

20 years of ACE data : how superposed
epoch analyses reveal generic features
in interplanetary CME profile.

Florian REGNAULT

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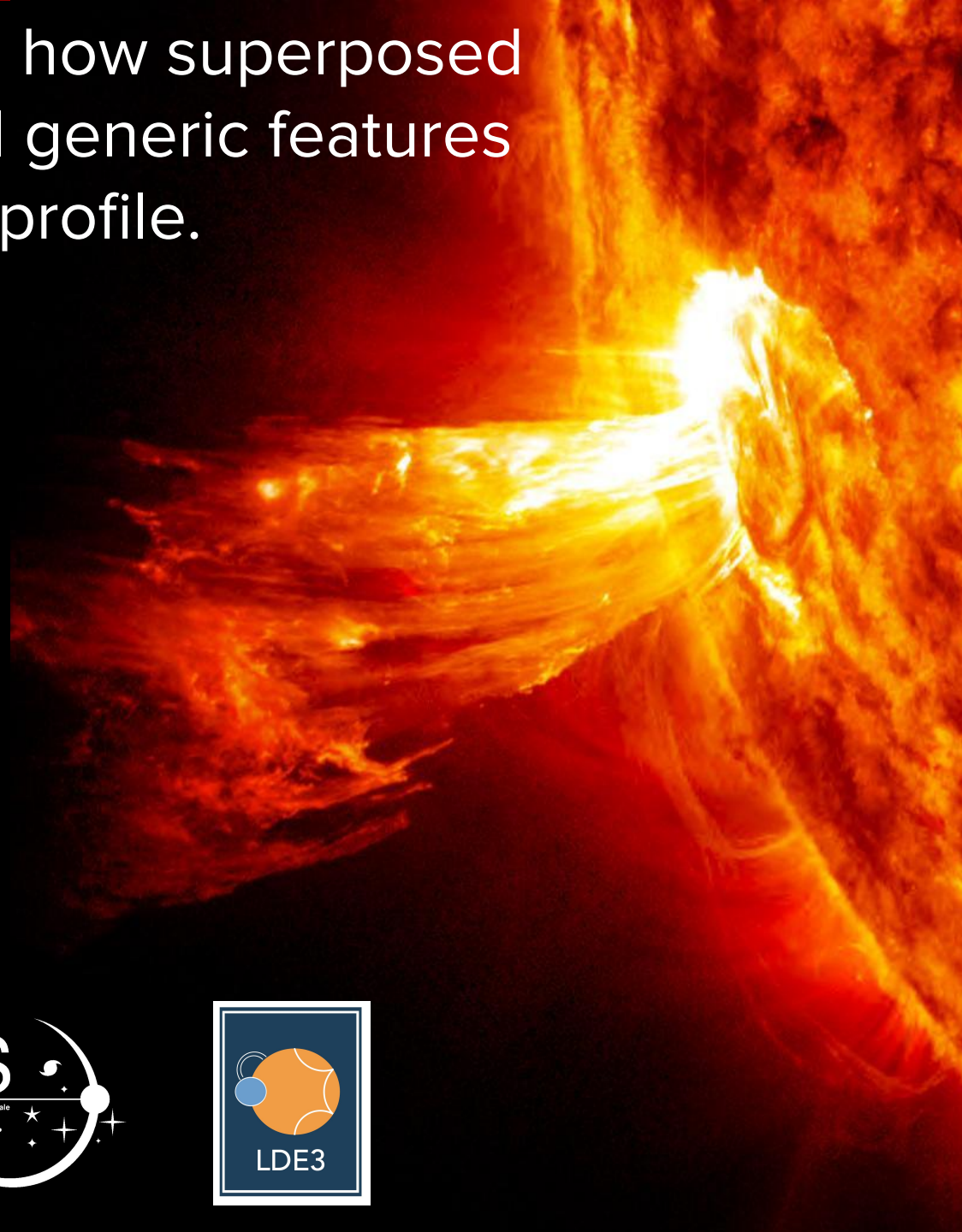
Miho JANVIER

Antoine STRUGAREK

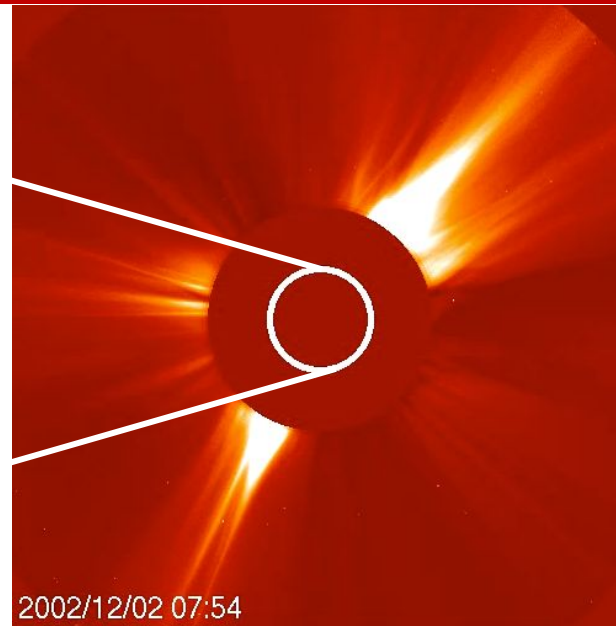
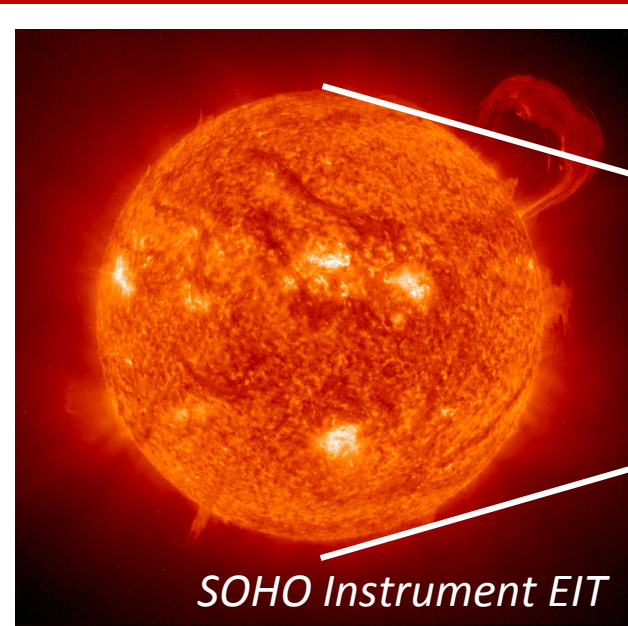


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Introduction to solar physics

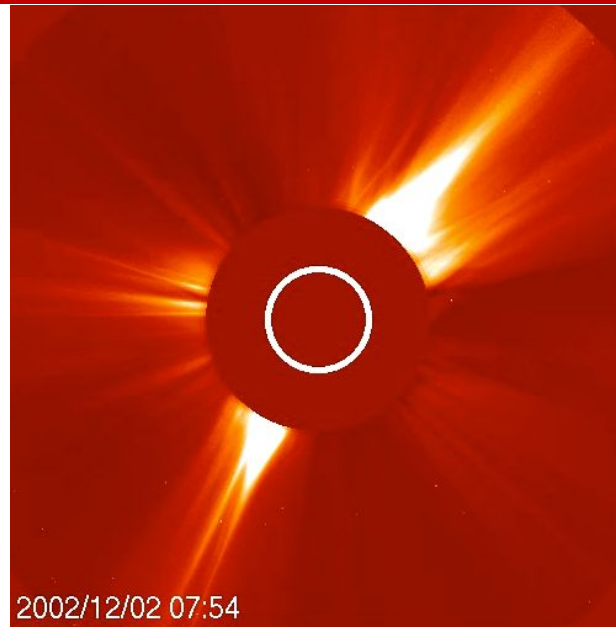
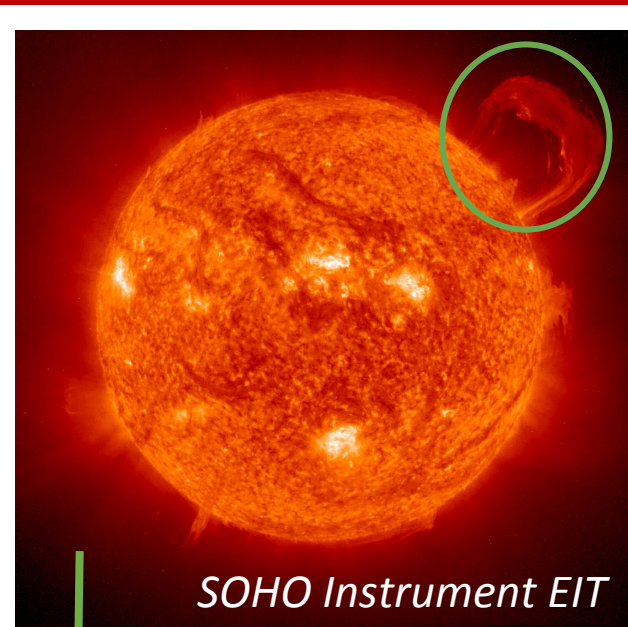


SOHO Instrument LASCO C2

Solar wind

The sun is releasing charged particles from its upper atmosphere (also called solar corona)

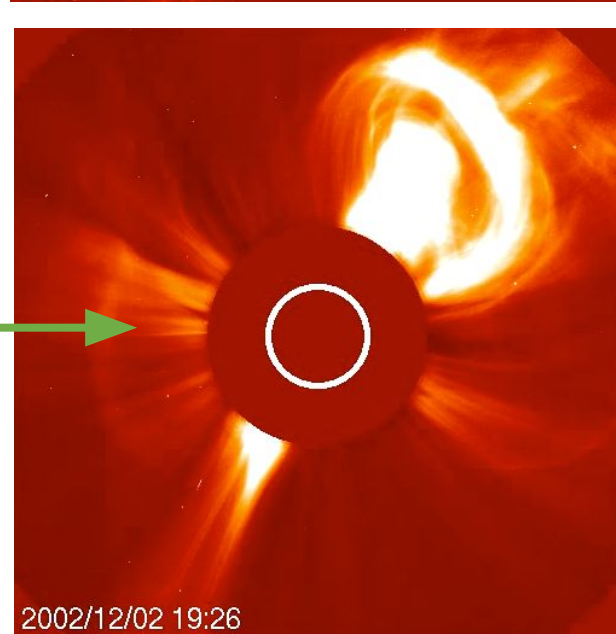
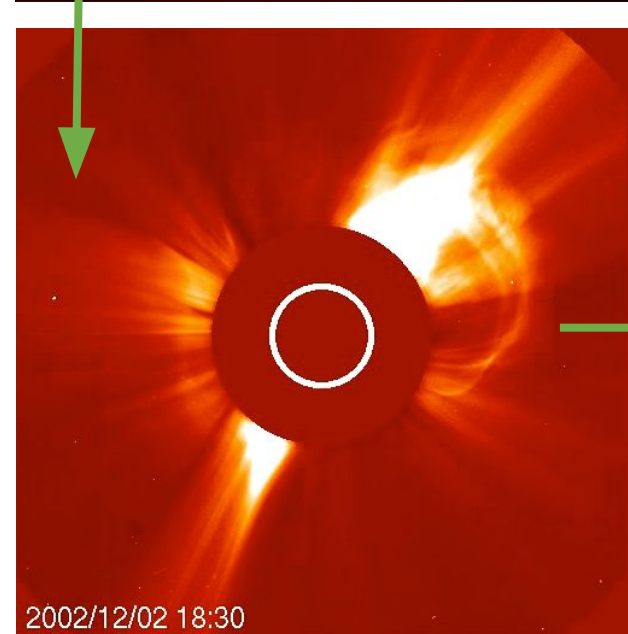
Introduction to solar physics



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Coronal Mass Ejections (CMEs)

