Are Switchbacks boundaries observed by Parker Solar Prob closed?

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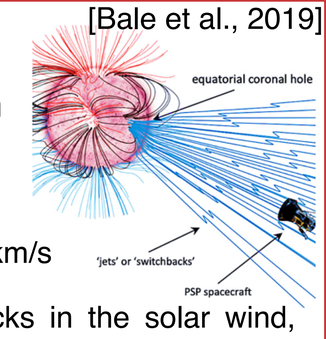
Context

[Bale et al., 2019]



Switchbacks = Sudden magnetic deflection observed in the solar wind

Parker Solar Probe : closest mission to the Sun

Solar wind: stream of solar plasma at speed of 400km/s

What's new ? PSP detected ubiquitous switchbacks in the solar wind, whose origin and propagation are still unexplained

Objectives : Understanding the nature of magnetic deflections

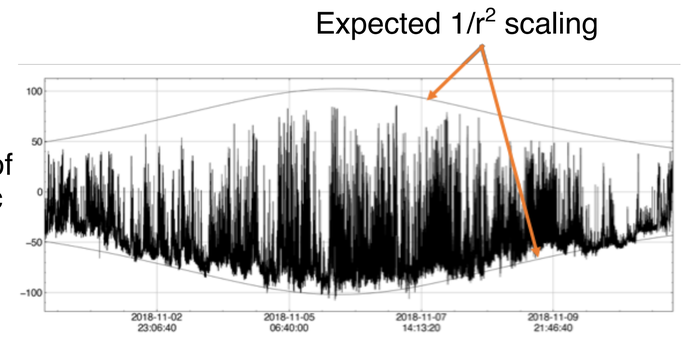
What do we investigate : Analyse of their boundaries to determine their nature and the possible dependance on the magnitude of deflections

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

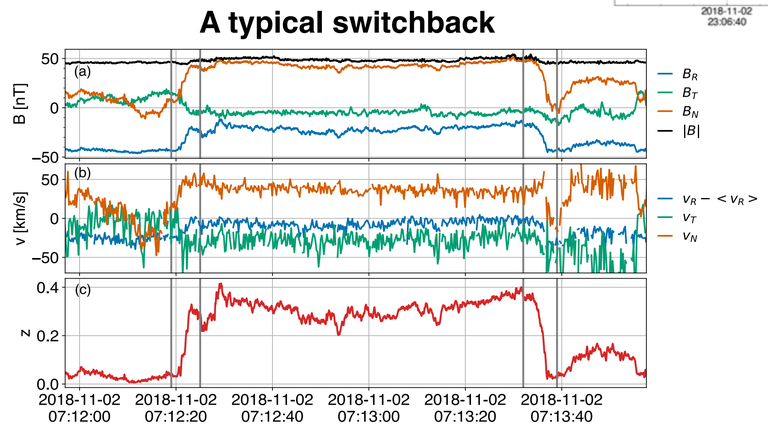
Why is it interesting ? May be linked to the anormal temperature of the solar corona and the acceleration of the solar wind

Switchbacks

Radial component of the magnetic field



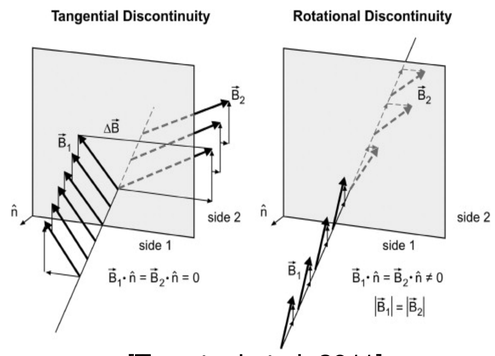
A typical switchback



Interesting properties:
- Limitation of analysis of 3D structures with one spacecraft
- Alfvénic nature: Constant IBI and correlated fluctutations v and B
- Duration: from 1s to few hours
- No characteristic deflection angle

Methods

General theory of MHD discontinuities

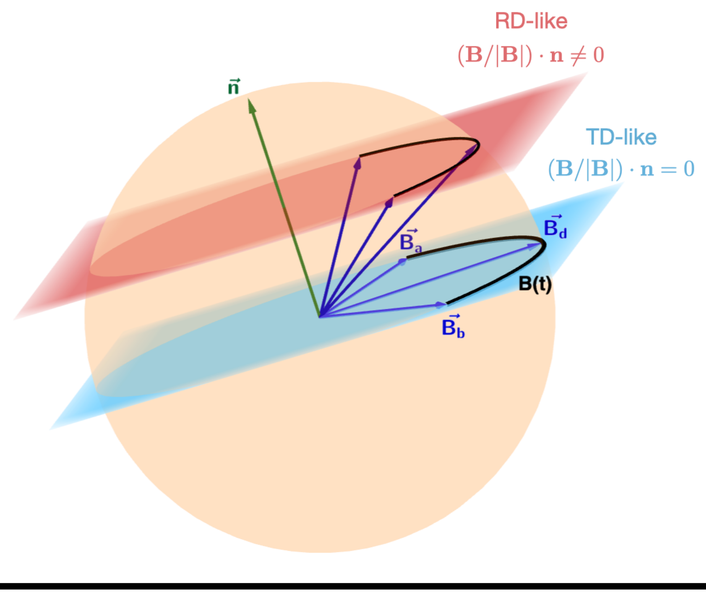


[Tsurutani et al.,2011]

