# Nanoscale Dust Production at 1AU: Identification And Tracking With 12 Spacecraft

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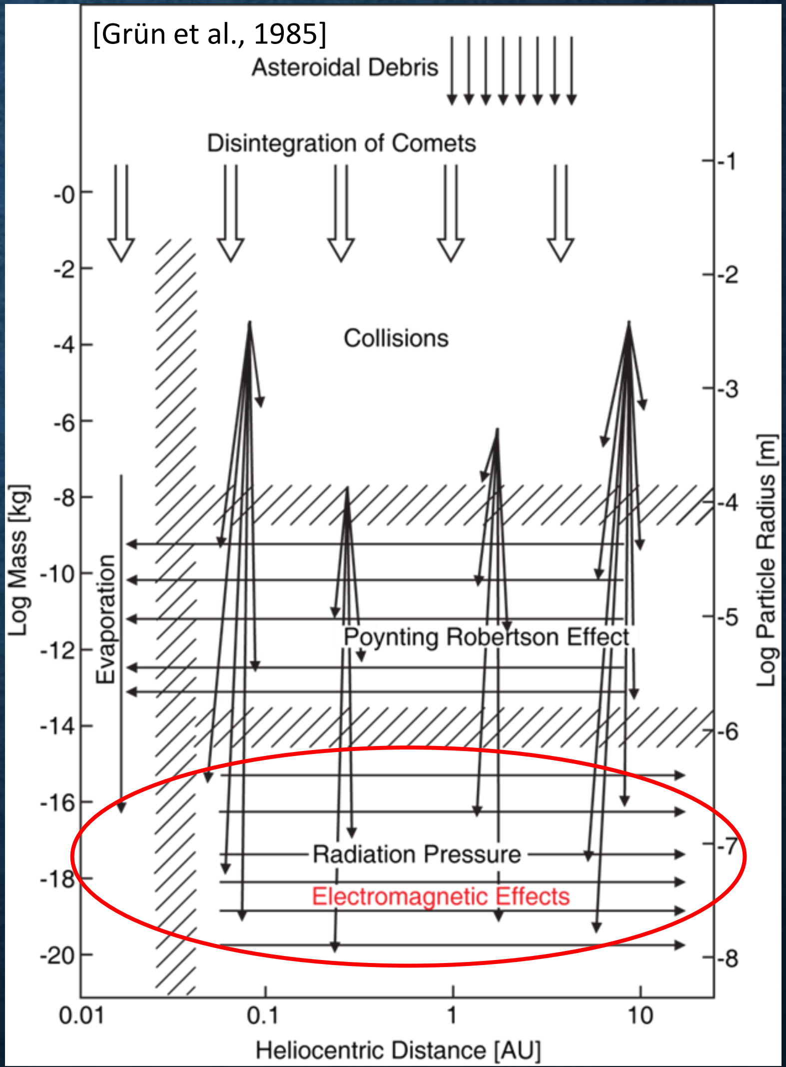
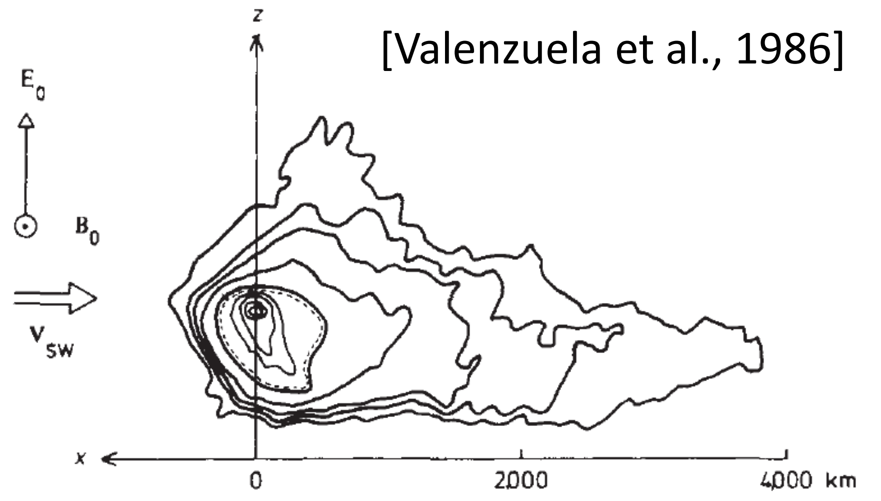
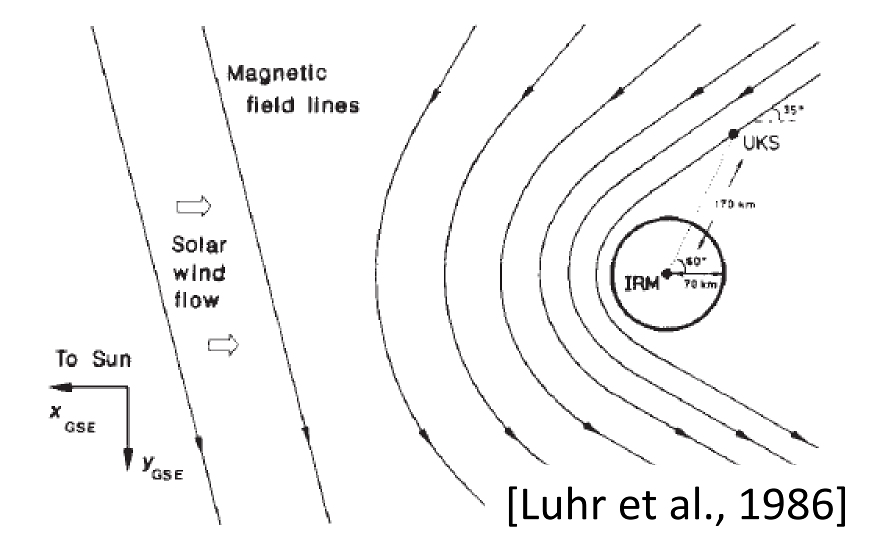
# Sub-micron Dust in the Interplanetary Space




The sub-micron dust gets charged in the solar wind and is then accelerated by the electromagnetic forces.