→ Impact on planets (aurora, technology)

Introduction to solar physics

SOHO Instrument LASCO C2

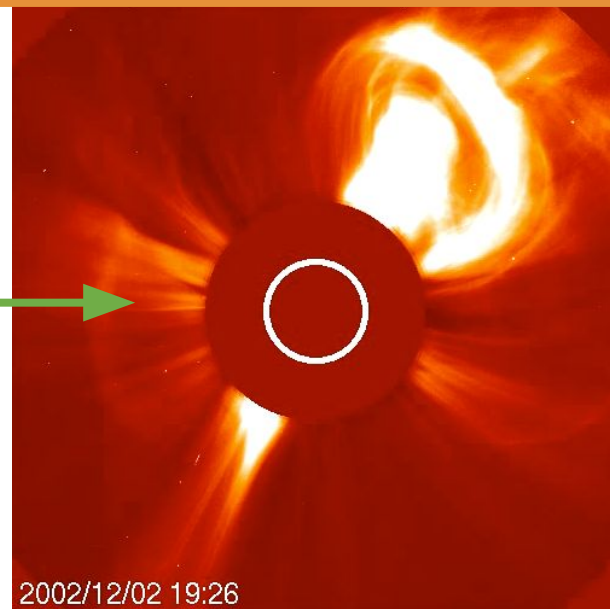
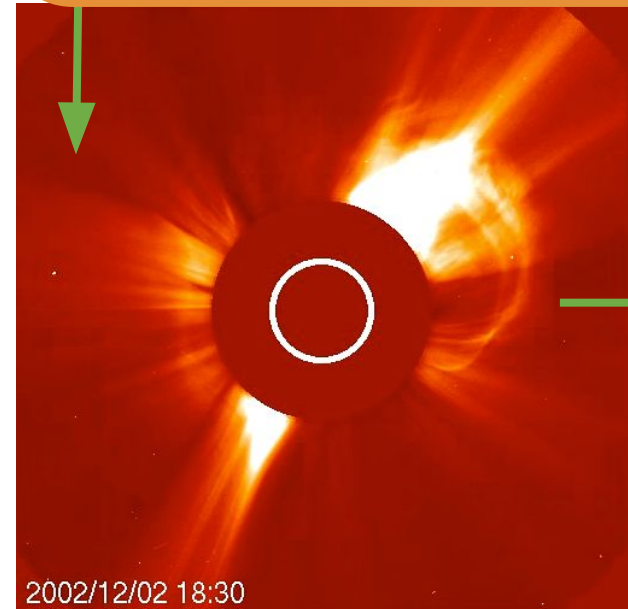
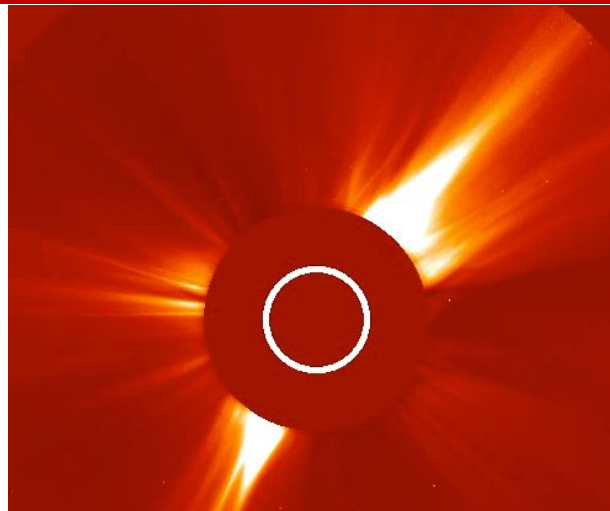
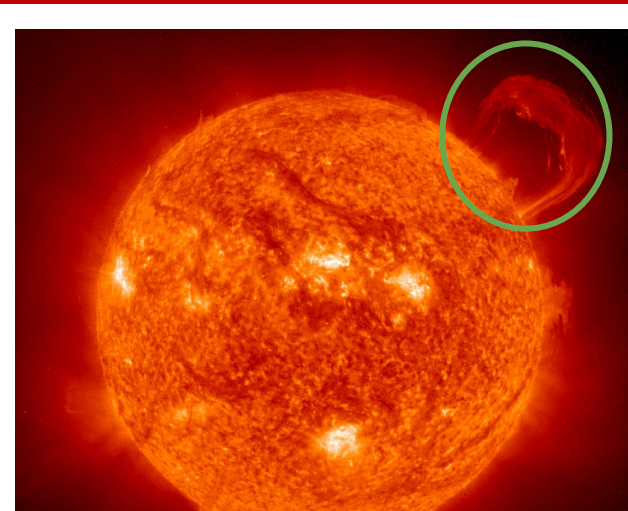
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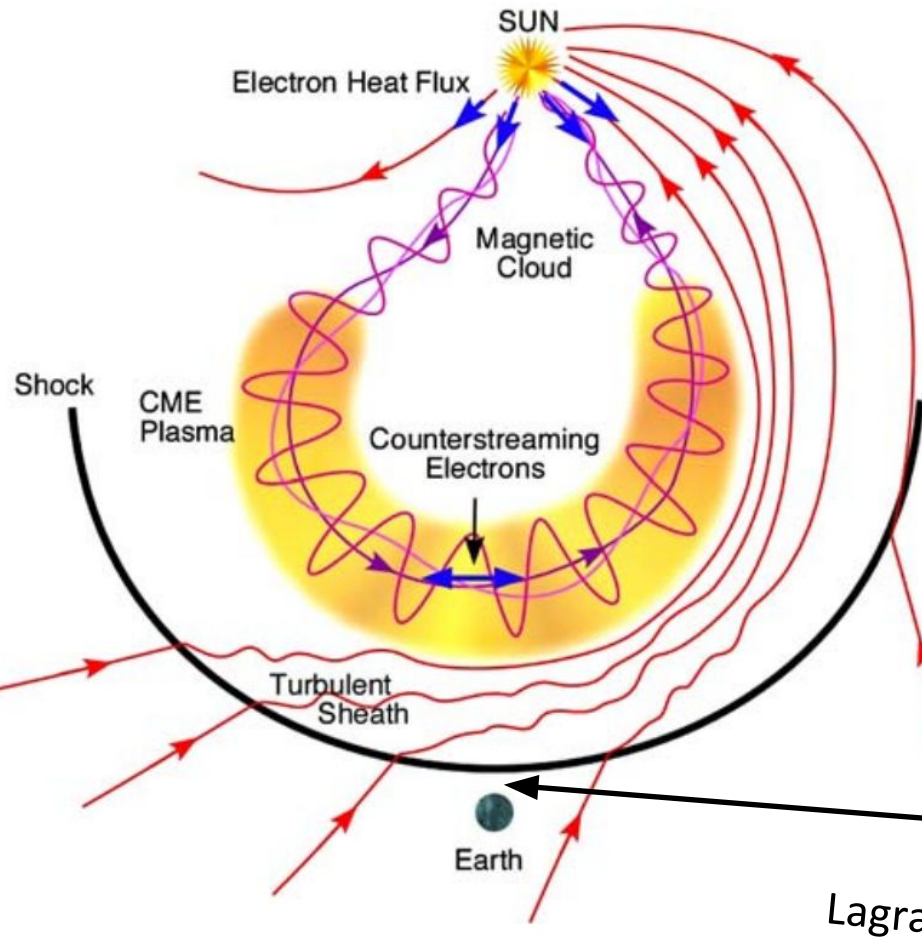
How these coronal mass ejections propagate into the interplanetary medium ?

Coronal Mass Ejections (CMEs)

→ Impact on planets (aurora, technology)



Structure of an Interplanetary Coronal Mass Ejection



Schema of ICME's structure

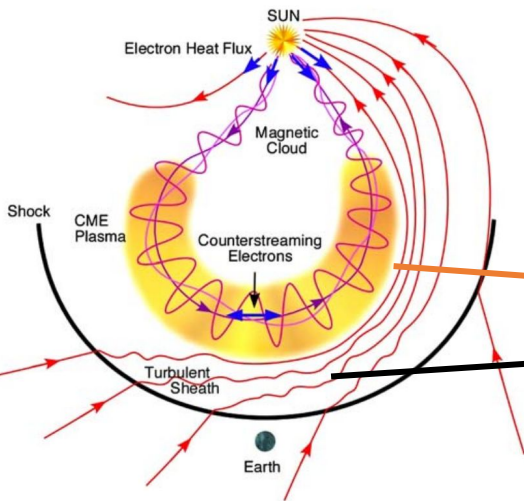
An interplanetary CME (ICME) is composed of:

- a discontinuity (sometimes a shock)
 - a **turbulent sheath**
 - a **magnetic ejecta (ME)**
- } if $V_{ICME} > V_{solar\ wind}$



ACE measurements allow us to probe the property of the different substructures of an ICME

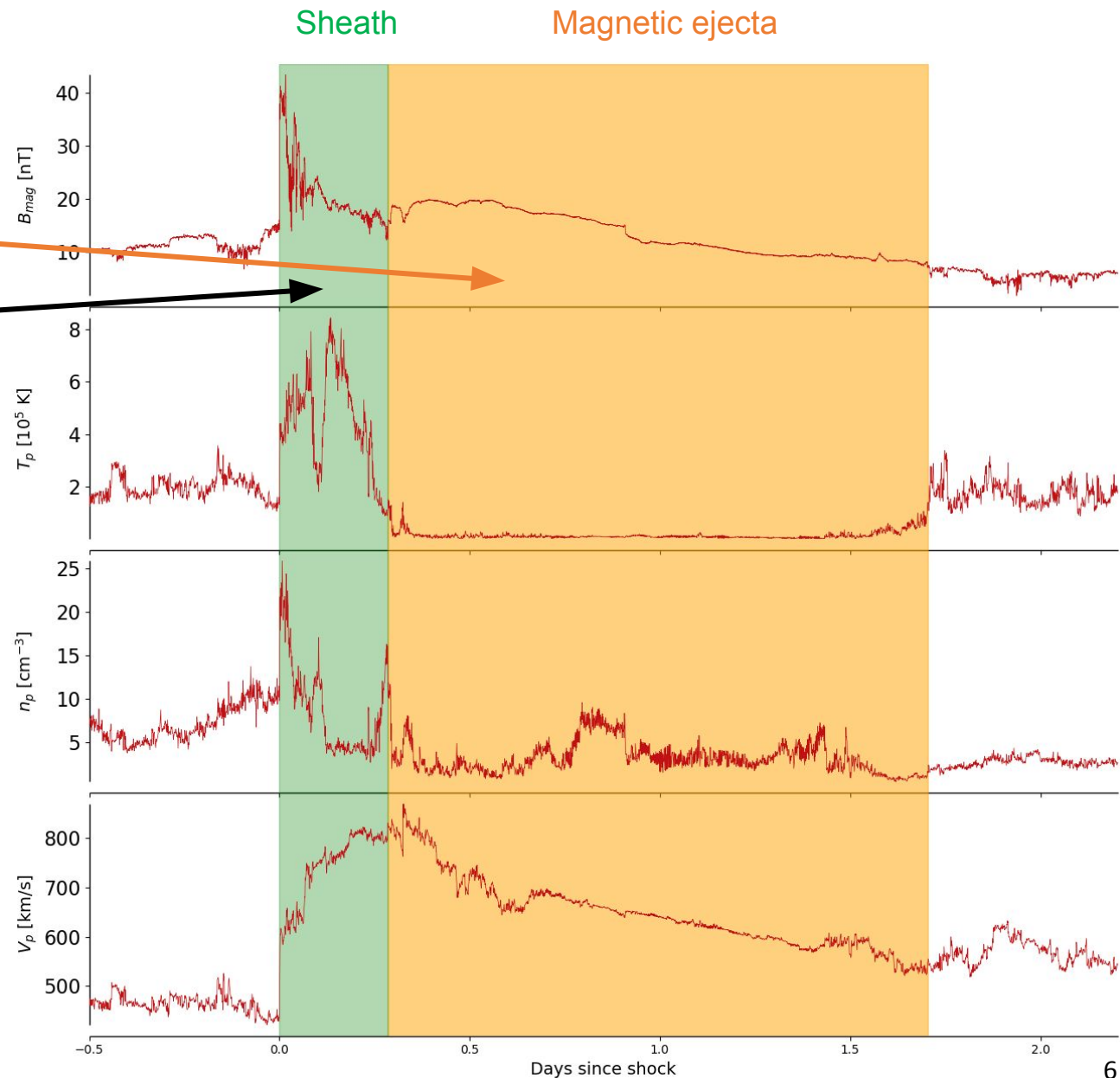
ACE data : Detecting ICME's substructures



