Astrophysical Collisionless Shocks

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Abstract

Collisions of supersonic flows occur frequently in astrophysics, and the resulting shock waves are responsible for the properties of many astrophysical objects, such as supernova remnants, Gamma Ray Bursts and jets from Active Galactic Nuclei. For typical astrophysical parameters the shocks are "collisionless" and form due to plasma instabilities and self-generated magnetic fields. These shocks are inferred to accelerate particles and in some cases strongly amplify magnetic fields. How this happens remains to be clarified through theory, observations and lab experiments. 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. The fundamental physics of collisionless shocks is now addressable with laboratory experiments. I will discuss the physical constraints that need to be satisfied by such experiments, and the current progress of shock experiments on Omega.