Probing the solar wind energetics in the inner heliosphere with Solar Orbiter

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Solar wind plasma is weakly collisional, and the velocity distribution functions (VDFs) of the constituent particle species typically deviate from the Maxwell-Boltzmann distribution function. Instead, typical solar wind particle VDFs exhibit non-equilibrium features, such as temperature anisotropies, high-energy tails, flat-tops, and field-aligned beams. Since the beginning of space exploration, researchers have utilised available spacecraft observations in order to understand the evolution and energisation of such systems.

The Solar Wind Analyser instrument suite, on board Solar Orbiter, comprises three sensors dedicated to resolve the VDFs of solar wind protons and alpha particles, electrons, and heavier ions. The high time, energy, and angular resolution of these particle sensors enables the detailed characterisation of the kinetic features of the VDFs and their evolution within the inner heliosphere.

In this presentation, we introduce our newly developed analysis tools which characterise solar wind proton and electron VDFs, measured by Solar Orbiter. We present the radial profiles of the bulk parameters calculated from the analysis of the observed VDFs and compare them to standard solar wind expansion models. Additionally, we quantify the relative drift between the proton core and the proton beam and the heating rate associated with its radial evolution, and compare it with the overall heating rate we estimate from the observations. We also show the evolution of protons and electrons within identified dynamic structures, such as compressive fluctuations and shocks, and assess the applicability of kinetic and MHD models to these observations. Finally, we discuss our future plans to quantify the thermal energy budget of the solar wind plasma.