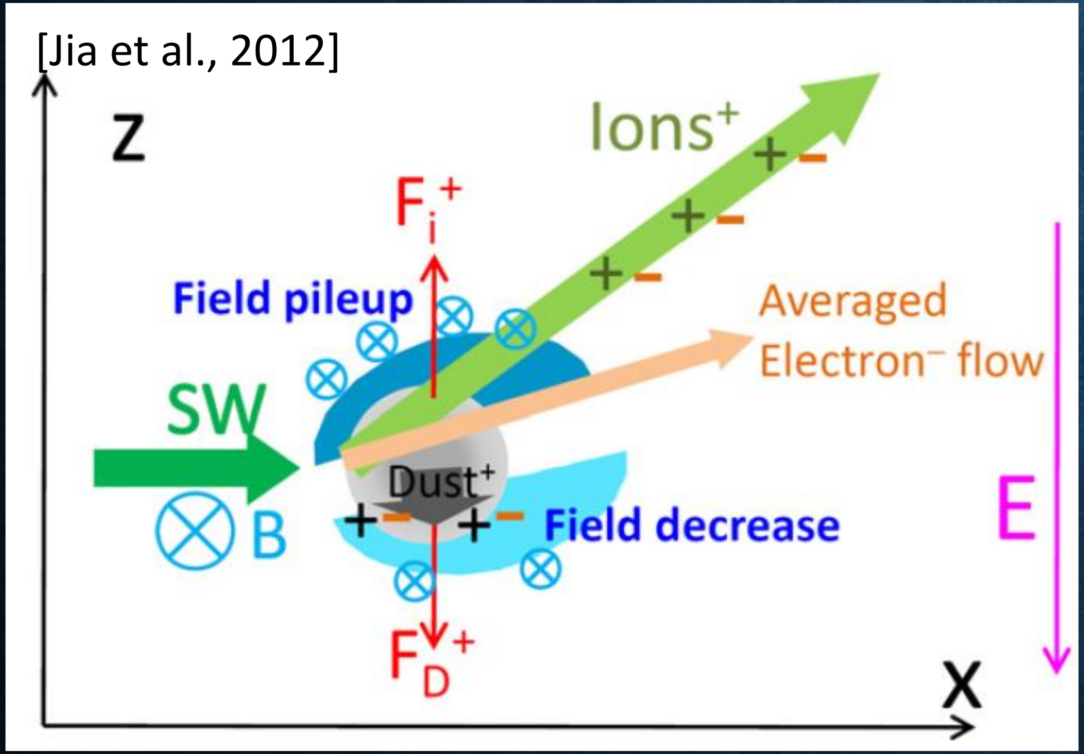
# AMPTE Experiment




- On Dec. 27 1984, 2kg of Ba was released in the solar wind . It was fully charged in 30s and formed a cloud of 100km in diameter. The observed perturbation in IMF is over 2000km in diameter.
- Ba cloud
  - Moved in the convection E direction
  - Accelerated in the solar wind direction
- Solar wind
  - Diverted in the E direction
  - Slowed down
- IMF
  - Enhanced due to the pile up
  - Bended in the E direction

