THE MAGNETOPAUSE: AN ALMOST TANGENTIAL INTERFACE BETWEEN THE MAGNETOSPHERE AND THE MAGNETOSHEATH

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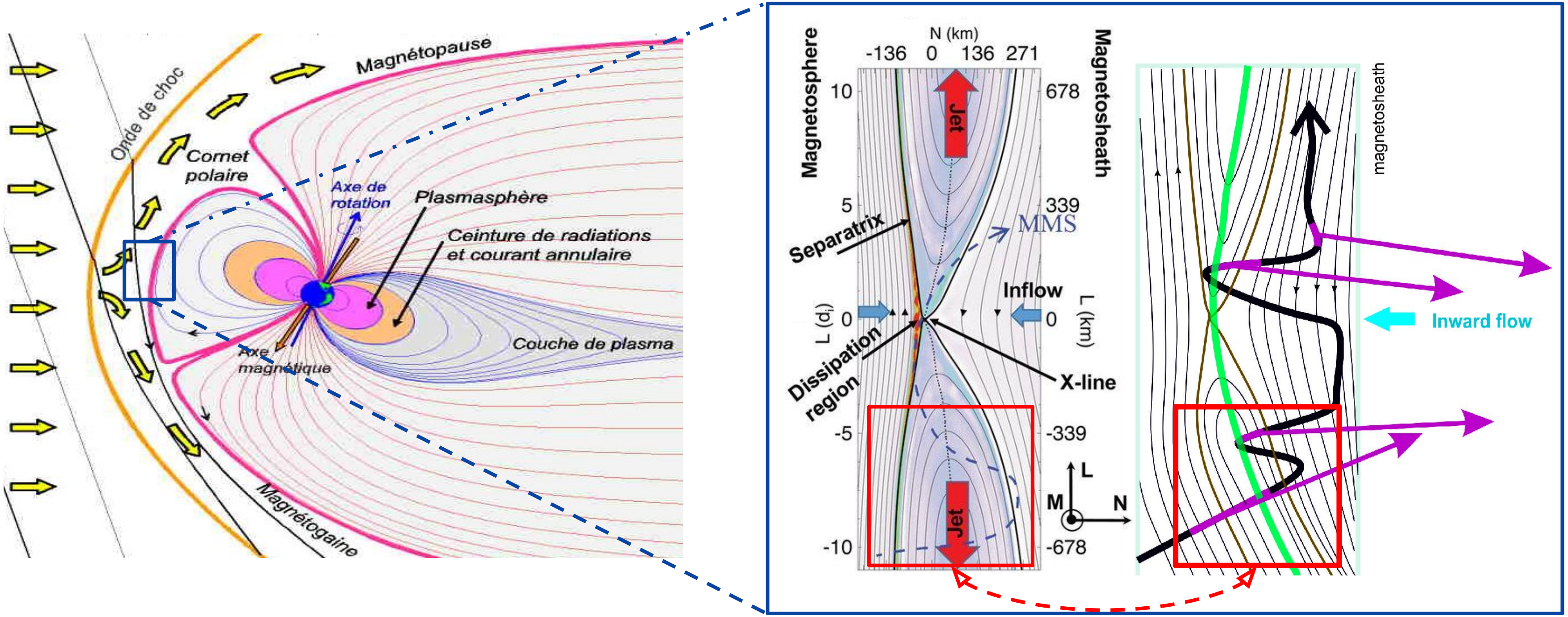
Magnetopause: Global vs Local



