On the location of magnetic reconnection

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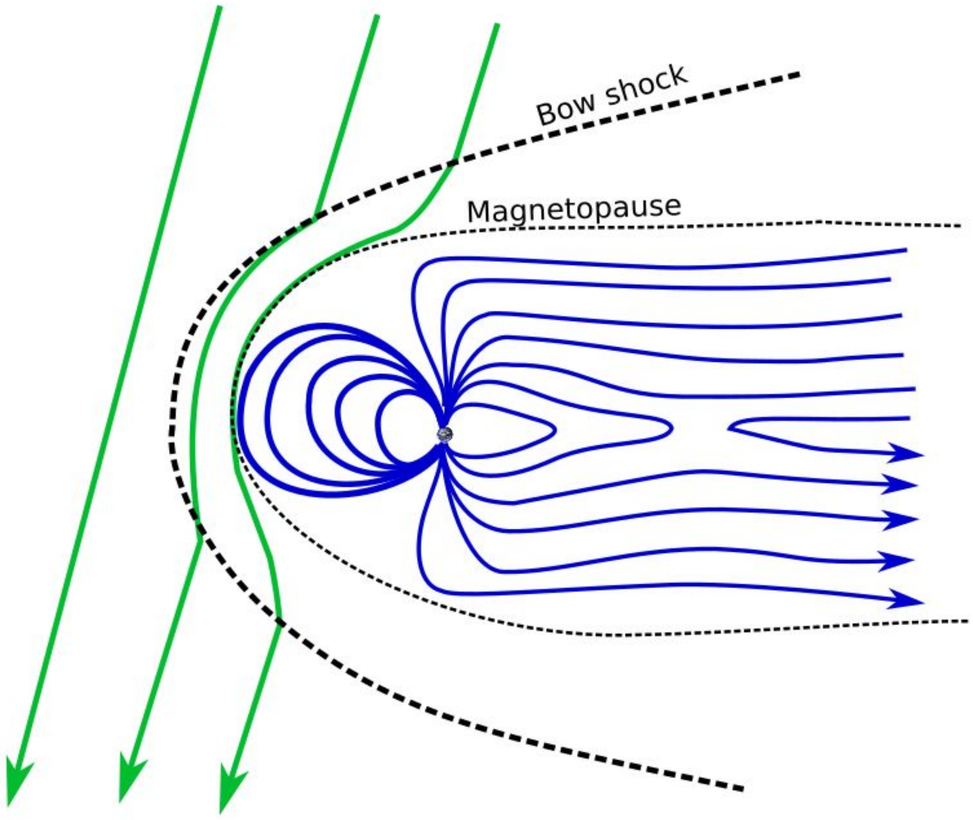
Where is the reconnection point ?



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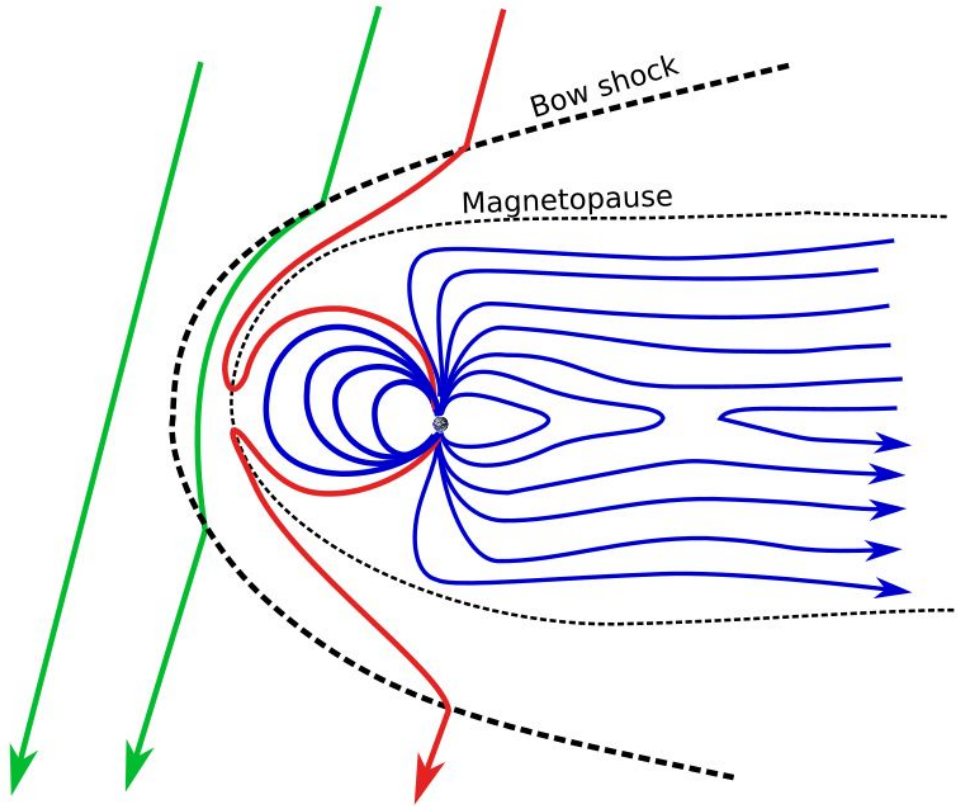
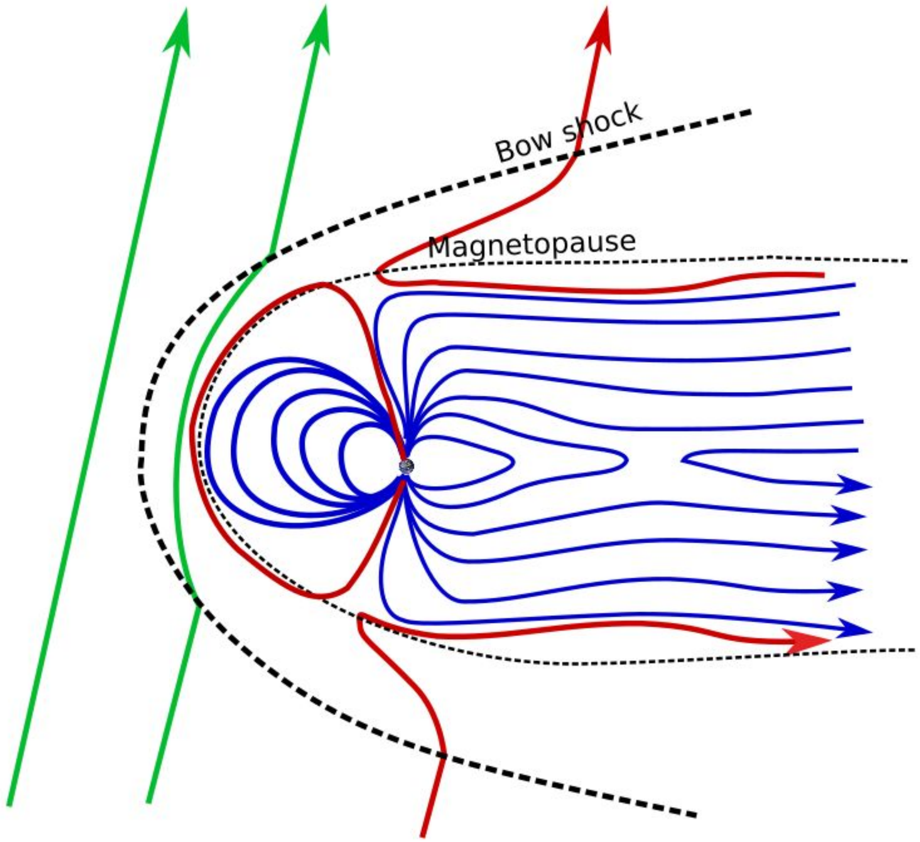


Southward IMF

⬇

Low latitude reconnection

Where is the reconnection point ?

