

# Foreshock and Magnetosheath Transients

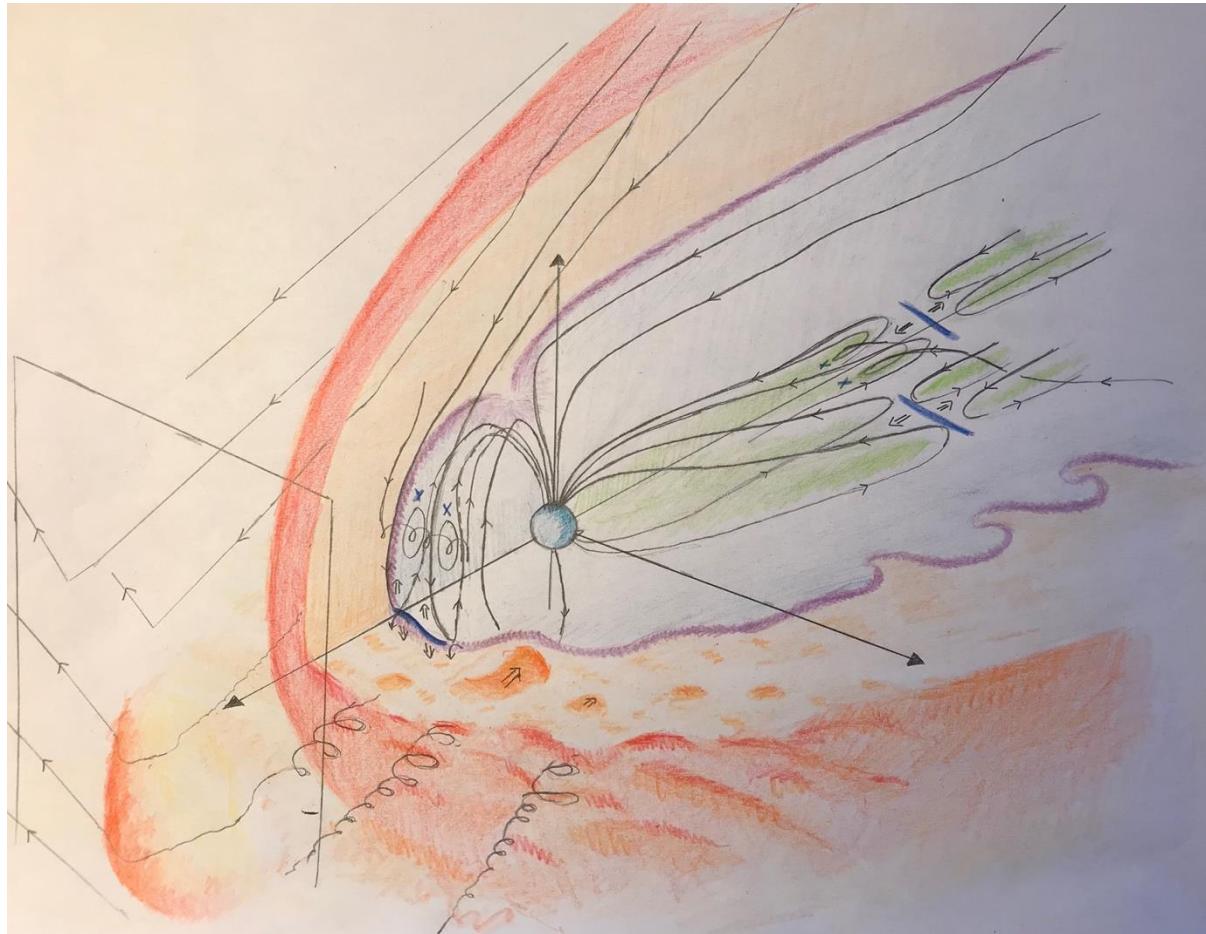
Heli Hietala

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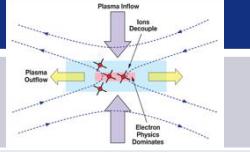
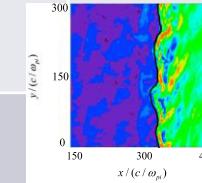
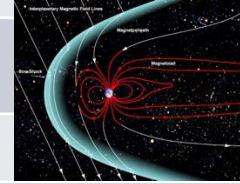
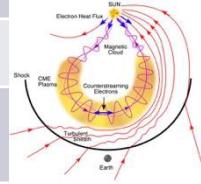
with thanks to Ferdinand Plaschke, Lucile Turc, early-career jet researchers,  
ISSI Teams 350 and 465, and many more!

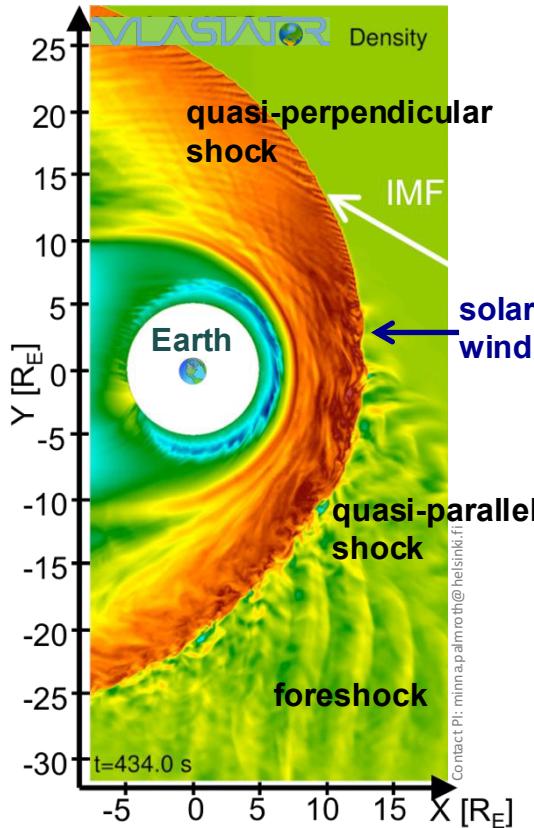
# Why do we care? about the foreshock, the bow shock, and the magnetosheath

- Process the solar wind before it interacts with the magnetosphere
- Generate structures
- Accelerate particles
- Host fundamental plasma physics processes



# Some spatial scales in heliophysics

$1d_i^{\text{SW}} = 100\text{km}$	$1R_E = 6,371\text{km}$	$1 \text{ AU} = 1.5 \times 10^8 \text{km}$	phenomena	
$< 1d_i$			reconnection starts	
$10 - 100d_i$	$1R_E \sim 60d_i^{\text{SW}}$		interesting ion kinetics; Earth radius	
$100 - 1,000d_i$	$10R_E$		magnetopause stand-off distance	
	$\sim 50R_E$		Earth's magnetosphere	
	$\sim 235R_E$	0.01 AU	L1 point	
		$\sim 0.3 \text{ AU}$	CME	
		1 AU	Earth's distance from the Sun	

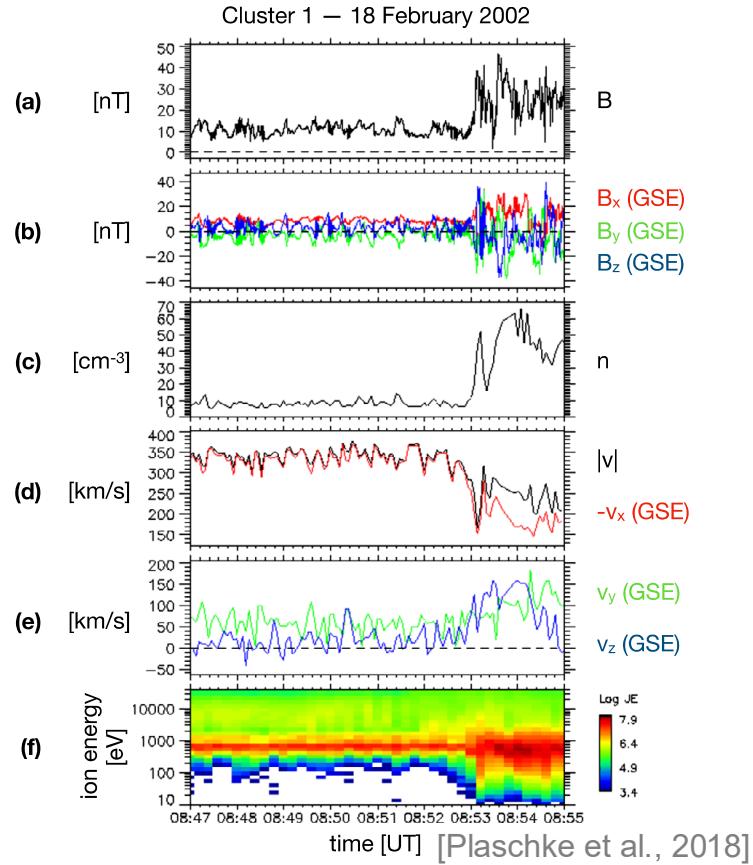
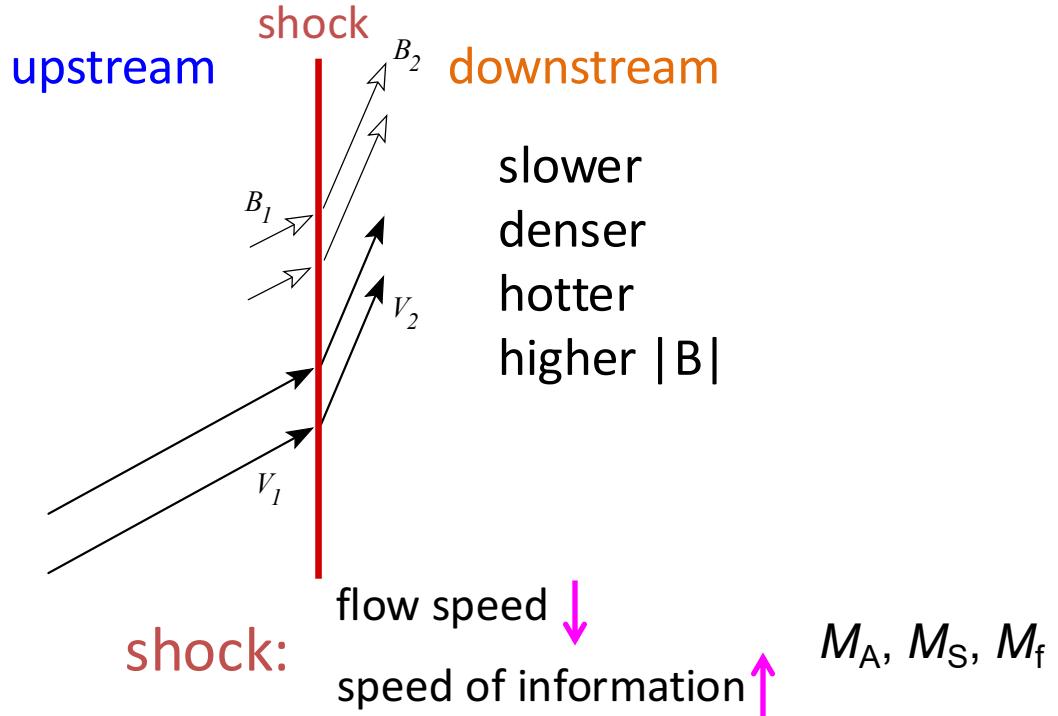


# Foreshock outline: from large to small

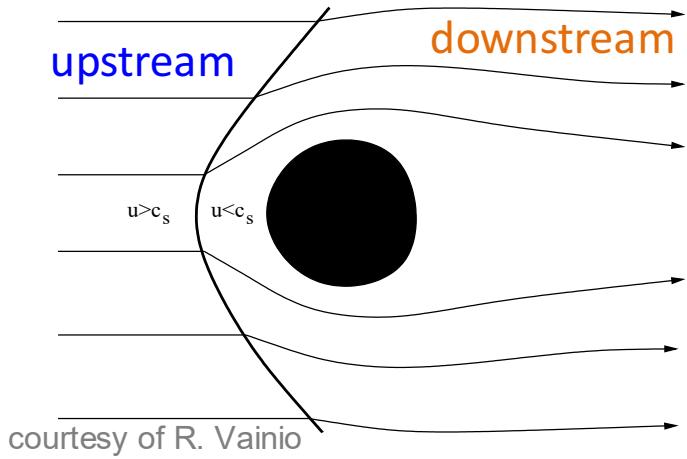
1. What is a shock? ( $15\text{-}50 R_E$ )
2. Shock obliquity:  
quasi-perpendicular and quasi-parallel ( $\sim 20 R_E$ )  
Electron and ion foreshocks
3. Foreshock structures
  1. Driven foreshock structures ( $2\text{-}10 R_E$ )
  2. Intrinsic foreshock structures ( $1 R_E$ )
4. Fine structure ( $10\text{-}100 \text{ km}$ )
 

