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Radial properties and evolution of magnetic reconnection near the Sun

Laboratoire d'Astrophysique de Bordeaux – M1 NPU Internship

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Summary

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- The Sun and its Surrounding Environment
- Parker Solar Probe Mission and Instrumentation
- Method : Flux Rope Fitting
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- Discussion and Conclusion

Introduction

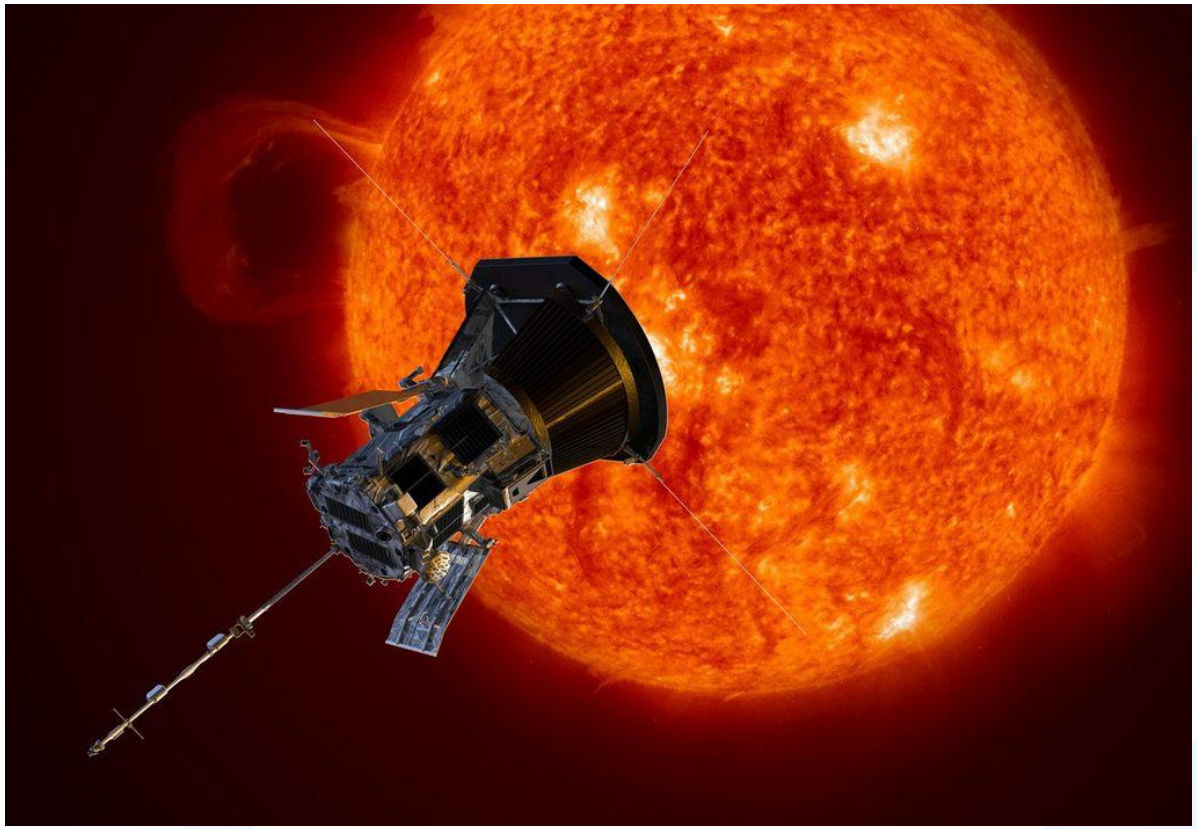


Figure 1 : Artistic view of PSP flying near the Sun

- **Solar corona** : source of the solar wind
- **Magnetic reconnection** : field restructuring, energy release
- **Flux ropes** : twisted magnetic structures from reconnection
- **Parker Solar Probe** : in-situ data near the Sun

