Plasma kinetic effects in space and astrophysical plasmas

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Many phenomena in space and astrophysical plasmas are of fluid nature, so they can be described by means of single-fluid MHD or multi-fluid approximations. But space and astrophysical plasmas are usually often collisionless. In this case wave-particle resonances, micro-turbulence and particle acceleration phenomena become essential. They require a kinetic description of the plasma beyond the fluid approximation. We shortly discuss examples of such phenomena like the multiscale magnetic reconnection process and collisionless shock waves. From the examples it is clear that essentially kinetic phenomena in collisionless plasmas quickly turn even initially linear instabilities into a non-linear regime where multiple and non-local interactions between waves, turbulence, and particles take place. As a result numerical simulations have to be carried out to model these interaction and multiple feedback actions in order to understand the resulting plasma dynamics. The main simulation kinetic approaches are either semi-Lagrangian or Eulerian grid based, the either directly solve the Vlasov equation for the particle distributions or consider – in the Particle-In-Cell (PIC) approach – the orbits of macro-particles. We finally review currently obtained new insights into essentially kinetic effects in collisionless magnetic reconnection which apply to astrophysical, space and even laboratory plasmas.