Perpendicular shock ripples  
Reconnection within the shock front

# 1 What is a space plasma shock?

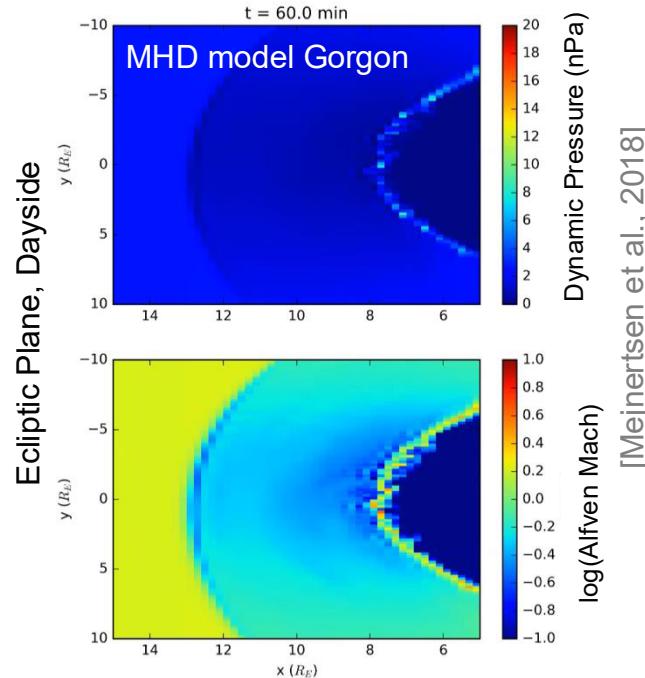


# 1 Obstacles: magnetospheres



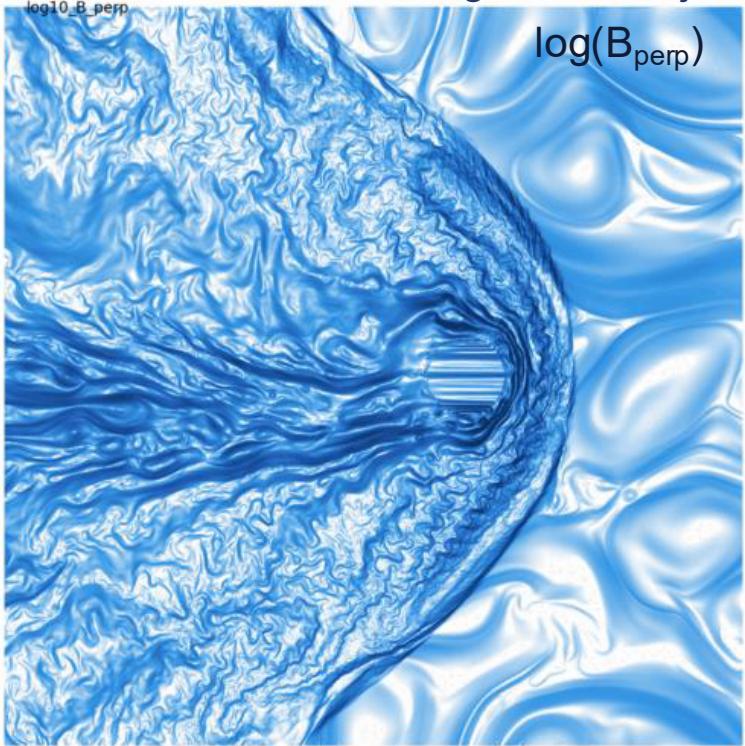
shock: flow speed ↓ speed of information ↑  $M_A, M_S, M_f$

Bow shock position varies  
mainly with solar wind dynamic pressure



# 1 Obstacles: ionospheres, CME flux ropes...

Interaction with an unmagnetized object



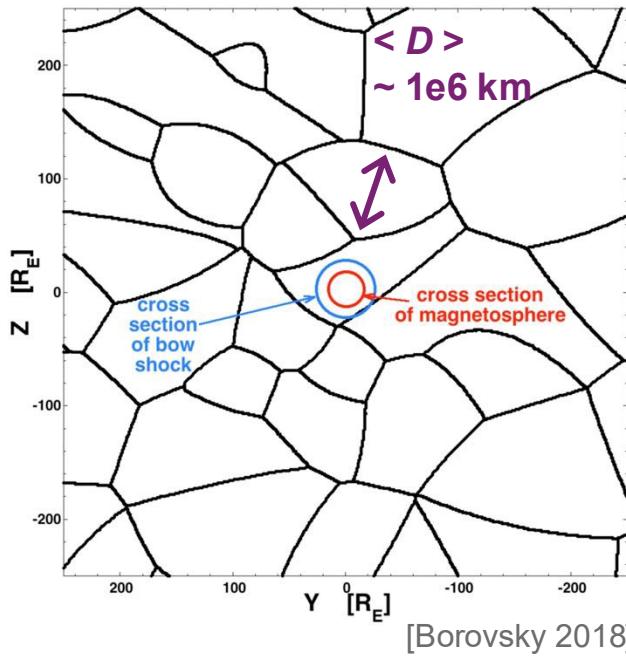
[Menura simulation; E. Behar]

Solar wind  
coherence scale  
(size of flux tubes)  
 $70 - 100 R_E$

→ conditions across  
Earth's bow shock  
often relatively  
uniform

Real solar wind is **turbulent**:

variations in upstream conditions over a range of scales



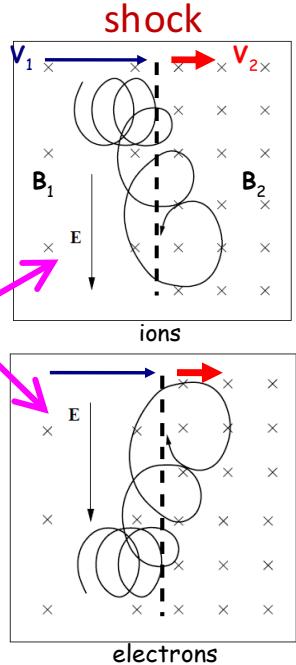
[Borovsky 2018]

# 1 Particle acceleration 101

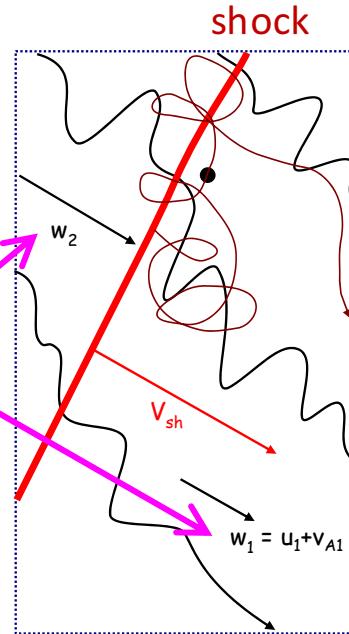
## Shock Drift Acceleration

## Diffusive Shock Acceleration

particles gain energy by drifting along/against the convective electric field



multiple interactions with waves upstream and downstream lead to multiple shock crossings



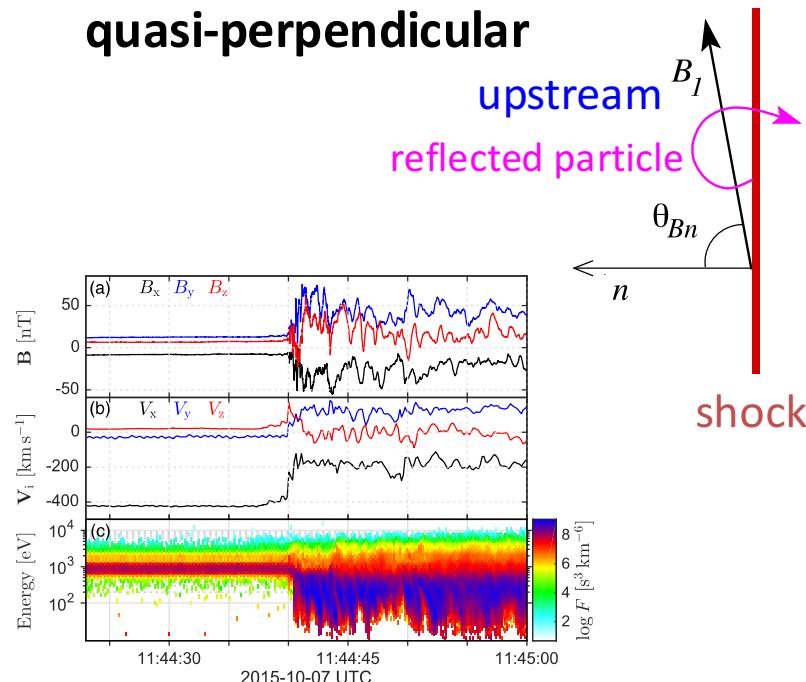
figures: R. Vainio

**Earth's bow shock is relatively small:**  
Under typical solar wind conditions and without an interplanetary seed population, it does not accelerate ions above 200-330 keV

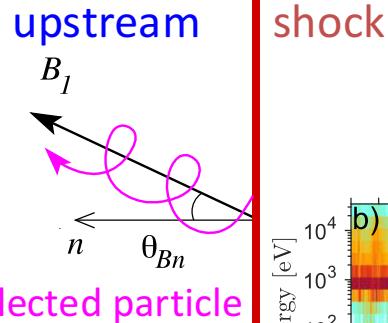
[Meziane et al., 2002]

## 2 Magnetic field orientation: shock obliquity

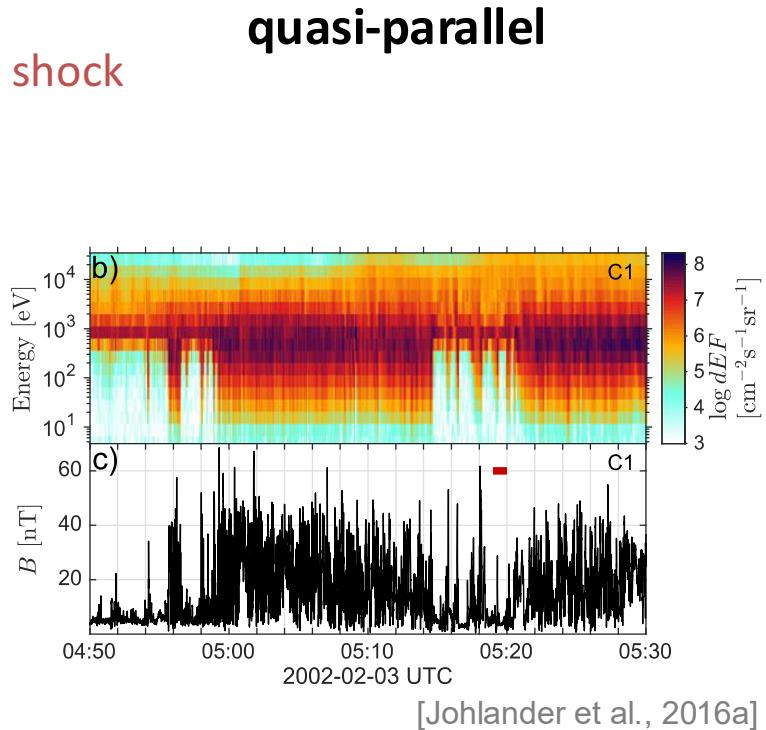
quasi-perpendicular



oblique

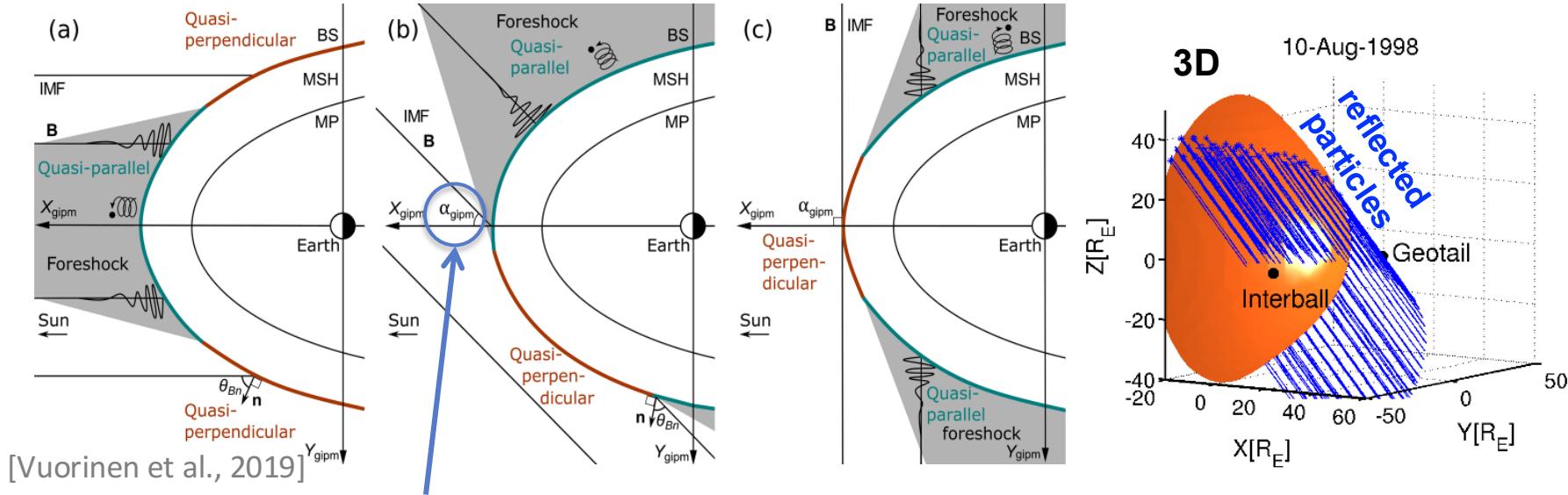


quasi-parallel



## 2 Curved bow shock

quasi-perpendicular and quasi-parallel regions coexist

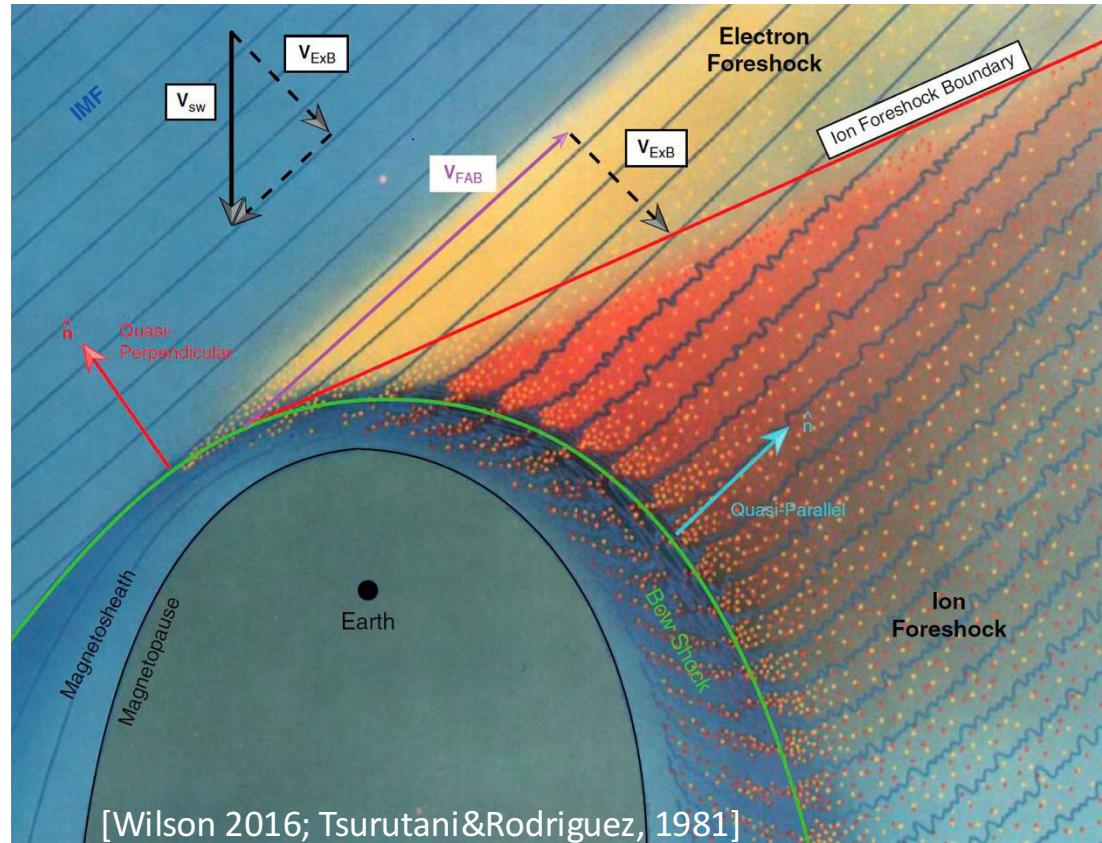


key quantity: IMF cone-angle  $\alpha = \arccos\left(\frac{B_x}{B}\right) \in [0^\circ, 90^\circ]$

