Statistical study of SLAMS at the Martian foreshock using MAVEN data

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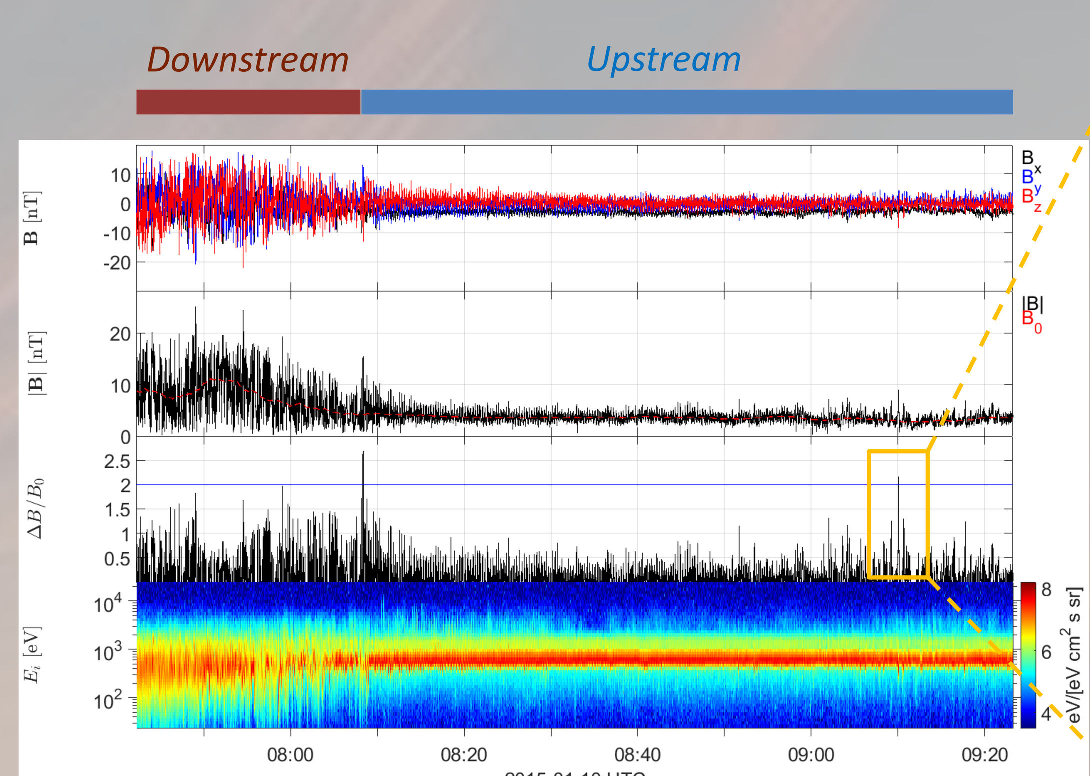
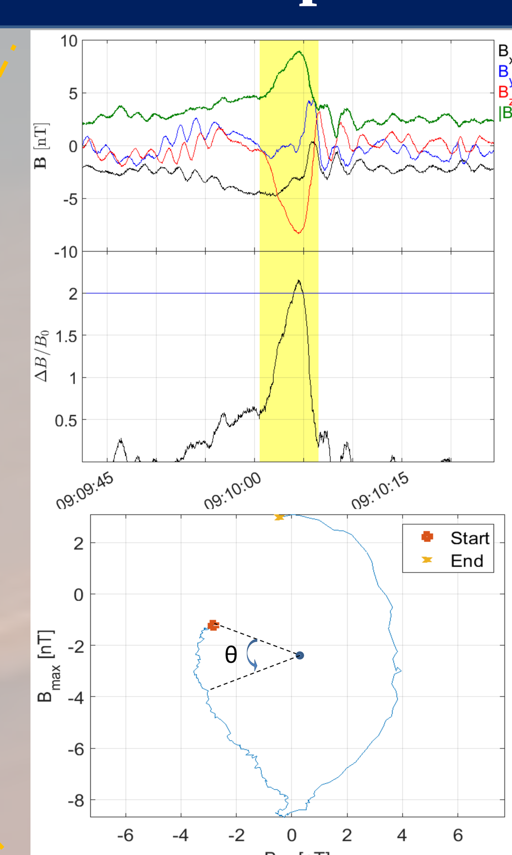
A. Introduction

