University of Crete
Department of Physics

FORTH
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Joint Physics & IA/FORTH Colloquium

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Self-defeating Alfvén waves and self-sustaining sound in collisionless plasma (or, how to reduce stress and surf in a storm)

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ABSTRACT

Many space and astrophysical plasmas are so hot and dilute that they cannot be rigorously described as fluids. These include the solar wind, low-luminosity black-hole accretion flows, and the intracluster medium of galaxy clusters. All of these plasmas are magnetized and weakly collisional, with plasma beta parameters of order unity or even much larger ("high-beta"). In this regime, deviations from local thermodynamic equilibrium ("pressure anisotropies") and the kinetic instabilities they excite can dramatically change the material properties of such plasmas and thereby influence the macroscopic evolution of their host systems. In this talk, I will present two key results obtained from an ongoing programme of kinetic calculations aimed at elucidating from first principles the physics of waves, turbulence, and transport in weakly collisional, high-beta plasmas. First, I will demonstrate that Alfvén waves "interrupt" at sufficiently large amplitudes by adiabatically driving a field-biased pressure anisotropy that both nullifies the restoring tension force and excites a sea of ion-Larmor-scale instabilities that pitch-angle scatter particles. This physics places a beta-dependent limit on the amplitude of Alfvén waves, above which they do not propagate effectively. Second, I will demonstrate that similar physics afflicts compressive fluctuations, except that it is the collisionless damping of such waves that is interrupted. Above a beta-dependent amplitude, ion-acoustic waves excite Larmor-scale mirror and firehose fluctuations, which trap and scatter particles, thereby impeding the maintenance of Landau resonances that enable these waves' otherwise potent collisionless damping. The result is wave dynamics that evince a weakly collisional fluid: the ion distribution is near-Maxwellian, the field-parallel flow of heat resembles its collisional form (except in regions where large-amplitude mirrors strongly suppress particle transport), and the relations between various thermodynamic quantities are more "fluid-like" than kinetic. Implications of these results for theories of magneto-kinetic turbulence in space and astrophysical systems will be briefly presented.

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