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Cosmic Ray Acceleration via Turbulence-Induced Magnetic Reconnection: From Micro to Macro Scales

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Turbulence-driven magnetic reconnection is increasingly recognized as a crucial mechanism for accelerating cosmic rays (CRs) to ultrahigh energies (UHEs) in magnetized astrophysical environments, ranging from compact sources to more extended regions. In this talk, I will provide an overview of this acceleration process and present a comparative analysis of 3D magnetohydrodynamic (MHD) and particle-in-cell (PIC) simulation results.

I will explore how cosmic ray acceleration unfolds across both microscopic and macroscopic scales, drawing insights from 3D PIC kinetic simulations, hybrid 3D MHD-PIC models, and large-scale 3D MHD simulations. While micro-scale simulations are essential for understanding the initial stages of particle acceleration—commonly referred to as the injection problem—macro-scale MHD models help determine the maximum energies particles can reach. I will discuss the key similarities and differences between these regimes, their influence on acceleration rates and spectral properties, and the transition from microscopic to macroscopic scales.

Furthermore, I will examine how 3D turbulent-reconnection efficiently accelerates particles to high energies in a Fermi-like process and its implications for astrophysical sources, particularly AGN accretion disks and jets. This mechanism offers a compelling explanation for the observed gamma-ray and neutrino emissions from magnetized regions. In particular, I will discuss applications to sources such as TXS 0506+056 and MRK 501 blazars, which have been associated with very high energy gamma-ray flares and neutrino detection.

Collaboration(s)

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