Focus on studying the internal structure of the discontinuity

Magnetopause: Non-stationary and Non-planar

Data from MMS, 05/02/16

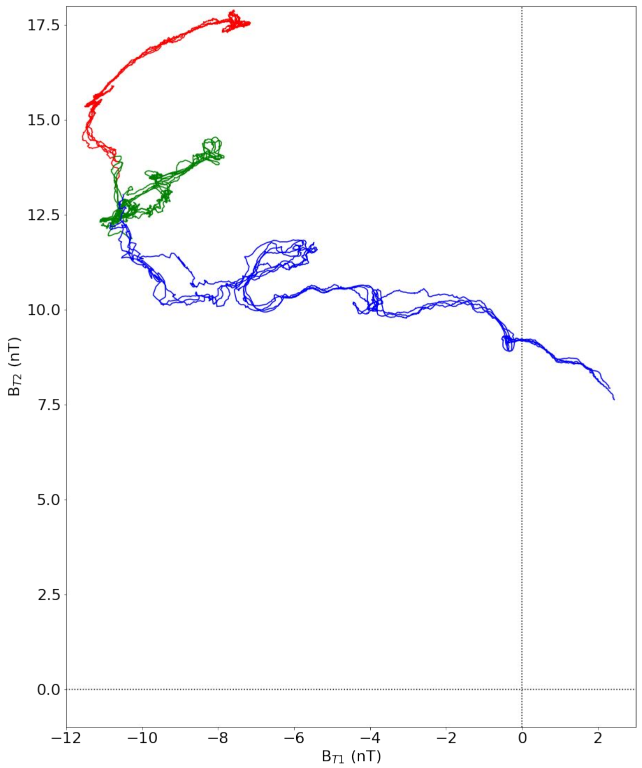
Classic Theory of discontinuities

- Two solutions: purely rotational and compressive discontinuities

Observations

- Compressional and rotational variations observed in a close vicinity

➔ The classic theory of discontinuities is insufficient for describing the magnetopause

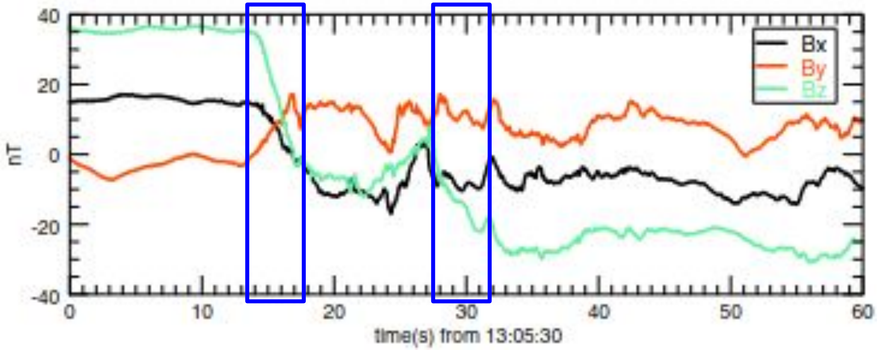


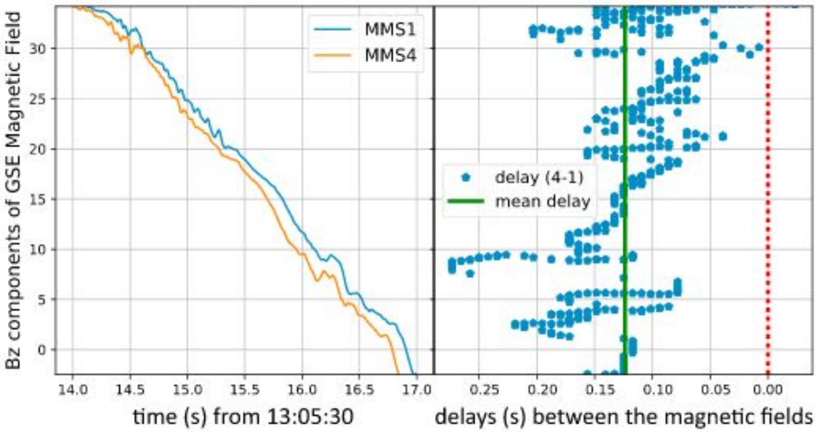
Magnetopause: Non-stationary and Non-planar

Data from MMS, 16/10/15

Nonstationarity

- ➢ Constant delay for a stationary boundary crossed at a constant velocity
- ➢ Variations with a mean value of the same order -or shorter- than the fluctuations



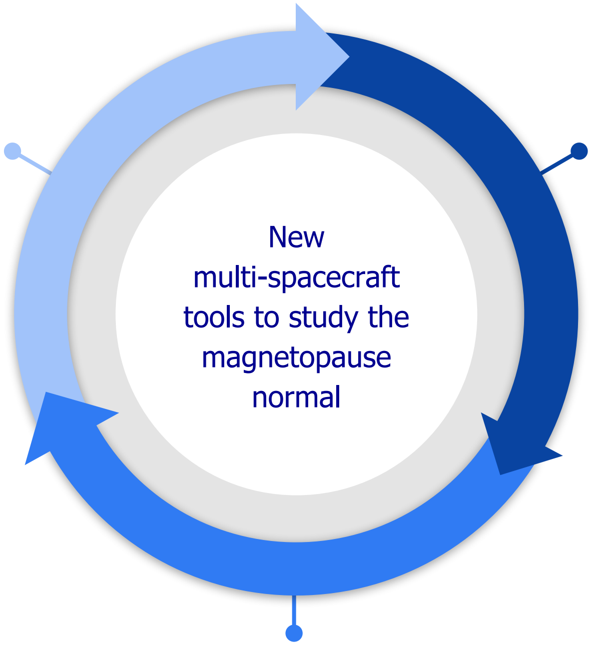


Comparison of Normals

- ➢ Different normals in the two “subparts” of the same crossing

Purpose

Assuming less strong hypotheses about its structure



Obtain the normal by using both

- Magnetic field data
- Ions velocity and density

Aiming at comparing the particles and fields structures

Purpose: obtaining the normal to the magnetopause by using the gradient matrix **G** of the magnetic field