Magnetic Reconnection and Flux Ropes

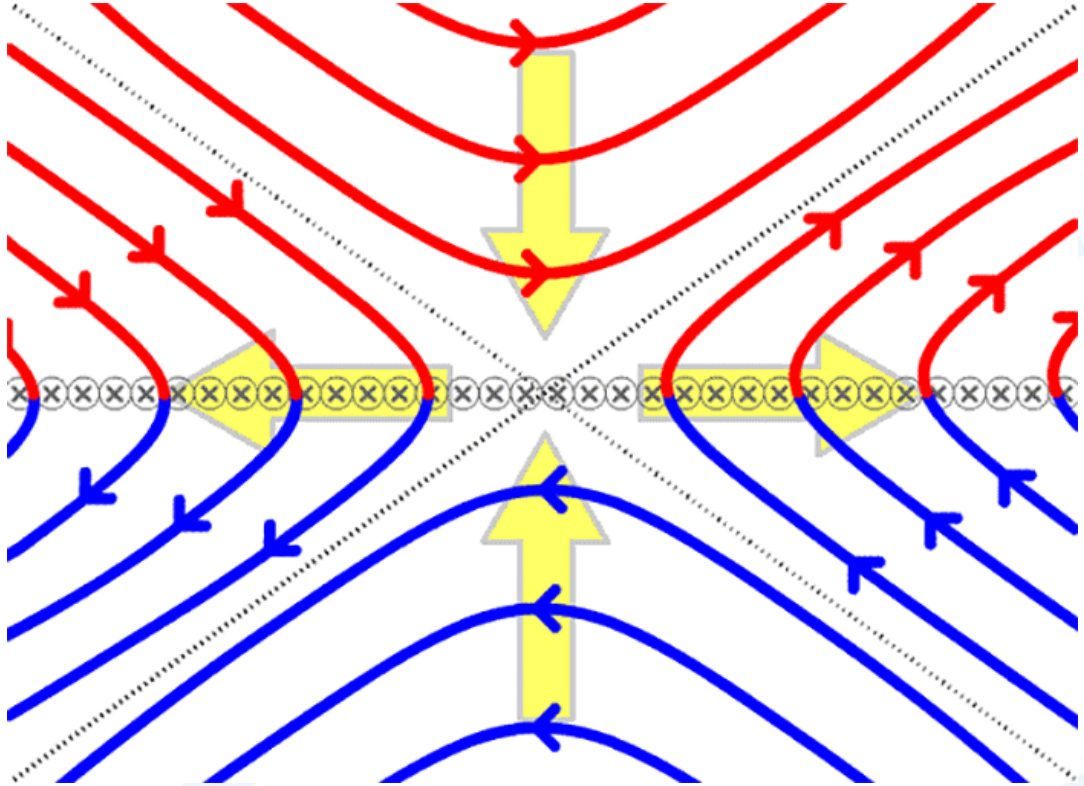


Figure 5 : Magnetic reconnection process

- **Reconnection** = magnetic field lines break & reconnect
- **Releases energy** → plasma heating & acceleration
- Key process near the Sun (dense, turbulent plasma)
- Forms **small-scale structures** → **flux ropes**

