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A Systematic Search for Spectral Hardening in Gamma-ray Blazars

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Blazars are among the most powerful gamma-ray emitters, displaying rapid variability and extreme spectral properties. In this study, we systematically search for the most extreme high-energy blazars using 12 years of Fermi Large Area Telescope data, aiming to identify instances of spectral hardening in their gamma-ray spectra. This phenomenon is characterized by a flux that decreases with energy up to a break in the GeV range, after which the spectrum hardens as the flux begins to rise. While previous studies have reported spectral hardening in a few individual sources, this work presents the first dedicated, systematic analysis of this effect. We examine hundreds of blazars with high synchrotron peak frequencies from the 4FGL-DR2 catalog, detecting flaring periods using two methods based on Bayesian Block Analysis. Our results reveal a select population of blazars undergoing pronounced spectral hardening during flares, highlighting some of the most extreme gamma-ray accelerators known. These flares show a broader duration distribution than the general blazar population, suggesting that spectral hardening is more likely to occur in long-lasting flaring episodes. The observed spectral hardening could arise from a transition between synchrotron and inverse Compton emission, multiple emission zones in the jet, changes in particle acceleration, or even hadronic contributions. These findings refine the observational characterization of extreme blazars and lay the groundwork for future multi-wavelength and very-high-energy studies to better understand their variability and underlying physical mechanisms.

Collaboration(s)

Fermi-LAT collaboration

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