Are Switchback boundaries observed by Parker Solar Probe closed?

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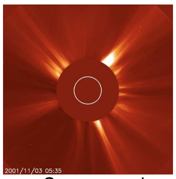
Solar wind

Constant outflow of highly ionised solar plasma:
- protons and electrons
- speed up to 700 km/s

Parker Solar Probe: closest mission to the Sun

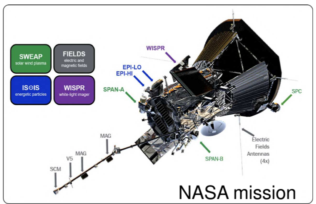


Coronagraph

Launch: Aug. 2018
Max speed: 692 000 km/h
→ Paris - Toulouse in 3.5s

Min Distance: 1/20 of Earth-Sun distance (150.10^6 km)

Heatshield Temp: 1400°C



NASA mission

What's new? PSP detected omnipresent magnetic kinks in the solar wind, whose origin and propagation are still unexplained

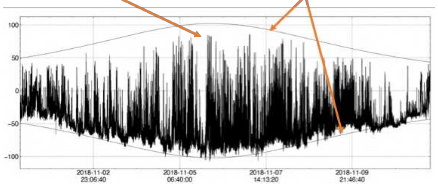
Why is it interesting? May be linked to the anormal temperature of the solar coronal and the unexplained acceleration of the solar wind

Switchbacks

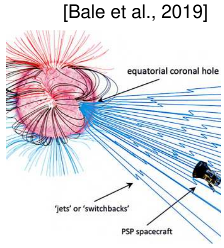
Switchback= Sudden magnetic deflection observed in the solar wind

Switchbacks — Expected $1/r^2$ scaling

Radial component of the magnetic field



[Bale et al., 2019]



Objectives: Understanding the nature of the boundary of these magnetic deflections

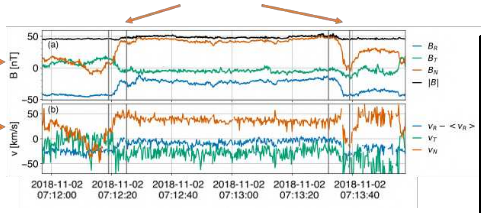
What we find: They are mostly closed boundaries, with self-similar properties, which suggest a slow erosion as they propagate. This is in agreement with a solar origin

Switchback boundaries

Boundaries

Magnetic field

Proton velocity

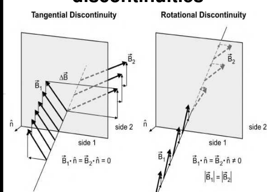


Main parameter for the classification: $(\mathbf{B}\cdot\mathbf{n})/|\mathbf{B}|$
Small → Tangential Discontinuities
Large → Rotational Discontinuities

Objective: Identify the plane of the discontinuity and its normal **n** to classify the boundary

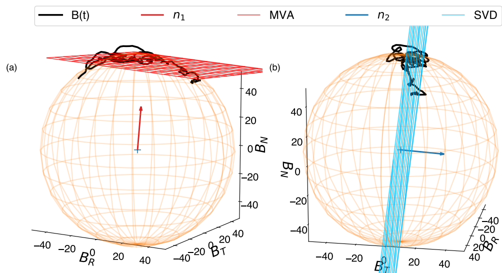
Our methodology:
Apply two methods Minimum Variance Analysis (MVA) and Singular Value Decomposition (SVD) to estimate this plane in 3D and its normal

General theory of MHD discontinuities



[Tsurutani et al.,2011]

Example of a boundary in 3D



The view is rotated between the two panels

Properties:
- Arc-polarized structures with a rotation always contained in a plane
- Alfvénic structures → Constant magnitude |**B**|
→ Deflection at the intersection of a plane and a sphere
- Superimposed fluctuations
- SVD plane includes the origin
- MVA captures fluctuations, usually tangent to the sphere

Results

- Visual identification of 250 boundaries

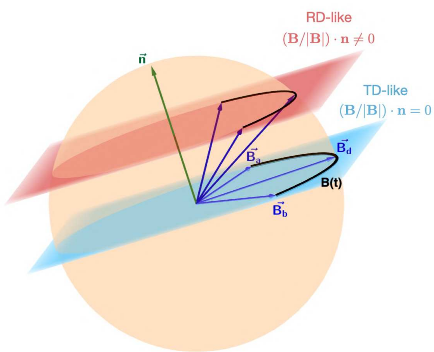
- All boundaries are **arc-polarized structures** with constant |B| and included in a plane

We find that:
→ most discontinuities are Tangential (71%)
→ some are Rotational (3%)
→ remaining are unclassified (26%)

- No clear dependance on the magnitude of the deflection
→ self-similar

Nature of the boundary boils down to:
Does the plane include the origin or not ?

Discontinuities in the context of switchbacks



Comparison with previous analyses:
[Larosa et al., 2021][Akhavan-Tafti et al, 2021]
- Mostly Rotational
- Use of MVA only which biased towards Rotational

Physical implications:
- Closed boundaries : no plasma flow across the boundary
- Slower erosion of the structures
- Compatible with a solar origin of the structures
- Self-similar : small structures are not large structures which evolved and were eroded to become smaller

Conclusion

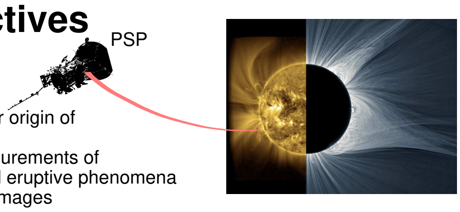
- Switchbacks are arc-polarised structures whose rotation is always contained in a plane

- Mainly closed structures (TDs)
- Stark contrast with previous analyses (RDs) → Use the MVA with great caution

→ stable structures which may survive until larger distances (observed at Earth's orbit)

- Switchback origin is likely to be rooted deep in the solar corona

My perspectives



Investigation of the solar origin of switchbacks:
Connecting in situ measurements of switchbacks at PSP and eruptive phenomena observed in solar EUV images