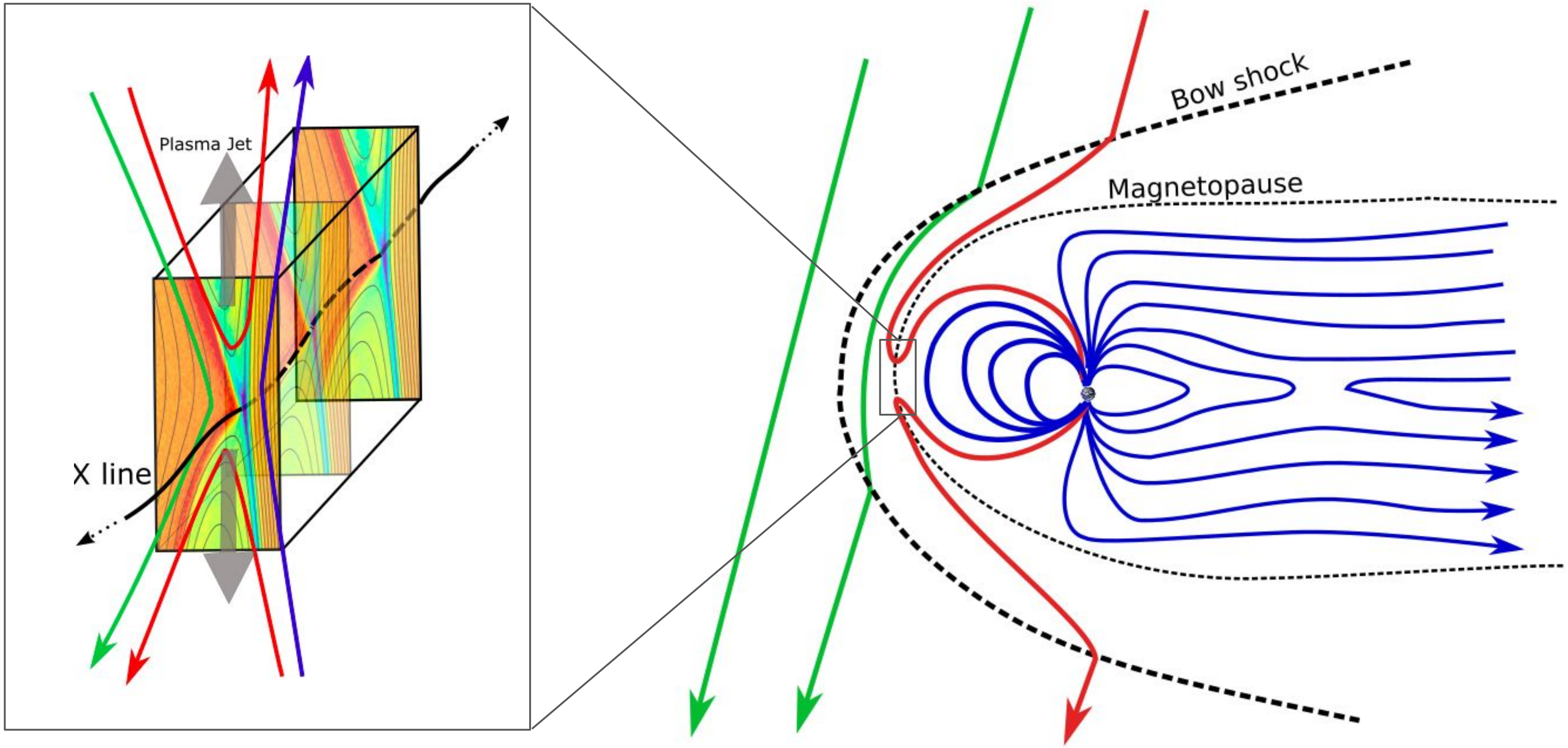


Northward IMF

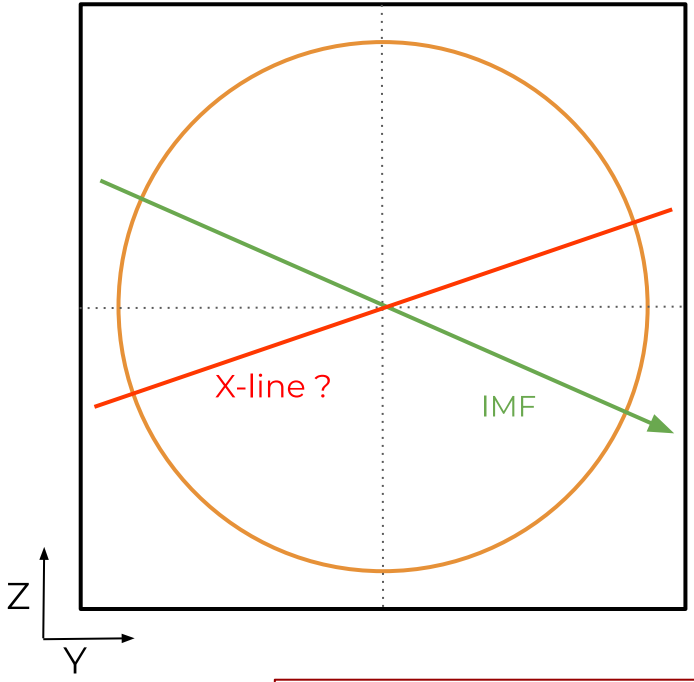
⬇

high latitude reconnection

In 3D: Where is the reconnection ***line*** ?



Why is it important to locate the reconnection line?