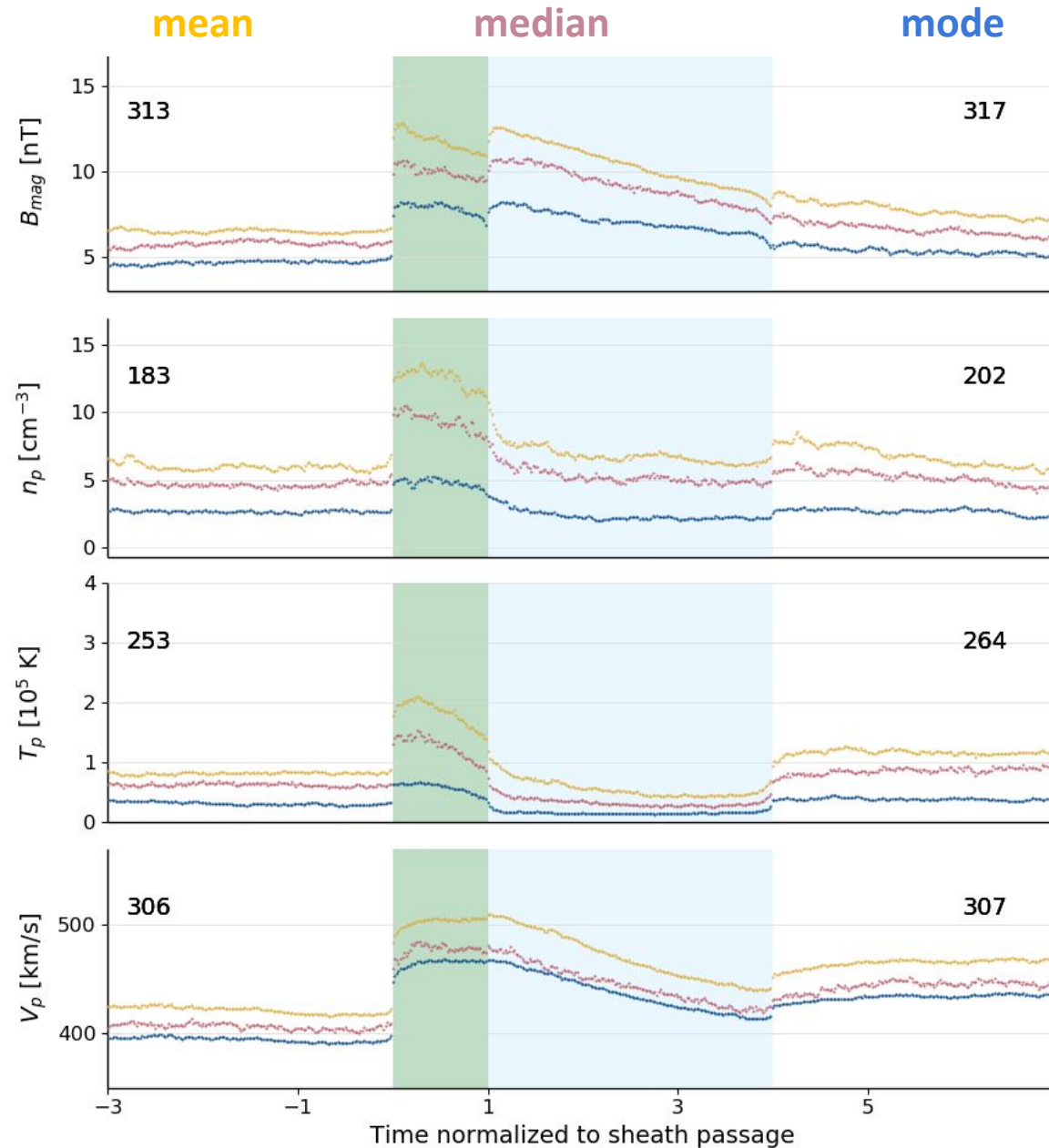
Schema of ICME's structure

We can set these frontiers for all ICME events detected in the 20 years of ACE observations and run a statistical study : the **superposed epoch method**

ACE data
(Time series)



Typical profile of an ICME



Typical profiles for all events with a sheath

- ❑ Compression of the plasma in the sheath : increase of B , n_p , T_p and V_p .
- ❑ The passage of the ME is highlighted by an enhancement of B and a decrease of T_p .
- ❑ Monotonic decrease of the speed within the ME showing its expansion.
- ❑ The speed of the post-ICME solar wind (wake) is disturbed by the passage of the ME.

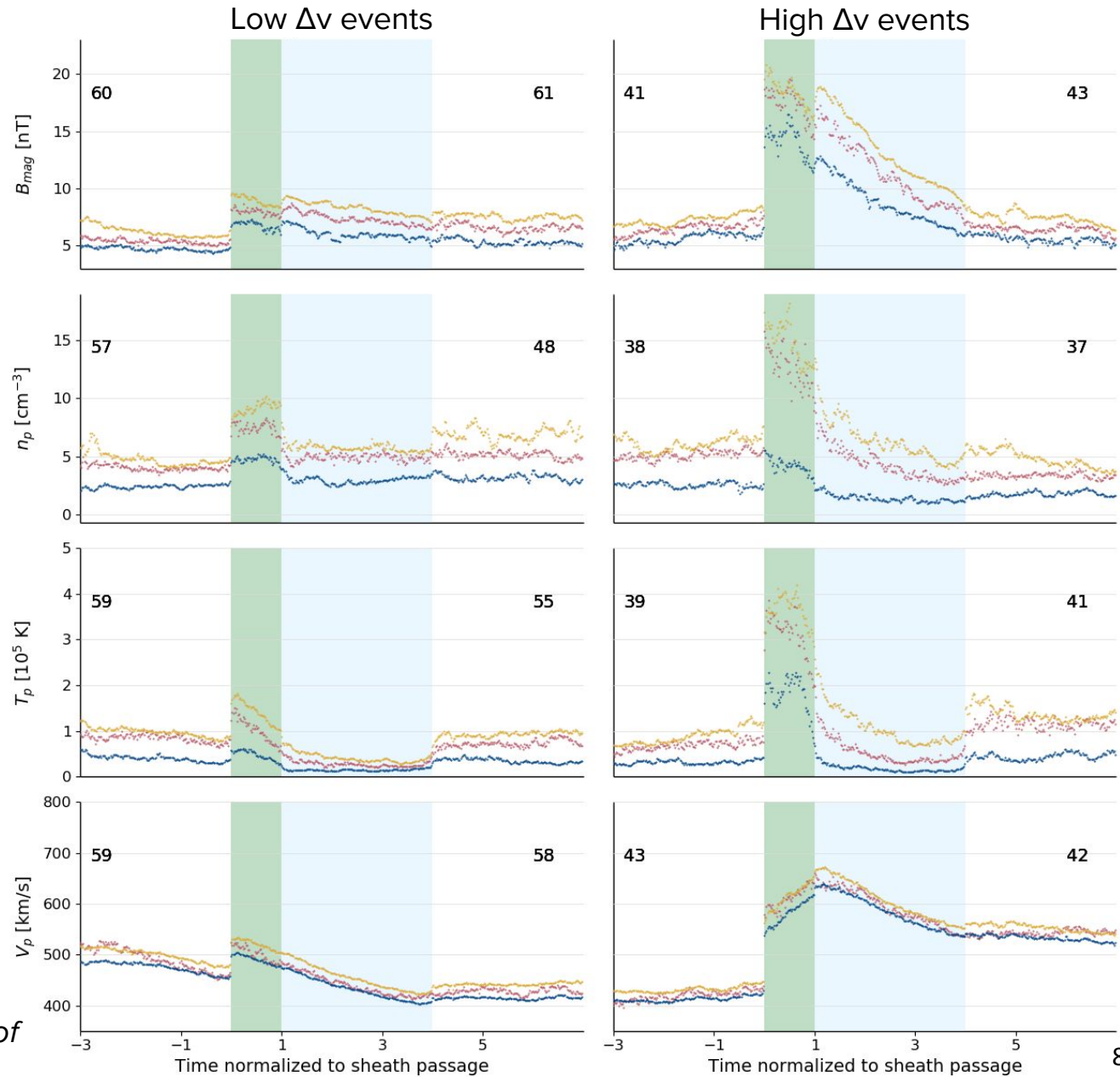
The superposed epoch method allow us to extract typical profiles of physical parameters.

What is the impact of the speed on the sheath property ?

Classification using the relative speed

$$\Delta v = v(\text{ME}) - v(\text{solar wind})$$

mean median mode



SE with a classification in speed of all events with a sheath

Classification using the relative speed

$$\Delta v = v(\text{ME}) - v(\text{solar wind})$$

mean median mode

Fast events have reinforced sheath :

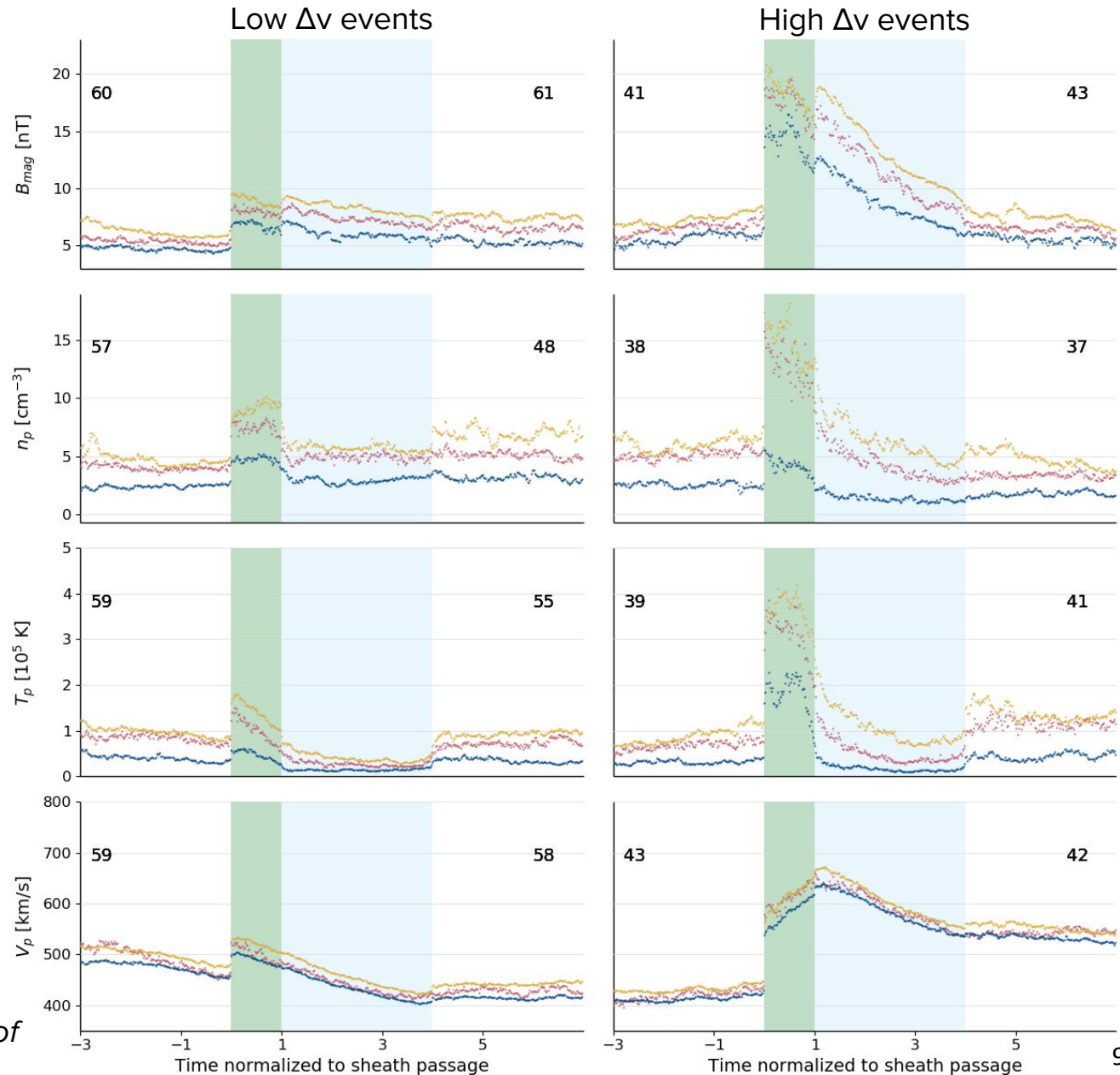
- increased discontinuity
- hotter sheath

The higher speed causes an upstream compression of the magnetic ejecta.

