

Machine Learning identification of magnetopause Boundary Layer signatures to constrain the location of the global reconnection line

Ambre Ghisalberti

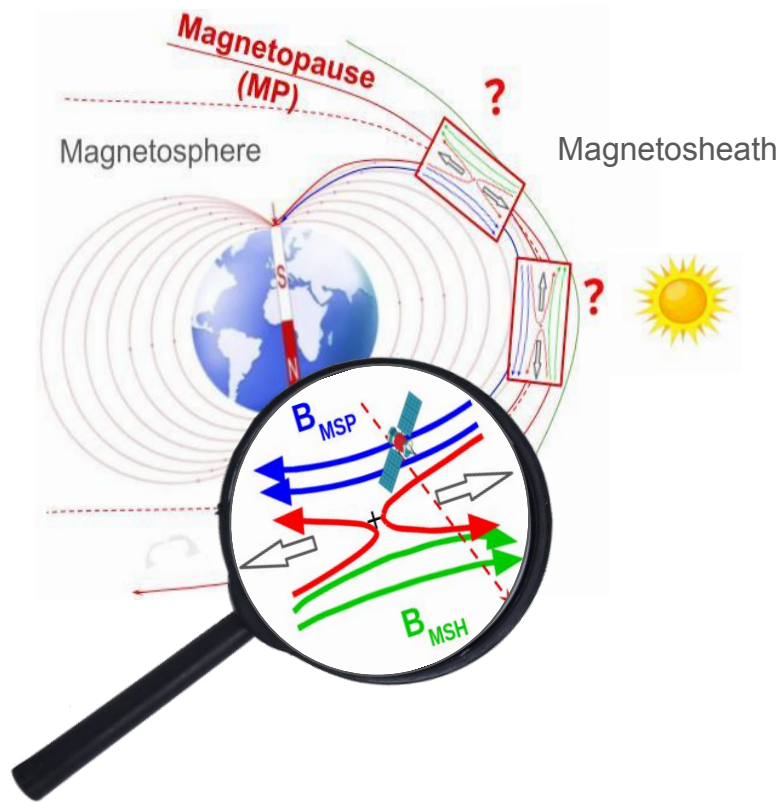
Nicolas Aunai (LPP) & Benoît Lavraud (LAB)

Bayane Michotte de Welle, Alexis Jeandet

ATST, 04/06/2026

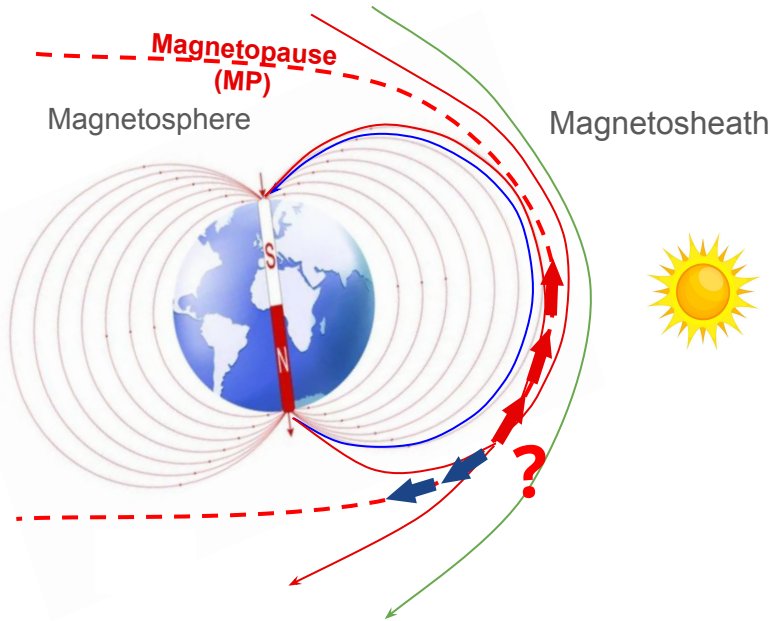


In-situ data can help constrain reconnection position



Where does magnetic reconnection happen at the magnetopause ?

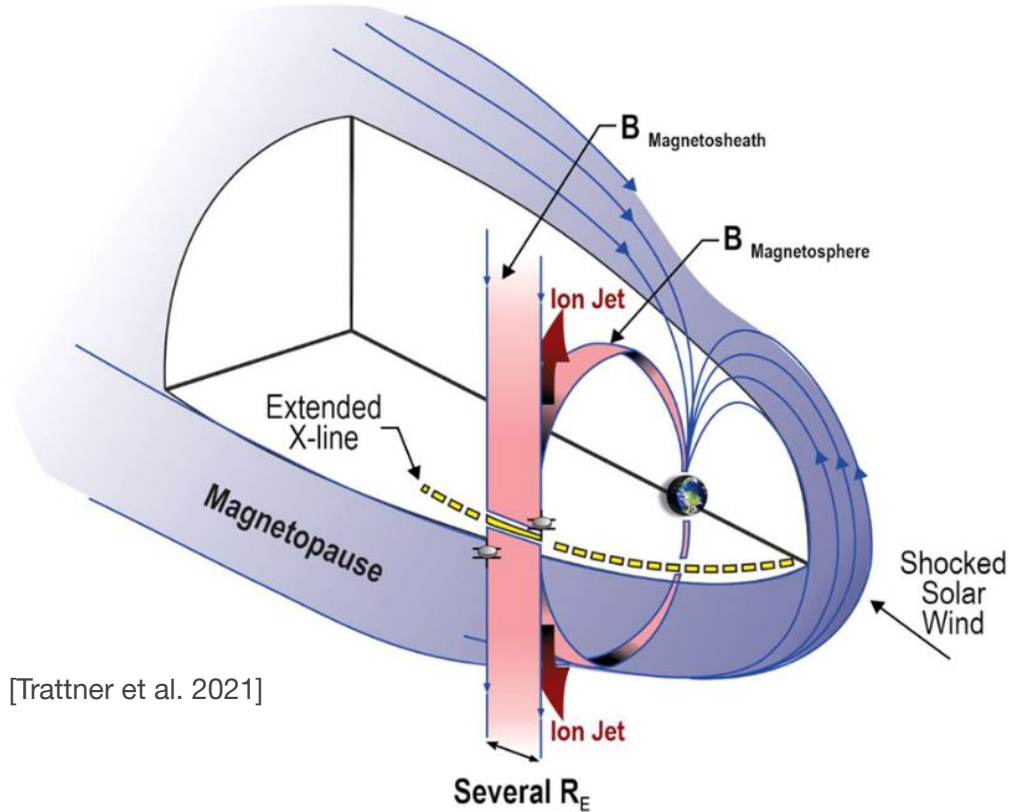
In-situ data can help constrain reconnection position



Accelerated flows in the Boundary layer (BL) in both directions coming from reconnection site :

- **northward** in red
- **southward** in blue

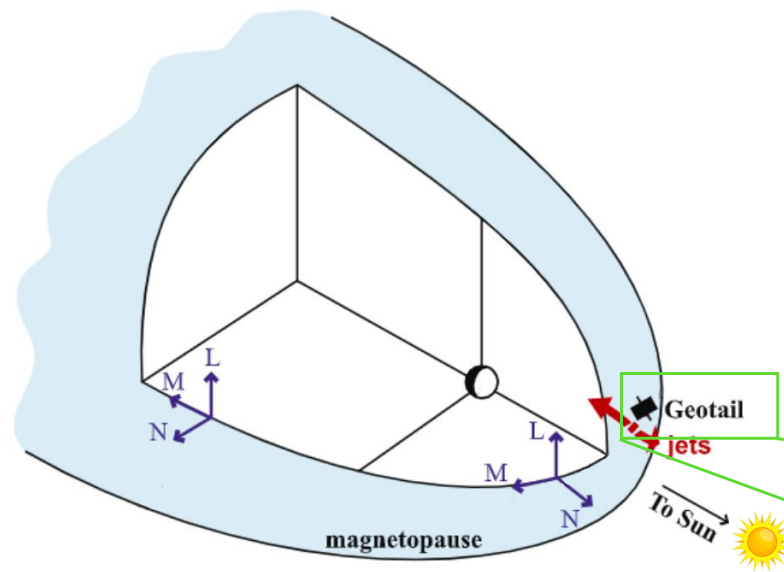
In 3D : a global X-line?



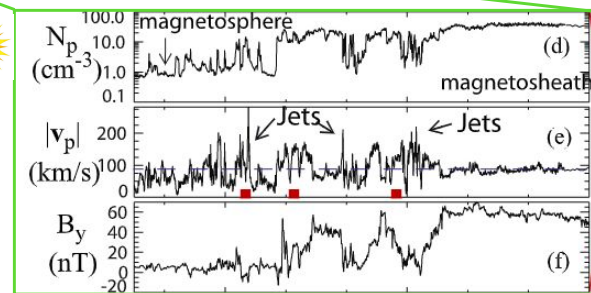
- In 3D: reconnection occurs along a **X-line**
- Some observations support a **long global X-line**

[Fuselier et al. 2002, Fuselier et al. , Trattner et al. 2007, Trenchi et al. 2008, Dunlop et al. 2011, Hoshi et al. 2018]

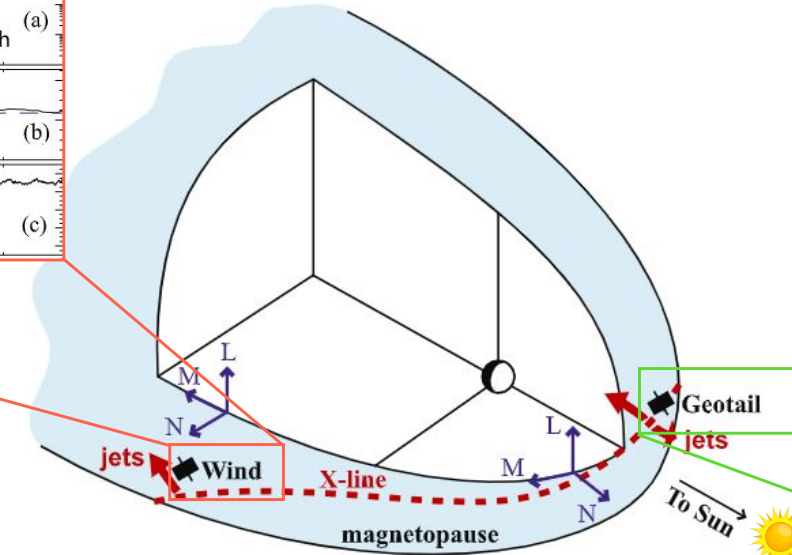
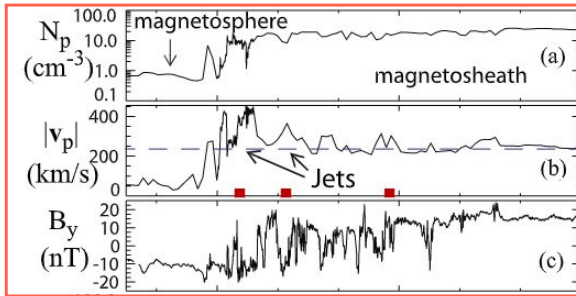
Jet reversals at magnetopause crossings



