Results From the MAVEN Mission to Mars

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(slides by Bruce Jakosky, PI
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Mars appears to meet or have met all of the environmental requirements for the occurrence of life:

- Liquid water
- Access to the biogenic elements
- Source of energy to drive metabolism

**Did Mars ever have life?**

*How did any life interact with its planetary environment?*

*How has the habitability of Mars changed over time?*
Evidence for Surface Water on Ancient Mars
Where Did the Water Go? Where Did the CO\textsubscript{2} Go?

Abundant evidence for ancient water

Volatiles can be lost to space

Volatiles can go into the crust

Carbonate deposits in a Martian meteorite

Escaping ions detected from Mars Express
MAVEN Explores Escape of Atmospheric Gases to Space

- Measure energetic drivers from the Sun, response of upper atmosphere and ionosphere, and resulting escape to space
- Understand the key processes involved, allowing extrapolation to loss over Mars history
The MAVEN Science Instruments:

- Sun, Solar Wind, Solar Storms
  - SWEA
  - SEP
  - EUV
  - SWIA

- Neutrals and Ions Plus Evolution
  - IUVS
  - NGIMS

- Ion-Related Properties and Processes
  - STATIC
  - MAG
  - LPW
MAVEN Mission Architecture

Launch on 18 Nov 2013
Orbit Insertion on 21 Sept 2014

Orbit Precession Provides Coverage

One Year of Science Operations

Deep Dips Cover All Altitudes
MAVEN’s Primary Mission Occurs on the Declining Phase of the Solar Cycle
Discovery of Metal-Ion Layer Following Encounter With Comet Siding Spring

- Cometary dust entering Mars’ atmosphere is vaporized and ionized
- IUVS saw very bright UV emissions due to metal ions (left)
- Emission observed at tangent altitude of ~120-150km

- NGIMS detected 11 different metal ions (right); detected *in situ* as low as periapsis altitude of ~185 km
- Metals not detected prior to CSS encounter
- Ions lasted hours to days, consistent with model predictions
- No previous detection of metal-ion layer at Mars; electron layers had been detected

*(Schneider et al. 2015, Benna et al. 2015)*
Discovery of Long-Lived Metallic-Ion Layer During Deep-Dip Campaign

Mass ~55-60 (Fe⁺)

- Observed four months after Comet Siding Spring, likely no connection to it
- Previously, electron layers had been detected intermittently by Mars Express
- First detection of long-lived metallic-ion layer

STATIC

- Ions observed during deep dip at altitudes as low as 130 km
- STATIC (left) shows detection of ions at mass expected for Fe⁺
- NGIMS (below) shows detection of two different isotopes of Fe⁺; Mg⁺ also seen

O₂⁺ straggling
O₂⁺
O₂⁺ sputtering
O₂⁺ background

NGIMS

MODE = OSIO - TID 14986 - Start: 2015 FEB 16 19:52
Discovery of Dust Cloud Surrounding Mars, Observed by LPW

Dust-impact signature

*In the lab:* 

And at Mars:

Observed distribution of dust impacts:

(Andersson et al. 2015)
IUVS Detection of Diffuse Aurora

- “Christmas lights” aurora observed for five days on 18-23 December 2014
- Nightside emission at same wavelengths as dayglow; characteristic of aurora in general and of those observed by Mars Express
- Diffuse distribution throughout northern hemisphere; no connection to magnetic anomalies

(Schneider et al. 2015)
IUVS Observations of Atomic Components of H$_2$O and CO$_2$ on Their Way to Escaping
Hydrogen distribution and escape

- Hydrogen distribution not modeled well by single-component, spherically symmetric model
- Radiative-transfer degeneracy in terms of number density and temperature
- Analysis ongoing in order to derive unique density profile and infer escape rate

(Chaffin et al. 2015)
Ion Escape Driven by the Solar Wind (1 of 2)

- Single orbit shows upstream pickup ions, tailward escape, and polar plume in STATIC observations

(Dong et al. 2015)
Accumulation of all data shows that polar plume is a substantial and stable feature. Accounts for significant fraction of total escape.
Acceleration in Polar Plume (1 of 2)

$O_2^+$

$O^+$

$He^+$

$H_2^+$

$H^+$

$Z = 250$ km

(McFadden et al. 2015)
Acceleration in Polar Plume (2 of 2)

MAYEN c6 32e64m eflux
2014-10-18/16:05:10-16:05:26

Z = 500 km

O$_2^+$
O$^+$
He$^+$
H$_2^+$
H$^+$
Total Escaping Flux

- Precessing orbit provides good geographical coverage of escaping species in all directions
- Depends on solar-wind electric field variations that fill in coverage map
- Can use this to determine total number of escaping ions

(Brain et al. 2015)
Total Escaping Flux

- Ion escape rate $\sim 3 \times 10^{24} \text{ s}^{-1}$, or $\sim 100 \text{ g/s}$
- Not expected to be constant through time
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Determining the Effects of Solar Storms

- Three solar events occurred, on March 1st, 6th, then 8th
- March 8 event was largest, but complicated by preceding events
- Flare and CME also observed by SOHO
- Examine energy input, atmospheric response

(Jakosky et al. 2015)
Increased Dynamic Pressure of Solar Wind

Highest dynamic pressure thus far
Regions of Near-Mars Space Defined by SWIA and MAG Measurements

(Halekas et al. 2015)
Aurora Triggered by Both Events

…and compared to the earlier “Christmas lights” aurora
• Limited geographic coverage during ICME precludes unique determination of total escape, integrated over all angles
• Measurements indicate minimal change to tailward flux, and significant enhancement of flux on sunward side
Loss Resulting From Sputtering

Energy spectrum of precipitating ions from STATIC (blue) and SWIA (red)

MAVEN sputtering estimate (red dot) superimposed on Luhmann et al. model of escape history

Spatial distribution of sputtered ion flux

(Leblanc et al. 2015)
Mission Status Summary

• MAVEN continues to operate well as it completes its one-Earth-year primary mission
• First round of science results just published in Science and GRL
• First two releases of data to the community have taken place via the PDS
• MAVEN has been approved for an initial extended mission
• Science team preparing next extended-mission proposal for Senior Review