Martian Bow Shock Oscillations Simultaneous Observations from Tianwen-1 and MAVEN

MOMAG Team

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The Magnetometer (MOMAG) onboard Tianwen-1 Orbiter

- 2020.7 Launch
- 2021.2 Arriving at Mars
- 2021.5 Landing
- 2021.11 MOMAG starting to operate routinely
- Two fluxgate sensors on a 3.19m long boom
- In-flight calibration to remove the interference from the spacecraft
 (Wang et al., EPP, 2023; Zou, et al., SCTS, 2023; Wang et al., JGR, 2024)

MOMAG Level2(2C) Data







- 1 Hz and 32 Hz (full time since 2023) data
- Updated to 2024.8
- For more details, visit MOMAG Team website: https://space.ustc.edu.cn/dreams/tw1_momag/

Bow shock: The First Gate for SW impacting Mars



w/ intrinsic magnetic field



w/o intrinsic magnetic field

The factors influencing the BS

EUV, Dynamic pressure, Mach number, IMF orientation, Martian crustal fields, etc.

- EUV and Mach number are the primary drivers
- Dynamic pressure, crustal field
 are secondary
- IMF rotation also has a significant effect



Garnier et al., JGR, 2022

BS under Extreme SW Conditions

Strong SW due to the passage of an ICME

'Disappeared' SW due to a trailing rarefaction region

Radial IMF



- Boundaries vary dramatically
- Ion escape enhanced by more than one order of magnitude

- MAVEN completely behind BS inside the magnetosheath
- Nightside ionospheric expansion was significant

- Induced magnetosphere degenerated
- No dayside BS

Martian Bow Shock Crossings



- Data during 2021.11-12 are used for bow shock study
- 7.8 hr an orbit for TW1, and about 4 hr for MVN

Single-Crossing Events



Multiple-Crossing Events



Cheng, Lillis, Wang et al. GRL, 2023



Multiple-Crossing Events



Multiple Crossings due to the BS Oscillations





Oscillations for the two events were driven by

- IMF rotations
- Dynamic pressure variations

The response timescale less than one minute

The timescale of the oscillations

at minutes

□ The amplitude of the oscillations

at hundreds of kilometers

BS Oscillations under Weakly Disturbed Solar Wind



Causes of Such Oscillations

Two possible causes

- 1. Crustal field due to the rotation of Mars
- 2. Still being the external solar wind variations





Causes of Such Oscillations

Is it possible to be triggered at a certain IMF condition? ---- No

Discrete aurora \rightarrow enhanced magnetic reconnection

- Strongest crustal field at dusk-side
- IMF is -y oriented

Schneider et al., 2021; Xu et al., 2022; Johnston et al., 2023; Bowers et al., 2023





Causes of Such Oscillations

2. Still being the external solar wind variations?



Low Mach number \rightarrow Weak BS \rightarrow More easily be oscillated

Numerical Simulations using BATS-R-US by Dr. Yingjuan Ma (Ma et al., 2014)

For Event 3, two simulation cases: w/o vs. w/ the crustal field shifted forward



- Almost no difference between w/o and w/ crustal field
- Global minute-scale oscillations are reproduced

Numerical Simulations using BATS-R-US by Dr. Yingjuan Ma (Ma et al., 2014)

Multi-Crossing Event vs. a Single-Crossing Event

- Larger disturbance
- Higher Mach number
- Smaller oscillations

Mach number is a more sensitive parameter for BS oscillations. A weak BS is easily disturbed.



Summary

- Tianwen-1 and MAVEN for the first time provide the simultaneous observations of the magnetic field environment of Mars.
- The Oscillations of Martian BS as well as their causes are investigated through the simultaneous data. A weaker BS is more easily disturbed.
- Except the BS dynamics, such data may provide new insight into other topics, like (1) response of induced magnetosphere, magnetotail, and/or ionosphere, (2) atmosphere escape, (3) turbulence evolution, etc. See more at posters: PS1.4 (5823), PS1.5 (2747, 5681, 7760),









Future: Era of Multi-Obs. Thank you for your attention! **Double-Point Obs.** Four-Point Obs. **Five-Point Obs.** 2021.11 2026 2029 Tianwen-1/Orbiter ESCAPADE **Tianwen-3/Orbiter** MAVEN