

MAGNETIC STRUCTURES AND REFORMATION AT QUASI-PARALLEL SHOCKS

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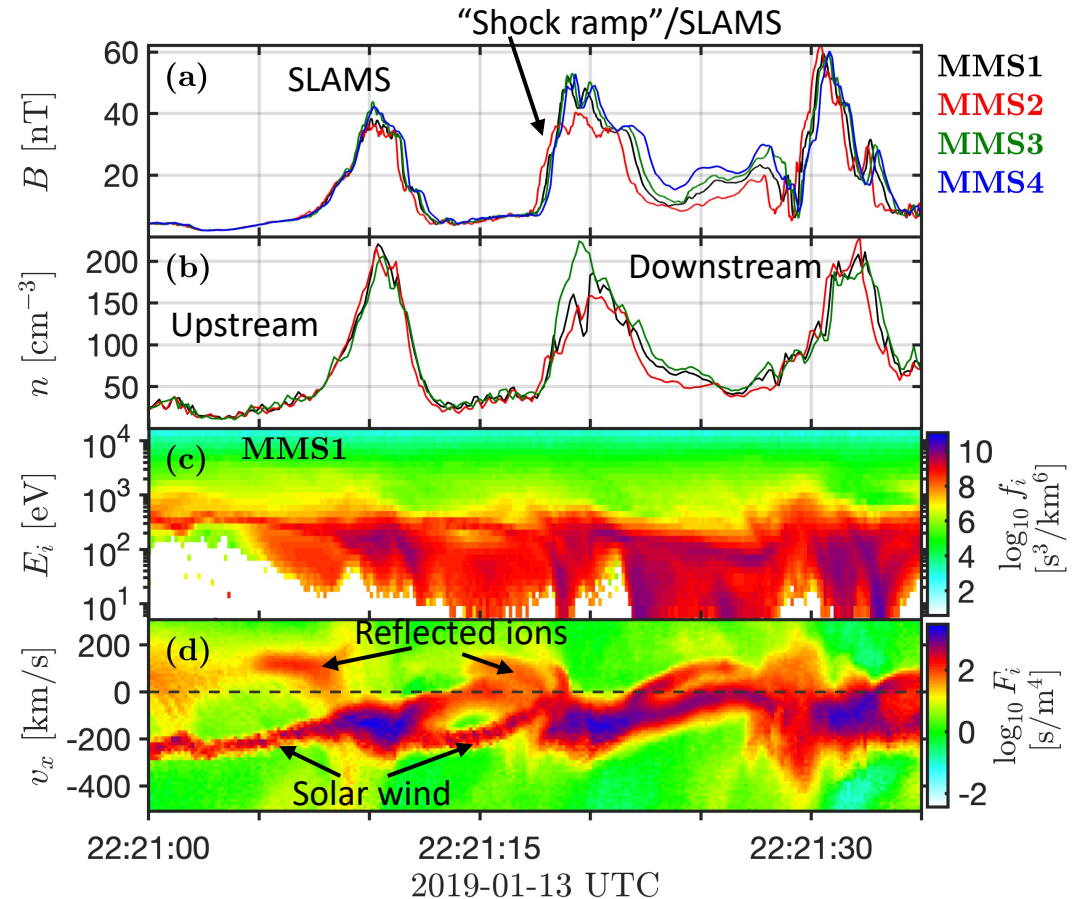


1. Introduction

Collisionless shocks are found in a wide variety of plasma environments where they heat the plasma and accelerate particles. Shock self-reformation is a process where a new shock ramp forms upstream of the old ramp. In quasi-parallel shocks, the reformation process is often assumed to be governed by upstream waves and structures. Here, we present evidence of Short Large Amplitude Magnetic Structures (SLAMS) impacting the quasi-parallel bow shock constituting reformation of the shock.

2. MMS observations

The figure to the right shows the four MMS spacecraft traversing the quasi-parallel bow shock from upstream to downstream. The spacecraft observe one SLAMS just upstream of the shock. A second SLAMS is then observed after which the spacecraft observe shocked magnetosheath plasma. This magnetic signature may appear to be the shock ramp but is, as we shall see, the leading edge of a SLAMS merging with the bow shock.



