Linear waves and instabilities in plasmas with kappa velocity distributions

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Until fairly recently, the customary approach to wave and instability studies in space plasmas relied on the Maxwellian distribution or one of its variants. This approach prevailed despite a body of evidence indicating that the plasmas being considered were effectively collisionless and in dynamical states far from equilibrium. Modelling the widely observed superthermal power law tails on nonthermal particle velocity distributions by sums of Maxwellians was a well established tradition among the community of space plasma researchers despite some early recognition [1] that the less well known kappa distribution provided a better fit.

The kinetic theory of waves and instabilities in space plasmas based on the kappa distribution or variant is now more widely adopted by researchers. A barrier to its widespread acceptance, the perception that the kappa distribution had no physical theory underpinning its existence, began to fall with the emergence in statistical mechanics of non-extensive Tsallis statistics. The primary advantage of kinetic theory based on the kappa distribution is that it more accurately represents the velocity distributions measured in space plasmas, especially those having power law tails. Use of a kappa distribution model does not change any microphysical processes, but it does alter their probabilities of occurrence, which in turn affects important average quantities such as instability growth and wave damping rates. Dispersion relations also often show features distinguishable from their Maxwellian equivalents, providing valuable signatures for out of equilibrium plasma behaviour.

After briefly reviewing the theoretical framework for kinetic studies of plasma waves, this talk presents results from some of the investigations of waves and instabilities in plasmas modelled with kappa distributions carried out by the authors and collaborators. Amongst others, the whistler [2] and EMIC [3] instabilities driven by thermal anisotropy will be discussed, as well as perpendicularly propagating electron and ion Bernstein waves. In addition, some recent results of 1D and 2D simulations of oblique waves in plasmas having a kappa distribution, will be presented.

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