Perpendicular temperature anisotropy instability near mirror instability threshold

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The instability driven by a finite temperature anisotropy is important in understanding the dynamics of collisionless space plasmas. The transport of a collisionless plasma in an inhomogeneous magnetic field easily produces a finite temperature anisotropy because of the conservation of the first and second adiabatic invariants. However, there exists a limit on the anisotropy beyond which waves are excited by plasma instabilities and resulting pitch-angle scattering reduces the anisotropy. Understanding the anisotropy instability thus provides a key ingredient to determine the equation of state for a collisionless plasma in a macroscopic sense.

It is known that both parallel (Tpara > Tperp) and perpendicular (Tperp > Tpara) anisotropies drive instabilities of at least two different kinds: One propagates nearly parallel and another in an oblique direction with respect to the ambient magnetic field. In the case of perpendicular anisotropy, the parallel mode is called as the Alfven-ion-cyclotron (AIC) instability, and the oblique mode is called as the mirror instability. In general, the AIC instability has a larger growth rate than the mirror instability at low to moderate plasma betas. However, magnetic field fluctuations likely to be generated by the mirror instability have been observed in planetary magnetosheaths and magnetospheres even at moderate plasma beta conditions. It is not known how the nonlinear mirror mode structures observed in space are generated in AIC dominant plasma environments.

In this study, we used a hybrid simulation code to investigate the relationship between the AIC and mirror instabilities. The code includes cold electron and ion fluids, as well as a hot ion population being solved via the particle-in-cell scheme. Numerical simulations for a homogeneous plasma with an initial temperature anisotropy at the marginal stability condition for the mirror instability (but unstable against the AIC instability) have been performed. Initially, the AIC instability develops and Alfvenic fluctuations generated by the instability scatter the particles in pitch-angle. While this reduces the anisotropy as expected, there also appears a mirror-mode like structure with magnetic and perpendicular pressures anti-correlated with each other. We found that a non-Maxwellian nature of the velocity distribution function generated via the pitch-angle scattering makes the system linearly unstable against the mirror instability. In other words, the AIC generated waves help the growth of the mirror mode despite the reduction in the temperature anisotropy. The consequence of the interplay between the AIC and mirror instabilities will be discussed.

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