Evolution of kappa-distributed protons downstream of the heliospheric termination shock in the presence of charge-exchange

E.J. Zirnstein

Princeton University

Kappa functions have long been used in the analysis and modeling of suprathermal particles in various space plasmas. In situ observations of the supersonic solar wind show its distribution contains a cold ion core and power-law tail, which is well-represented by a kappa function. In situ plasma observations by Voyager, as well as observations of energetic neutral atom (ENA) spectra by the Interstellar Boundary Explorer (IBEX), showed that the compressed and heated inner heliosheath (IHS) plasma beyond the termination shock can also be represented by a kappa function. IBEX exposes the IHS plasma properties through the detection of keV ENAs generated by charge-exchange in the IHS. However, charge-exchange modifies the plasma as it flows through the IHS, making it more difficult to ascertain the parent proton distribution.

In this talk, we first investigate the evolution of the IHS proton distributions, initially represented by a kappa distribution immediately downstream of the termination shock, that experience losses due to energy-dependent charge-exchange with neutral hydrogen atoms. We discuss the effects of fitting a kappa function to the IHS proton distribution over limited energy ranges as a function of distance from the termination shock, its dependence on the initial proton distribution properties at the termination shock, and implications for understanding the observations.

Next, we look at recent IBEX observations of the hydrogen ENA spectrum from the heliotail, which suggest the existence of a roll-over in the ENA spectrum at energies below 0.1 keV. We seek to understand the origin of these ENAs based on a model of the proton distribution function propagating down the heliotail by including the gain and loss of pickup ions by charge-exchange with neutral hydrogen atoms from a 3D kinetic-Monte Carlo simulation of neutral atoms in the heliosphere. We find that most ENAs observed above 0.1 keV come from termination shock-processed pickup ions, initially kappa-distributed with index 2, that propagate down the heliotail. Very low energy ENAs originate from pickup ions injected into the IHS plasma via charge-exchange with neutral hydrogen from the very local interstellar medium and the outer heliosheath. We will discuss the implications of the initial proton distribution at the termination shock, and the source of ENAs that IBEX can see from the heliotail.

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