Nonlinear evolution of current- and pressure-driven instabilities

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Modeling the nonlinear development of current- and pressure-driven nonresonant instabilities in astrophysical environments is essential to understand scattering and self-confinement of high-energy cosmic rays and the observed non thermal spectra radiated in astrophysical objects such as young supernovae remnants and relativistic jets. A complete description of the migration of dominant modes, the inherent multiscale coupling between these and the effect of higher-order anisotropies in the cosmic ray distribution require the combination of state-of-the-art kinetic numerical simulations and theoretical appraisals.

By making use of large scale particle-in-cell simulations, we study the self-consistent generation and nonlinear evolution of current-driven instabilities with various degrees of pressure anisotropies in magnetized astrophysical environments. We develop an analytic model for mode coupling of the fastest growing mode with larger scale modes, and discuss the resulting energy injection, the feedback on the cosmic ray distribution and the subsequent saturation mechanism for systems dominated by Bell and firehose type instabilities.