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Particle acceleration in a relativistic magnetosonic shock with pre-existing cosmic rays in pair-ion plasmas

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The acceleration of relativistic particles in astrophysical sources of synchrotron emission is one of long-lived unsolved problems. Most of those non-thermal astrophysical sources have shock structures; termination shocks of pulsar winds, hot-spot shocks of jet from radio galaxies, internal shocks of jet in AGN or microquasar or GRB. So collision-less shock waves in relativistic flow have been implicated to energize particles.
However, the particle acceleration processes in collisionless shocks have not fully understood yet. For example, how the upstream flow energy can be divided into downstream kinetic energies of ions and electron? What mechanisms generate non-thermal particles? These questions are not simply addressed by the macroscopic view point of MHD framework, and we need to approach these questions by microscopic view point.
In order to study these unresolved issues of collisionless shocks, particle-in-cell (PIC) simulation have been recently used as a useful tool to investigate the microscopic acceleration mechanisms. For example, Hoshino et al.(1992) and Amato & Arons (2006) have studied the structure of relativistic shock wave in electron-positron-ion plasma by PIC simulation, and concluded that the pair plasmas can be efficiently accelerated in a relativistic perpendicular shock. Although this kind of simulation study is powerful to understand the kinetic shock structures by collective plasma processes, the current simulations can only address a small scale and early time evolution of collisionless shocks. The shock structure and particle acceleration for a large scale and long time evolution in astrophysical settings may differ from what we have studied in PIC simulation so far. A well developed shock may contain a lot of relativistic nonthermal particles and cosmic rays, whose energy density is not necessarily negligible against the thermal plasma, and the cosmic rays are believed to modify these shock structures by their pressure and/or they may amplify the magnet field by exciting turbulences.
In this presentation, we extend the simulation study by Amato and Arons, and study the effect of pre-existing cosmic rays on the pair plasma acceleration by using PIC simulation. Namely, we include very hotter electrons,positrons and ions into the upstream relativistic flow than those studied by Amato & Arons, and investigate the behavior of synchrotron instabilities and particle acceleration. We discuss how and why these effects can change downstream non-thermal particle spectra.