Inferring Magnetic Topology at Mars with MAVEN/SEP Data

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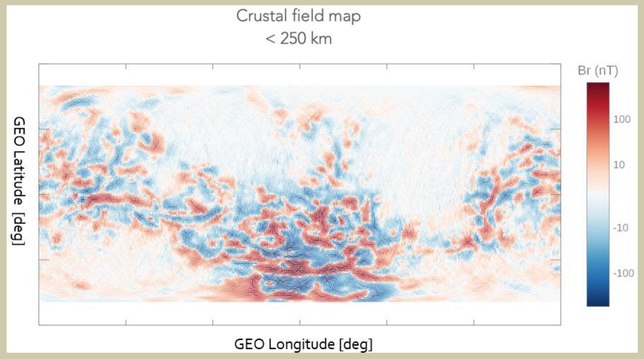
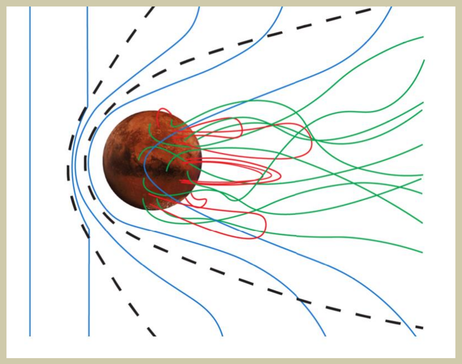
Introduction





Background
Mars does not have an intrinsic global magnetic field like that of the Earth but has localized crustal magnetic fields spreading across the planet. The strongest crustal magnetic fields at Mars are well understood from in-situ orbiter measurements but not so much for weaker magnetic fields because of their interaction with the solar wind plasma and solar wind magnetic fields. To better characterize Mars' weakly magnetized regions, we utilize electron measurements from the SEP (Solar Energetic Particle) instrument onboard the MAVEN (Mars Atmospheric Volatile and EvolutioN) spacecraft. We use SEP to "remote-sense" magnetic connectivity to the Mars surface and isolate magnetic field lines that are solely connected to Mars' surface on both ends (or closed magnetic fields). These connected fields are indicative of pure Mars sourced magnetic fields.

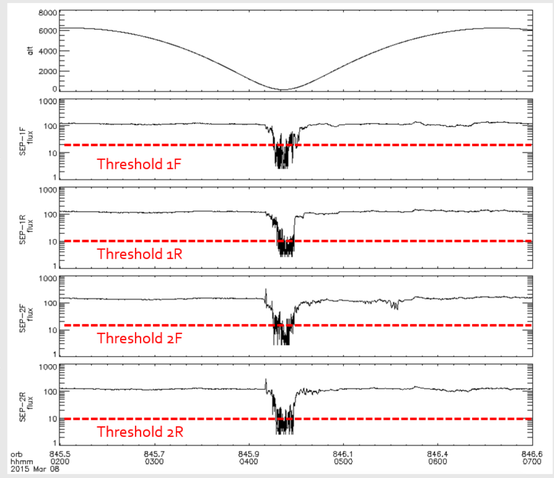
In this project we:
- Start with the March 2015 ICME, a solar transient event
- Performed a parameter study to better understand correlations between different parameters
- We then developed automated procedures to identify closed magnetic fields
  - Found that there are indeed closed field lines that exist over weakly crustal magnetisms

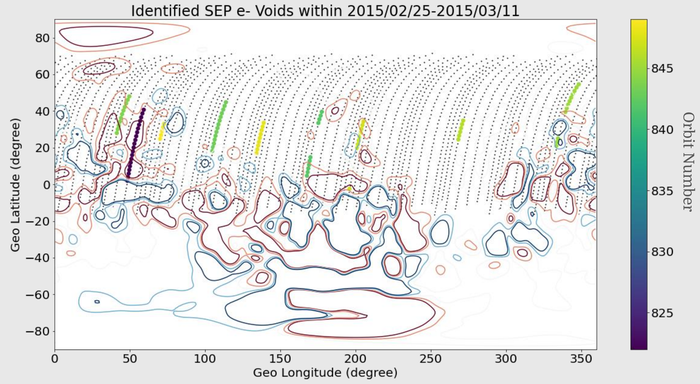
This project will provide better characterization of:
- Mars' crustal magnetism (particularly weakly magnetized regions)
- ion escape at Mars, one form of atmospheric loss at Mars.

