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MAVEN IUVS Observations of the Aftermath of the Comet Siding Spring Meteor Shower on Mars

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Abstract

We report the detection of intense emission from magnesium ions in Mars' atmosphere caused by a meteor shower following Comet Siding Spring's close encounter with Mars. The observations were made with the Imaging Ultraviolet Spectrograph, a remote sensing instrument on the Mars Atmosphere and Volatile EvolutioN spacecraft orbiting Mars. Ionized magnesium caused the brightest emission from the planet's atmosphere for many hours, resulting from resonant scattering of solar ultraviolet light. Modeling suggests a substantial fluence of low-density dust particles 1 – 100 μm in size, with the large amount and small size contrary to predictions. The event created a temporary planet-wide ionospheric layer below Mars' main dayside ionosphere and above the persistent layer that exists due to sporadic meteors. These observations inform our understanding of the meteoric atmospheric chemistry and dynamical processes.

1. Introduction

Shortly after the discovery of comet C/2013 A1 (Siding Spring), orbit determinations identified a very close passage by Mars on 19 October 2014. Motivated by concerns over spacecraft safety, detailed modeling of cometary dust predicted relatively low risk of spacecraft damage from dust impacts [1, 2, 3,4]. The effect of dust on Mars was of particular interest for its potential ionospheric effects [5]. Cometary gas impact was also considered for its potential effects on Mars' upper atmosphere [6], yet no significant enhancements were detected [7]. Accurate predictions were challenging due to the lack of precedent: the interval between such near miss events of the observed distance of 141,000 km has been estimated at 100,000 years [8]. Dust ejected from the comet was expected to remain confined in a stream that lags behind the comet in its orbit and predicted to intercept the planet about 2h after the comet's closest approach.

The Mars Atmosphere and Volatile EvolutioN (MAVEN) spacecraft entered Mars orbit on 21 September 2014 on a mission to study the behavior of the upper atmosphere and the escape of its constituent gases to space [9]. MAVEN carries one remote sensing instrument for the study of Mars' upper atmosphere, the Imaging UltraViolet Spectrograph (IUVS) [10]. The instrument captures spectra of the planet in the far and mid UV (110 – 340 nm), ideal for recording well-known atmospheric emissions from CO2 and its dissociation and ionization products.

2. Observations

During periapse, IUVS makes observations in a limb viewing geometry and construct vertical profiles of the atmosphere by using a scan mirror inside the instrument.

IUVS repeated its periapse observations from 18 October 16:05 UT (Orbit 109) to 22 October 07:49 UT (Orbit 128), with the exception of Orbit 115 when the spacecraft stood down during maximum predicted dust flux. Data were corrected for detector dark current, scaled according to intensity calibration and binned in altitude above the surface. Cleaned spectra and vertical profiles of individual emissions were obtained through multiple linear regression fits of independent spectral components, accounting for molecular bands, atomic lines and reflected solar spectrum background, as well as instrumental resolution and instrumental offsets [11].

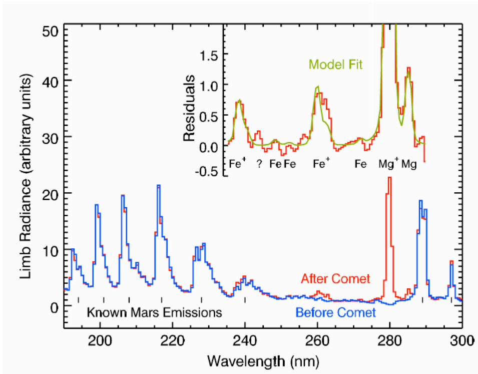

Figure 1: Spectra of Mars' atmosphere immediately before and after the closest approach of Comet Siding Spring. The inset shows a smoothed residual spectrum in red on an expanded vertical scale.

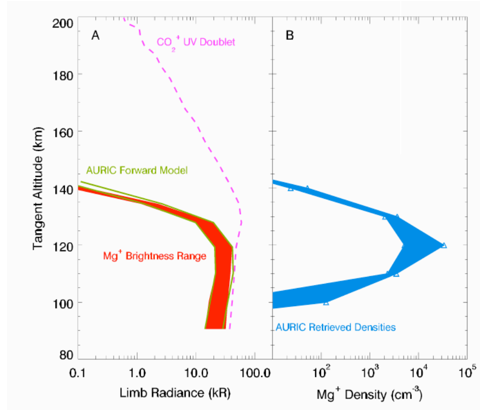

Figure 2: Vertical profiles of metal species and CO_2^+ UVD obtained from the same scan as Figure 1.

3. Results

Figure 2a shows a vertical profile of Mg^+ emission from one altitude scan of Orbit 116, peaking around 115 km and falling off rapidly with increasing altitude with an exponential scale height of ~2 km. A profile of the CO_2^+ UV doublet at 289 nm emission is shown as a fiducial for the background atmosphere and ionosphere, with its peak at 130 km and an ~16 km scale height. Together, these profiles demonstrate that the Mg^+ was narrowly confined in a layer 10–20 km below the CO_2^+ UV doublet peak located at a few nanobars pressure.

We will show the spatial distribution and temporal evolution of Mg^+ emission captured with IUVS observations over the course of this campaign. Such observations can then be used to compare to models of chemical ablation, particularly to determine the expected concentration of neutral species, which was not detected in the persistent layer [12].

4. Summary

- IUVS observed the largest meteor shower in modern history.
- Observations of Mg^+ constrain the delivered dust, and call for reexamination of cometary debris models.
- Temporal and spatial evolution constrain our understanding of meteoric chemistry and dynamical transport of these species at Mars.

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