The solar wind is affected by the passage of the ICME :

- shift in speed

SE with a classification in speed of all events with a sheath



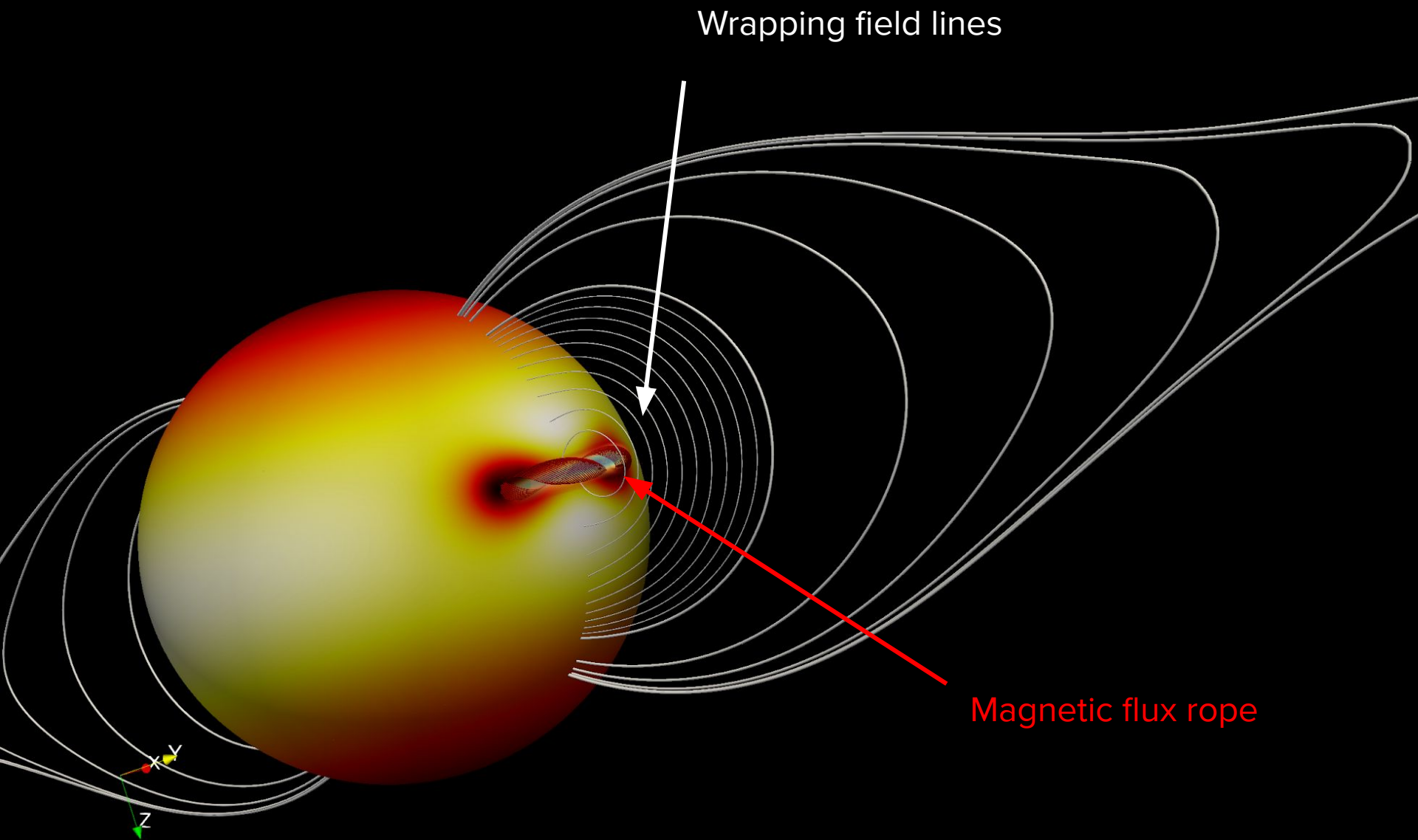
Conclusion

- ❑ The superposed epoch method allows us to get the general properties of ICME close to the earth.
 - ❑ Parameter profiles observed near-earth are affected by :
 - the speed of the ICME
 - the solar cycle (not shown here)
 - the trajectory of the spacecraft through the ICME (not shown here)
- ➡ **Help to understand physical processes that happen during the propagation**
- ➡ **It can then constrain simulations of ICME's propagation**

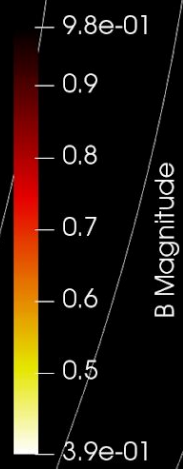
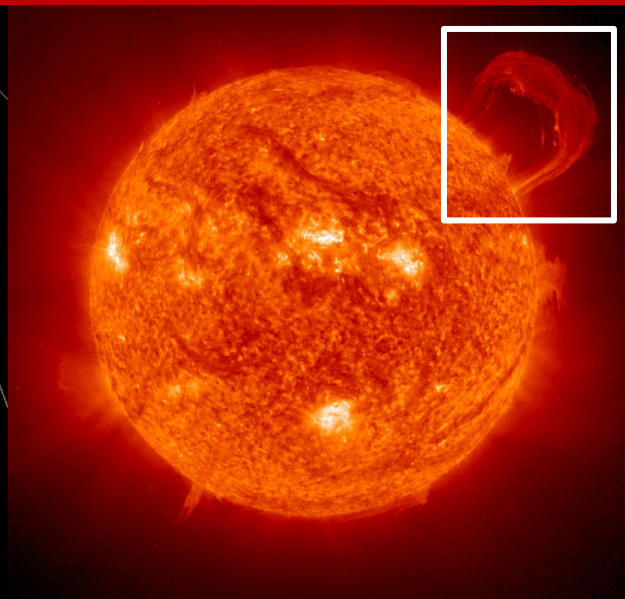
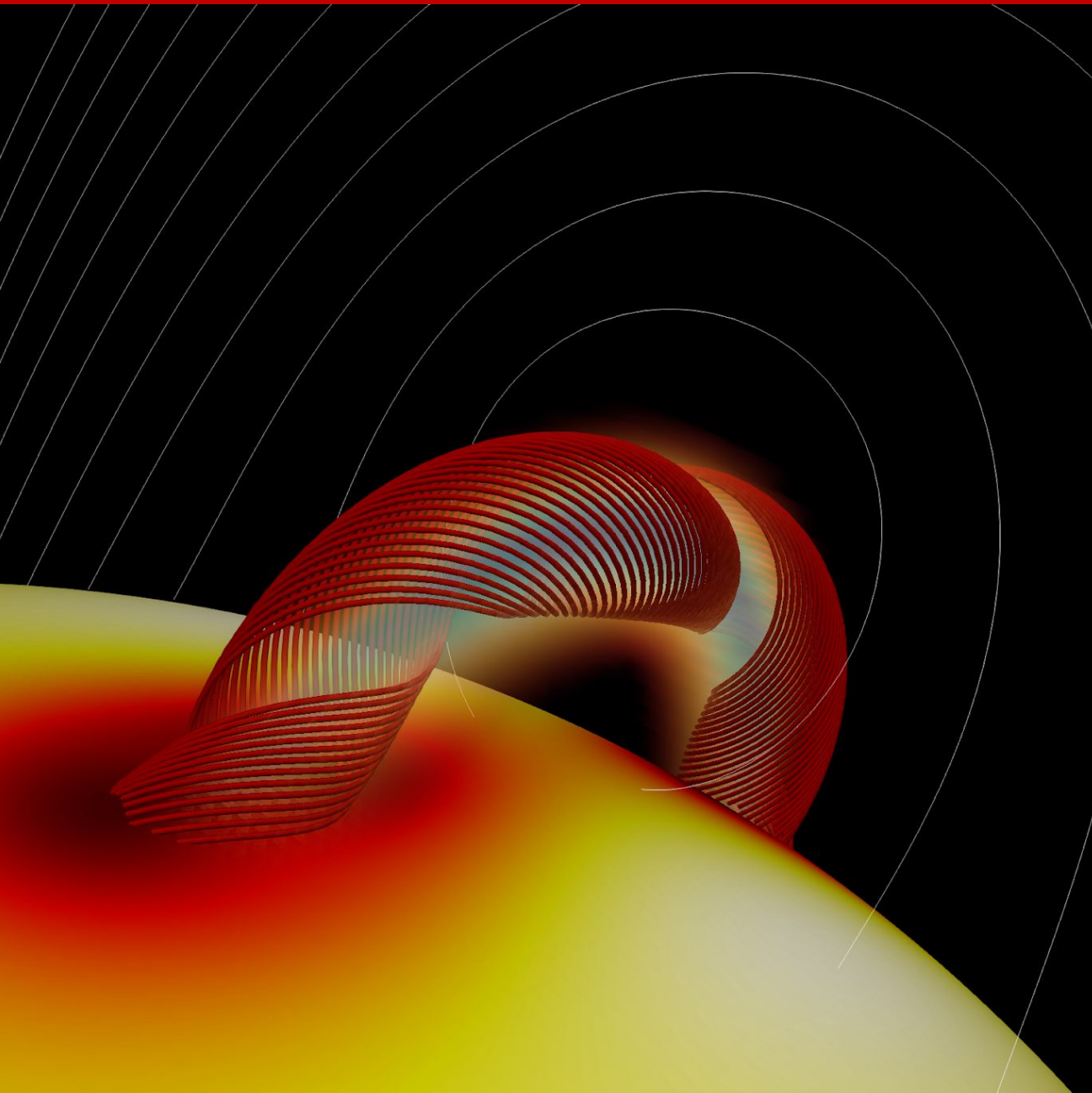
On going work

- ❑ 3D MHD simulation of the propagation of an ICME.

