DOCDAY

OCTOBER 3RD, 2022

Magnetosheath jets and their relation to large-scale solar wind structures

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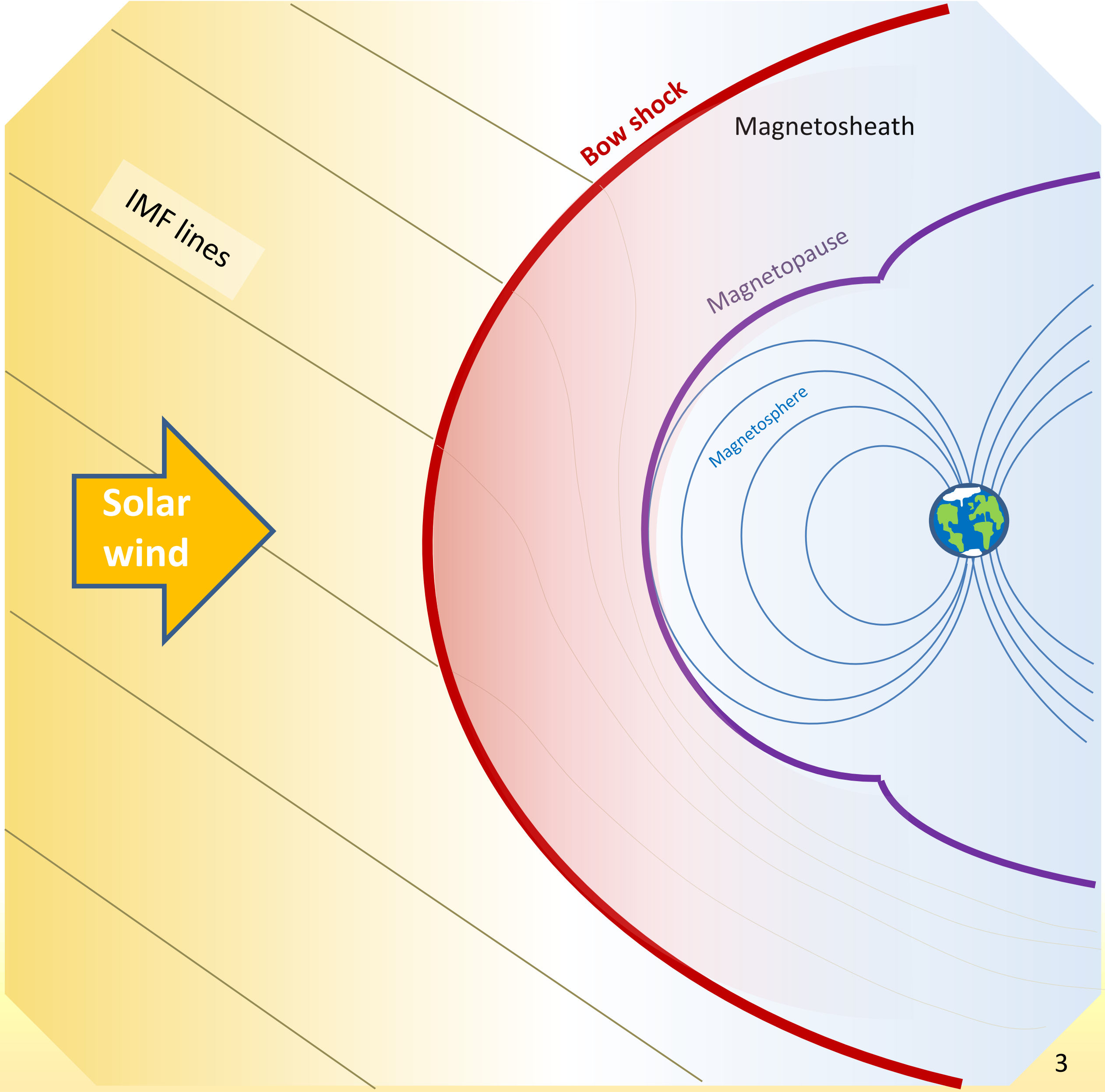
Content of talk

- **Introduction**
  - Introduction into the system
  - MS Jets: Properties & consequences
  - Solar wind structures
- **Motivation**
- **Datasets**
- **Results**
  - Paper #1
  - Current results
- **Conclusions & Outlook**

Earth’s dayside magnetosphere and magnetosheath

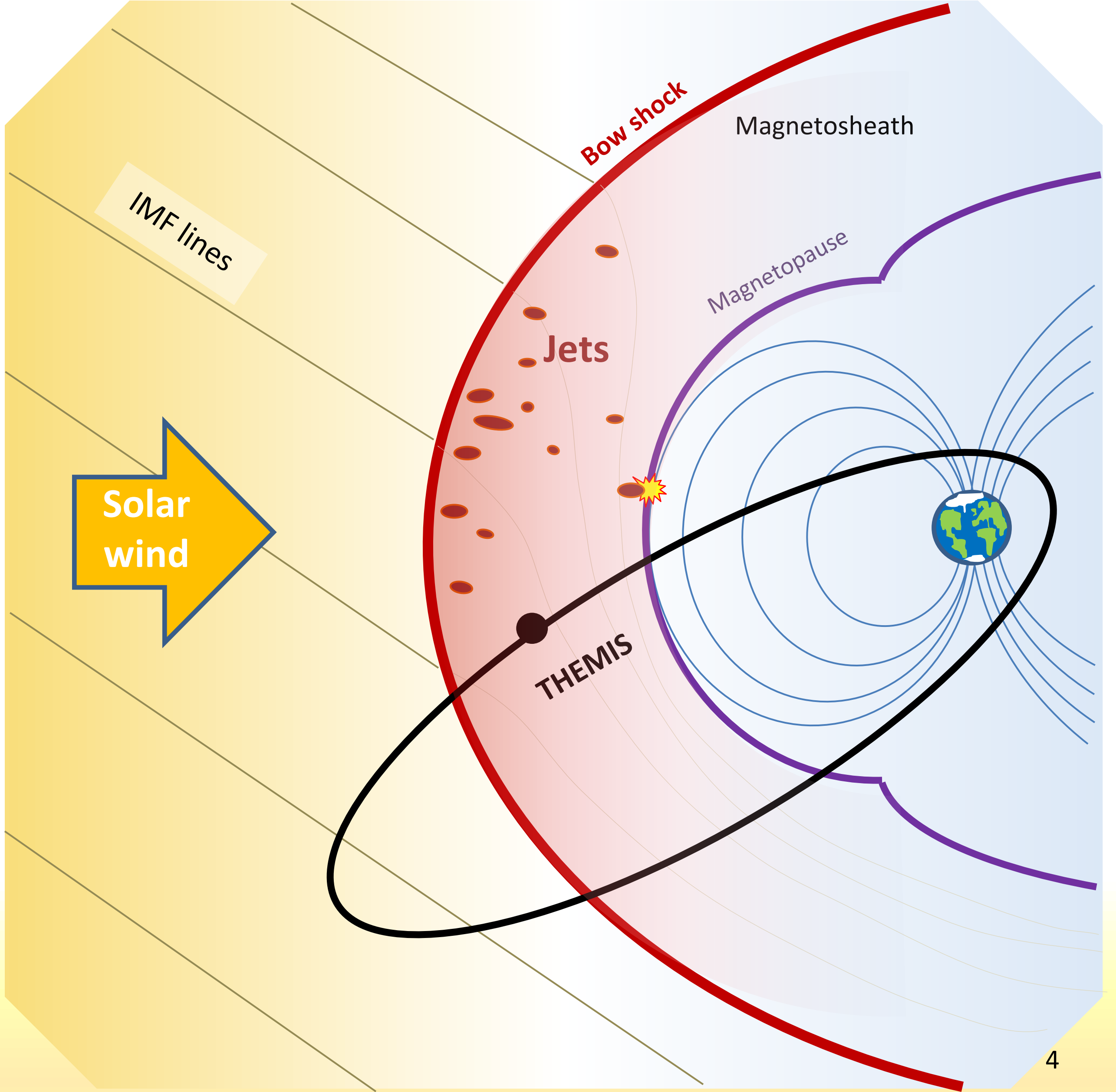
- Solar wind
  - High Mach numbers
  - Connected to the interplanetary magnetic field (IMF)
- Bow shock
  - Sudden deceleration
- Magnetosheath
  - Consists of shocked plasma
  - Velocity ↓
  - Density ↑
  - Temperature ↑
- Magnetopause
  - Outer boundary of magnetosphere



Earth's dayside magnetosphere and magnetosheath

Magnetosheath Jets

- Enhancements in dynamic pressure ρv^2
- Move (in general)towards Earth's Magnetopause
- Detectable using spacecraft
  - e.g. THEMIS, MMS, Cluster
- First detected in 1998
  - (Němeček et al.1998)



Consequences of jets: Impact on Magnetopause

- Triggering reconnection at magnetopause

  (Hietala et al. 2018, Ng et al. 2021)

- Jet-related aurora signatures have been reported

  (Wang et al. 2018)

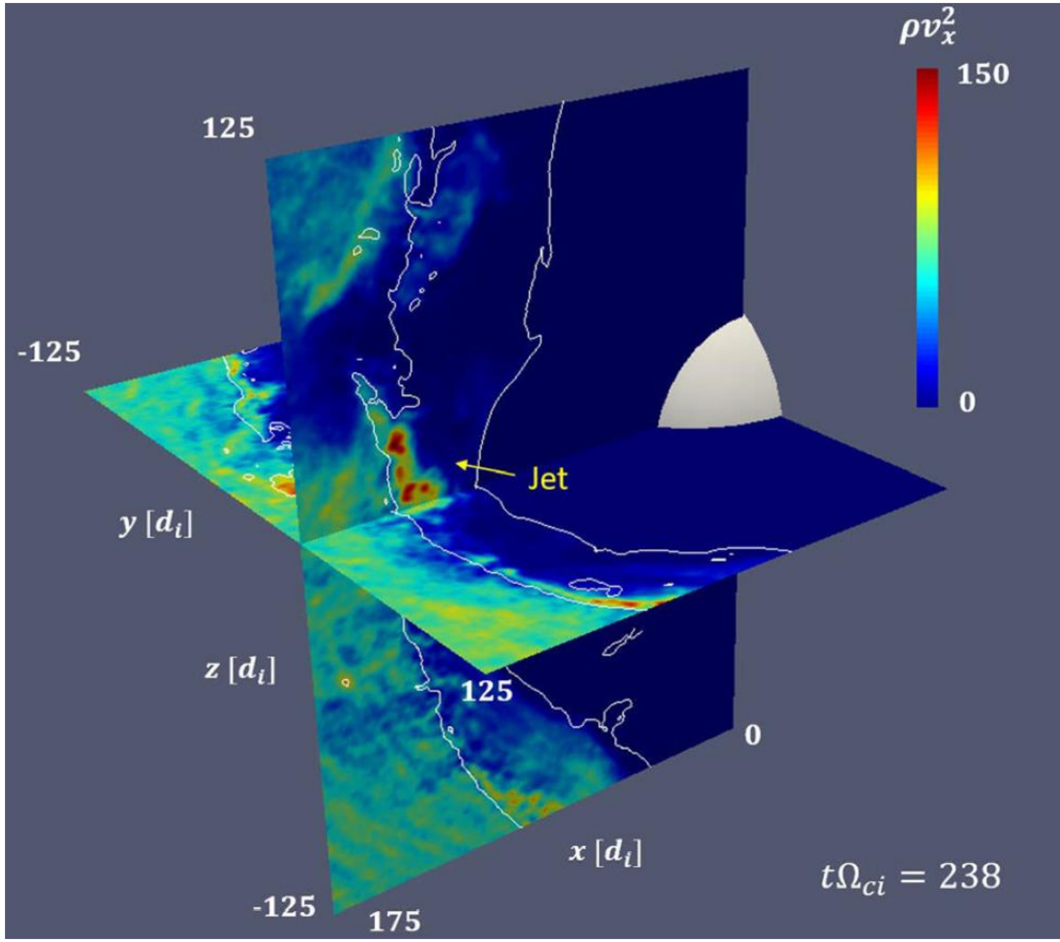
- Ground-based magnetometer responses to impacting jets detected

