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Dissecting the Radiative Puzzle of VHE GRBs: Insights from Multi-Wavelength Modeling

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The recent detection of very high-energy gamma-ray emission (VHE, $>$ 100 GeV) from a subset of gamma-ray bursts (GRBs) has opened new opportunities for GRB research. The temporal and spectral evolution of VHE GRB afterglows requires comprehensive modeling and high-cadence, multi-wavelength observations across the electromagnetic spectrum (radio to VHE). Standard afterglow emission from VHE GRBs comprises a combination of synchrotron radiation from forward and reverse shocks, synchrotron self-Compton (SSC) emission, and external Compton (EC) radiation. To date, SSC models, assuming both stellar wind and constant density circumburst scenarios, have been the primary framework for interpreting VHE emission. In our study, we utilized the NAIMA code, which offers a suite of radiative models and Markov chain Monte Carlo (MCMC) tools, to fit multi-wavelength data for seven VHE-detected GRBs acquired from the literature. By fitting these data, we constrain key parameters associated with the burst and its surrounding environment. Our findings suggest that SSC is the dominant emission mechanism for VHE GRBs, with a negligible contribution from EC. Most VHE GRBs are well explained by a spherical jet with a forward shock model, except for GRB 221009A. Additionally, we find that VHE GRBs tend to occur in environments with lower magnetic fields and higher ambient medium densities. This population study improves our understanding of VHE GRBs and offers insight into the future detection and interpretation of VHE emission in GRBs.

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