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Propagation of solar coronal jets in the inner heliosphere

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Project description:

During its unprecedented approaches of the Sun, the recently launched Parker Solar Probe (PSP) mission (NASA), has made the puzzling discovery of very frequent abrupt deflections of the magnetic field in the solar wind, so called “switchbacks”, which have since also been regularly observed by the Solar Orbiter (SolO) mission of ESA. Many theories have emerged to try to explain these observations, which now need to be properly tested and discriminated. A family of scenarios place the origin of these event in the small scale activity occurring continuously at the base of the solar atmosphere. The switchback would be induced thanks to events involving magnetic reconnection low in the solar atmosphere. The kinked/twisted magnetic field generated would eventually propagate toward the inner heliosphere and produce the switchback observational features detected by PSP.

Jet-like activity is commonly seen in the solar atmosphere over a wide range of (spatial and temporal) scales, corresponding to a vast zoology of events (e.g. spicules, photospheric jets, chromospheric jets, surges, macro-spicules, EUV jets, X-ray jets). Their generation involves magnetic reconnection and the production of kinked/twisted magnetic field. Solar jets thus appear as possible natural phenomena that could induced switchback in the inner heliosphere. Whether the magnetic field driving the jet can indeed propagate and survive over several solar radius needs to be validated.

Based on a state-of-the-art 3D numerical model of solar jets (Pariat et al. 2009 and following paper), The PhD candidate will design new numerical experiments in order to follow the jet dynamics over tens of solar radius. The numerical experiment will be based on the ARMS code, running on high performance computing center. Preliminary simulations have already been carried and started to be analyzed during student internships. New simulations need however to be developed in order to increase the realism of the numerical experiment. The PhD candidate will run the new simulations on different meso-scale clusters as well as national high-performance computing centers (e.g. CINES, IDRIS) thanks to the yearly computing grants obtained by E. Pariat (1-2 million CPU hours/year).

The PhD candidate will analyze the dynamics and properties of the jet, and its inner-heliosphere evolution. The goal will be to determine the key physical process which permits the propagation of the different structure of the coronal jets. The simulation data will permit to product synthetic

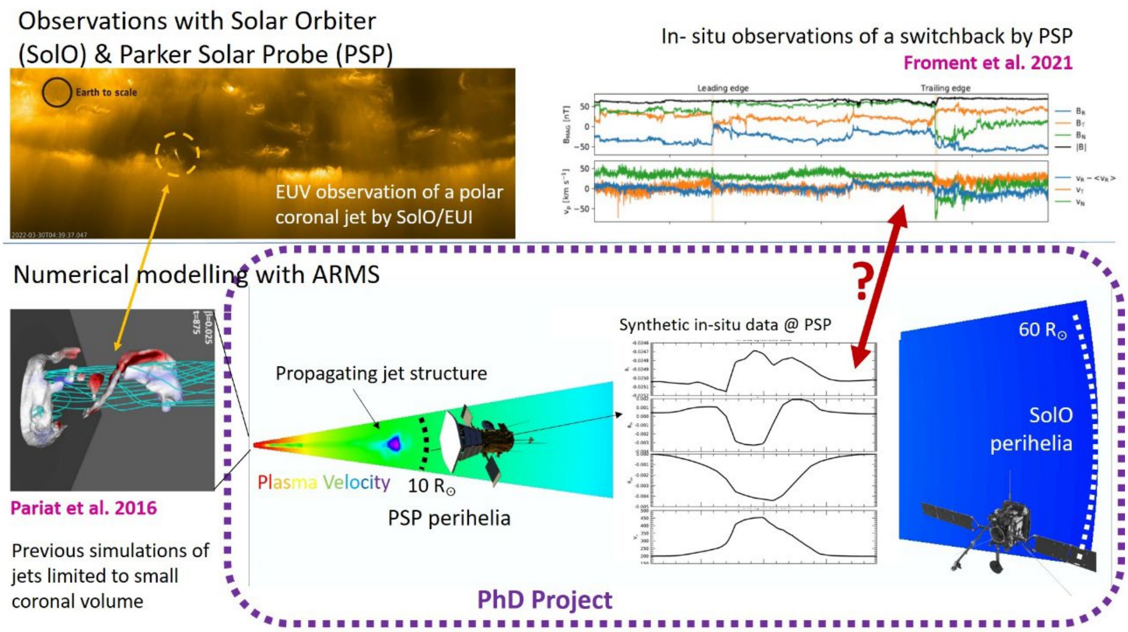

Figure: Context of the proposed PhD project

observations that could be compared with those acquired by the instruments of PSP and SolO. From the simulations, the PhD candidate will produce: synthetic coronographic data similar to SolO/METIS; in-situ magnetic field data similar to SolO/MAG and PSP/FIELDS; in-situ bulk speed and plasma density data similar to SolO/SWA and PSP/SWEAP. The PhD candidate will directly compare the synthetic observations with the relevant observations from PSP and SolO, benefiting from the collaboration with C. Froment (LPC2E), who has an extensive expertise on observations of switchbacks (e.g. Froment et al. 21) and is member of the lead Co-investigator team of the FIELDS instrumental suite of PSP.

Over the course of the PhD, the PhD candidate will carry multiple parametric simulations to produce jets with different properties (size, magnetic twist, …) in order to create a rough catalogue of possible signature of coronal jets in the inner heliosphere. Thanks to comparison between the simulated jets signatures and the actual observation, the PhD candidate shall be able to determine whether such jets can indeed explain switchbacks.

PhD project global schedule:

- Year 1: Analyze of the first innovative 3D MHD simulations of the propagation of jets in the inner heliosphere (under the supervision of E. Pariat); study of their structure, kinematics, evolution & driving mechanisms
- Year 2: Production of synthetic observational signatures; Comparison of these synthetic data with the latest observations from the PSP and SolO missions (in collaboration with C. Froment)
- Year 3: Production of parametric simulations of jets with different properties. Generation of a knowledge base/catalogue of synthetic observational properties of jet signature in the inner heliosphere. Comparison with PSP and SolO observations (in collaboration with C. Froment) to determine the trigger conditions compatible with the generation of switchbacks.

Selected relevant bibliographical references:

- “A model for solar polar jets”; Pariat E. et al.; ApJ, Vol. 691, pp. 61-74, 2009. https://doi.org/10.1088/0004-637X/691/1/61
- “A model for straight and helical solar jets: II. Parametric studies of the plama beta”; Pariat, E. et al. ; Astronomy & Astrophysics, Vol. 596, id.A36, 20 pp., 2016 ; https://doi.org/10.1051/0004-6361/201629109
- “Direct evidence for magnetic reconnection at the boundaries of magnetic switchbacks with Parker Solar Probe” ; Froment, C. et al. ; Astronomy & Astrophysics, Vol. 650, id.A5, 10 pp. 2021. https://doi.org/10.1051/0004-6361/20203980