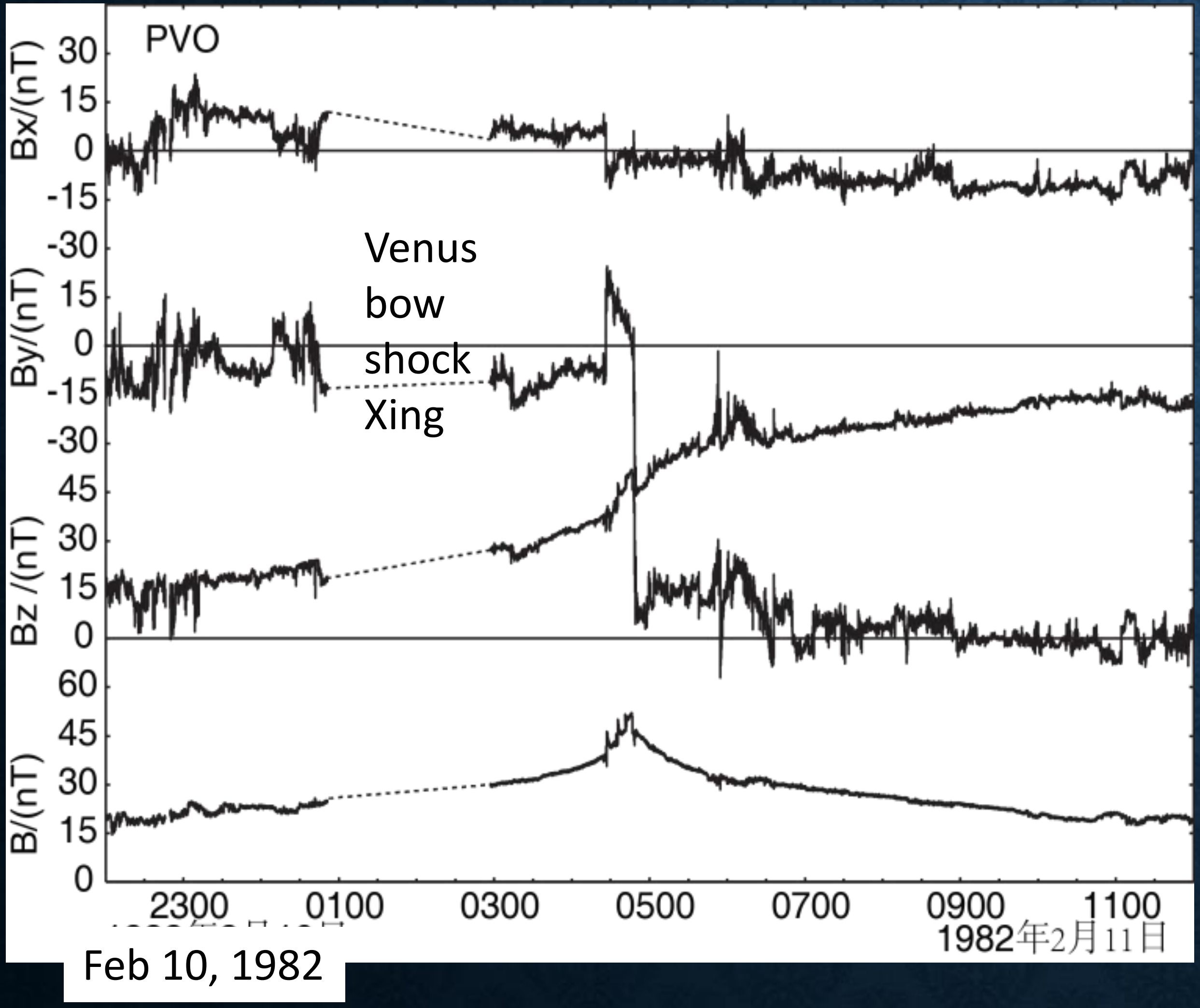
# Multi-Fluid Plasma Simulation



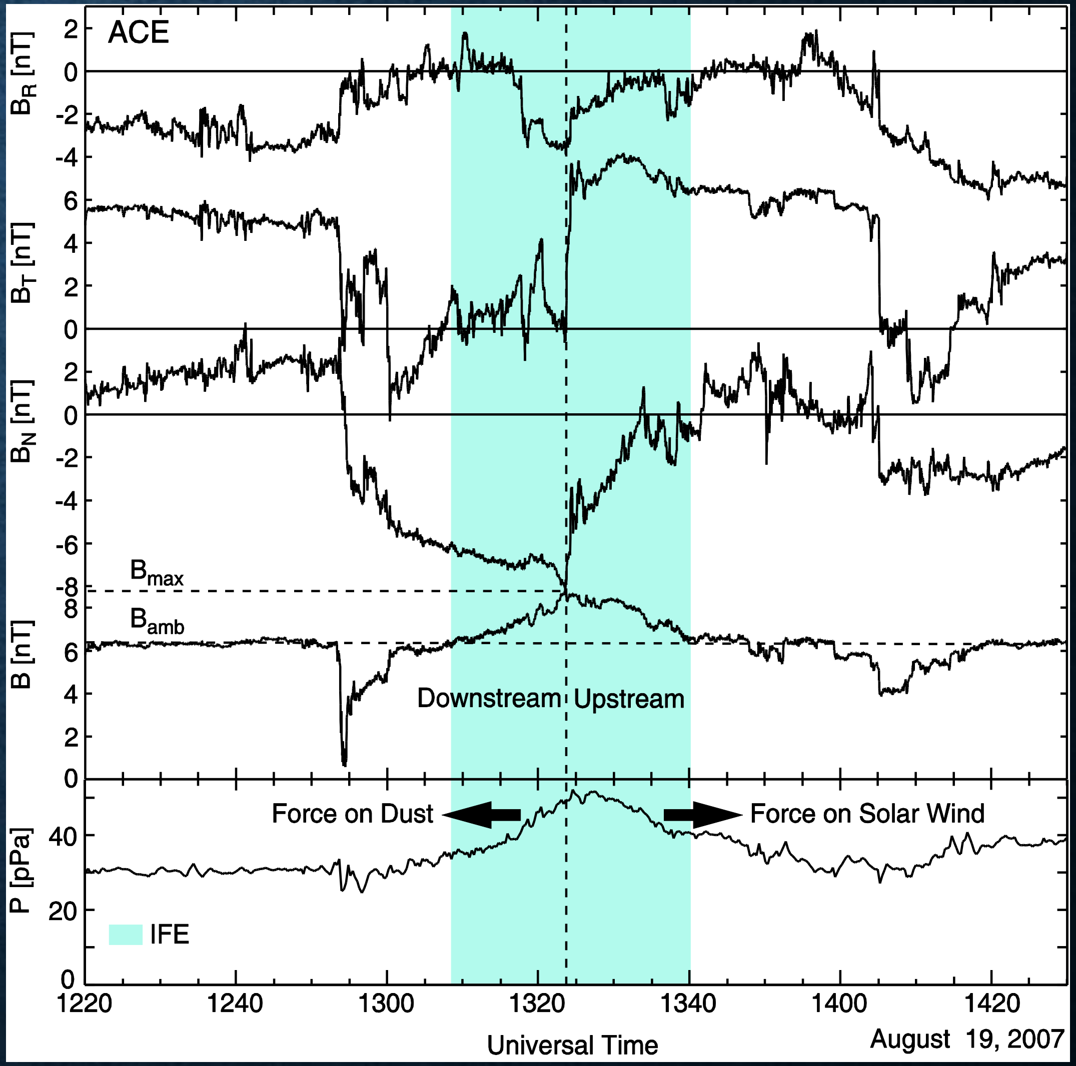
[Jia et al., 2012]

- Dust cloud
  - Moves in the E direction
  - Gets accelerated
- Plasma flow
  - Diverts in the E direction
  - Slows down
- Magnetic field
  - Pile up in front of the dust cloud
  - Bend in the –E direction

