Fast-Mode Waves in the Martian Magnetosheath and Same Periodic Ion Flows in the Induced Magnetosphere: Observations from Tianwen-1 and MAVEN

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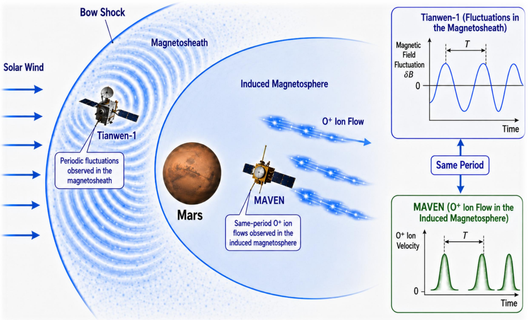
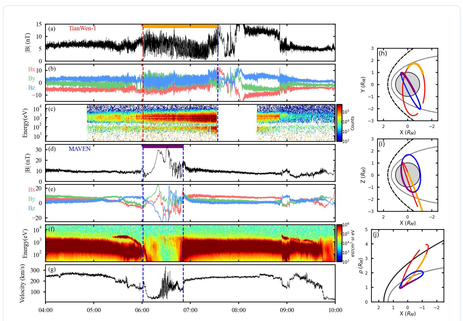
Abstract



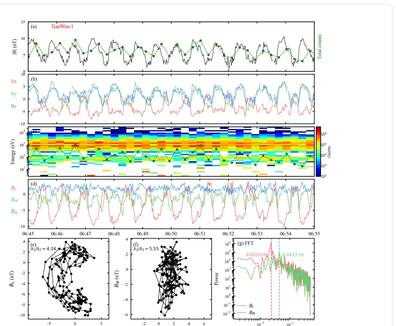
Mars is currently the only planet besides Earth where its space environment can be investigated through coordinated multi-spacecraft observations. Here, using magnetic field (MOMAG) and plasma (MINPA) measurements from Tianwen-1, we found fast-mode waves in the Martian magnetosheath with a period of approximately 50 s. Meanwhile, MAVEN, located in the Martian induced magnetosphere, observes ion flows with the same period, predominantly composed of O^+ ions. The coordinated observations from the two spacecraft indicate that periodic fast mode waves in the Martian magnetosheath can significantly modulate O^+ ion flows in the induced magnetosphere.

Result

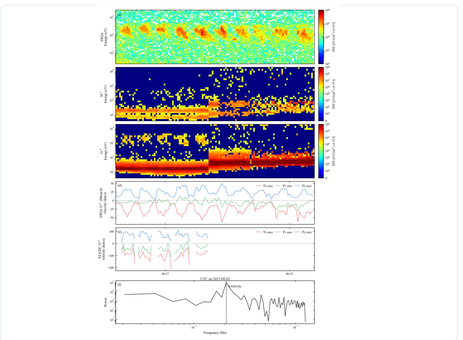
(a) Simultaneous observations by Tianwen-1 and MAVEN on August 3, 2022.



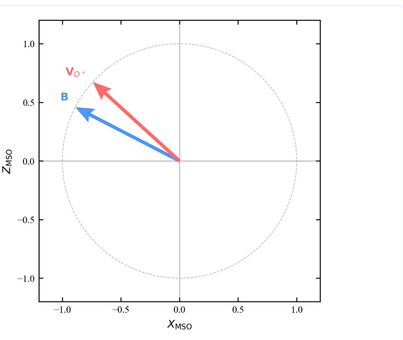
(b) Tianwen-1 observed ~50 s fast-mode waves in magnetosheath.



(c) ~50 s Periodic O^+ Ion Flows Observed by MAVEN in the Induced Magnetosphere

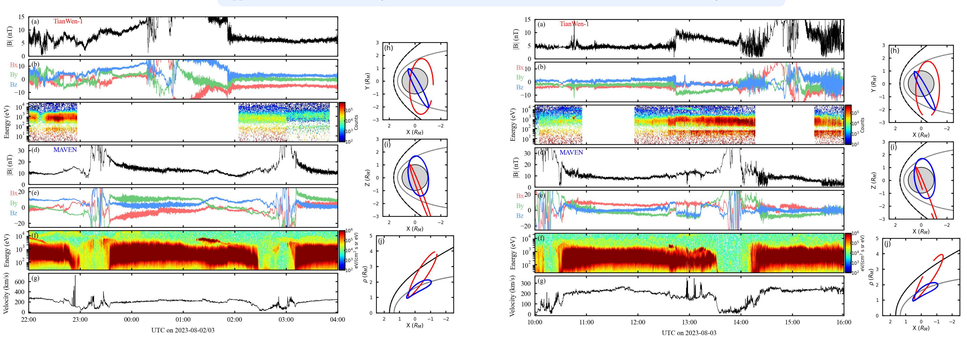


(d) O^+ Ion Flow and Magnetosheath Magnetic Field Direction in the XZ Plane



➢ **Tianwen-1 observed a significant enhancement in both the magnetic field fluctuations and ion counts, indicating that the spacecraft had entered the Martian magnetosheath, while MAVEN was located within the induced magnetosphere (Figure a). In the magnetosheath, the Tianwen-1 magnetometer (MOMAG) detected magnetic field fluctuations with a period of approximately 50 s, characterized by strong compressibility. Simultaneously, the MINPA instrument observed periodic enhancements in the total ion counts that were synchronized with the magnetic field fluctuations. In addition, a clear second harmonic was identified. The existence of fast-mode waves and their second harmonics in the Martian magnetosheath was first reported by Bharati Kakad et al. (2024). These observational signatures provide strong evidence that the waves observed by Tianwen-1 are fast-mode waves (Figure b). At the same time, MAVEN, located within the induced magnetosphere, observed periodic ion flows with a similar period of approximately 50 s. Measurements from STATIC indicate that these periodic ion flows were dominated by O^+ ions, and their velocity vectors were primarily confined to the XZ plane. At present, two mechanisms have been proposed to explain the generation of periodic ion flows in the Martian induced magnetosphere. One attributes them to a periodically varying solar wind electric field (Halekas et al., 2015), while the other suggests that they are generated by periodic magnetic reconnection (Zhang et al., 2021). Considering that the observed O^+ ion flow direction is nearly aligned with the magnetosheath magnetic field projected onto the same plane, we propose that the periodic O^+ ion flows were generated by magnetic reconnection.**

Appendix. Observations during the 6 hours before and 6 hours after the time interval shown in Figure a.



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