Multi-Spacecraft Observations of Interplanetary Shocks

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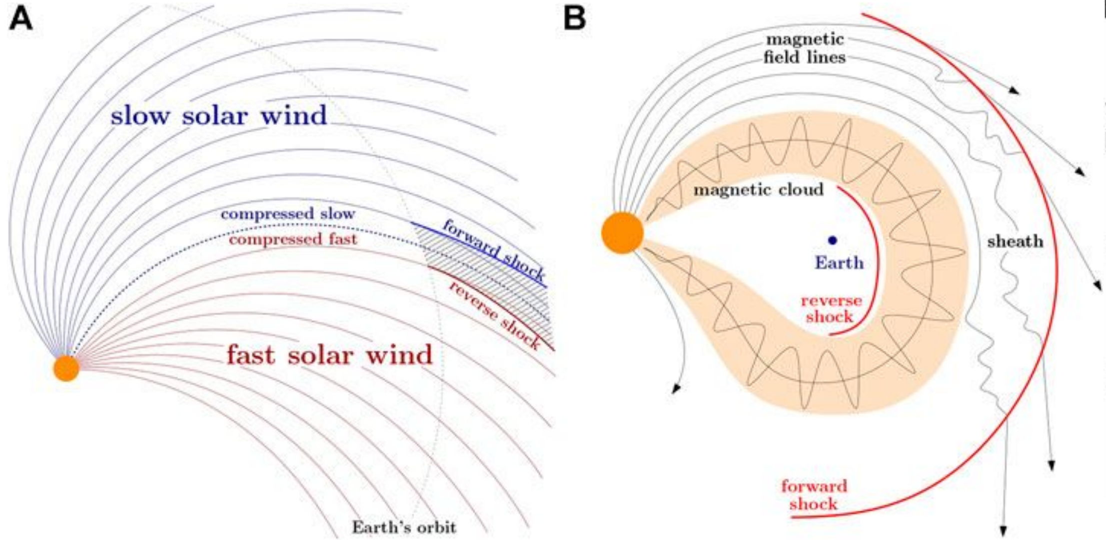
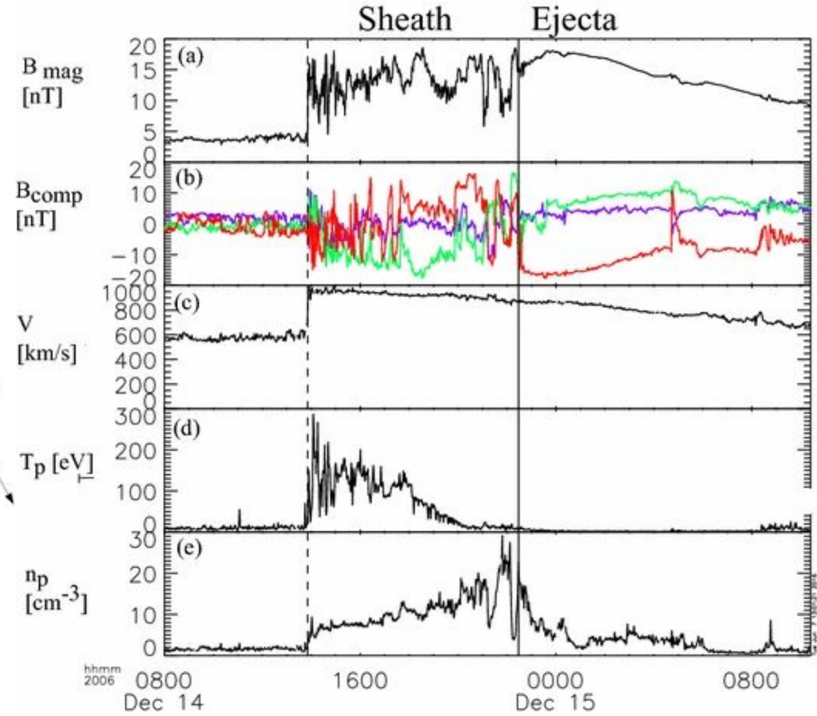
UMBC

Interplanetary Shocks



(A) Schematics of the Co-rotating Interaction Region (CIR) which leads to a formation of CIR bounded by forward and reverse shocks; (B) A fast forward shock formation in front of an ICME and a possible reverse shock at the trailing edge of the magnetic cloud.