Theoretical model

- Assume 1D structure

$$\mathbf{G}_{fit} = \mathbf{n}\,\mathbf{B'}$$

Variation of **B** along the normal

$\mathbf{B'}=[\partial \mathbf{B}_x/\partial \mathbf{n}\ ,\ \partial \mathbf{B}_y/\partial \mathbf{n}\ ,\ \partial \mathbf{B}_z/\partial \mathbf{n}]$

Normal vector to the structure

MMS Data

- Obtain **G** by using reciprocal vector method

$$\mathbf{G} = \sum_s \mathbf{k}_s\ \mathbf{B}_s$$

+

Minimize the difference between **G** and $\mathbf{G}_{fit}$ to obtain the normal

Purpose: obtaining the normal to the magnetopause by using the gradient matrix **G** of the magnetic field

Theoretical model

❖ Assume 1D structure

$$\mathbf{G}_{fit} = \mathbf{n}\ \mathbf{B'}$$

- 2 free parameters for **n**
- 3 free parameters for **B'**
- Impose **∇.B**=0

➔ $\mathbf{G}_{fit}$ depends on 4 parameters

MMS Data

❖ Obtain **G** by using reciprocal vector method

$$\mathbf{G} = \sum_s \mathbf{k}_s\ \mathbf{B}_s$$

+

Minimize the difference between **G** and $\mathbf{G}_{fit}$ to obtain the normal

Defined Magnetic normal $\mathbf{n_B}$

Purpose: obtaining the normal to the magnetopause by using the gradient matrix **G**

Theoretical model

❖ Assume 1D structure

$$\mathbf{G}_{\text{fit}} = \mathbf{n}\ \varrho \boldsymbol{v}_i{}'$$

- 2 free parameters for **n**
- 3 free parameters for $\boldsymbol{\varrho}\mathbf{v}_i{}'$
- Impose $\nabla.\ (\varrho\boldsymbol{v}_i) = -\partial_t \varrho$

→ $\mathbf{G}_{\text{fit}}$ depends on 4 parameters

MMS Data

❖ Obtain **G** by using reciprocal vector method

$$\mathbf{G} = \sum_s \mathbf{k}_s\ (\varrho \boldsymbol{v}_i)_s$$

+

Minimize the difference between **G** and $\mathbf{G}_{\text{fit}}$ to obtain the normal