# On the other hand, we are seeing IFEs

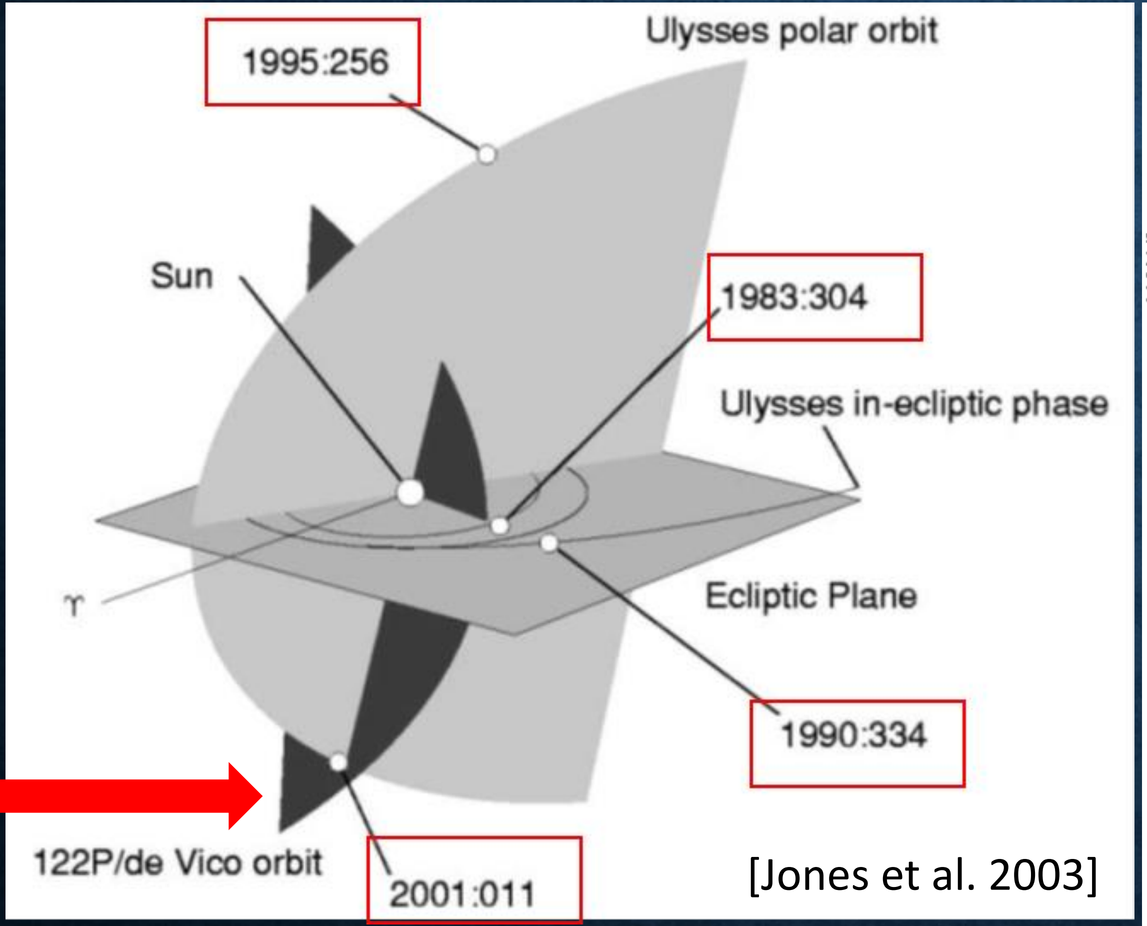



[Russell+ Nature 1983]

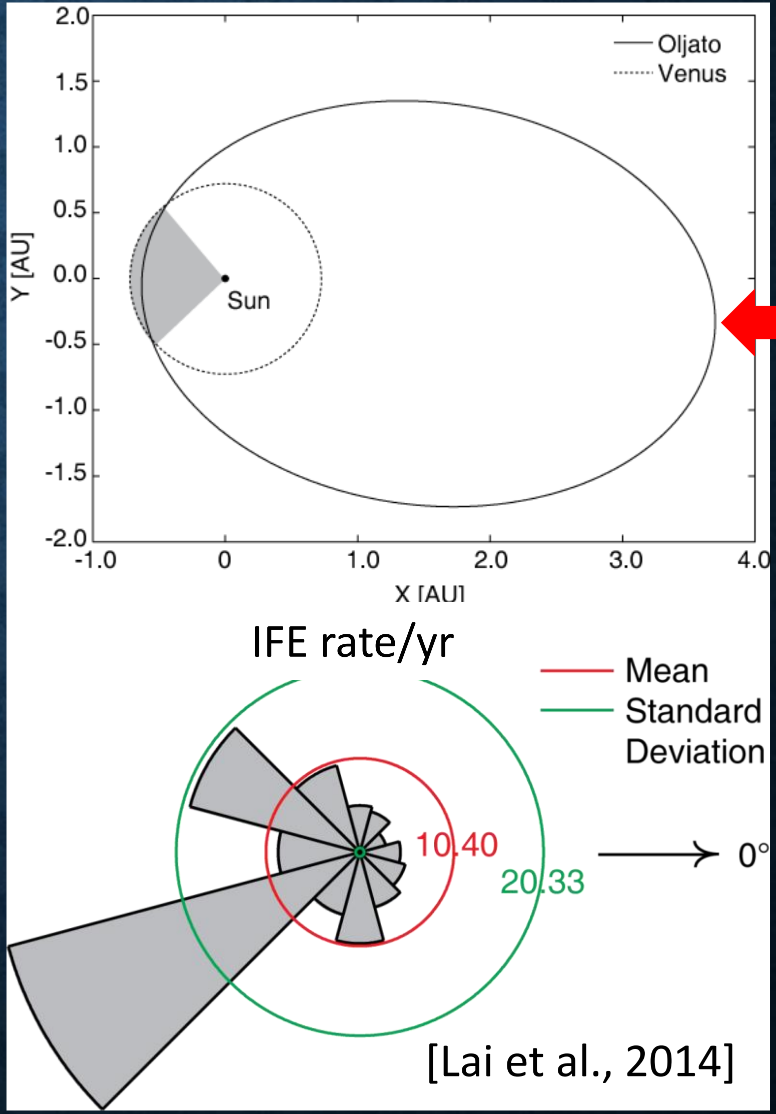



[Lai+ PSS 2018]

