right)^2$$

- Consequences are significant:
  - Kinematics of $\begin{matrix}\pi^+\to\mu^+\nu_\mu\\ \pi^-\to\mu^-\bar{\nu}_\mu\end{matrix}$ having common maximum energy $E_\nu^{\rm max}$ dictates that $\pi^\pm$ are stable above $\sim 2E_\nu^{\rm max}$
  - π is certainly stable if $E_\pi > E_{\nu_\mu}^{\rm max} + E_\mu^{\rm max}$ and $E_\pi > E_{\nu_e}^{\rm max} + E_e^{\rm max}$
  - Stabilized π could be UHECR primaries with $E > 2E_\nu^{\rm max}$
    (at or above the knee)
  - π showers more p-like than γ-like and so not excluded by data
  - Generally speaking ☞ $E_{\nu_\mu}^{\rm max} \neq E_\mu^{\rm max} \neq E_{\nu_e}^{\rm max} \neq E_e^{\rm max}$
    hence track to shower ratio may be anomalous for $E_\nu \sim 1$ PeV
- For details see arXiv:1404.0622

Final Remark

Of course ☞ Ockham's razor favors the absence of this baroque explanation for the cutoff. The simplest means to raise the search limit for $E_\nu^{\rm max}$ (and reduce the motivation for our speculation) is to observe neutrinos with energies extending to higher and higher values. However ☞ if the absence of observed neutrinos above some energy persists, it would be evidence that Nature is more whimsical than William of Ockham.

References and Acknowledgements

[1] IceCube Collaboration, arXiv:1405.5303; [2] IceCube Collaboration, arXiv:1010.3980; [3] Fermi Collaboration, arXiv:1002.3603;
[4] Loeb and Waxman, astro-ph/0601695; [5] Anchordoqui, Paul, da Silva, Torres, and Vlcek arXiv:1405.7648;
[6] Anchordoqui, Goldberg, Lynch, Olinto, Paul, Weiler, arXiv:1306.5021; [7] Murase, Ahlers, and Lacki, arXiv:1306.3417.

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