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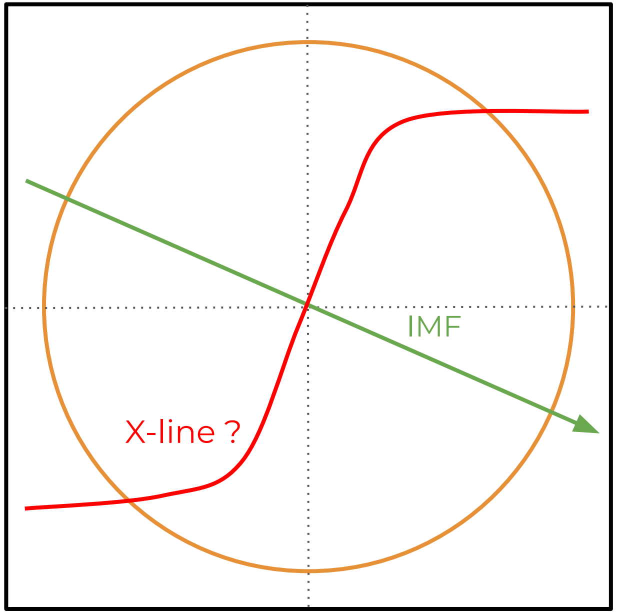
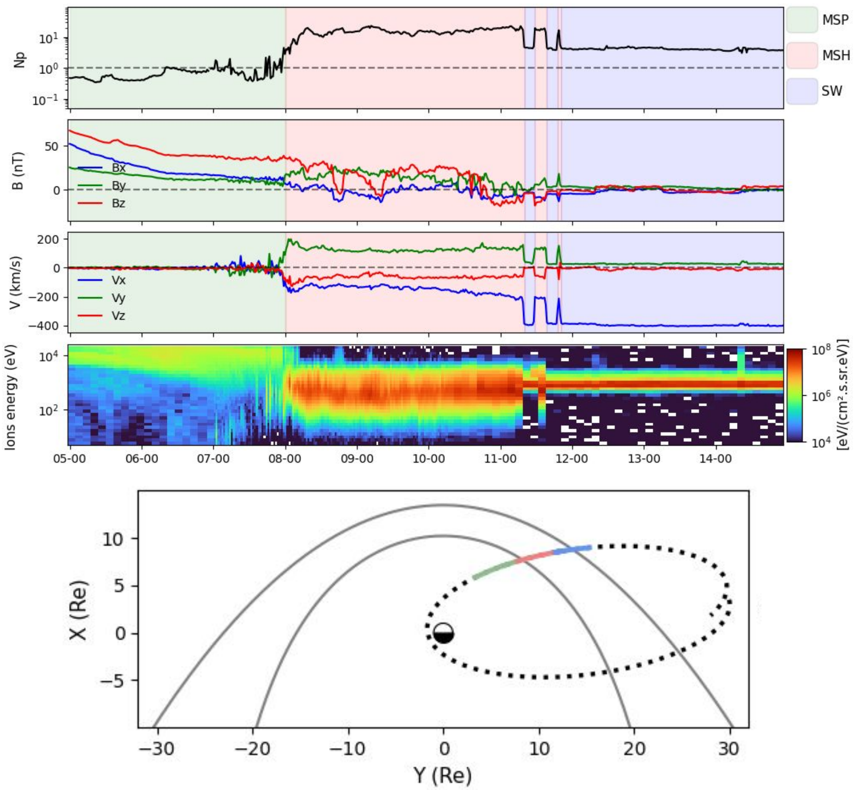
quantity of magnetic flux that undergoes reconnection



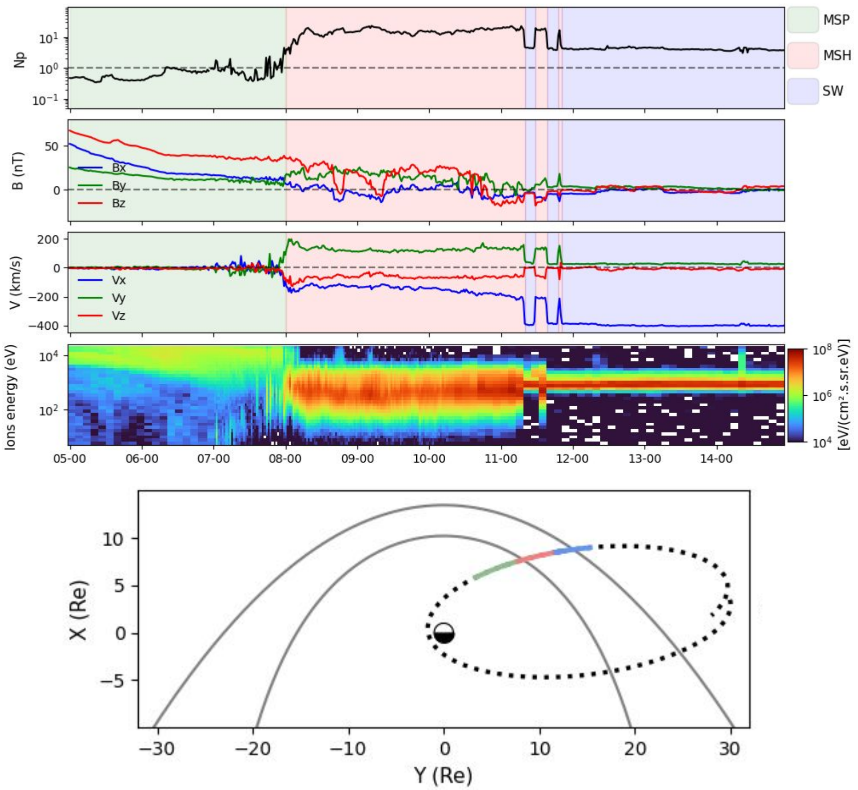
Critical to understand the magnetosphere/interplanetary medium coupling

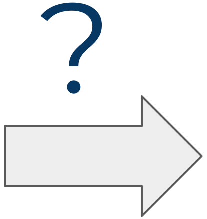
Multi-scale challenge

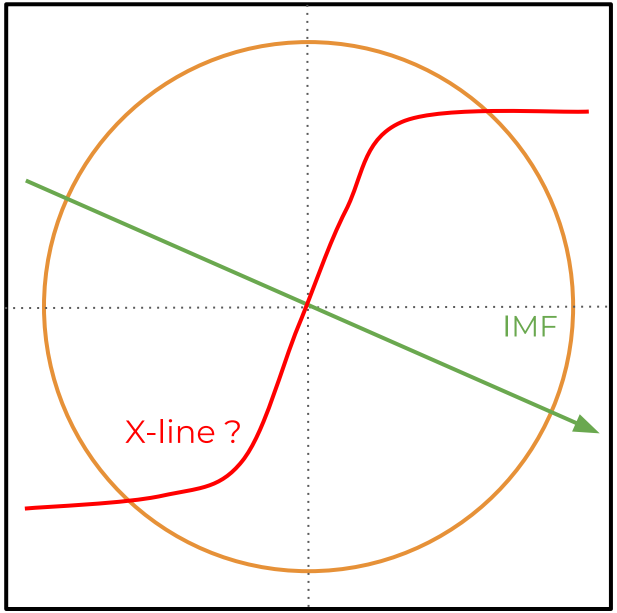


- Space/time ambiguity due to unsteady complex 3D system
- Spatial bias due to satellite orbital planes
- Dependence on IMF orientation requires continuous solar wind monitoring
- Estimation of causal IMF orientation may have substantial errors

Multi-scale challenge







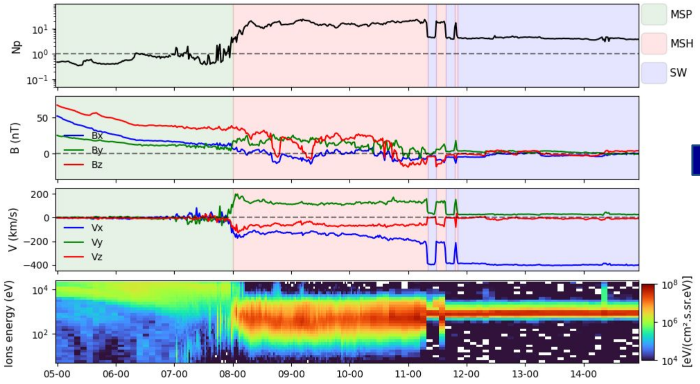
Methodology

From in-situ measurements to global 3D maps

The magnetic draping in the magnetosheath

From in-situ data to global 3D maps

In-situ data : intrinsically local in both time and space



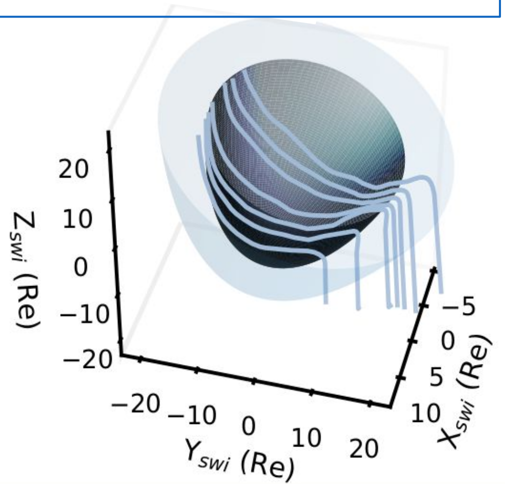
Missions :
- Cluster
- DoubleStar
- THEMIS
- MMS