# IFES Are More Frequent Downstream of Asteroids/Comets



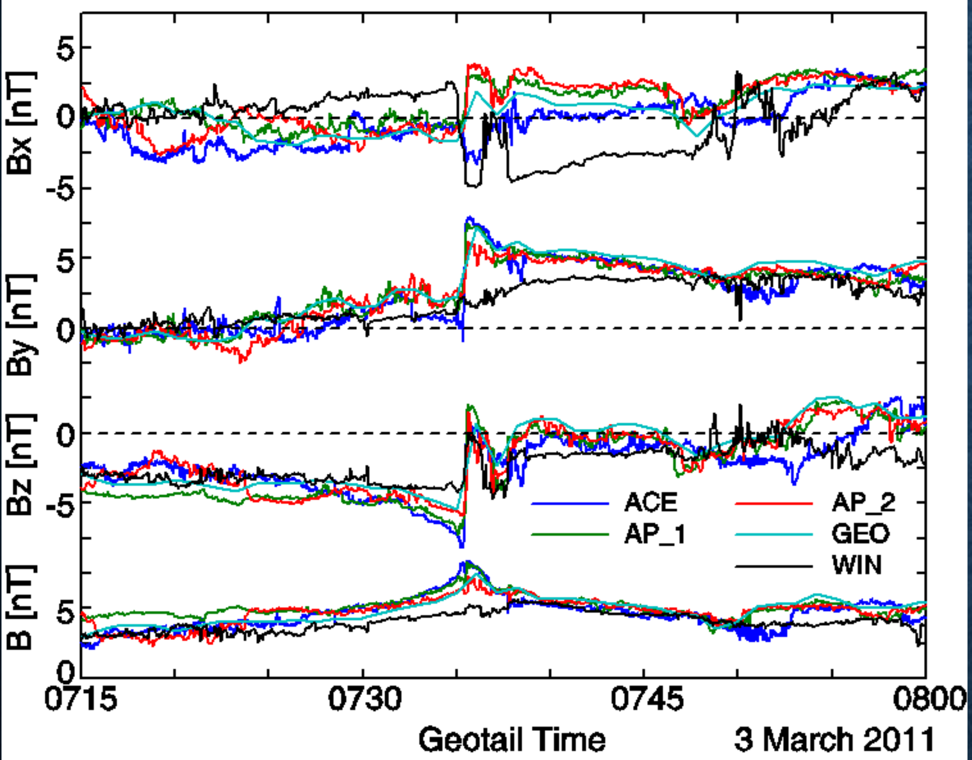

Orbit of 122P/de Vico

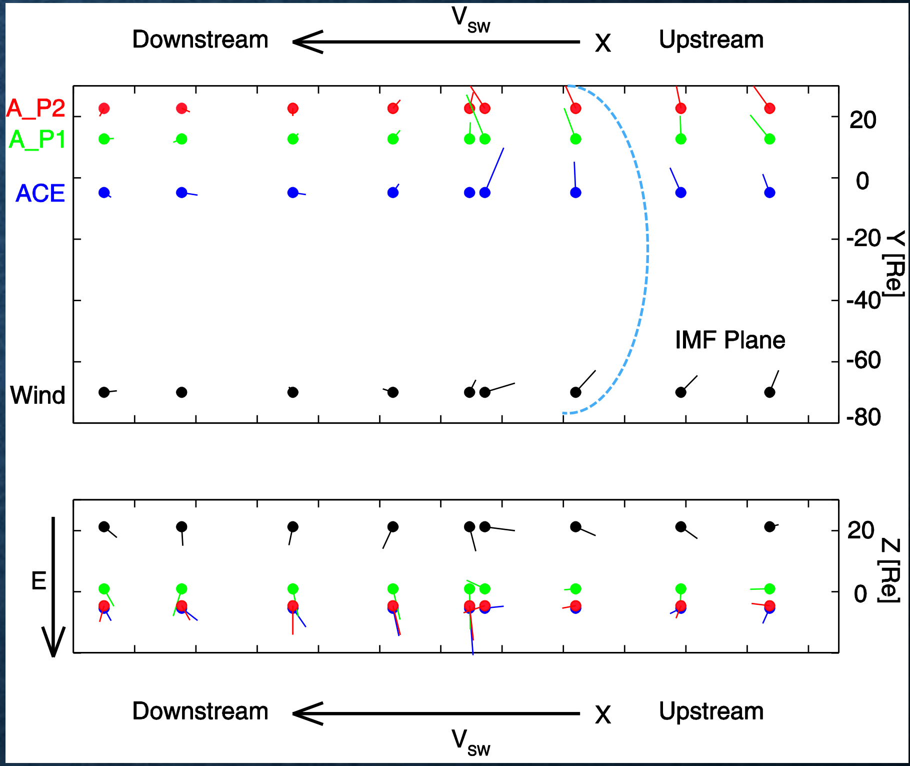



Orbit of asteroid 2201 Oljato

IFEs are formed in the dust cloud-solar wind interactions.