The Sun and its Surrounding Environment

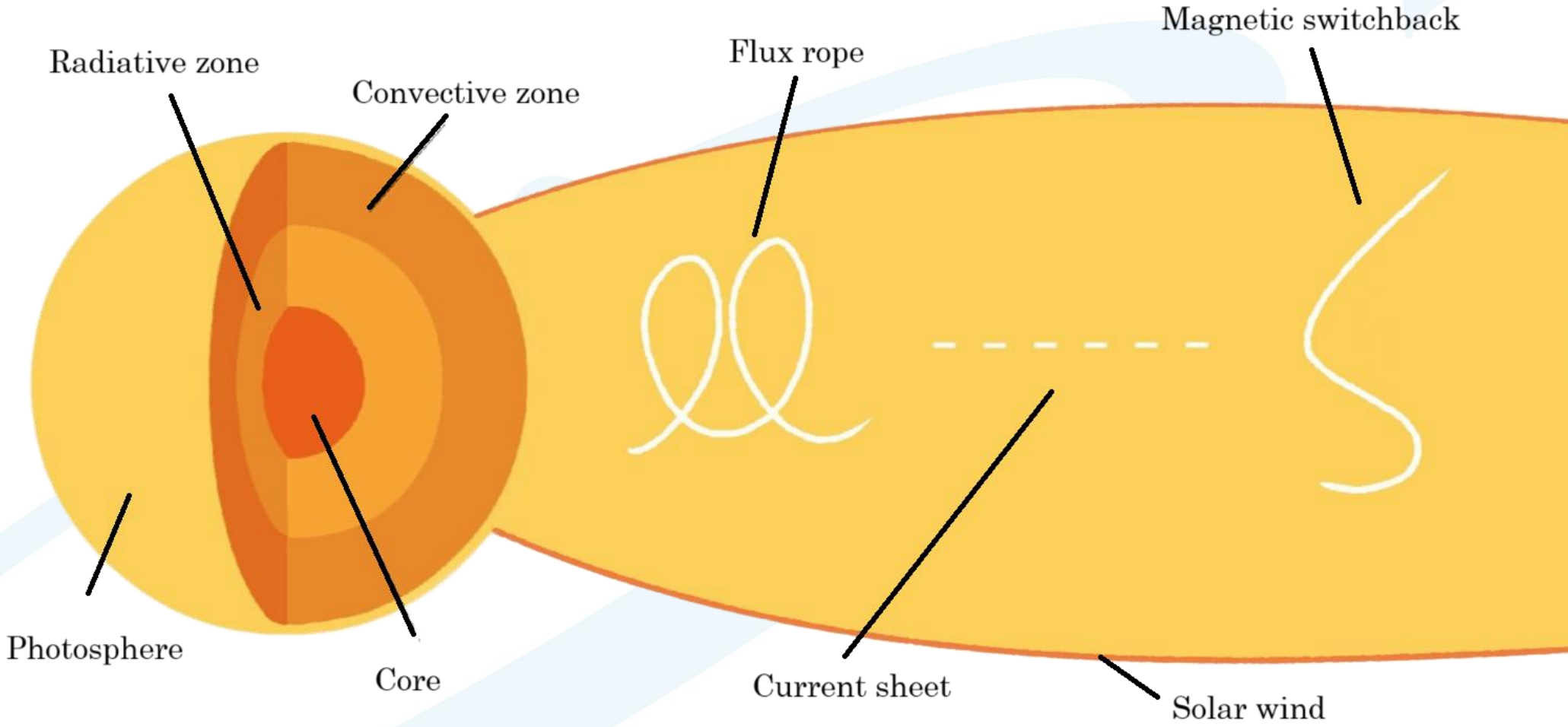


Figure 2 : Structure of the Sun

Parker Solar Probe Mission

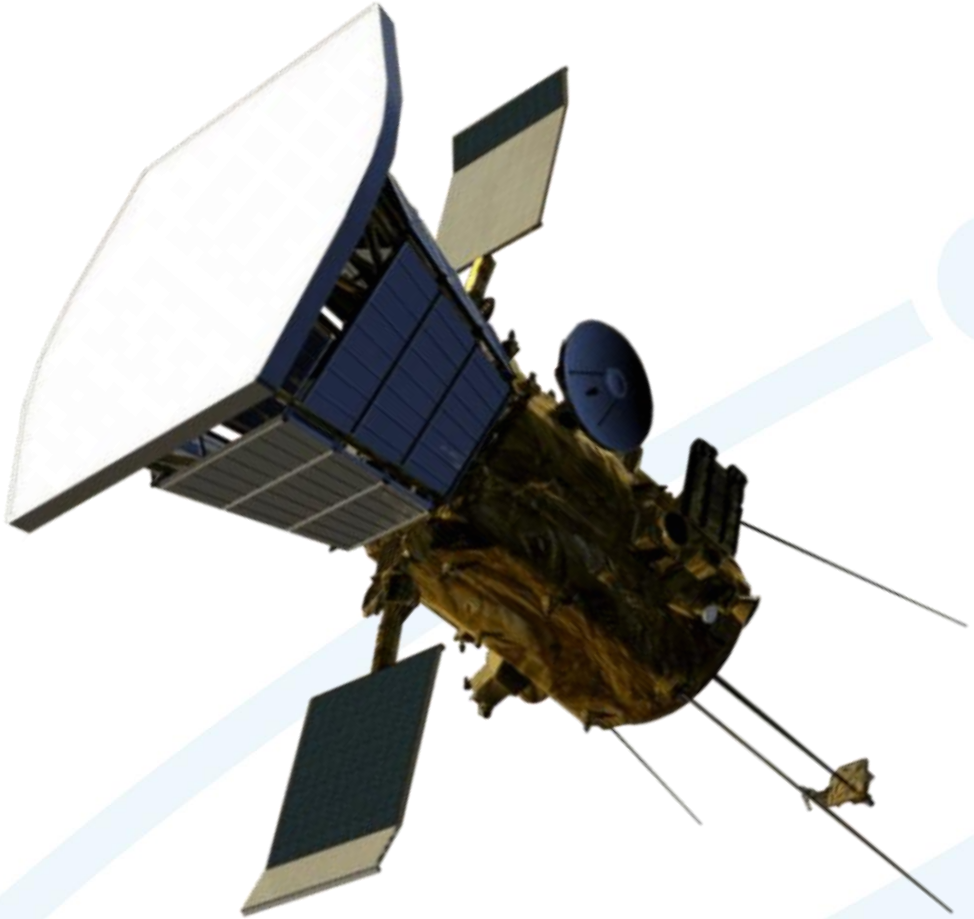


Figure 3 : Parker Solar Probe

- Launched in **2018** – first probe within **10 R⊙**
- Studies **coronal heating** and **solar wind acceleration**
- In-situ measurements in **turbulent magnetic environment**

Parker Solar Probe Instrumentation

- **FIELDS** : Magnetic & electric fields
  - Reconnection, turbulence
- **SWEAP (SPAN-e)** : Electron distributions
  - Strahls, bidirectional flows
- **IS⊙IS** : Energetic particles
  - Acceleration, propagation