  (Norenius et al. 2021)

> “*We also examine if jets can be harmful for human infrastructure and cannot exclude that such events could exist*.” -Norenius et al. 2021

- Jets may trigger magnetic substorms

  (Nykyri et al. 2019)



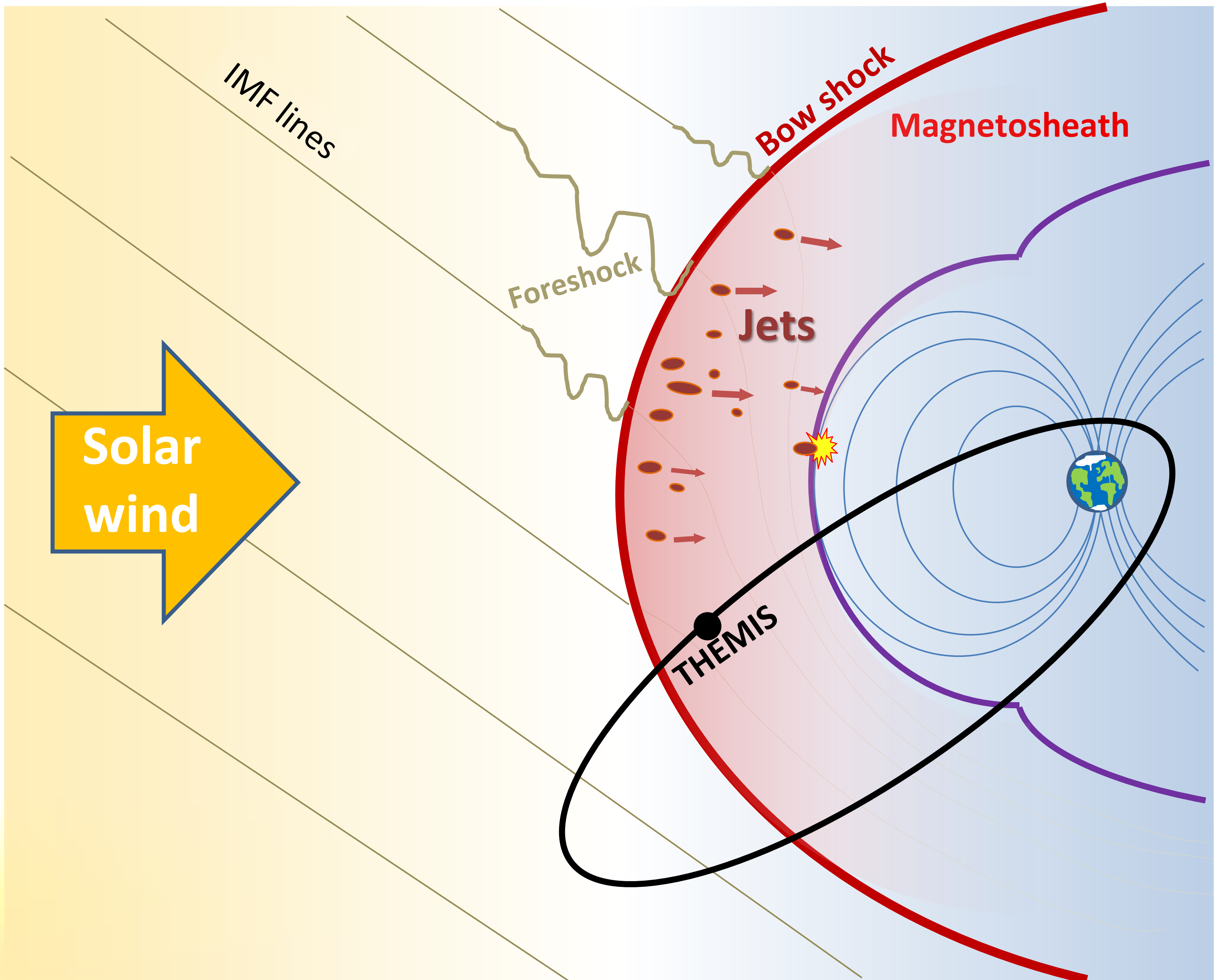
Credit: Ng et al.(2021)

Earth’s dayside magnetosphere and magnetosheath

Magnetosheath Jets

- dynamic pressure enhancements
  ρv^2

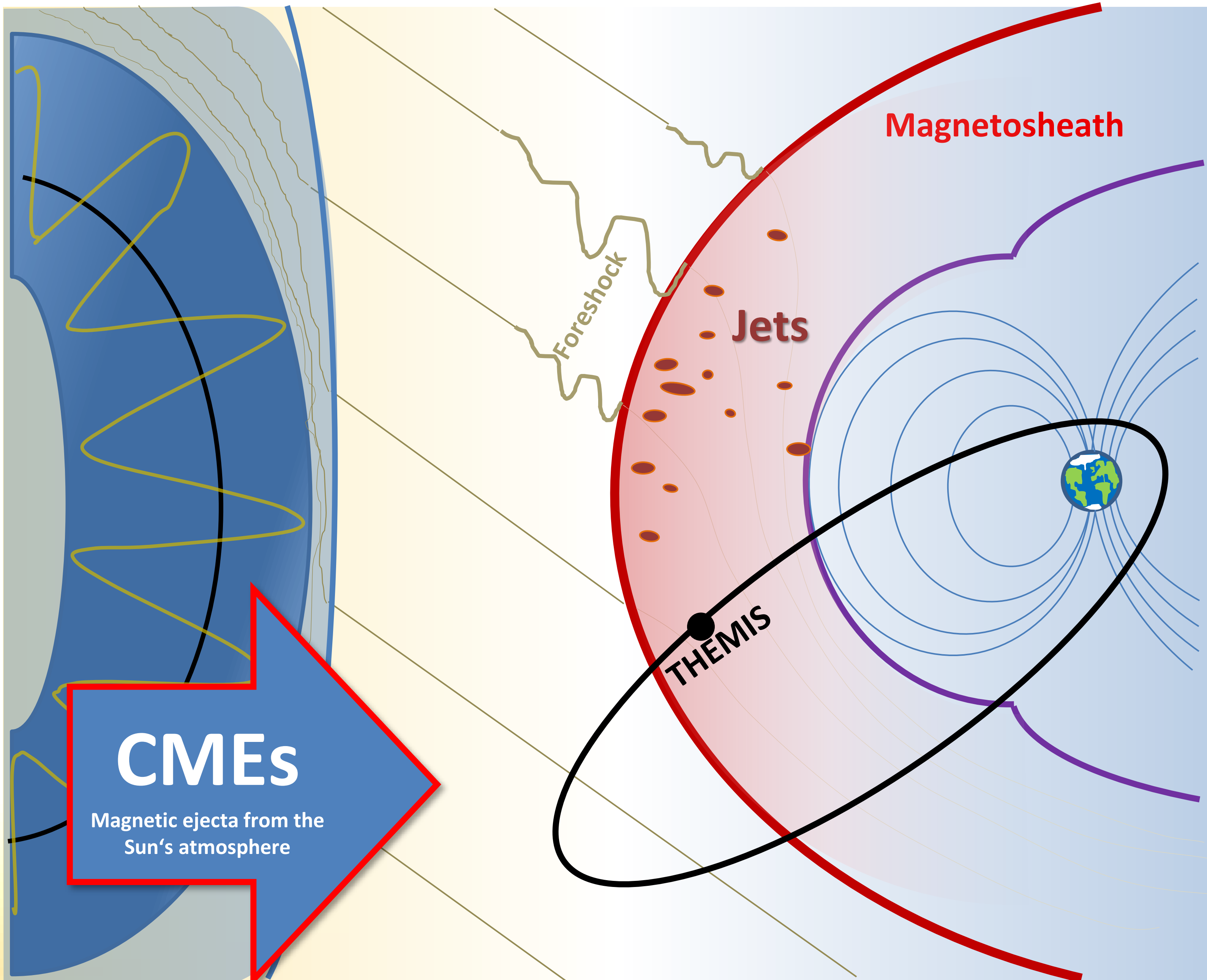
- Majority jets are linked to **foreshock processes** e.g.
  - Due to shock reformation (Raptis et al. 2022)
  - Foreshock SLAMS/ SW plasmoids transmitted into MS
    e.g. Karlsson et al. 2012, 2015, 2016, Suni et al. 2021)
  - Rippling of the bow shock (Hietala et al., 2009)



Incoming solar wind structures : CMEs

- Coronal mass ejections (CMEs) - large clouds of plasma expelled from the star

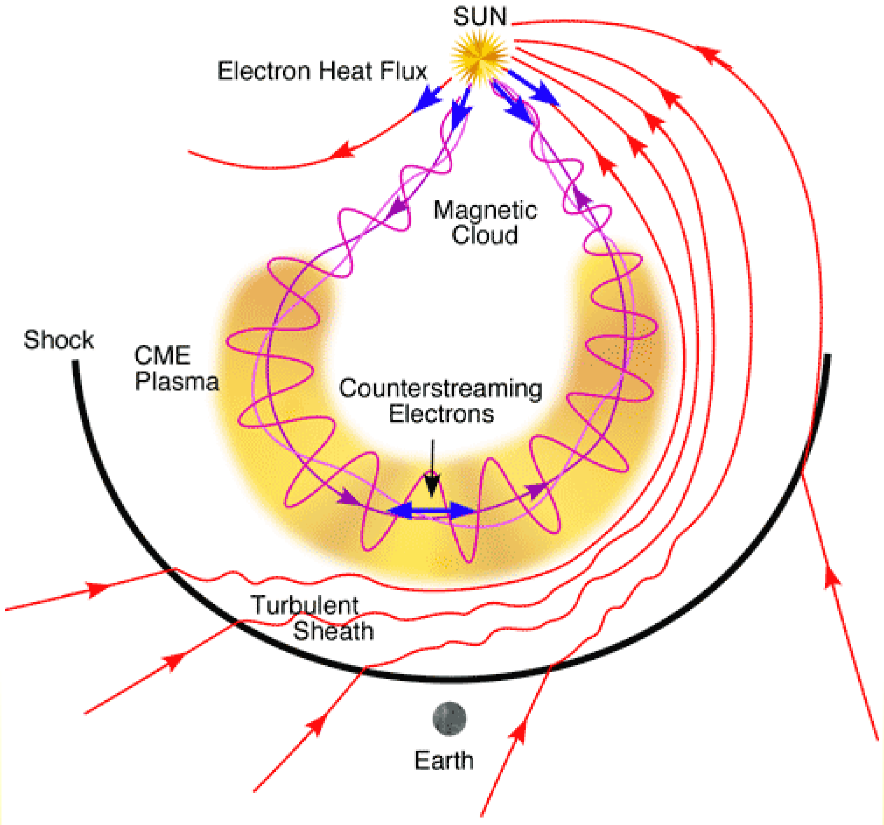
- Inside the magnetic cloud: high B field, “rolling B-Vector”



