The outer heliosphere: a zoo of non-equilibrium plasma's.

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The outer heliosphere, beyond some 10s of au from the Sun, is characterized largely by particle systems, which do not reside at thermal equilibrium, and have velocity distributions that are not even close to Maxwellian. Some of these distributions can be well fit by kappa distributions, and their thermodynamics are described by non-extensive statistical mechanics. Other distributions are far more complicated. For example, pickup ion distributions are generated when interstellar neutrals are ionized in the solar wind. These distributions start as a ring with a cutoff at twice the solar wind speed (four times the energy); this ring rapidly angularly scatters in velocity space and then more slowly cools as new pickup ions are continually added to the outer shell of the distribution. Pickup ions have been well measured from ~20 to beyond 50 au by the Solar Wind and Pickup Ion (SWAP) instrument on New Horizons. While these ions do not resemble even kappa distributions, their thermodynamics can still be addressed through their entropy and the recently discovered properties of an entropy defect. This concept accounts for the entropy decrease caused by the order induced in assembling a system, such as when adding the low dimensionality of the phase-space of pickup ions or the long-range correlations among particles. Pickup ions dominate the internal pressure in the distant solar wind and are the primary population producing energetic neutral atoms (ENAs) in the heliosheath – beyond the termination shock – that are remotely observed by the Interstellar Boundary Explorer (IBEX) mission. This talk briefly summarizes the observations from SWAP and IBEX of the “zoo” of different non-equilibrium plasmas that inhabit the outer heliosphere and points to some of the work that has begun to connect them to their deeper thermodynamic properties. We also describe advances in the observations of these plasmas promised by the Interstellar Mapping and Acceleration Probe (IMAP) mission, launching in 2025.