# Field draping seen by 5 spacecraft

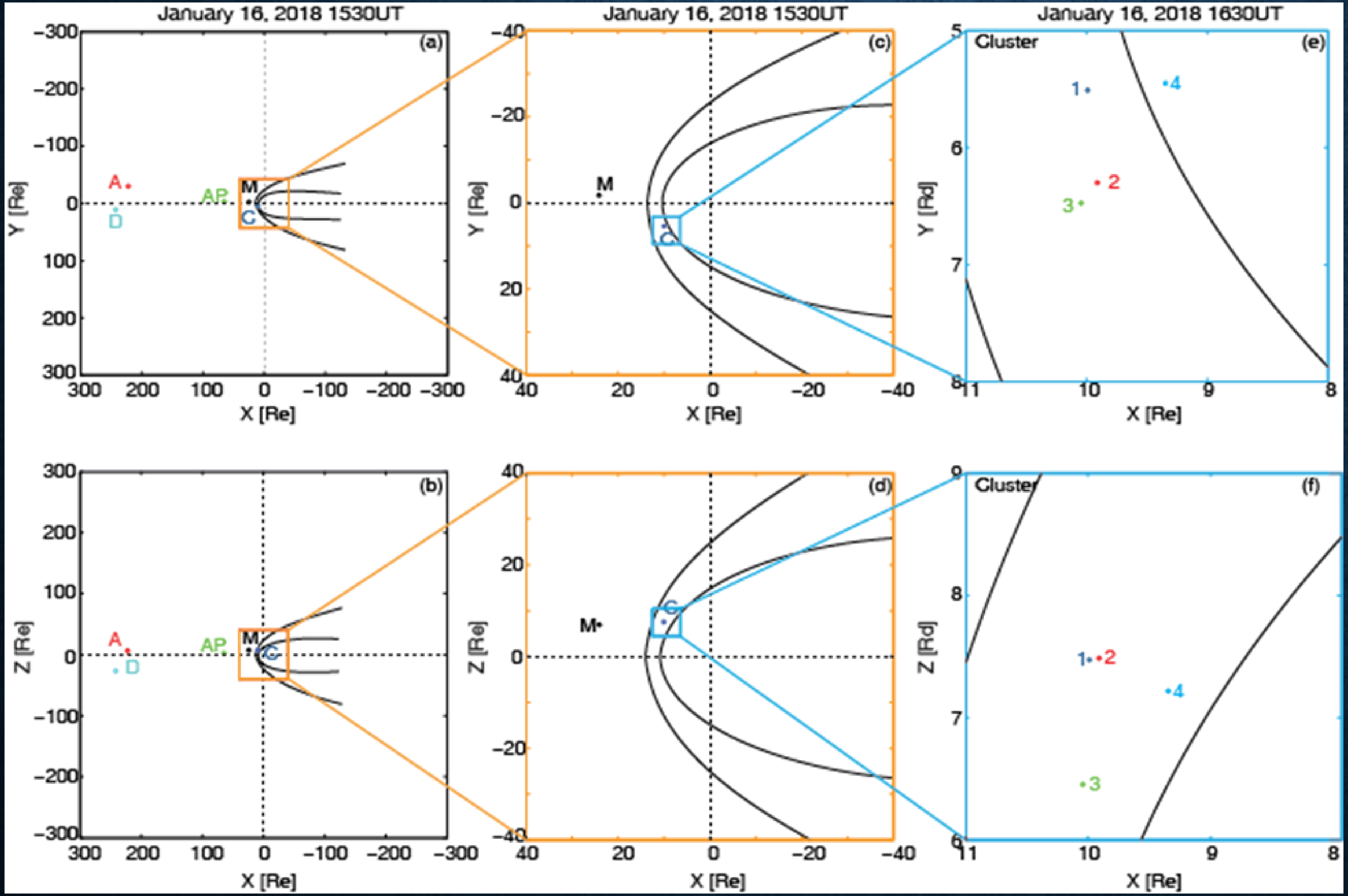



[Lai+ GRL 2015]

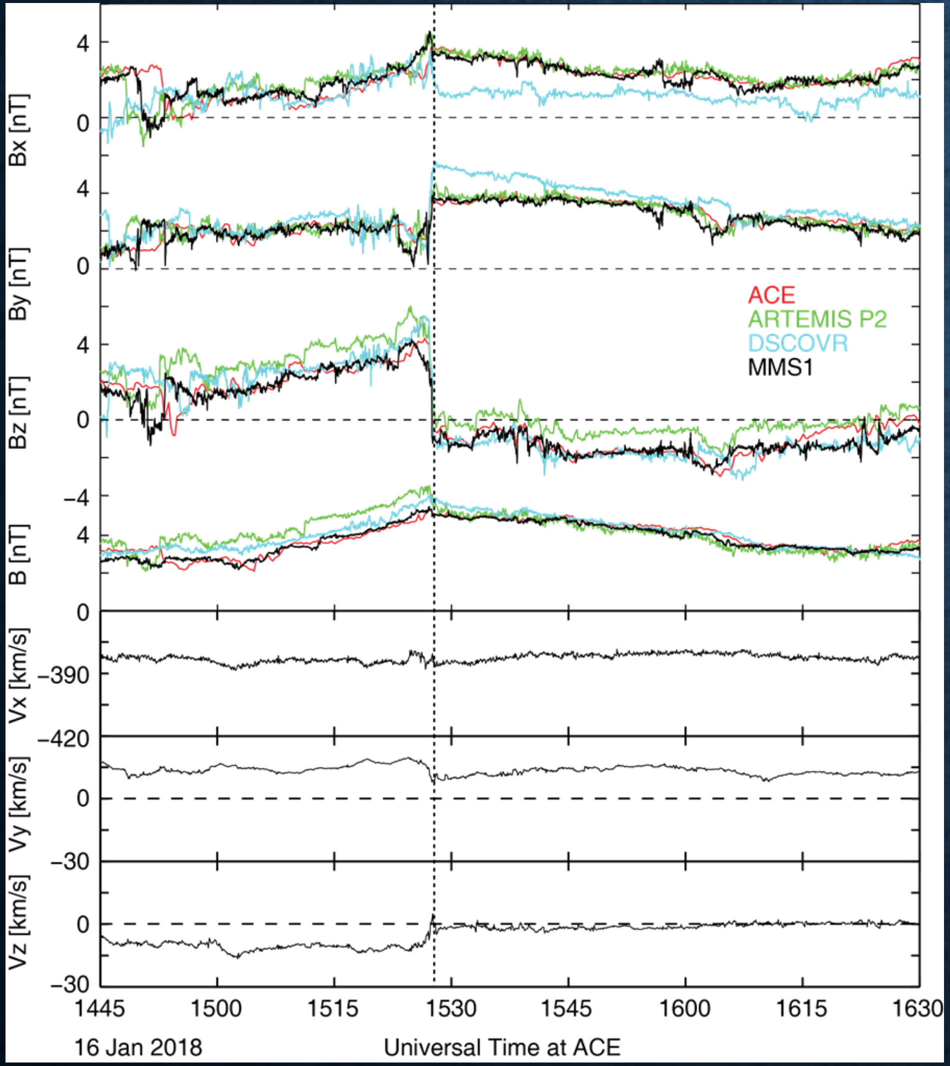
- IMF piles up, resulting an enhancement in strength
- IMF raises a component in –E direction