(also for the magnetospheric effects of shock dynamics)

## 2 Foreshock and velocity filter effect

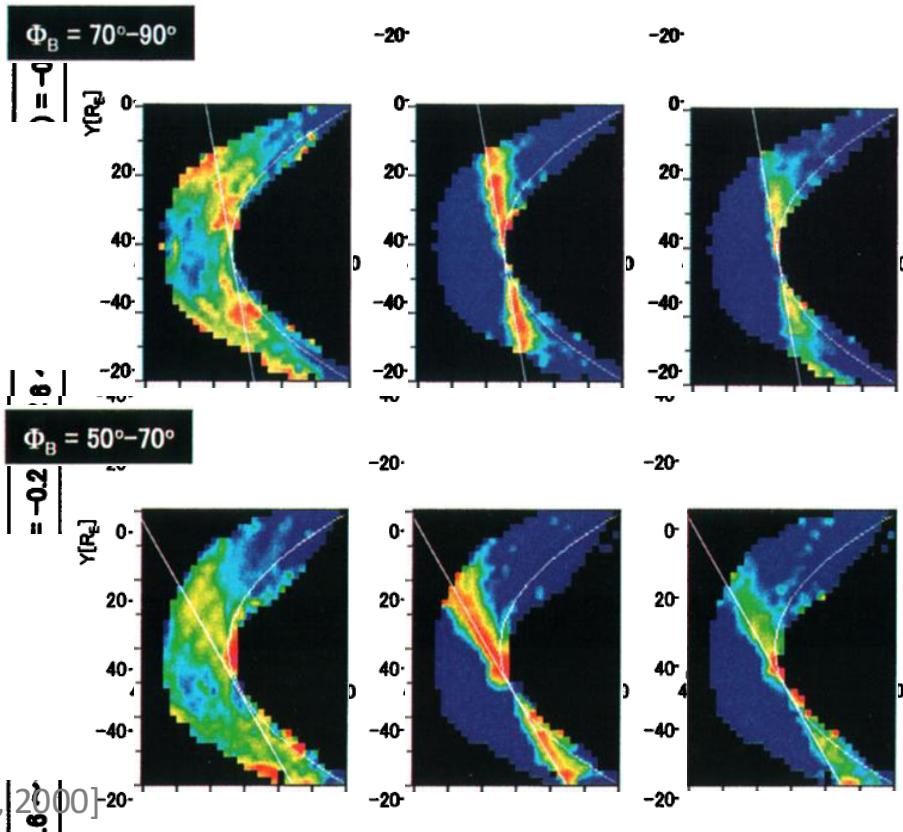
- Foreshock = region upstream of and magnetically connected to the shock and filled with reflected particles and associated instabilities/waves
- $(E \times B)$ -drift velocity is the same for all particles
  - fastest reflected particles seen closest to the tangent field line
  - separation to electron and ion foreshocks
  - particles reflected at a higher  $\theta_{Bn}$  will advect to and modify the shock front at a lower  $\theta_{Bn}$



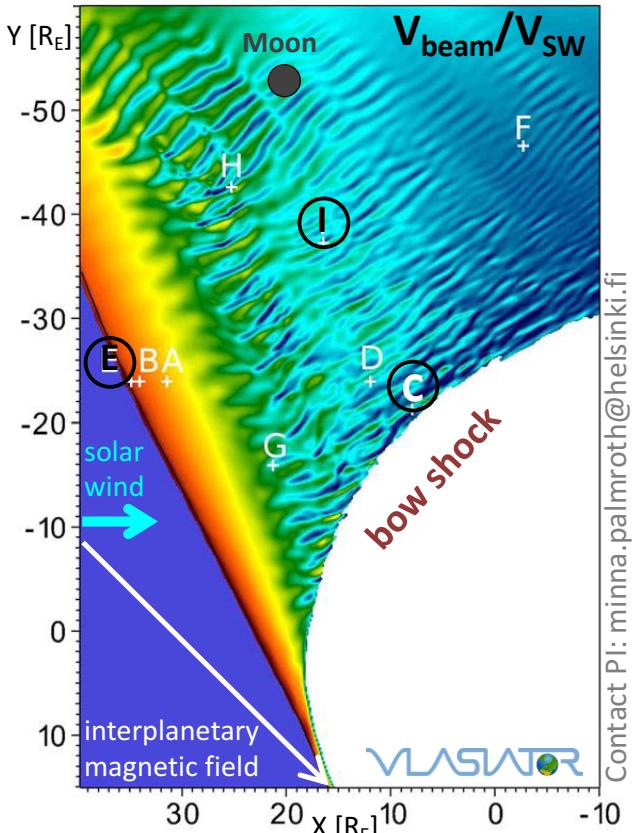
## 2 Electron foreshock

- Electron beams ( $>1$  keV) generate Langmuir waves at the electron plasma frequency, which convert to radio emission at twice the electron plasma frequency
- ISEE-1, Wind, Cluster measurements
- Examples of statistical maps built from Geotail observations [Kasaba et al., 2000]
- Same process as radio emissions from CME-driven shocks in the corona
  - *it's all heliophysics!*

[Kasaba et al., 2000]

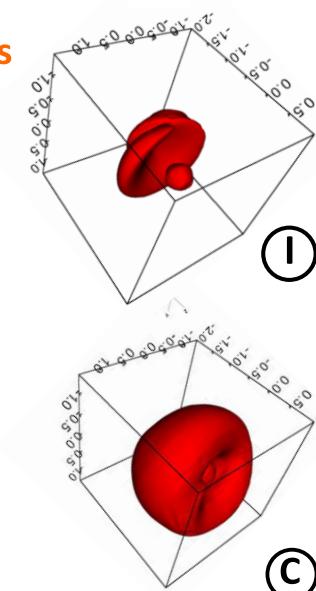
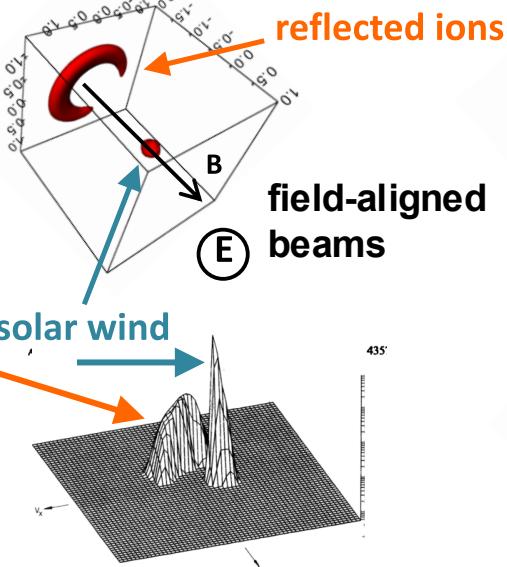


colour:



## 2 Ion foreshock: distribution functions

hybrid-Vlasov simulations and ISEE observations



subject of a separate study [Paschmann et al., 1980]. There was shown that ions reflecting off the bow shock are accelerated because they are displaced parallel to the interplanetary  $\mathbf{v} \times \mathbf{B}$  electric field (see, e.g., Sonnerup [1969]). Varying geometries between the local shock normal  $\hat{\mathbf{n}}$ ,  $\hat{\mathbf{v}}$ , and  $\hat{\mathbf{B}}$  account for the observed variation in beam speed. In fact, the excellent agreement between observed beam speeds and predictions of the  $\mathbf{v} \times \mathbf{B}$  acceleration model is the most convincing evidence that such beams do indeed originate at the bow shock.

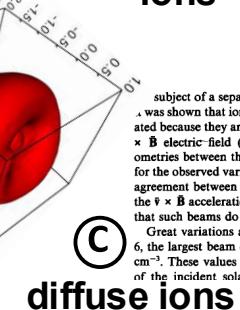
Great variations also occur in the beam density. In Figure 6, the largest beam density  $n_b$  is  $0.8 \text{ cm}^{-3}$ , the smallest  $\sim 0.02 \text{ cm}^{-3}$ . These values correspond, respectively, to 13% and 0.3% of the incident solar wind densities, as measured with the

bution could, for example, have only a single-beam which is always aligned with the temporally varying magnetic field. This would require the magnetic field to undergo substantial ( $\sim 90^\circ$ ) changes in direction within a 3 s period which does not seem to be the case (C. T. Russell, private communication, 1980). Regardless of the explanation, distributions such as shown in Figure 15 demonstrate the need for short snapshot times and good time resolution for studies of upstream ions.

### 4. OBSERVATIONAL SUMMARY

The results described in section 3 may be summarized as follows:

1. The reflected ions have beam-like distribution functions
2. The intermediate ions

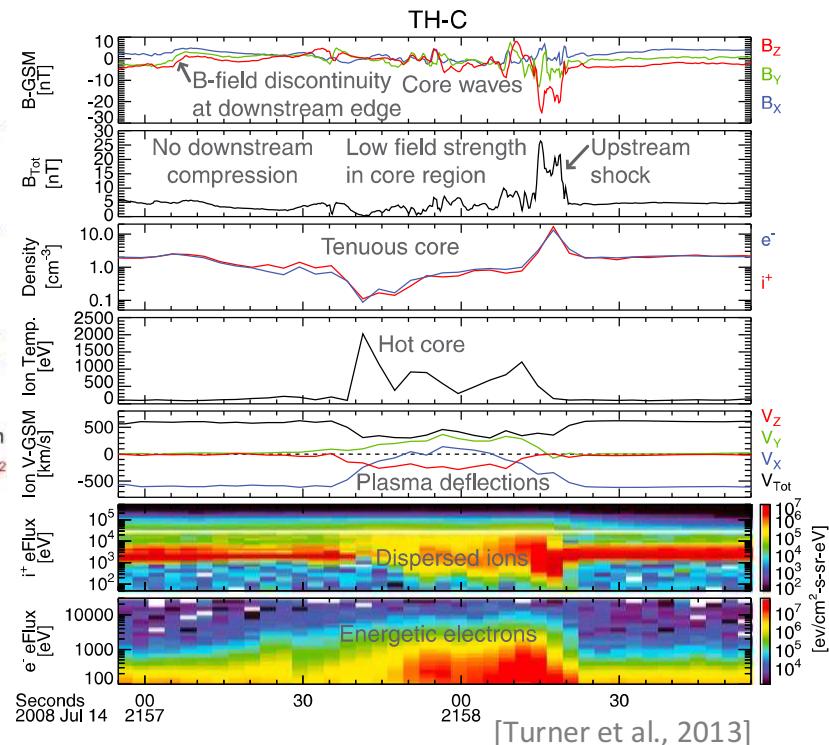
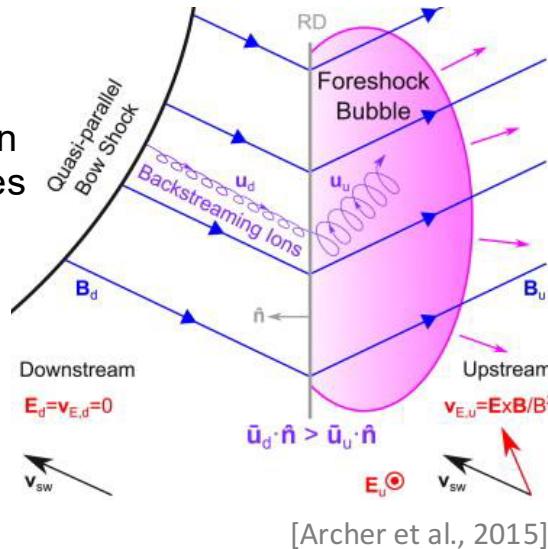


# 3.1 Driven foreshock structures

## foreshock bubbles

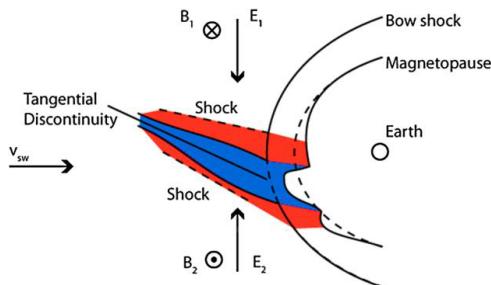
= non-uniform upstream B-field

- what:** a hot core of low density, low magnetic field, with an upstream shock
- driven by** rotational and thin tangential IMF discontinuities [e.g., Liu et al., 2015]
- size  $> 3 R_E$**   
simulations indicate up to the same size as the whole foreshock [Omidi et al., 2010; Liu et al., 2019]
- occurrence rate**  $\sim 1/\text{day}$   
under favorable high solar wind speed conditions [Turner et al., 2013]

