Paper ID: 39283
interactive

SYMPOSIUM ON FUTURE SPACE ASTRONOMY AND SOLAR-SYSTEM SCIENCE MISSIONS (A7)
Technology Needs for Future Missions, Systems, and Instruments (3)

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REVISITING THE THERMODYNAMICS OF COLLISIONLESS PLASMA EXPANSION IN SOLAR MAGNETIC FUNNELS.

Abstract

Plasma expansion in diverging magnetic fields are commonly encountered in astrophysical plasmas. Magnetic funnels on the surface of our sun direct plasma along open field lines into interplanetary space and are commonly considered the genesis of the solar wind. The optical data have to be interpreted with caution as details of the electron energy distribution function can easily lead to mis-interpretations. Measurements in a laboratory helicon double layer experiment have shown that the effective electron temperature and density show a polytropic correlation with an index of $\gamma_e = 1.17 \pm 0.02$ along the divergent magnetic field, implying a nearly isothermal plasma ($\gamma_e = 1$) with heat being brought into the system. However, the evolution of electrons along the divergent magnetic field is essentially an adiabatic process, which should have a $\gamma_e = 5/3$. The reason for this apparent contradiction is that the nearly collisionless plasma is very far from local thermodynamic equilibrium and the electrons behave nonlocally. The corresponding effective electron enthalpy has a conservation relation with the potential energy, which verifies that there is no heat transferred into the system during the electron evolution. The electrons are shown in nonlocal momentum equilibrium under the electric field and the gradient of the effective electron pressure. The convective momentum of ions, which can be assumed as a cold species, is determined by the effective electron pressure and the effective electron enthalpy is shown to be the source for ion acceleration. For these nearly collisionless plasmas, the use of traditional thermodynamic concepts can lead to very erroneous conclusions regarding the thermal conductivity.