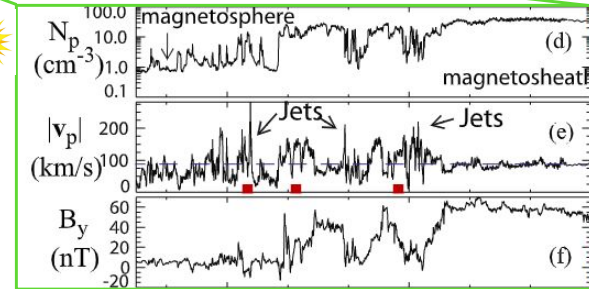
[Phan et al. 2006]



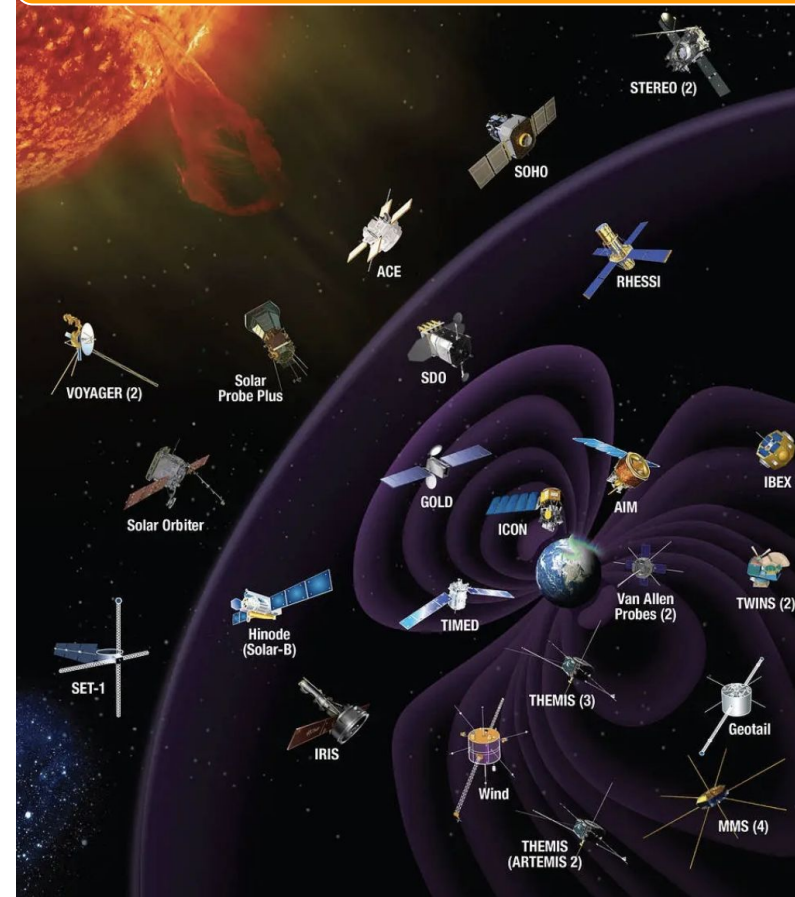
Jet reversals at magnetopause crossing conjunctions



[Phan et al. 2006]



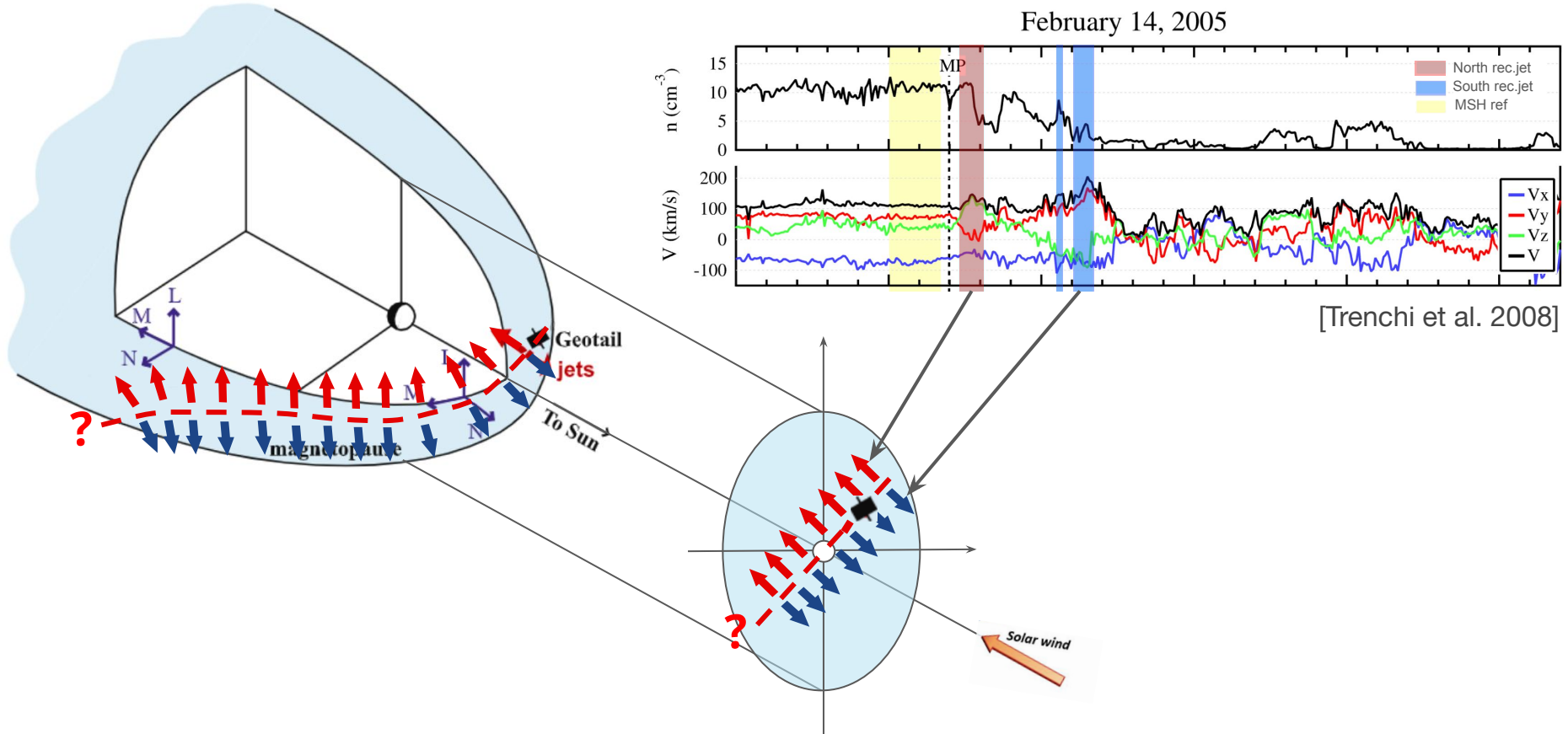
Material for large scale statistics



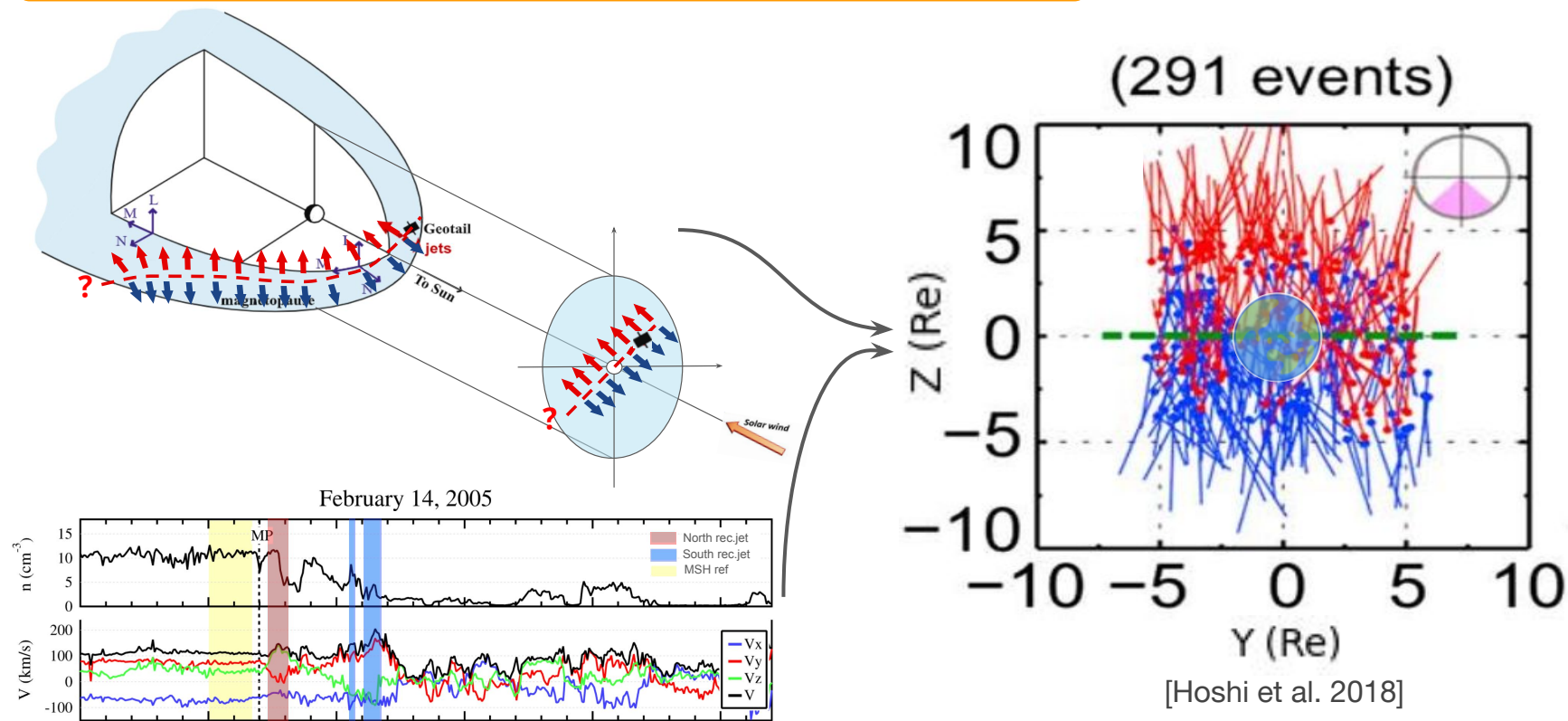
Taken alone : **local** and **sparse**
view of the system