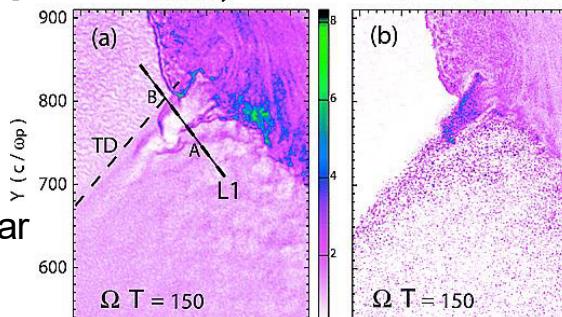


### 3.1 Driven foreshock structures: hot flow anomalies

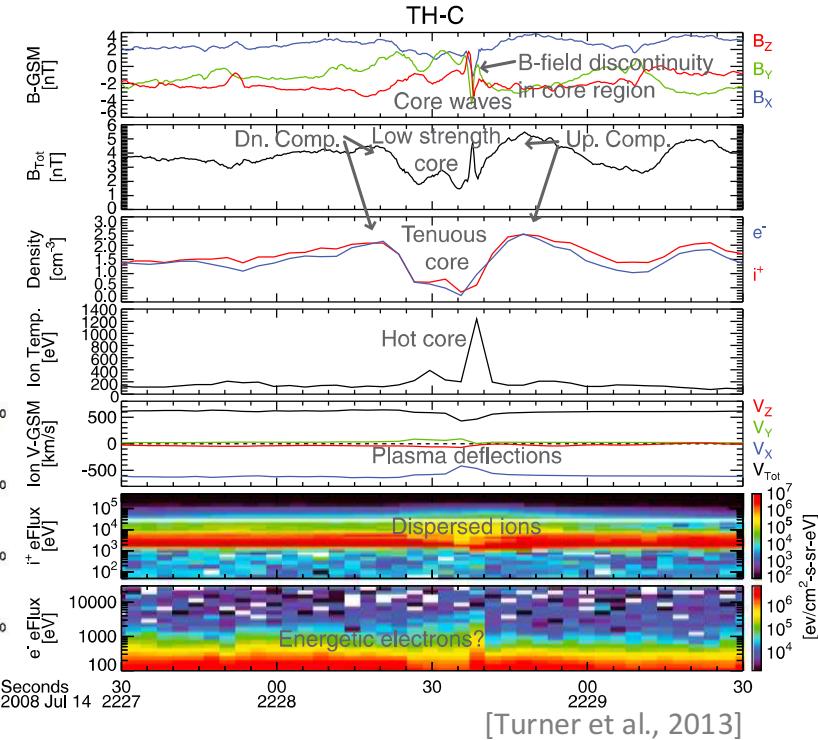
- **what:** suprathermal ions channeled upstream at the **intersection** of a discontinuity with the bow shock, with compressions at its edges
  - AMPTE-UKS: Schwartz et al. [1985]
  - MMS: Schwartz et al. [2018]
- **size a few  $R_E$**   
increases as it travels across the shock
- **occurrence rate**  $\sim 2/h$   
under favorable high solar wind speed conditions  
[Turner et al., 2013]



Density      Ion Temperature



[Omidi&Sibeck, 2007]



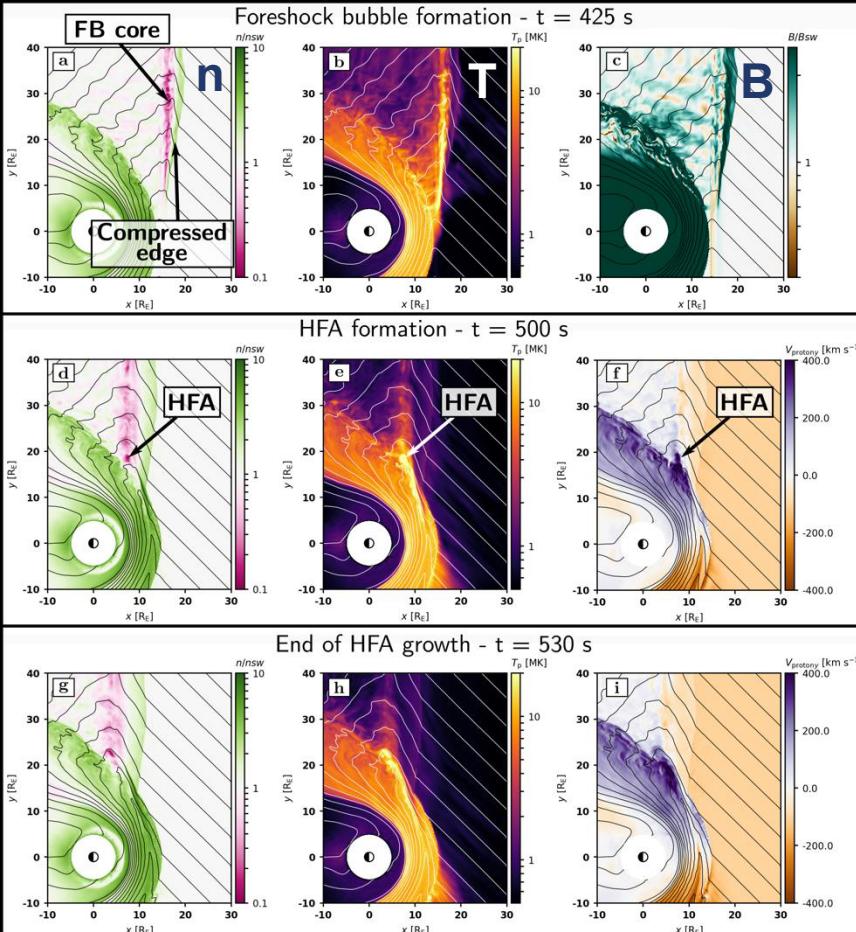
## 3.1 Driven foreshock structures

time

An IMF discontinuity may form both a bubble and an HFA, and in observations it's often difficult to distinguish which structure it is.

**Main point:** a structure with a hot tenuous core driven by a discontinuity.

[Vlasiator simulation, courtesy of L. Turc]

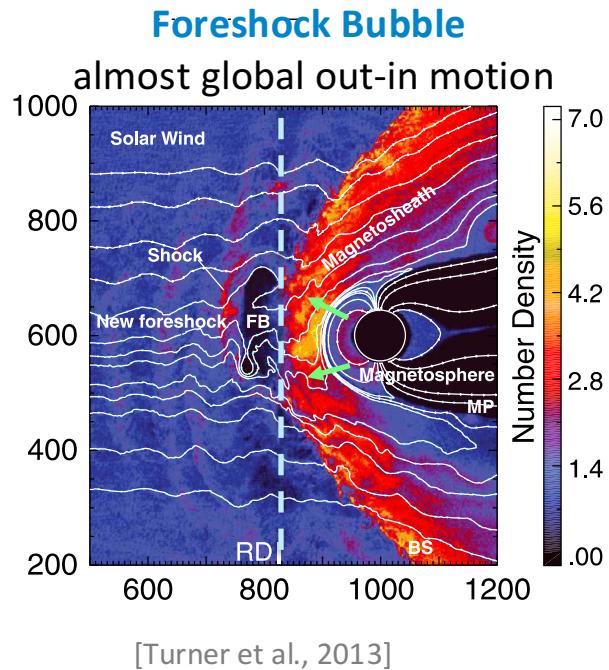


# 3.1 Driven foreshock structures: key effects

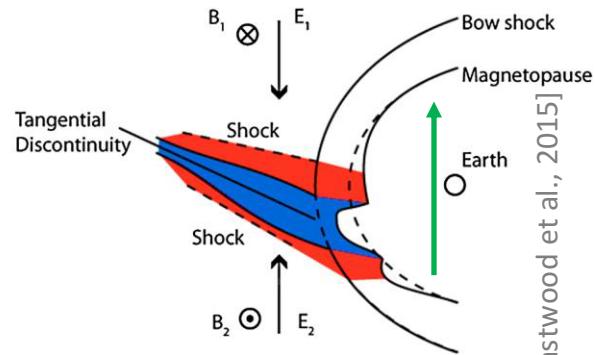
## Particle Acceleration

- **Transients with hot, low-density cores and compressional boundaries**
  - leading shock reflects solar wind ions (secondary foreshock) [Liu et al., 2016]
  - occasional ion acceleration [Liu et al., 2017a; Turner et al., 2018]
  - energized ions leak out of the core [Liu et al., 2017b]
  - **electrons almost always energized**, up to 100s of keVs [e.g., Wilson et al., 2016, Liu et al., 2017a,c Raptis et al., 2024, Shi et al., 2025]

## Magnetospheric Response



**Hot Flow Anomaly**  
a sweeping bulge



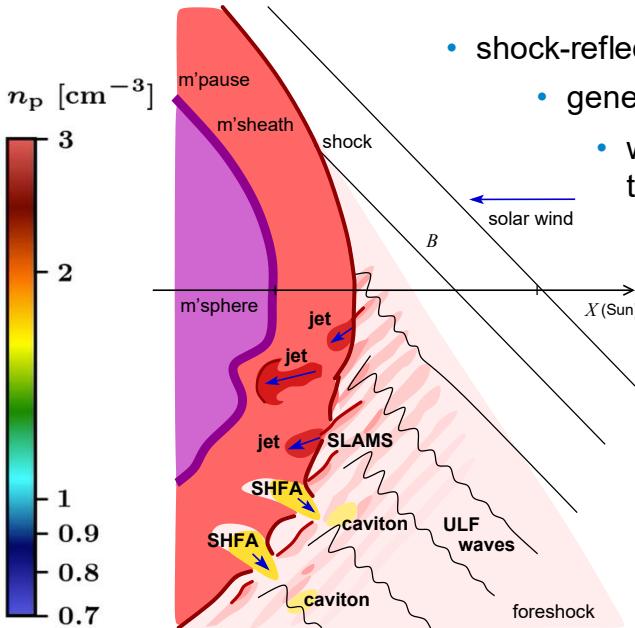
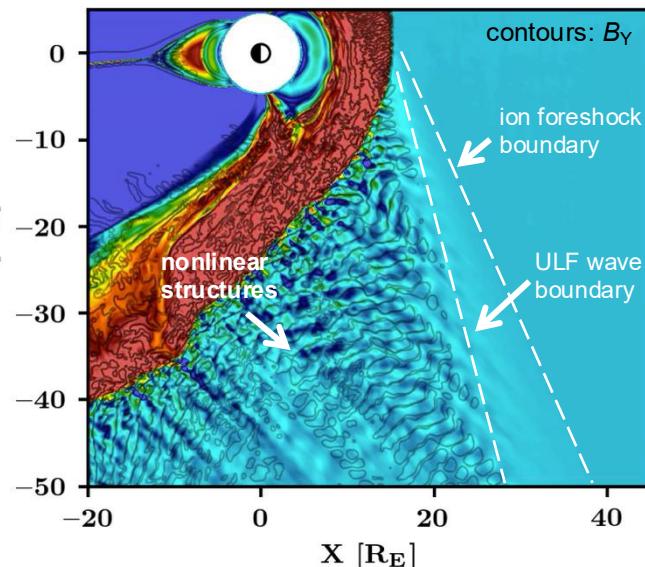
- magnetospheric waves
- aurora
- ground-magnetometers

[Eastwood et al., 2015]

## 3.2 Intrinsic foreshock structures: overview

VLASIATOR

$t = 850$  s



- shock-reflected ions stream against the solar wind
- generate waves ( $\sim 30\text{s}$ ;  $\sim 1R_E$ )
- waves are advected back towards the shock
  - waves undergo nonlinear interactions with themselves, the ions, and locally generated waves, generating structures:
  - troughs/depressions
    - **cavitons**
    - **spontaneous hot flow anomalies**
  - peaks/enhancements
    - **shocklets**
    - **short large amplitude magnetic structures (SLAMS)**

Contact PI: minna.palmroth@helsinki.fi; movie by M. Battarbee

## 3.2 Where it starts: waves

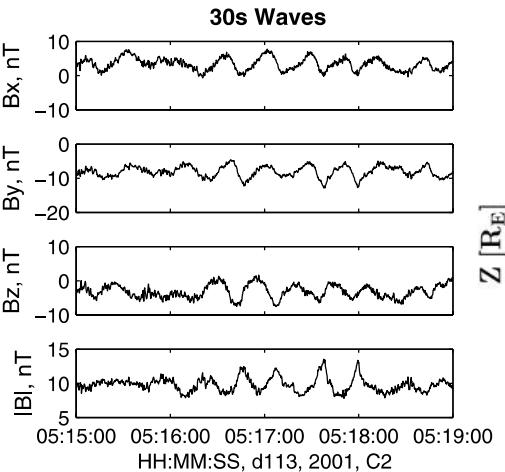
- **focus:** sunward propagating fast magnetosonic waves
- **generated by** right-hand ion-beam instability between SW and reflected ions
- **period** depends on IMF strength and orientation:

$$\omega_{sc} = \frac{qB}{m} \frac{\cos \theta_{Bx} \cos \theta_{Bn}}{\cos \theta_{nx}}$$

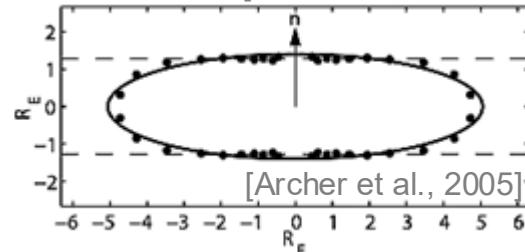
[Takahashi et al., 1984; Le&Russell, 1996]

**~30s period at Earth; ~1  $R_E$  wavelength**

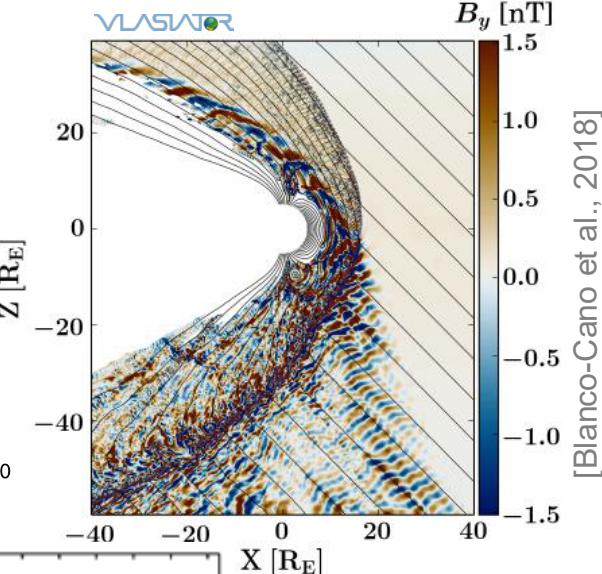
- large amplitude  $|\delta\mathbf{B}|/B \sim 1$
- $\mathbf{k}$  deflected from  $\mathbf{B}$   $\sim 20^\circ$  due to refraction by spatially varying suprathermal ions
- convected by the solar wind towards the shock, modify it, and transmit into the magnetosphere



[Eastwood et al., 2005]



[Archer et al., 2005]