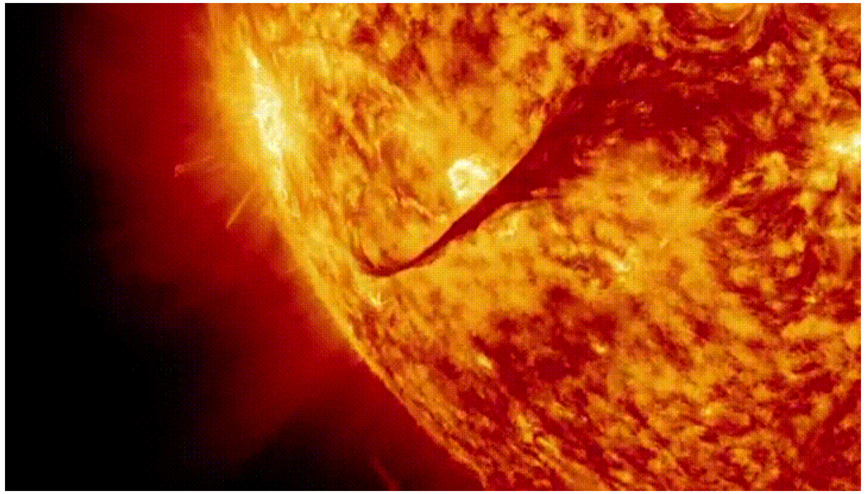
Coronal Mass Ejections

- Coronal mass ejections (CMEs) - large clouds of plasma expelled from the star

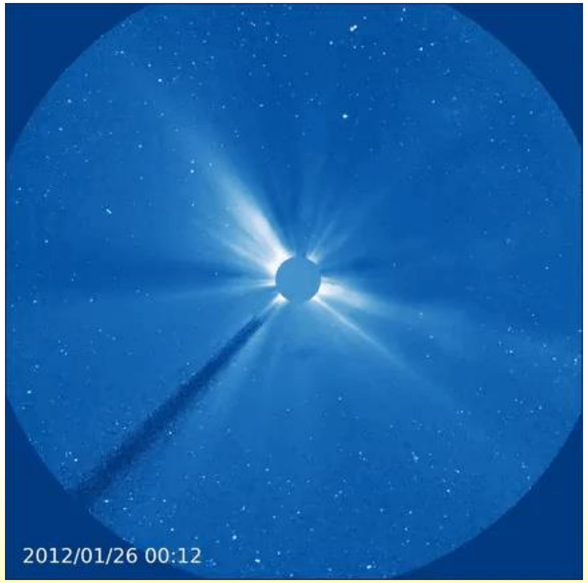
- Violent outbursts form our sun



Source: Zurbuchen & Richardson 2006



Source: SDO / NASA Goddard



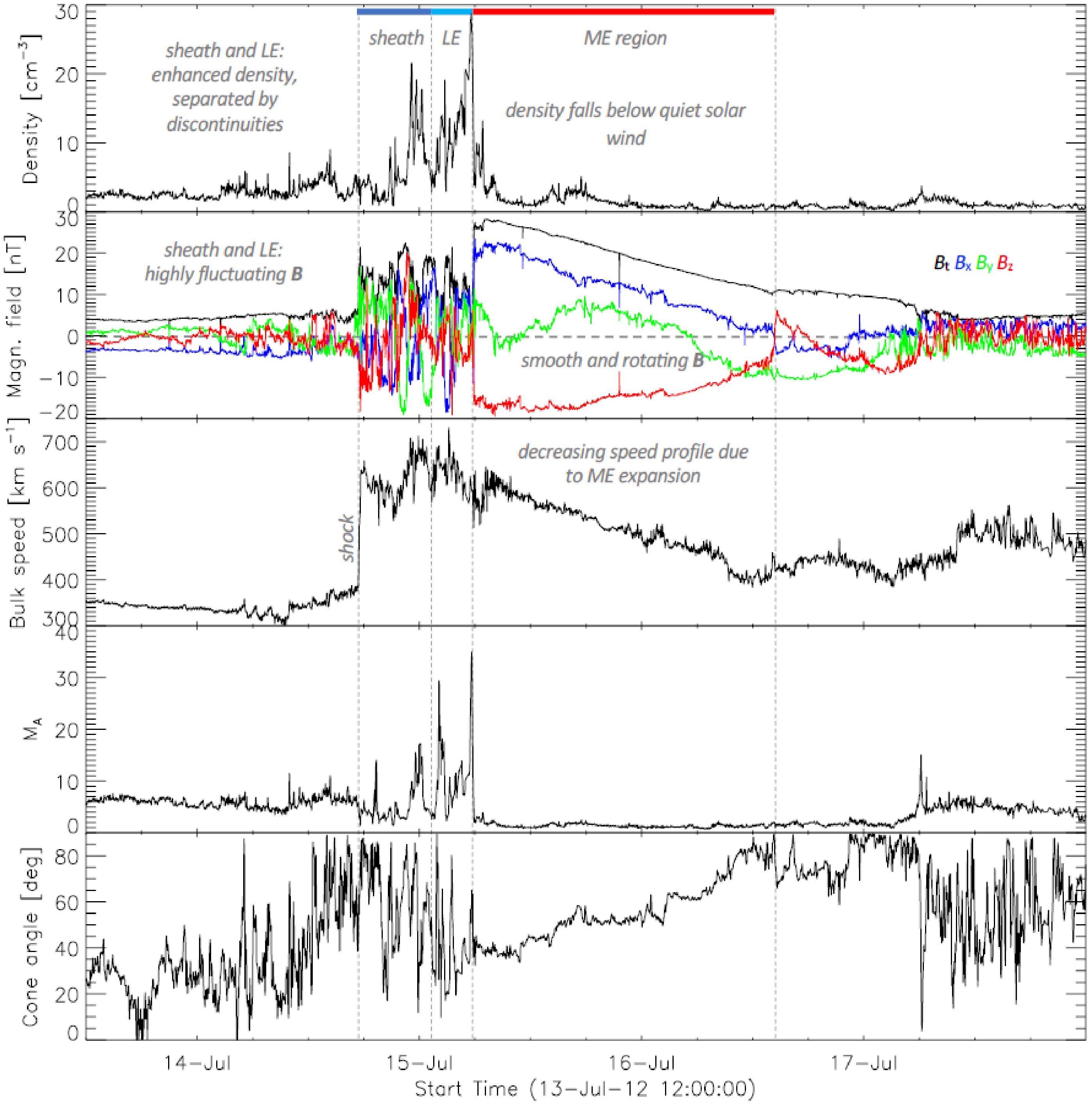
Source: ESA/NASA Solar and Heliospheric Observatory (SOHO)

Introduction

The inside of CMEs

- Coronal mass ejections (CMEs) - large clouds of plasma expelled from the star

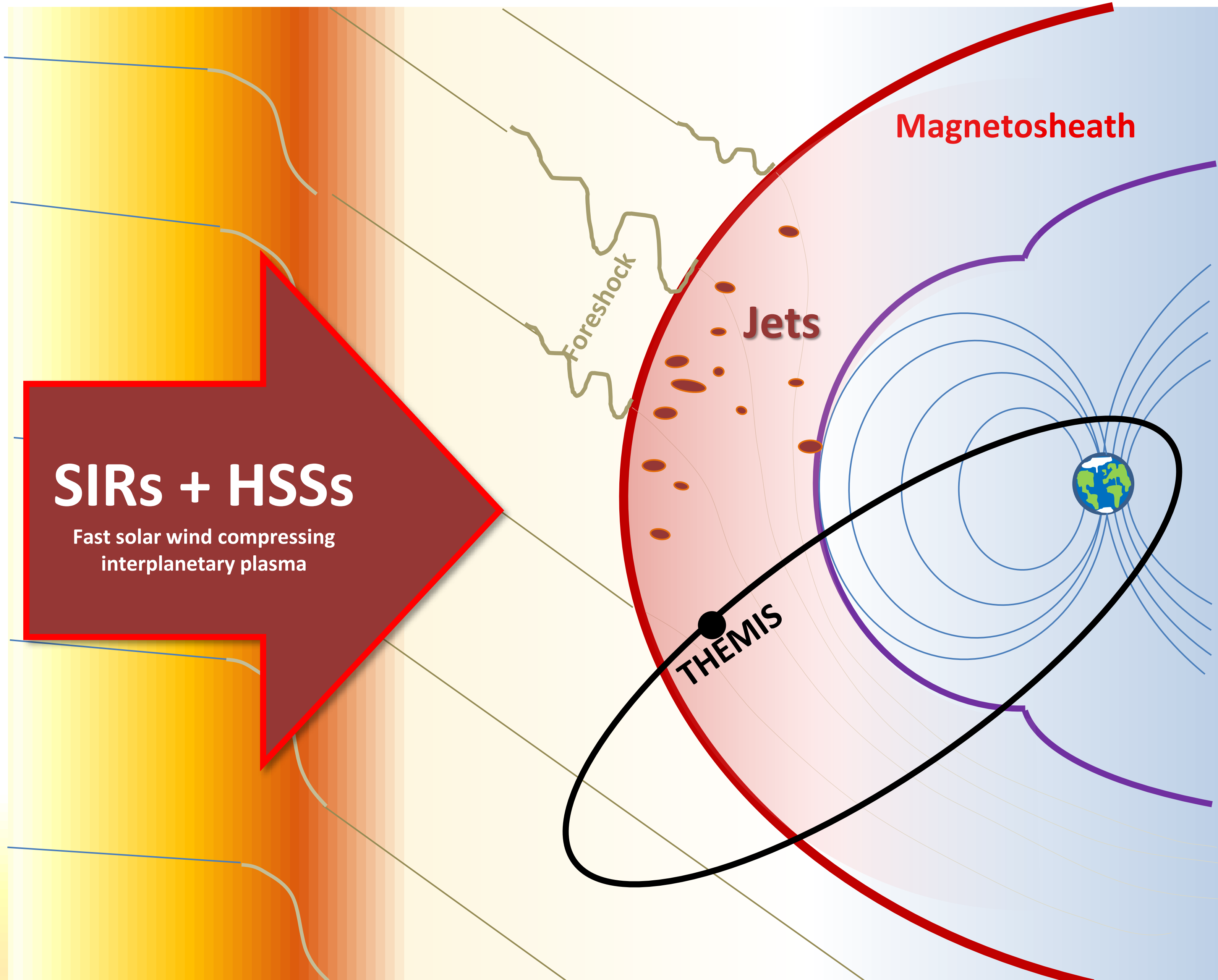
- Inside the magnetic cloud: high B field, “rolling B-Vector”
- Low density



Incoming solar wind structures : SIRs + HSSs

- Stream Interaction regions (SIRs) – dense and turbulent solar wind plasma compressed by high speed streams (HSSs)
- High density, turbulent magnetic field, increased velocity