Altogether: amazing sampling
in time and causal conditions

Inferring the X line from plasma jets

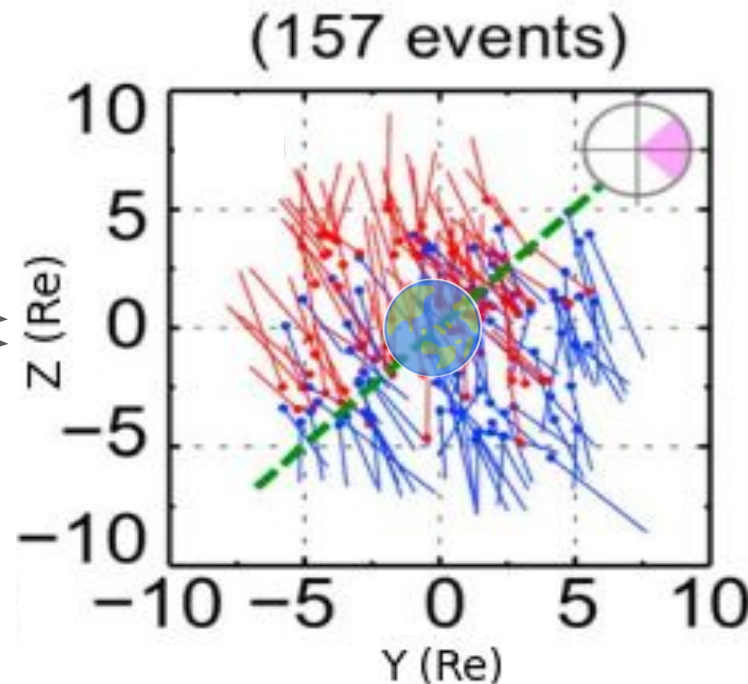
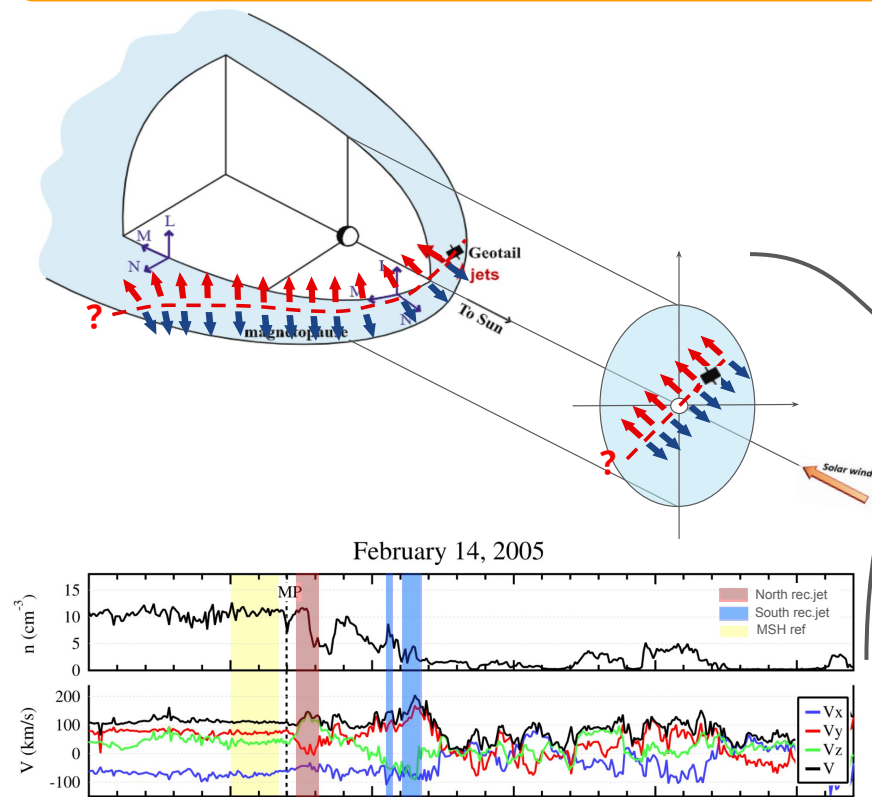


Inferring the X line from plasma jets



→ **Statistical studies** of reconnection jets give information on reconnection position

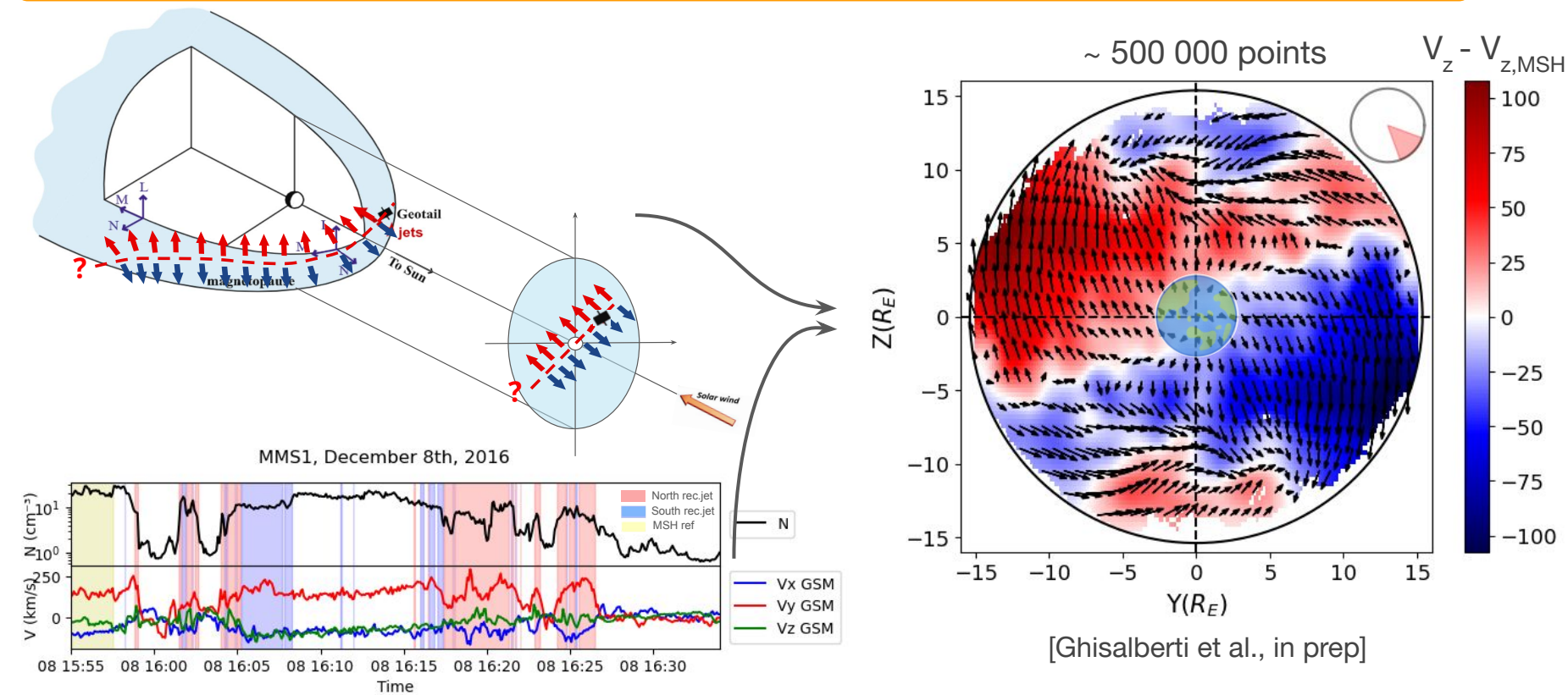
Inferring the X line from plasma jets



[Hoshi et al. 2018]

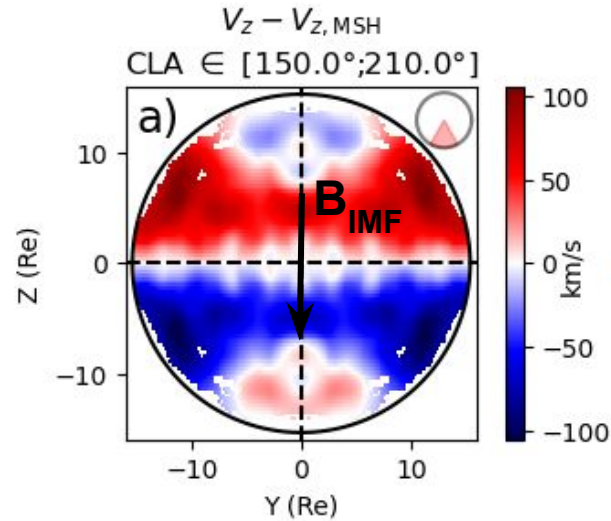
→ **Statistical studies** of reconnection jets give information on reconnection position

Inferring the X line from plasma flow in the Boundary Layer

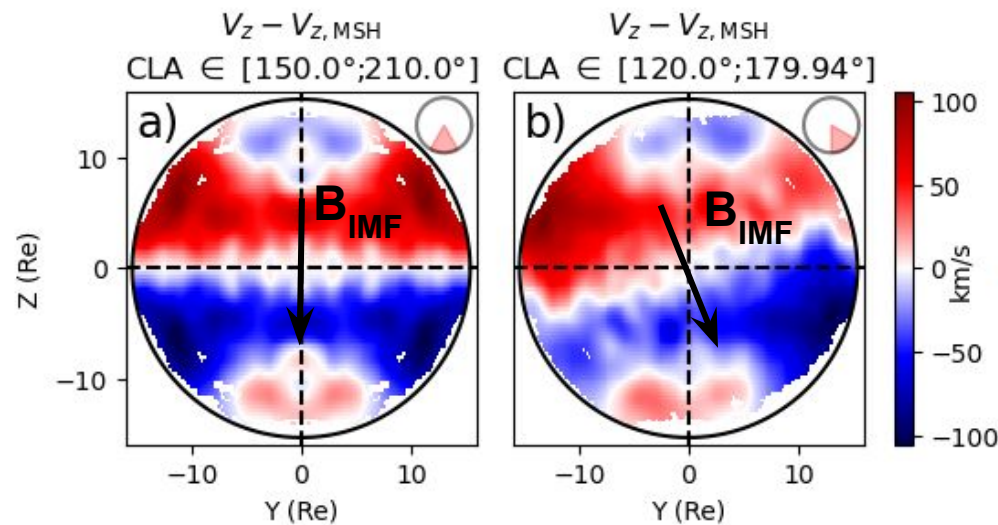


→ **Statistical studies** of reconnection jets give information on reconnection position

