Multi-Point Observations of Magnetic Reconnection in the Martian Magnetotail Triggered by IMF Rotation

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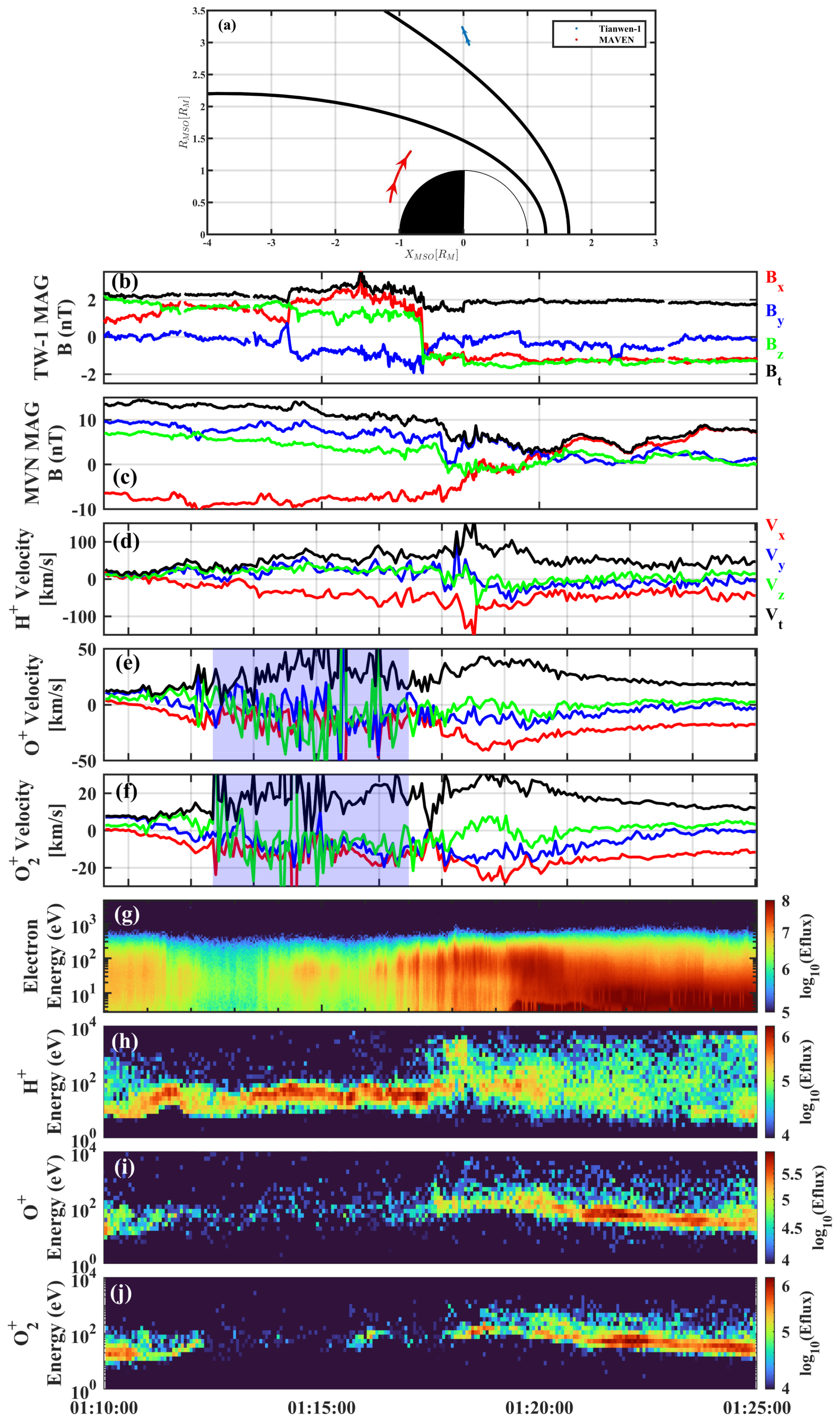
1. Overview of the IMF Rotation Event