- HSSs: fast solar wind coming from coronal holes
- High velocity, low density

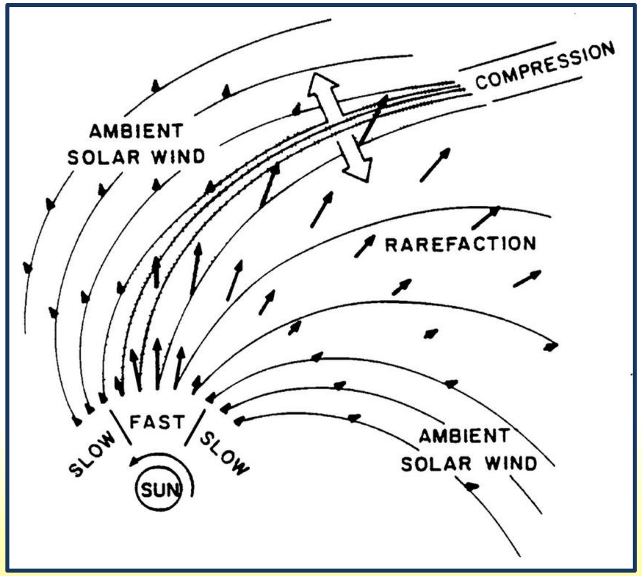


SIRs + HSSs

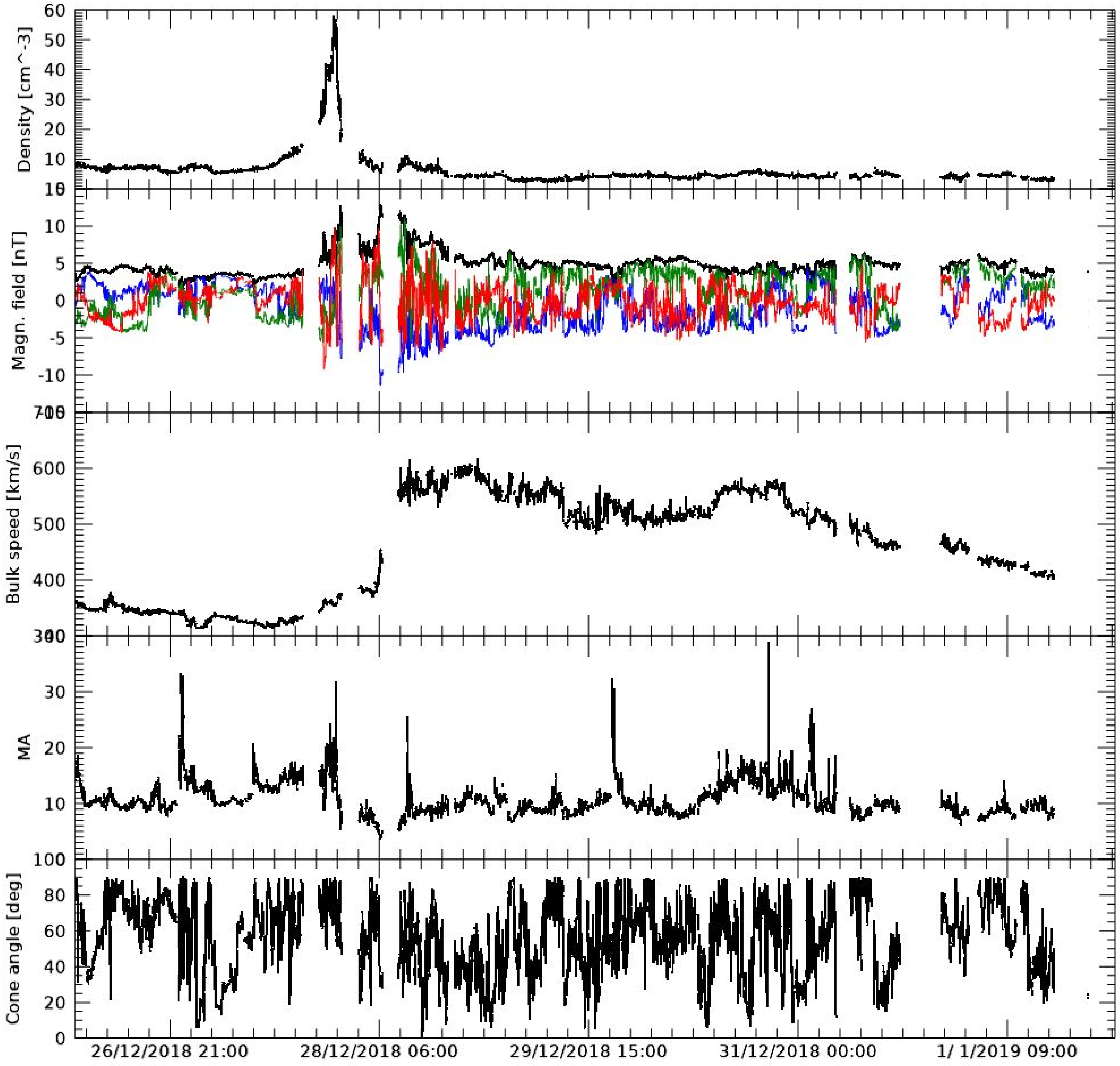
Fast solar wind compressing interplanetary plasma

SIRs

- SIR - Stream Interaction regions: parts of the heliospheric plasma, where fast solar wind meets slow solar wind
- At 1 AU: plasma shows a sharp peak in density (pile-up)
- Followed by an increase in velocity (high speed stream, HSS)
- May drive a shock



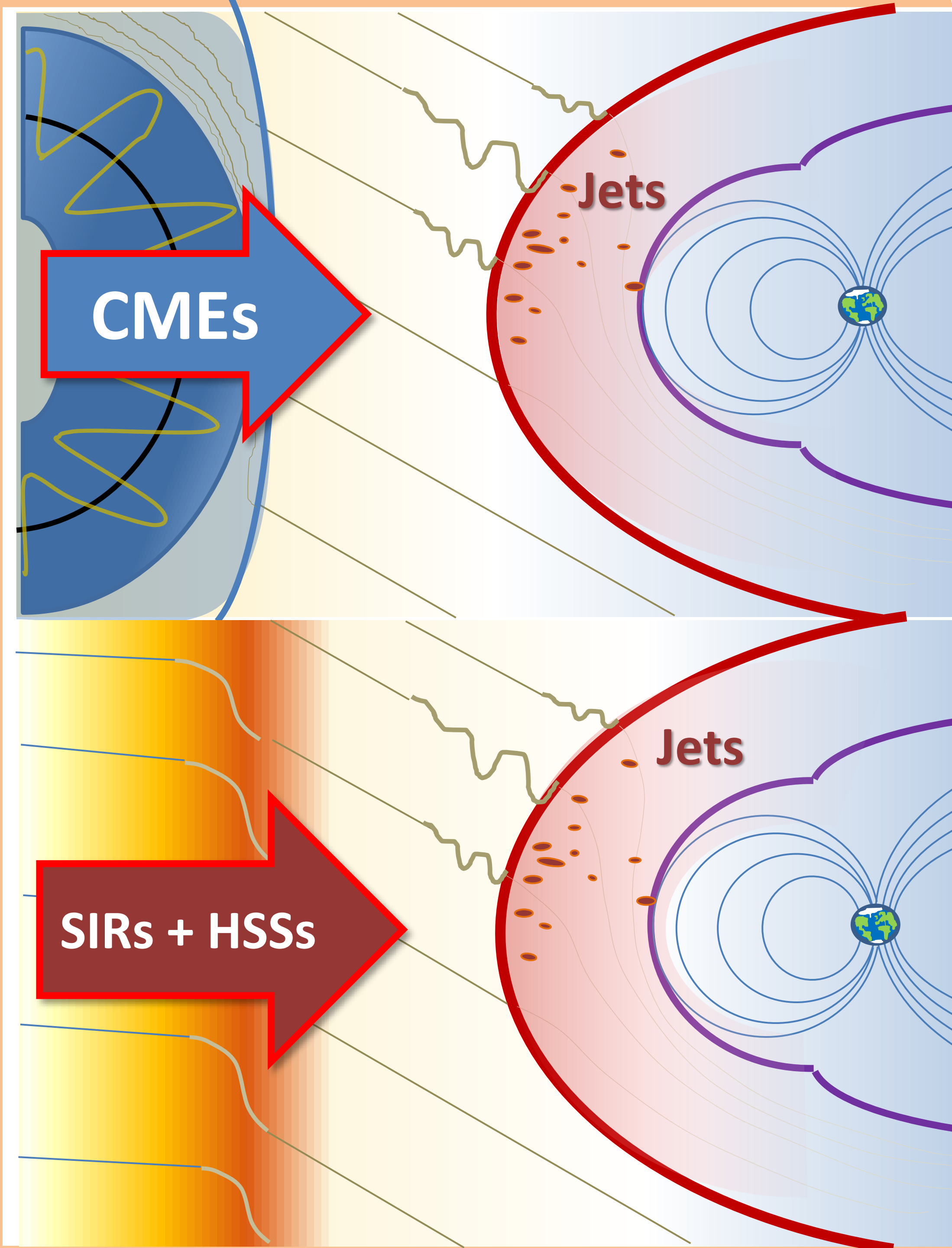
Source: Pizzo, 1978



Research Motivation

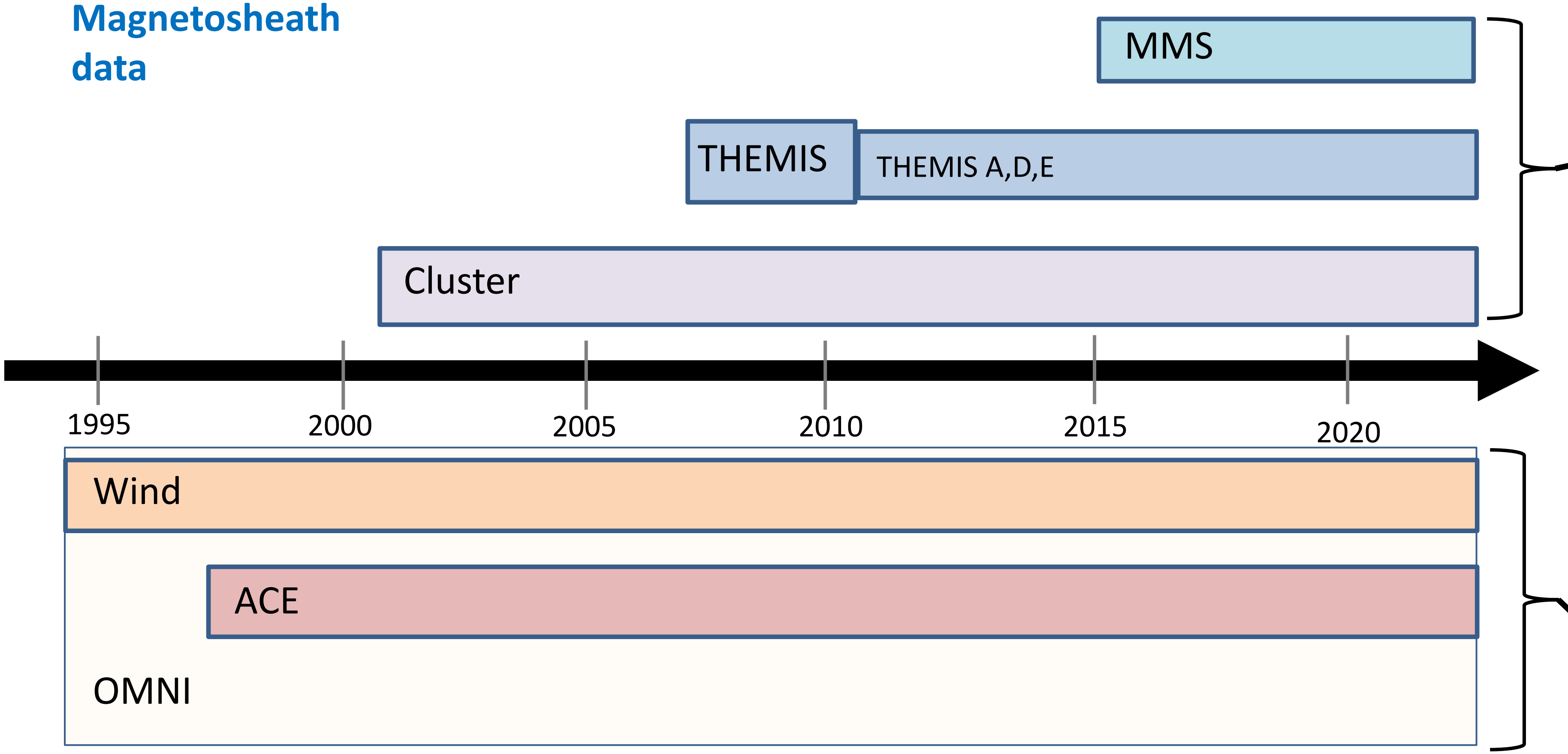
- **We want to learn how CME, SIRs and HSSs affect jets, meaning:**
  - Effects on number of the jets (Koller et al. 2022)
  - Effects on generation mechanisms
    - What happens to the foreshock in a CME?
  - Effects on jet properties

Jets are a key linking effect between the solar wind and Earth's magnetic field!



