Neutrals and Electromagnetic drift-Rossby-Alfvén turbulence: Drag, Entrainment, and Ambipolar Diffusion

Chang-Chun Chen[1], Patrick H. Diamond[2], Mikhail Malkov[2], S. M.Tobias[3]

[1] Los Alamos National Laboratory, Los Alamos, NM 87545, USA
[2] University of California San Diego , La Jolla, CA, USA
[3] Department of Applied Mathematics, University of Leeds, Leeds LS2 9JT, United Kingdom

Interest in the effect of neutrals on drift-Rossby wave turbulence at the plasma boundary is increasing as a consequence of the relevance in high-density regimes, detachment, etc. It has been known[1] that neutral friction damps zonal flows, increases drift wave fluctuations, in the vein of predator-prey trade-offs. More interestingly, edge zonal flow actually entrains neutrals, by 'shaving off' the neutrals layers, via momentum conserving coupling. We analyze the coupled system of heat-flux drift wave turbulence, zonal flows, and a neutral population to understand the mechanism of Drift-Rossby-Alfvén turbulence (DRAT).

Zonal flows in DRAT are regulated by the competition between Reynolds and Maxwell stresses. In the simplest model[2,3], magnetic stress is in turn determined by the evolution of mean square magnetic potential. Magnetic dissipation is of paramount importance here, since it damps magnetic fields and thus Maxwell stresses, and so regulates zonal flows and drift wave turbulence. With neutrals, the process of ambipolar diffusion[4], leading to the balance which determines the existence of zonal flows and thus turbulence levels. These differ qualitatively and quantitatively from the previous findings.

Finally, we offer a related discussion of a novel state of two-fluid turbulence of drift waves and neutrals. Interestingly, the plasma turbulence is quasi-2D while the neutrals turbulence is 3D. This system features the coexistence and coupling of 2D and 3D turbulence. The implications for boundary turbulence and transport will be discussed.

This work is supported by the U.S. Department of Energy under Award No. DE-FG02-04ER54738

---

[1] B. A. Carreras, P. H. Diamond, and G. Vetoulis. Role of neutrals in the phase transition model. *Physics of Plasmas,* 3(11):4106–4114, 1996.

[2] S. M. Tobias, P. H. Diamond, and D. W. Hughes, "β-plane magnetohydrodynamic turbulenceinthesolartachocline," *Astrophys.J.*667, ,L113–L116(2007).

[3] C.-C. Chen, P. H. Diamond, R. Singh, and S. M. Tobias, Physics of Plasmas 28, 042301 (2021).

[4] F.H. Shu. Gas Dynamics. Series of books in astronomy. University Science Books, 1992.