Mars Express Pickup Ion Observations as an Interplanetary Magnetic Field Proxy

Laboratory for Atmospheric and Space Physics
University of Colorado Boulder

Matthew Davis[1], Yaxue Dong[2], Robin Ramstad[3]

Laboratory for Atmospheric and Space Physics, Boulder, CO, University of Colorado Boulder

Email: matthew.davis@lasp.colorado.edu

Abstract

The European Space Agency's Mars Express (MEX) has been studying the Martian atmosphere since 2004. However, it lacks a magnetometer and therefore the ability to measure the interplanetary magnetic field (IMF), which controls the orientation of the induced magnetosphere of Mars. Therefore, we can use pickup ion measurements as a proxy for the upstream IMF and electric field orientations. We identify these pickup ion events from MEX Ion Mass Analyzer (IMA) data and compare them to the IMF data from the magnetometer on the NASA Mars Atmosphere and Volatile EvolutioN (MAVEN; 2014-present) spacecraft (Connery et al. 2015) to validate this proxy. We have seen that preliminary results show good consistence between several events.

Introduction

- Mars lacks a global dipole magnetic field to shield it, therefore the atmosphere is susceptible to impinging solar wind and IMF.
- The energy from solar activity is transferred to particles in the upper atmosphere causing them to become ionized and then accelerated by the motional electric field and eventually escape the planet.

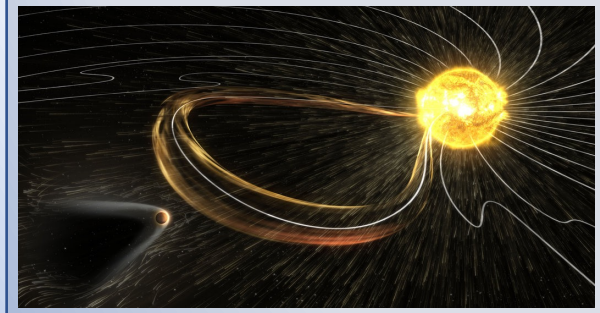

Figure 1: Solar Wind and Interplanetary Magnetic Field (IMF)
Credit: (NASA/Goddard Space Flight Center)

- MAVEN data analysis has shown that high energy ions in the beginning phase of the pickup ion process are well aligned with the upstream electric field directions ($E = -V_{SW} \times B_{IMF}$) in the Mars-Solar-Orbit coordinate system yz plane. (Dong et al. 2015)

Results

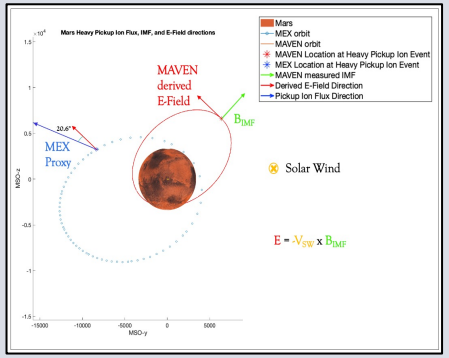

Figure 5: Jan 13th, 2018 event plotted to show difference of ion flux and derived electric field clock angles for proxy validation

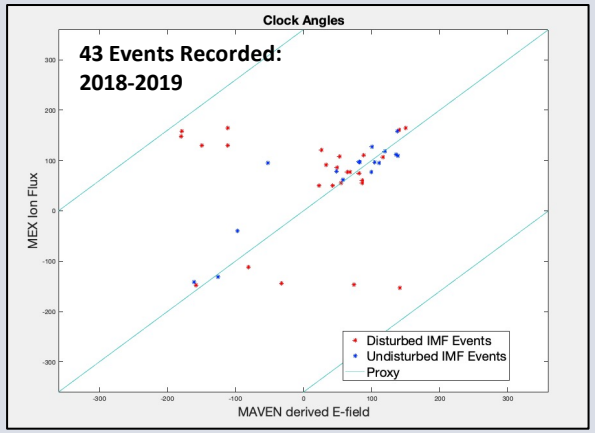

Figure 6: Angles measured from y-axis on MSO-yz plane to E-Field or Ion Flux vector. Proxy line periodically repeats every 360°

- 43 total events recorded over 2018-2019
- 17 "Undisturbed IMF" Events
  - Median: 20.6°
- 26 "Disturbed IMF" Events
  - Median: 28.9°
- Most events fall close to a proxy line showing good validation for proxy as compared to previous work (~90° acceptable) (Dong et al. 2019)