$B_y$  [nT]

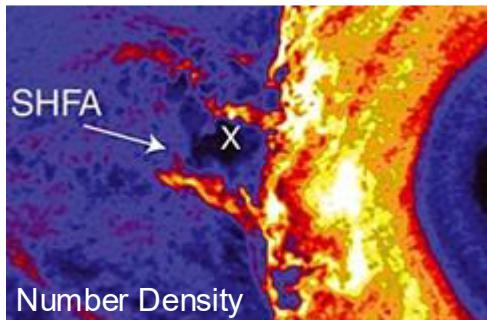
[Bianco-Cano et al., 2018]

Review:  
[Wilson 2016]

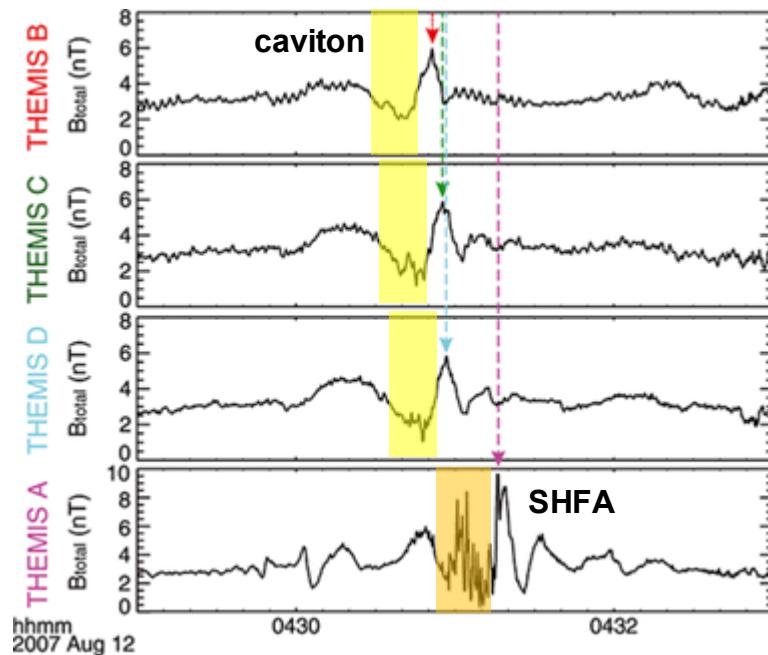
## 3.2 Troughs: cavitons and spontaneous hot flow anomalies

- **cavitons:** depressions of n and B, but no T increase, with “shoulders” at outer edges
- **where:** deep in the ion foreshock, surrounded by waves [Kajdic et al., 2017]
- **form by interaction of parallel and obliquely propagating waves**  
[Blanco-Cano et al., 2009]
- **Spontaneous Hot Flow Anomalies:** decrease in n and B, with increase in T
- **form from cavitons**  
[Zhang et al., 2013]

- **size  $\sim 1 R_E$**   
same as 30s waves
- **effects:** modify (weaken) the bow shock

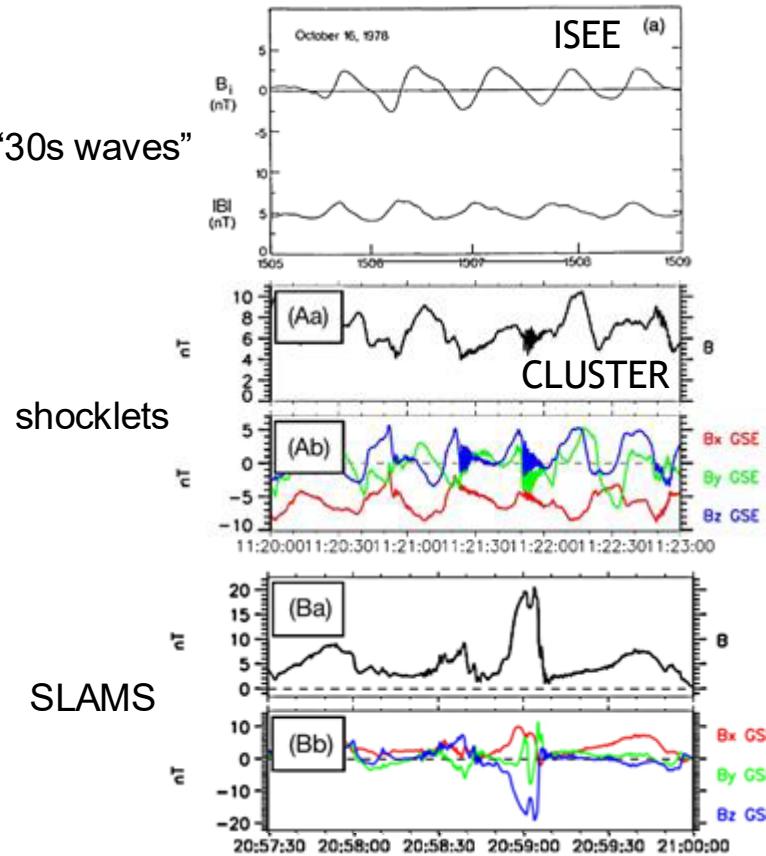


[Omidi et al., 2013]



## 3.2 Peaks: shocklets and SLAMS

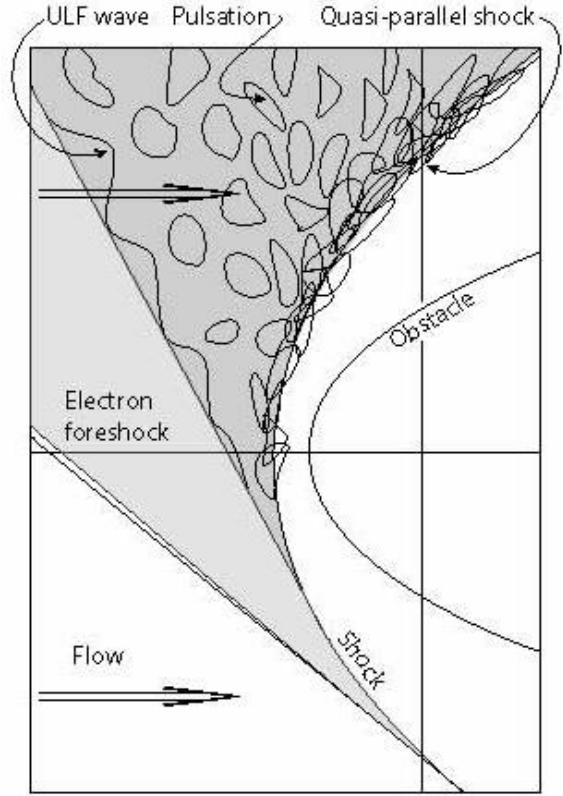
- “**30s waves**”: fast magnetosonic waves  $|\delta B|/B_0 \sim 1$
- **shocklets**: steepened waves, associated with whistler wave packets and diffuse backstreaming ion distributions,  $1 \lesssim |\delta B|/B_0 \lesssim 2$  [e.g., Hoppe et al., 1981]
- **where**: close to the bow shock
- **size ~ 1  $R_E$**  (~30s) [e.g., Le and Russell, 1994]
- **Short Large Amplitude Magnetic Structures (SLAMS)**: fast mode pulsations, monolithic,  $|\delta B|/B_0 > 2$  (up to 10)  
fast mode pulsations, monolithic,  $|\delta B|/B_0 > 2$  (up to 10)
- **where**: close to the bow shock (they are the shock)
- **size > 1000 km** [Lucek et al., 2004; 2008]
- **importance**: ion energization by reflection and trapping  
slow down the incoming flow  
“building blocks” of the quasi-parallel shock  
[e.g., Schwartz et al., 1991; 1992; Johlander et al., 2016a]



[Hoppe et al., 1983]

[Plaschke et al., 2018]

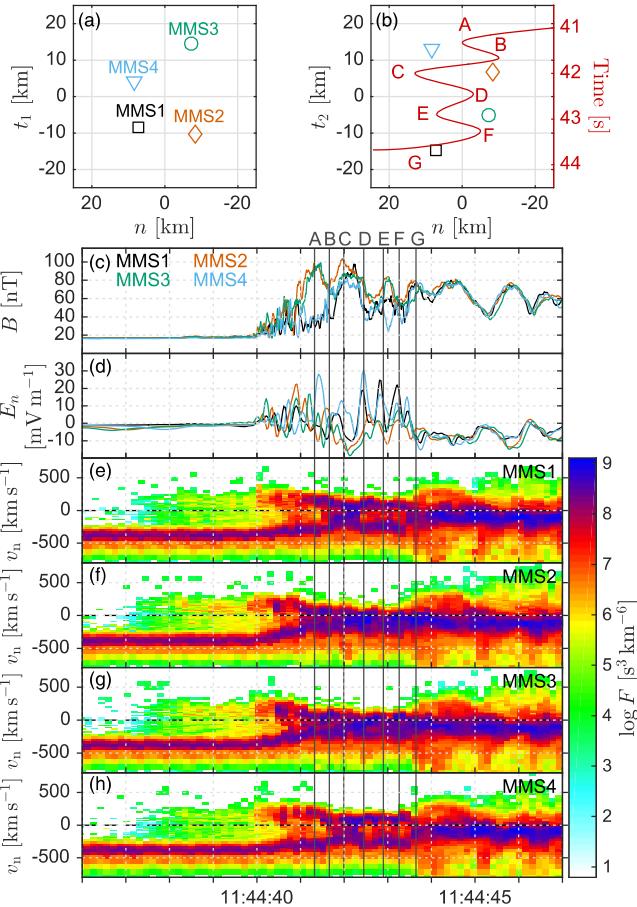
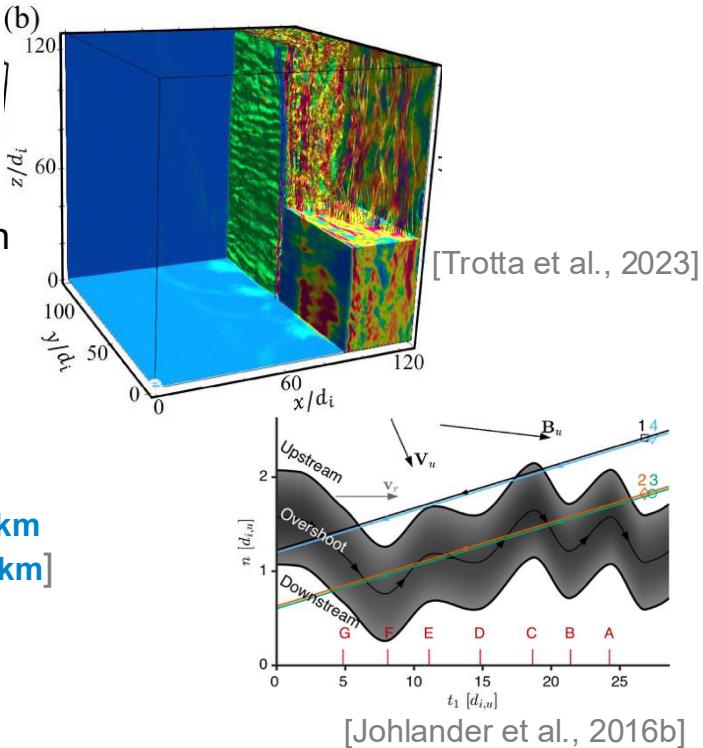
# From meso-scale to fine structures



[Treumann&Jaroschek, 2008]

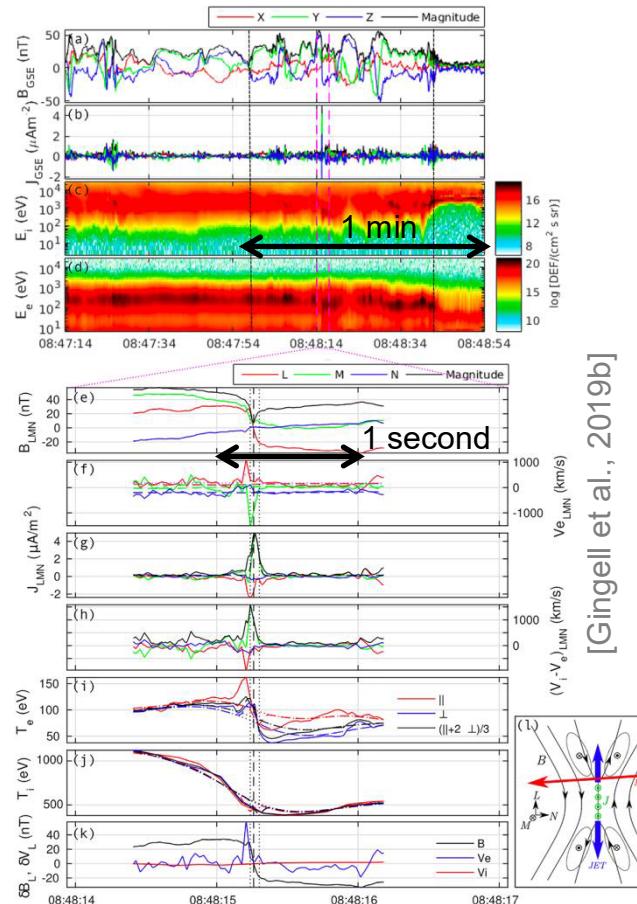
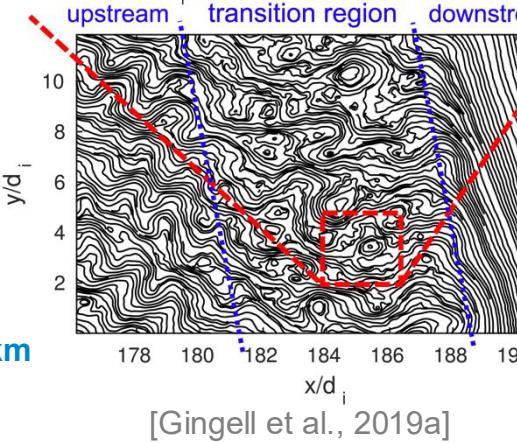
# 4 Fine structures: quasi-perp shock surface ripples