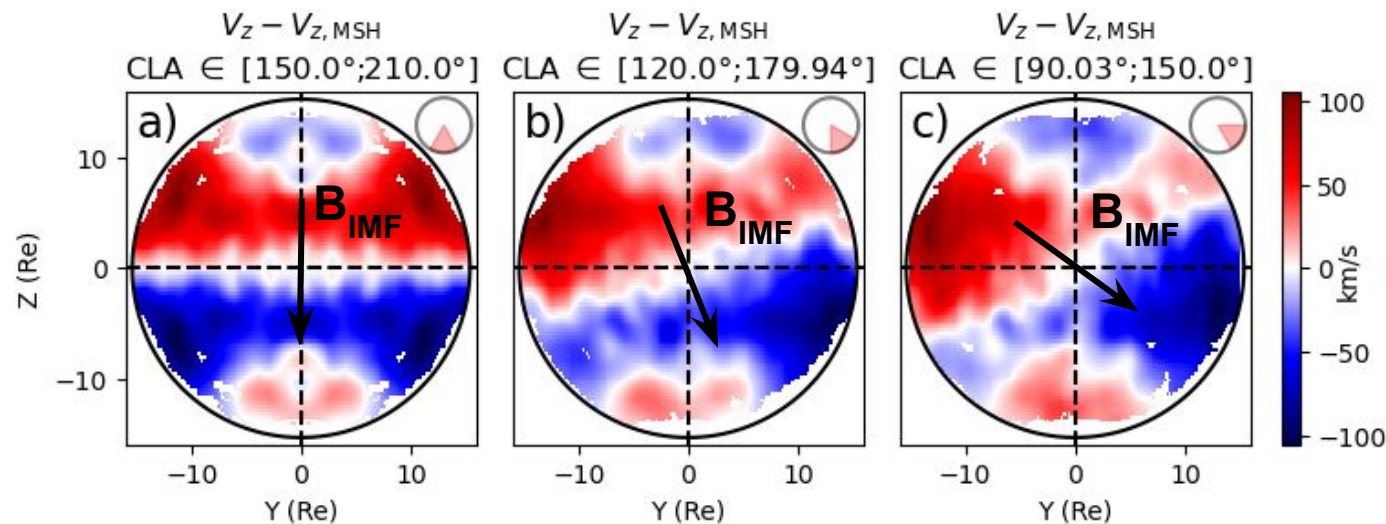
Parametric dependance on the IMF clock angle



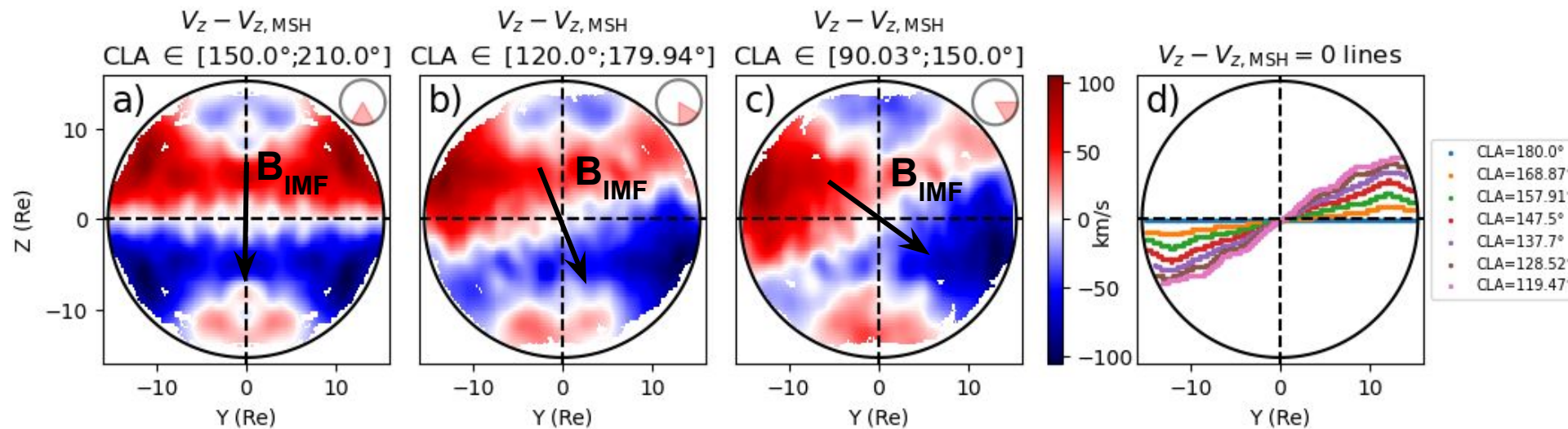
Parametric dependance on the IMF clock angle



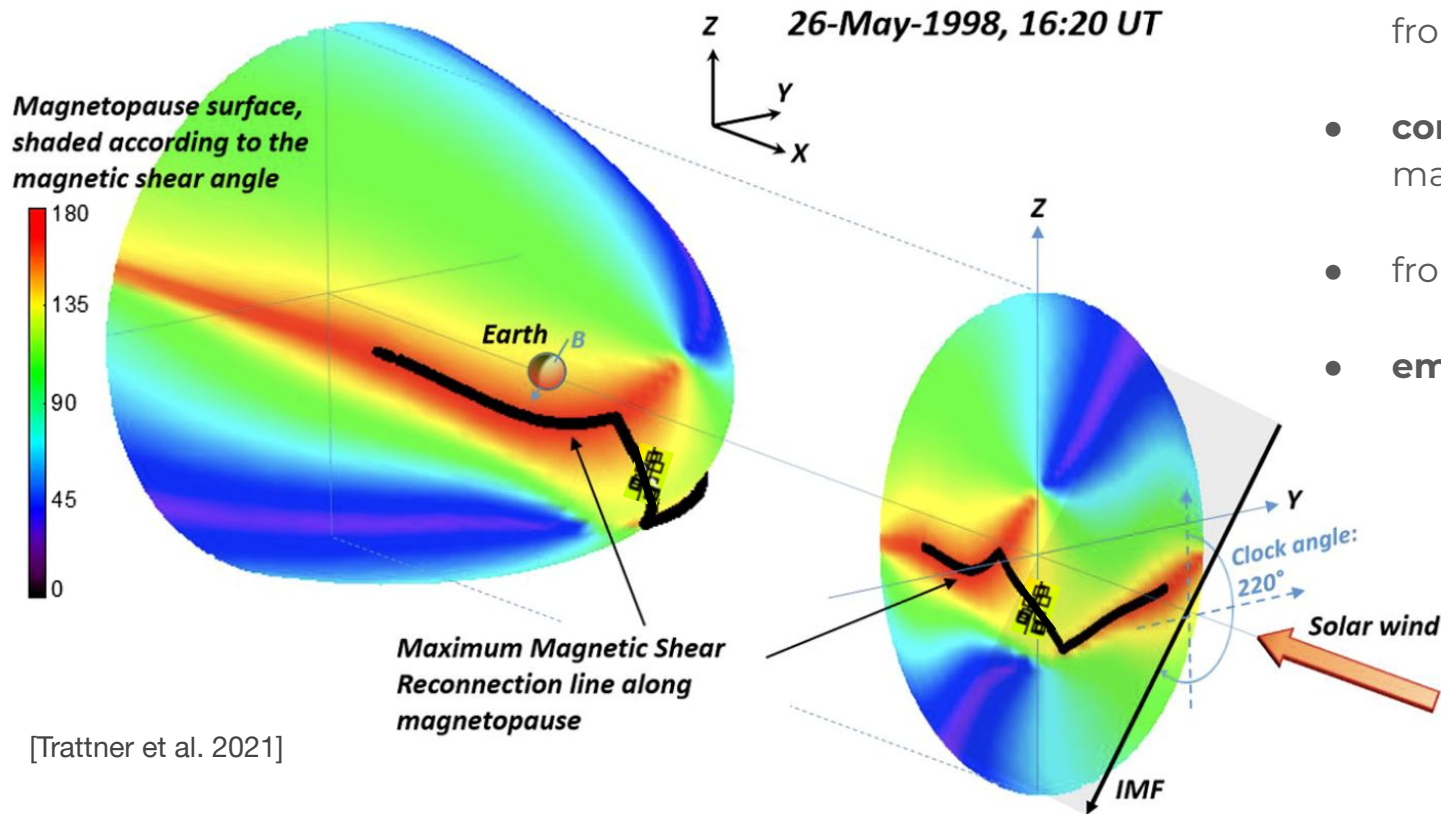
Parametric dependance on the IMF clock angle



Parametric dependance on the IMF clock angle



The Maximum magnetic shear model

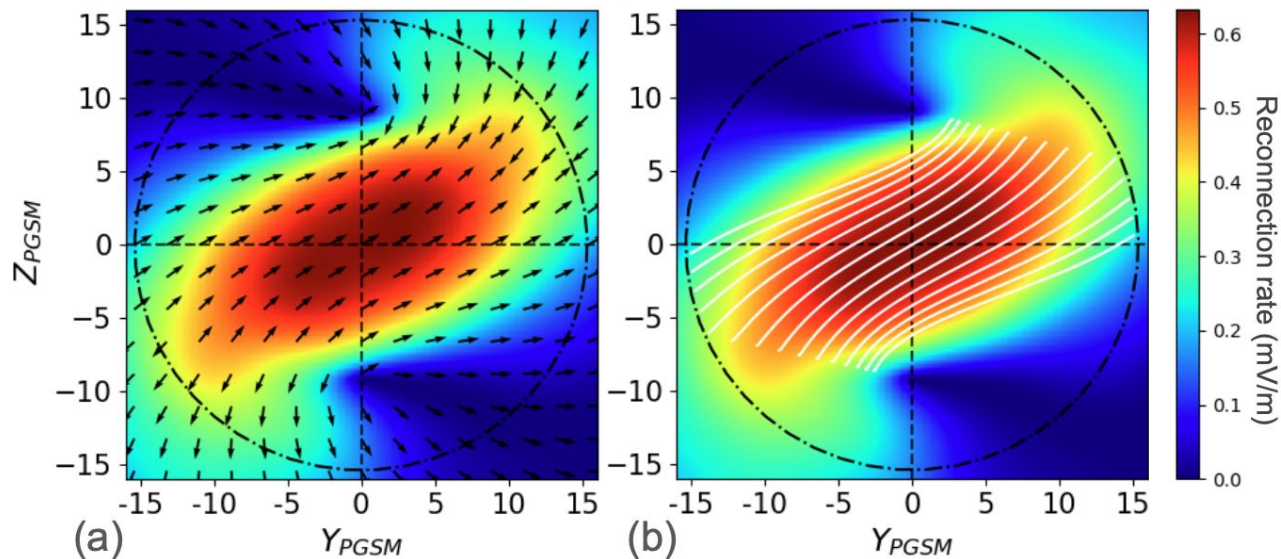


[Trattner et al. 2021]

- remote measurements from **130** events
- **compatible** with the line maximizing shear angle
- from low statistics
- **empirical model**