Pipeline

- Region detection
- Association with SW/IMF params
- Normalization between MP/BS
- kNN / field line integration

~ 45 millions magnetosheath
and
~ 55 millions magnetosphere
data points

Stationary and 3D representation



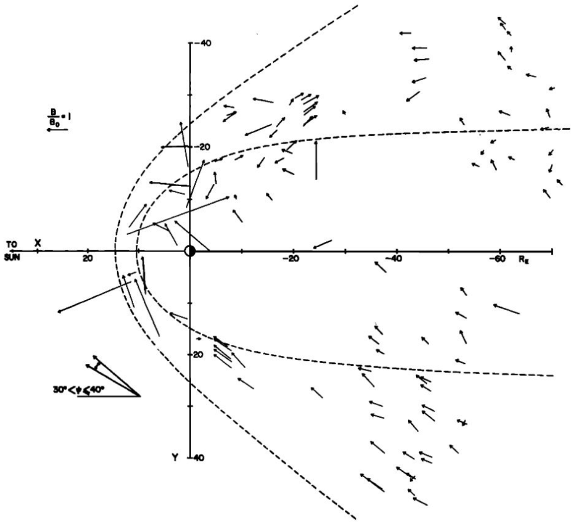
Michotte de Welle et al. 2022

Methodology
From in-situ measurements to global 3D maps

The magnetic draping in the magnetosheath

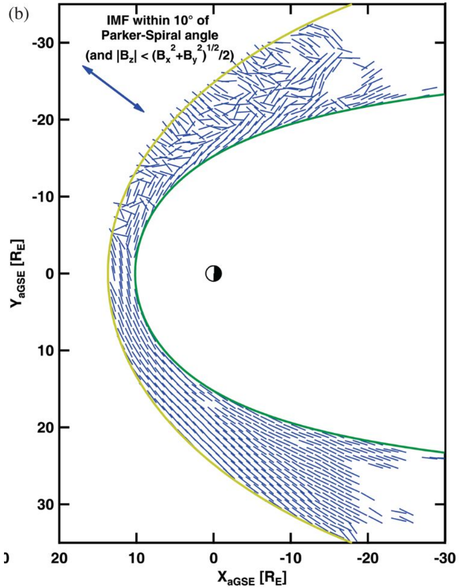
Magnetic shear maps from observations

Magnetic field in the magnetosheath from in-situ data



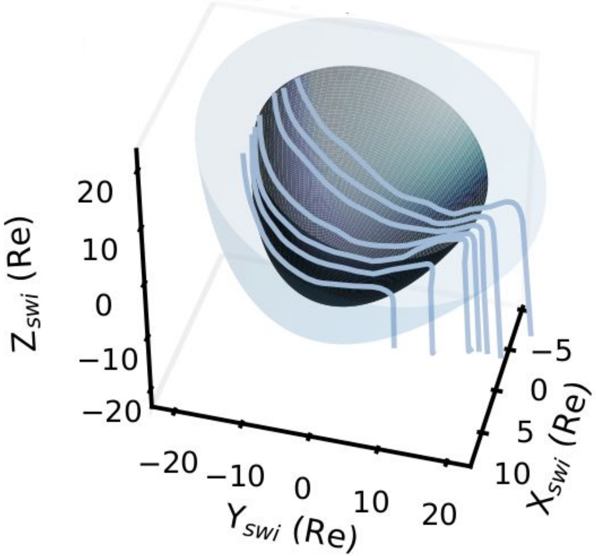
Behannon et al. 1969

Missions :
- Explorers



Petrinec 2012

Mission :
- THEMIS



Michotte de Welle et al. 2022

Missions :
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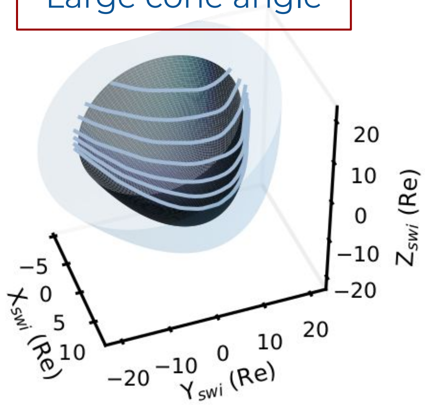
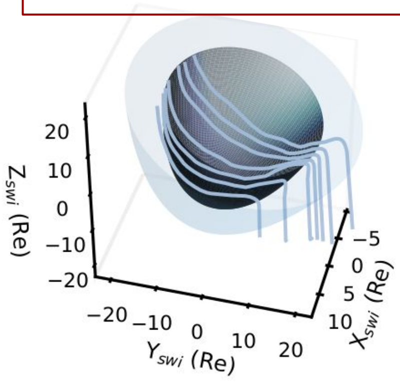
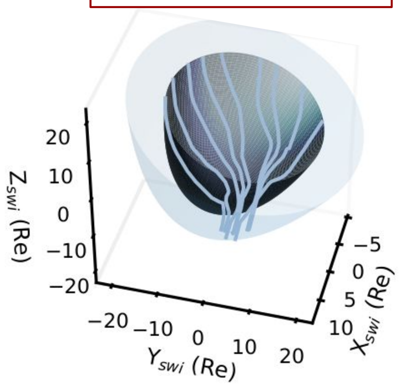
Disagreement model/data for intermediate IMF inclination

Large cone angle	Intermediate cone angle	Low cone angle







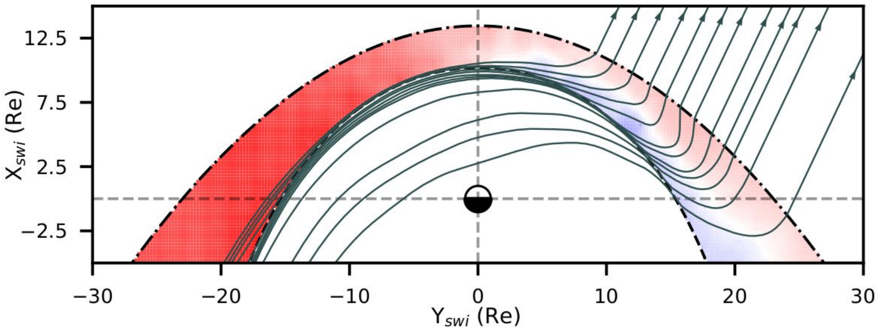
Michotte de Welle et al. [2022]