Shock parameters

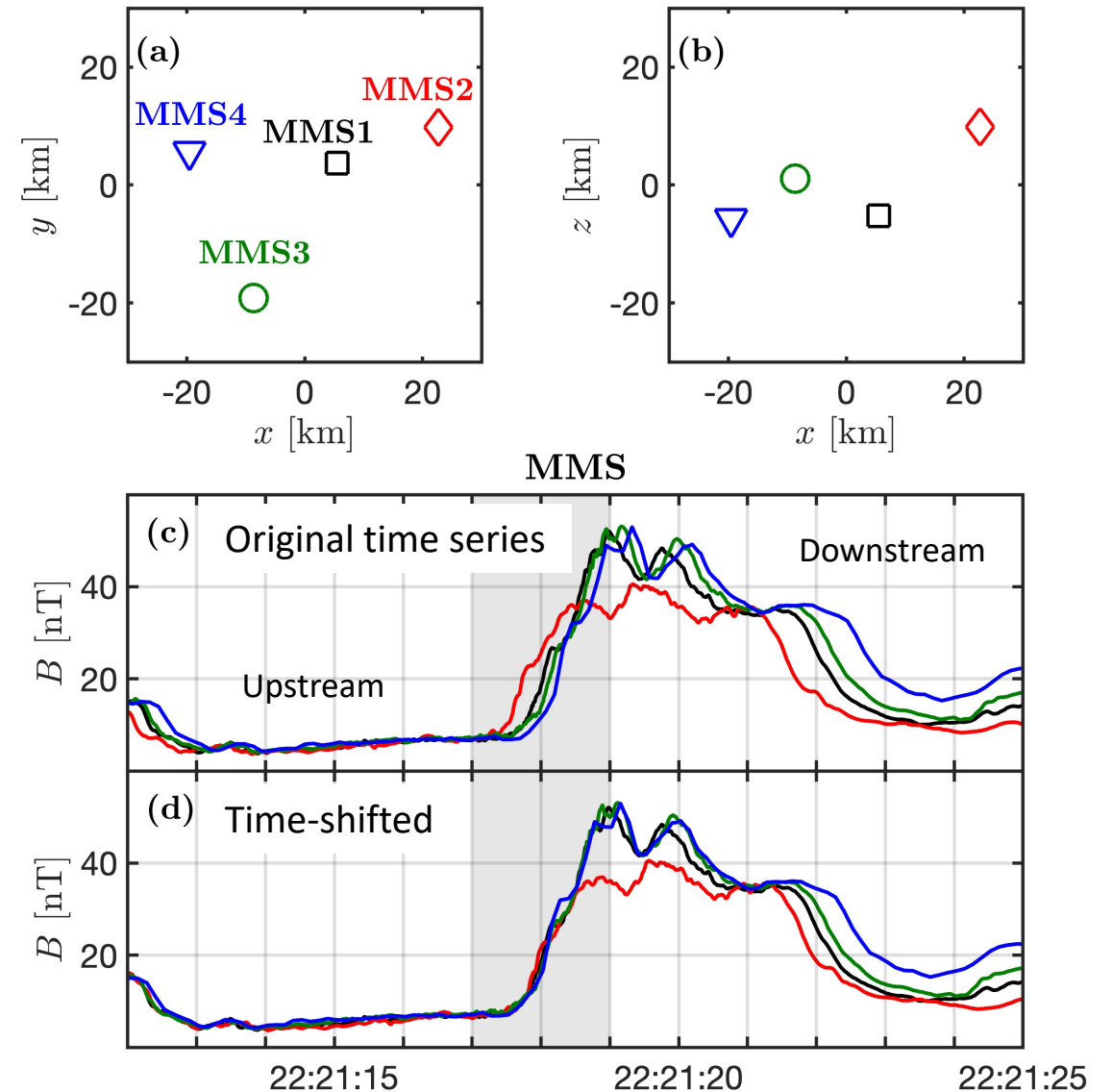
$$M_A \sim 12$$

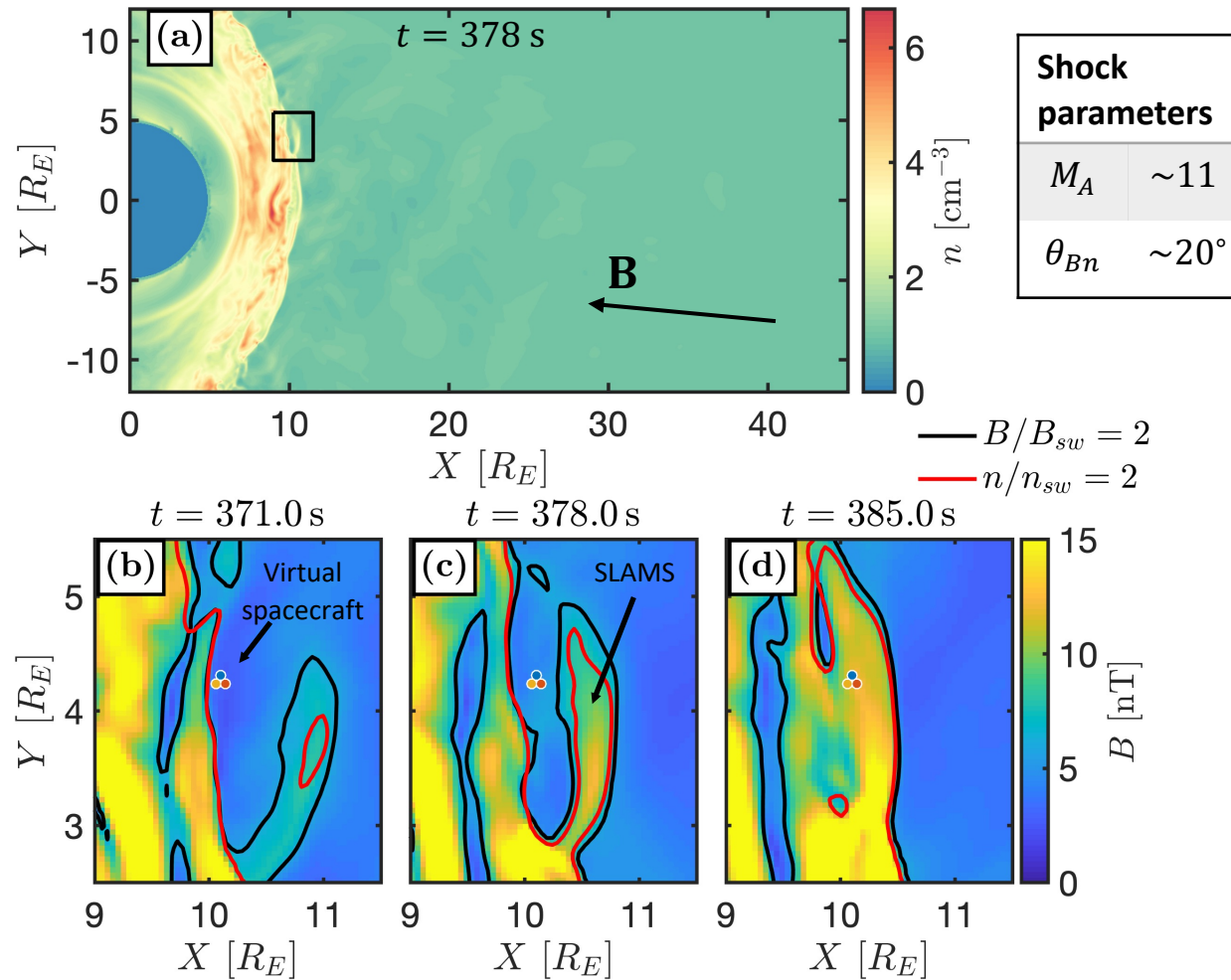
$$\theta_{Bn} \sim 30^\circ$$

3. Multi-spacecraft observations

The figure to the left shows the position of the four MMS spacecraft and the multi-point measurements of the magnetic field. Since the spacecraft are crossing the shock from the upstream to downstream, we would expect the shock ramp to move in the positive x-direction relative to the spacecraft. Instead we see that the spacecraft furthest upstream (MMS2) observes the shock crossing first and the spacecraft furthest downstream (MMS4) observes it last.

