

# Coronal shock waves properties and solar energetic particles

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SERPENTINE Symposium — 28/06/2023





## ❖ Introduction

## ❖ Shock wave model

- Model shock waves with 3D ellipsoidal shape
- Analyse their geometry and kinematics

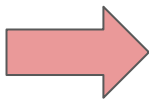
## ❖ New shocks

- New tool for shock fitting
- Example for the 5 september 2022 event
  - Observations timeline
  - Fitting results

## ❖ Shock analysis method → for the same event as an example

- Reconstruct the magnetic connectivity of spacecrafts
- MHD shock properties
- Possible links with SEPs : preliminary results

## ❖ Conclusion



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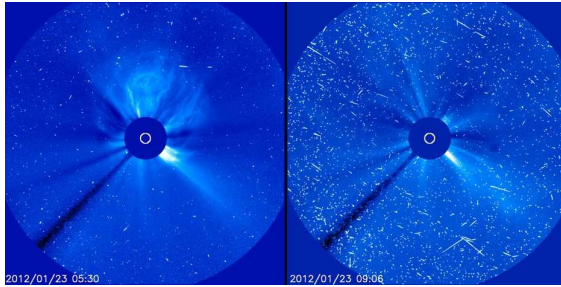
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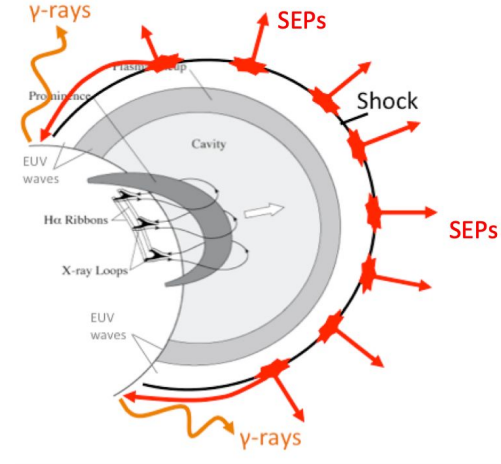
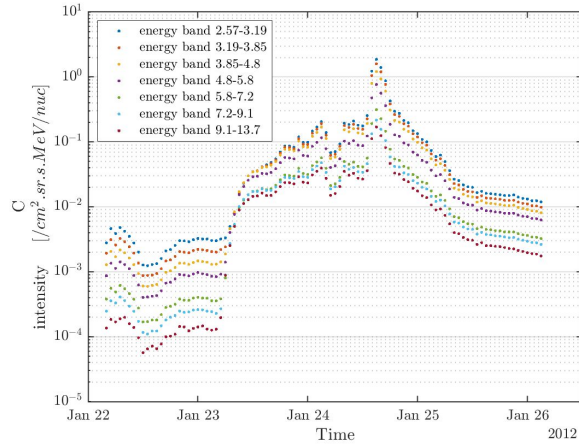
## ❖ Conclusion



# ❖ Introduction



SoHO/LASCO



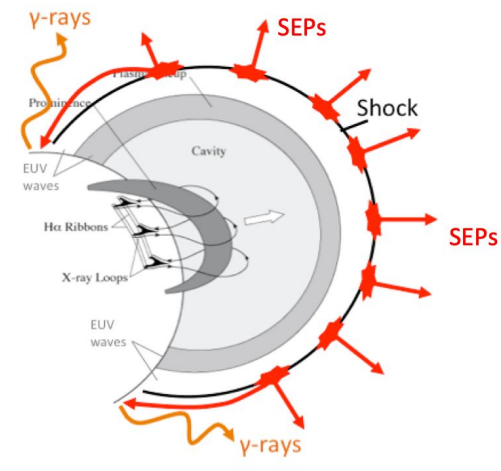
## ❖ Introduction

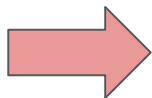
**Context :** Some coronal mass ejections (CMEs) produce shock waves in the solar corona that can lead to solar energetic particle (SEP) events.

**Goal :** Better understand the shock contribution in the production of SEPs

### Steps :

- Shock wave model
- Tool for new shocks
- Magnetic connectivity
- MHD shocks properties
- Possible links with SEPs characteristics





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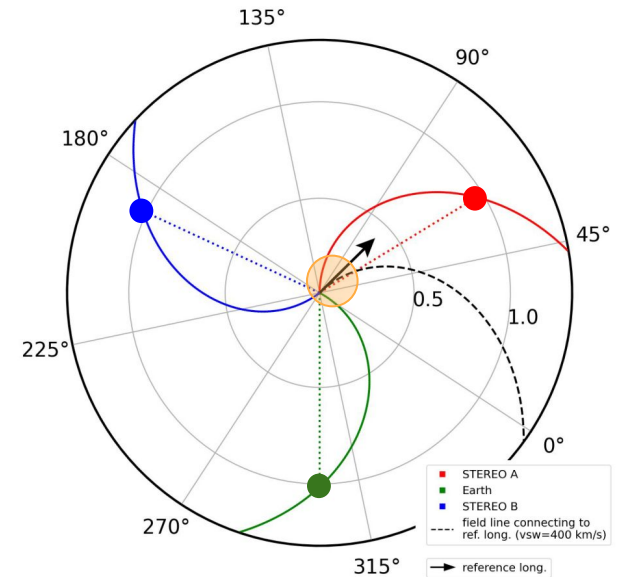
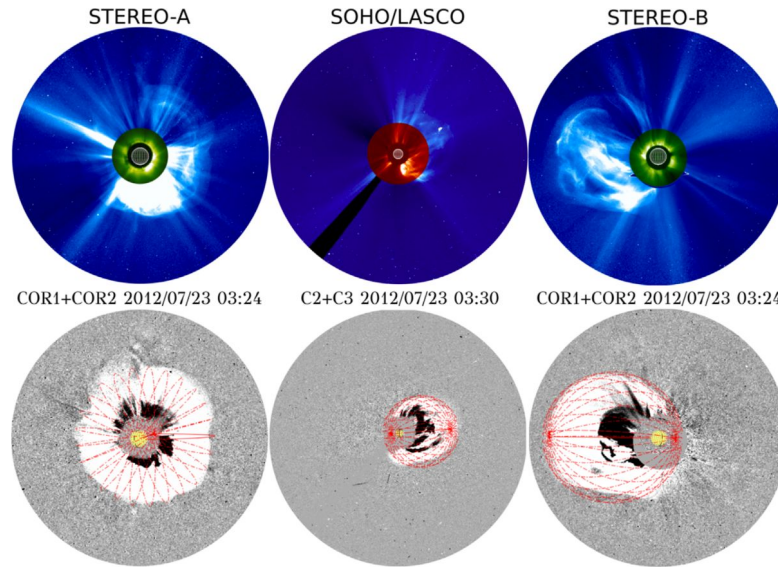


