Neutrino Energy Distributions: The GRB example.

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X-rays

Optical

ν

ν

γ

γ

ν

NED construction

External shocks (PeV)

After the prompt emission phase, the jet starts interacting with the ISM and gets decelerated as a forward shock propagates through the ISM and a short-lived reverse shock crosses the jet. The accelerated protons interact with the afterglow photons, producing ~PeV neutrinos through photomeson processes.

The spectrum depends on the shock evolution, which could be adiabatic or radiative, and on the density profile of the interstellar medium (ISM).

Prompt emission (TeV)

Non-thermal particles are accelerated via internal energy dissipation in the jet. The accelerated protons interact with the photons emitted by the electrons, leading to production of high-energy neutrinos via the photomeson production process.

There exists different models for the acceleration mechanisms, involving diffuse shock acceleration, or magnetic reconnection. They mainly differ by the radius at which the dissipation occur.
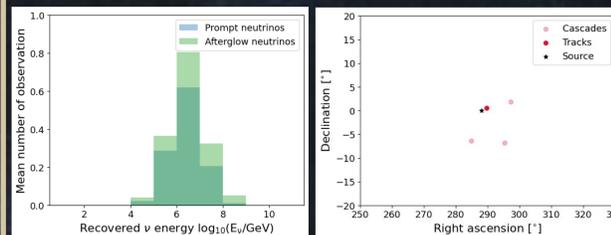
Early production (GeV)

• Proton-neutron decoupling:
If the neutron-proton decoupling occurs before the coasting, neutrons will collide with the accelerated protons, producing ~1-10 GeV neutrinos
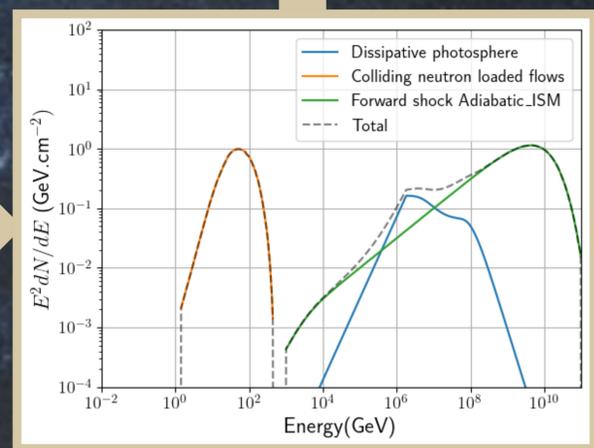
• Neutron-loaded outflow collision:
Otherwise, the presence of inhomogeneities in the jet leads to internal collisions between neutron-loaded flows, enabling the production of ~100 GeV via hadronuclear reactions.

Search for astrophysical sources

One can use the NEDs to make pseudo-experiments taking into account instruments response function. Here is an example with the IceCube PSTracks sample.
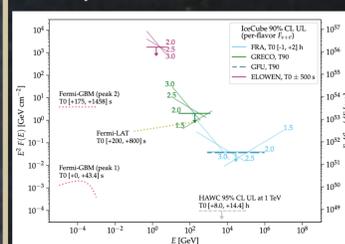

A database of signal-like events can be generated for each event-selection sample to train a machine learning classifier. Once trained, the classifier can efficiently search for sources in both archival and future data by combining information across the entire energy spectrum
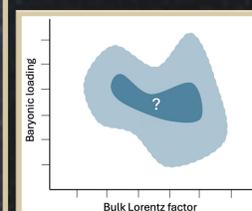

Better follow-ups

Current IceCube follow-ups are carried independently in each event-selection database, often assuming a simple power-law spectrum, and return flux normalization.

Abbasi, R. *et al.* ApJL **946**, L26 (2023).

NEDs give us the opportunity to combine data from different event samples into a single statistical analysis. Beyond the gain in sensitivity from combining datasets and the improved flux modeling, this approach allows us to explore the intrinsic parameter space of the GRB source itself.

GRB parameters

• Bulk Lorentz factor
• Baryonic loading
• « Magnetic » loading
• Isotropic energy
• Redshift
• Isotropic luminosity
• np ratio
• γ break energy
• γ HE spectral index
• γ LE spectral index
• CR injection index
• Internal dissipation radius
• ISM profile
• ISM density

Our objective is to build NEDs for other promising neutrino-emitting sources, starting with:
• Supernovae
• Active Galactic Nuclei
• Tidal disruption events
• Any interesting model you would like to see implemented

Next sources