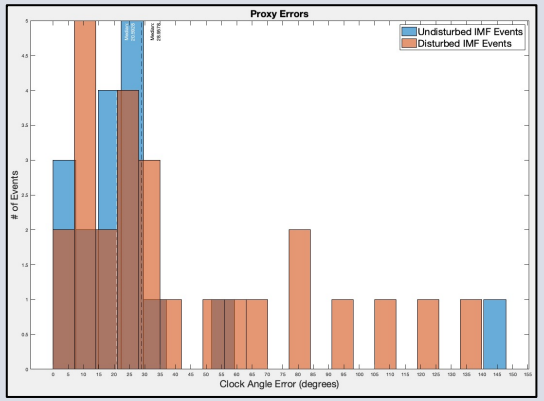

Figure 7: Histogram results showing proxy errors for "undisturbed IMF" (blue) and "disturbed IMF" (red) cases

Methods

- MEX detects ionized particles escaping the planet using the Ion Mass Analyzer (IMA) instrument. Heavier ions such as O+, O_2+, and CO_2+ can easily be detected and stored as events for validation (Barabash et al. 2006)

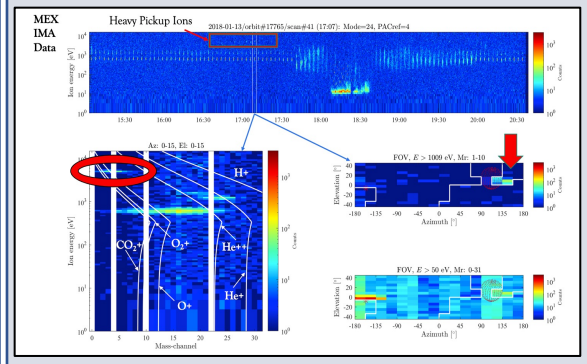

Figure 2: Heavy pickup ions detected at 17:07 UTC on January 13th 2018 in energy (eV)/time spectrogram (top), energy (eV)/mass spectrogram (bottom left) and angular distributions (bottom right)

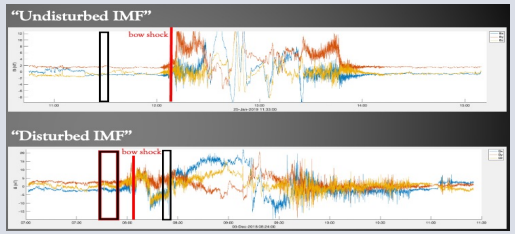

Figure 4: If events occurred when MAVEN was inside bowshock region, manual times were chosen and averaged for 15 minutes to measure IMF ("Disturbed IMF" cases)

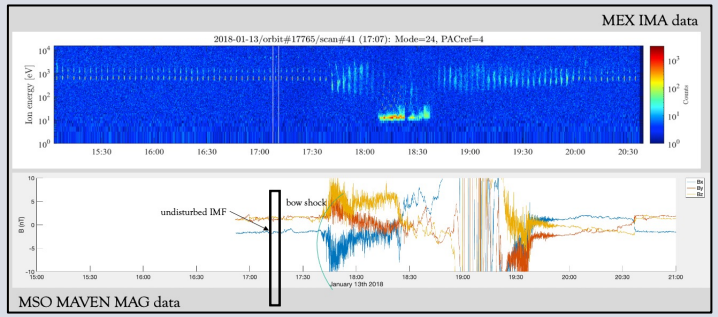

Figure 3: By comparing these events to MAVEN MAG data, we can validate the proxy and eventually produce results from the entire MEX mission before MAVEN arrived (2004-2014)

Conclusions & Future Work

- The preliminary results show that the proxy has an error <~30 degrees for electric field directions in the yz plane of the MSO coordinate system in most instances, which is .
- With the validated proxy, we can use it to find IMF for the entire MEX mission up until MAVEN arrived (2004-2014)
- Future work includes making proxy more accurate by using IMA angular distribution plots to find more accurate ion flux directions

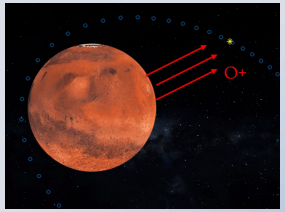

Figure 8: Heavy pickup ions being observed by MEX (yellow star) Assumption was made that ion flux directions were originated at the center of Mars

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