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Implications to particle acceleration at relativistic shocks from gamma-ray burst afterglows

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Recent TeV detections of gamma-ray burst afterglows offer new insights into particle acceleration at relativistic shocks. Kinetic simulations have improved our understanding of shock microphysics, enhancing models of particle acceleration relevant to afterglows. We explore scenarios for determining the maximum achievable energy, comparing our findings with data from GRB 190829A. This comparison reveals a tension between observations and theoretical expectations. Motivated by this, we developed a Monte Carlo code to revisit acceleration theory for relativistic shocks in uniform and non-uniform magnetic field configurations. In uniform fields, we demonstrate that acceleration requires only strong scattering on one side of the shock. For non-uniform fields, we consider a cylindrical magnetic-field structure typical of astrophysical jets. We find that curvature drifts enable repeated shock-crossings for particles of favourable charge, and neglecting losses extends the maximum energy to the system's confinement limit. These results challenge the misconception that ultra-relativistic shocks cannot serve as effective accelerators, offering a fresh perspective on relativistic shock acceleration. The findings suggest new features on maximum achievable energy and spectral index, indicating the need to revisit current knowledge on relativistic shocks. This could open promising avenues for producing ultra-high energy cosmic rays.

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