## ❖ Shock wave model

### ➤ Model shock waves with 3D ellipsoidal shape

Catalog of shock waves [Kouloumvakos et al. (2019)]

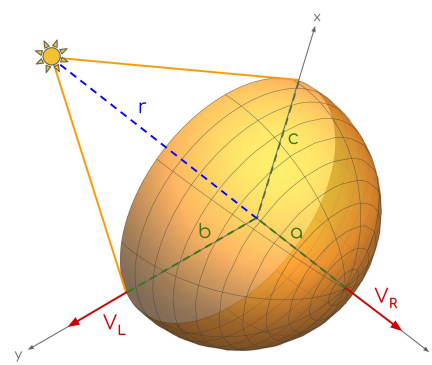
- Selection of 33 CMEs shock waves
- Reconstruction of their time-evolving 3D ellipsoidal shape





## ❖ Shock wave model

- Analyse their geometry and kinematics

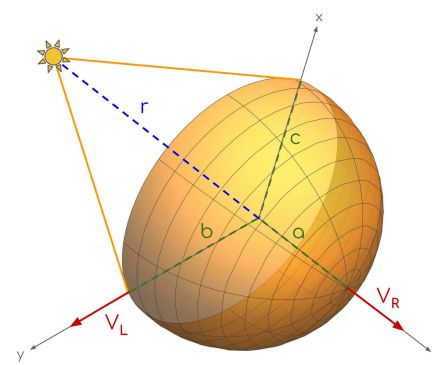
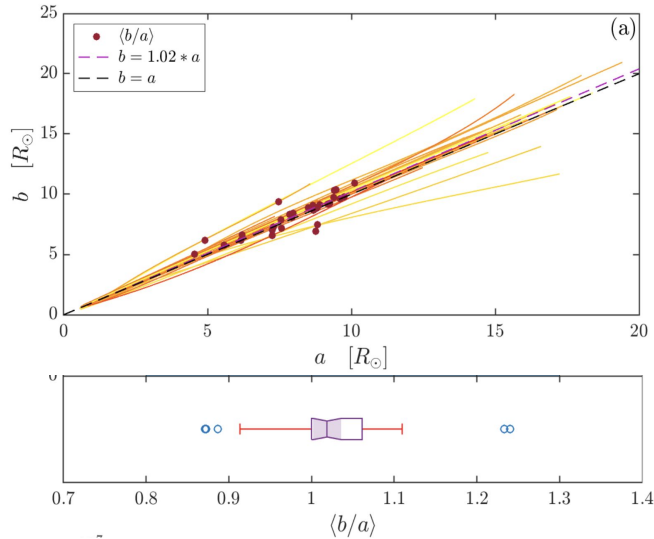


## ❖ Shock wave model

- Analyse their geometry and kinematics

Results between 2 and 25 solar radius :  
[Jarry et al. (2023)]

$$\langle b/a \rangle = 1.03 \pm 0.08$$



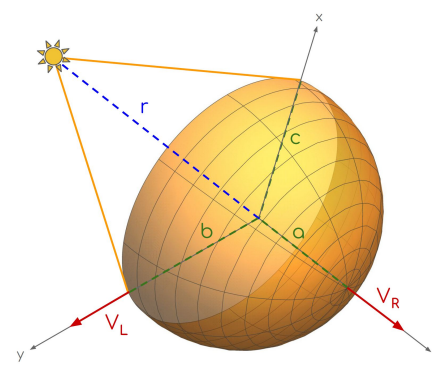
$$a \sim b \sim c$$



## ❖ Shock wave model

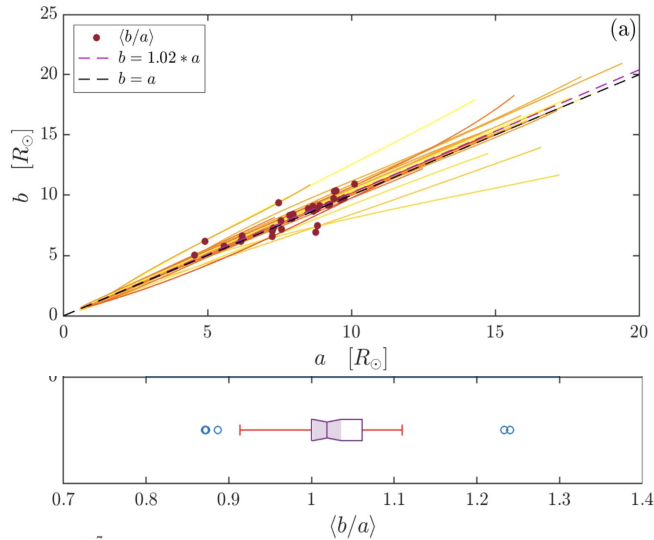
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Results between 2 and 25 solar radius :  
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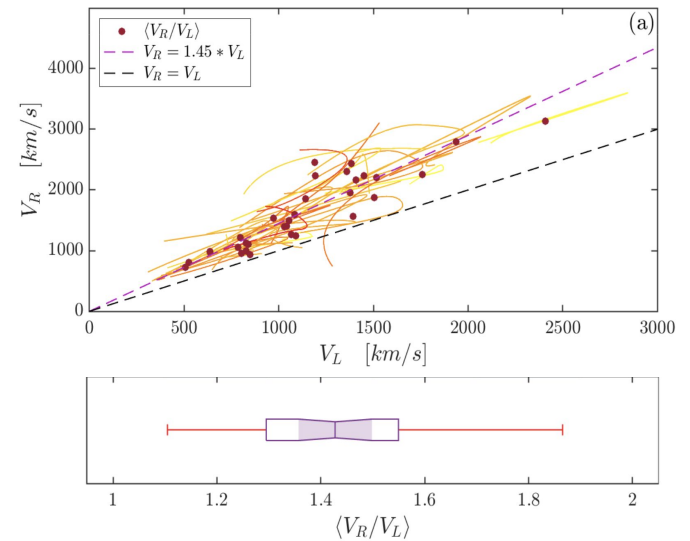