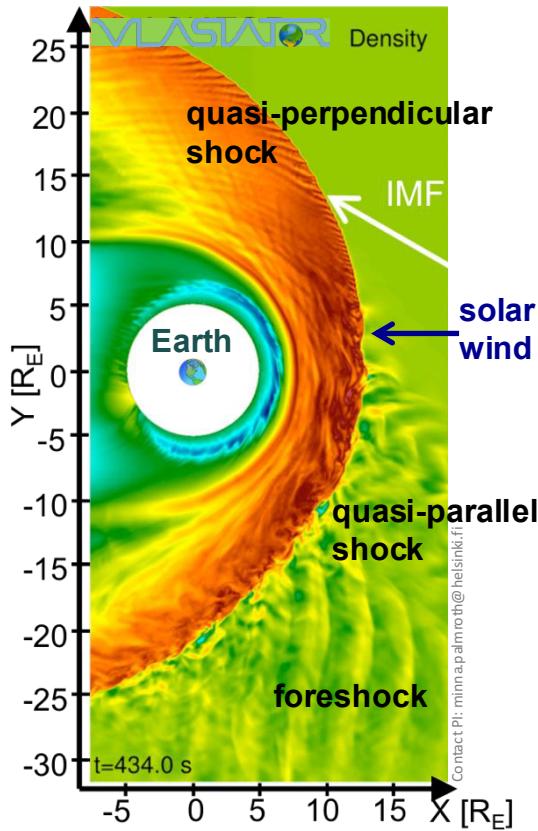
- Shock non-stationarity: ripples and reformation
- Affects electron acceleration and ion reflection
- Simulation predictions [e.g., Lowe&Burgess 2003]
- Quantitative observations [Johlander et al., 2016b]
  - ripple wavelength  $\sim 4 d_{iu} \sim 175$  km
  - ripple amplitude  $\sim 0.25 d_{iu} \sim 10$  km



# 4 Fine structure: reconnection within the shock front

- First observed at oblique and quasi-parallel geometries  
[Wang et al., 2019;  
Gingell et al., 2019a]
- Statistical observations  
[Gingell et al., 2019b]
  - present for all shock obliquities
  - current sheet widths  $\lesssim 10 d_e \sim 8\text{ km}$
  - typically feature electron-only reconnection
  - **primary consequence:** **relaxing magnetic topology** (not heating)
- Simulations
  - [e.g., Bohdan et al., 2017; Gingell et al., 2017; Matsumoto et al., 2015]





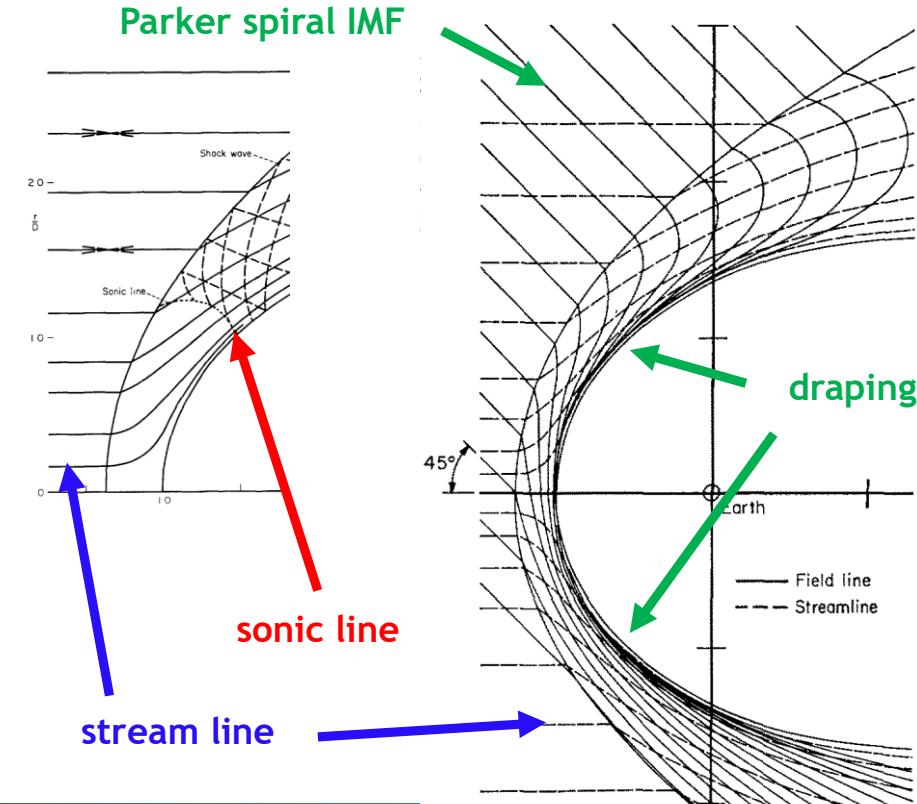
# Magnetosheath outline: from large to small

1. Large scale flow and properties ( $15\text{-}50 R_E$ )
2. Shock obliquity:  
quasi-perpendicular and quasi-parallel sheath ( $\sim 20 R_E$ )
3. Magnetopause: ( $\sim 20 R_E$ )  
open or closed
4. Instabilities  
mirror modes vs turbulence ( $10\text{-}100 \text{ km}$ )  
reconnection in turbulence ( $4\text{-}100 \text{ km}$ )
5. Transient jets ( $600 \text{ km} - 1 R_E$ )

# 1 Early magnetosheath modelling

Spreiter et al. (1966)

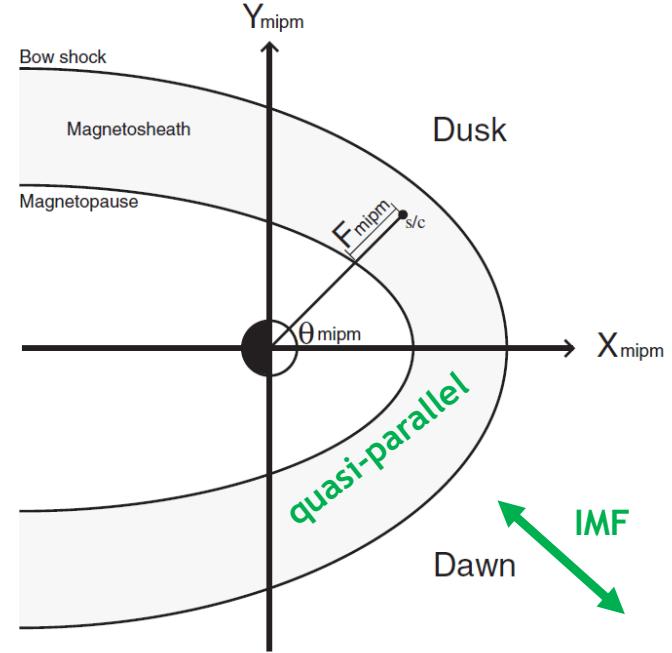
- modelling of flow and shock wave:
  - gas dynamic theory (hydrodynamic)
- magnetopause:
  - tangential discontinuity
  - pressure balance
  - axisymmetric
  - field inside:  
twice the geomagnetic dipole field
- magnetic field:
  - frozen-in, added afterwards



# 2 Compiled observations: taking shock obliquity into account

magnetosheath interplanetary medium  
reference frame: MIPM

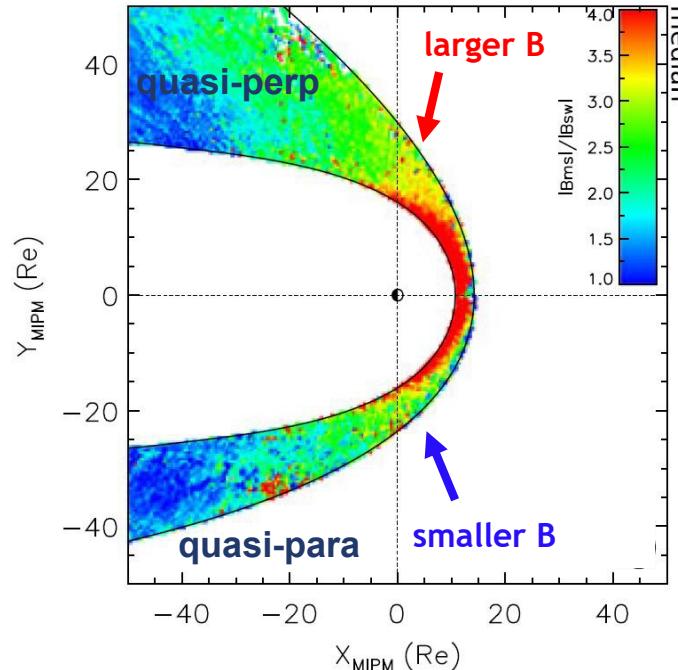
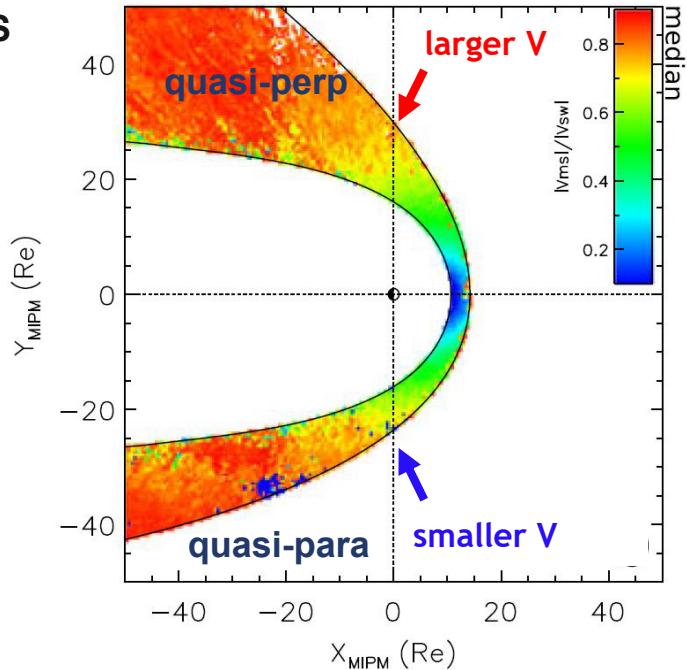
- X:
  - against solar wind flow
  - aberrated Earth-Sun-line
- Y:
  - IMF in X-Y-plane
  - quasi-parallel on -Y side
- bow shock and magnetopause models
  - Verigin et al. (2001)
  - Shue et al. (1998)
- F:
  - radial fractional distance between boundaries



Dimmock and Nykyri (2013)

## 2 Compiled observations: velocity and magnetic field differences

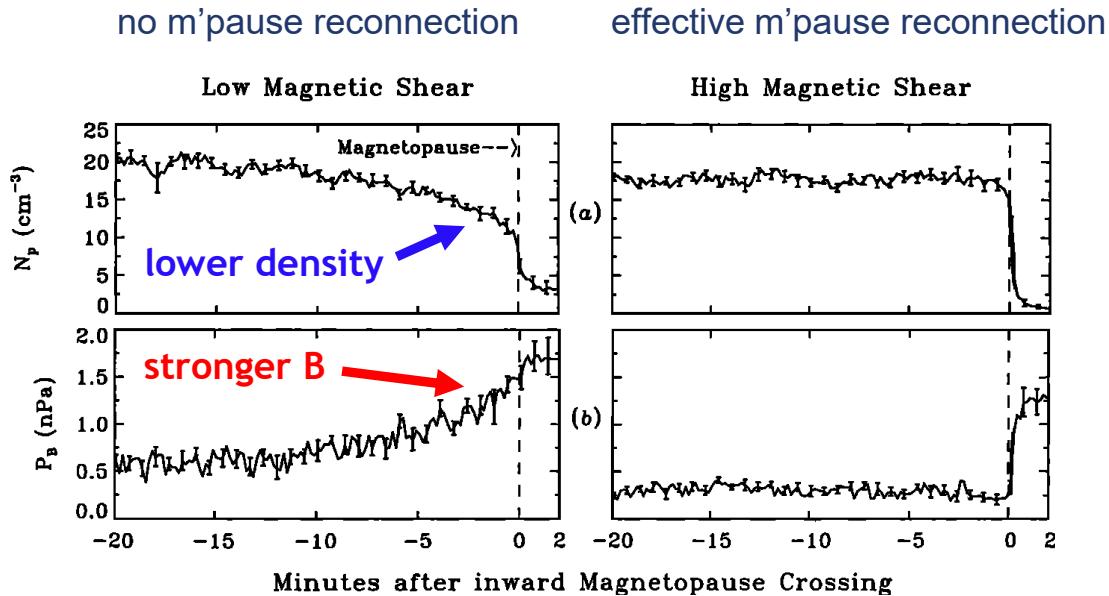
THEMIS



Dimmock and Nykyri (2013)

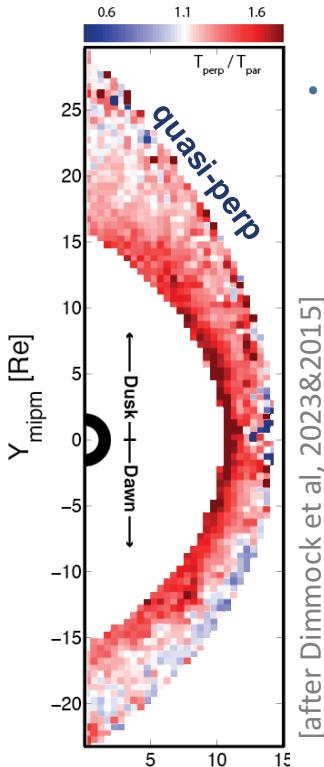
# 3 Closed magnetopause leads to plasma depletion layer

- conditions
  - strongly northward IMF
  - effect enhanced during low  $M_A$
- observations
  - plasma-depleted flux tubes piled-up against magnetopause
  - strong acceleration on the flanks due to magnetic pressure gradient and magnetic tension forces

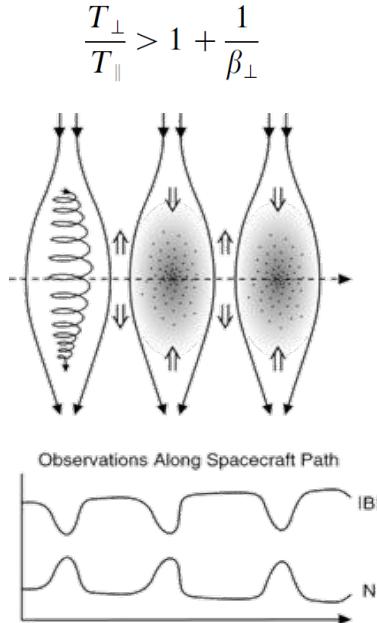


[Phan et al, 1994]