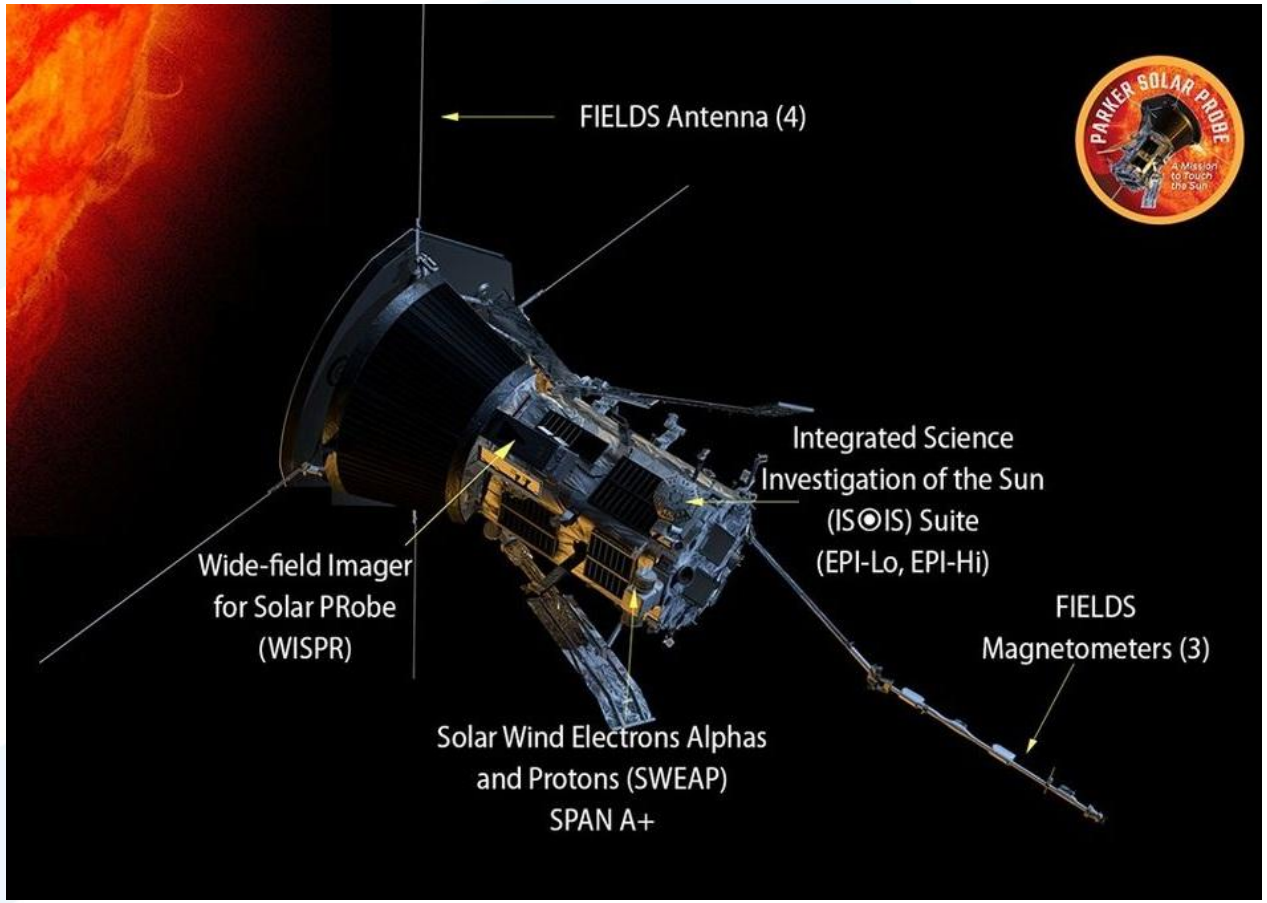


Figure 4 : Artistic view of PSP Instrumentation

Method : Flux Rope Fitting

- **Flux ropes** = twisted magnetic structures
- **Signature** : enhanced |B| + smooth rotation of B components
- Identified visually in PSP magnetic field data
- **Key parameters** :
  - $\boldsymbol{\theta_0}$: elevation angle
  - $\boldsymbol{\phi_0}$: azimuthal angle
  - $\boldsymbol{b_0}$: closest distance to magnetic axis