$a \sim b \sim c$

$$\langle b/a \rangle = 1.03 \pm 0.08$$



$$\langle V_R/V_L \rangle = 1.44 \pm 0.22$$

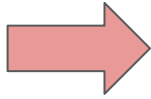




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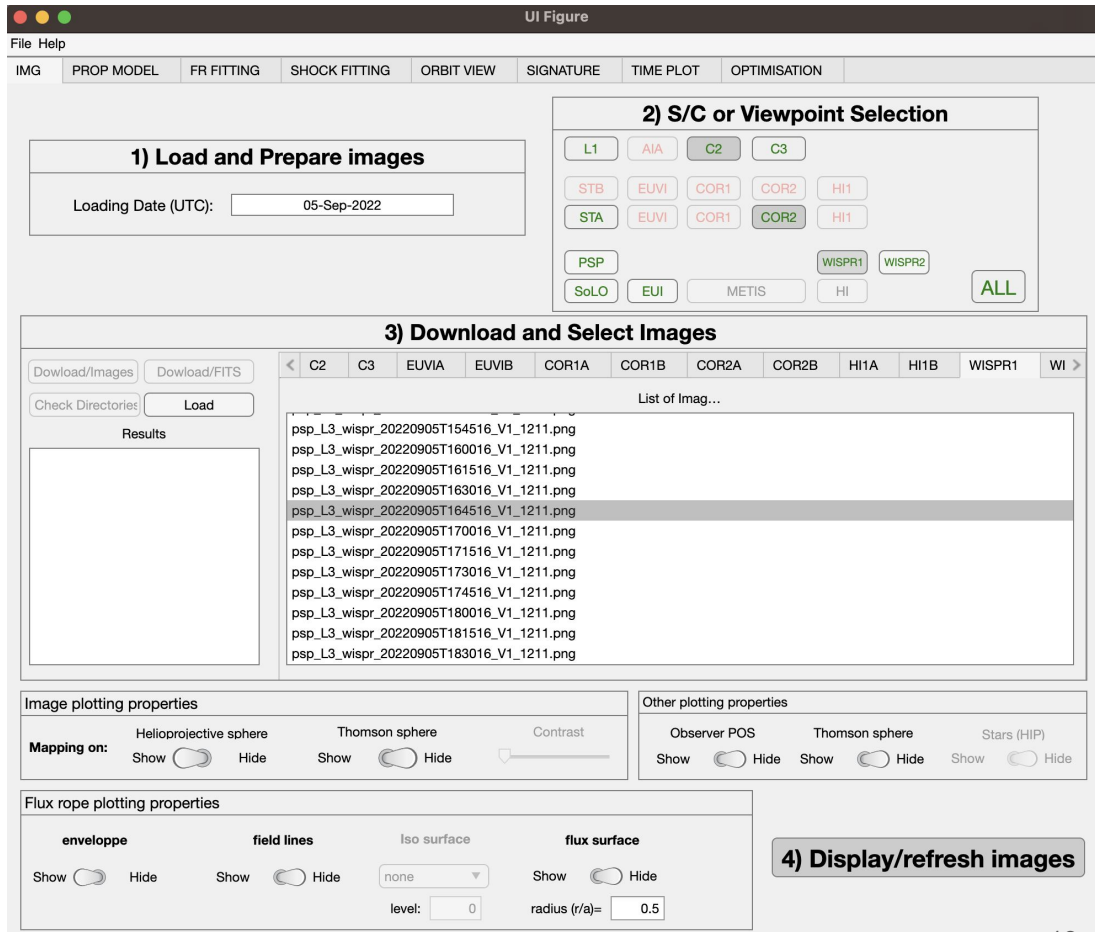
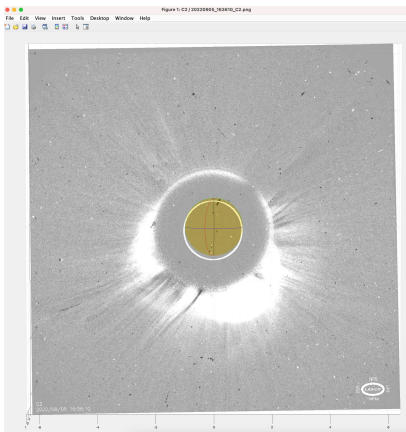
- Reconstruct the magnetic connectivity of spacecrafts
- MHD shock properties
- Possible links with SEPs : preliminary results

## ❖ Conclusion

# ❖ New shocks

## ➤ New tool for shock fitting

- Matlab tool
- originally created to fit flux ropes but now adapted to fit shocks
- added the possibility of fitting WHISPR data



**1) Load and Prepare images**

Loading Date (UTC):

**2) S/C or Viewpoint Selection**

L1 AIA C2 C3

STB EUVI COR1 COR2 HI1

STA EUVI COR1 COR2 HI1

PSP WISPR1 WISPR2

SoLo EUJ METIS HI ALL

**3) Download and Select Images**

Download/Images Download/FITS

Check Directories:

Results

← C2 C3 EUVIA EUVIB COR1A COR1B COR2A COR2B HI1A HI1B WISPR1 WI →

List of Imag...

psp\_L3\_wispr\_20220905T154516\_V1\_1211.png  
psp\_L3\_wispr\_20220905T160016\_V1\_1211.png  
psp\_L3\_wispr\_20220905T161516\_V1\_1211.png  
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psp\_L3\_wispr\_20220905T183016\_V1\_1211.png

**Image plotting properties**

Mapping on: Helioprojective sphere Thomson sphere Contrast

Show  Hide  Show  Hide

**Other plotting properties**

Observer POS Thomson sphere Stars (HIP)

Show  Hide  Show  Hide  Show  Hide

**Flux rope plotting properties**

enveloppe field lines Iso surface flux surface

Show  Hide  Show  Hide  Show  Hide

level:  radius (r/a)=

**4) Display/refresh images**



# ❖ New shocks

➤ Example for the 5 september 2022 event

UI Figure

File Help

IMG PROP MODEL FR FITTING SHOCK FITTING ORBIT VIEW SIGNATURE TIME PLOT OPTIMISATION

Shock wave parameters -- manual fitting

Longitude  deg  
0 40 80 120 160 200 240 280 320 360

Latitude  deg  
-90 -75 -60 -45 -30 -15 0 15 30 45 60 75 90

r  R<sub>sun</sub>  
0 5 10 15 20 25 30

a  R<sub>sun</sub>  
0 5 10 15 20 25 30

b  R<sub>sun</sub>  
0 5 10 15 20 25 30

c  R<sub>sun</sub>  
0 5 10 15 20 25 30

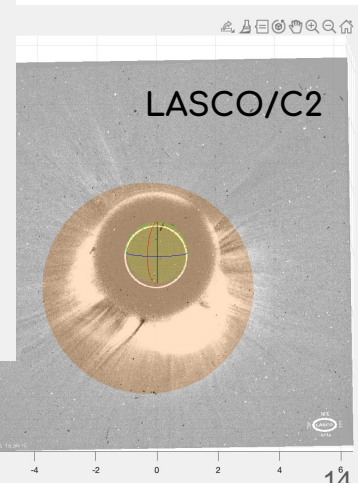
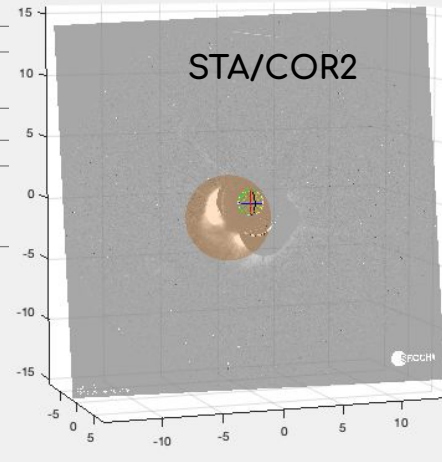
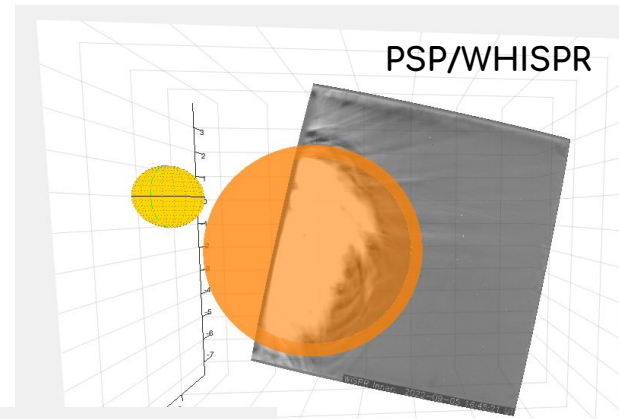
Tilt  deg  
-90 -70 -50 -30 -10 10 30 50 70 90