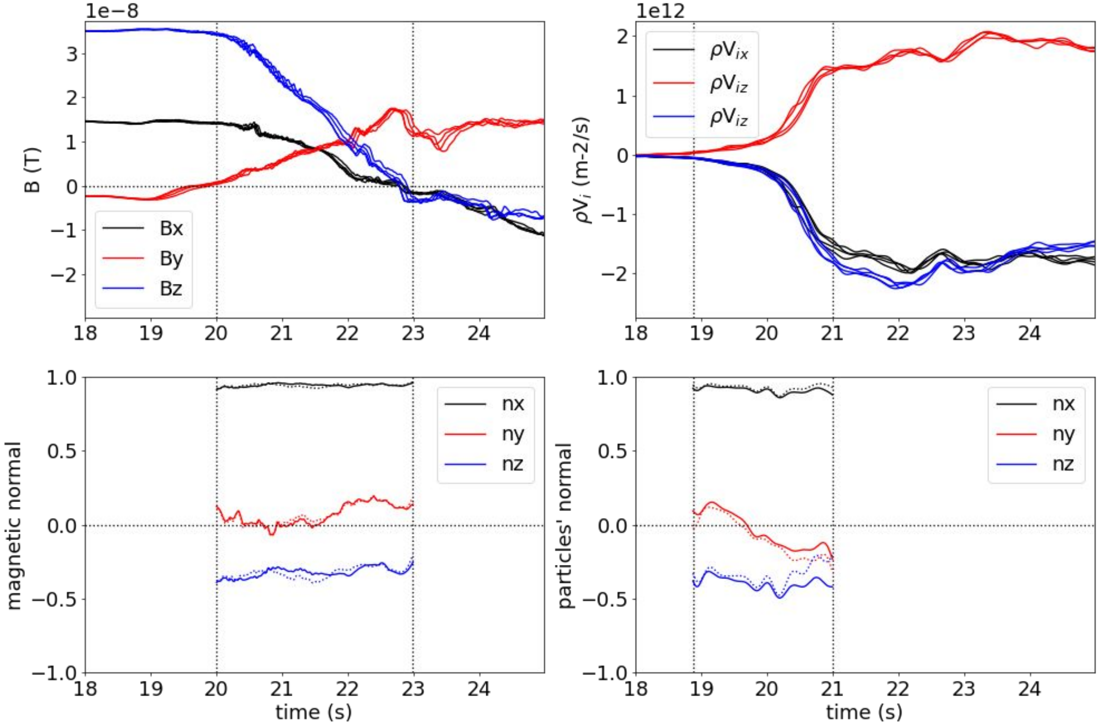
Linked by a different relation

Defined Particles' normal $\mathbf{n}_{\text{ions}}$

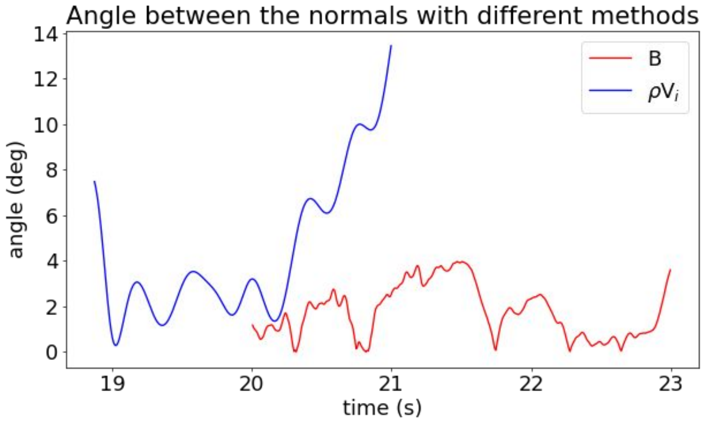
LPP

Results: Comparison with MDD tool (Shi et al, 2006)

Data from MMS, 16/10/15

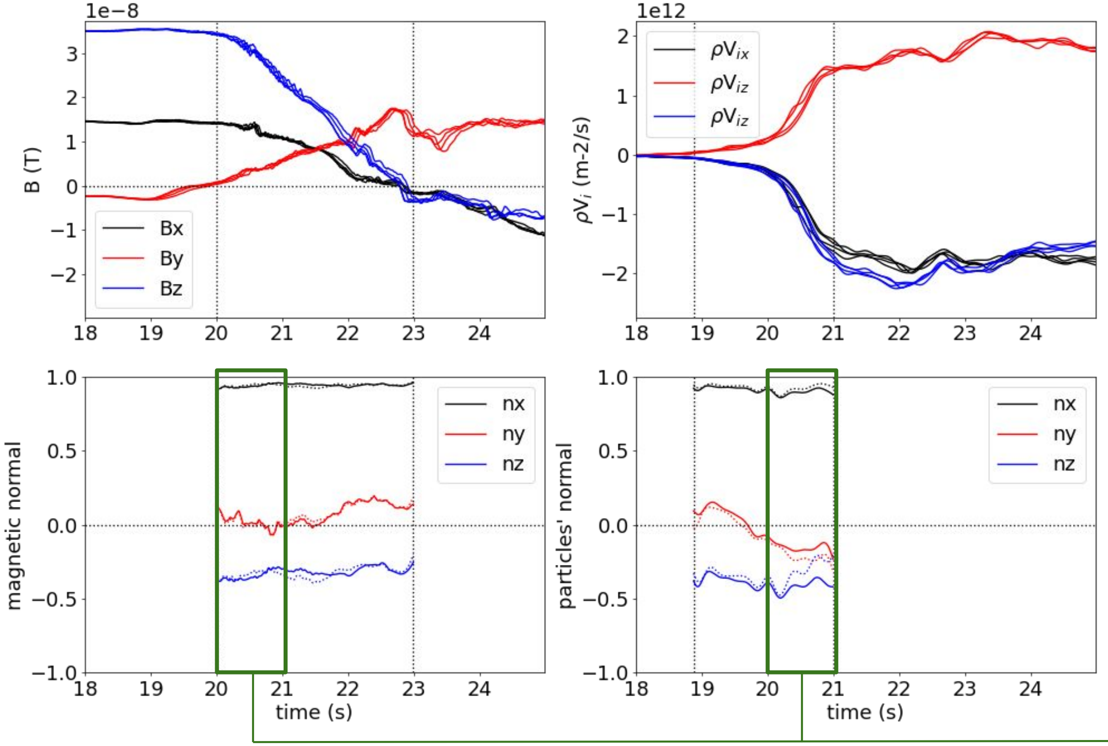


- ➢ New tool: continuous line
- ➢ MDD: dotted line
- ➢ Agreement between the two methods



