Origin of switchbacks: parametric simulations of solar jet propagation into the inner heliosphere

Abstract

The recent discovery of switchbacks, localized magnetic deflections in the solar wind, by Parker Solar Probe (PSP) has spurred investigations into their origin. One prominent theory suggests their formation in the lower corona through a process of magnetic reconnection akin to solar jet formation. To explore this hypothesis, I will present parametric simulations using a three-dimensional numerical magnetohydrodynamic (MHD) model of solar-jet-like events (such as e.g., coronal jets, jetlets, chromospheric jets, …). Within the MHD framework, I examine the influence of varying atmospheric plasma beta on the dynamics of solar-like jets.

Employing the ARMS (Adaptively Refined Magnetohydrodynamics Solver) code, I modeled the self-consistent generation of a solar jet, based on the model proposed by Pariat et al. 20009. The study investigates the jet's propagation within different solar atmospheric and Parker solar wind conditions, encompassing fully sub-Alfvénic wind and variations in Alfvén surface radius. Across these simulations, similar temporal energy variations were observed. Notably, magnetic energy injection exhibited consistency, with a partial conversion into kinetic energy during jet generation. Common structural characteristics in solar jets, including a dense bulk flow of plasma and a magnetic wavefront propagating at an Alfvénic speed in the atmosphere, were identified. However, the propagation ratio of these structures varied among simulations, revealing intricate influences of atmospheric stratification on jet dynamics.

Producing synthetic in-situ velocity and magnetic field measurements, akin to those observed by PSP or Solar Orbiter, I demonstrated that the magnetic wavefront does correspond to an Alfvénic deflection consistent with switchbacks observations. Focusing on the possible propagation of U-loops, I illustrated that these structures, although prevalent at the jet onset, do not survive in the low-beta corona. Consequently, this hinders the direct formation of full-reversal switchbacks from the lower atmosphere into the super-Alfvénic wind. Our findings may elucidate the absence of full reversal switchbacks in the sub-Alfvénic wind.

Overall, these simulations unveiled the propagation of magnetic deflections thanks to jet-like events, shedding light on the possible formation processes of switchbacks, combining both low-solar atmosphere and in-situ mechanisms.