- IMF cone angle ~ [90°,45°±5°]
- ~ 70% of the IMF cone angle

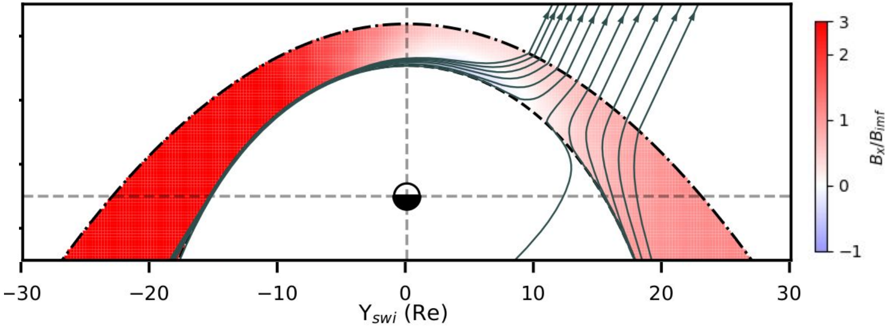
- IMF cone angle ~ [45±5°, 12.5°±5°]
- ~ 28% of the IMF cone angle

- IMF cone angle ~ [12.5°±5°,0°]
- ~ 2% of the IMF cone angle

Data



Magnetostatic model (KF94)



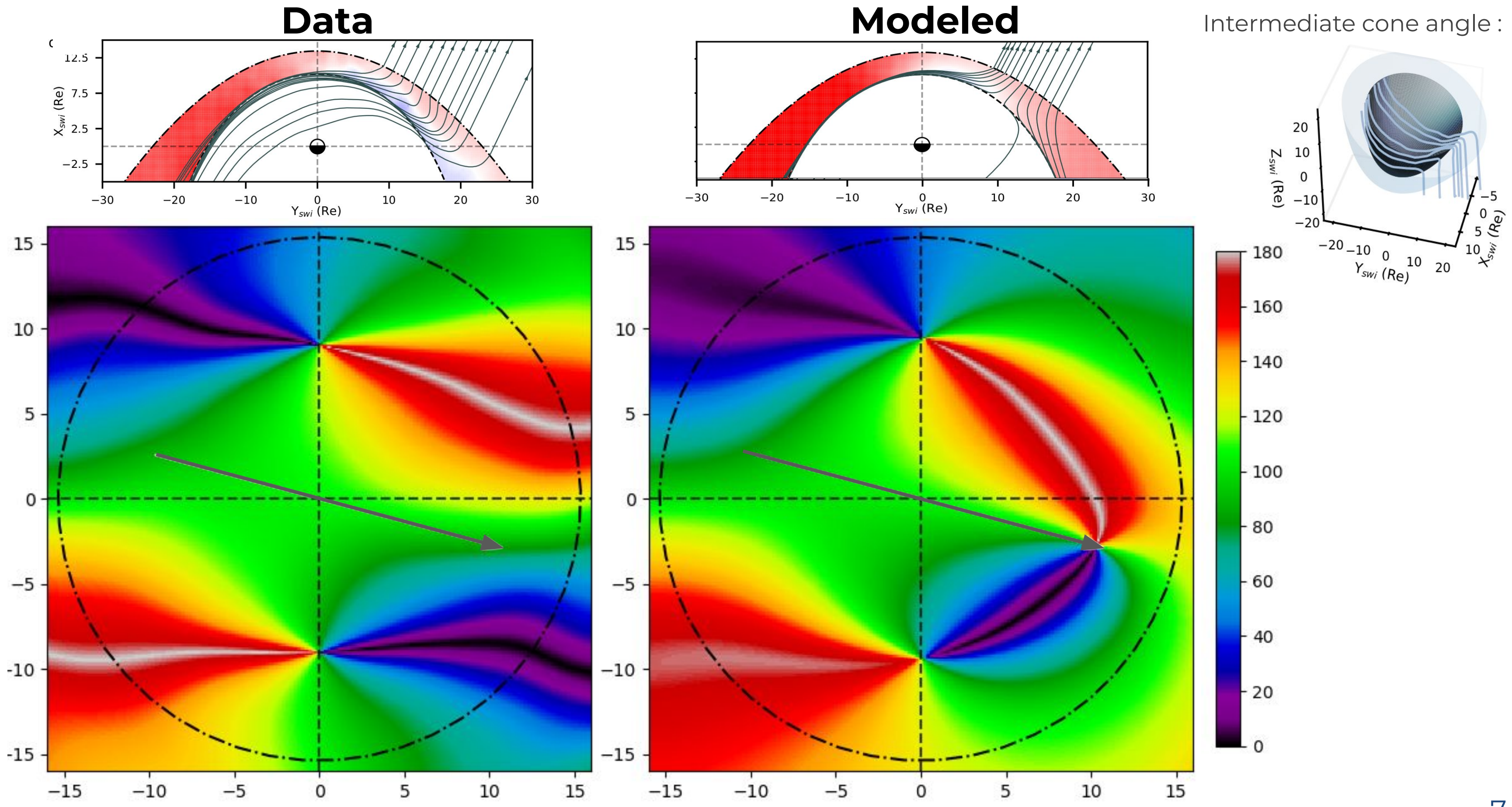
The magnetic draping in the magnetosheath

Magnetopause maps

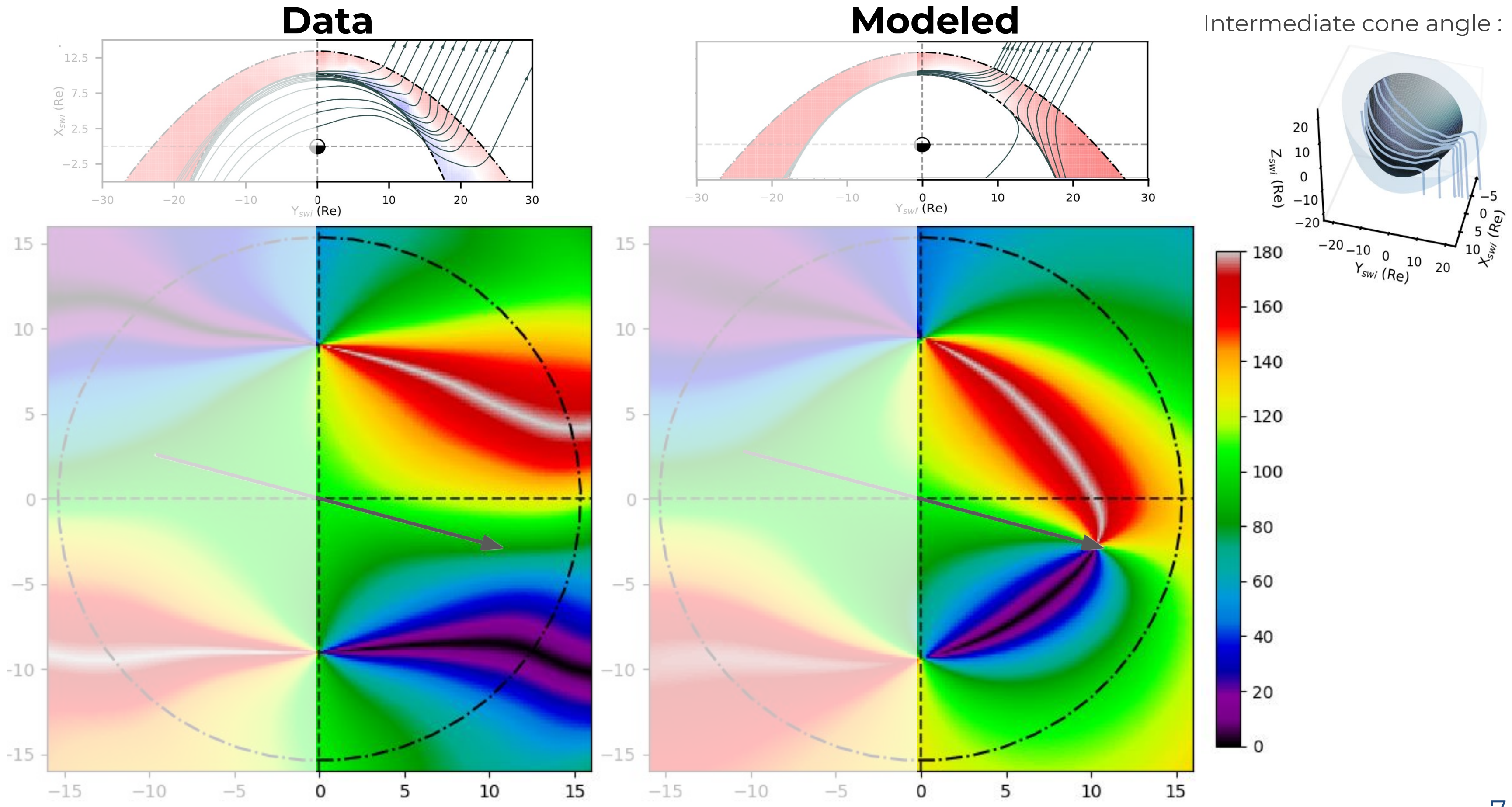
Magnetic shear, current density, and reconnection rate