Results: Magnetic field vs Ions velocity

Data from MMS, 16/10/15

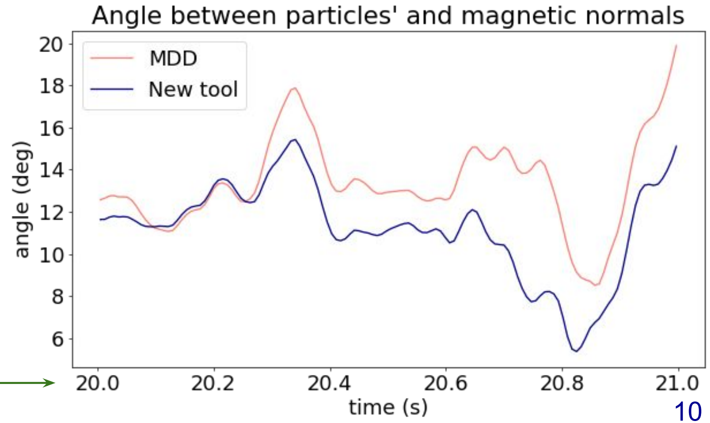


zoom on the common gradient time interval

Obtain a tilt angle between the magnetic and particles’ normals

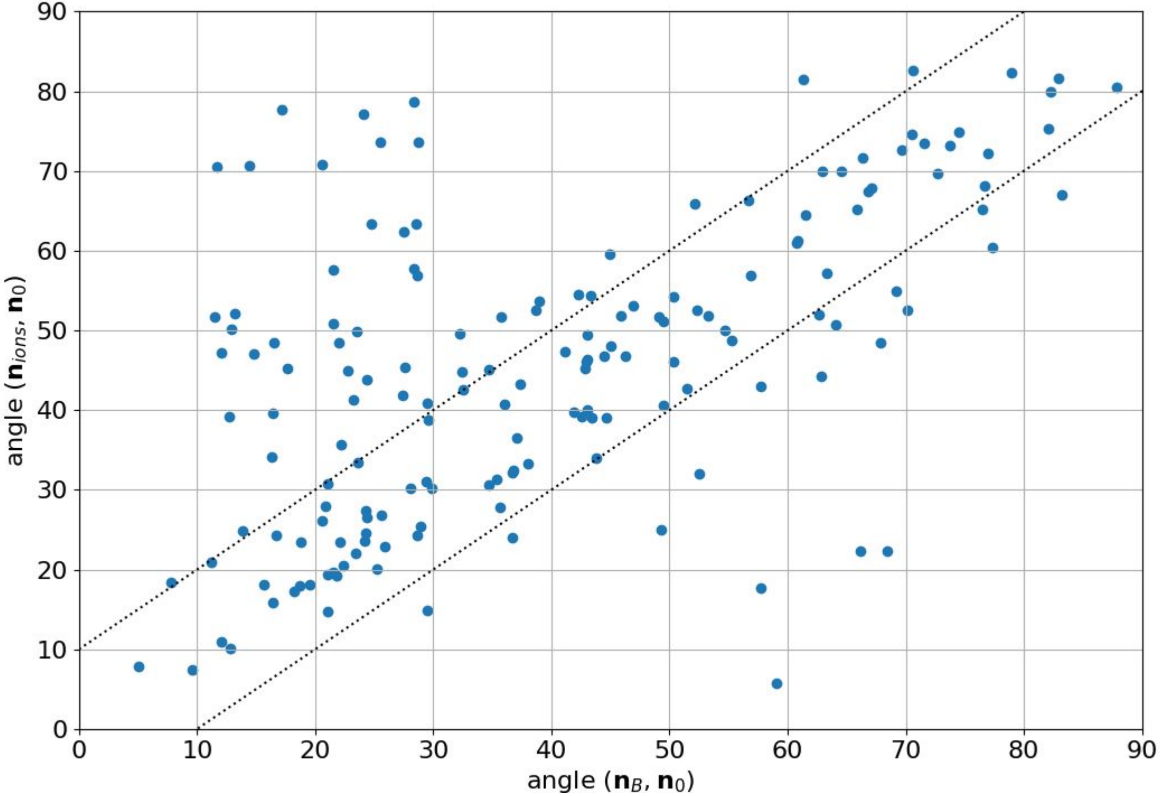
Avg. angle:

- ➢ **MDD:** 10.7 deg
- ➢ **New tool:** 9.2 deg



Statistical study

* n_0 : Nominal normal (Shue et al (JPR, 1997))