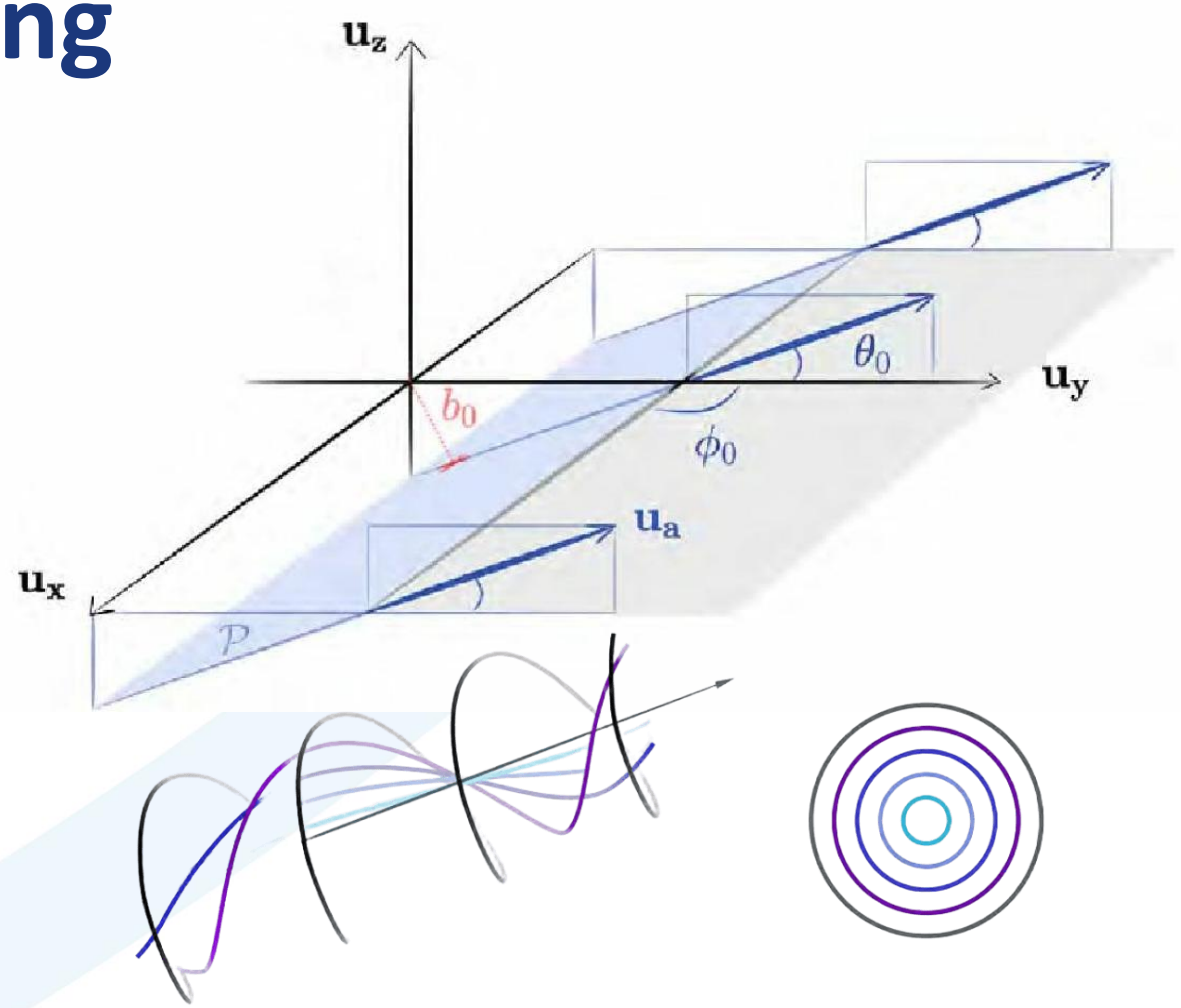
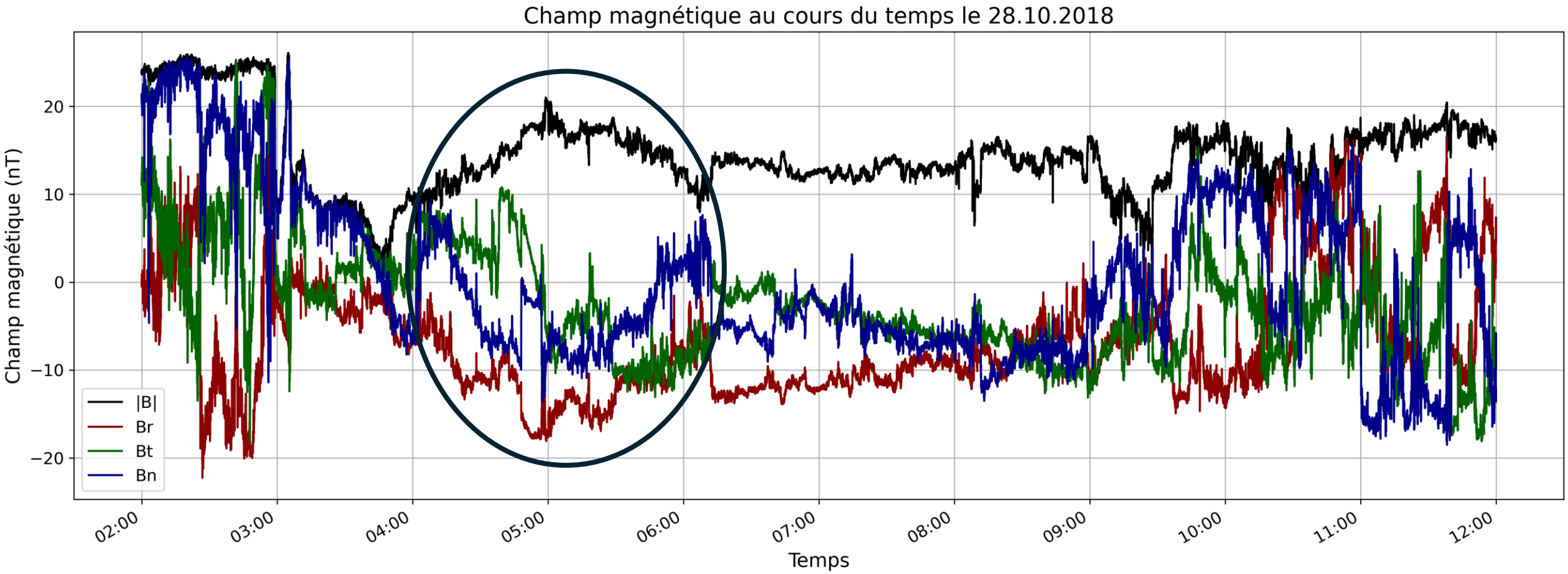