Toward a new X-line model

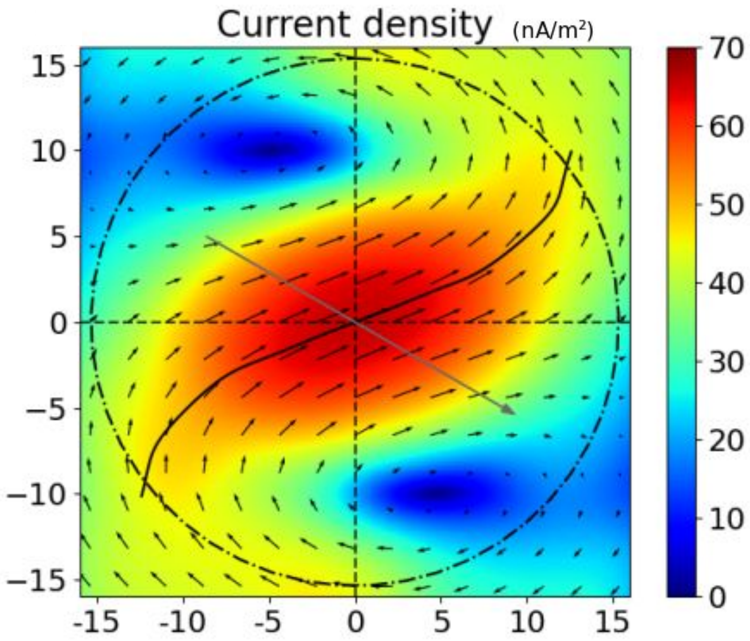
Intermediate cone: Observed shear differs from modeled one



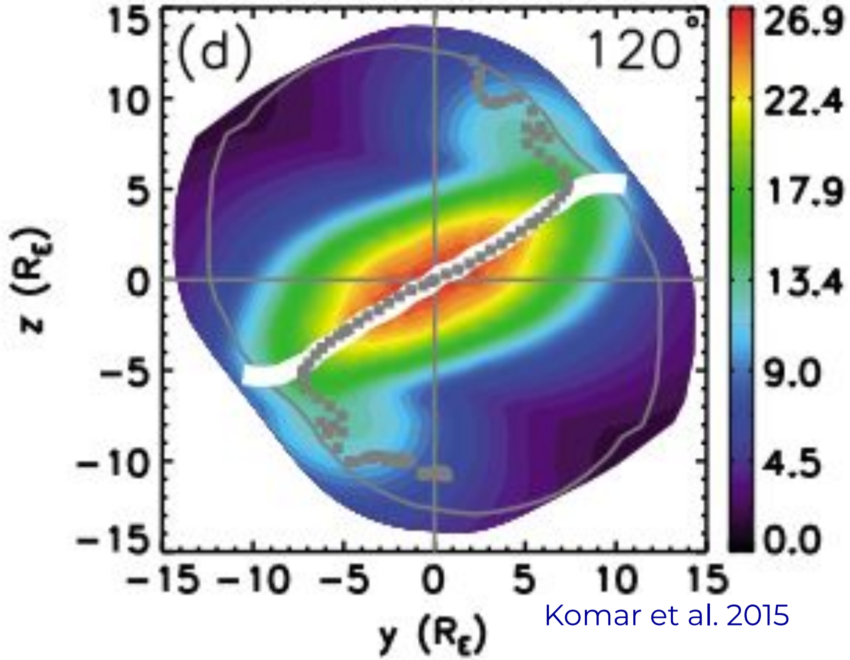
Intermediate cone: Observed shear differs from modeled one



Global distribution of the current density ~ MHD models/Obs



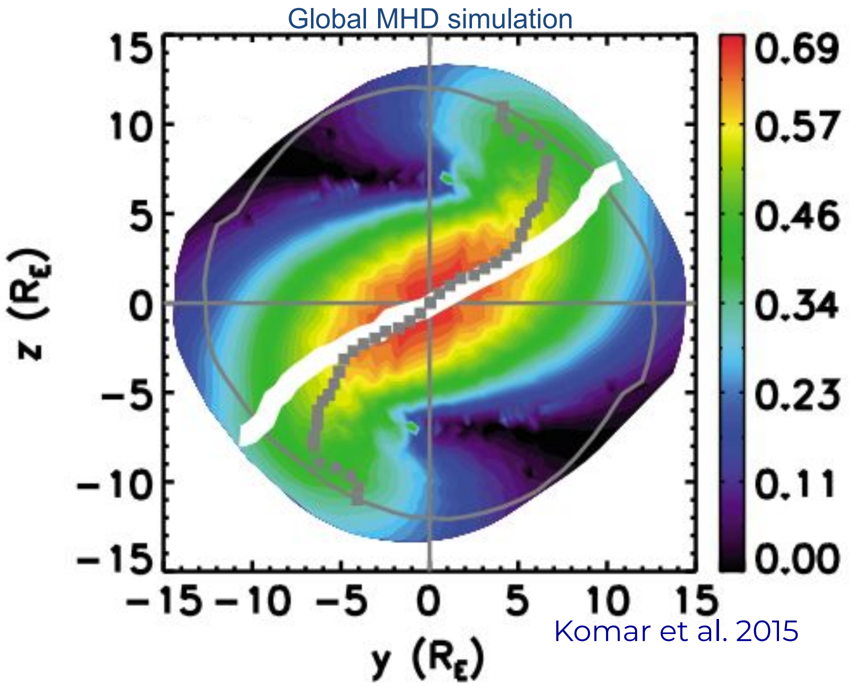
Assumed MP thickness = 800 km
(Haaland et al. [2020])