Number of points:

**Shock**  
Show  Hide

Heliographic coordinates  
 Stonyhurst  Carrington

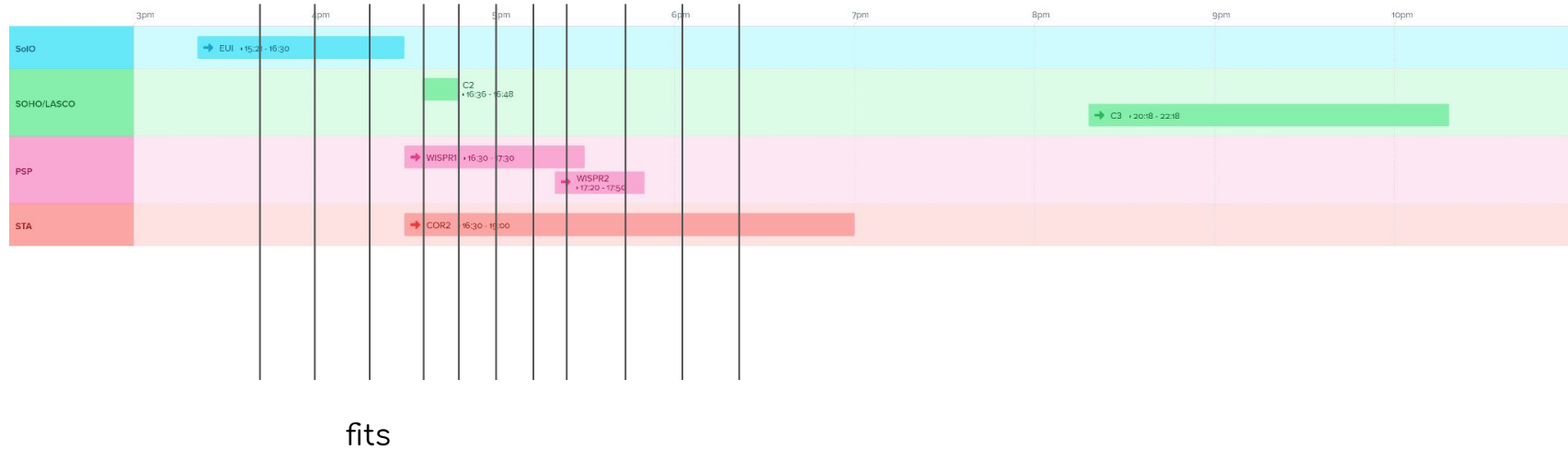
Shock axes  
 r,a,b,c  h,e,k,alpha  
 Spheric shape (a=b=c)



## ❖ New shocks

### ➤ Example for the 5 september 2022 event

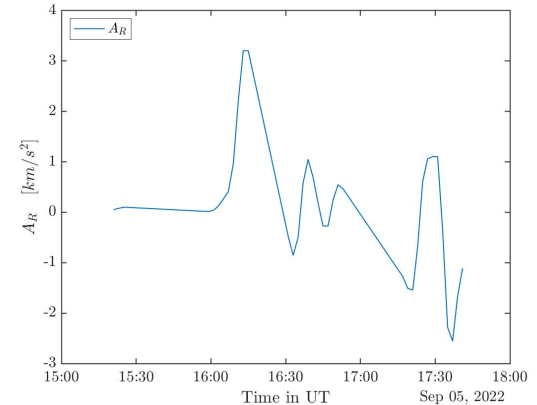
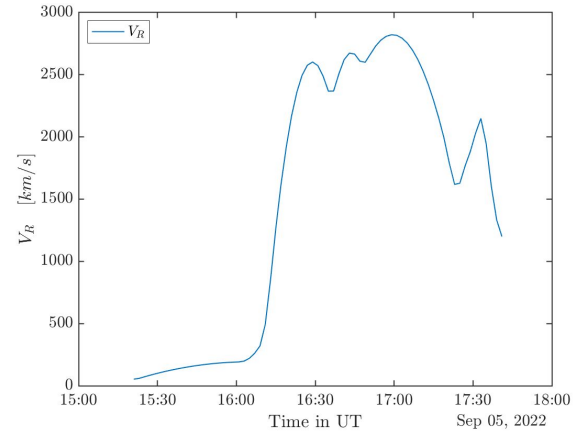
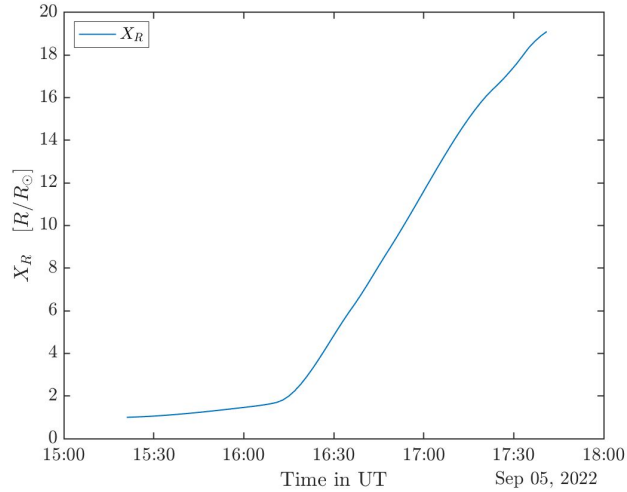
#### ■ Observations timeline