The Martian Bow shock is formed due to the interaction between the incoming supermagnetosonic solar wind and the Martian atmosphere. At the quasi-parallel region of the shock (where the angle between the interplanetary magnetic field lines and the shock normal, $\theta_{BN} < 45^o$), a portion of incoming ions from the supercritical solar wind is reflected. These reflected ions then travel upstream into the foreshock region and trigger the ion-ion instability. This instability results in the generation of ultra-low frequency (ULF) waves which has a typical period of around 25 s on Mars (Shan et al., 2020). These waves may grow non-linearly due to further interaction with reflected ions, into isolated structures which have an increased magnetic field. These structures are named Short Large-Amplitude Magnetic Structures (SLAMS) (Schwartz and Burgess, 1991) and are believed to play a vital role in the quasi-parallel shock formation.

Cases of SLAMS have been observed previously at the Martian fore shock (Chen et al., 2022; Shuvalov and Grigorenko, 2023). Therefore we aim to study the nature of SLAMS by conducting statistical analysis with SLAMS detection in Martian foreshock for 2015 using the NASA MAVEN space probe.

B. Method: SLAMS identification & Example





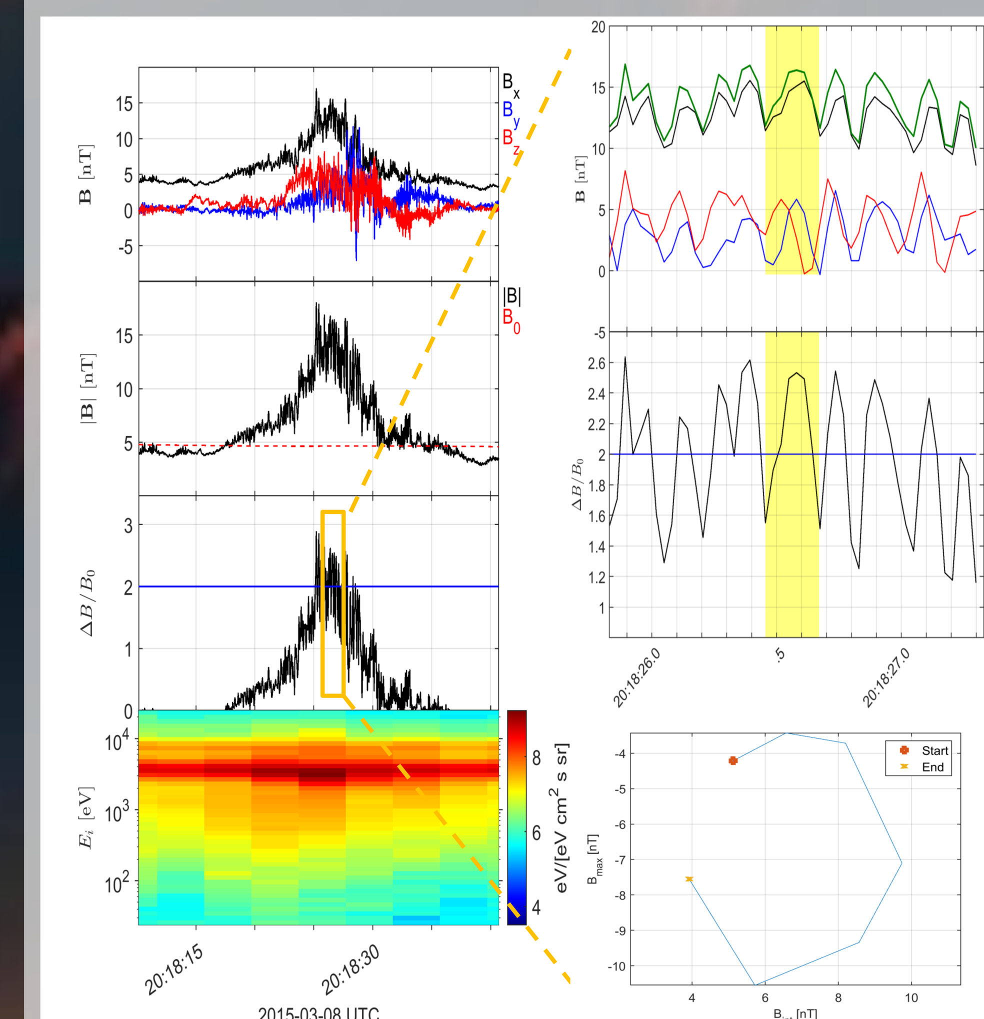
- The upstream is identified using magnetic field data (MAG) and ion spectrogram (SWIA) with criteria $B < 13$ nT, $N_i < 30$ cm^{-3}, $T_i < 500$ eV and $\alpha < 17°$ (angle between local ion propagation direction and anti-sunward direction).
- An instance where $\Delta B/B_0 > 2$ is found, a candidate is considered for a SLAMS.
- An ***elliptical polarization*** is detected using minimum varience analysis (MVA)