Main parameter for the classification: (**B**·**n**)/I**B**I
Small →Tangential Discontinuities
Large → Rotational Discontinuities

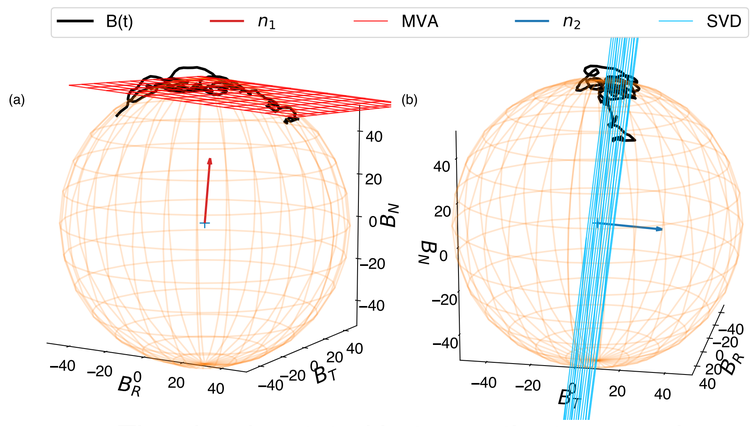
Objective: Identify the plane of the discontinuity and its normal **n** to classify the boundary

Discontinuities in the context of switchbacks :



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

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 I**B**I
→ 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 IBI and included in a plane

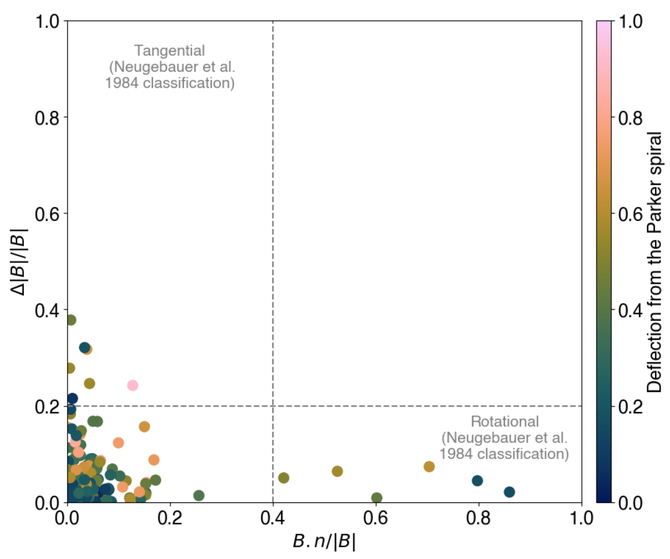
We find that:
→ most discontinuities are Tangential (71%)
→ some are Rotational (3%)
→ remaining are unclassified (26%)

- 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 ?

Classical scheme for discontinuities

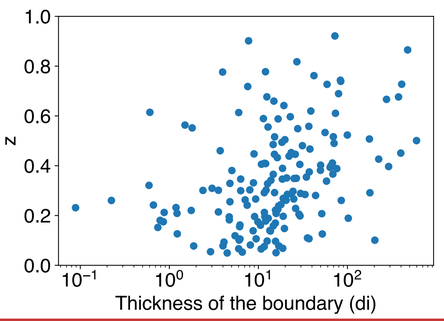
Neugebauer et al. 1984 classification



- Most of the boundaries have a small I(**B**·**n**)I/I**B**I (≤0.2)and a small IΔ**B**I/I**B**I (≤0.1)
- No clear dependance on the magnitude of the deflection → self-similar
- Mostly unclassified boundaries with the scheme

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



$$D = (t_d - t_b) \cdot (\langle \mathbf{V}_{pl} \rangle - \mathbf{V}_{SC})$$

Comparison of thickness with plasma scales :
- Exceed proton inertial length di
- In the MHD scales

Conclusion

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

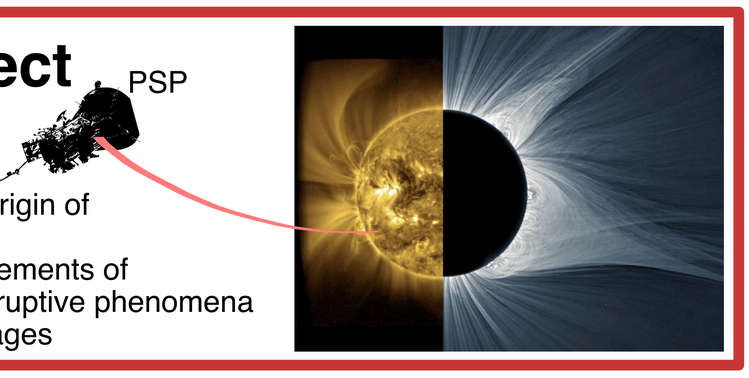
- Mainly closed structures (TDs)
- Stark contrast with previous analyses (RDs) → Use the MVA with great caution

→ 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

Current project

Talk on wednesday



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