## ❖ New shocks

### ➤ Example for the 5 september 2022 event

#### ■ Fitting results



faire une moyenne des stats J2023  
et la superposer avec ces figures  
en rouge







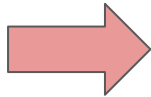
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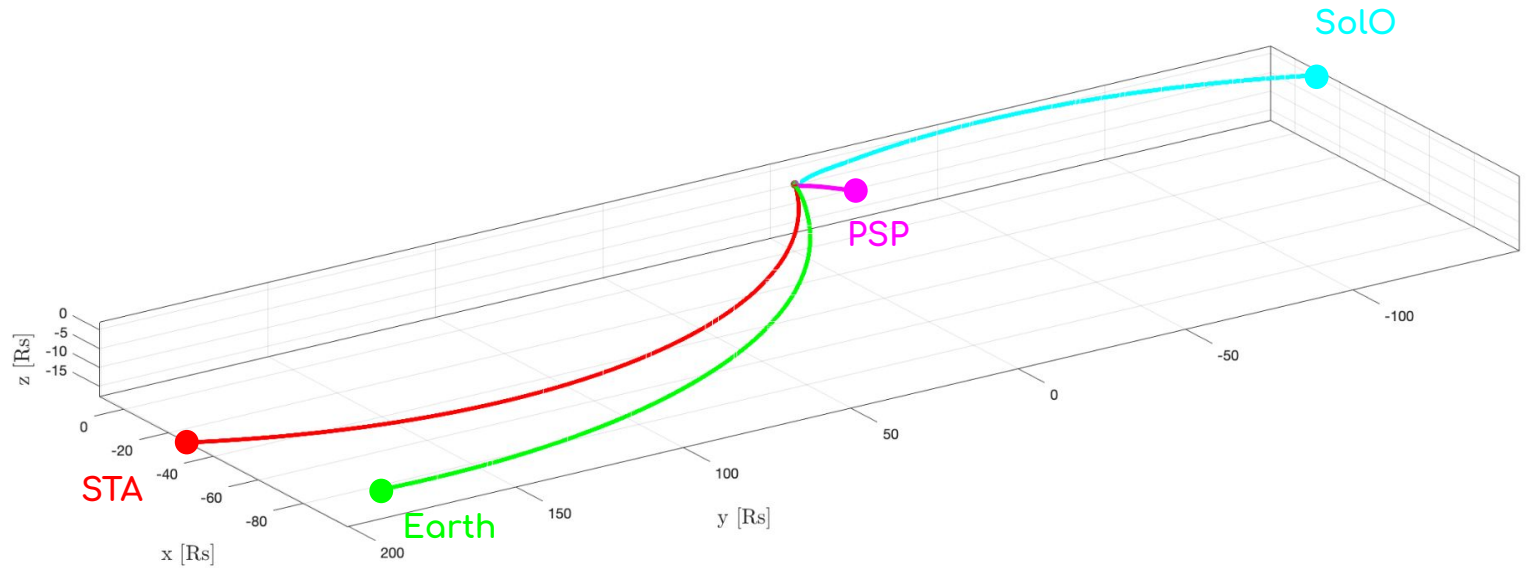
→ for the same event as an example

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## ❖ Shock analysis method

- Reconstruct the magnetic connectivity of spacecrafts



exemple for the 5 Sept 2022 CME event

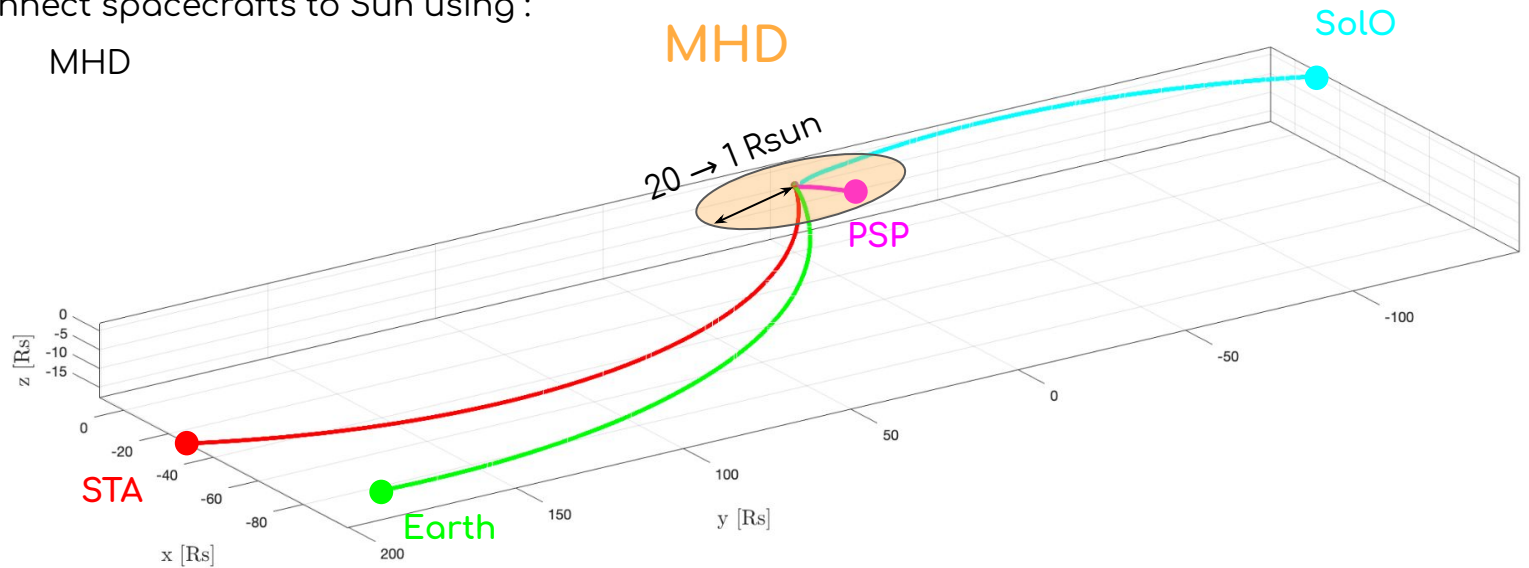


## ❖ Shock analysis method

### ➤ Reconstruct the magnetic connectivity of spacecrafts

Connect spacecrafts to Sun using :

