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Executive Summary

Propagation of Cosmic Rays in Plasmoids of AGN

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Research is still being conducted to determine how energy is transmitted from the black hole and/or accretion disk to cause enormous radio jets to be launched. AGN are also among the few places in the universe that have enough overall energy to qualify as a candidate for the flux of ultra-high energy cosmic rays (UHECRs) measured, and they may hold the key to understanding particle acceleration up to the highest observed particle energies. The literature frequently discusses how leptonic particle dynamics dominate blazar jets, which fits observational quiescent data on blazar spectrum energy concentrations. However, a thorough understanding of the SEDs' intricate, time-varying structure is still a long way off.

Hadronic jet models have been used to provide an explanation for the neutrino signatures seen coming from TXS 0506+065 in that direction. The two potential flares appear to be evolving in very different ways: the gamma-ray light curve at GeV is in a minimum state, while the neutrino signal above the atmospheric background detected in 2014/2015 lasted about 100 days and was made up of 8 to 18 particles with energies between 10 and 100 TeV. A single, extremely energetic high-energy neutrino (300 TeV) served as the foundation for the 2017 detection. The arrival of the neutrino coincided with the observation of a gamma-ray flare. The absence of TeV or even GeV gamma-ray emission is a mystery in all the many high-energy neutrino detections (from diffuse and prospective sources).

If these environments only become transparent at MeV energies, as predicted by, for example, Halzen *et al.*, this is not observable right now because there isn't a mission specifically designed to detect the MeV spectrum of the gamma-ray sky. These questions will be further clarified by upcoming missions like e-Astrogam, MeVCube, or AMEGO. In general, modelling of steady-state emission is difficult, but modelling of flares is significantly more difficult and needs careful consideration of all aspects of jet physics, including various hypotheses for the acceleration zone, gas and photon targets, and magnetic field structure. There are many different scenarios and parameter spaces covered by models of high-energy neutrino and electromagnetic up to gamma-ray emission in the jets of AGN.

The propagation regimes in the plasmoids of blazars are examined in this work as sources of high-energy cosmic rays, which later transform into emitters of high-energy gamma-rays and neutrinos. It is demonstrated that a distinction between the various energy and time regimes of ballistic and diffusive transport is required to understand the spectral energy distributions and light curves of this high-energy emission. Both the spectral energy distribution and the temporal evolution of a flare are impacted by the specifics of this transport models. For the energy behaviour, the diffusion timescale, which is dominated by the diffusion coefficient, causes the diffusive component of the spectrum to become steeper. Using a ballistic escape time and a transport equation technique, it can be roughly calculated.

When modelling these flares using the diffusion approximation at the greatest energies, the shape of the flare will be misconstrued because it deviates when the particles escape more quickly than the diffusion time scale.

KEYWORDS
Cosmic rays; cosmic-ray diffusion; active galactic nuclei (AGN)