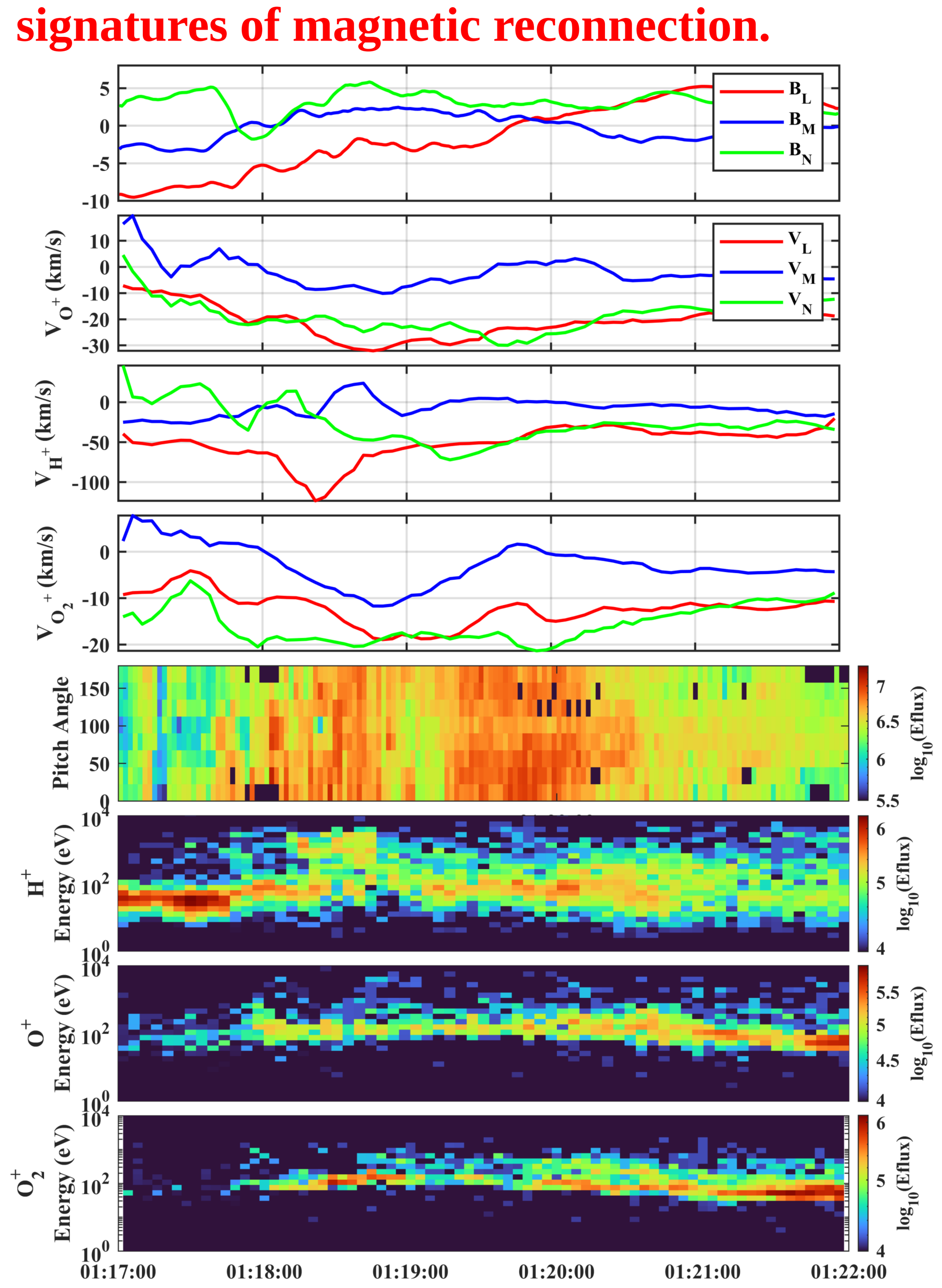
In December 2021, Mars experience a magnetospheric event influenced by an interplanetary magnetic field (IMF) rotation. Observations from two spacecraft captured this dynamic interaction. **Tianwen-1** detected a rapid IMF rotation with both Bx and Bz components flipping signs, **MAVEN** was located in the Martian magnetotail and observed a current sheet crossing shortly after the IMF rotation. The crossing was marked by magnetic field strength reduction, a reversal in the Bx component, and enhanced ion and electron energy flux, and co-occurrence of ion jet suggests that magnetic reconnection may have occurred within this current sheet. **This event provides a rare opportunity to investigate the Martian magnetosphere's rapid response to upstream solar wind changes using simultaneous multi-point observations.**