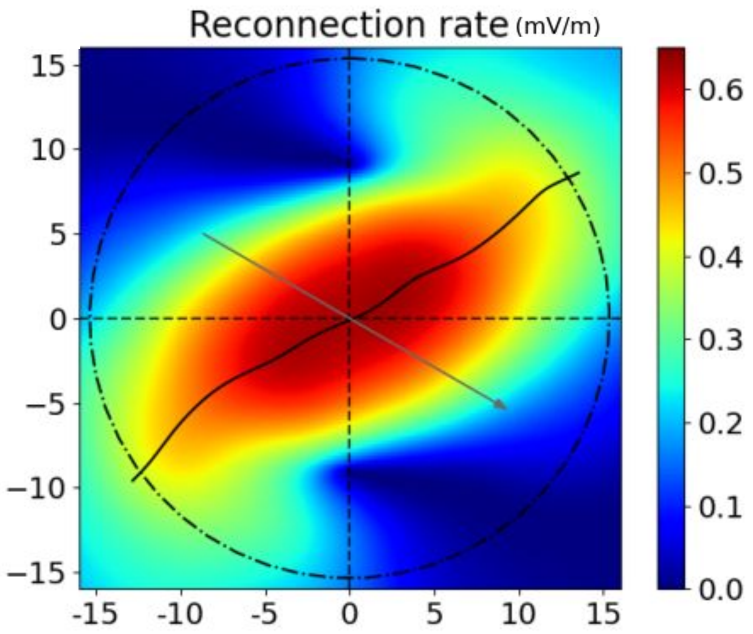
Komar et al. 2015

Pattern similar to MHD simulations for multiple IMF orientation

Global distribution of the reconnection rate ~ MHD models



Komar et al. 2015

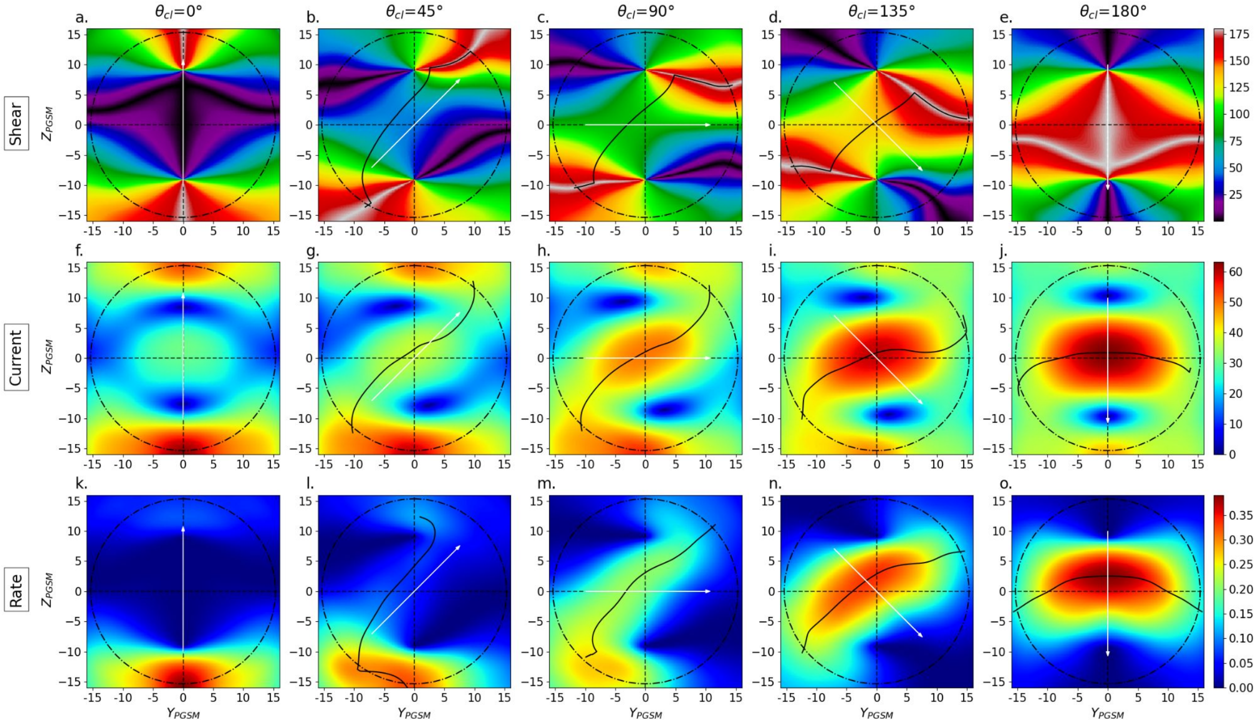


Cassak-Shay formula (2007) :

$$R = 0.1\frac{(B_1 B_2)^{3/2}}{\sqrt{\mu_0(B_1\rho_2 + B_2\rho_1)}}$$

Pattern similar to MHD simulations for multiple IMF orientation

Global constraints on magnetic reconnection from in-situ data



Parametric study of the global distribution of key parameters on the magnetopause.

Michotte de Welle et al. [in review]

Impact of the IMF cone angle :

- Changes the amplitude of the quantities and their symmetries
- Changes the dependence to the IMF clock and dipole tilt angles

Magnetopause maps

Magnetic shear, current density, and reconnection rate

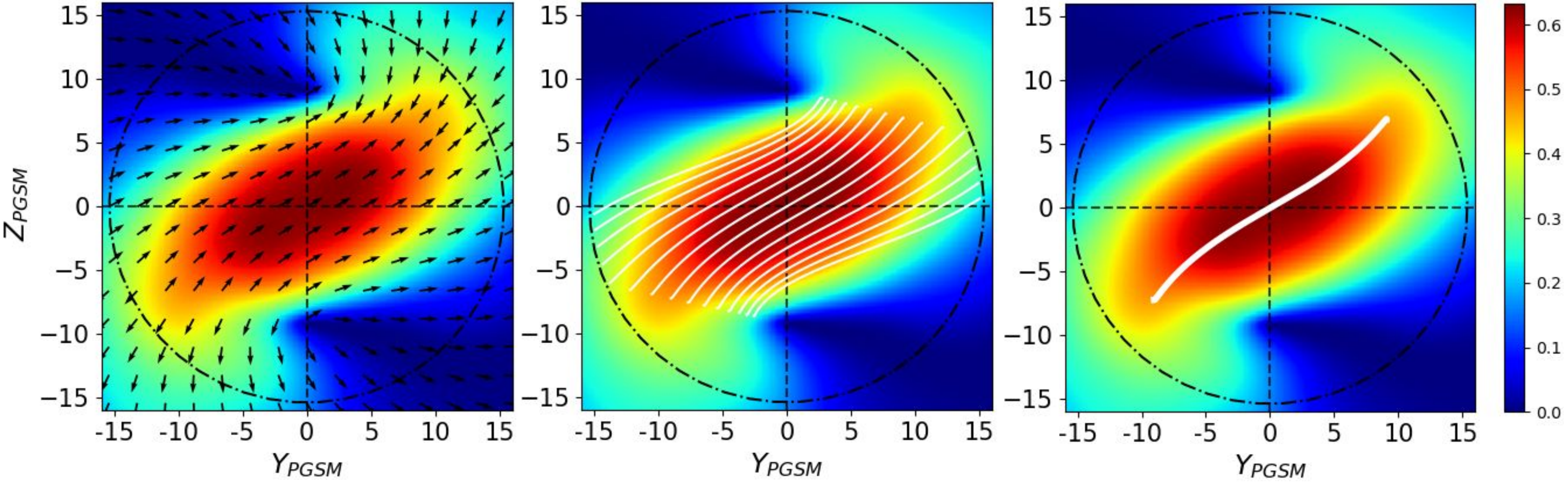
Toward a new X-line model

X-line maximizes locally and globally the reconnection rate?

