Contribution ID: **396** Type: **Talk**

Non-thermal particle spectra from Fermi acceleration at oblique magnetised shocks

Friday 18 July 2025 15:20 (15 minutes)

We revisit the process of particle-acceleration at magnetised shocks having an oblique large scale magnetic field. We find the surprising result that even in the test-particle limit, curved spectra may be produced.

For many years, diffusive shock acceleration (DSA) has been viewed as one of the central mechanisms to accelerate cosmic rays (CRs). It is applied to many astrophysical scenarios, such as supernova remnants (SNRs), and is regarded as the main acceleration mechanism for CRs in the galaxy. Therefore, the spectrum obtained with DSA is used as the injection spectrum for CRs to model their spectrum observed at Earth, after transport through the galaxy.

One of the key predictions of DSA is that it produces power laws, that depend on only a single parameter, namely the compression ratio of the shock. Extending this result to oblique shocks, where the upstream magnetic field is not aligned with the shock normal, is, however, not trivial, as the assumption of a nearly isotropic distribution function breaks down in the neighbourhood of the shock.

To capture the resulting anisotropies, we use Sapphire++ (https://sapphirepp.org), a code that simulates CR propagation and acceleration. We find that even in the test-particle limit, curved spectra are produced. Discussing how energy-dependent scattering can affect the spectra and thereby the spectral index, we observe different spectral indices in various energy regimes, producing curvature in the spectra. Furthermore, we discuss the impacts of spatially dependent scattering on the spectra.

Collaboration(s)

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Session Classification: CRD

Track Classification: Cosmic-Ray Direct & Acceleration