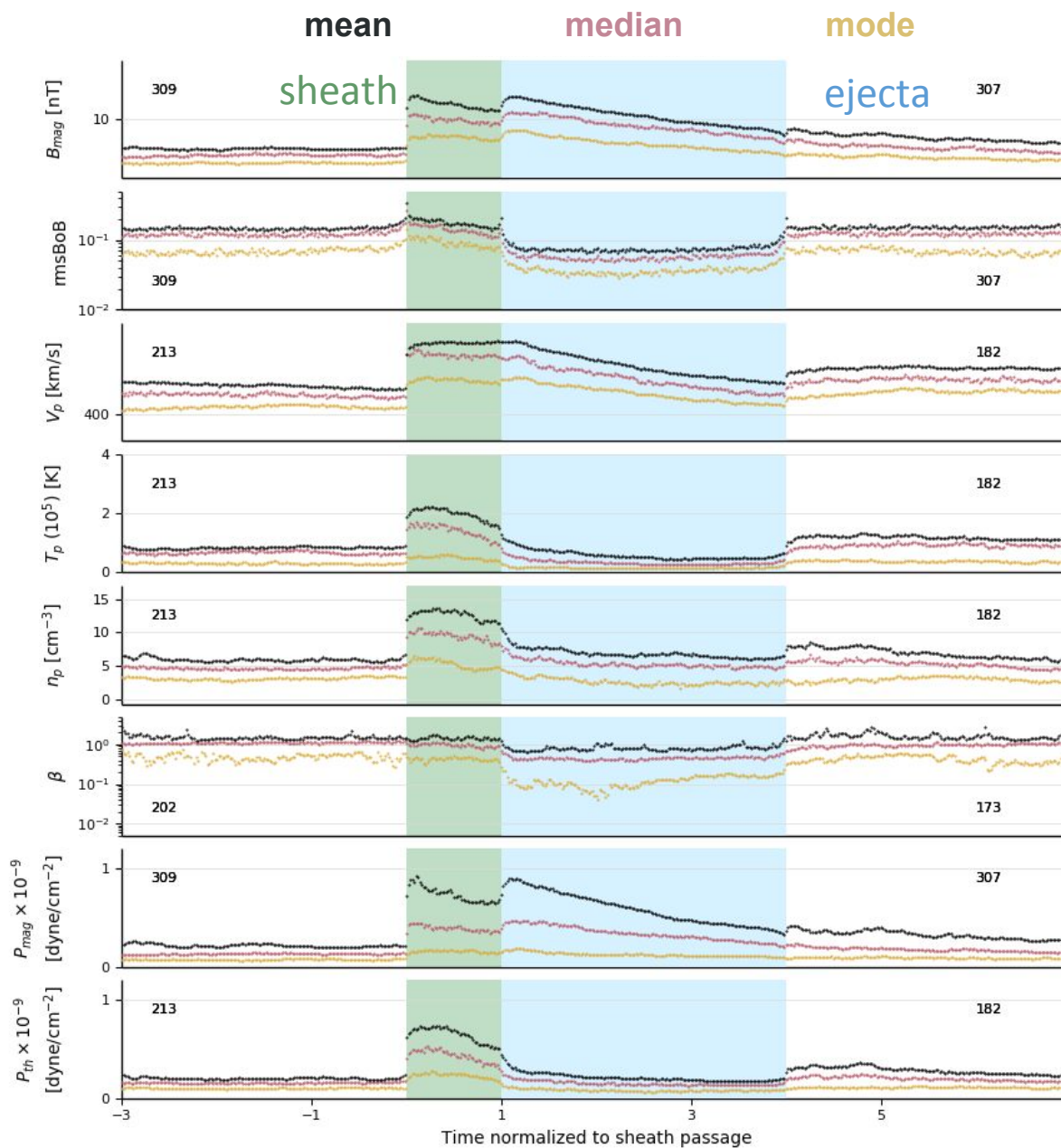
3D MHD Simulation



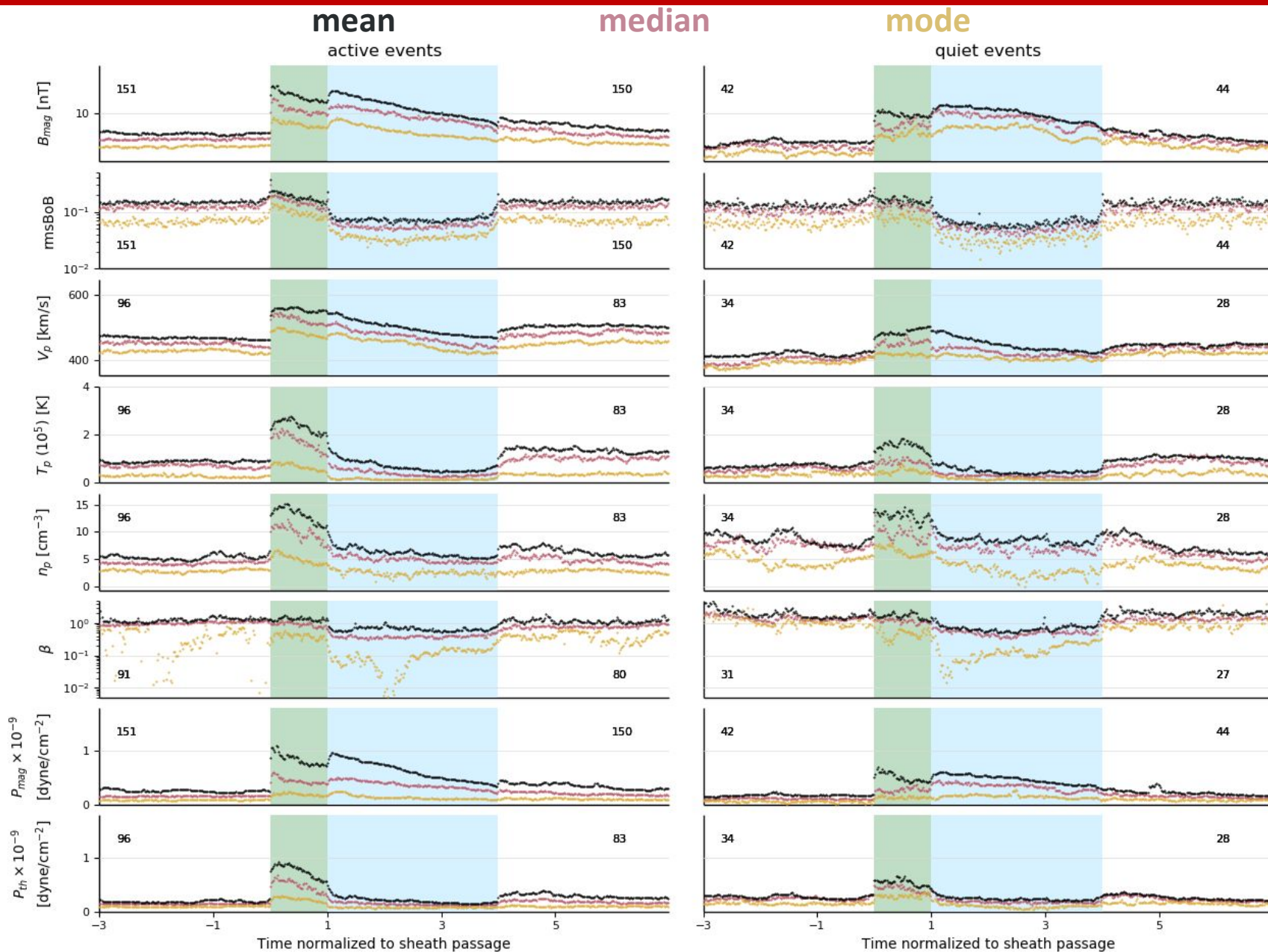
3D MHD Simulation



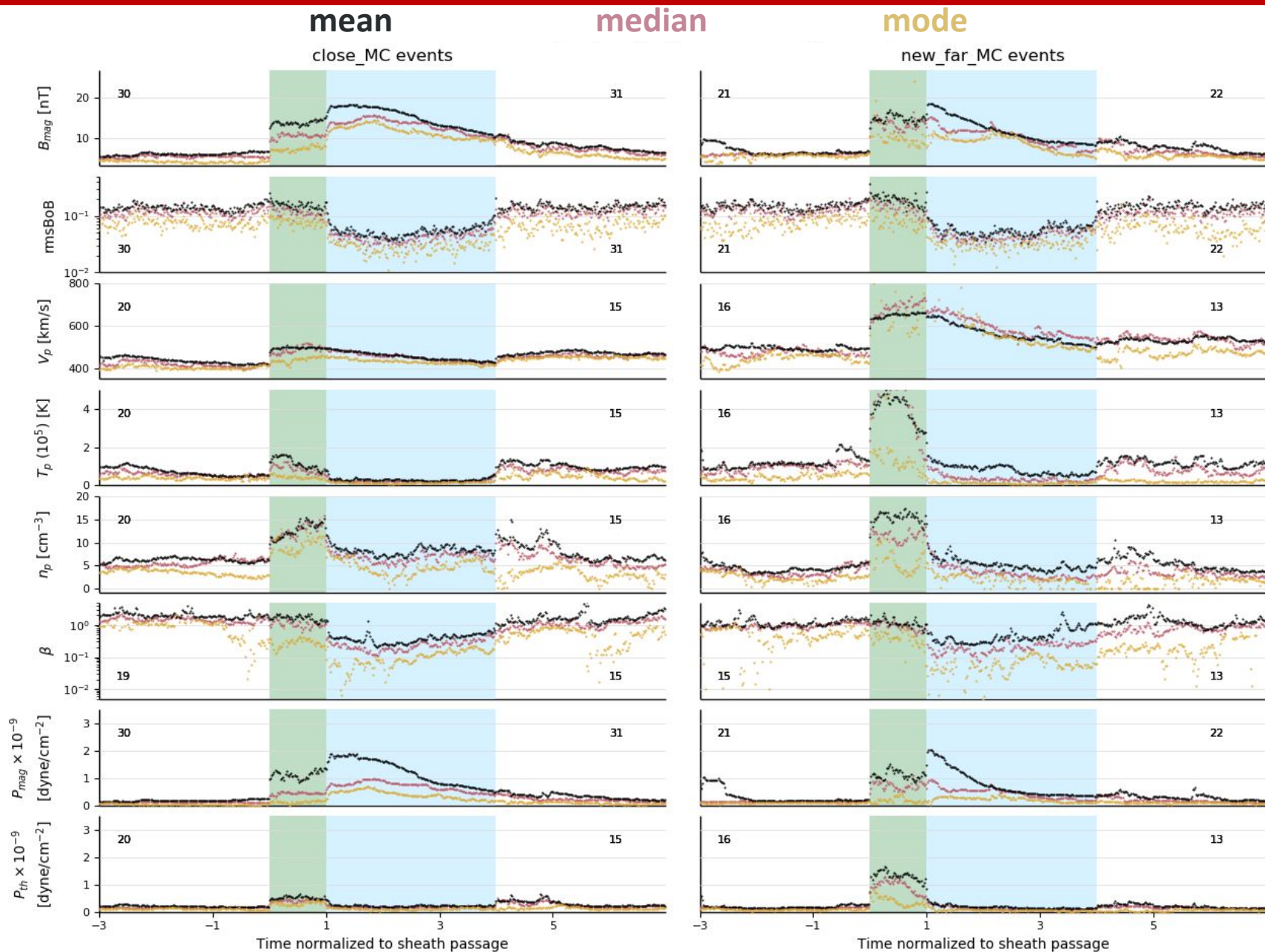
Typical profile of an ICME



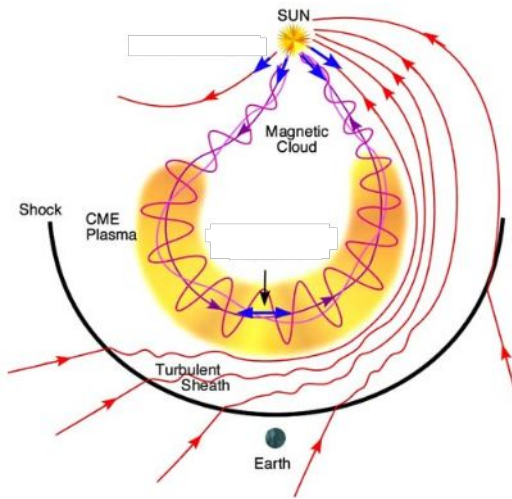
The effect of the Solar Cycle