# An IFE from Interplanetary Space to the Terrestrial Magnetosheath: 12 spacecraft observation



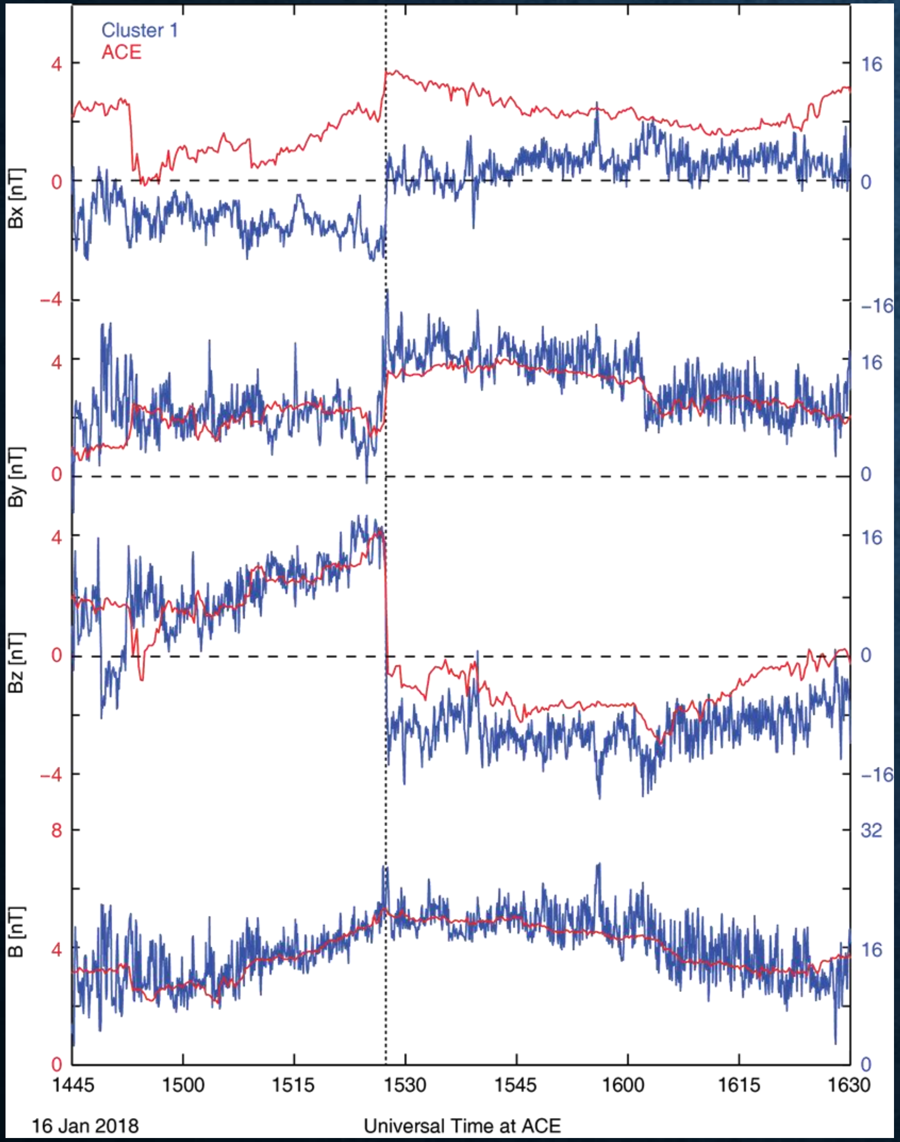

- Interplanetary space
  - L-1(~200$R_E$)：ACE, DSCOVR
  - Lunar orbit(~60$R_E$): ARTEMIS P1, P2
  - Outside bow shock (~24$R_E$): MMS1, MMS2, MMS3, MMS4
- Earth's magnetosheath
  - Outside magnetopause(~10$R_E$): Cluter 1, Cluster 2, Cluster 3, Cluster 4