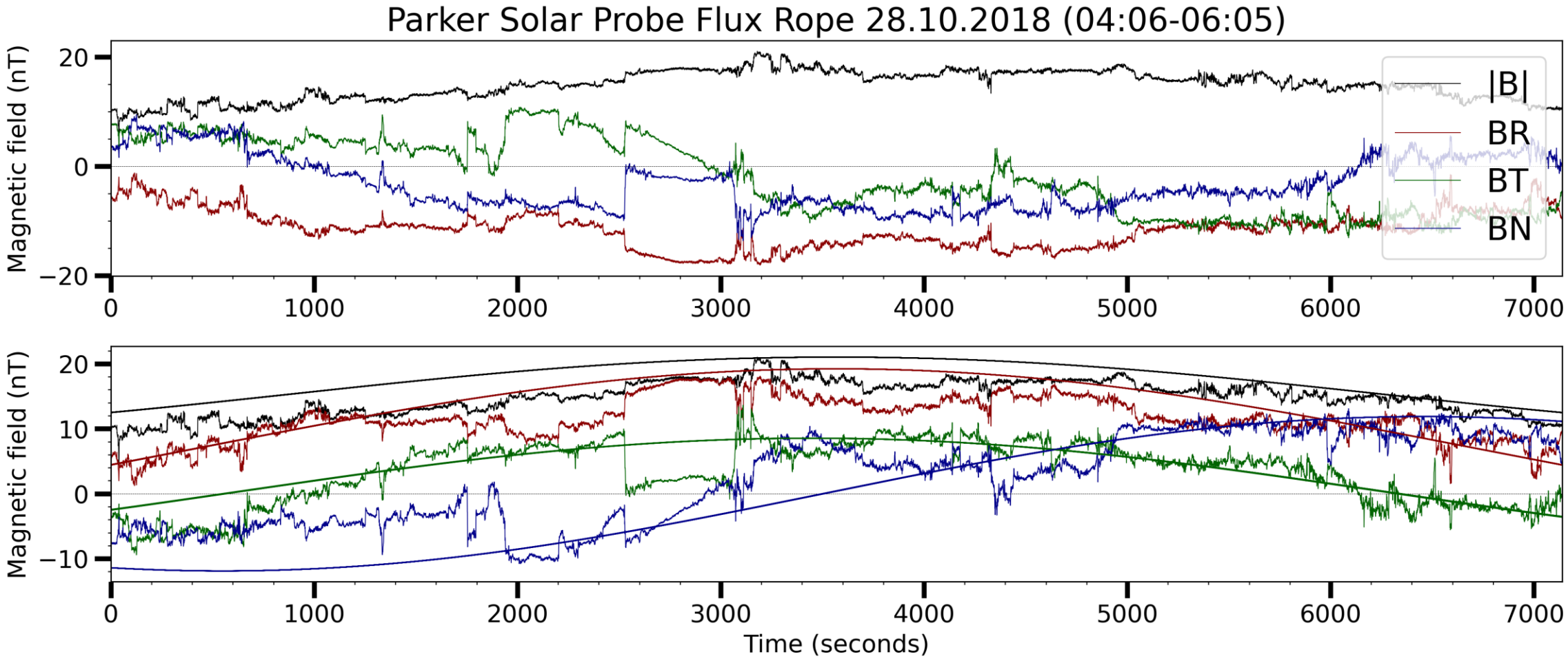