This project will therefore further our understanding of Mars' atmosphere evolution, as ion motions are largely impacted by electromagnetic fields, one of which is Mars crustal magnetism.

- Draped: Solar plasma flow and magnetic fields
- Closed: Mars crustal magnetism
- Open: Connected to "Mars" on one end and to solar wind on the other end

Results

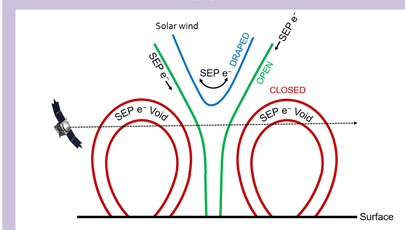


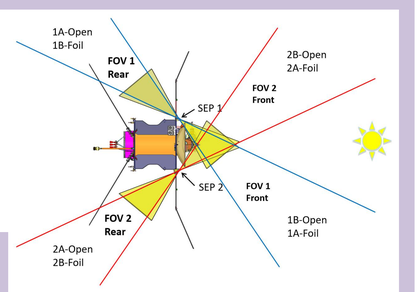


Finding SEP e- voids
- SEP e- voids are identified as fluxes below a threshold for each orbit from all four detectors
- The thresholds were defined as the average flux from each detector times 0.1 for each orbit at high altitudes
- The fluxes that go below the threshold at a certain point correspond to closed Mars magnetic field lines
- The solar wind electrons are not able to reach these closed loops of magnetic fields, therefore creating the electron voids as seen by the SEP instrument.

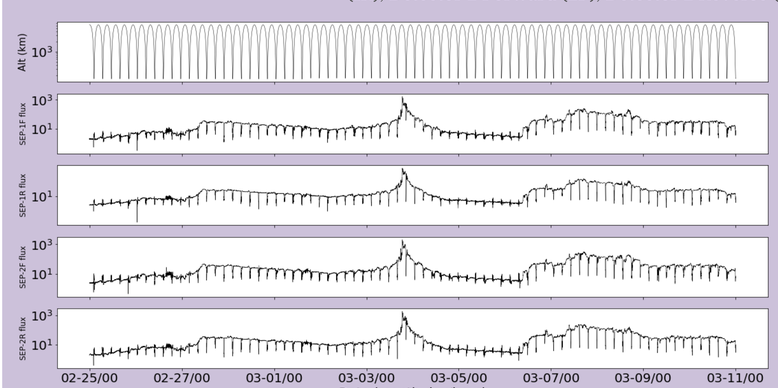
- The figure above shows the geographical location of each identified SEP e-void (shown in colored dots) for the entire ICME event
- We are overlaying our findings of the voids in the electron measurements by the SEP instrument on top of crustal magnetic fields in order to assess the correlation between the electron voids and the magnetic structure (topology) at Mars
- This method allows us to remotely gain insight into the distribution of the magnetic field line at altitudes that have not been directly measured before.
- The magnetometers flown on the previous Mars missions were not sensitive enough in order to accurately measure magnetic fields that are weak in the Northern hemisphere of Mars, therefore there are currently gaps in the map of the magnetic field contours as shown above.
- Our methodology aims to fill this gap using the high energy electron measurements of the SEP instrument on MAVEN.

Methodology



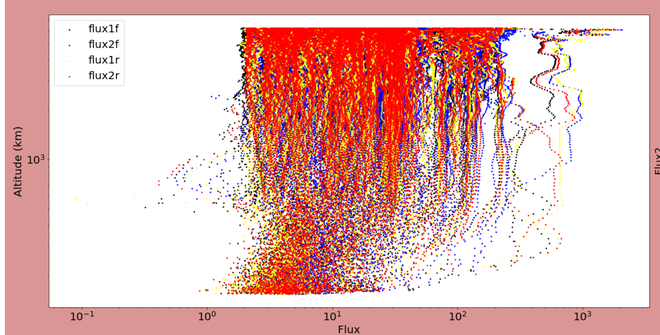


Main methodology:
- Finding SEP e- voids to identify closed fields (pure Mars field)
- Particularly important for weak crustal magnetism
- SEP instrument has four detectors in looking directions: Detector 1 Forward (1F), Detector 1 Reverse (1R), Detector 2 Forward (2F), Detector 2 Reverse (2R)

