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Constraints on Models of Gamma-ray Bursts with Observations of Fermi on Bright GRBs

Gamma-ray bursts (GRBs) are widely suggested as potential sources of ultrahigh-energy cosmic rays (UHECRs). The kinetic energy of the jets dissipates, leading to the acceleration of protons or nuclei which interact with the intense radiation field of GRBs via the photomeson and Bethe-Heitler processes. These processes initiate a series of electromagnetic cascades, giving rise to a broadband emission up to GeV-TeV gamma-ray regime. The expected gamma-ray flux from cascades depends on properties of the GRB jet, such as the dissipation radius, the bulk Lorentz factor, and the baryon loading factor. Therefore, observations of Fermi-LAT can impose constraints on these important parameters. In this work, we calculate the cascade emissions from some bright GRBs, compare the expected fluxes with the measurements of Fermi-LAT on these GRBs, and obtain allowable ranges of aforementioned parameters. We find that the brighter the GRB is, the more stringent constraint for the baryon loading factor will be obtained. For the brightest GRBs, such as GRB 221009A and 130427A, the baryon loading factor can be limited to be smaller than unity for a large ranges of dissipation radius and bulk Lorentz factor, which are much more stringent than the stacking limits based on GRB neutrino measurements. The obtained constraints from gamma rays disfavor GRBs as the main sources of UHECRs if the constraints can be generalized to all GRBs. Our results also shed some lights on the jet composition and the jet-launching mechanism.

Summary

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