Pitna et al. (2021)

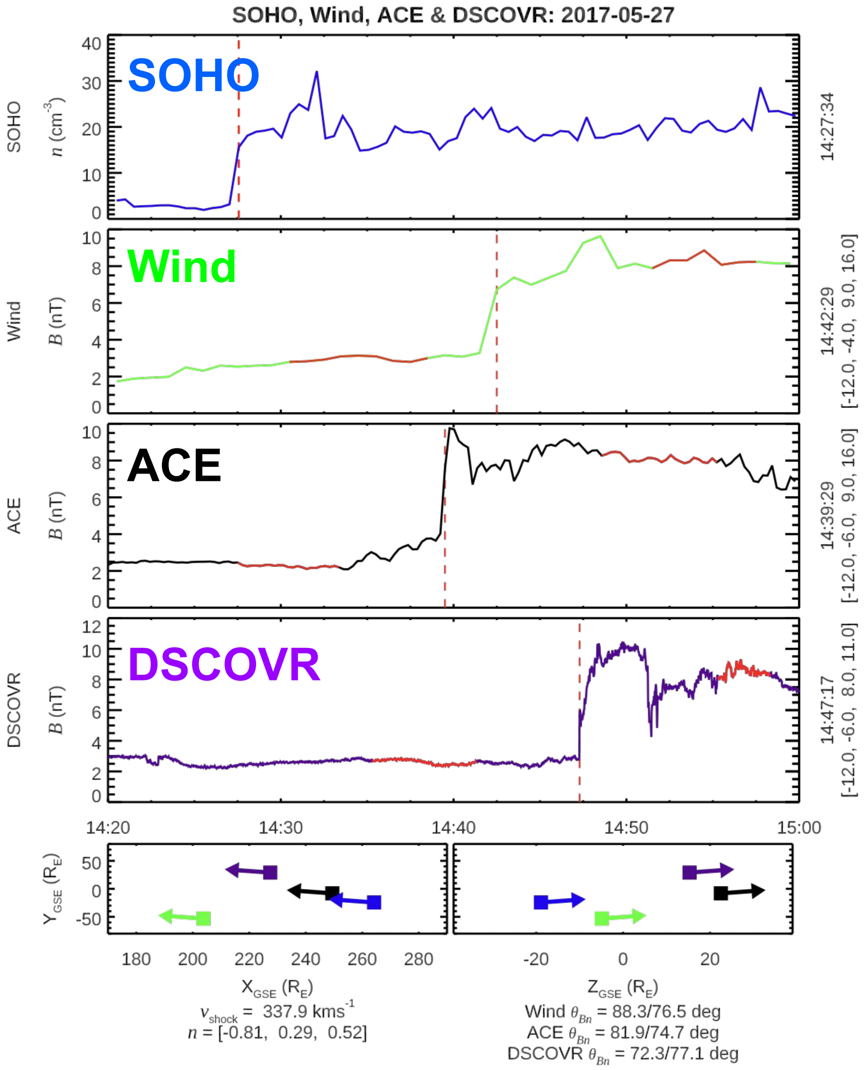


An example of a sheath region between a forward shock and an MC. The panels show from top to bottom: a the magnetic field magnitude, b components of the magnetic field in GSE coordinates, solar wind c speed, d proton temperature, and e proton density. The dashed line shows the shock and the solid line the leading edge of the ICME. The measurements are from the ACE spacecraft.

Kilpua et al. (2017)