- MHD



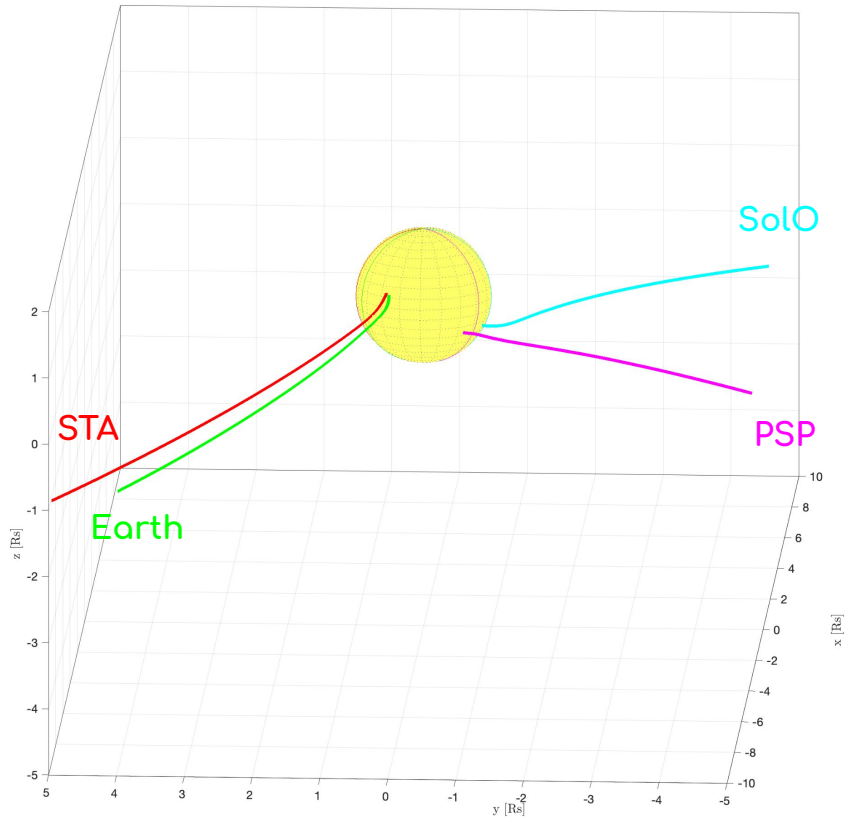
exemple for the 5 Sept 2022 CME event





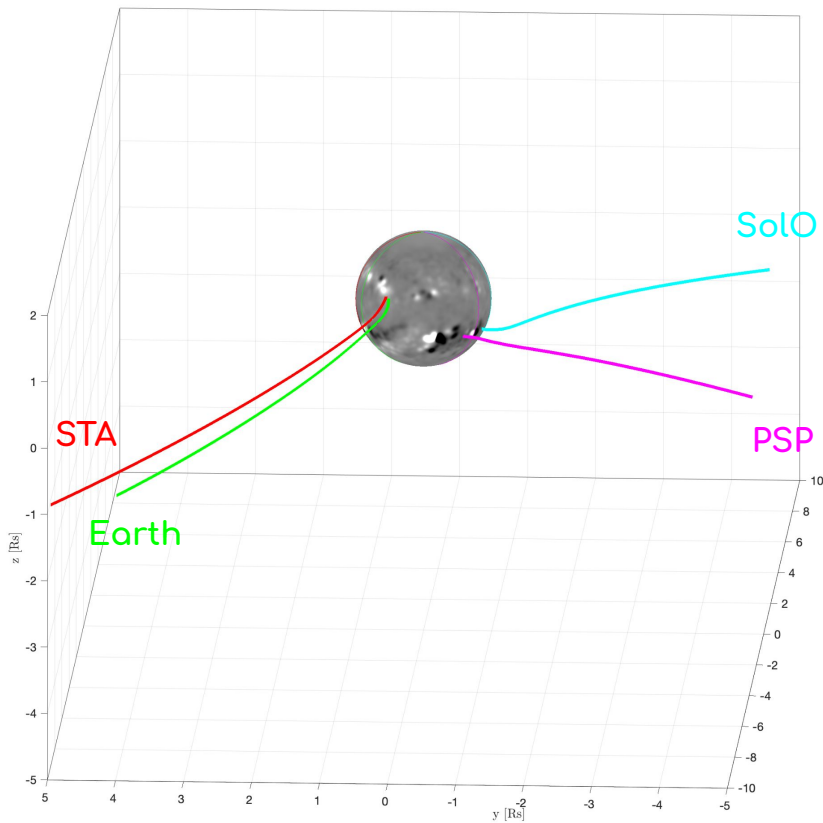
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### ➤ MHD shock properties

