Correlation between $\gamma$-rays and PeV Neutrinos in Blazar PKS B1424-418?

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Abstract

A potential correlation between an IceCube PeV-neutrino event and the gamma-ray burst phase of the flat spectrum radio quasar PKS B1424-418 was recently suggested. In this study, we simulate both the multi-wavelength photon and the neutrino emission from this source using a self-consistent radiation model. Using analytical arguments and numerical studies of the large parameter space we find that a simple hadronic model cannot adequately describe the spectral energy distribution for this source, but a lepto-hadronic model with sub-dominant hadronic component can reproduce the multi-waveband photon spectrum observed during various activity phases of the blazar. Up to about 0.4 neutrino events may coincide with the outburst, and tension with spectral energy distribution arises for larger neutrino event rates. We point out that simply assuming a direct relation between the neutrino fluence and the $\gamma$-ray fluence in a certain waveband ignores the leptonic contribution in that energy band which may in fact dominate the emission.

Motivations

Why blazars
• Contribute to the most of extra-galactic background $\gamma$-rays which may be neutrino counter-parts
• Relativistic Beaming: boosts luminosity & point-source identification possible

Why PKS B1424-418 (by Kadler et al. 2016)
• Sufficient energy budget for a PeV $\nu$ event, if $L_{\nu} \sim L_{\gamma}$
• Spatial and temporal consistency with IC35 (2-PeV $\nu$ event)

Why this work
• Needs a self-consistent model for this source
• The assumption $L_{\nu} \sim L_{\gamma}$ must be critically reviewed
• Parameter scan & model analysis, taken full advantage of multi-wavelength observation

General Analysis

Veto “LH-SSC”:
- Allowed parameter-regions in color, on bulk Lorentz factor $\Gamma$ and magnetic field $B$
- No region has all four colors — LH not viable

Veto “pure hadronic”:
- 1st ($p$-syn) and 2nd ($p$-decay) peak requires different $B$

Conclusion: leptonic + sub-dominant hadronic, model 1 or 2 OK

Numerical Simulation

Method:
• Solving the coupled time-dependent integro-differential kinematic equations for $e^\pm$,$p$, $\nu_e$, $\bar{\nu}_e$,$\nu_\mu$, $\bar{\nu}_\mu$:
• Find best-fit leptons first (syn + SSC)
• Then add protons to obtain the full SED and $\nu$

Conclusions

- Our self-consistent one-zone model results in a far emission region of $\sim$pc size and low magnetic field $\sim$mG. Conventional hadronic LHRT model does not work for PKS B1424-418. Leptonic + sub-dominant hadronic viable.
- Relation $L_{\nu} \sim L_{\gamma}$, no longer holds. $L_{\nu} \sim 0.1L_{\gamma}$ for this case $\Rightarrow$ an additional correction factor needs to be considered in future neutrino searches with blazars.
- With SED consistency, up to $\sim$5% chance to reproduce observation (IC35 + null in other energies) in either IC-3yr or Burst phase. Predicting up to 0.4 events during the IC-3yr or Burst, or 0.6 in 2LAC phase, for a total $\sim$PeV all-flavor $\nu$-count.