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First Results From MAVEN's Imaging UV Spectrograph

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Abstract

We report the first results from The Imaging Ultraviolet Spectrograph (IUVS) aboard the Mars Atmosphere and Volatile and EvolutioN (MAVEN) spacecraft orbiting Mars. The instrument is accomplishing its goals of characterizing the atmospheric composition and structure, enabling studies of atmospheric escape that will contribute to our understanding of Mars' atmospheric evolution. In addition, the instrument has made unexpected discoveries concerning meteor showers, aurora and nightglow on Mars.

1. Introduction

The Imaging Ultraviolet Spectrograph (IUVS) [1] is one of nine science instruments aboard the Mars Atmosphere and Volatile and EvolutioN (MAVEN) spacecraft which entered Mars orbit on 21 September 2014. IUVS is designed to explore the planet's upper atmosphere and ionosphere and examine their interaction with the solar wind and solar ultraviolet radiation. The instrument is one of the most powerful spectrographs sent to another planet, with several key capabilities: (1) separate Far-UV & Mid-UV channels for stray light control, (2) a high resolution echelle mode to resolve deuterium and hydrogen emission, (3) internal instrument pointing and scanning capabilities to allow complete mapping and nearly-continuous operation, and (4) optimization for airglow studies.

2. MAVEN Science Goals

IUVS, along with other MAVEN insturments, obtains a comprehensive picture of the current state of the Mars upper atmosphere and ionosphere and the processes that control atmospheric escape. Data returned by MAVEN will allow us to determine the role that loss of volatile species from the atmosphere to space has played in shaping the history of Mars climate, liquid water, and habitability. MAVEN is designed to answer three top-level science questions [2]:

- What is the current state of the upper atmosphere and ionosphere, and what processes control it?
- What are the rates of escape of atmospheric gases to space today and how do they relate to the underlying processes that control the upper atmosphere?
- What has been the total atmosphere loss to space through time?

3. IUVS Objectives

MAVEN's instrument complement answers these questions by combining observations of Mars' atmosphere and ionosphere with observations of the solar influences that control it. MAVEN has four instruments for atmospheric measurements that record atoms, molecules and ions through *in situ* measurements, probing conditions at the location of the spacecraft as it passes through the upper atmosphere. By contrast, IUVS derives atmospheric properties at a distance through spectroscopic measurements of UV emissions from atmospheric gases. IUVS makes quantitative measurements of the Mars atmosphere between altitudes of 30 and 4500 km, over all latitudes, longitudes and local times. Specifically, IUVS measures the composition and structure of the upper atmosphere by measuring:

- Thermosphere profiles of neutrals (H, C, O, N, CO, CO_2, N_2) and ions (C^+, CO_2^+) using limb scanning.

- Column abundance maps of H, C, O, CO_2, O_3 and dust in the upper atmosphere over the portion of the planetary disk that is illuminated and visible from high orbital altitudes using disk mapping.
- Coronal vertical profiles of hot species (H, D and O) using coronal scans.
- Mesosphere/thermosphere vertical profiles of CO_2 and O_3 using stellar occultations.

These observations offer three major contributions to MAVEN science: (1) making independent measurements of key properties also measured by *in situ* instruments for validation and redundancy; (2) providing the global context for *in situ* measurements taken along the spacecraft orbit, and (3) making unique measurements of atmospheric constituents and properties not possible with other instruments. Furthermore, thanks to instrument design and spacecraft accommodation, IUVS can observe Mars nearly continuously throughout the mission.

4. IUVS Initial Results

Each IUVS observational mode has successfully observed the spectral features and spatial distributions as intended, confirming and expanding our understanding of the Mars upper atmosphere as observed by the Mariner spacecraft, Viking and Mars Express. Initial results include:

- Observations of the aftermath of a meteor shower, in the form of intense emission from metal ions and neutrals from ablated Siding Spring meteors (Fig. 1);
- Diffuse auroral emissions of substantially greater nightside extent than seen by MEX/SPICAM, and frequent detections of nitric oxide nightglow;
- Significant persistent structures in the thermospheric dayglow emissions, dependent primarily on solar zenith angle, along with significant variability on daily timescales;
- Confirmation of N_2 emission in the VK band, as first reported by MEX/SPICAM;
- Spatially-resolved measurements of the D/H ratio in the upper atmosphere and its temporal evolution;
- The most complete maps and vertical profiles of H, C and O in the Mars corona (Fig. 2);
- The first global snapshot of the middle atmosphere obtained by a day-long stellar occultation campaign;
- Global ozone maps spanning six months of seasonal evolution.

5. Figures

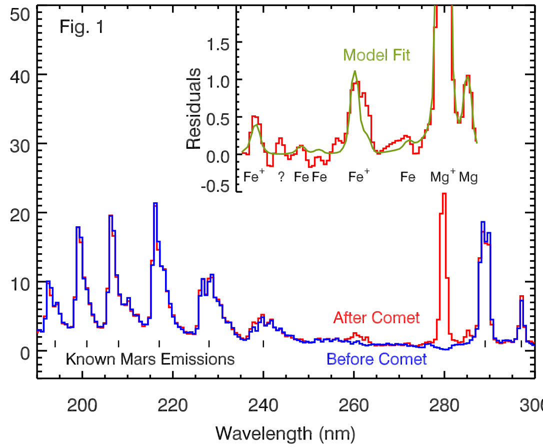

Figure 1: Spectra of Mars' atmosphere immediately before and after the closest approach of Comet Siding Spring. Spectra have been scaled and their backgrounds matched. The inset shows a smoothed difference spectrum, obtained by modeling and subtracting known Mars emissions and backgrounds. Numerous emissions from Mg^+, Mg, Fe^+, Fe, and other unidentified features are indicated.

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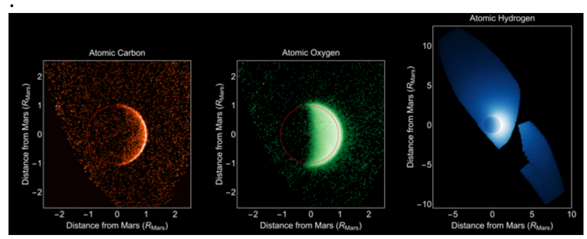

Figure 2. Three views of an escaping atmosphere, showing atomic carbon (166 nm), oxygen (130 nm) and hydrogen (122 nm). By observing all of the products of water and carbon dioxide breakdown, IUVS can characterize the processes that drive atmospheric loss on Mars.

References

[1] McClintock, W.E. *et al.* (2014), The Imaging Ultraviolet Spectrograph (IUVS) for the MAVEN Mission, *Space Sci. Rev.*, DOI 10.1007/s11214-014-0098-7.

[2] Jakosky, B., *et al.* (2014), The 2013 Mars Atmosphere and Volatile Evolution (MAVEN) mission to Mars. *Space Sci. Rev.*, doi: 10.1007/s11214-015-0139-x.