1.2.2.8 What determines the azimuthal flow of the near-Sun solar wind?

Description of the Objective

The first observations of the Parker Solar Probe (PSP) reveal that the azimuthal flow of the solar wind near the Sun is larger than expected (Kasper et al., 2019). During its first and second perihelia, the PSP finds transverse speeds of up to 40 km/s at a distance of about 35 solar radii from the Sun. The classic Weber-Davis model, based on an MHD description of the plasma release in the decreasing Parker magnetic field, only predicts transverse plasma speeds of a few km/s at these distances (Weber & Davis, 1967). Possible explanations for these observations include amongst others: (a) the solar wind co-rotates at larger distances than expected, (b) density or field structures deflect the solar wind significantly into the azimuthal direction, or (c) the kinetic dynamics of the plasma has a major impact on the azimuthal flow. Moreover, the observed scaling of the transverse speed with distance does not follow the expected profile for a torque-free setup or for Parker's assumption, and sometimes PSP even observes azimuthal flows in the direction opposite to the Sun's sense of rotation. The azimuthal flow is important for the Sun's angular-momentum loss. If the PSP observations are indeed confirmed, this finding will have a major impact on our understanding of the evolution of the Sun's rotation during its lifetime – with implications on our understanding of the Sun's dynamo – and the evolution of other stars.

Needed Observations

The azimuthal plasma flow can only be observed near the Sun, since the azimuthal component decreases like 1/r with distance r in a mostly ballistic outflow. Therefore, Solar Orbiter must measure the detailed properties of the plasma flow at small distances from the Sun. Detailed modelling (MADAWG) of the coronal magnetic field based on precise magnetograms from Solar Orbiter is required in order to analyse the co-rotation and the mechanisms that release the solar wind from its source regions. Solar Orbiter must analyse spatial variations in the in-situ plasma and field properties before and after measuring the azimuthal flow in order to analyse structures that potentially deflect plasma (e.g., co-rotating interaction regions, rarefactions, compressions). Since alpha-particles can contribute significantly to the dynamics of the solar wind (Verscharen et al., 2015), we must study the kinetic fine structure of the ion distribution functions. For example, a variation in the relative drift between alpha particles, the proton beam, and the proton core through kinetic processes like instabilities has a (possibly strong) impact on the proton-core flow velocity due to momentum conservation. This effect depends on the direction and strength of the magnetic field, and it is expected to be stronger near the Sun.

References

Kasper, J. C., et al., Nature 576, 228, 2019

Verscharen, D., et al., Astrophys. J. 806, 157, 2015

Weber, E. J. & Davis, L. Jr., Astrophys. J. 148, 217, 1967