Figure 6 : Structure of a flux rope

Example of an Event : Detection



Example of an Event : Fitting



Event Illustration: Analysis

- **5 key parameters**
  - α = twist
  - b_0 = distance to the center
  - θ_0, ϕ_0 = orientation
  - loc = relative center position
- **Derived quantities**
  - Radius = based on b_0, Δt, V_r
  - Confidence intervals for θ_0 & ϕ_0
  - Parameter distributions
- **Data processing**
  - 32 “ants” per event
  - Python code for automated statistics

Detailed examination of the previous studied flux rope

Δt automatically computed from data: 7139.51 seconds

===== PARAMETER STATISTICS =====

	Min	Max	Mean	Std
alpha	0.0351	0.9850	0.5204	0.3191
b0	-6.0603	6.9853	1.9135	4.0238
phi0	-3.0682	2.6304	-0.1279	1.7752
theta0	-1.5681	1.4820	0.1451	0.9704
Radius [$R_\odot$]	1.7959	1.7959	1.7959	0.0000

===== 95% CONFIDENCE INTERVALS FOR ORIENTATION =====

Theta0: from -1.386 to 1.466 radians

Phi0 : from -2.894 to 2.507 radians

Statistical Catalog of Fitted Flux Ropes

- **11 flux ropes** analyzed using the same fitting method
- **Key findings**
  - Radius ≈ similar for most events (1-2 R⊙)
  - α and b_0 highly variable : diverse internal structures
  - Mean θ_0 & ϕ_0 near equator : global orientation trend
  - Large spreads : reconnection likely not uniform

Event	α (mean $\pm$ std)	b_0 (mean)	θ_0 (mean)	ϕ_0 (mean)	Radius (R⊙)
20181028T0406	0.52 ± 0.32	1.91	0.15	-0.12	1.80
20181029T2118	0.47 ± 0.27	1.30	0.00	-0.03	1.52
20181030T0628	0.61 ± 0.28	0.69	0.34	-0.67	1.64

Discussion and Conclusion

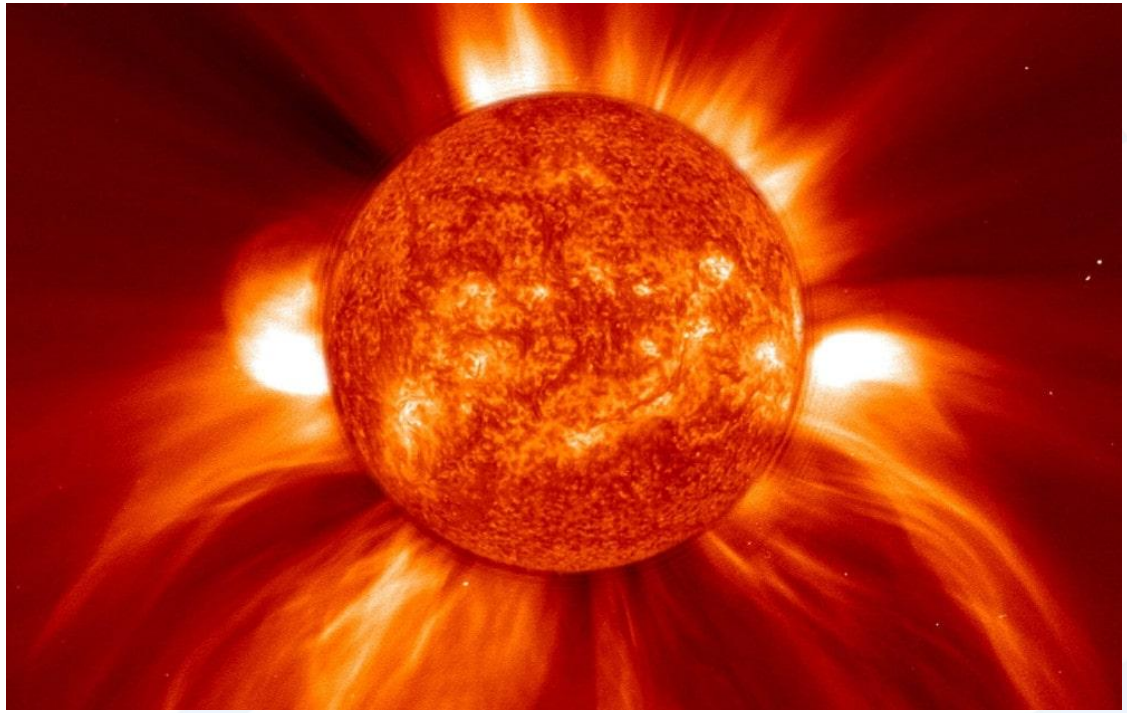


Figure 7 : Artistic view of the Sun

- **Identified flux ropes in PSP data** via visual inspection + model fitting
- **October 28, 2018 event** : clear, well-structured force-free flux rope
- Statistical analysis shows **diverse** flux ropes, mostly equatorial, similar sizes
- Reconnection likely frequent in solar wind at various scales
- Current models limited → need for **advanced methods**

Thank you for your attention

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Questions

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