Dataset: overview of availability

Magnetosheath data



MMS

THEMIS

THEMIS A,D,E

Cluster

1995

2000

2005

2010

2015

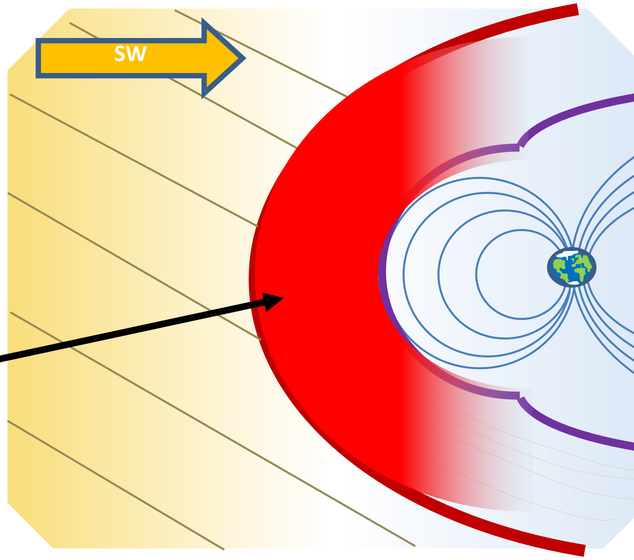
2020

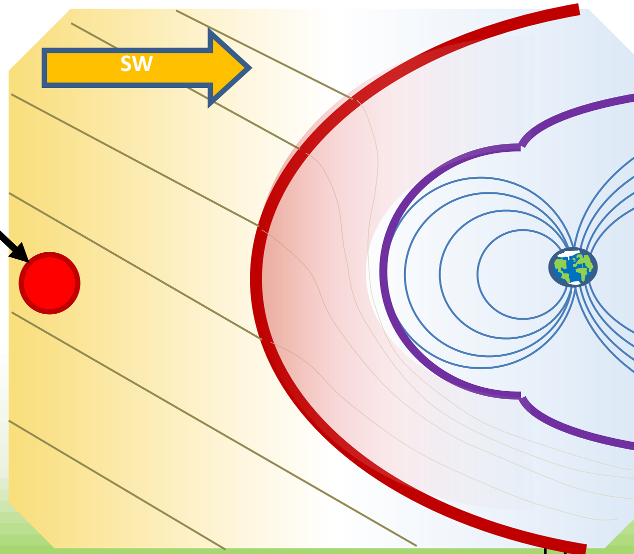
Wind

ACE

OMNI

Solar Wind data (examples)





Datasets: available lists & jet criterion

- We use THEMIS data from 2008 to 2021
- Different thresholds are used (e.g. Plaschke et al. 2013, Koller et al. 2022)
- Jets detected by using the Archer & Horbury (2013) criterion:

$$P_{dyn,\,sh} > 2\,x\langle P_{dyn,sh}\rangle_{20\,min}$$

- For all available Magnetosheath data we take the corresponding SW data
- CME-list by Richardson & Cane (2010), extended SIR+HSS collection described in Koller et al. (2022)

Overall detected Jets: 51,737

(largest jet dataset to date)

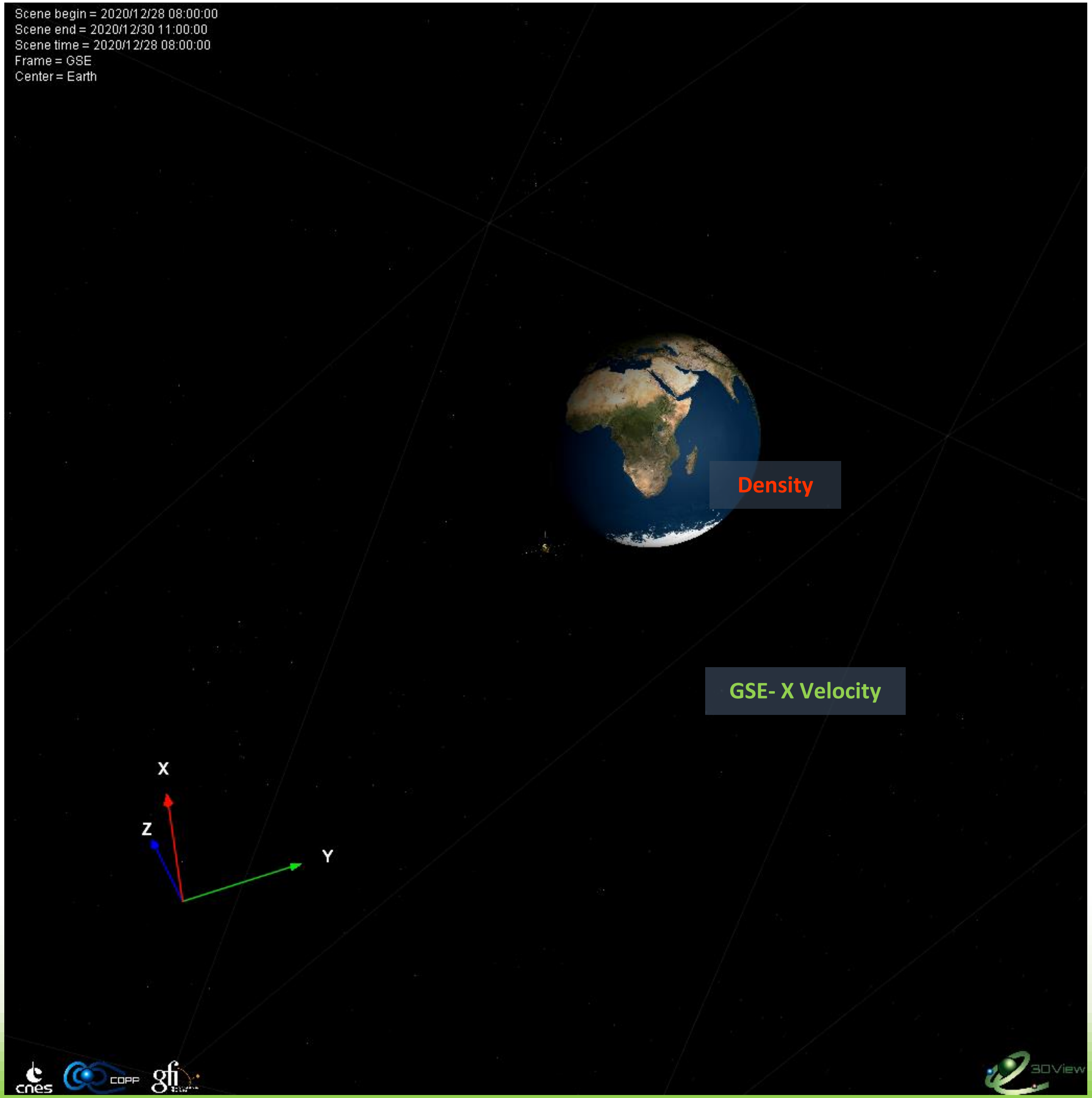
- CME Magnetic ejecta: 2,105
- CME Sheaths: 1,007

- High speed streams: 10,617
- Stream Interaction Regions: 9,766

Challenge of using magnetosheath data

- No continuous observations: spacecraft move through magnetosheath sporadically
    - Magnetosheath observation time ~ 5 – 500 minutes
    - Highly depended on current spacecraft orbit
- Magnetopause and bow shock move in / outward based on SW conditions
- Overlap between times of available magnetosheath data and large-scale solar wind structures is limited

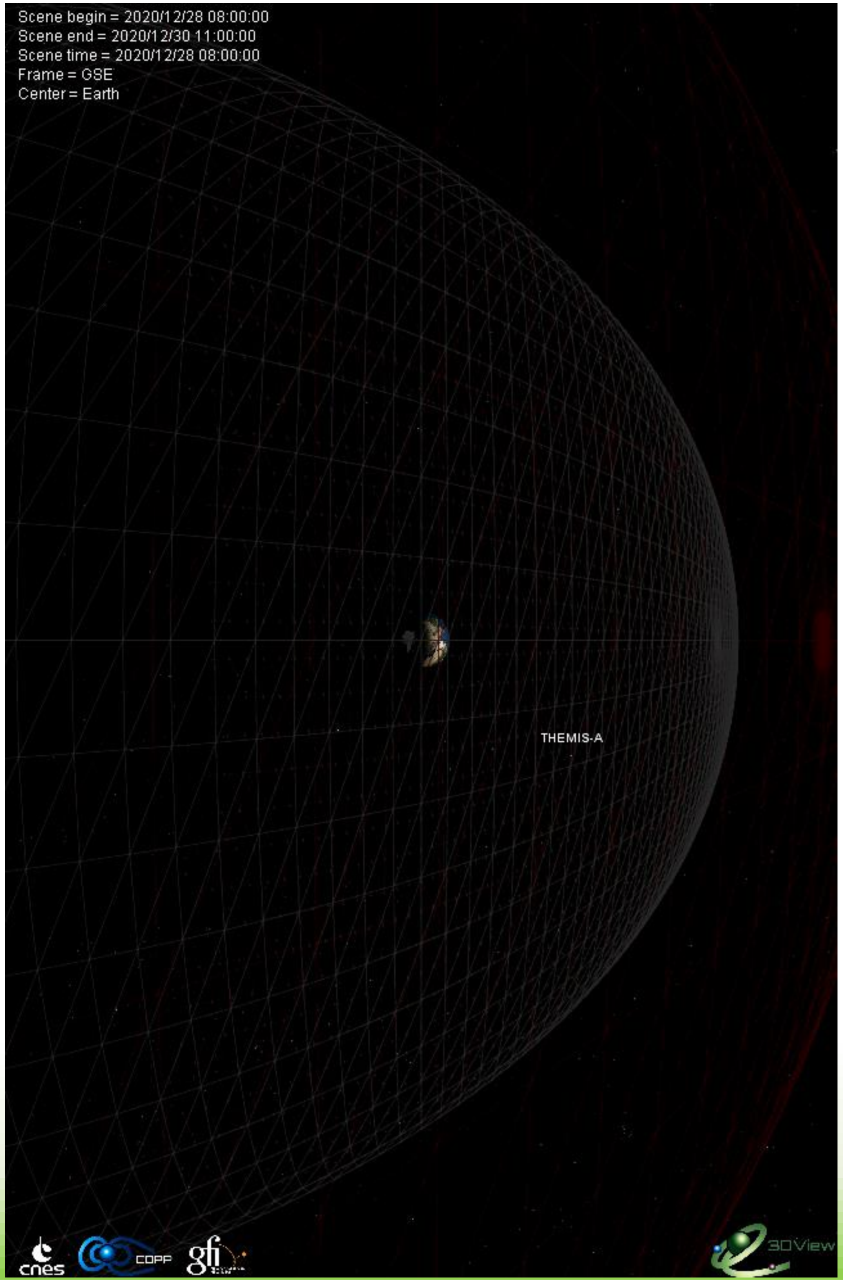
Challenge of using magnetosheath data



Scene begin = 2020/12/28 08:00:00
Scene end = 2020/12/30 11:00:00
Scene time = 2020/12/28 08:00:00
Frame = GSE
Center = Earth