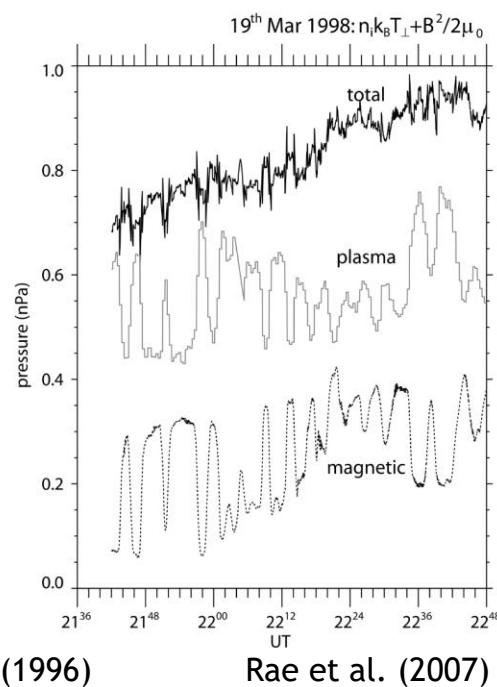
# 4 Instabilities: quasi-perp sheath mirror modes



- ion T anisotropy:  
 $T_{\text{perp}} > T_{\text{para}}$ 
  - high beta: mirror modes
    - spatially periodic pattern of “magnetic bottles”
    - $B$  and  $n$  anti-correlated, slow-mode type disturbance, pressure balance
    - no motion in plasma rest frame
    - size: several ion gyroradii, hundreds of km
  - Laitinen et al. (2010):
    - modulation of MP reconnection by mirror modes (beta variations)



Treumann and Baumjohann (1996)



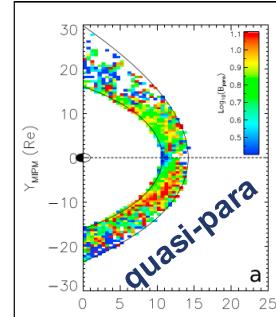
Rae et al. (2007)

# 4 Turbulent fluctuations: quasi-para sheath has more power

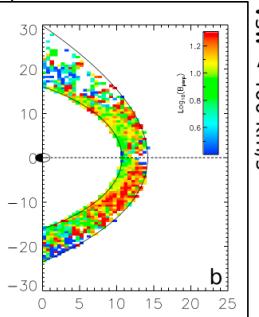
compressional:

transverse:

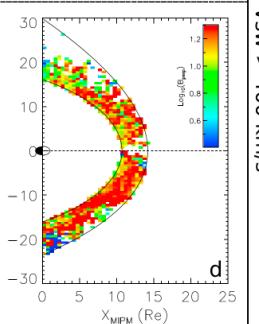
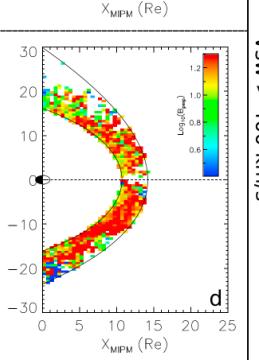
$B_{\text{para}}$



$B_{\text{perp}}$



fluctuations: 0.1 - 2 Hz



Dimmock et al. (2014)

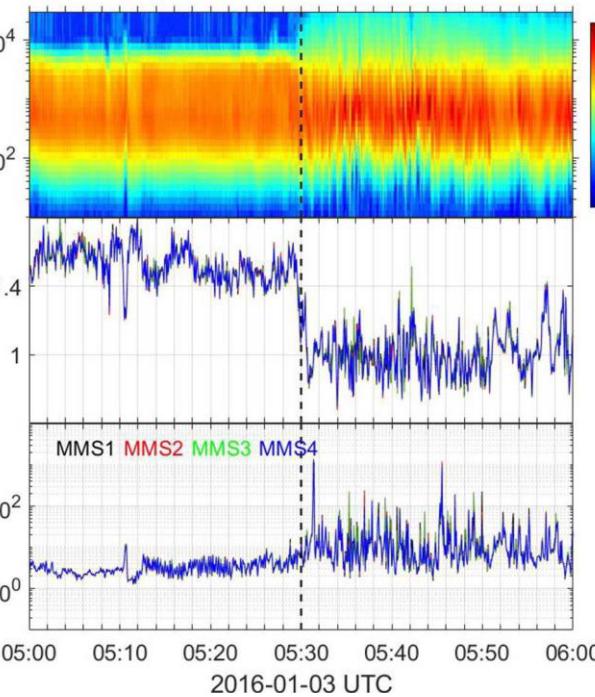
quasi-perpendicular

quasi-parallel

$E_i$  (eV)

$T_{\perp}/T_{\parallel}$

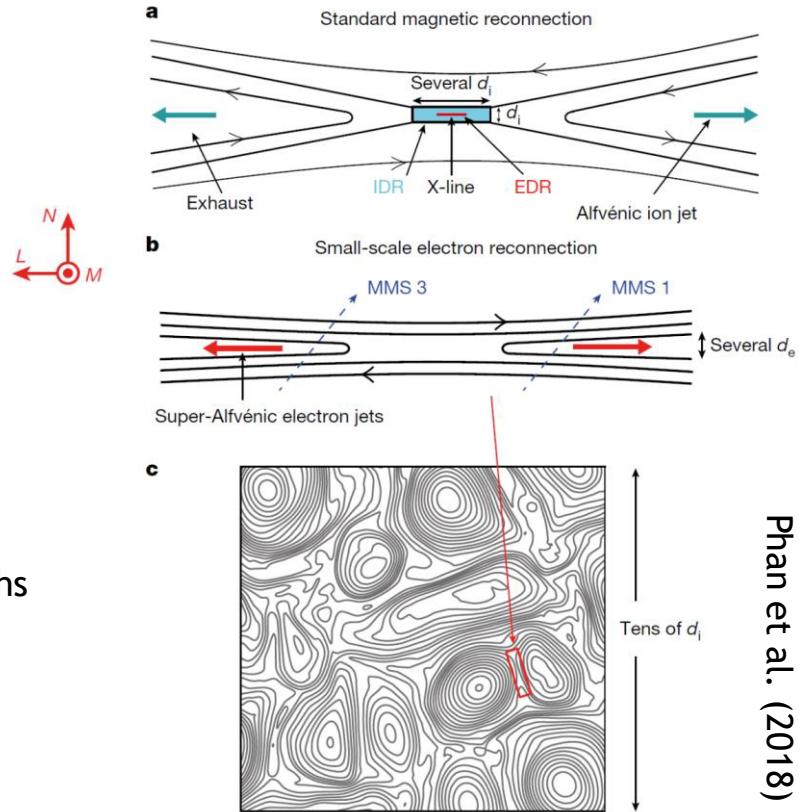
$\beta$



Yordanova et al. (2020)

# 4 Turbulent fluctuations: reconnection in thin current sheets

- Cluster observations
  - Retino et al. (2007)
    - current sheet scale: ion inertial length  
 $d_i = 1\text{s} = 100\text{km}$
    - in situ evidence of reconnection and crossing of the ion diffusion region
- MMS observations
  - Vörös et al. (2017)
  - Phan et al. (2018): electron-only reconnection
    - current sheet scale: few electron inertial lengths  
 $4 d_e = 45\text{ms} = 4\text{km}$
    - intense electron outflow and current
    - $J^*E' > 0$
    - no ion-scale current layer, no ion jets



# 5 Transients: magnetosheath jets

localised downstream dynamic pressure enhancements:  $\rho V_x^2$

size:  $\sim 0.5 R_E \sim \text{tens of } d_i$

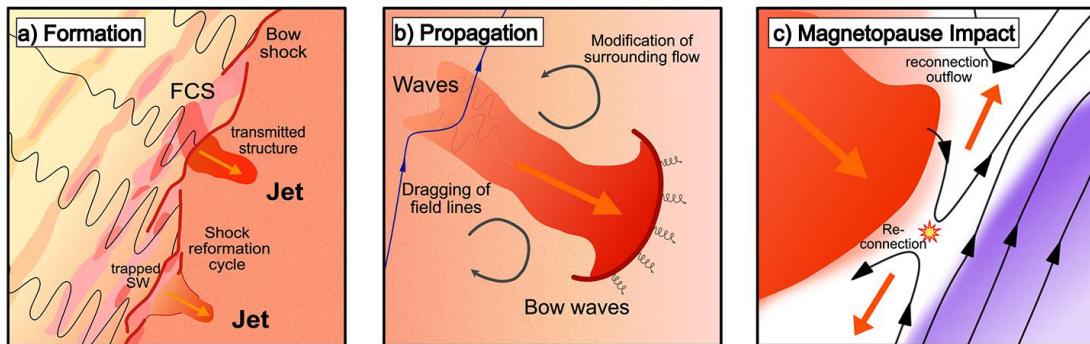
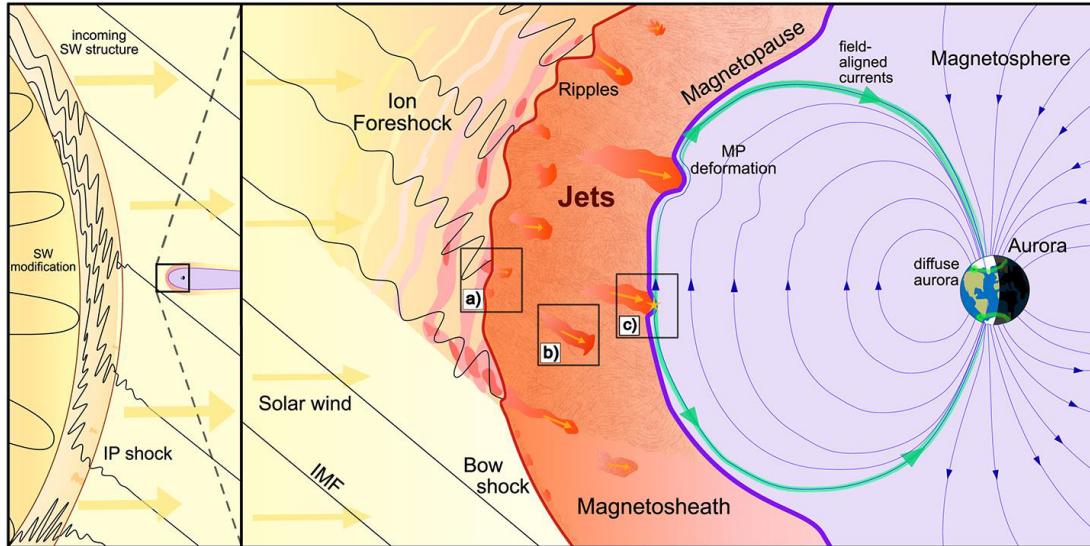
occurrence:  $\sim 3 \text{ jets/h}$

from: shock kinetic processes

drive: particle acceleration,  
large amplitude waves,  
reconnecting current sheets

reviews:

[Plaschke et al., 2018; Kraemer et al., 2025]



[courtesy of F.Koller]



# Transient structures near shocks

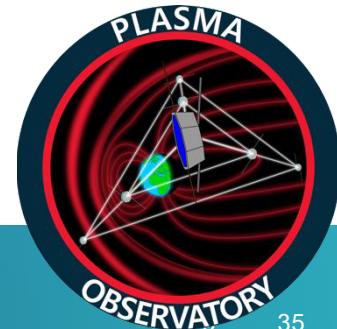
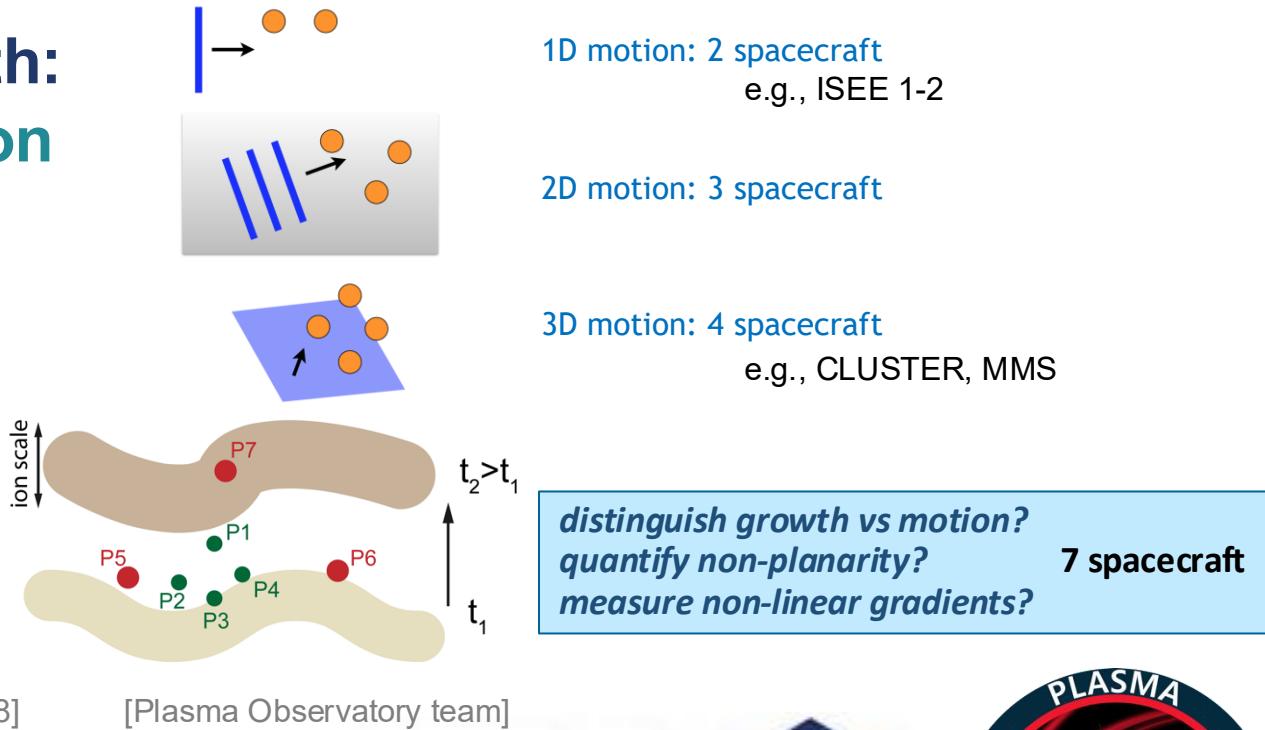
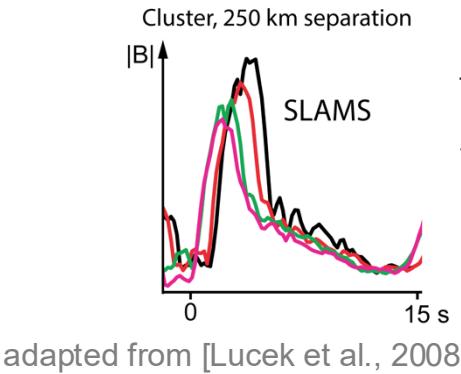
## summary

	coronal shocks	interplanetary shocks	Mercury	Venus	Earth	Mars	Jupiter	Saturn	Titan	comets	termination shock
ULFs	?	yes	yes	yes	yes	yes	yes	yes	?	yes	?
shocklets	?	rare	yes?	yes	yes	yes	yes	yes	yes	yes	?
SLAMS	?	no?	yes	yes	yes	yes	yes	yes	?	yes	?
SHFAs	?	?	?	yes	yes	yes	?	?	yes?	?	?
HFAs	?	?	maybe?	yes	yes	yes	yes	yes	?	?	?
FBs	?	?	?	?	yes	?	?	?	?	?	?
jets	?	yes	maybe?	?	yes	yes?	yes?	yes?	?	?	?

