Kinetic simulations of particle acceleration in astrophysical collisionless shocks

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Nonthermal emission from a variety of astrophysical sources, including relativistic jets and supernova remnants, is often attributed to collisionless shocks. These shocks are inferred to accelerate particles and in some cases strongly amplify magnetic fields. How this happens remains to be clarified through both theory and observations. In this talk, I will present a summary of recent progress in modeling of particle acceleration in collisionless shocks using kinetic simulations with particle-in-cell (PIC) and hybrid methods. I will discuss a survey of properties of collisionless shocks as a function of shock speed and the magnetization of the medium. Both relativistic and nonrelativistic shocks transition from being mediated by magnetic reflection to filamentation instabilities as the magnetization of the medium decreases. The physics of the shock affects particle injection into the acceleration process. I will present simulations which show ab-initio Fermi acceleration of particles and address the injection efficiencies for electrons and ions. In particular, I will discuss a new mechanism for pre-acceleration of electrons by whistler waves in the shock ramp of quasi-perpendicular nonrelativistic shocks. These pre-accelerated electrons achieve Larmor radii comparable to the Larmor radii of the ions and can then be injected into a large scale diffusive acceleration process. I will use the results of these kinetic simulations to place first theoretical constraints on the Alfvenic Mach numbers of supernova remnant shocks.