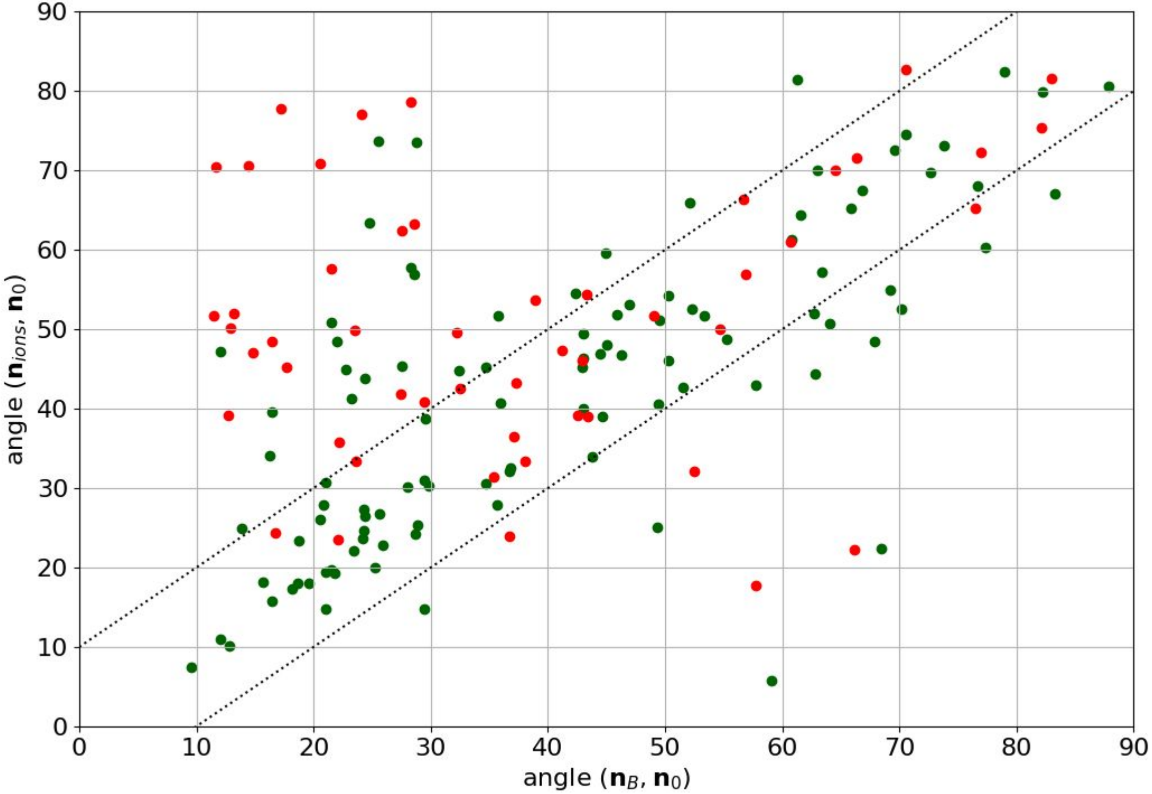
➢ Done on ~150 crossings

➢ Selected by using the results by Michotte de Welle et al (Prep, 2022)

