The downstream magnetic field structure in quasi-parallel shocks

אוניברסיטת בן-גוריון בנגב
جامعة بن غوريون في النقب
Ben-Gurion University of the Negev

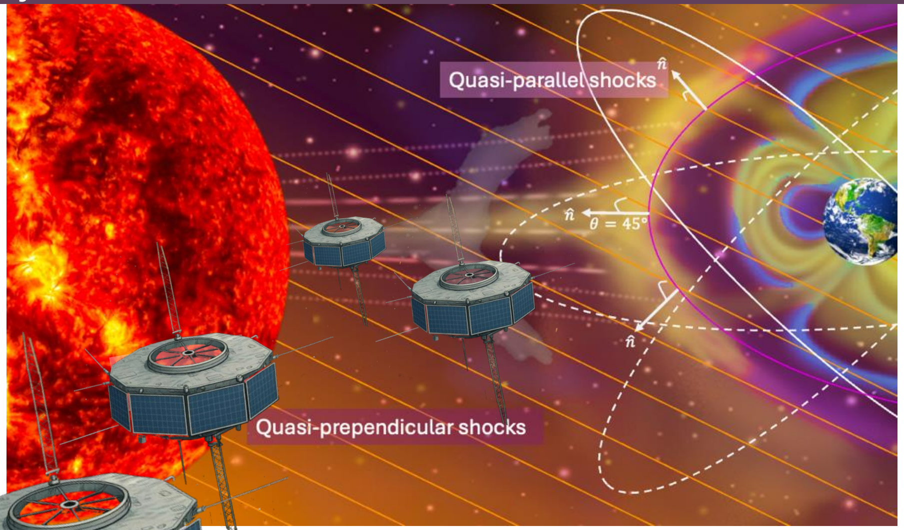
Michal Golan, Michael Gedalin
Ben-Gurion University of the Negev, Beer Sheva, Israel

AGU25
New Orleans, LA | 15–19 December 2025

Background

- In collisionless shocks, the redistribution of directed-flow energy is described by mass, momentum, and energy conservation through the Rankine–Hugoniot (RH) relations.
- Standard RH theory assumes that far from the shock, the magnetic field is well ordered, giving $\langle B^2\rangle = \langle B\rangle^2$.
- Quasi-perpendicular shocks are expected to have a coherent downstream field, whereas quasi-parallel shocks are typically considered turbulent.
- MMS observations reveal quasi-parallel shocks where $\left(\langle B-\langle B\rangle\rangle\right)^2 \gtrsim \langle B\rangle^2$, showing downstream fluctuations that exceed the mean field.
- These fluctuations result from rotation of the downstream magnetic-field vector, which can be large, intermittent, and strongly non-uniform.
- Therefore, downstream magnetic fluctuations in quasi-parallel shocks may be ordered rather than random, implying that RH boundary conditions may need refinement.

System Model



Objectives

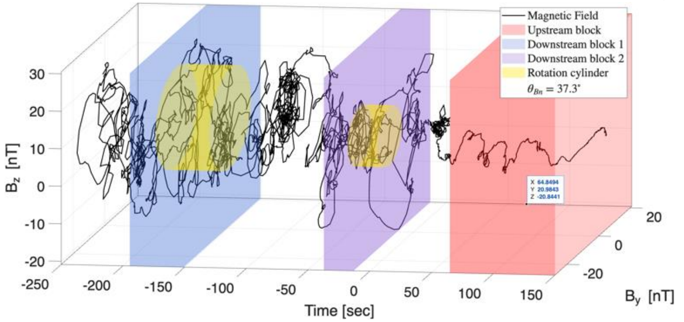
- Characterize the magnetic structure of quasi-parallel bow shocks using MMS observations.
- Explain the unique rotational structure observed in the downstream magnetic field and identify its physical origin.
- Determine the importance of this non-uniform rotational behavior when estimating the downstream magnetic field and evaluating shock properties.

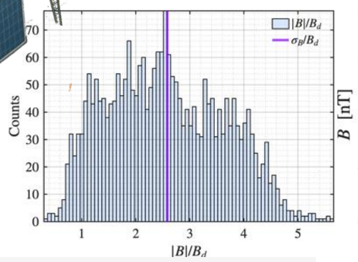
Data Collection and Analysis

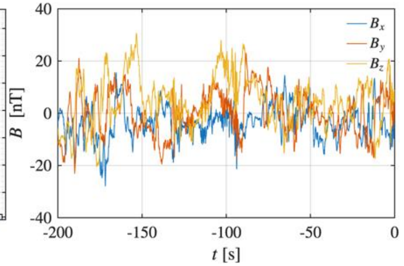
1. Selected a well-defined quasi- parallel shock crossing observed by MMS. Computed the full set of upstream and downstream plasma and field parameters.
2. Examined the magnetic-field vector in both 3D and 2D as a function of time. Identified periods of coherent rotation, transitions between different rotational states, and intervals with strong directional variability.
3. For each identified rotational region, determined how the choice of the averaging interval of downstream magnetic field affects the derived shock parameters—particularly the magnetic- field jump, downstream pressure, and applicability of RH relations.
4. Investigated the relation between rotational non-uniformity and the fluctuation-pressure term by evaluating $\left(\langle B-\langle B\rangle\rangle\right)^2$ and determining when rotational variability leads to significant $\frac{\langle \Delta B^2\rangle}{\langle B\rangle^2}$.

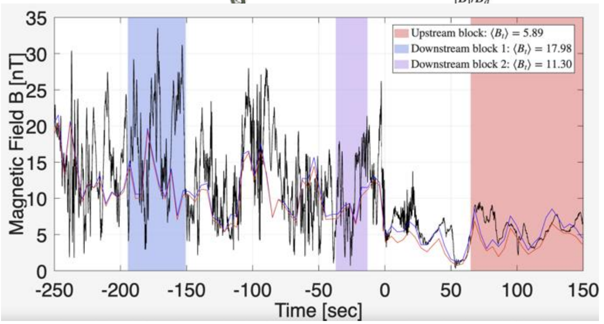
Results

Shock crossing 22.11.2017 05:29:44. UTC









Conclusions

- Quasi-parallel shocks have a unique structure characterized by rotation of the magnetic-field vector in the shock frame.
- These rotations are not uniform.
- Variations in the rotation radius of the magnetic-field vector can become significant when $\left(\langle B-\langle B\rangle\rangle\right)^2 \gtrsim \langle B\rangle^2$
- Different choices of downstream regions can significantly affect derived shock parameters in quasi-parallel shocks, where the fluctuations are large and strongly anisotropic.

golanmic@post.bgu.ac.il