The Dominant X-line model

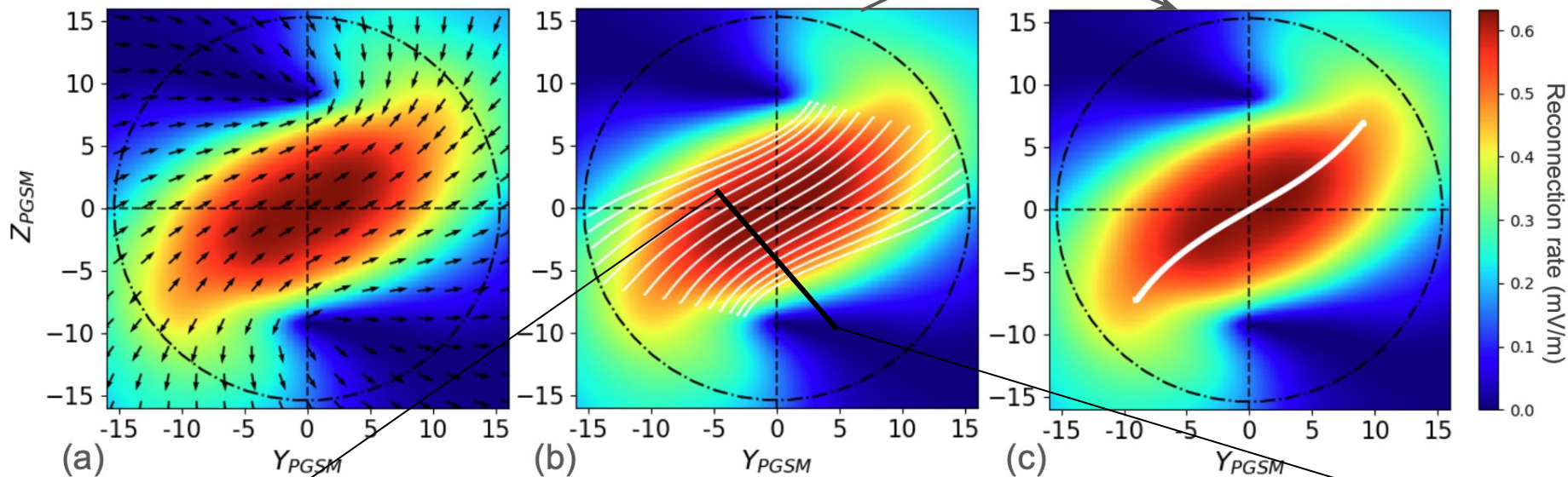


Possible X-lines follow the
bisector direction

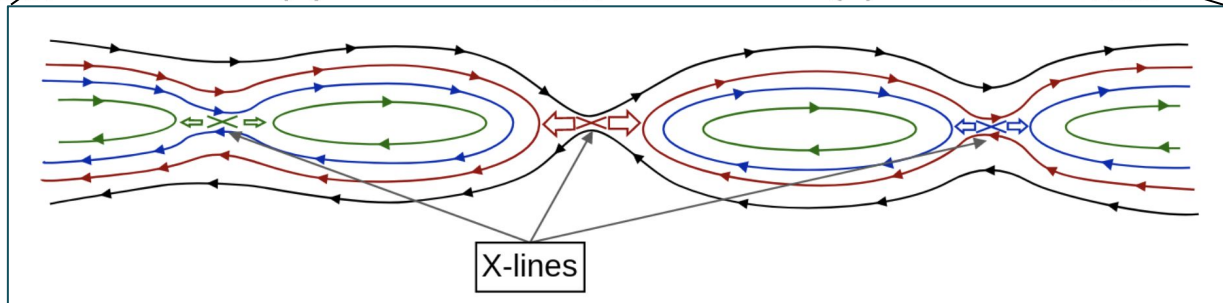
[Michotte de Welle
et al. 2025]

The Dominant X-line model

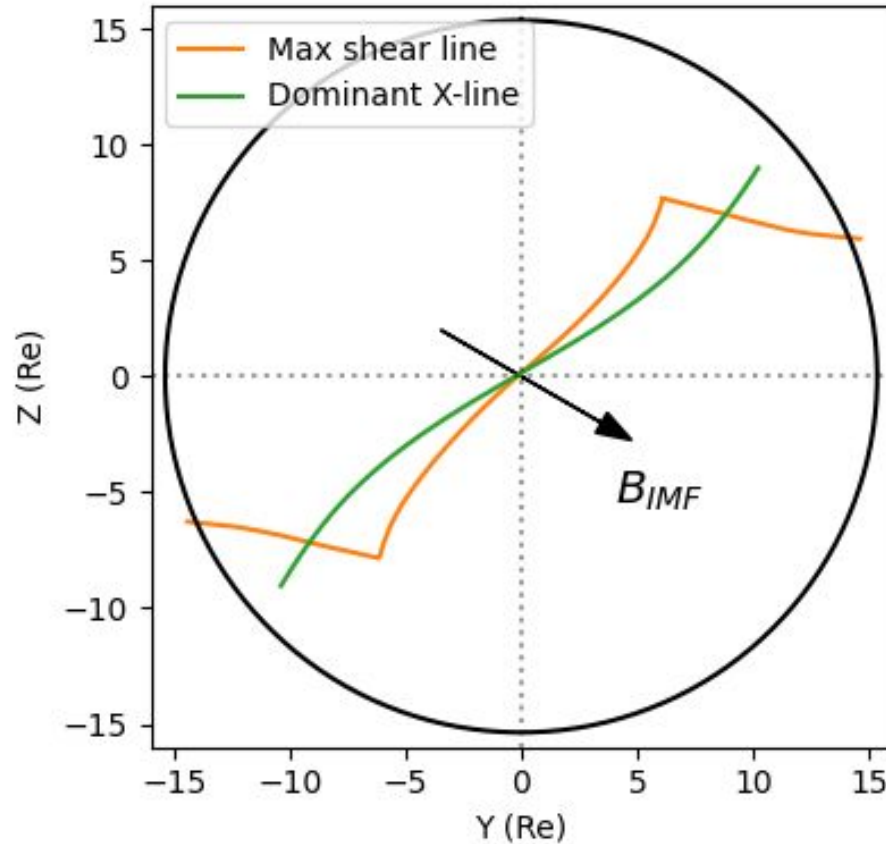
The dominant X-line
expels all others



[Michotte de Welle
et al. 2025]



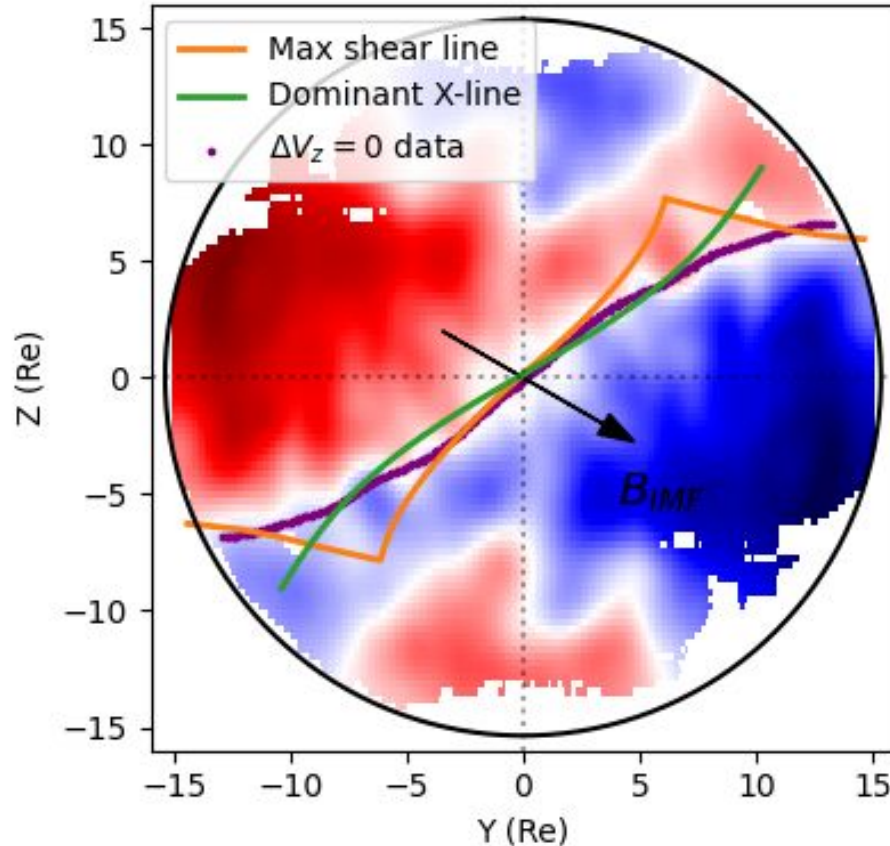
Validating or invalidating models



CLA = 120°
Tilt = 0°

Validating or invalidating models

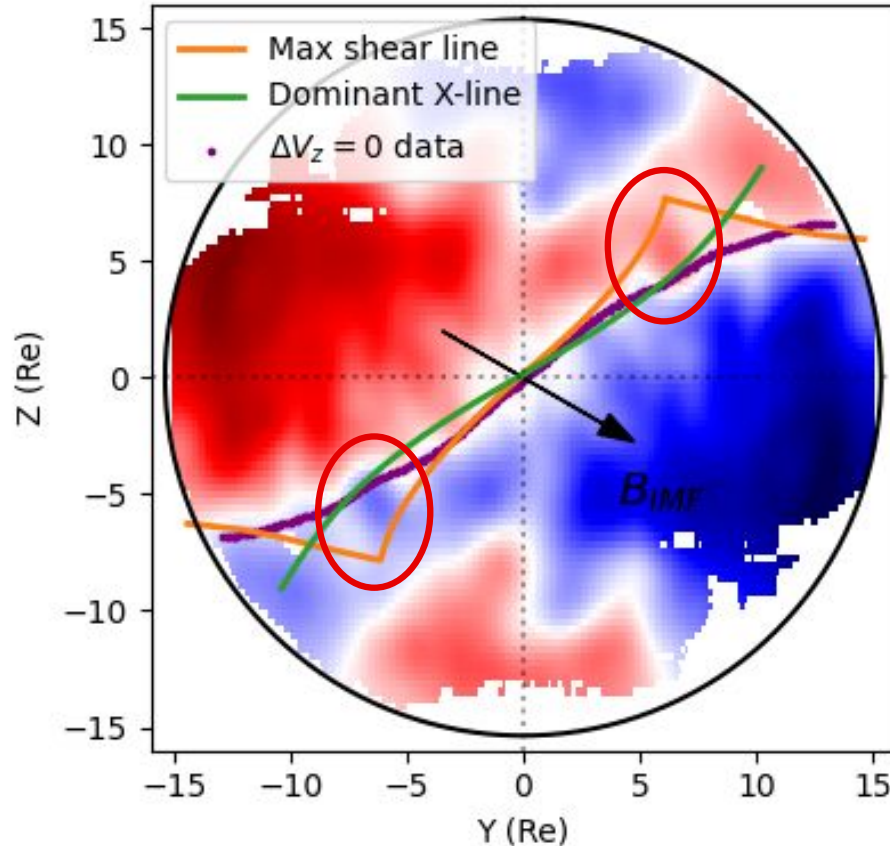
Amazing
agreement
with the
Dominant
X-line model
prediction!!



