Contribution ID: **96** Type: **Invited/Solicited talk in mini-symposium**

MHD-PIC Simulations of the Cosmic-ray Gyro-resonant Instabilities

Friday, 15 December 2023 11:15 (25 minutes)

Cosmic-ray (CR) gyro-resonant instabilities represent the key physical mechanism behind CR feedback at macroscopic (e.g., galactic) scales, whose microphysics involves gyro-resonance between the low-energy (GeV) CRs and background MHD waves. Using the MHD-particle-in-cell (MHD-PIC) method, we design a streaming box and an expanding box frameworks to study two flavors of the instabilities, the CR streaming instability and the CR pressure anisotropy instability. Our 1D simulations achieve the steady-state balance between wave growth and damping, as well as between driving CR streaming/anisotropy and isotropization via wave scattering. It allows us to measure the CR transport coefficients from first principles as a function of background environment, which can be eventually incorporated into subgrid prescriptions for studies of CR feedback. These simulations are being generalized to 2D, revealing the importance of oblique waves in CR transport.

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Session Classification: Plasma Astrophysics