➢ Mean angle between the magnetic and particles' normals: 26 deg

➢ Correlation: 0.56

Statistical study: Southward vs Northward SW



Southward SW Magnetic Field

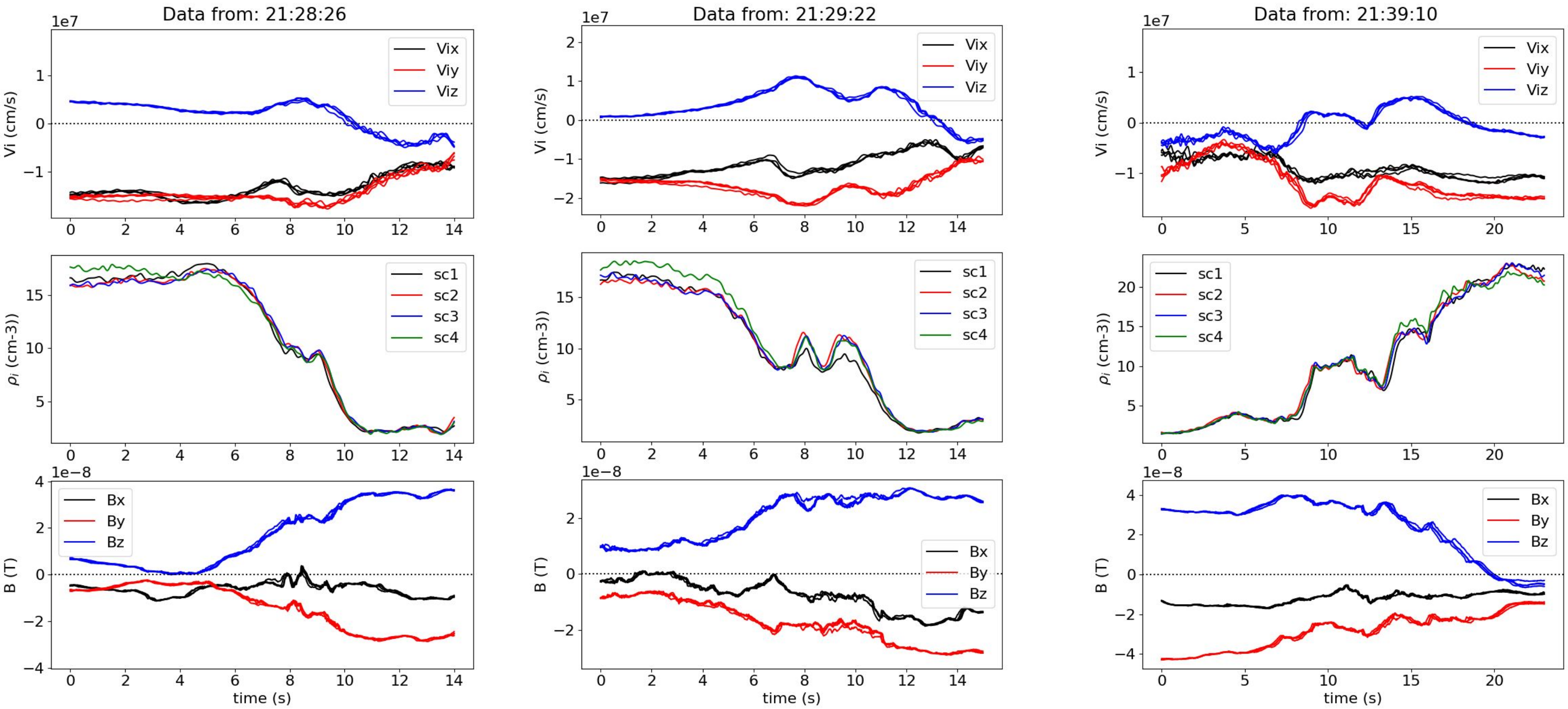
- Cases: 103
- Correlation: 0.70
- Mean angle between the magnetic and particles' normals: 24.0 deg

Northward SW Magnetic Field

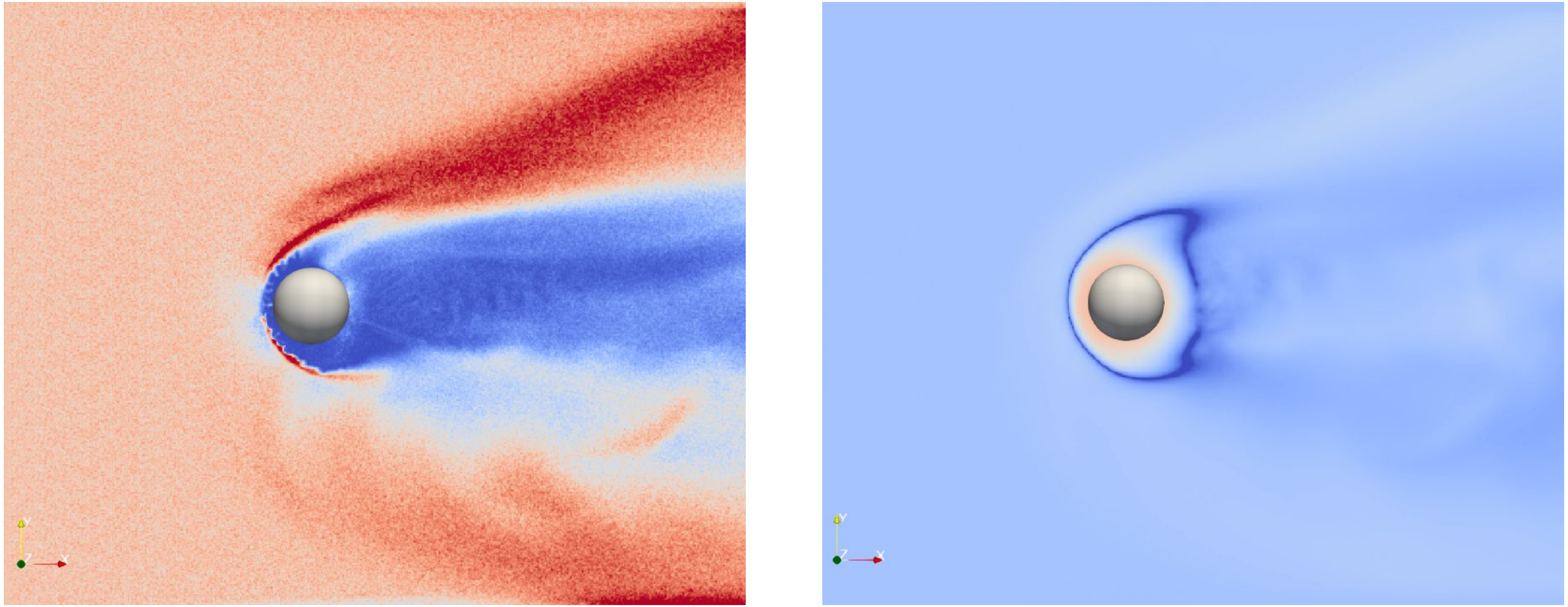
- Cases: 51
- Correlation: 0.24
- Mean angle between the magnetic and particles' normals : 32.2 deg