CLA = 120°
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Validating or invalidating models

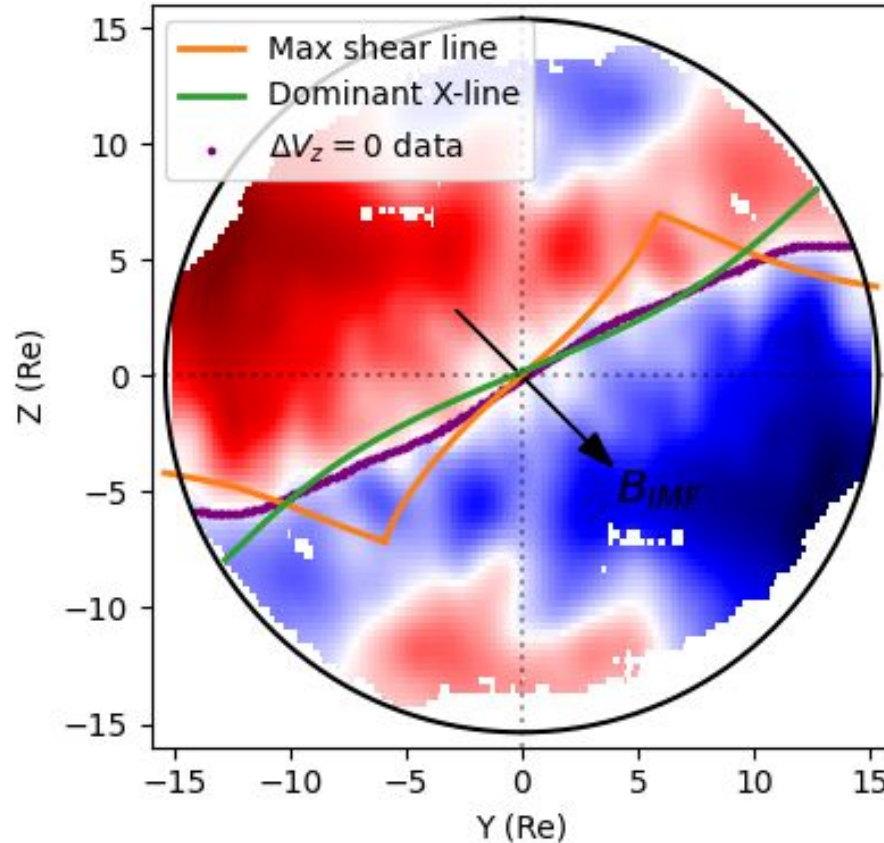
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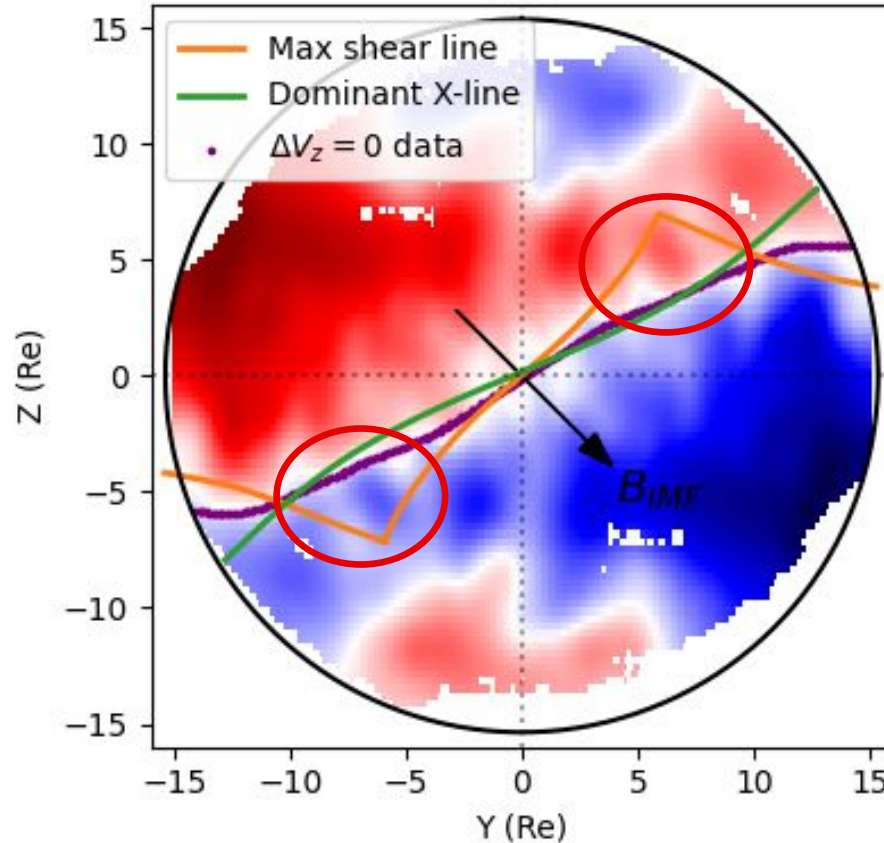
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CLA = 135°
Tilt = 0°

Validating or invalidating models

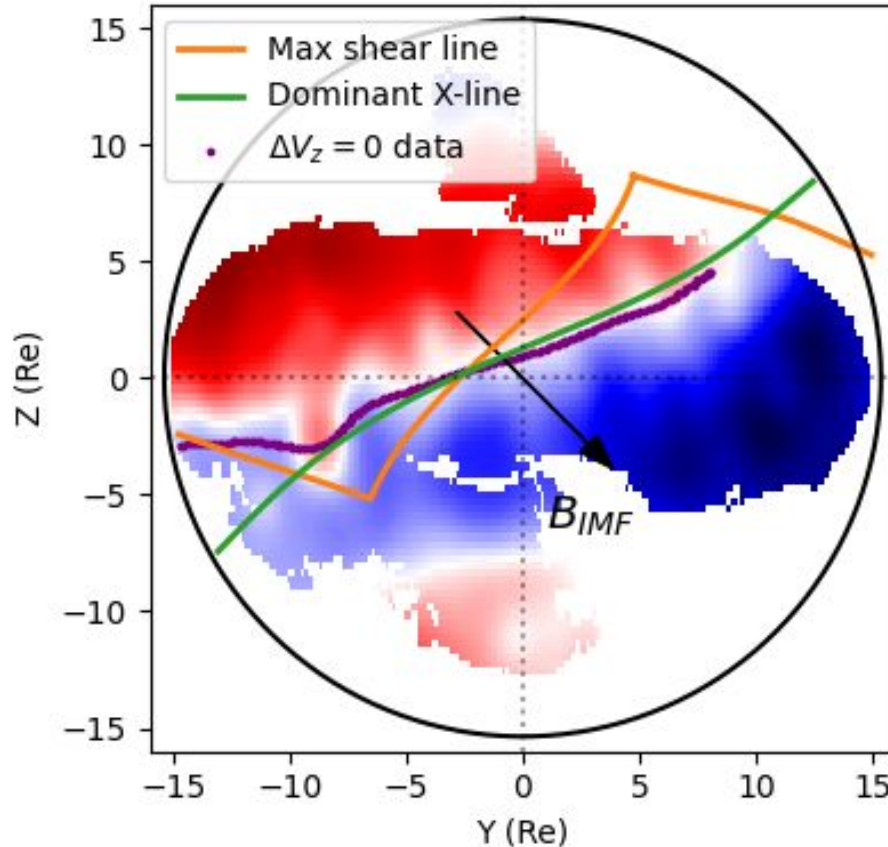
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CLA = 135°
Tilt = 0°

Validating or invalidating models

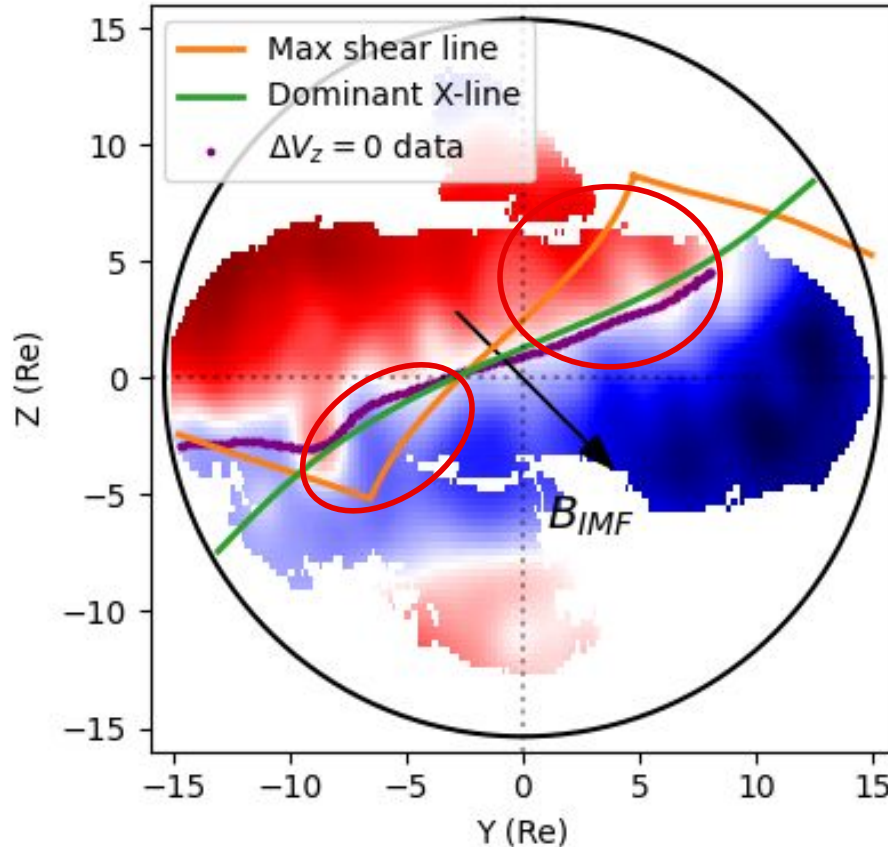
Amazing
agreement
with the
Dominant
X-line model
prediction!!



CLA = 135°
Tilt = -10°

Validating or invalidating models

Amazing
agreement
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CLA = 135°
Tilt = -10°

Recap

- Automatic **detection** of the **BL**
- Global dayside parametric flow **maps**
- Global flow at the MP **structured by reconnection**
- Reconnection line inferred from in-situ data
- **Good match** with dominant Xline predictions
- **Good match** with global MHD simulations

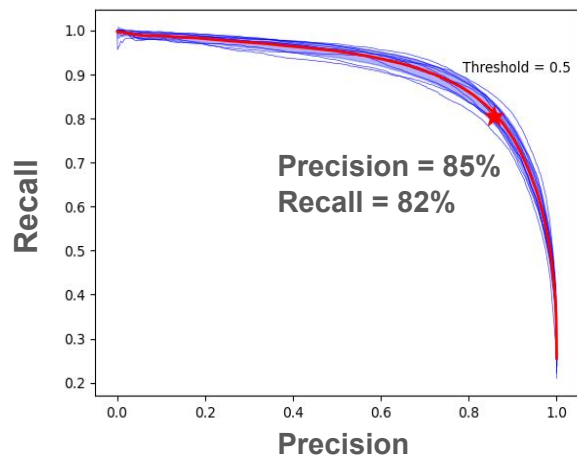
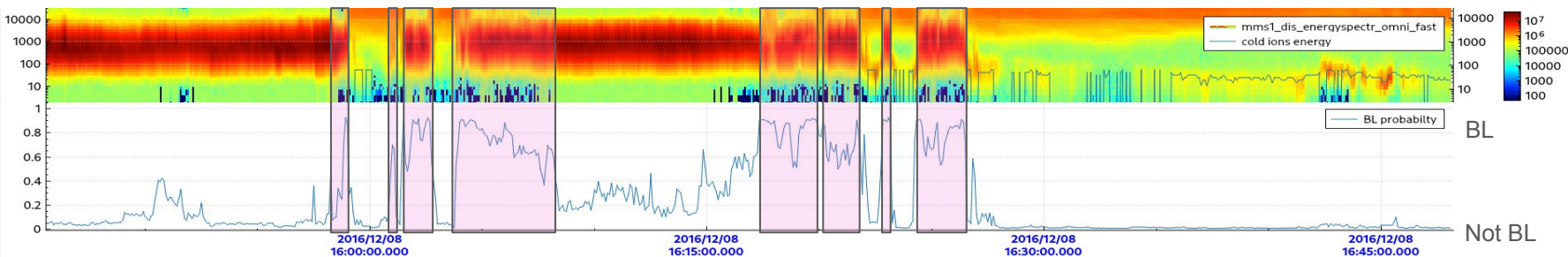
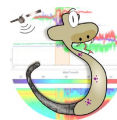
Questions

- This is an **average** view....Is it meaningful?
- How does the BL evolve with **varying** IMF?
- New method for low exhaust velocities? (**northward IMF** in the dayside, high M_a number, low shear, etc)
- Increasing coverage at **high latitudes** with SMILE?

