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Accelerating Steep Cosmic Ray Spectra with Revised Diffusive Shock Acceleration

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Galactic cosmic rays (CRs) are accelerated by astrophysical shocks, primarily supernova remnants (SNRs), via diffusive shock acceleration (DSA), an efficient mechanism that predicts power-law energy distributions of CRs. However, observations of both nonthermal SNR emission and Galactic CRs imply CR spectra that are steeper than the standard DSA prediction, $\propto E^{-2}$. Recent kinetic hybrid simulations suggest that such steep spectra may be the result of a "postcursor", or drift of CRs and magnetic structures with respect to the thermal plasma behind the shock. Using a semi-analytic model of non-linear DSA, we generalize this result to a wide range of astrophysical shocks. By accounting for the presence of a postcursor, we produce CR energy distributions that are substantially steeper than E^{-2} and consistent with observations. Our formalism reproduces both modestly steep spectra of Galactic SNRs ($\propto E^{-2.2}$) and the very steep spectra of young radio supernovae ($\propto E^{-3}$).

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Cosmic rays

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