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Plasma Physics of Cosmic Ray Acceleration[1]

DONALD ELLISON, North Carolina State University

For more than 30 years, first-order Fermi particle acceleration in collisionless shocks has remained the mechanism of choice for producing cosmic rays and other superthermal particle populations in various astrophysical environments. The high efficiency, and therefore nonlinear nature, of the mechanism has presented challenges and surprises for modelers over the years and I will briefly describe some of these. In particular, I will focus on magnetic field amplification and particle escape; two phenomena that highlight the difficult plasma physics involved and which are undergoing active current research. While collisionless shocks, with associated particle acceleration, are believed to exist on scales from the Earth bow shock to galaxy clusters, supernova remnants (SNRs) offer perhaps the best place to study the mechanism. This is the case because several SNRs show extremely broadband continuum emission from radio to TeV gamma rays, sometimes accompanied with thermal X-ray emission. Other aspects, such as the morphology and observed evolution of some young remnants, offer unique clues to fundamental properties of the underlying plasma physics of both the remnant and the coupled acceleration mechanism. I will show how the consistent modeling of SNR observations can result in important constraints on the underlying acceleration mechanism.

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