Supplementary material

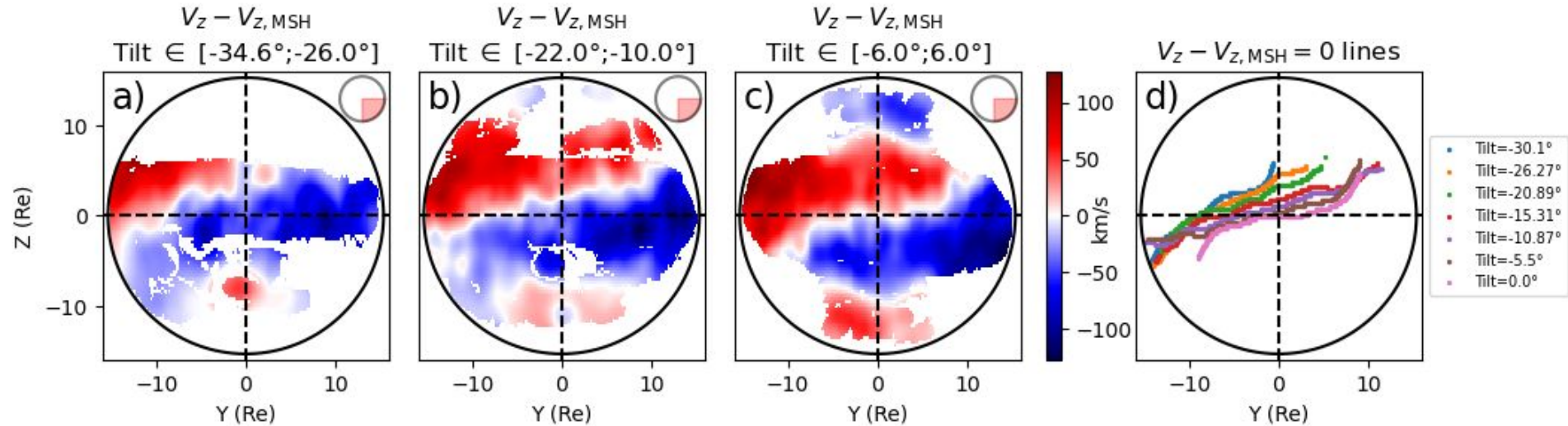
Building a massive BL dataset with machine learning

Manual selection done with [SciQLop](#) tool (open access github)



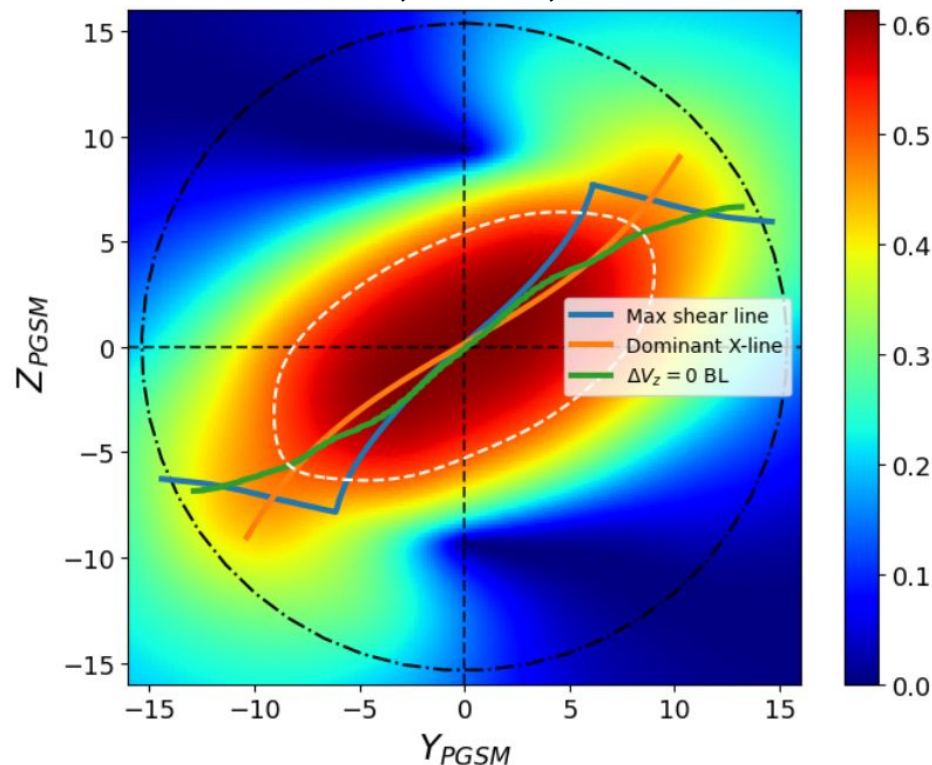
- Good results given label ambiguity
- 5 millions of BL points

Parametric dependence on the dipole tilt angle

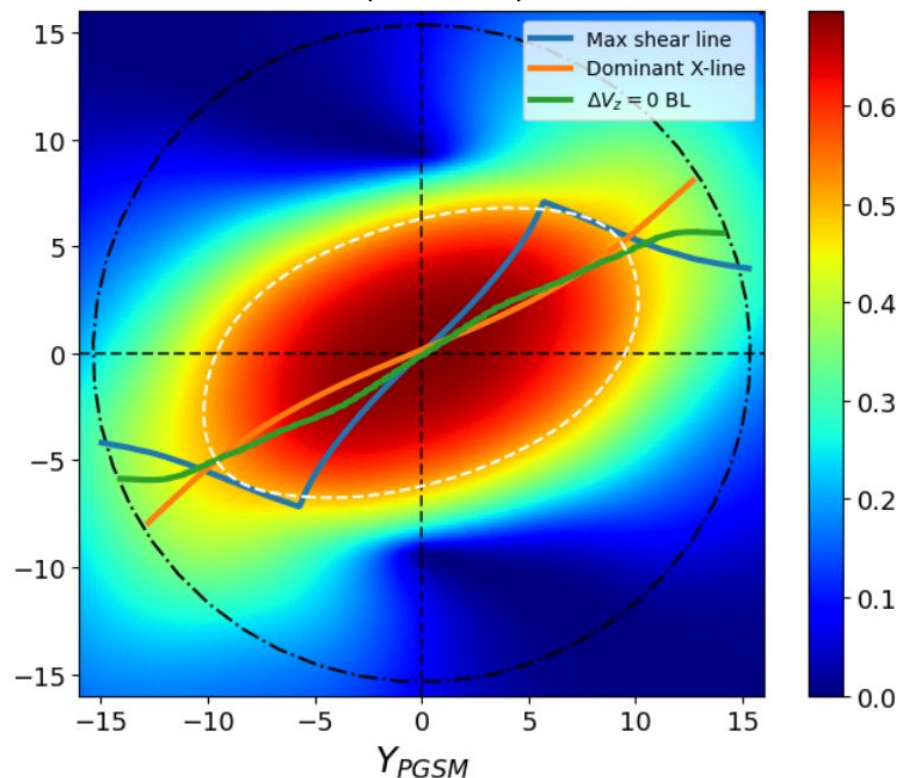


Bias in low reconnection rate regions?

Reconnection rate
CLA = 120° , tilt = 0° , level = 0.5



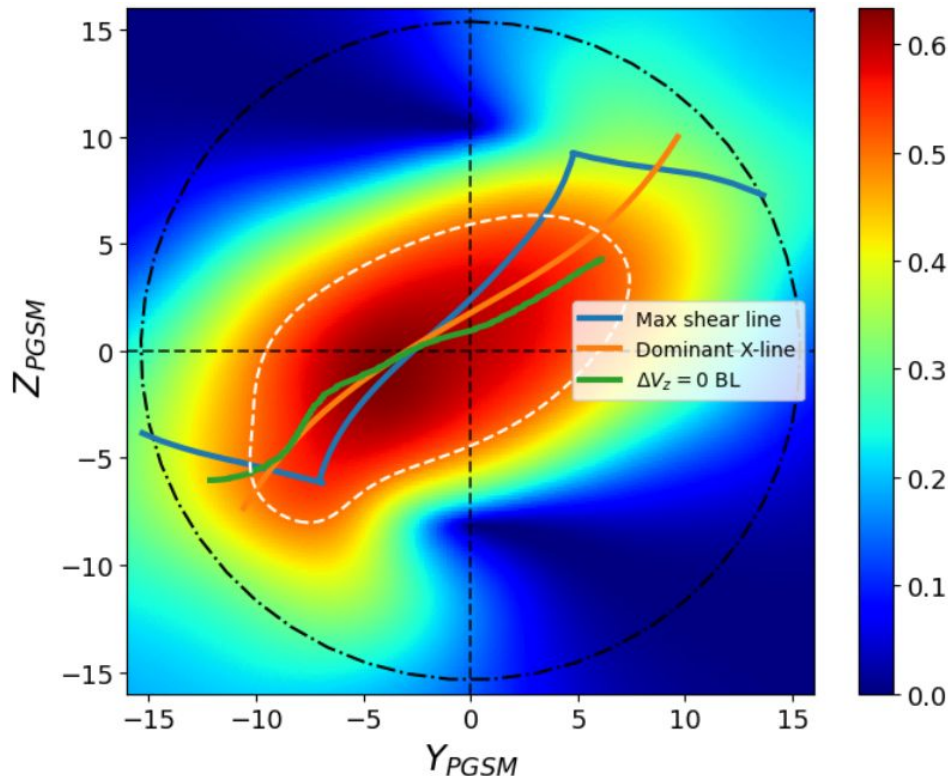
Reconnection rate
CLA = 135° , tilt = 0° , level = 0.5



Bias in low reconnection rate regions?

