PROPAGATION OF ALFVÉN WAVES IN AURORAL DENSITY CAVITIES

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Abstract

The auroral zone contains density cavities on a variety of scales. Such cavities modify the Alfven speed and thus change the propagation characteristics of Alfven waves through this region. These cavities can support normal modes of the plasma that give discrete wave structures in this region. Numerical simulation shows that Alfven waves can be trapped in such cavities and that parallel electric fields form on the cavity boundaries. Simulations also can verify the Alfven wave dispersion relation in this region, indicating that the perpendicular group velocity and phase velocity are in opposite directions.

Summary

We have developed a model for the mode structure of Alfvén waves in the presence of perpendicular density gradients, such as those that exist in the auroral zone as well as in lab plasmas. The kinetic Alfvén wave dispersion relation can be generalized to finite frequency and finite ion gyroradius effects by including corrections to the Alfvén speed, the electron inertial length and the ion gyroradius based on kinetic theory. These considerations give a basis for the two-fluid model frequently used based on the full kinetic dispersion relation. Being able to write the dispersion relation in a two-fluid form facilitates the generalization of the dispersion relation to inhomogeneous plasmas. It is noted that kinetic Alfvén waves propagate with parallel phase velocities between the Alfvén speed and the effective electron thermal speed, regardless of which of these speeds is larger. This consideration allows the use of relatively simple diagrams to qualitatively determine the nature of Alfvén wave solutions on either side of an interface. Such diagrams may be useful in the interpretation of lab and space observations when measured parameters can be used to determine the relevant speeds on either side of the interface.

While the existence of discrete Alfvén wave modes in an inhomogeneous plasma is an important result, equally important is the evolution of Alfven waves in inhomogeneous systems in time. We have developed fluid simulations to study this propagation. This model considers the effect of parallel gradients in the Alfvén speed, which is particularly important in the context of the Earth's auroral zone, where such gradients lead to the so-called ionospheric Alfvén resonator. These results show the characteristic backward wave nature of the kinetic Alfvén wave in a cold plasma, with the perpendicular group velocity being in the opposite direction to the perpendicular phase velocity. The evolution of the system in the auroral zone is strongly affected by the ionospheric conductance. High values of conductance allow for narrower structuring of the auroral currents and electric fields. In addition, Hall effects lead to a twisting of the electric field pattern, leading to the detailed structuring of auroral arcs that has been observed by high-speed auroral imagery.