# The IFE in Interplanetary Space



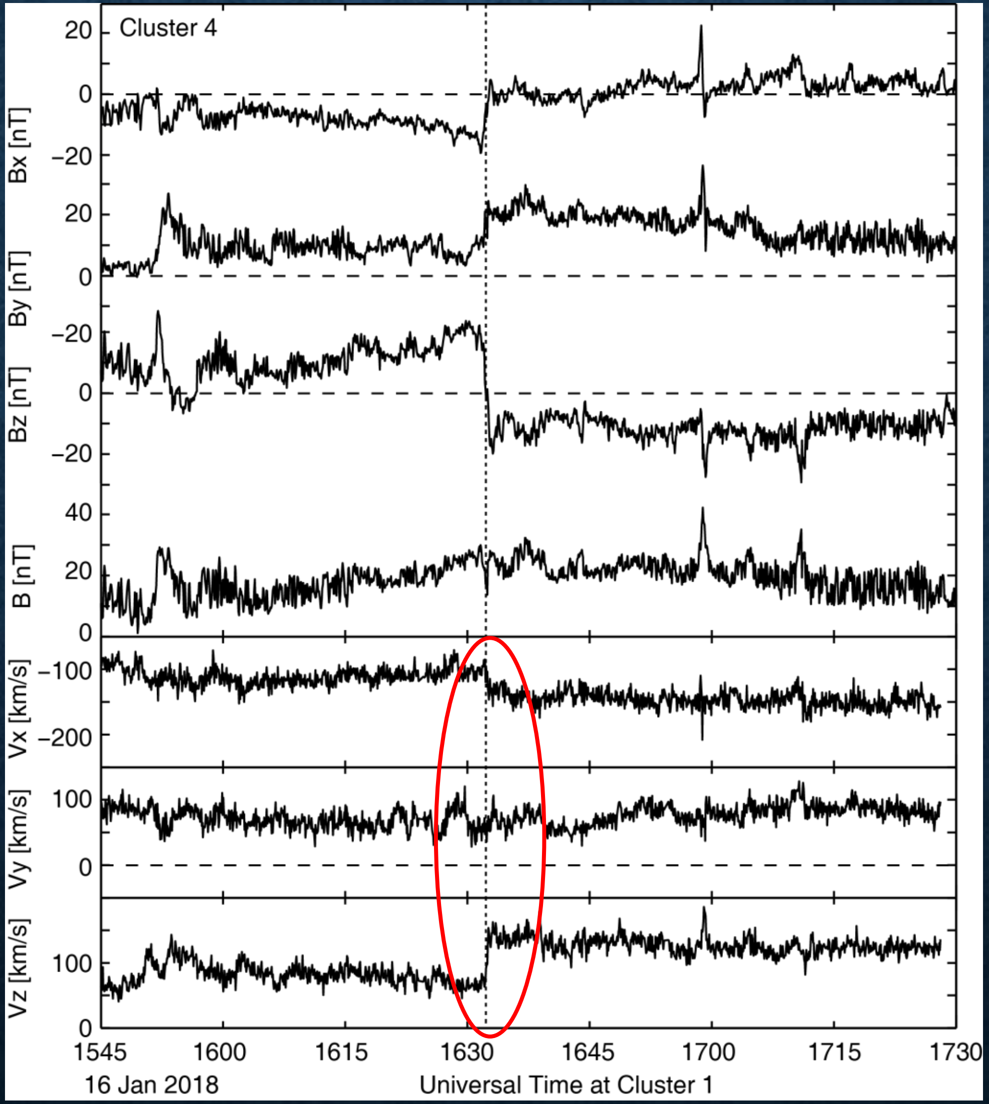

- The IFE speed is ~365km/s, close to the in situ solar wind speed
- The radial scale is ~140$R_E$, the estimated dust cloud scale is ~7$R_E$
- Solar wind flow is diverted in Y and Z directions.

# The IFE Across the Bow Shock




- Similarities
  - The patterns of the field strength, $B_Y$ and $B_Z$
  - Duration
- Differences
  - The field strength is 4 times that in the solar wind (velocity ¼)
  - More turbulent
  - The sign of $B_X$ in the leading part of this event is opposite

# The IFE in the Magnetosheath



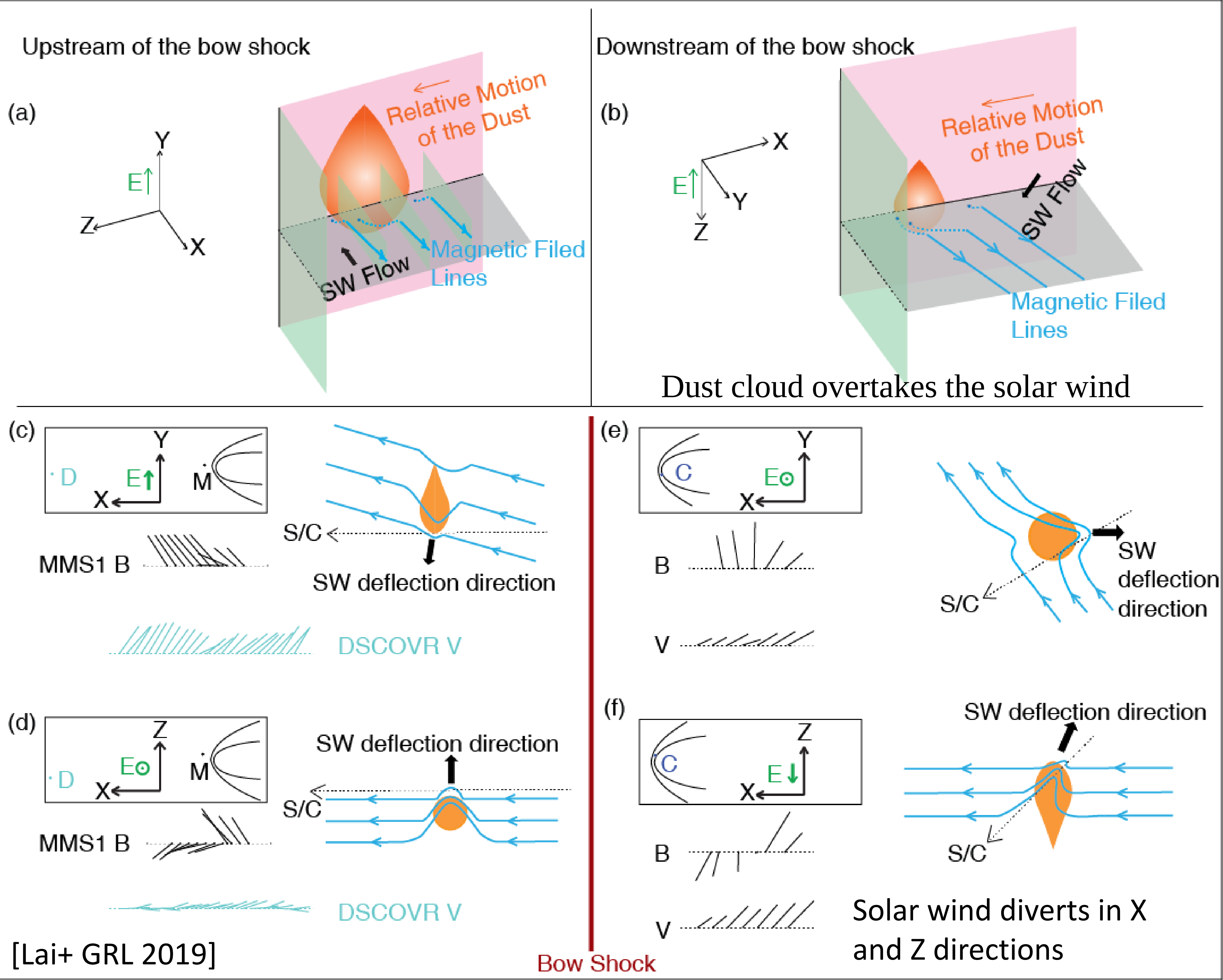

Solar wind diverted in the Y and Z directions

IFE speed averages 300 km/s from ARTEMIS1 to Cluster1

# Interpretation

Dust cloud moves in Z direction relative to the solar wind

Solar wind diverts in Y and Z directions




[Lai+ GRL 2019]

# Summary

- This is the first time that an IFE has been traced from interplanetary space to the terrestrial magnetosheath with the help of 12 spacecraft observations [Lai+ GRL 2019].
- The dust cloud is travelling slower than the surrounding solar wind upstream of the bow shock but it is travelling faster than the magnetoheath plasma down stream from the shock
- With such observations, we can use IMF observations to investigate the dynamics of the interplanetary dust clouds.
    - to improve our understanding of how the mass and momentum are transported in the solar system
    - to determine the locations of potentially hazardous material in heliocentric orbit