Electron-Hole Instabilities in Cross-Field Plasma Wakes

I H Hutchinson, C B Haakonsen, C Zhou

Plasma Science and Fusion Center,
Massachusetts Institute of Technology,
Cambridge MA USA

Cross-field plasma flow past an object is key to the physics underlying Mach-probes, spacecraft charging, and the wakes of non-magnetic bodies: the solar-wind wake of the moon is a typical example. We demonstrate analytically[1, 2] and using PIC simulation[3] that the wake is unstable because of electron velocity-distribution ($f_e$) distortions. The magnetic field, here perpendicular to the wind velocity, defines the 1-D direction of particle dynamics. Small electron holes — non-linearly self-binding electron density deficits — are spawned by a localized unstable depression (the “dimple”) in $f_e(v)$ near the phase-space separatrix. See Fig. 1.

Most of the holes move rapidly out of the moon wake, along $B$. However, some remain near the potential energy ridge of the wake, and grow until they are large enough to disrupt the two ion-streams, well before the ions are themselves linearly unstable. This non-linear hole growth is caused by the same mechanism that causes the dimple: cross-field drift from a lower to a higher density. Quantitative hole growth curves are calculated by analytic theory. Related mechanisms cause plasma near magnetized Langmuir probes to be unsteady.

References