ID contributo: **69** Tipo: **Poster**

Scattering and transport of energetic electrons in solar flares

martedì 25 maggio 2021 13:00 (40 minuti)

The role of whistler waves in scattering energetic electrons as they undergo acceleration during magnetic energy release in solar flares is explored with particle-in-cell (PIC) simulations and in an analytic model. Energetic electrons accelerated in flares reach relativistic velocities. The transit time of these energetic electrons across the energy release region in flares (< 0.1s) is much shorter than the energy gain time of these electrons (~10s). This disparity of time scales is associated with the fact that the Alfvén speed in the corona is much smaller than the velocity of light. Further, there is evidence from observations that energetic electron fluxes into the chromosphere are significantly below those measured higher in the corona, suggesting that electrons are self-confined. PIC simulations have established that oblique whistler waves can resonate with and scatter energetic electrons through high-order cyclotron resonances (Roberg-Clark et al., 2019). However, these simulations did not provide sufficient information to establish a complete model for electron scattering in flares. It remains unclear if the whistlers are able to scatter field-aligned, high-energy electrons past 90 degrees in pitch angle. Further, because the energy release regions in flares are enormous compared with all kinetic scales, PIC models are typically only able to explore systems with free energy that greatly exceeds that expected in real flares with the result that scattering time scales are far shorter than expected in real systems. We have begun a modeling effort based on both PIC simulations and analytic analysis to explore how gradients in distributions of energetic electrons self-consistently drive whistlers and are scattered. The goal is establish the physics basis for describing whistler growth and saturation along with electron scattering rates for realistic flare energy release domains.

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Classifica Sessioni: Poster session: SQ4 and SQ5

Classificazione della track: Particle Transport