Crossing of 05 February 2016 - Out of the diagonal data

- 3 crossings in 10 minutes
- Same two parts crossing in all cases



Virtual satellites on two PIC simulations



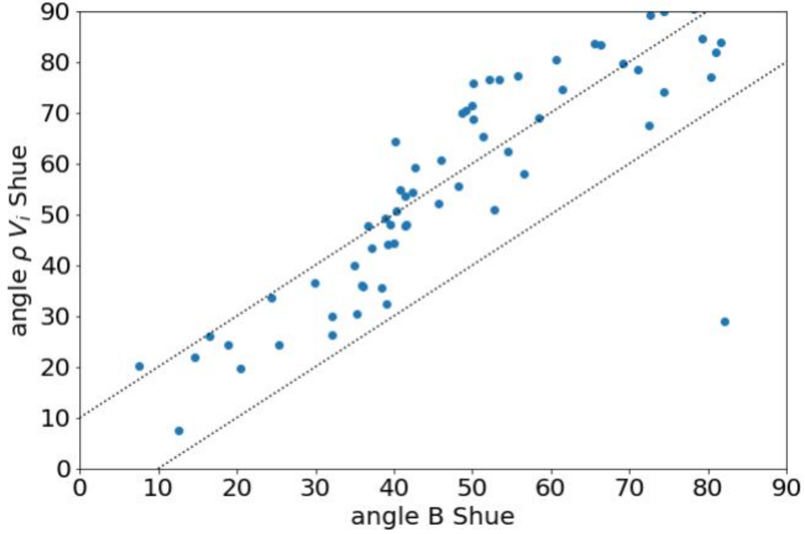
- ➢ Simulations run by Federico Lavorenti (OCA, UniPi)
- ➢ Purely Northward and Southward SW magnetic field

Virtual satellites on two PIC simulations

LPP

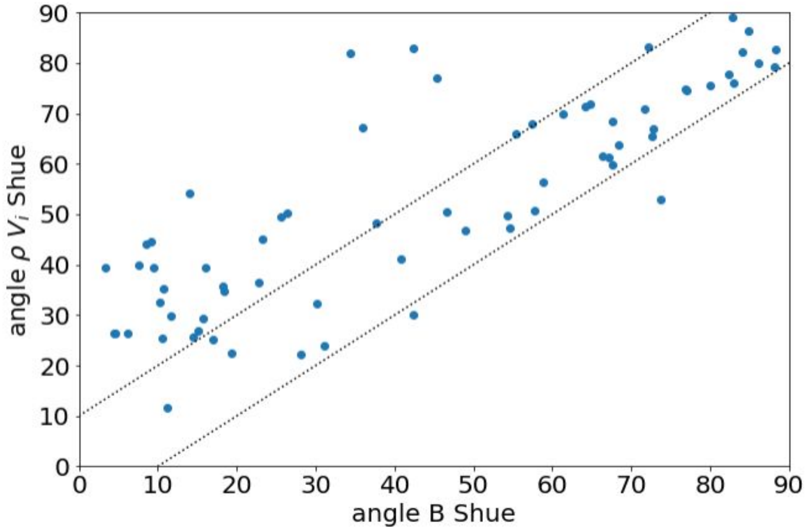
Purely Southward SW Magnetic Field

- 100 random crossings with interpolation
- Correlation: 0.88
- Mean angle between magnetic and particules' normals : 20.5 deg



Purely Northward SW Magnetic Field

- 100 random crossings with interpolation
- Correlation: 0.79
- Mean angle between magnetic and particules' normals : 24.6 deg



Conclusions and Future Perspectives

A new tool

- ➢ Allows us to compare particles and magnetic field structures
- ➢ Agreement with MDD method

Future perspectives

- ➢ Determine the precision of the normals
- ➢ Study cases with different magnetic and particles' normals

Thank you for any feedback

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