New insights on solar wind electrons at 1 AU: Collisionality, heat flux, and thermal force

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The origin and evolution of non-equilibrium characteristics of electron velocity distribution functions (eVDFs) in the solar wind are still not well understood. They are key in understanding heat conduction and energy transport in weakly collisional plasma, as well as in the scenario at the origin of the solar wind. Due to low collision rates in the solar wind, the electron populations develop temperature anisotropies and velocity drifts in the proton frame, as well as suprathermal tails and heat fluxes along the local magnetic field direction. These non-thermal characteristics are highly variable, and the processes that control them remain an open question.

We present here a recent work on enhanced measurements of solar wind eVDFs from Wind at 1AU. This work is based on a sophisticated algorithm that calibrates eVDFs with plasma Quasi Thermal Noise data in order to accurately and systematically characterize the non-thermal properties of the eVDFs, as well as those of their Core, Halo and Strahl components. Indeed, the core, halo and strahl populations are fitted to determine their densities, temperatures and temperature anisotropies as well as their respective drift velocities with respect of the ion velocity (or solar wind speed). The density, temperature and temperature anisotropy, as well as the parallel heat flux of the total eVDFs are also computed.

We use a 4-year-long dataset composed of all these parameters at solar minimum to enable statistically significant analyses of solar wind electron properties. We estimate collisional proxies such as collisional age and Knudsen number, and discuss usually neglected effects. In addition to the total electron heat flux, we also compute the heat flux contributions from the core, halo and strahl and discuss the interplay between these three components. We finally show estimates of the so-called Thermal Force, a drag or Coulomb friction between ions and the electron components that arises naturally from the non-thermal character of the eVDFs, even in the absence of current. This TF enhances the parallel electric field and plays an important, but usually neglected, role in two fluid energy transfers between electrons and ions. It is parallel to the heat flux that causes it, however its role in understanding the observed heat flux remains to be explored. This statistically-significant work allows a local, quantitative measure of Coulomb coupling that maybe important with possibly other microphysical processes to locally control non-thermal properties.