Density

GSE- X Velocity



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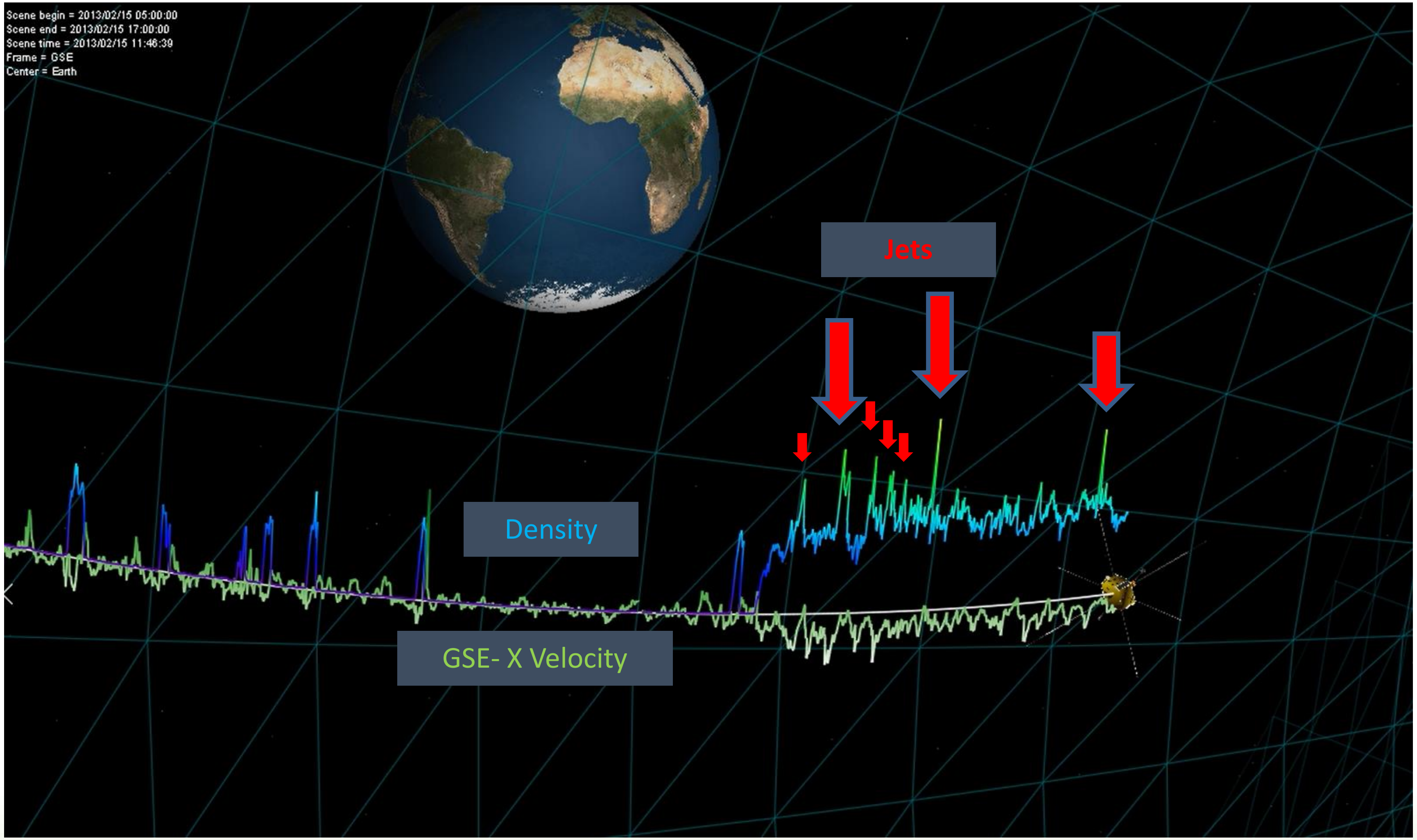
Challenge of using magnetosheath data

Upper line: density
Lower line: Vx (negative values)

Credit: 3DView CDPP



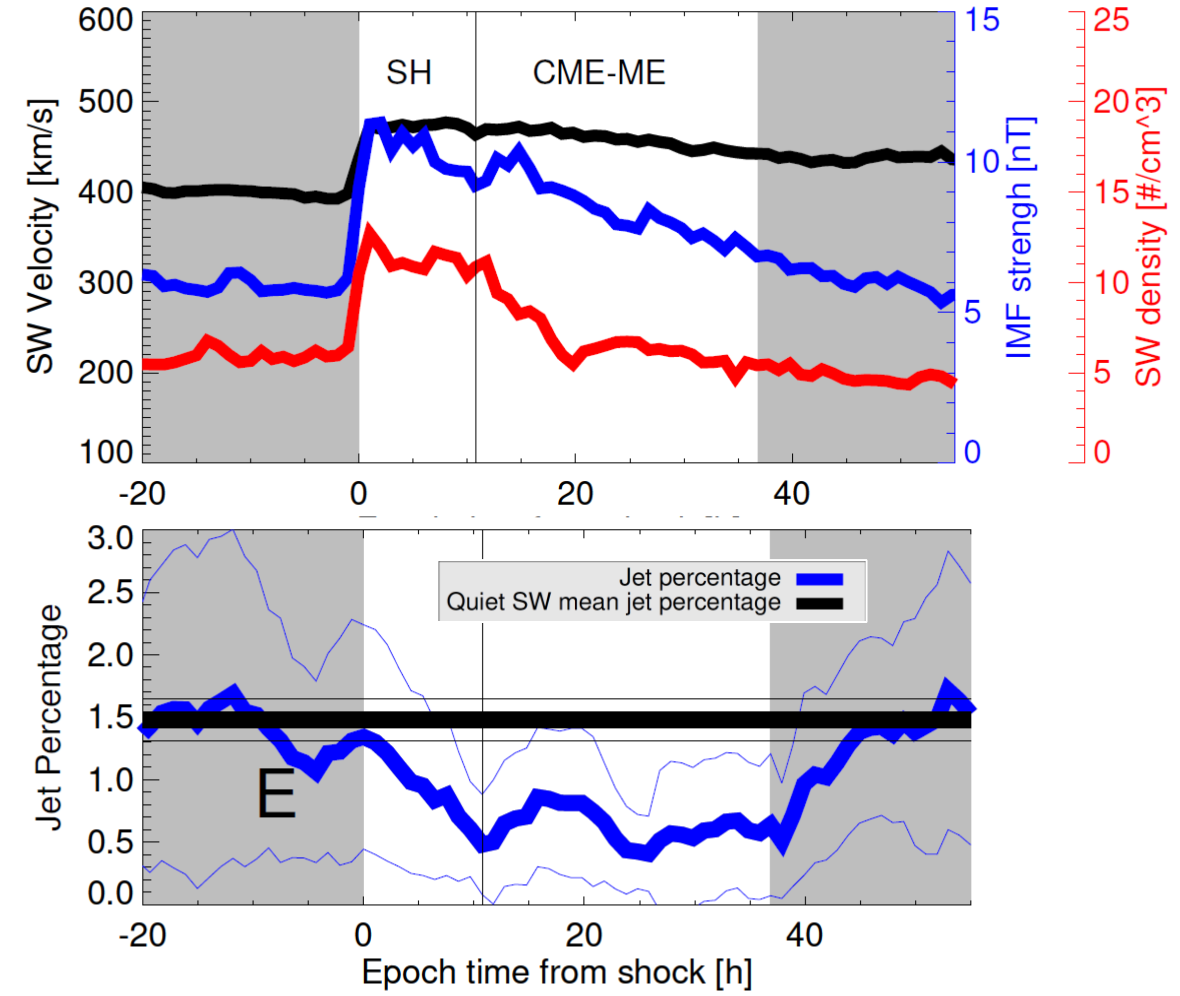
Results

- We want to figure out: How are jets related to
  - Coronal mass ejection (CMEs)
  - Stream interaction regions (SIRs) and high speed streams (HSSs)
- What SW parameter is responsible for jet formation?
  - During large-scale SW structures
- We check overlapping times of CMEs and SIRs+HSSs with magnetosheath data

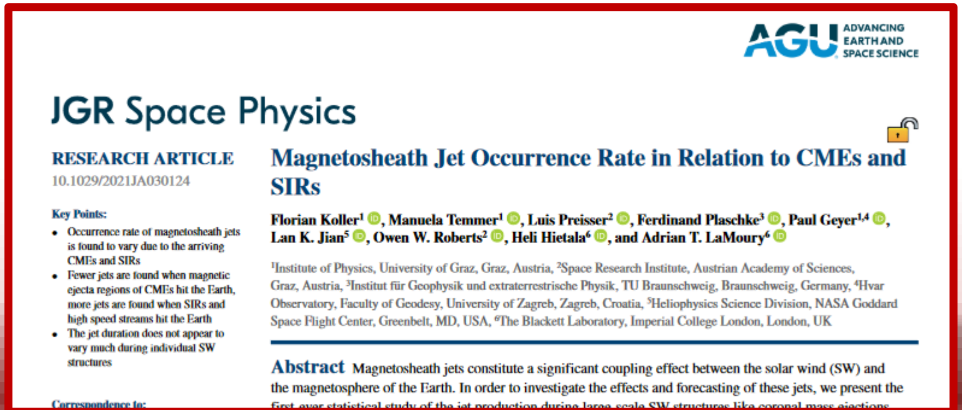
Results

Decrease of jets during CMEs (→ Koller et al. 2022)

- Number of jets **continously low** during CME-Magnetic ejecta
- Relation was previously unknown
- We further investigate this trend in jet occurrence



Credit: Koller et al. 2022



JGR Space Physics

RESEARCH ARTICLE

10.1029/2021JA030124

Key Points:

- Occurrence rate of magnetosheath jets is found to vary due to the arriving CMEs and SIRs
- Fewer jets are found when magnetic ejecta regions of CMEs hit the Earth, more jets are found when SIRs and high speed streams hit the Earth
- The jet duration does not appear to vary much during individual SW structures

Correspondence to:

Magnetosheath Jet Occurrence Rate in Relation to CMEs and SIRs

Florian Koller[1], Manuela Temmer[1], Luis Preisser[2], Ferdinand Plaschke[3], Paul Geyer[1,4], Lan K. Jian[5], Owen W. Roberts[2], Heli Hietala[6], and Adrian T. LaMoury[6]

