EPSC Abstracts
Vol. 11, EPSC2017-375, 2017
European Planetary Science Congress 2017

The Metals Delivered by Comet Siding Spring to Mars

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Abstract

On October 19th 2014, comet C/2013 A1 (Siding Spring) had a close encounter with Mars and deposited cometary dust particles into the Martian atmosphere. Dust that impacted Mars was readily identifiable as the meteoric deposition of Mg, Fe, Na, etc. by the Imaging Ultraviolet Spectrograph (IUVS) and Neutral Gas and Ion Mass Spectrometer (NGIMS) on the Mars Atmosphere and Volatile EvolutioN (MAVEN) spacecraft. While Mg^+ from comet Siding Spring and in a persistent layer was identified previously by IUVS, this is the first report on the abundance, spatial distribution and temporal evolution of Mg, Fe, and Fe^+. We compare these observations to the Leeds 1-D Chemical ABlation MODel (CABMOD), and derive constraints on meteoric ablation, which helps to constrain chemistry at high altitudes.

1. Introduction

MAVEN's remote sensing instrument for studying Mars' upper atmosphere is the Imaging Ultraviolet Spectrograph (IUVS) [1]. This instrument observes in the far and middle UV (110-190 nm and 190-340 nm) in separate channels, and measures atmospheric emissions from CO_2, its dissociation and ionization products as well as atomic and molecular species such as O and N_2 [2, 3]. The instrument uses a scan mirror to construct vertical profiles of emergent radiation from the atmosphere at the limb.

We use observations from the periapse segment of each orbit, where IUVS produces limb scans over the altitude range 75-250 km. During each orbit, IUVS takes up to 12 limb scans in a ~22 minute observation period spanning ~45 degrees around the planet. MAVEN's elliptical orbit precesses about Mars on timescales of months to provide complete coverage of the planet. Data processing techniques are outlined in detail in previous MAVEN/IUVS papers [2, 3, 4, 5, 6].

High-speed collisions with air molecules cause rapid heating of interplanetary dust particles (IDPs), melting and evaporating their constituent minerals [7]. This ablation process deposits a variety of atomic constituents at the ~1 μbar level (80-110 km on Earth). Non-volatile elements such as Mg, Fe and Na act as direct tracers of the ablation process, as no other processes transport these species to these altitudes. In addition to the quasi-steady-state supply from random (or "sporadic") meteors, the ablation of cometary dust during meteor showers can supply additional metals to the upper atmosphere, as shown by comet Siding Spring.

2. Data

We relate the column brightness of these species to their tangent point densities by their scattering efficiencies and an Abel transform. This is a simplification, as these species are generally not optically thin, and future work will use a fully radiative transfer code to determine the true densities. The optically thin approximation (Abel transform) will underestimate the total ion concentration, and distorts the altitude profile below the peak emission altitude (Figure 3).

To determine the total dust deposition, we will relate these observations to a model of 1D Chemical Ablation (CABMOD) [8]. This model uses the speed of comet Siding Spring, assumes the material is deposited uniformly and is of chondritic composition. At these speeds a majority of the Mg+ are produced through the ablation process, in contrast to the persistent layer where the ions are produced through charge exchange with O_2^+ [9].

3. Results

Of the many elements that ablate from interplanetary dust particles, Mg^+ is most readily detectable in ultraviolet (UV) remote sensing, and was observed in a transient layer after the passage of comet Siding Spring [4]. The other dominant species by mass, Fe, is only detected in this time period because the delivered masses are extremely high compared to the persistent layer [10].

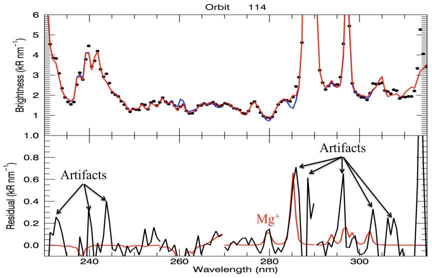

Figure 1: Top: IUVS data from a single scan on Orbit 114 is shown is black. A composite of known airglow emissions is shown in blue, while the red includes Mg, Mg^+, Fe and Fe^+. Bottom: Residuals, which are consistent with an incomplete knowledge of the shape of the CO Cameron bands, and left shoulder of the CO_2^+ UV Doublet.

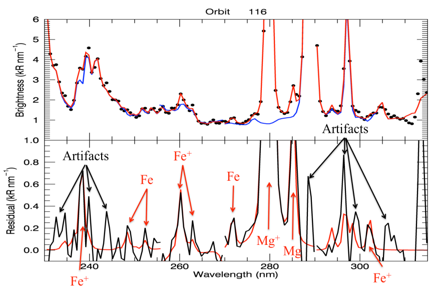

Figure 2: Same colors as Fig. 3. Top: Orbit 116, demonstrating a marked increase in Mg^+, Mg, Fe^+, and Fe. Bottom: Compared to bottom of Fig. 3 one can see that emissions from these new metal species are identifiable near 239 nm, 245 nm, 260 nm, 272 nm, and perhaps near 295nm.

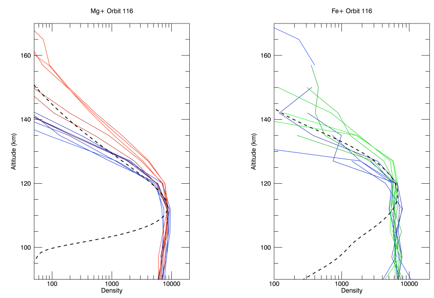

Figure 3: Altitude profiles of Mg^+ and Fe^+ shown for orbit 116, directly after dust deposition at Mars. In both profiles, blue represents the beginning of a scan, whereas red or green (Mg^+ or Fe^+, respectively) represents the end of the scan. A model from the Leeds Chemical Ablation Model (CABMOD) is shown as the dotted black line and scaled to match the data.

4. Summary

- We observe metallic species only found at Mars during the meteor shower of comet Siding Spring.
- Using these species we can constrain both the total flux of dust, as well as informing chemical ablation models.
- Spatial evolution of the ions suggest these species are controlled by dynamical processes that require further explanation.
- Temporal evolution indicates lifetimes inconsistent with model expectations.

Acknowledgements

The MAVEN mission is supported by NASA in association with the University of Colorado and NASA's Goddard Space Flight Center. J.M.C.P. and J.D.C.S. are supported by the European Research Council (project 291332-CODITA).

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