Kinetic temperature anisotropy instabilities in inhomogeneous collisionless plasmas

Takanobu Amano[1]
[1] University of Tokyo

It is well known that the temperature anisotropy is ubiquitous in collisionless space plasmas. As the particles tend to conserve their first and second adiabatic invariants, a finite temperature anisotropy is naturally generated, for instance, when a plasma flow exists in an inhomogeneous magnetic field. Once the anisotropy grows over a threshold, the system becomes unstable against kinetic instabilities, which then tend to reduce the anisotropy to a marginal stability condition. This makes the evolution of the system closer to the magnetohydrodynamics (MHD) description. Therefore, understanding of temperature anisotropy instabilities is the key for macroscopic modeling of collisionless plasma dynamics.

In the Earth's magnetosphere, the earthward plasma convection from the plasma sheet easily generates a perpendicular anisotropy with the temperature perpendicular to the magnetic field larger than the parallel. In this case, both the electromagnetic-ion-cyclotron (EMIC) instability and the mirror instability may become unstable. Although a lot of theoretical and numerical studies have been reported for these instabilities, most of them treated instabilities in a homogeneous plasma. In application to magnetospheric physics, however, the inhomogeneity of the ambient magnetic field should be important. In addition, in the magnetosphere there often exists a cold plasma population. Such a cold plasma may be negligible in terms of the plasma pressure, whereas it can be dominant in terms of the mass density. The cold plasma density may also have a spatially inhomogeneous distribution. It changes the dispersion relation and thus may have a non-negligible impact on the instability properties. Finally, the distribution of the hot plasma population may also be inhomogeneous. It is well known that the mirror instability in spatially inhomogeneous plasmas acquires a finite real frequency due to diamagnetic drift and is called the drift-mirror instability. Nevertheless, nonlinear properties of this instability and also competition between the EMIC mode have poorly been understood.

In this report, we discuss how the inhomogeneity affects the kinetic instabilities driven by a perpendicular anisotropy. We use a generalized quasi-neutral plasma hybrid simulation model, in which the effect of cold plasma population is taken into account. In this model, the cold plasma dynamics is essentially determined by the MHD equations. The hot plasma population driving the temperature anisotropy instabilities is solved by the Particle-in-Cell (PIC) scheme. The effect of the hot, kinetic species is correctly taken into account in a self-consistent manner.

We discuss both two- and three-dimensional (2D and 3D) nonlinear simulations with spatially inhomogeneous initial conditions with and without a cold plasma population. In particular, how the competition between the EMIC and mirror instabilities is affected by the initial inhomogeneity will be discussed. The results will also be compared with simulations with the homogeneous system.