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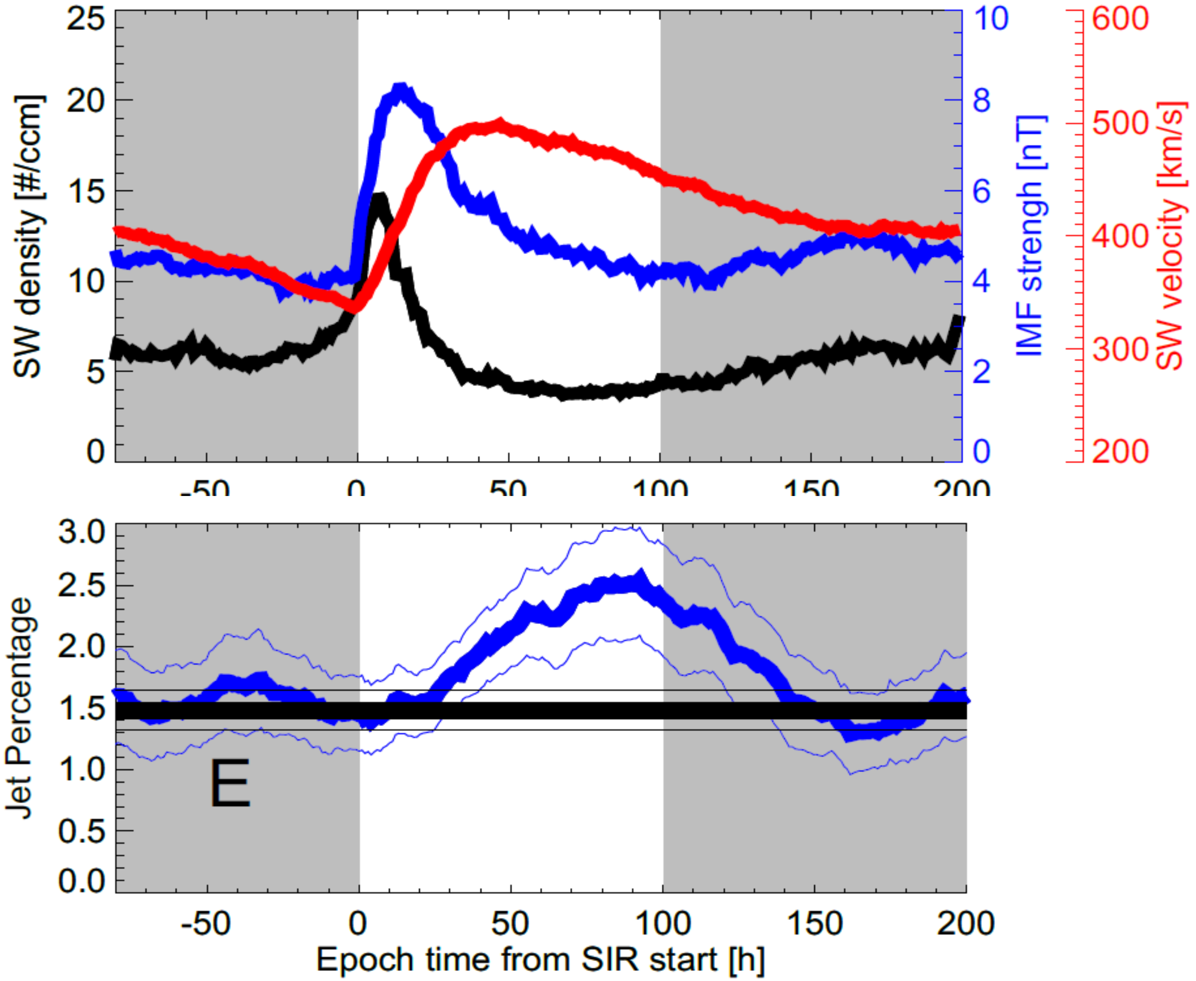
Abstract Magnetosheath jets constitute a significant coupling effect between the solar wind (SW) and the magnetosphere of the Earth. In order to investigate the effects and forecasting of these jets, we present the

Increase of jets during HSSs (→ Koller et al. 2022)

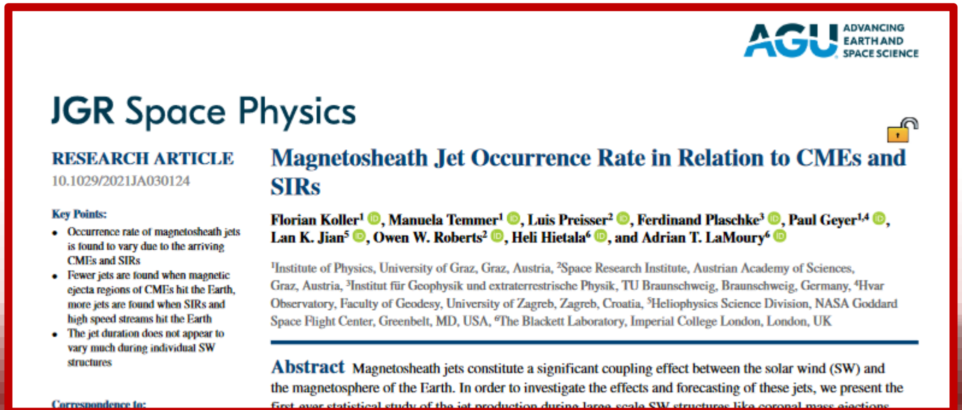
- Number of jets **very high** during High speed streams in SW

- Expected based on previous works

  (e.g. LaMoury et al. 2021)



Credit: Koller et al. 2022



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Abstract Magnetosheath jets constitute a significant coupling effect between the solar wind (SW) and the magnetosphere of the Earth. In order to investigate the effects and forecasting of these jets, we present the first ever statistical study of the jet production during large-scale SW structures like coronal mass ejections

Short summary

- Jets can happen **all the time,**

BUT!

- Number of jets is **higher during SIRs + HSSs**
- Number of jets is **lower during CMEs**

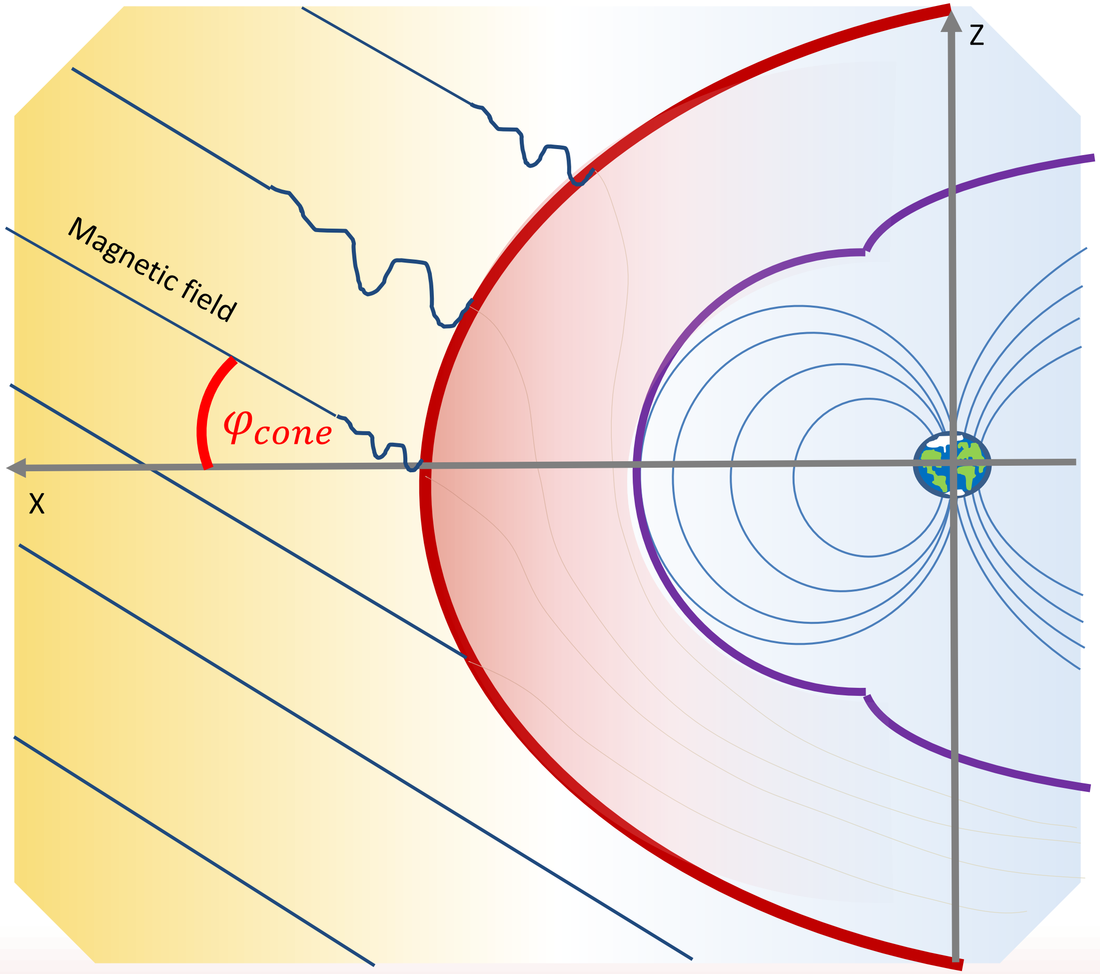
Analysis based on Solar wind (OMNI) data