System specific but  
universal physical processes

[Hietala et al. ISSI 2019]

# What's next for Earth: constellation mission



# Backups

# Shock scales exercise: interplanetary shocks

Each of you will get your own shock event observed by Wind spacecraft at L1 and **explore it at different scales**, and **compare with neighbor**

How to access and plot data on CDAWeb:

<https://cdaweb.gsfc.nasa.gov/>

1) Select Wind spacecraft (last in the alphabetic list)  
and  
magnetic fields (space)

and press “submit”

**Guides and Tutorials**

- CDAWeb Help
- Internet browser help

**Direct Access to Data**

- Direct HTTP Access to Data
- Direct File Transfer (FTP) (required)

**Additional Services**

- CDAWeb Home
- Overview of Alternative Data Access Methods
- All-Sky Image (NASA) interface to CDAWeb
- New Plot Werk for viewing pre-generated plots

**Additional Resources**

- 1-Minute Overview
- Space Physics Use of CDF
- Space Physics Bibliography
- CDAWeb Home Page
- Data Inventory Graphics
- PSP Home Page

**CDAWeb**

CDAWeb provides selected public non-solar heliospheric data from current and past heliospheric instruments products. Many products have current releases are updated regularly (hourly data), including measurements from one vehicle, and PSP only preserves the latest version. To find all of the public data and documents archived by the PSP, see the [SPDF archive](#). To search for additional heliospheric data products, check the heliosphere data portal.

**REMINDER: CDAWEB OFFERS CREATION OF SUBSETS/CREATES OF DATA (BY DATE AND VARIABLES).**

**CREATION OF CURRENTLY TIME BINNED DATA, PLOTS IN PDF, PS AND PNG FORMATED FILES, MOVIES OF SPECIFIC IMAGE SEQUENCES, ON-THE-FLY INVENTORY PLOTS, ADJUSTABLE HEIGHT TIME/SPEC/PROG PLOTS, etc., plus many more options...**

**NEW**

April 2025: The hourly ephemeris file (eck, helc) for the position for heliospheric/planetary missions, plasma parameters, and magnetic field values in SPDF database are now available. They are in ASCII text data in Helios (https://cdaweb.gsfc.nasa.gov/cdaWeb/Helios). The daily orbit data values equal to the hourly orbit data values at the beginning of each day (hour = 0). The daily orbit data values are also available in the CDAWeb database.

March 2025: The PSP data set was converted to December 2024 availability depending on the data sets), covering Encounters 20 and 21 and the inbound leg of Orbit 22. Please check the system, the PSP inventory page and the annual inventory plots for details.

**PREVIOUS DATA & SOFTWARE UPDATES ...**

**Select from OR More Sources** (Select - All Sources if r=1 Instrument Type is selected)

Balloons

Geophysical Investigations

Ground-Based Investigations

Heliophysics

Interplanetary Space (IP) Data, Magnetic and Solar Indices

Ionosphere/Cubesats

Sounding Rockets

ACE

AIM

AMPTE

ARTEMIS

AWE

Atmosphere

Apollo

Arase (ERG)

Biosatellite

CNES

Cluster

DIMP

DISCOV

Double Star Cluster Explorer

Equator-S

FAST

Formosa

GOES

GOLD

GPS

Genesis

Geotail

Hawkeye

Helios

BEX

ICON

IMAGE

IMP (AG)

ISEE

IBS

ISS

Interball

LAGEOS

MAVEN

MESSENGER

MMS

Mariner

Mars Global Surveyor (MGS)

Mars Science Laboratory (MSL)

NOAA

New Horizons

POES/MICrop

Polar-Solar Probe (PSP)

Pioneer

Polar

REACH

SAMPEX

SOHO

STS

STEREO

Solar Orbiter

THEMIS

TIMED

TSS-IR

TWINS

Ulysses

Van Allen Probes (RBSP)

Voyager

Wind

**Select from OR More Instrument Types** (Select - All Instrument Types if r=1 Source is selected)

Active Imagers

Electric Fields (space)

Electron Precipitation Bremsstrahlung

Electron Spectrometer

Electron/Wave Particle Detector

Engineering

EPIC

Ephemeral/Altitude/Auroral

Gamma X-Rays

Ground-Based Radiations

Ground-Based Images

Ground-Based Magnetometers, Rometers, Sounders

Ground-Based ULX/LULU/LULU+ Photometers

Heatmaps

Imaging and Remote Sensing (ITM/Earth)

Imaging and Remote Sensing (Mars)

Imaging and Remote Sensing (Sun)

Linear Energy Transfer Spectrometer

Magnetic Fields (Balloon)

Magnetic Fields (space)

Magnetic Fields (wave)

Particles (space)

Plasma and Solar Wind

Pressure gauge (space)

Radio and Plasma Waves (space)

Selected Potential Control

UV Imaging Sprites (Space)

# Shock scales exercise: interplanetary shocks

Submit

- OMNI\_HRO\_1MIN:** OMNI Combined, Definitive, 1-minute IMF and Plasma Data Time-Shifted to the Nose of the Earth's Bow Shock [Available Time Range: 1981/01/01 00:00:00 - 2025/04/20 23:59:00] [Info](#) [DOI](#) [Metadata](#)
- OMNI\_HRO\_5MIN:** OMNI Combined, Definitive, 5-minute IMF and Plasma, and Energetic Proton Fluxes, Time-Shifted to the Nose of the Earth's Bow Shock [Available Time Range: 1981/01/01 00:00:00 - 2025/04/20 23:55:00] [Info](#) [DOI](#) [Metadata](#)
- OMNI\_HRO2\_1MIN:** OMNI Combined, Definitive 1-minute IMF and Definitive Plasma Data Time-Shifted to the Nose of the Earth's Bow Shock [Available Time Range: 1995/01/01 00:00:00 - 2025/04/20 23:59:00] [Info](#) [DOI](#) [Metadata](#)
- OMNI\_HRO2\_5MIN:** OMNI Combined, Definitive 5-minute IMF and Definitive Plasma, and Energetic Proton Fluxes, Time-Shifted to the Nose of the Earth's Bow Shock [Available Time Range: 1995/01/01 00:00:00 - 2025/04/20 23:55:00] [Info](#) [DOI](#) [Metadata](#)
- OMNI2\_H0\_MRGR1HR:** OMNI Combined, Definitive, Hourly IMF and Plasma Data, and Energetic Proton Fluxes, Time-Shifted to the Nose of the Earth's Bow Shock [Available Time Range: 1963/01/01 00:00:00 - 2025/05/02 11:00:00] [Info](#) [DOI](#) [Metadata](#)
- OMNI\_COHO1HR\_MERGED\_MAG\_PLASMA:** OMNI Combined merged hourly magnetic field, plasma and ephemeris data - J.-H. F. [Info](#) [DOI](#) [Metadata](#)
- WI\_H0\_MFI:** Wind Magnetic Fields Investigation: 3 sec, 1 min, and hourly Definitive Data. - A. Koval (UMBC, NASA/GSFC) [Available Time Range: 1994/11/13 00:00:30 - 2025/05/07 23:59:30] [Info](#) [DOI](#) [Metadata](#)
- WI\_H2\_MFI:** Wind Magnetic Fields Investigation, High-resolution Definitive Data - A. Koval (UMBC, NASA/GSFC) [Available Time Range: 1994/11/13 15:50:26 - 2025/05/07 23:59:59] [Info](#) [DOI](#) [Metadata](#)
- WI\_H3-RTN\_MFI:** Wind Magnetic Fields Investigation: 3 sec, 1 min, and hourly Definitive Data (RTN). - A. Koval (UMBC, NASA/GSFC) [Available Time Range: 1994/11/13 00:00:30 - 2025/05/07 23:59:30] [Info](#) [DOI](#) [Metadata](#)
- WI\_H4-RTN\_MFI:** Wind Magnetic Fields Investigation, High-resolution Definitive Data (RTN) - A. Koval (UMBC, NASA/GSFC) [Available Time Range: 1994/11/13 15:50:26 - 2025/05/07 23:59:59] [Info](#) [DOI](#) [Metadata](#)
- WI\_K1-RTN\_MFI:** Wind Magnetic Fields Investigation, Key Parameters in RTN [PRELIM] - Andriy Koval (UMBC&GSFC) [Available Time Range: 2017/01/01 00:00:19 - 2025/05/08 23:58:36] [Info](#) [DOI](#) [Metadata](#)
- WI\_K0\_MFI:** Wind Magnetic Fields Investigation, Key Parameters [PRELIM] - R. Lepping (NASA/GSFC) [Available Time Range: 2017/07/01 00:00:00 - 2025/05/11 23:59:32] [Info](#) [DOI](#) [Metadata](#)
- WI\_H1\_SWE:** Wind Solar Wind Experiment, 92-sec Solar Wind Alpha and Proton Anisotropy Analysis - K. Ogilvie (NASA GSFC) [Available Time Range: 1994/11/17 19:50:45 - 2025/03/19 23:53:26] [Info](#) [DOI](#) [Metadata](#)
- WI\_H1\_SWE\_RTN:** Solar wind proton and alpha parameters, including anisotropic temperatures, derived by non-linear fitting of the Wind data - K. Ogilvie (NASA GSFC) [Available Time Range: 1994/11/17 19:50:45 - 2025/03/19 23:53:26] [Info](#) [DOI](#) [Metadata](#)
- WI\_K0\_GIFWALK:** Links to Wind KP pre-generated survey and other plots - Polar-Wind-Geotail Ground System (NASA GSFC) [Available Time Range: Select dataset for details] [Info](#) [DOI](#) [Metadata](#)

Submit Reset

# Shock scales exercise: interplanetary shocks

3) Here you will insert your event time (in a moment)

and here you will select your magnetic field data at different cadences

and press “submit”

## CDAWeb Data Explorer

Select start and stop times from which to GET or PLOT data:

Start time (YYYY/MM/DD HH:MM:SS.mmm): 2025/05/07 00:00:00.000

Stop time (YYYY/MM/DD HH:MM:SS.mmm): 2025/05/08 00:00:00.000

Compute uniformly spaced binned data for scalar/vector/spectrogram data (not available with noise filtering)

Use spike removal to filter data without binning (not available with noise filtering)(Warning: Experimental !!).

Select an activity:

Data Availability Chart : Generate a chart showing when data is available for the selected data set(s) and time range (Select > 1day).

Plot Data : select one or more variables from list below and press submit.

- Also create PS and PDF best quality outputs (all plot types except images and plasmagrams). Many panels per dataset are allowed but <4 panels optimal for standard Y-axis height and single page display.
- Use coarse noise filtering to remove values outside 3 deviations from mean of all values in the plotted time interval.
- Change the X-axis width for time-series and spectrogram PNG plots (NEW default=3).
- Change the Y-axis height for time-series and spectrogram plots (NEW default=2).
- Autoscale time axis (useful for finding discrete bursts/events).
- Combine all time-series and spectrogram plots, for all requested datasets, into one plot file.
- Plot overlay options.

List Data (ASCII/CSV): select one or more variables from list below and press submit. (Works best for < 31 days)

Download original files : press submit button to retrieve list of files. (Max. 200 days - use [HTTPS site](#) for larger requests)

Create V3.9 CDFs for download: select one or more variables from the list below and press submit.

Create audio files based on data from selected variables. [More information about audification](#).

Note: [CDF patch](#) required for reading Version 3.9 CDFs in IDL or MATLAB.

Get [CDFX](#)- IDL GUI plotting/listing toolkit software. To be used with either the daily or "created" CDF files available above.

Pressing the "Submit" button will spawn a new window/tab in order to support the new "Previous" and "Next" functions.

Variable parameters (required for Listing, Creating and Plotting data only)

**WI\_H0\_MFI:** Wind Magnetic Fields Investigation: 3 sec, 1 min, and hourly Definitive Data. - A. Koval (UMBC, NASA/GSFC)

Available dates: 1994/11/13 00:00:30 - 2025/05/07 23:59:30 [Info/DOI](#) [Metadata Archive](#)

(Continuous coverage not guaranteed - check the [inventory graph](#) for coverage)

- Magnetic field magnitude (1 min)
- Magnetic field magnitude (1 min - log scaled)
- RMS magnitude (1 min)
- Magnetic field vector in GSM cartesian coordinates (1 min)
- RMS vector in GSM coordinates (1 min)
- Magnetic field vector in GSE cartesian coordinates (1 min)
- Magnetic field vector in GSE angular coordinates (1 min)
- RMS vector in GSE angular coordinates (1 min)

# Shock scales exercise: interplanetary shocks

## Task

- Assume ion inertial length  $d_i = 100\text{km}$ , and solar wind velocity  $V_{sw} \sim 500\text{km/s}$
- **What temporal scales you need to look at** if you're interested in
  - a) Reconnection in turbulence
  - b) Shock ion kinetic structures
  - c) Fluid scales ( $100\text{-}1000 d_i$ )
  - d) Space weather simulation output  
(zoom out until you see the shock driver (CME))

11Hz, 3s, 1min, or 1 hour cadence?

How long a window size?

- Make plots for each and discuss with neighbours