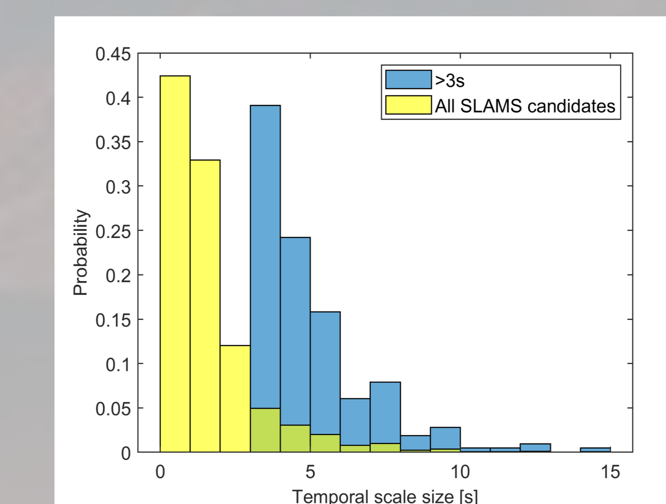
The elliptical shape was detected by checking if θ increases monotonically towards > 300°

$$\frac{\Delta B}{B_0}(t) = \frac{|\boldsymbol{B}(t)| - B_0}{B_0}, \qquad B_0 = \langle|\boldsymbol{B}(t)|\rangle_{240s}$$

Definition of SLAMS consists of $\Delta B/B_0 > 2$ and ***elliptical polarization***