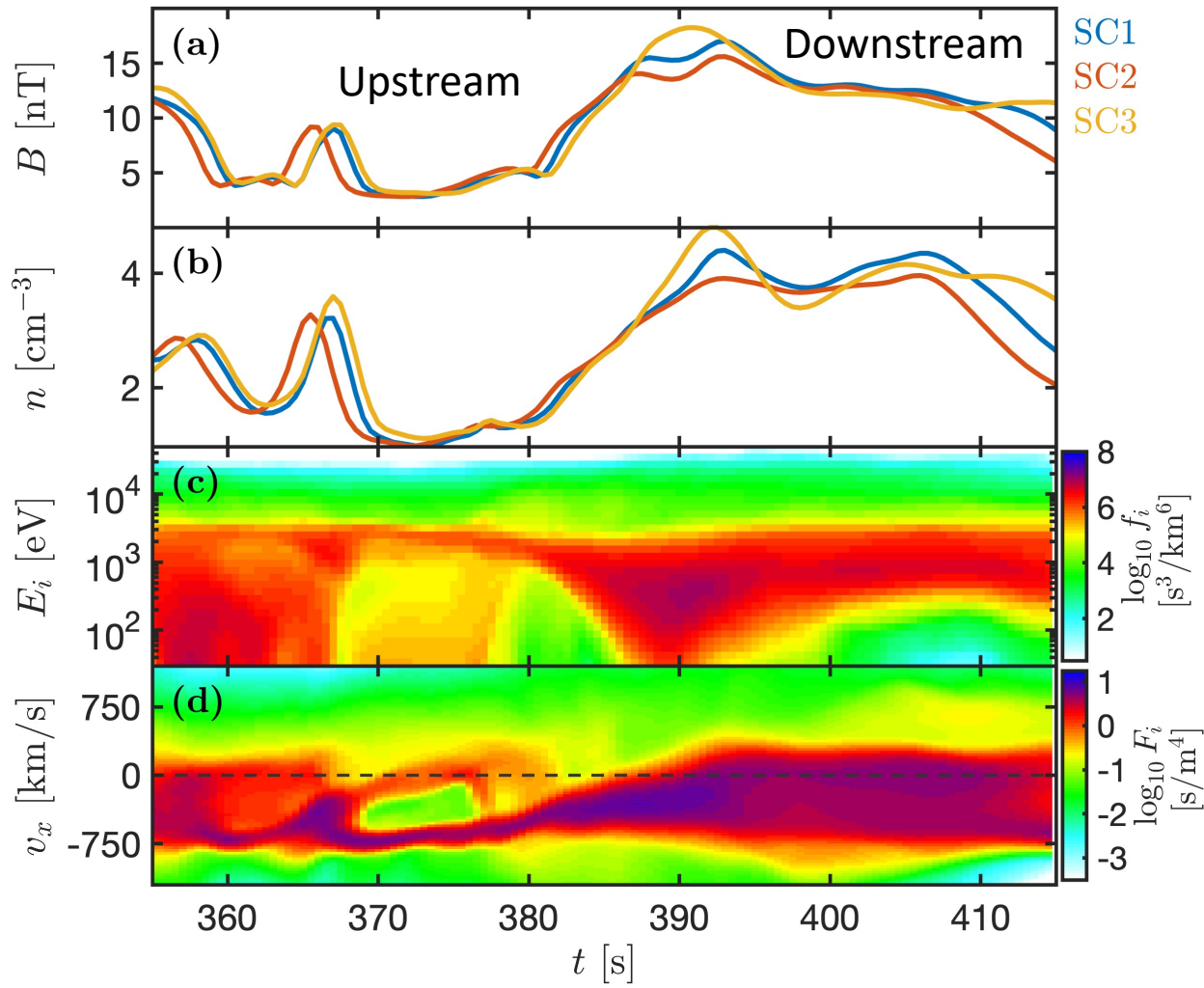
Four spacecraft timing analysis reveals that the crossing takes place $\sim 140^\circ$ from the model shock normal. This result shows that what appears to be the shock ramp is, in fact, the downstream edge of a SLAMS that is merging with the bow shock, constituting shock reformation.





4. Vlasiator simulation

To test and validate the MMS observations, we perform a 2D hybrid-Vlasov Vlasiator simulation of the Earth's bow shock, seen in the Figure to the left. During the simulation, several SLAMS form just upstream of the bow shock. We place three "virtual spacecraft" close to the bow shock in one of these events to replicate the multi-spacecraft observations of a shock crossing. In the three time steps, we can see a SLAMS forming upstream of the spacecraft. The SLAMS grows in amplitude and becomes the new shock ramp causing the shock to jump forward over the spacecraft.



5. Multi-point virtual spacecraft observations

The resulting virtual spacecraft observations are shown in the Figure to the left. Like in the MMS observations, the spacecraft cross the shock from upstream to downstream. Again, the spacecraft positioned furthest upstream (SC2) observes the shock crossing first. Timing analysis shows that the structure is moving with an angle of $\sim 160^\circ$ to the shock normal vector.

These simulation results therefore successfully recreates the MMS multi-spacecraft observations. Together, the observations and simulation shows that SLAMS can constitute reformation at quasi-parallel shocks.

Acknowledgements

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