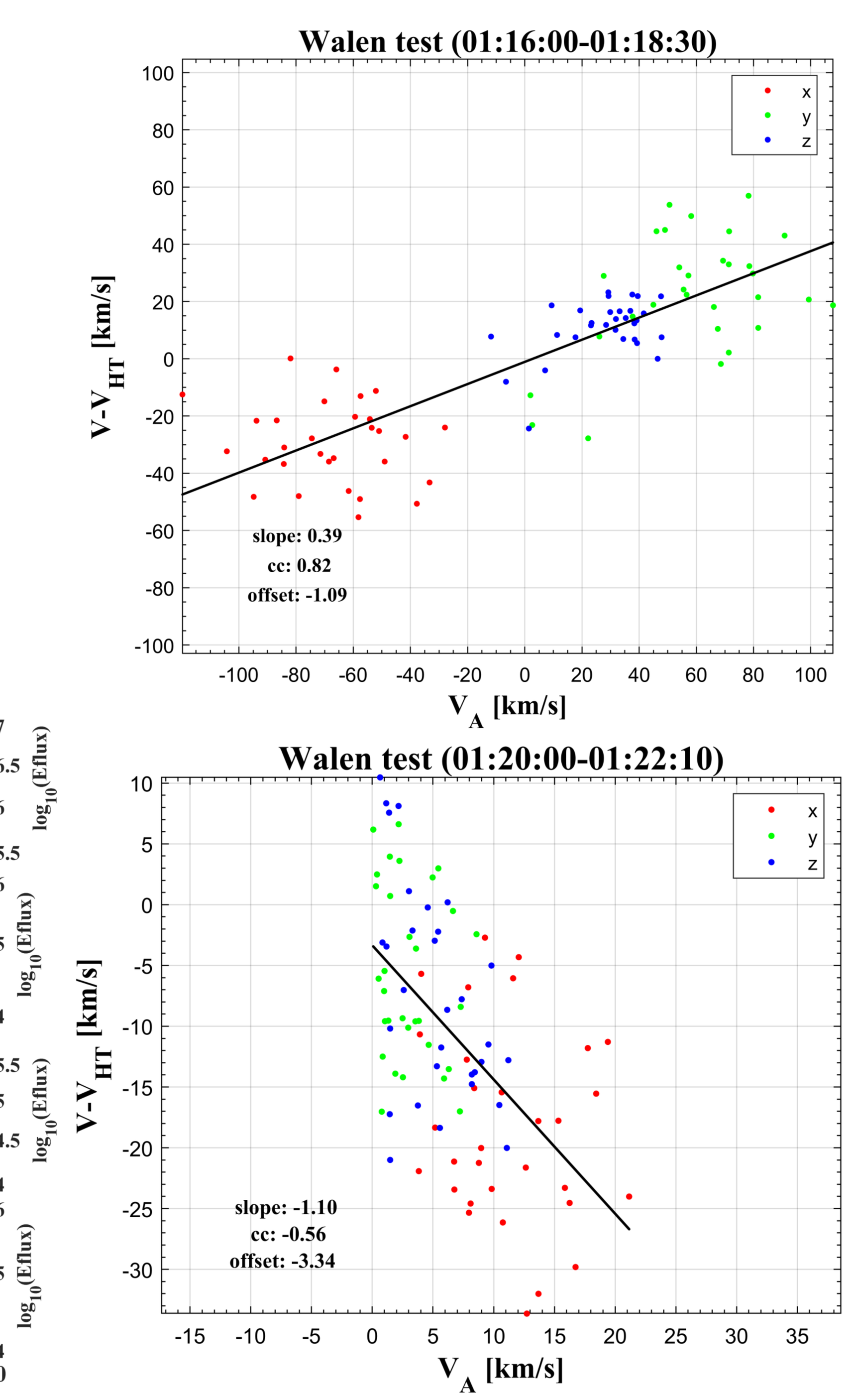


2. Magnetic Reconnection Analysis

Hall magnetic field signatures, characterized by a B_L-B_M bipolar structure, indicated the presence of an ion diffusion region. H^+ ions showed significant acceleration, with tailward velocities reaching up to ~100 km/s during the current sheet crossing. The magnetic field and ion flow pattern are consistent with the type-4 magnetic reconnection in Harada et al. (2017).