C. Results: Clarification

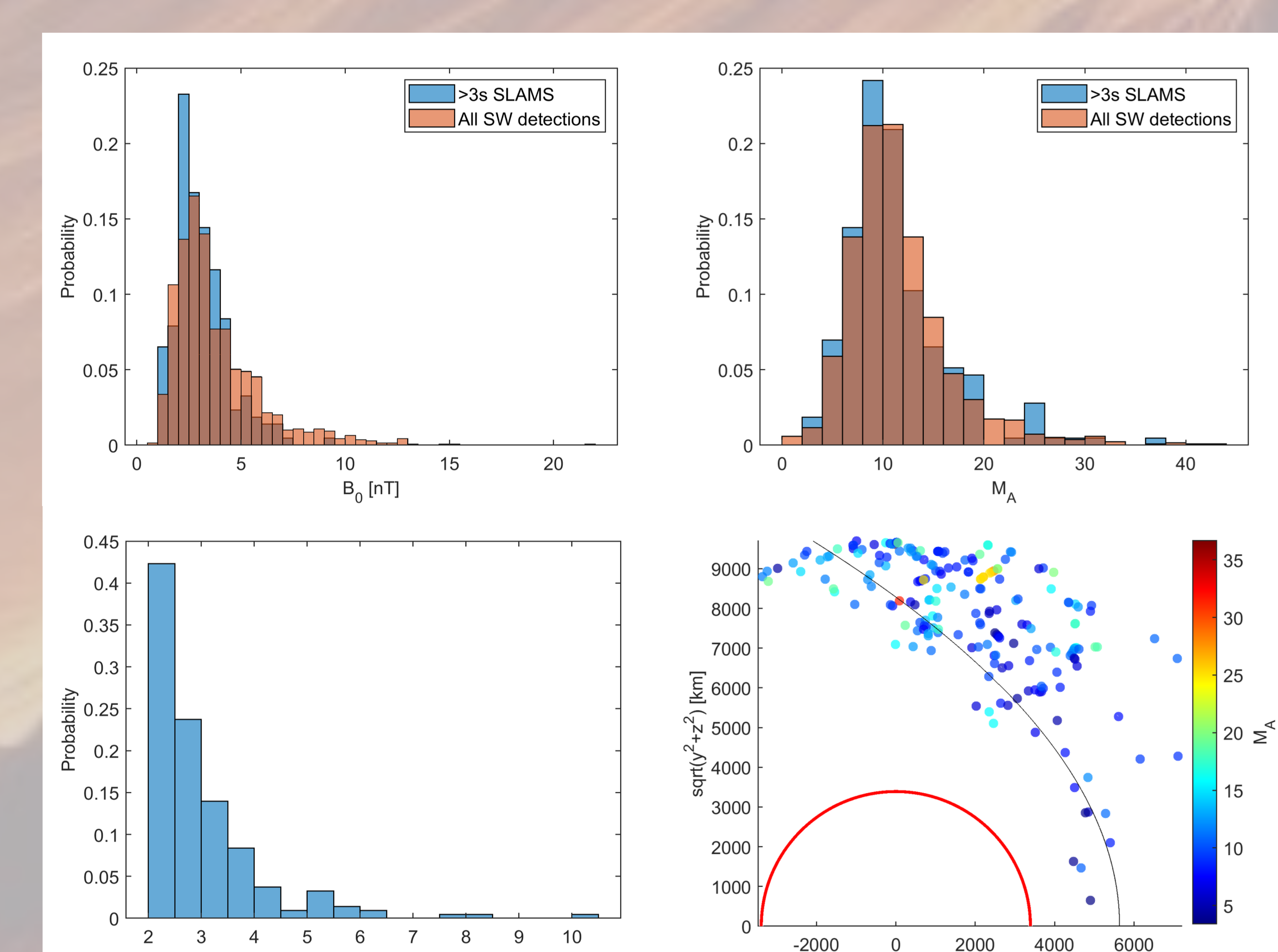




The SLAMS detection was done automatically. The algorithm however also picked up many instances when higher frequency whistler wave is superposed on the ULF wave. Spikes with high $\Delta B/B_0$ can be generated by this superposition. With the circular polarised whistler wave, the hodogram would be elliptic-like. Thus it can be mistaken by the algorithm as a single SLAMS by the algorithm.

For the sake of this poster, only SLAMS with a temporal scale size $\Delta t \geq 3$s are presented in the preliminary statistical results.

D. Results: Preliminary statistics



- A total of **266** SLAMS were detected from 2015.
- SLAMS are often found in an upstream environment that is **typical** for Mars in 2015, with respect to IMF ($\boldsymbol{B_0} \approx \mathbf{3}$ **nT**) and Alvénic mach number ($\boldsymbol{M_A} \approx \mathbf{10}$).
- Most SLAMS have a B-field amplitude of $\Delta B/B_0 = 2 \sim 3$.
- SLAMS are evenly distributed across the bow shock except for the noon-side.

E. Summary

Shock crossing data from MAVEN's MAG and SWIA instruments in 2015 were analyzed.

An algorithm was made and function as the following:

1. Identify upstream time intervals using a set of criteria.
2. Detect instances where $\Delta B/B_0 > 2$.
3. Confirm SLAMS candidate when an elliptical polarization is detected with MVA.

All candidates with $\Delta t \geq 2$ are filtered out and require further analysis due to potential superposition of high frequency whistler wave and ULF wave.

A preliminary statistics with **266** SLAMS detections

- ❖ SLAMS are often found in an upstream environment that is typical for Mars in 2015, with repect to IMF ($\boldsymbol{B_0} \approx \mathbf{3}$ **nT**) and Alvénic mach number ($\boldsymbol{M_A} \approx \mathbf{10}$)
- ❖ Most SLAMS have a B-field variation of $\Delta B/B_0 = 2 \sim 3$
- ❖ SLAMS are even distributed across the bow shock except for the noon-side

Comparable with SLAMS statistical results on

- ❖ Mercury ($\boldsymbol{B_0} \approx \mathbf{2}$ **nT**; $\boldsymbol{M_A} \approx \mathbf{14}$) (Karlsson et al., 2023)
- ❖ and Earth ($\boldsymbol{M_A} \approx \mathbf{12}$; $\Delta B/B_0 \approx \mathbf{2.9}$) (poster X3.22)

F. Future works

- Improve the algorithm to be able to separate SLAMS and whistler-ULF wave superposition
- Expand the statistics results beyond 2015
- Further detailed comparison of statistical results between SLAMSs on Mars and SLAMSs on different planets

References

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