1.2.2.2 What drives the evolution of the solar wind distribution functions in situ?

Description of the objective:

The in-situ interactions between the fluctuating electromagnetic fields and the particle distribution have a strong effect on the evolution of the solar-wind distribution functions (Kasper et al., 2002; Maksimovic et al., 2005; Matteini et al., 2007). Wave-particle interactions, for example, can lead to a secular transfer of energy from the fluctuating fields to the particles or – as in the case of instability – to a secular transfer of energy from the particles to the fluctuating fields.

An important outstanding question is the role of the multi-scale interplay between local kinetic processes (wave-particle interactions, instabilities, turbulence), global kinetic processes (expansion, electron heat flux), and collisions (Chandran et al., 2011; Hellinger et al., 2015). The combination of all of these different processes is thought to create the observed kinetic structure of the solar wind (beams, drifts, anisotropies, multi-temperature phenomena, etc.); however, their combined effects are poorly understood. In order to understand the heating and acceleration processes in the solar wind, we have to identify processes that explain this observed structure correctly. This objective is closely related to the nature and origin of waves and turbulence as well as the role of instabilities (see next objective, 1.2.2.3).

Needed Observations

In order to understand wave-particle interactions and the secular transfer of energy between fields and particles, we require synchronised observations of the field instruments and the particle instruments. The field-particle correlation method is an efficient way to determine these local interactions between field fluctuations and the particles if kinetic resonances dominate the evolution (Klein, 2017). It allows to separate reversible fluctuations in the observed distributions due to the wave polarisation from irreversible changes in the distribution due to actual dissipation.

In a similar way, energy transfer from the fields to the fluctuations is an indication for plasma instability (see, for example, Verscharen et al., 2013). Searching for structures in the distributions consistent with quasilinear diffusion (such as plateaus at the expected resonance speed) with unstable waves in the electromagnetic field at the consistent unstable wave vectors will help us to quantify the role of instabilities for the in-situ evolution (Seough et al., 2014).

The effect of turbulence and waves on the particles can be fully detected by measuring the solar-wind particle velocity distribution in great detail. Different dissipation mechanisms cause different shapes of the distribution function, allowing us to quantify their contributions (e.g., Marsch, 1999; Cranmer, 2002; Howes, 2011; Klein & Chandran, 2016). The mechanisms include cyclotron-resonant damping, stochastic heating, Landau damping, and the resistive thermalisation at small-scale structures like current sheets. All of these processes create different signatures in the particle distributions, so that concerted fields and particle observations can reveal the nature of the dissipation processes and thus the nature of the fluctuations in the turbulent spectrum.

Since these measurements require high-cadence and high-resolution measurements of the pristine solar wind, it is important to operate the fields and the particle instruments in high-resolution burst mode even at times of otherwise inconspicuous solar wind – outside of time intervals with the regular burst-mode triggers such as shocks, beams, or other strongly variable events.

- High time resolution variability in the magnetic field associated with particle distributions in different plasma parameter regimes (low and high plasma , fast and slow wind) in order to quantify the links between particle distribution evolution and wave-particle interactions (Kasper et al., 2002; Matteini et al., 2007; Maksimovic et al., 2005).
- Role of the electron heat flux. Characterize the non-thermal character of the electron distributions at perihelion and their evolution with heliocentric distance (Stverak et al., 2009; Maksimovic et al., 2005).
- Generation of non-thermal ion distributions (beams, drifting heavy ions, hot heavy ions, proton ‘strahl’).
- Generation of non-thermal electron distributions (beams, drifting ‘strahl’).
- What role do local evolution (turbulence, shears), global evolution (expansion), and collisions have in determining the properties of the proton distributions?
- Sub-Debye length electric fields (Randol & Christian, 2014), measure electric fields and suprathermal proton tails.