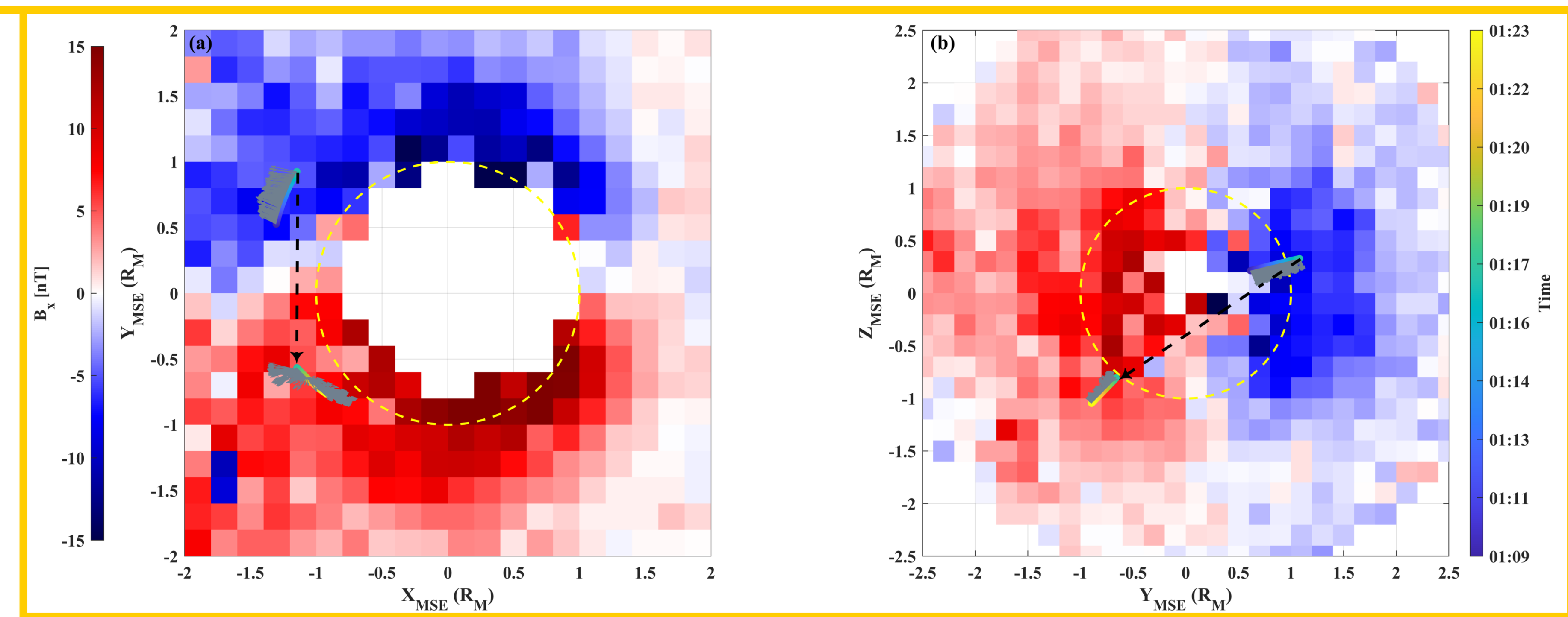
The results of the Walen test for this event are presented as a correlation between the observed flow velocity V′ in the de Hoffmann-Teller frame and the calculated Alfvén speed V_A. The Walen test shows a slope of 0.39 with a high correlation coefficient (0.82) before the current sheet crossing, indicating partially Alfvénic but sub-Alfvénic plasma flows. After the crossing, the slope increases to −1.10, closer to an ideal Alfvénic response**.** **These observations align with the expected signatures of magnetic reconnection.**





3. The Variation of the Induced Magnetic Field Draping

The magnetic field draping pattern around Mars undergoes significant reconfiguration during the event: **Pre-Rotation**: 1. Draped IMF lines formed stable lobes in the magnetotail, with MAVEN traversing the negative Bx hemisphere in MSE coordinates. **Post-Rotation**: 1. The IMF polarity reversal compressed the magnetospheric structure, leading to oppositely directed field lines and creating favorable conditions for reconnection. 2. MAVEN transitioned to the positive Bx hemisphere, with a rapid shift in magnetic field orientation. **Comparison with magnetic field draping models confirmed that the observed reconfiguration was consistent with an IMF-driven response**



4. Reconfiguration of the Induced Magnetosphere of Mars

The IMF rotation triggered a dramatic reconfiguration of Mars' induced magnetosphere, as illustrated in the schematic:

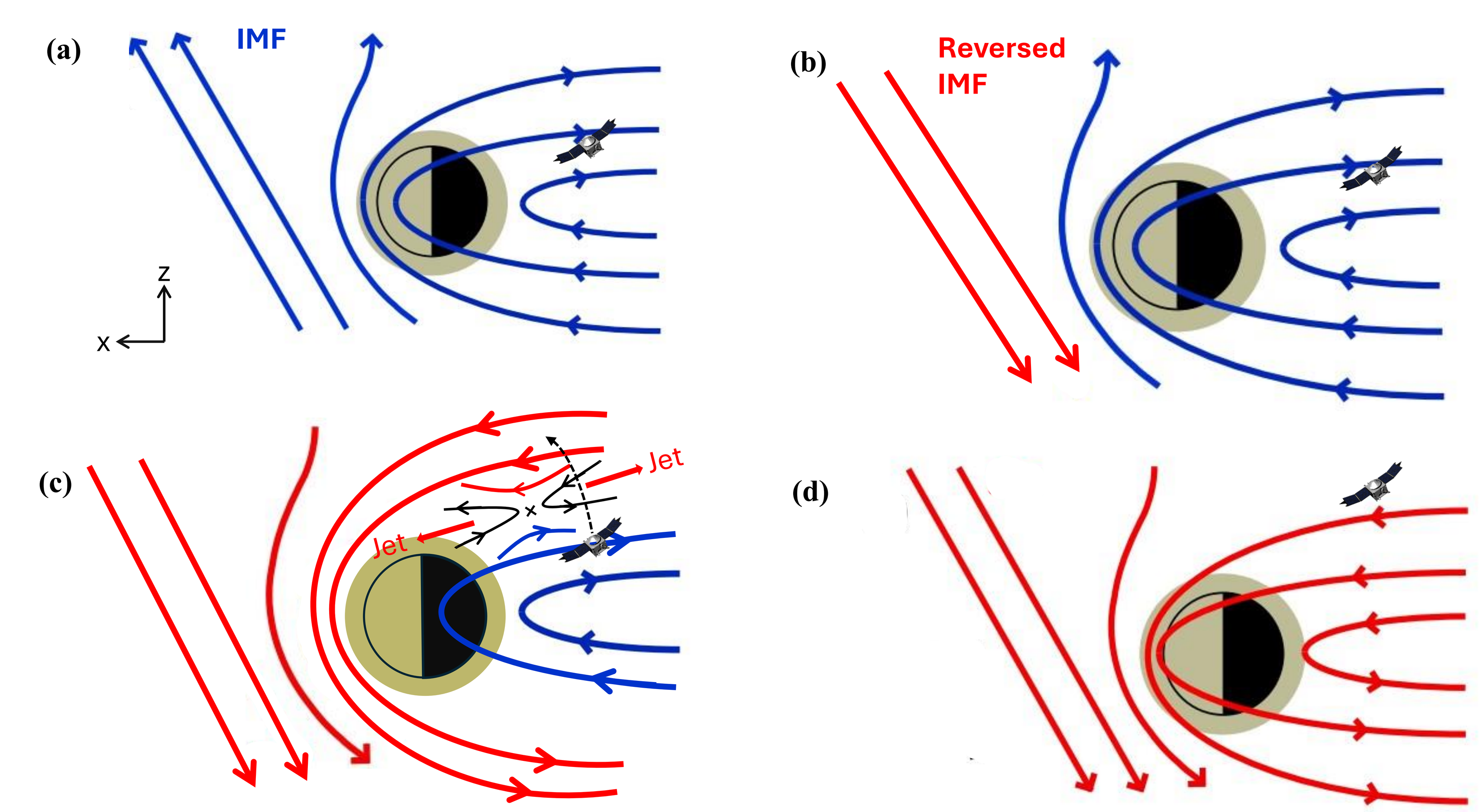
Phase 1 - Pre-Rotation: The IMF draped symmetrically around Mars, forming oppositely directed fields in the magnetotail.

Phase 2 - IMF Rotation: The polarity reversal of the IMF compressed the pre-existing magnetic field structure, causing field line convergence.

Phase 3 - Reconnection: Magnetic reconnection occurred at the convergence point, generating Hall magnetic fields, ion jets, and enhanced energy flux.

Phase 4 - Post-Rotation: The magnetosphere reconfigured with the new IMF orientation, leading to changes in plasma dynamics and ion escape patterns.

This reconfiguration process highlights how upstream IMF variations directly influence dynamic plasma processes in the Martian magnetosphere.



Not to scale

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