- We make **2D histogram parameter plots** using
  - **IMF cone angle**

$$\varphi_{cone} = arc\cos\left(\frac{|B_x|}{B_{tot}}\right)$$

  - **Alfvén Mach number**

$$M_A = \frac{v_{SW}}{v_A} = v_{SW} * \frac{\sqrt{\mu_0 \rho}}{|B|}$$



Results

Analysis based on Solar wind (OMNI) data

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  - **IMF cone angle**

$$\varphi_{cone} = arc\cos\left(\frac{|B_x|}{B_{tot}}\right)$$

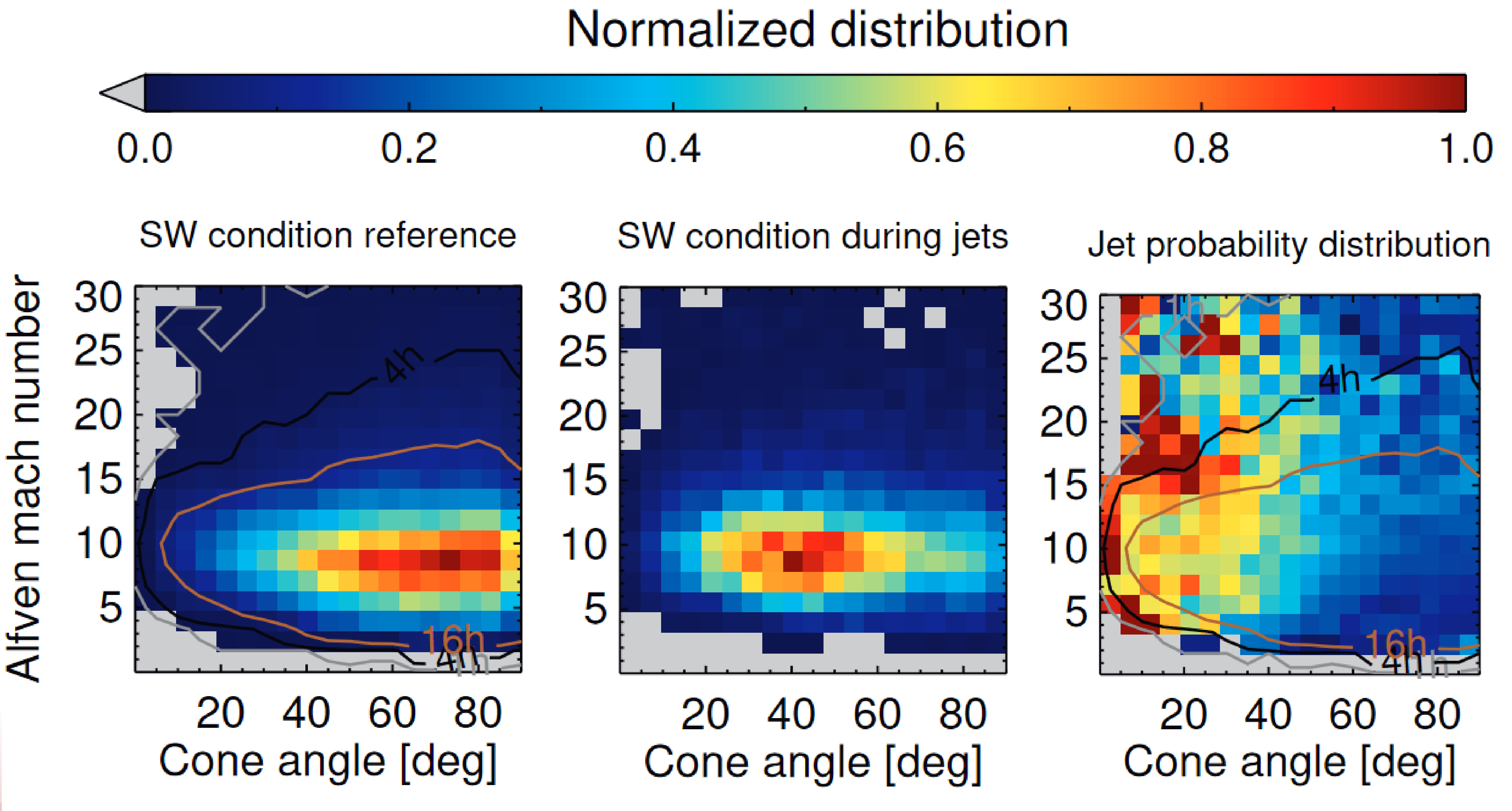
  - **Alfvén Mach number**

$$M_A = \frac{v_{SW}}{v_A} = v_{SW} * \frac{\sqrt{\mu_0\rho}}{|B|}$$

Why those two parameters?

- Foreshock is directly dependent on both
  - Low cone angle better for foreshock
  - High Mach numbers needed build foreshock
- CMEs changes both parameter!

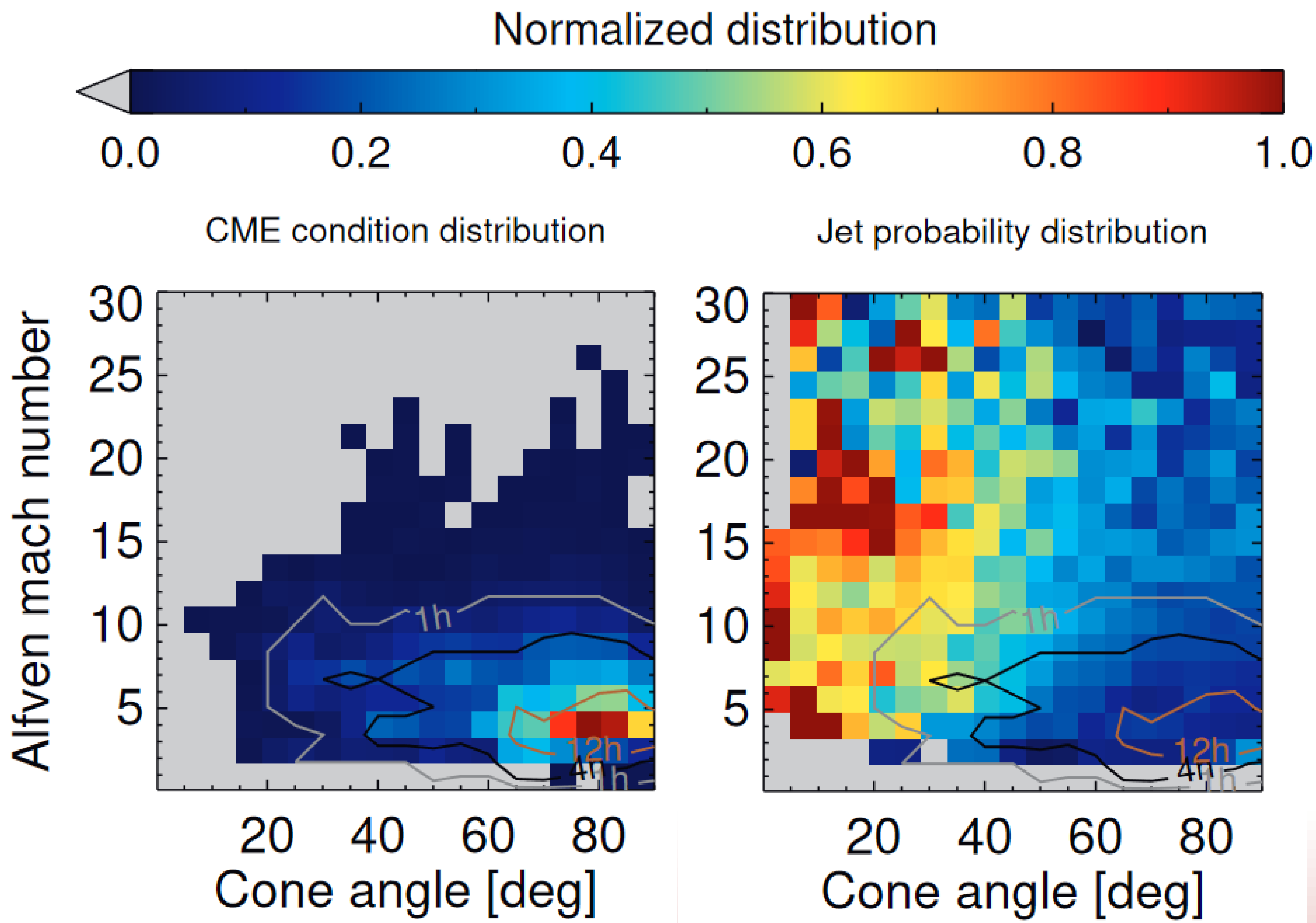
SW condition distribution: SW Mach number & cone angle



Koller et al., in preparation

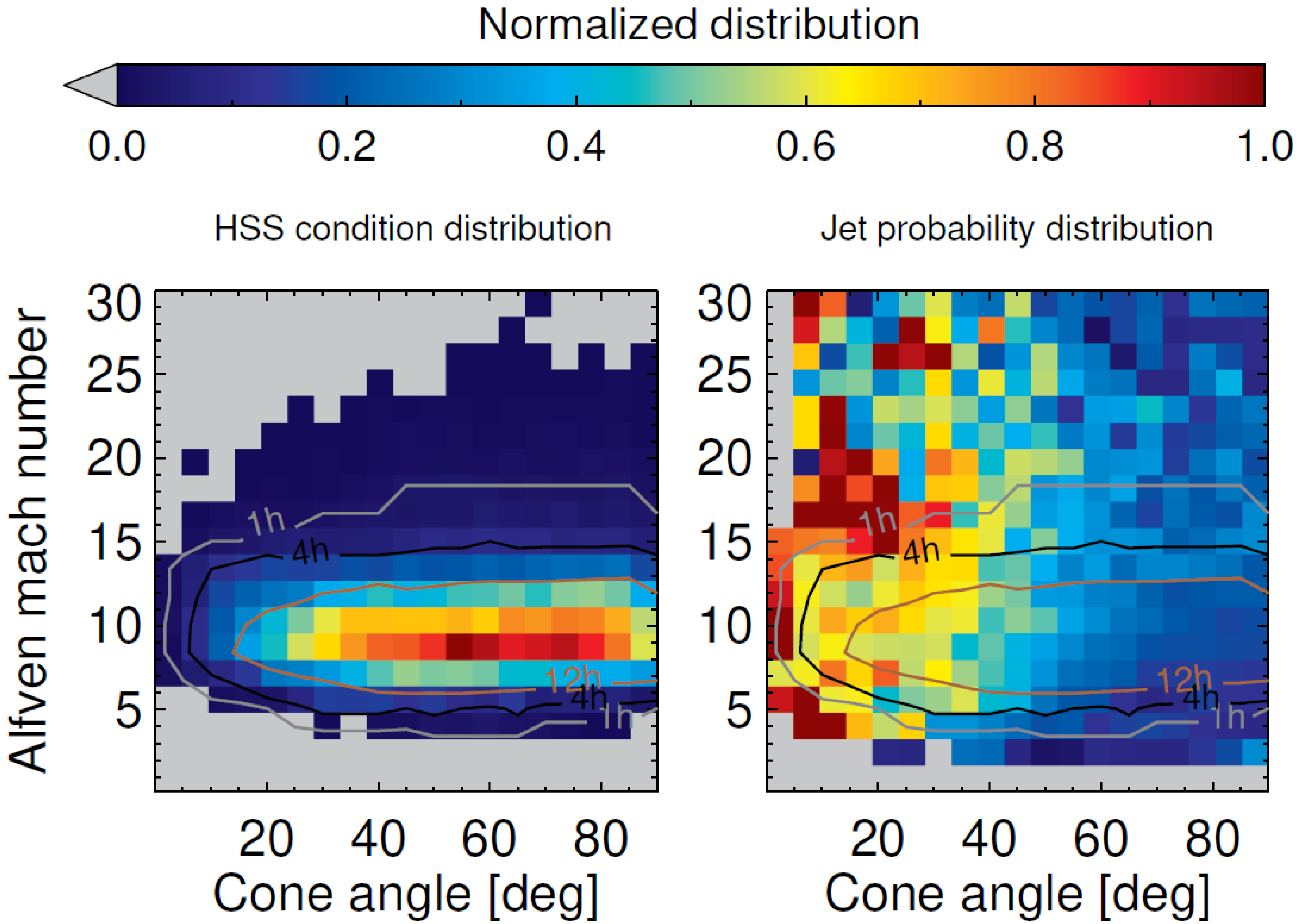
Results

SW condition during CMEs



Koller et al., in preparation

SW condition during HSSs



Outlook

- Analysis of differences is Magnetosheath Jets during each SW structure
- Expand dataset: using Cluster spacecraft (2001-now)
- Case studies (in preparation)
- Geoeffectiveness of jets – impacts on magnetosphere
- Jets around other planets – e.g. Mercury, Mars, …

Conclusion and summary

- Number of jets is **higher during SIRs + HSSs**
- Number of jets is **lower during CMEs – unfavorable conditions for jets**
- This is due to a mix of **low Alfvén Mach number** & **high cone angles**
- We hypothesize that this **inhibits the production of a proper foreshock**
- Gives implications to other magnetosheaths (e.g. low Alfvén Mach numbers at Mercury)

Thank you for your attention!

Sources:

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