The effect of the trajectory

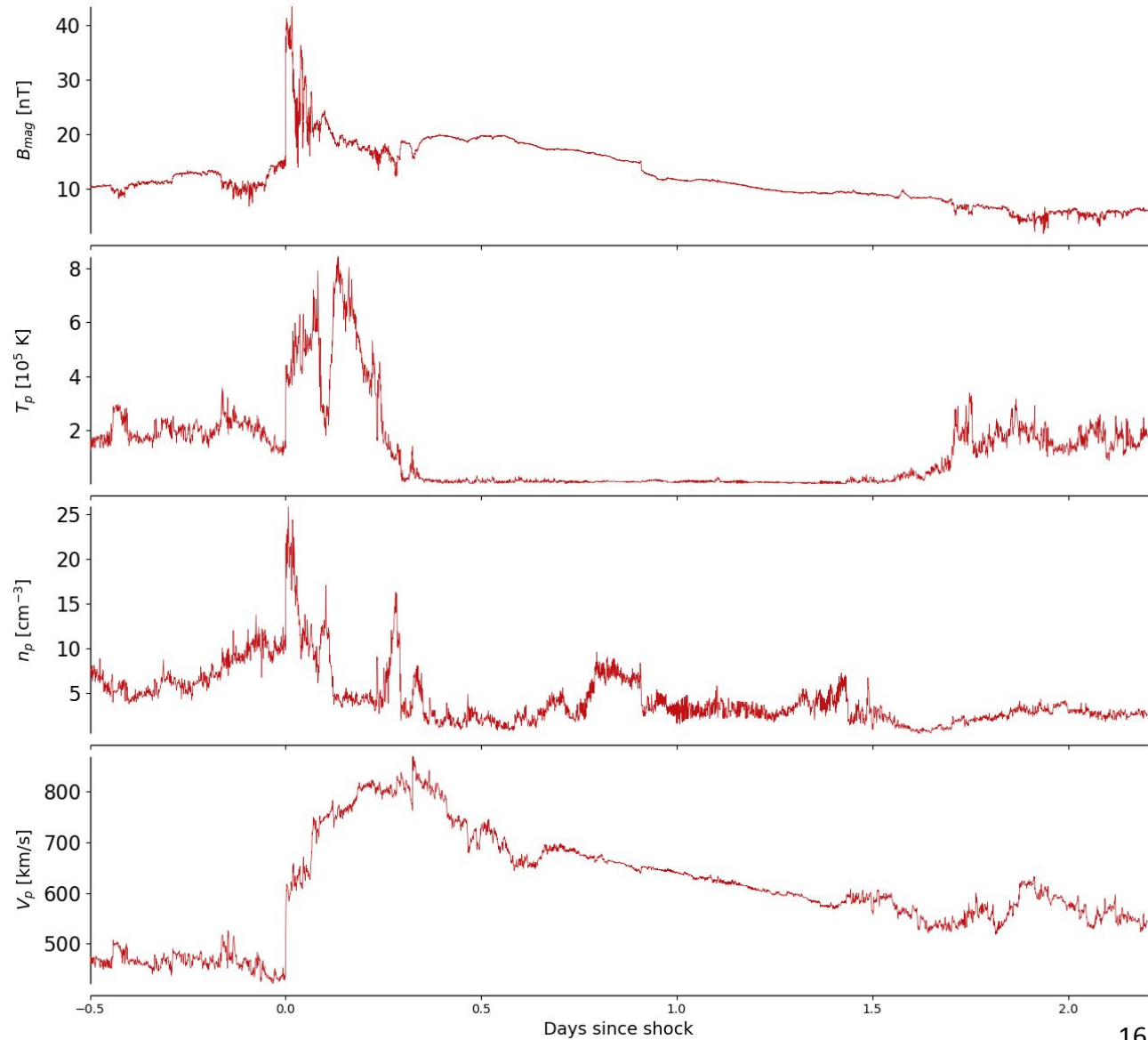


ACE data : Detecting ICME's substructures

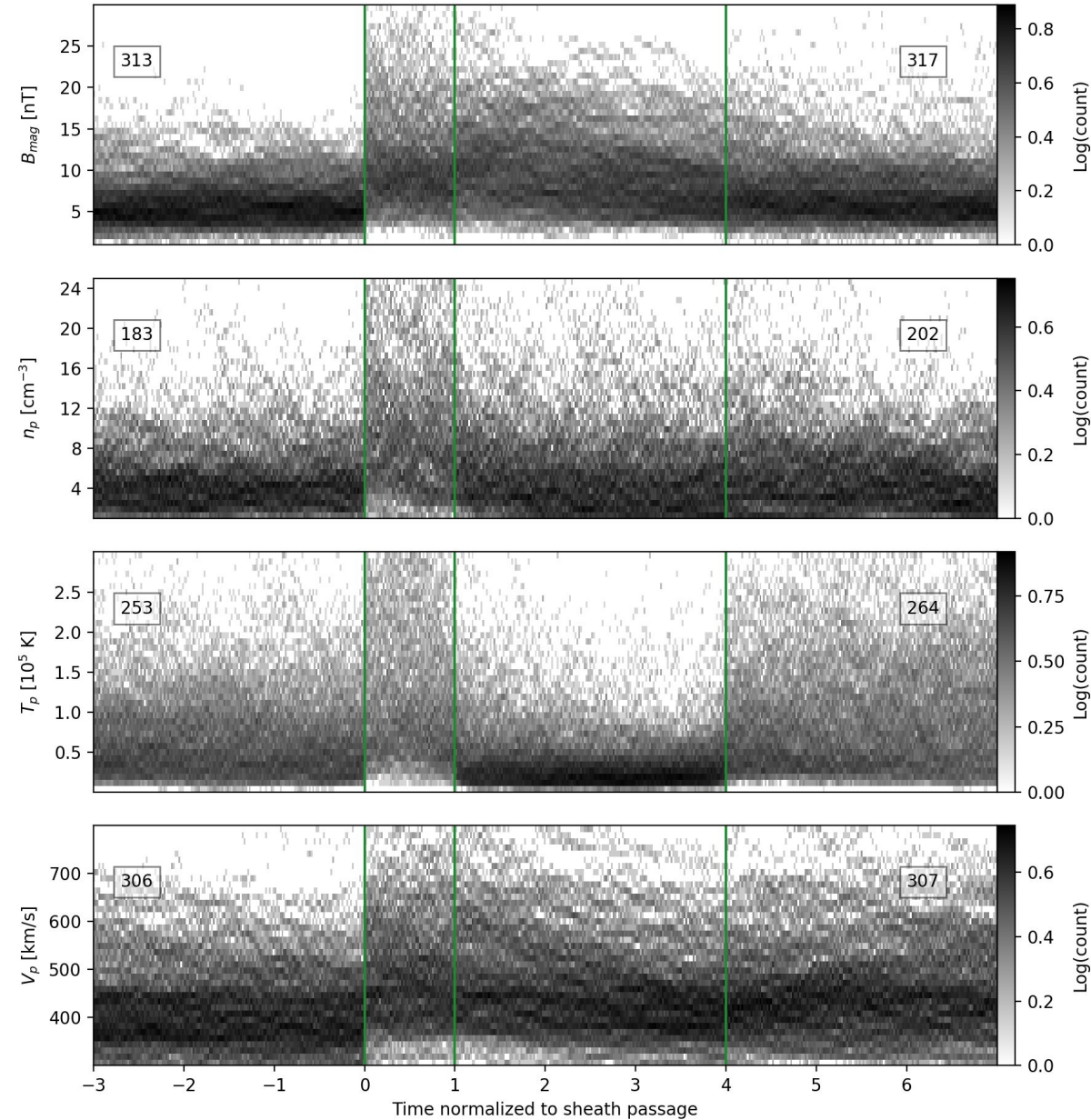


Schema of ICME's structure

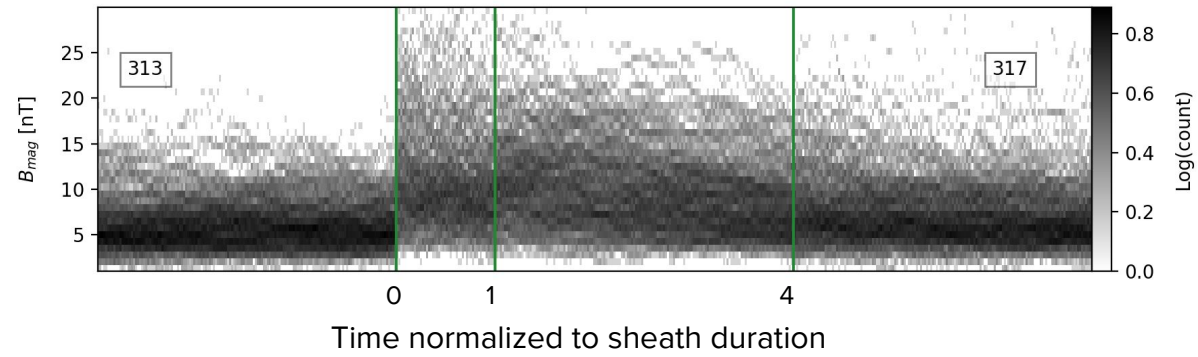
ACE data
(Time series)