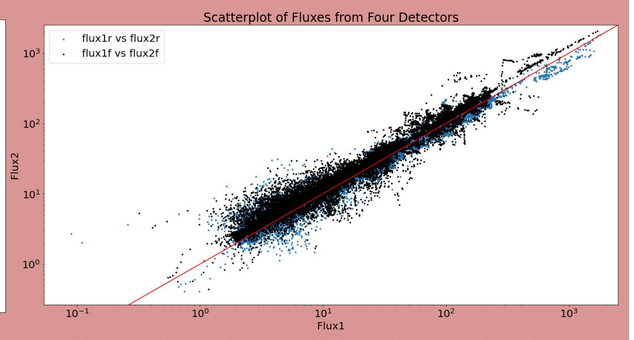


- Overview of MAVEN/SEP observations for 2015 March ICME event
- There tends to be lower fluxes at lower altitudes and higher flux at higher altitudes

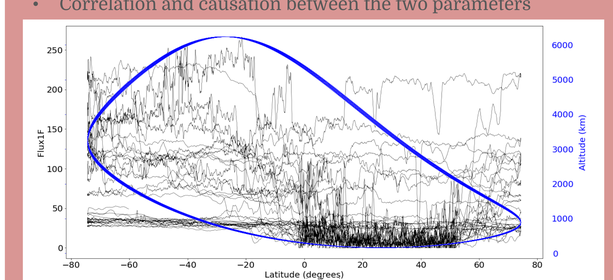
Parameter Study



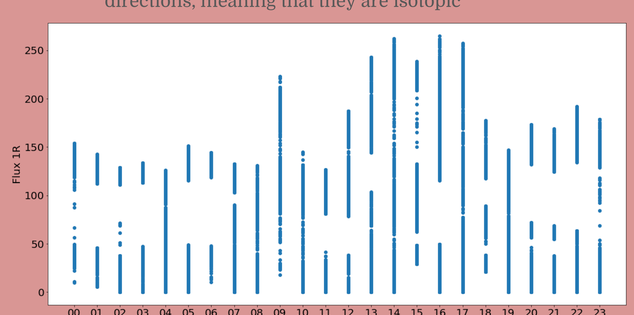
- Above a few hundred kilometers, fluxes are relatively constant with respect to altitude
- Below, the fluxes decrease rapidly as altitude decreases
- Correlation and causation between the two parameters



- Fluxes are being shown for all four different looking directions
- They largely follow the same trend and exhibit similar profiles
- Electron fluxes have the same value for different look directions, meaning that they are isotopic



- Flux appears to be lower from around 0-50 degrees latitude
- This is only because 0-50 degrees latitude has the lowest altitude
- Correlation but no causation between the two parameters



- No correction or causation between the two parameters (flux versus hour of day)
- Usually is the case for two unrelated parameters

Future Work

In the future, we will generalize this approach to the entire MAVEN dataset and establish a more robust map of closed magnetic fields at Mars. We hope to further explore correlation of SEP e-voids and Mars crustal magnetism. The threshold is also currently somewhat arbitrary and could be defined more precisely.

References

- Jakosky, Bruce M., et al. "The Mars atmosphere and volatile evolution (MAVEN) mission." Space Science Reviews 195.1 (2015): 3-48.
- Lillis, Robert J., et al. "Characterizing atmospheric escape from Mars today and through time, with MAVEN." Space Science Reviews 195.1 (2015): 357-422.
- Larson, Davin E., et al. "The MAVEN solar energetic particle investigation." Space Science Reviews 195.1 (2015): 153-172.
- Jakosky, Bruce M., et al. "MAVEN observations of the response of Mars to an interplanetary coronal mass ejection." Science 350.6261 (2015).
- Jakosky, Bruce, et al. "Loss of the Martian atmosphere to space: Present-day loss rates determined from MAVEN observations and integrated loss through time." Icarus 315 (2018): 146-157.
- Jolitz, R. D., et al. "Test particle model predictions of SEP electron transport and precipitation at Mars." Journal of Geophysical Research: Space Physics: e2021JA029132.

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