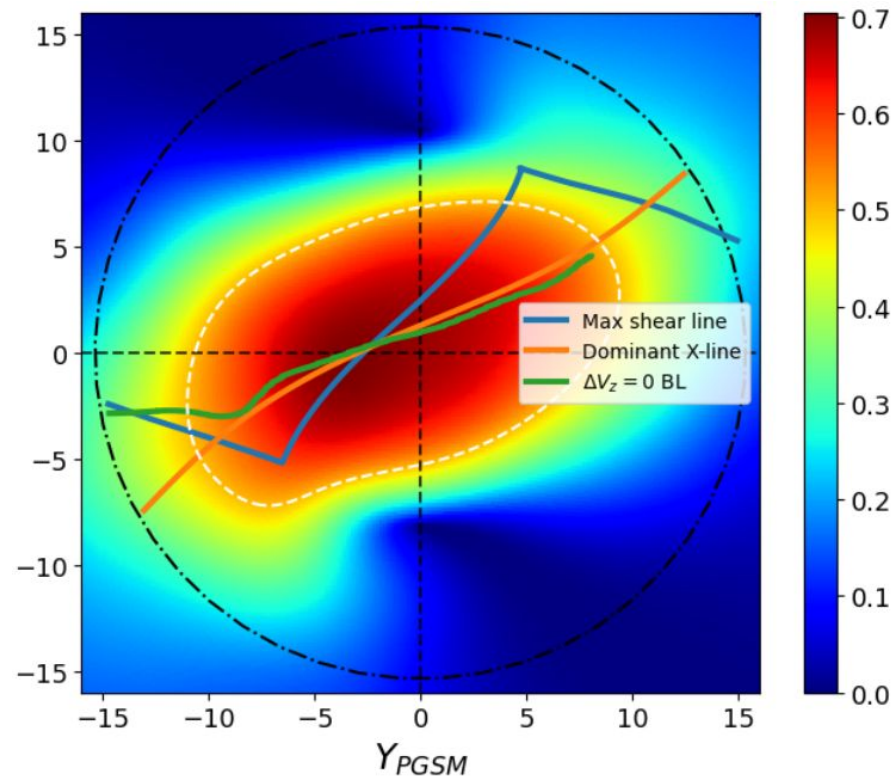
Reconnection rate

CLA = 120° , tilt = -10° , level = 0.5



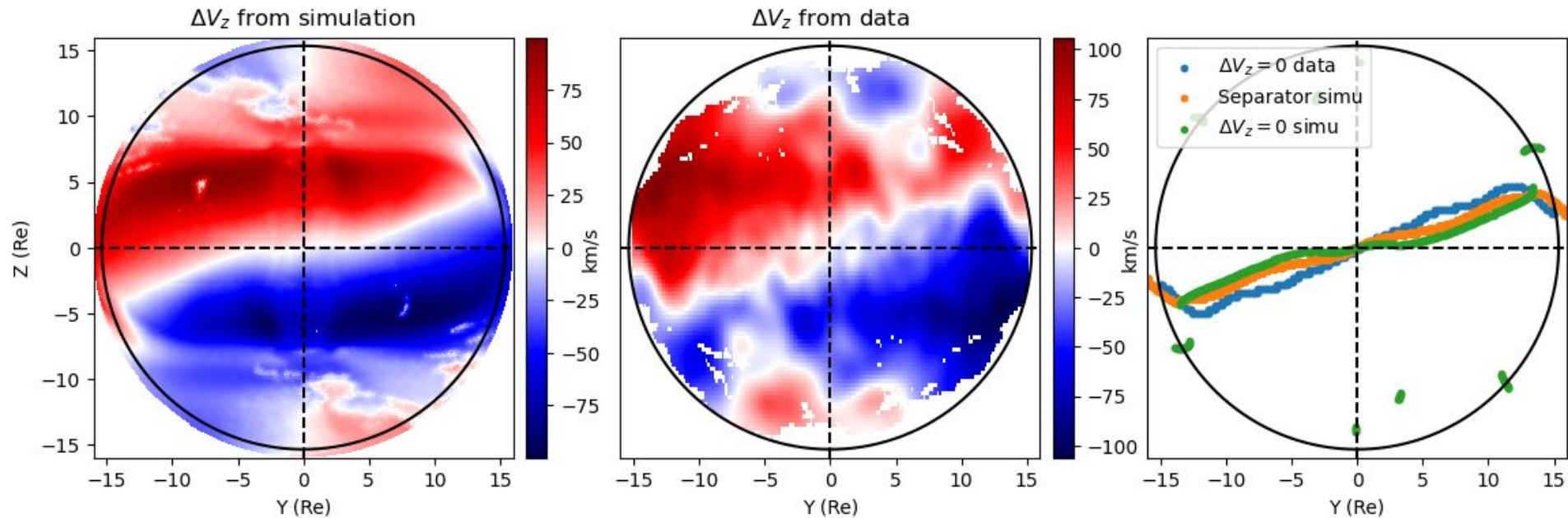
Reconnection rate

CLA = 135° , tilt = -10° , level = 0.5



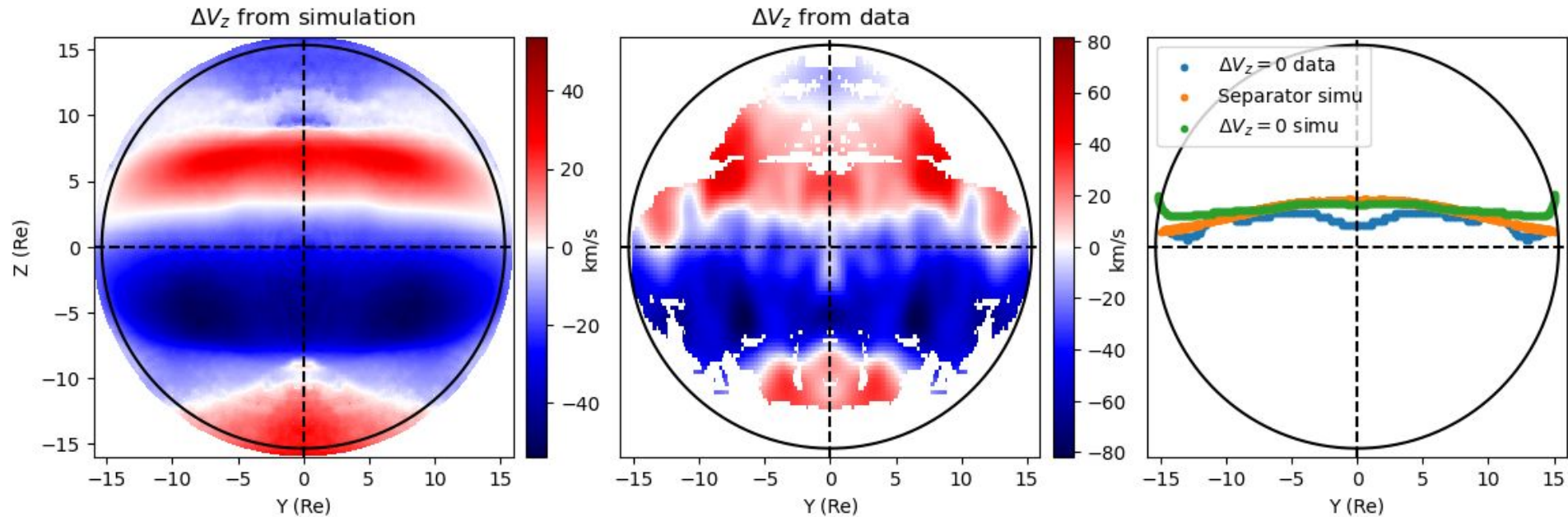
Comparison with global MHD simulation

COA = 90°, CLA = 150°, tilt = 0°



Comparison with global MHD simulation

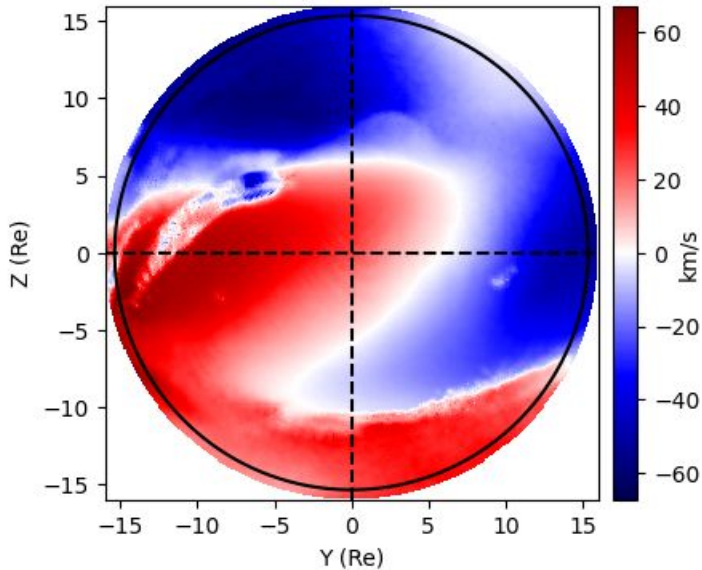
COA = 25°, CLA = 180°, tilt = 0°



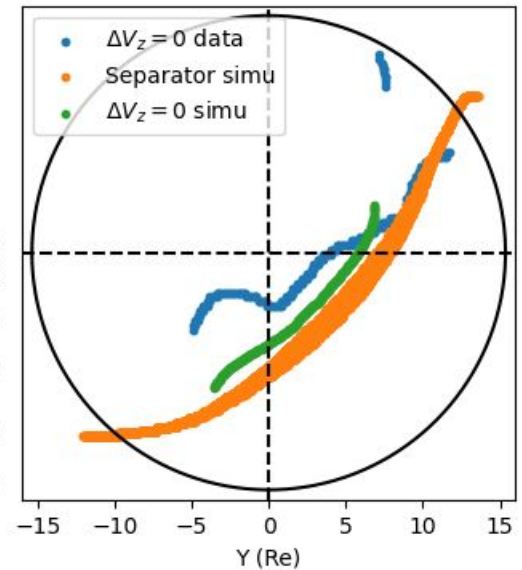
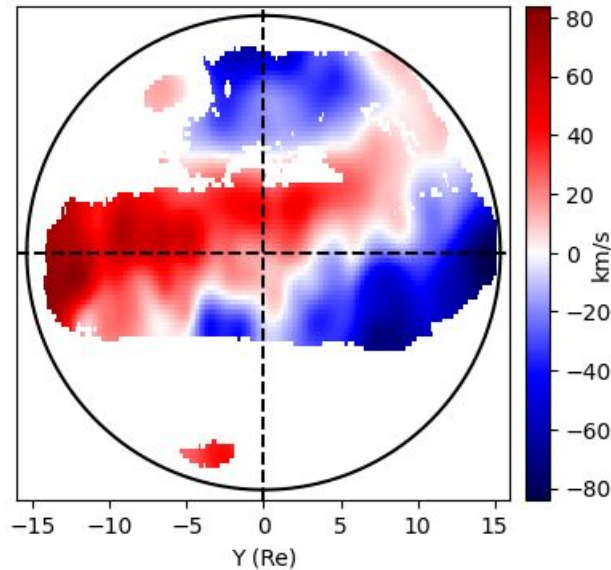
Comparison with global MHD simulation

COA = -45° , CLA = 90° , tilt = 15°

ΔV_z from simulation



ΔV_z from data



Comparison with global MHD simulation

COA = 90°, CLA = 30°, tilt = 15°