Interplanetary Shocks

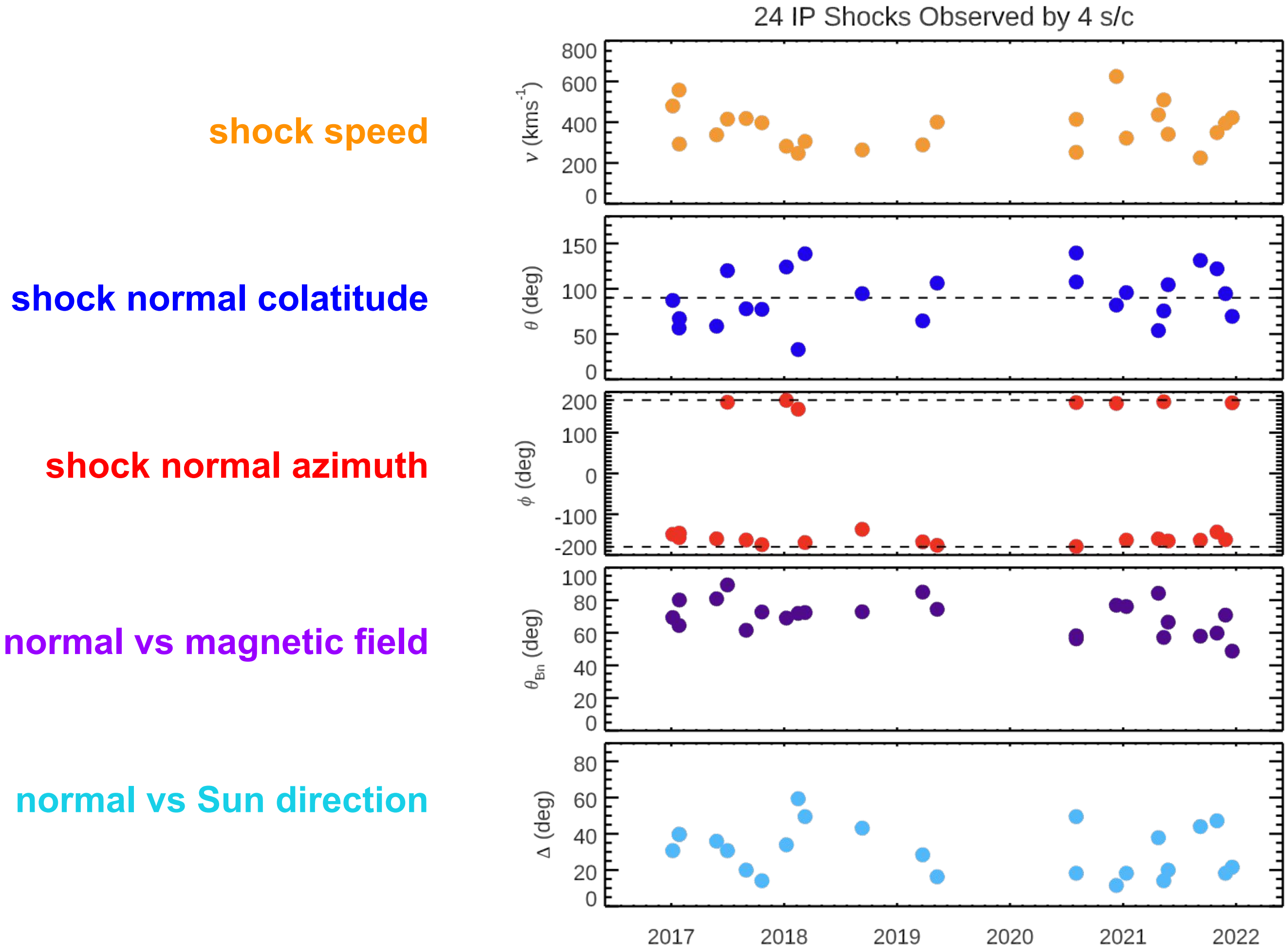
- 4 spacecraft located near L1
  - **Wind (1994)**
  - **SOHO (1995)**
  - **ACE (1997)**
  - **DSCOVR (2015)**
- Magnetic field and particle measurements by **Wind**, **ACE**, and **DSCOVR**
- **SOHO** provides only particle data