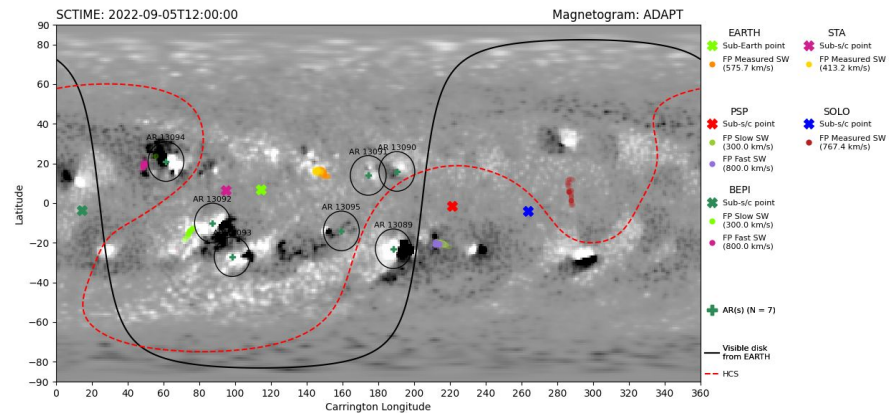


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## ➤ MHD shock properties



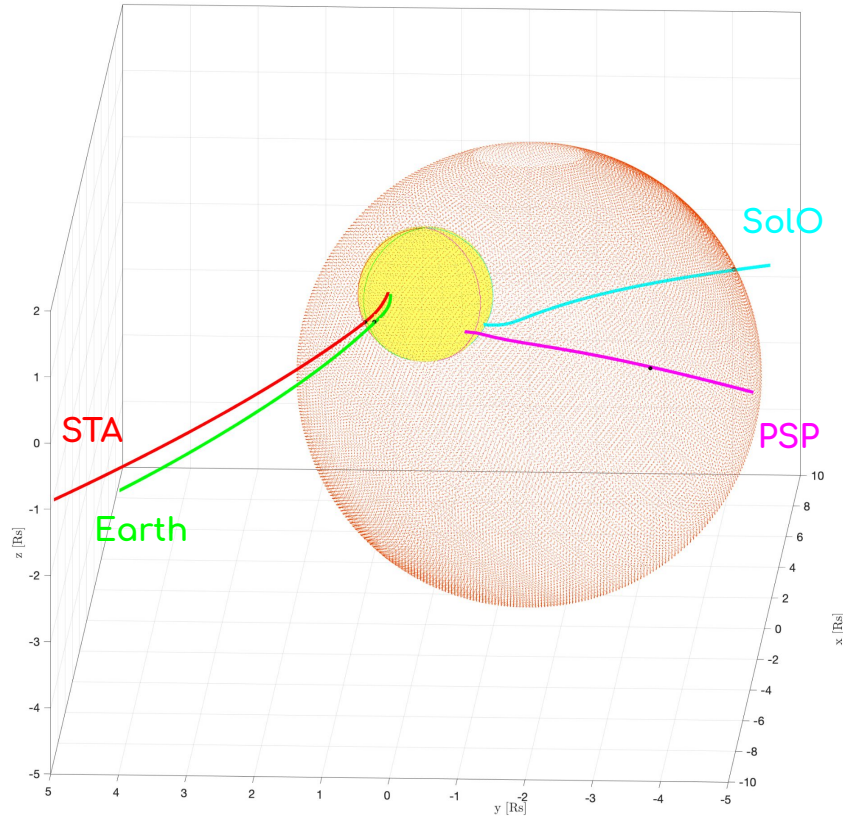
# Magnetic Connectivity Tool



## ❖ Shock analysis method

Add the reconstructed shock

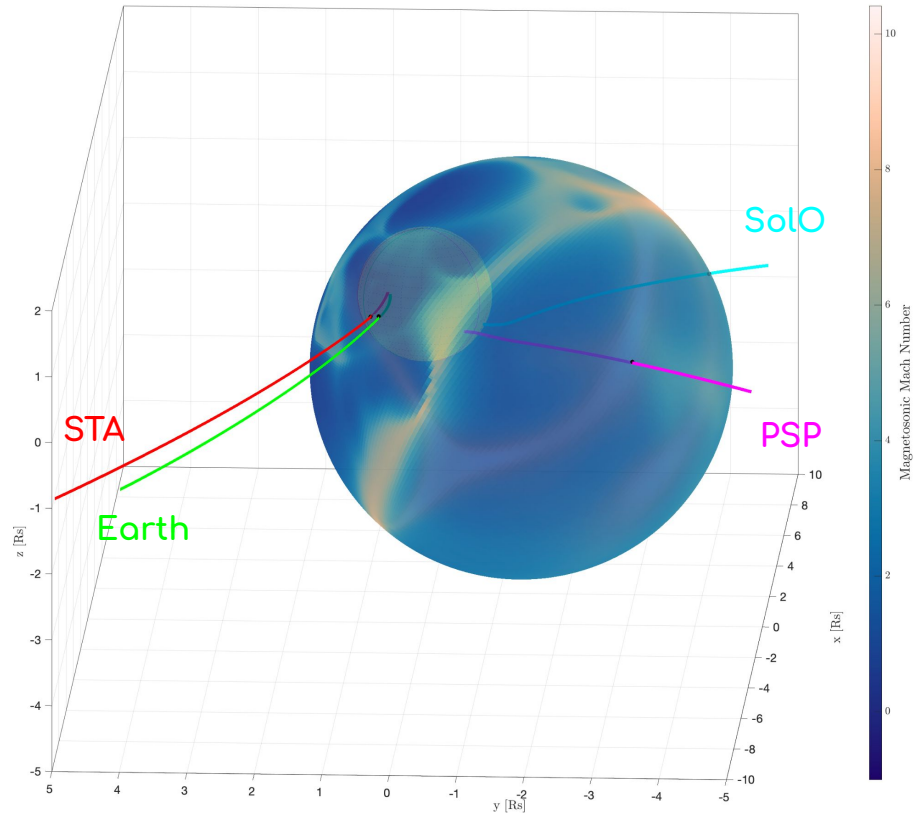
### ➤ MHD shock properties



## ❖ Shock analysis method

Determine its MHD properties

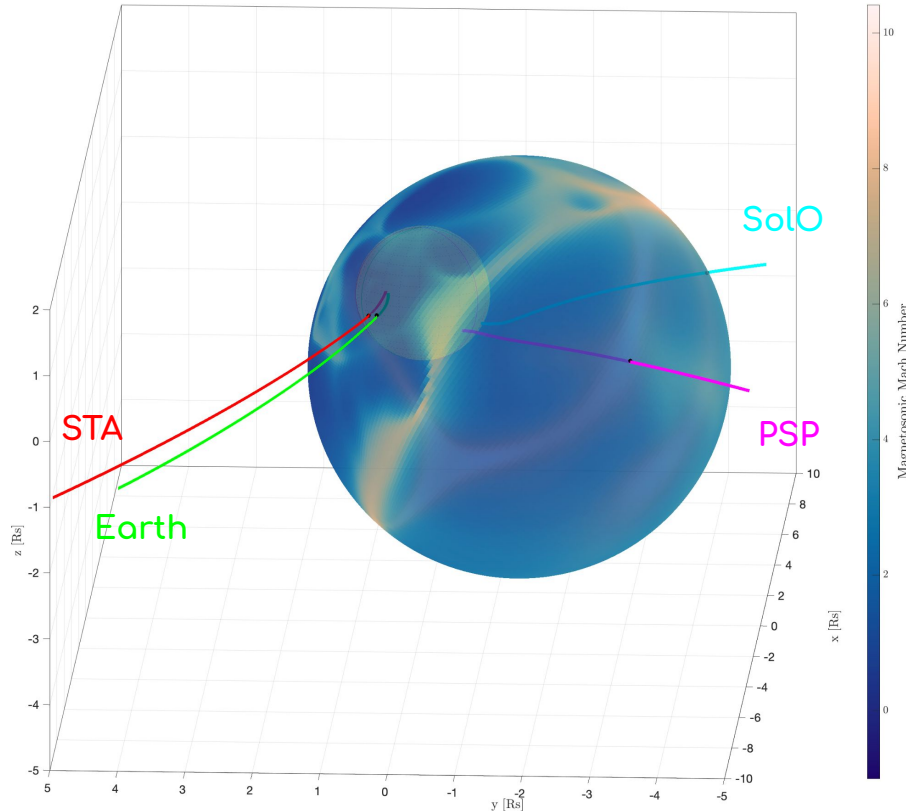
### ➤ MHD shock properties



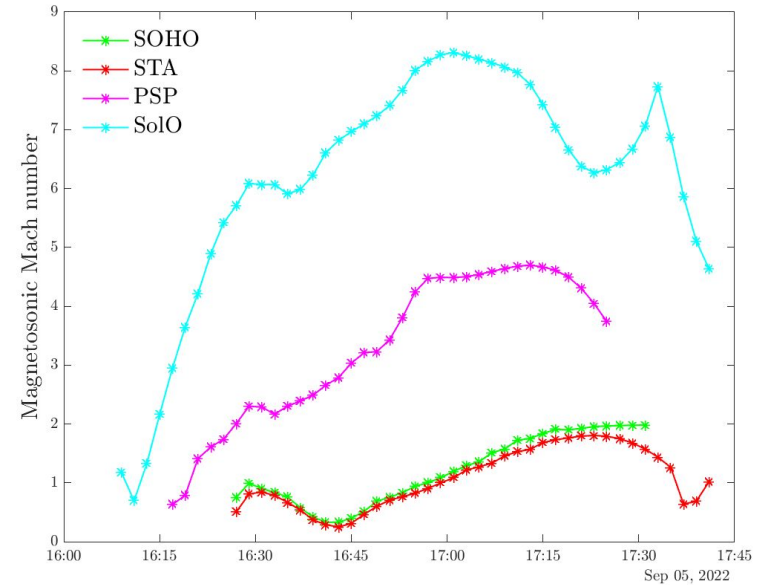


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### ➤ MHD shock properties



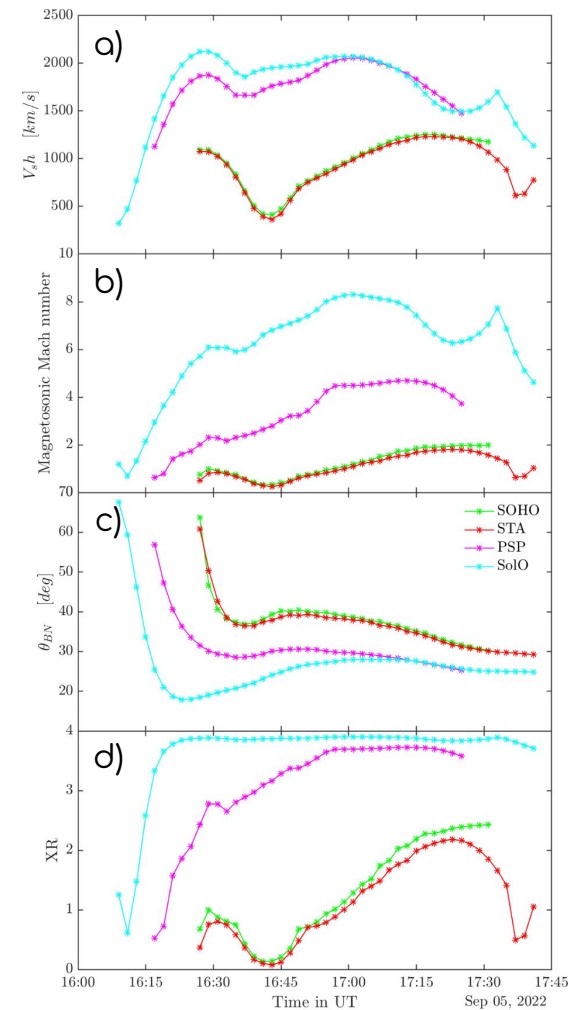
Dynamic evolution of the shock parameters along the field line magnetically connected to the spacecraft



## ❖ Shock analysis method

➤ Possible links with SEPs : preliminary results

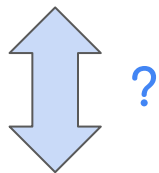
shock characteristics (MA,  
ThBN, XR, etc)



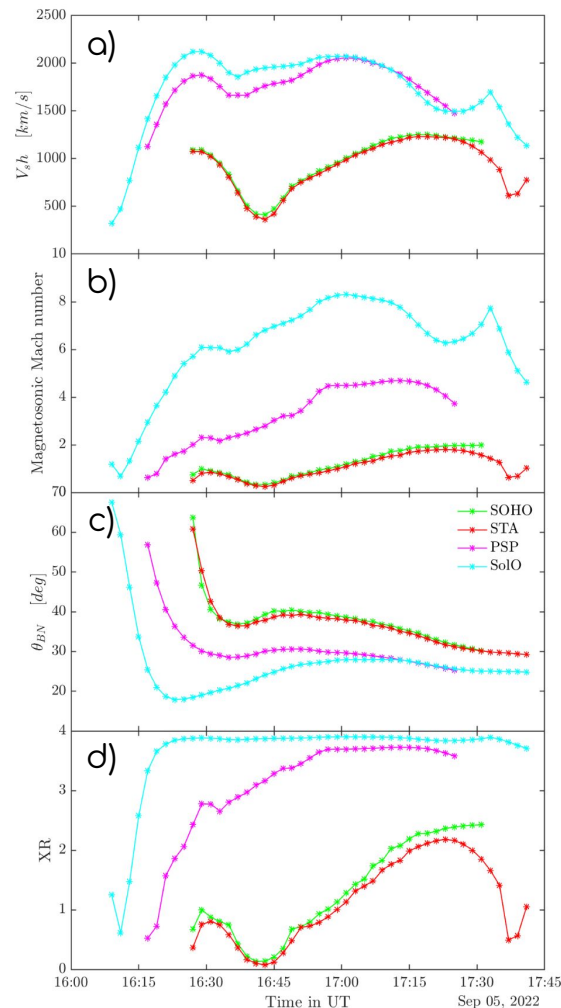
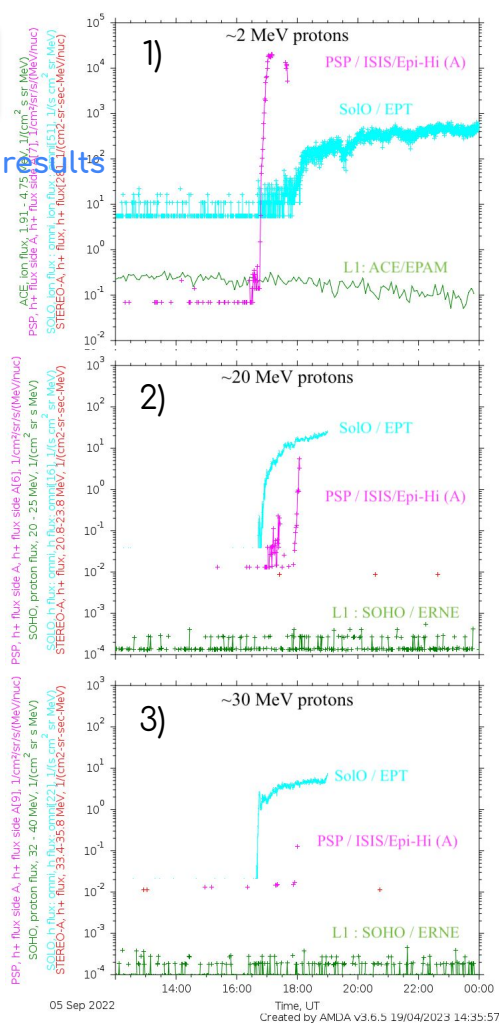
# Shock analysis method

Possible links with SEPs : preliminary results

SEP characteristics (like composition, variability, intensity, ..)



shock characteristics (MA, ThBN, XR, etc)





- ❖ Introduction

- ❖ Shock wave model

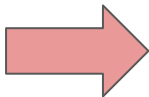
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- ❖ Conclusion

# Conclusion

- ❖ On shock wave geometry and kinematics :
  - Shock waves are spherical during their propagation in the interplanetary medium from 2 to 25 solar radius
  - Their radial expansion is 1.45 faster than their lateral expansion
- ❖ Future work :
  - on shock MHD :
    - refine these preliminary results
    - study new shocks that occurred after 2020 (with PSP and SolO)
  - on links between SEPs and shock properties
    - study different energies, type of particles, compositions, ...
    - test particle transport codes by including shocks and compare results with observations





Thank you for your  
attention