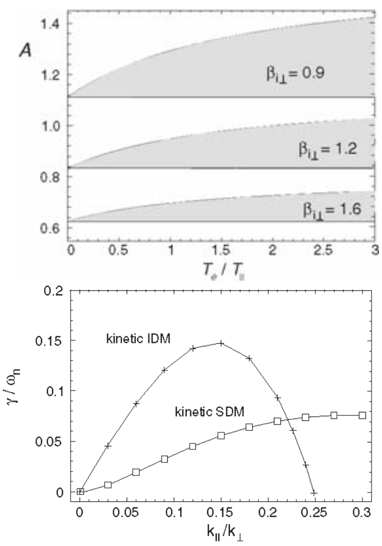
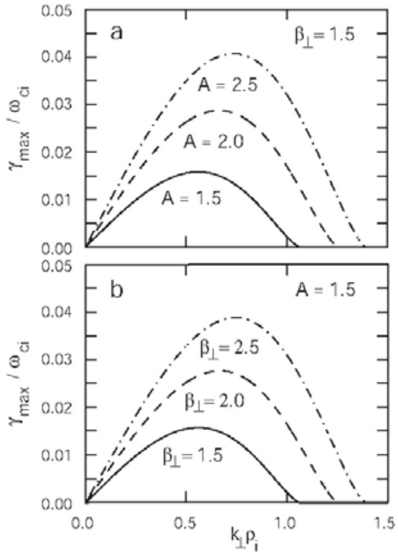
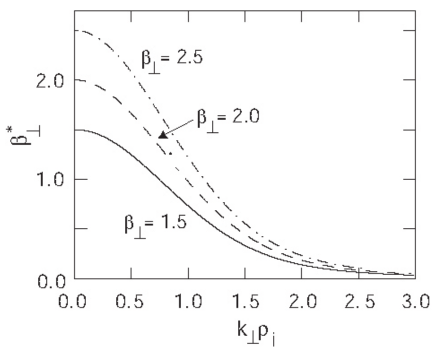
General Linear Mirror Mode Theory

A fully kinetic theory of the magnetic mirror instability in high-β plasma has been developed accounting for the effect of electrons respectively the effect of arbitrary ion-Larmor radii. Taking into account electrons we find that two entirely new modes can develop which we call slow ion and kinetic slow modes. On the other hand, accounting for finite Larmor radii, we find that at scales the order of the ion-Larmor radius the ordinary ion-mode instability growth rate and threshold are substantially modified because the effective elasticity of the magnetic field lines increases. In addition the magnetic field develops a non-coplanar component which is otherwise not included in the theory of the mirror mode.

The magnetic mirror mode is one of the most interesting extremely low-frequency modes developing in anisotropic temperature high-β plasmas typical for space plasmas. In the last few years we have worked intensely at its understanding in spite of the now 50 years between their discovery and today. The reason is that they are frequently observed in near-Earth space as one of the fundamental low-frequency modes which dominate magnetic turbulence in contrast to what is usually believed that magnetic turbulence is mainly determined by Alfvén modes. The latter might be true for low-β plasmas but does not generally apply in the high-β case. We treat







Left:The β-ranges and growth rates of the two new electron-modified mirror modes. *Center*: Growth rate Larmor-radius dependence. *Right*: Effective β for the kinetic mirror mode.

the mirror mode in two versions. First we investigate its dependence on the presence of a hot kinetic electron background. In this case we find that in addition to the ordinary ion-mirror mode the mirror mode develops two new branches, a slow-ion branch and a kinetic slow branch. The domains of existence of these branches are shown in the Figure (top left); the normalized growth rates are given below (bottom left) showing that the ion branch is restricted to small parallel wave numbers having large growth rate while the kinetic slow branch extends to larger parallel wave numbers. Both are oblique with the latter being more parallel. Another new mode appearing here is still under investigation. The center and right panels of the figure show the other case of the ordinary ion mode but for finite (kinetic) Larmor radius included. This causes the mode to have higher threshold for onset as seen in the right part of the effective β entering the threshold condition, and to have maximum growth rate at wavelength comparable to the ion Larmor radius and decaying both for shorter and longer wavelengths. This is an important finding since it tells that injection of turbulent energy by mirror instability at the lowest frequencies will take place at about the Larmor radius which is in approximate agreement with observation.

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