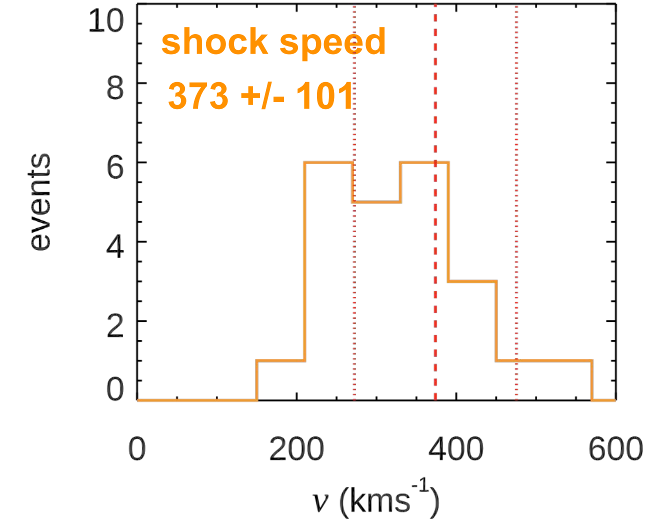


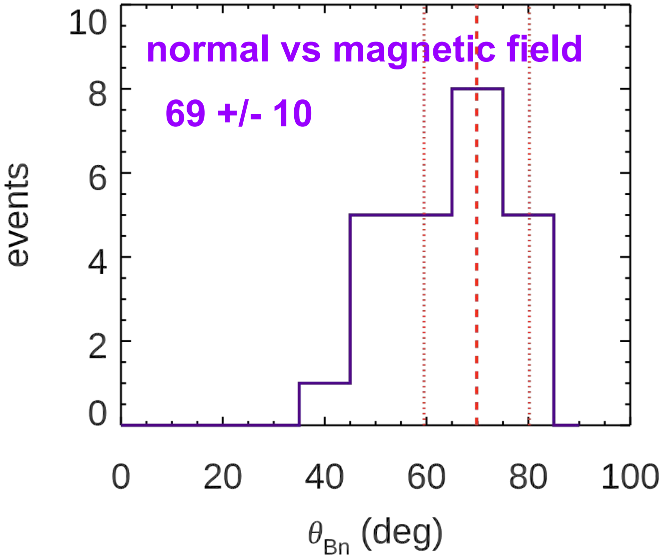
Data Analysis

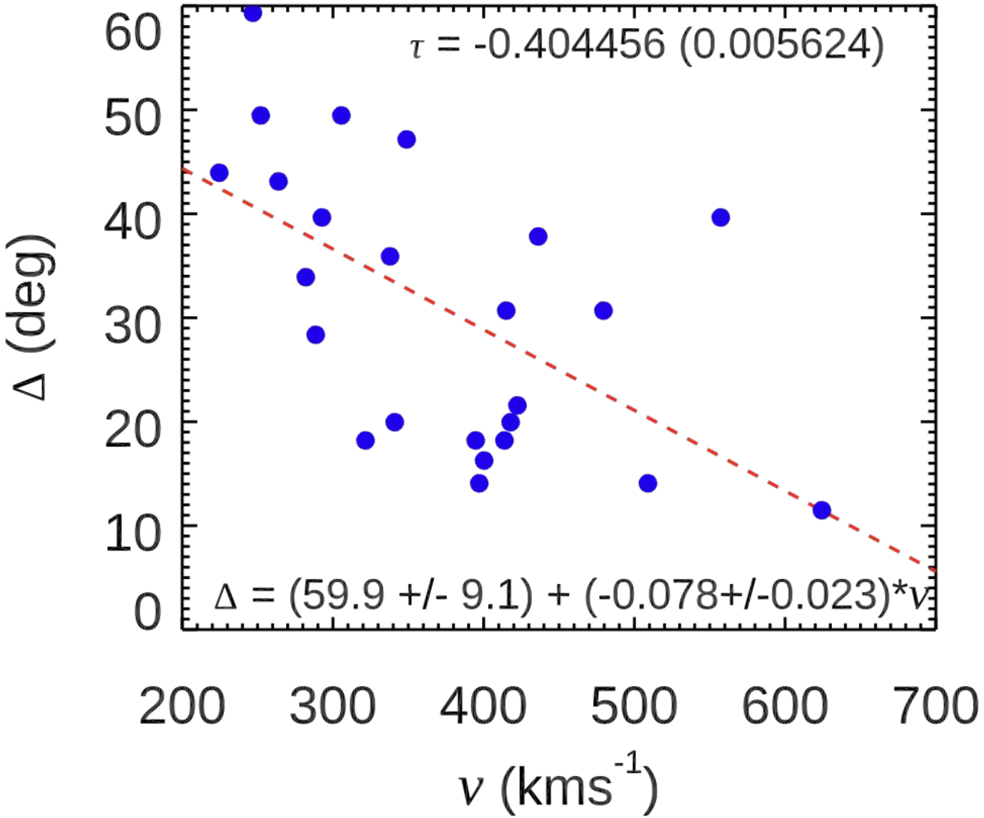
- We use the timing method to determine interplanetary shock normals and velocities along these normals.
- We assume that an interplanetary shock can be represented by a moving plane with a constant velocity, when observed at closely separated four points in space and time.

$$\begin{pmatrix} x_1 - x_2 & y_1 - y_2 & z_1 - z_2 \\ x_1 - x_3 & y_1 - y_3 & z_1 - z_3 \\ x_1 - x_4 & y_1 - y_4 & z_1 - z_4 \\ x_2 - x_3 & y_2 - y_3 & z_2 - z_3 \\ x_2 - x_4 & y_2 - y_4 & z_2 - z_4 \\ x_3 - x_4 & y_3 - y_4 & z_3 - z_4 \end{pmatrix} \begin{pmatrix} \frac{n_{\mathrm{SC}x}}{v_{\mathrm{SC}}} \\ \frac{n_{\mathrm{SC}y}}{v_{\mathrm{SC}}} \\ \frac{n_{\mathrm{SC}z}}{v_{\mathrm{SC}}} \end{pmatrix} = \begin{pmatrix} t_1 - t_2 \\ t_1 - t_3 \\ t_1 - t_4 \\ t_2 - t_3 \\ t_2 - t_4 \\ t_3 - t_4 \end{pmatrix}$$


24 IP Shocks Observed by 4 s/c
shock speed
shock normal colatitude
shock normal azimuth
normal vs magnetic field
normal vs Sun direction
v (kms^{-1})
θ (deg)
ϕ (deg)
θ_{Bn} (deg)
Δ (deg)
2017
2018
2019
2020
2021
2022







- **Shock speeds comparable to solar wind speeds**
- **Predominantly quasi-perpendicular shocks**
- **Faster shocks have smaller deviation from the Sun direction**