# Fluid Modeling of Anisotropic Heating and Micro-Instabilities in Space Plasmas

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Fluid models are not only more tractable than kinetic ones to simulate three-dimensional turbulence in space plasmas, but also provide a convenient framework for theoretical insight. Collisionless plasmas are however not readily amenable to a standard MHD description, especially in directions parallel to the ambient magnetic field.

In view of the importance to accurately capture the linear dynamics that plays a major role at small scales in such plasmas, closures of the fluid moment hierarchy have been developed that can keep into account the dissipative effects originating from the linear Landau damping, and also the finite Larmor radius corrections. It will be shown that in order to correctly describe the "slow dynamics" regime, and in particular the dynamics of mirror modes, an almost complete description of the heat flux tensor is needed. Two models will be discussed, pointing out their capabilities and limitations. One is limited to relatively large scales [1], while the other, the so-called FLR Landau fluid model [2], extends to sub-ionic scales. The achievements of the FLR-LF closure will be illustrated on two examples. The first one stresses the role of Landau damping in reducing the flow compressibility as well as on limiting the development of the turbulent cascade in a direction parallel to the ambient magnetic field [3]. The second one focuses on the generation of temperature anisotropy and the constraining effect of micro-instabilities [4]. Concentrating on the influence of small-scale low-frequency kinetic Alfvén wave turbulence, the simulations exhibit non resonant ion perpendicular heating (Fig. 1, left) that rapidly leads to the development of the mirror instability that self-regulates the dynamics and maintains the system close to the mirror threshold. Simulation results reproduce the frontier of the slow solar wind WIND/SWE satellite data in the ($T_\perp^i/T_{||}^i$, $\beta_{||}^i$) diagram [5]. The quality of the fit is improved in the presence of a small amount of collisions (Fig. 1, right), which suggests that the deviations from bi-Maxwellianity in the slow solar wind are weak enough not to significantly affect the mirror threshold.

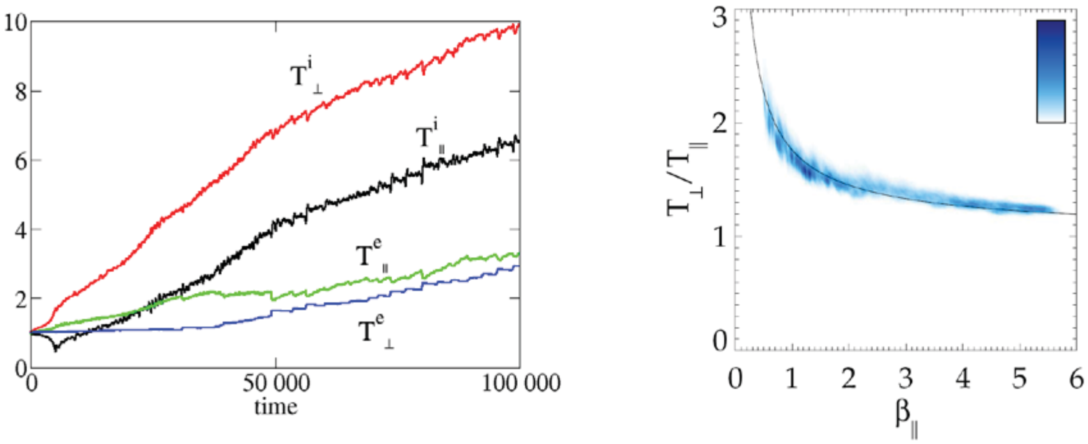


**Fig. 1.** Growth of the ion and electron temperatures as a function of time, showing the dominance of ion perpendicular heating (left). Simulation results of the ion temperature anisotropy as a function of the parallel ion beta parameter (blue points) superimposed on the theoretical mirror threshold.

## References


[1] P. Goswami, T. Passot, and P.L. Sulem, "A Landau fluid model for warm collisonless plasmas", Phys. Plasmas **12**, 102109 (2005).

[2] T. Passot and P.L. Sulem, "Collisionless magnetohydrodynamics with gyrokinetic effects" Phys. Plasmas. **14**, 082502 (2007).

[3] P. Hunana, D. Laveder, T. Passot, P.L. Sulem, and D. Borgogno, "Reduction of compressibility and parallel transfer by Landau damping in turbulent magnetized plasmas", Astrophys. J., **743**, 128 (2011).

[4] D. Laveder, L. Marradi, T. Passot, and P.L. Sulem, "Fluid simulations of mirror constraints on proton temperature anisotropy in solar wind turbulence", Geophys. Res. Lett. **38**, L17108 (2011).

[5] P. Hellinger, P. Travnıcek, J.C. Kasper, and A.J. Lazarus, "Solar wind proton temperature anisotropy: Linear theory and WIND/SWE observations", Geophys. Res. Lett. **33**, L09101 (2006).

[6] S. D. Bale, J. C. Kasper, G. G. Howes, E. Quataert, C. Salem, and D. Sundkvist, "Magnetic Fluctuation Power Near Proton Temperature Anisotropy Instability Thresholds in the Solar Wind", Phys. Rev. Lett. **103**, 211101 (2009).