Step 1: Definition of the bisection field

Step 2: Determine N potential X-lines

Step 3: Identification of the X-line with the largest reconnection rate

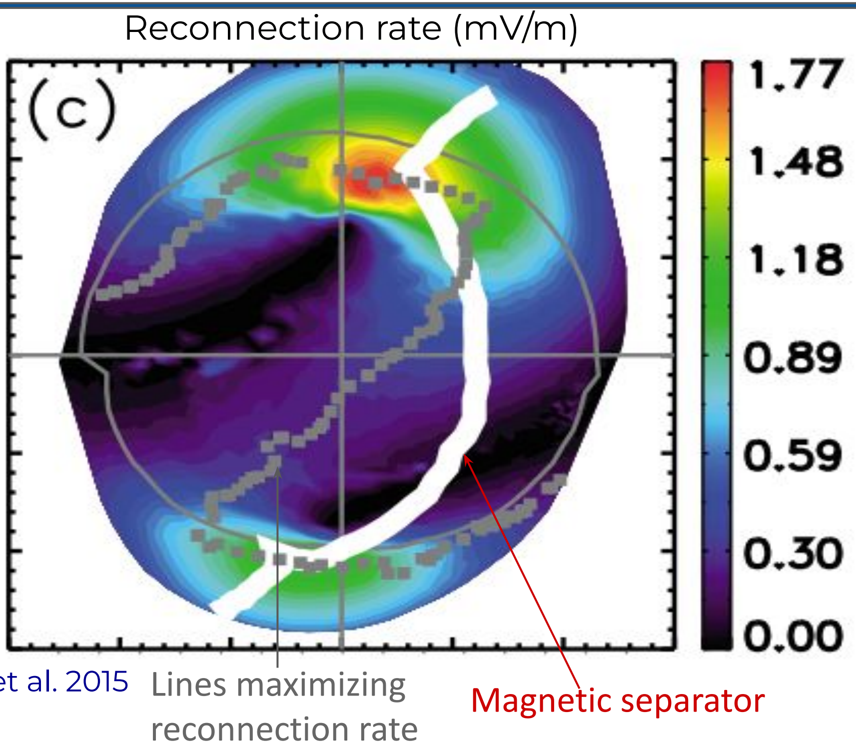


Vectors oriented locally along the direction which theoretically maximizes the reconnection rate.

Potential X-lines that could develop through the global tearing instability.

The X-line with the highest reconnection rate dominates as its separatrices encompass and expel all flux and plasma within.

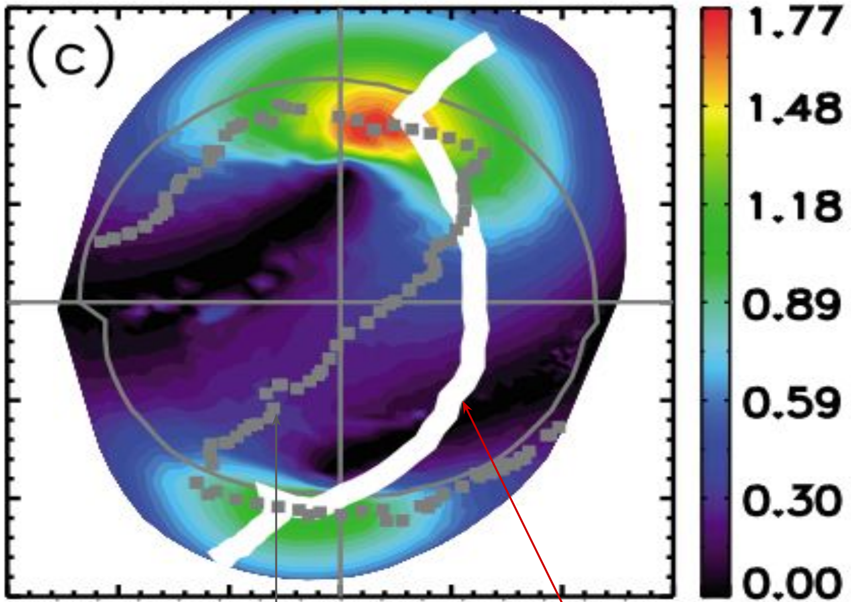
Promising preliminary results of this new X-line model



Komar et al. 2015

Promising preliminary results of this new X-line model

Reconnection rate (mV/m)

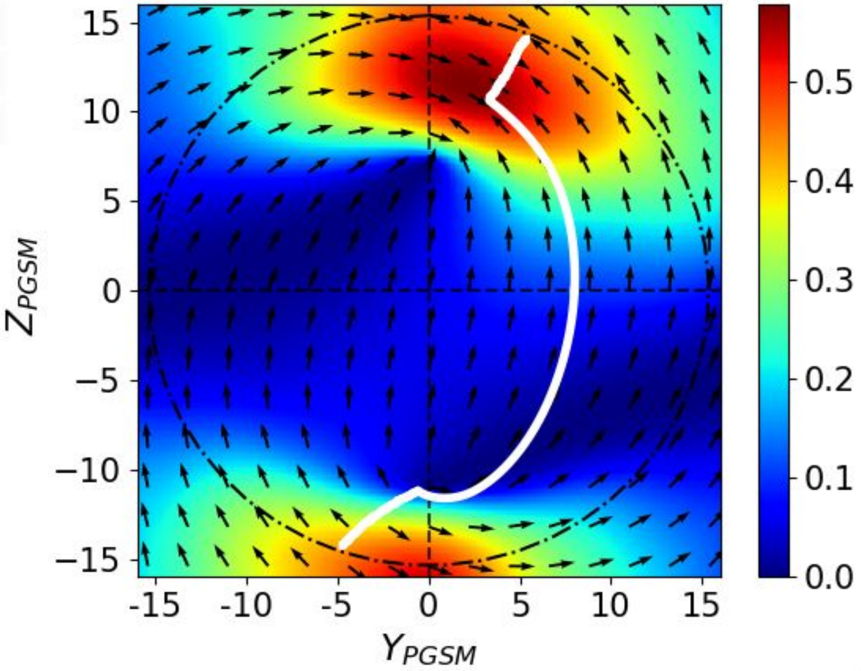


Komar et al. 2015

Lines maximizing reconnection rate

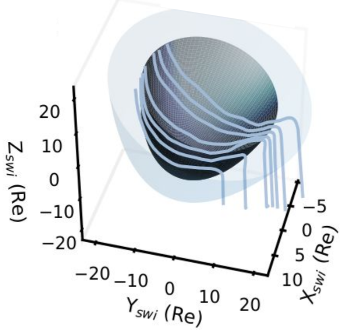
Magnetic separator

Reconnection rate (mV/m)

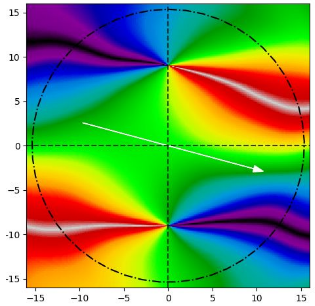


Consistent with the magnetic separator in a case where none of the existing models give good results

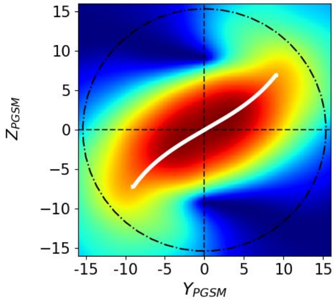
Global constraints on magnetic reconnection from in-situ measurements



3D reconstruction of the magnetic field around the magnetosphere (Michotte de Welle et al. 2022)



Parametric study of the global distribution of key parameters on the magnetopause (Michotte de Welle et al., in rev.)



New X-line model that maximize locally and globally the reconnection rate (in prep.)