Particle velocity distribution function measurements in the solar wind: Why we need to do better

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The solar wind is a supersonic flow of ionized particles, called a plasma, streaming away from the Sun. These particles are not observed to be in thermal or thermodynamic equilibrium. This is because nearly all particle dynamics are governed by non-collisional processes and the particles experience long-range forces (i.e., Coulomb potentials of nearby, charged particles). There are multiple particle species in the solar wind as well, including but not limited to electrons, protons, alpha-particles, and multiple charge states of heavier ions up past uranium. When we observe particle velocity distribution functions (VDFs), they exhibit non-Maxwellian features. In fact, we do not see any VDFs that are consistent with Maxwellian or even bi-Maxwellian distributions. All electron VDFs observed to date in the solar wind have nonthermal tails and/or multiple phase space density peaks and/or self-similar profiles. Presumably the proton and alpha-particle core populations of the solar wind exhibit similar subpopulations but we lack the measurement resolution to observe them. There is evidence of this much closer to the Sun observed by Parker Solar Probe, where the solar wind speed is lower and temperature much higher (i.e., effective velocity resolution of measurements increases). Near-Earth solar wind measurements, however, are all under-resolved. We discuss the consequences of these limitatiions using numerically integrated velocity moments.

References

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[4] Wilson et al., Front. Astron. Space Sci. 9 (2022).