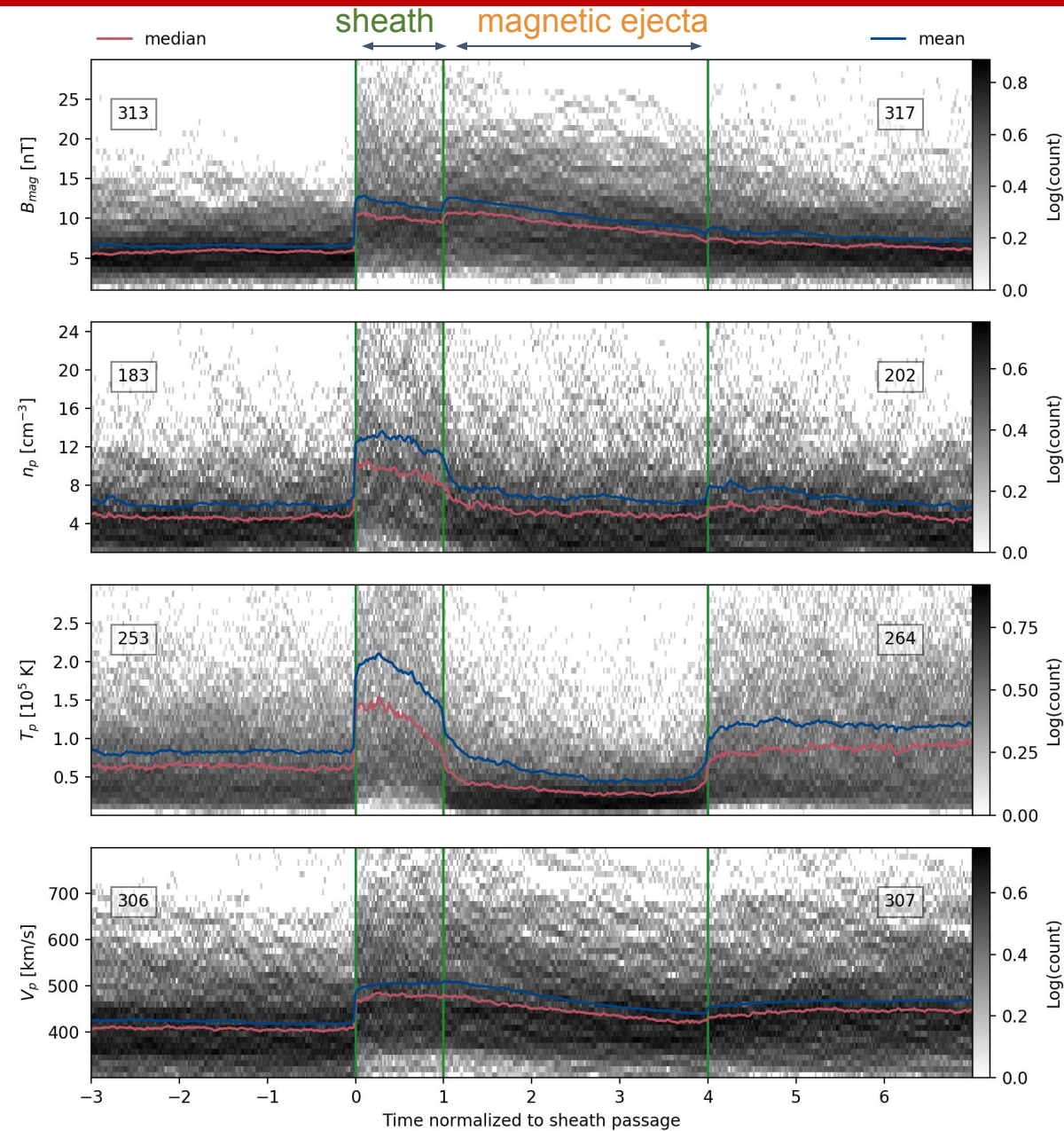
Statistical properties of ICME



Statistical properties of ICME

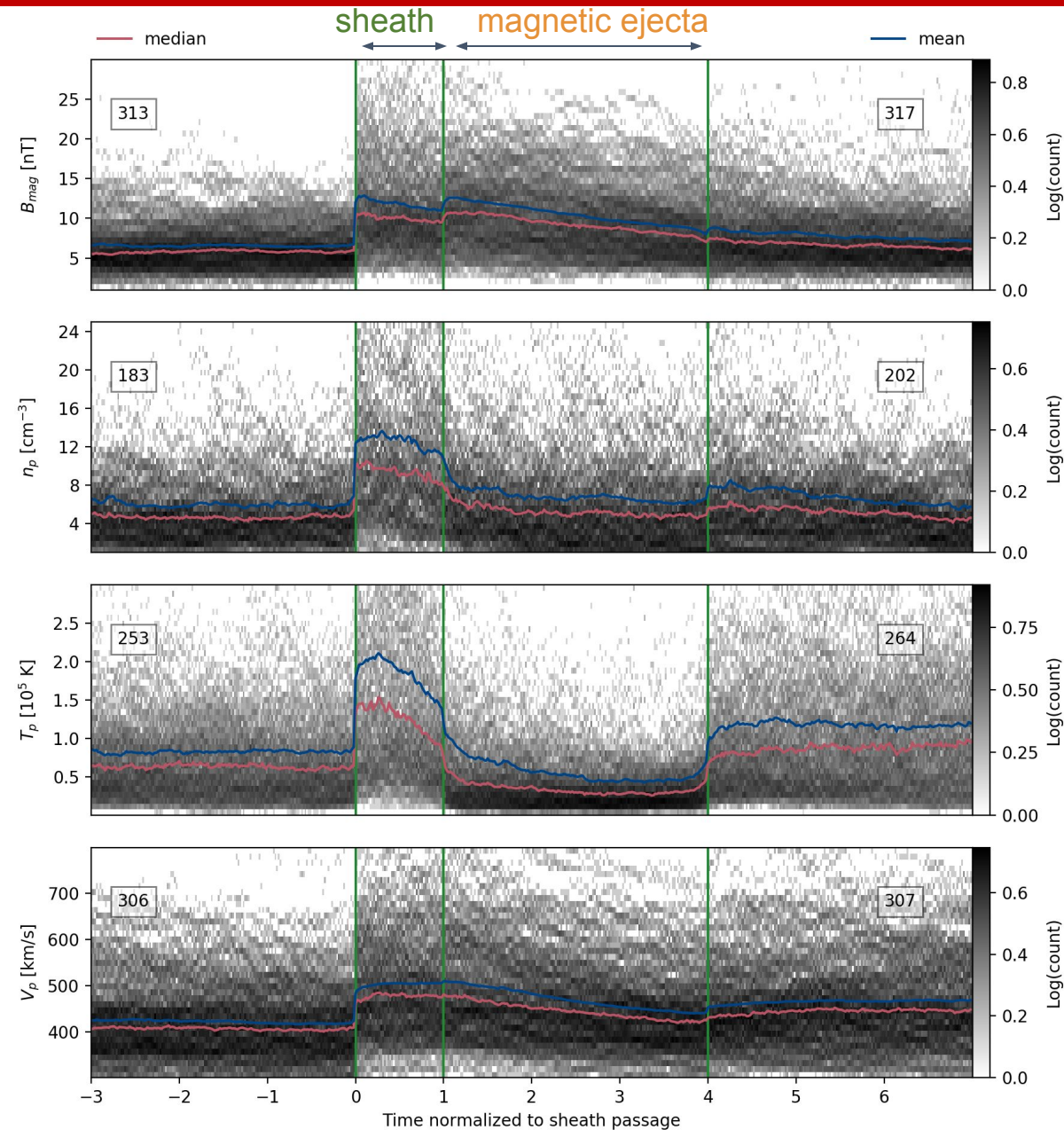


Typical profile of an ICME



Stacked histograms for all events with a sheath

Typical profile of an ICME



❑ Previous studies used the **mean** and **median** value to describe the sample of ICMEs

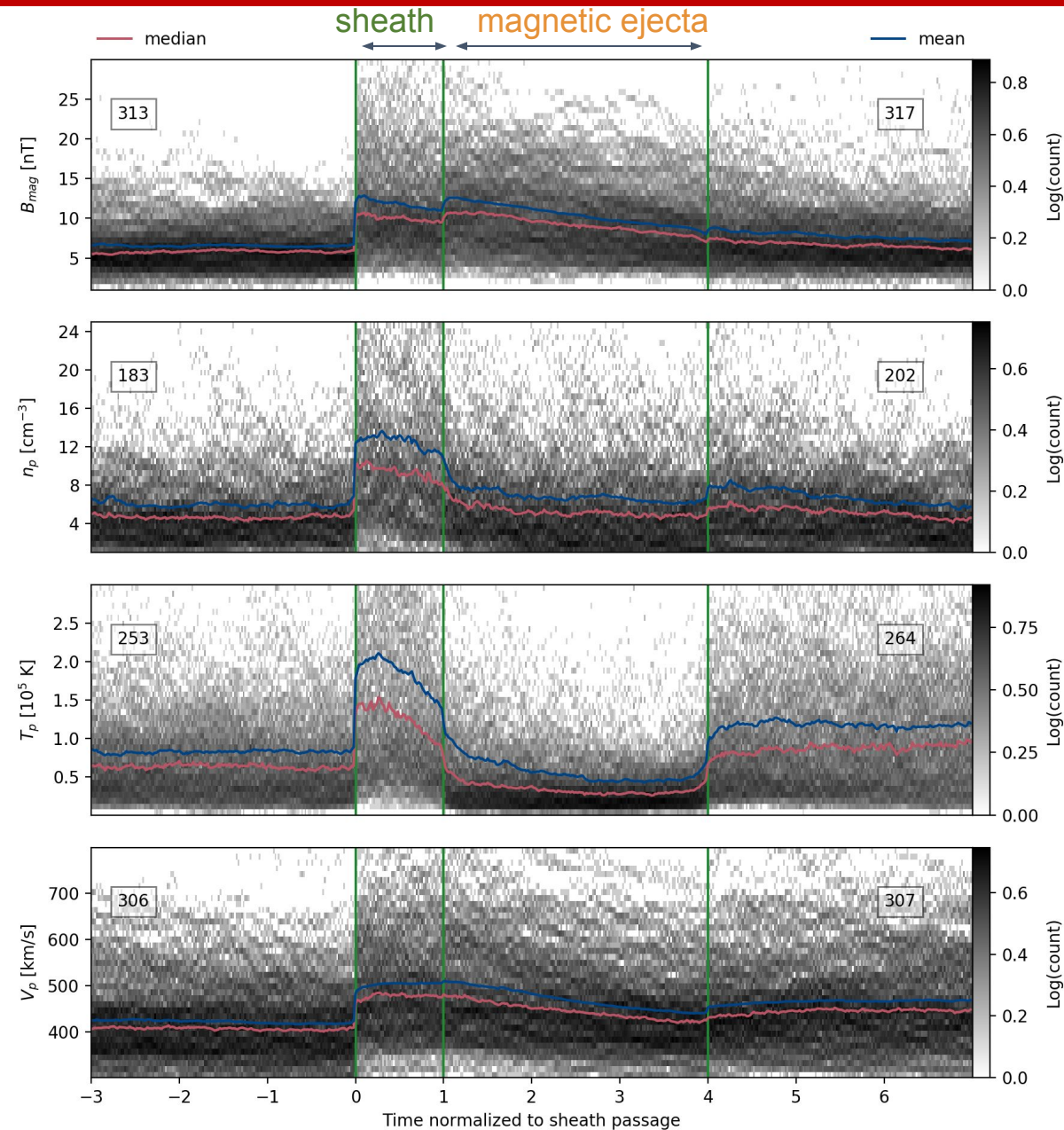
❑ The distribution is skewed : **mean** > **median**

❑ Darker area correspond to more probable values

The mean and the median may not be the best values to represent our sample of ICMEs

Stacked histograms for all events with a sheath

Typical profile of an ICME



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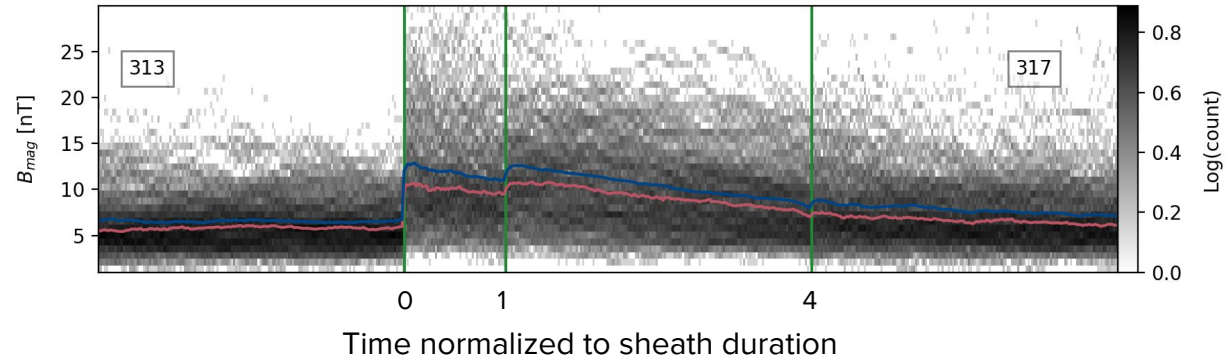
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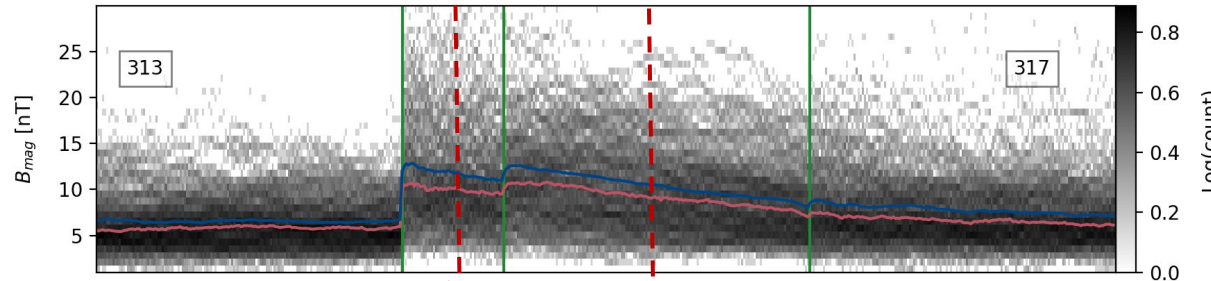
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Stacked histograms for all events with a sheath

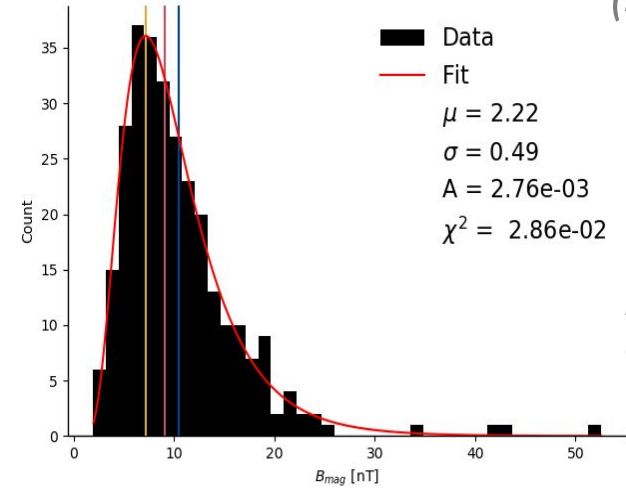
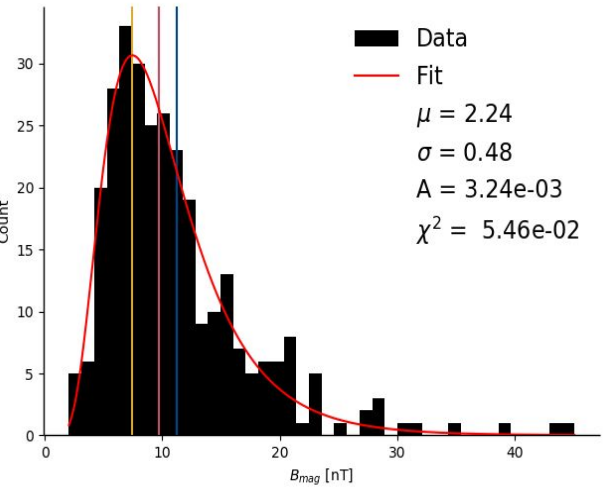
Typical profile of an ICME



Typical profile of an ICME



□ The distribution of B , n_p and T_p are well fitted by a log normal distribution. *Rodriguez et al. (2016), Mitsakou and Moussas (2014).*

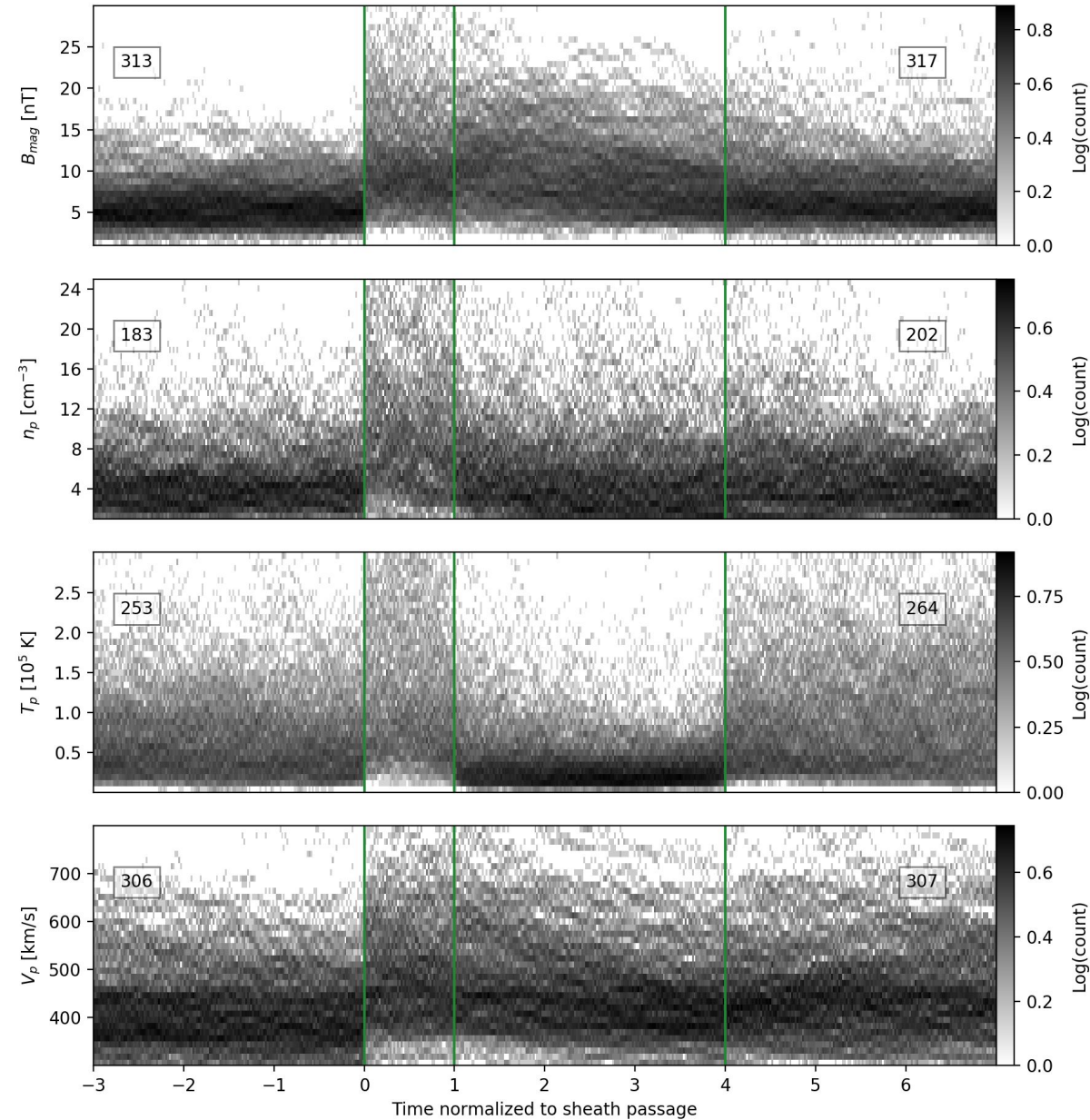


Distribution of the magnetic field over all ICME events with a sheath

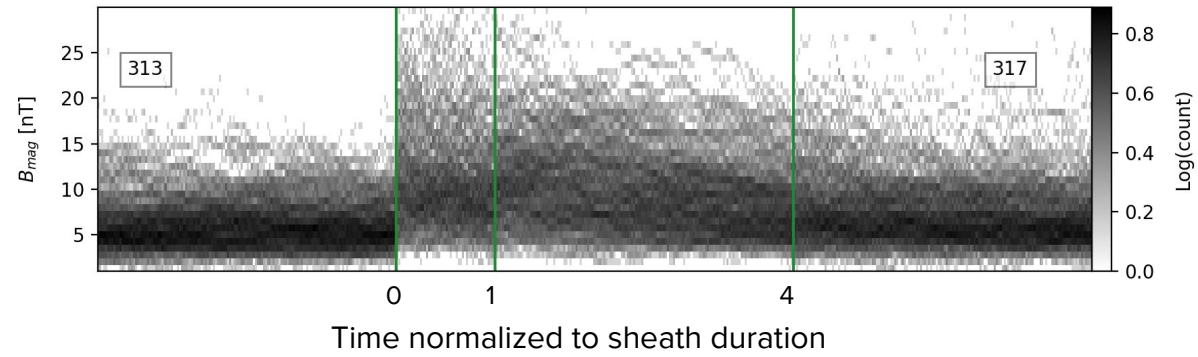
Stacked histograms of B for all events with a sheath

We decide to compute **the most probable value**, also called the mode, and to add it to the result of the superposed epoch method.

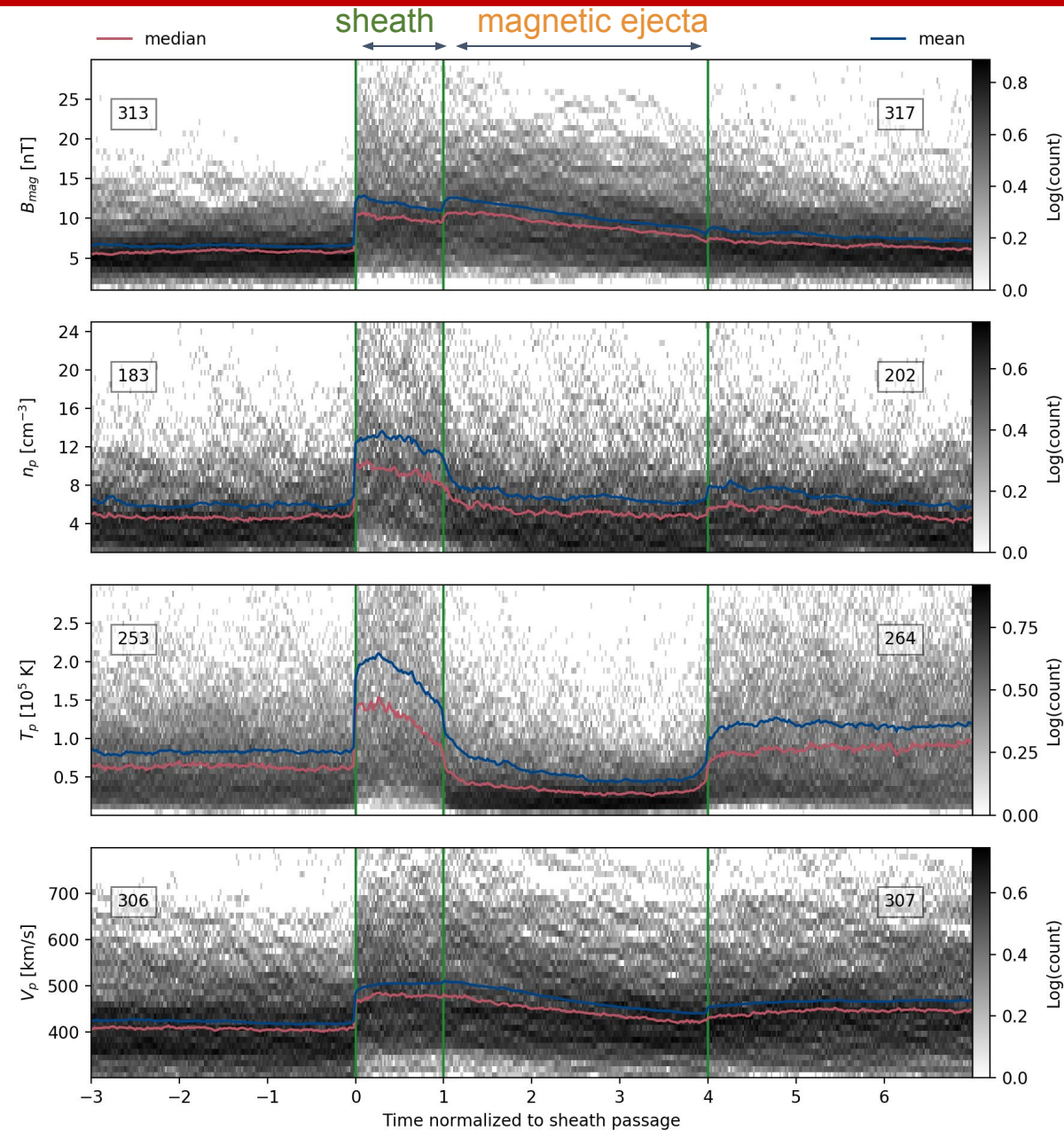
Statistical properties of ICME



Statistical properties of ICME



Typical profile of an ICME



Stacked histograms for all events with a sheath