Characterization of Mars' Persistent Meteoric Ion Layer

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Novel Chemistry and Dynamics

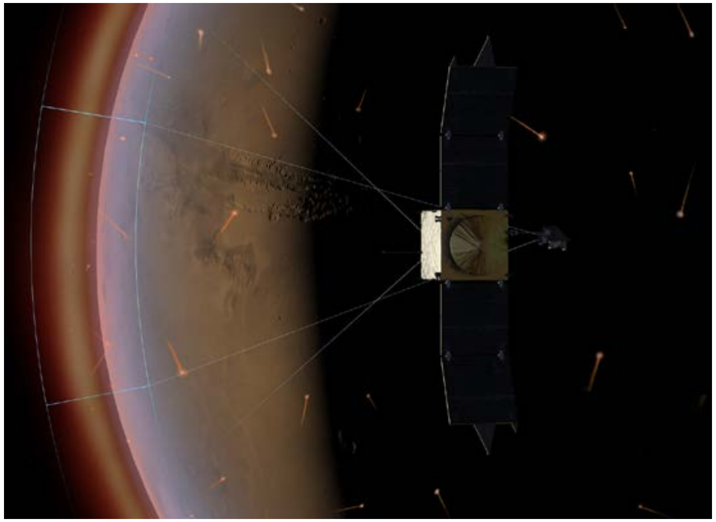
- IUVS observations of Mg^+ emission have prompted:
  - New chemical models
  - Interactions with the ionosphere
  - Reanalysis of previous ionospheric results

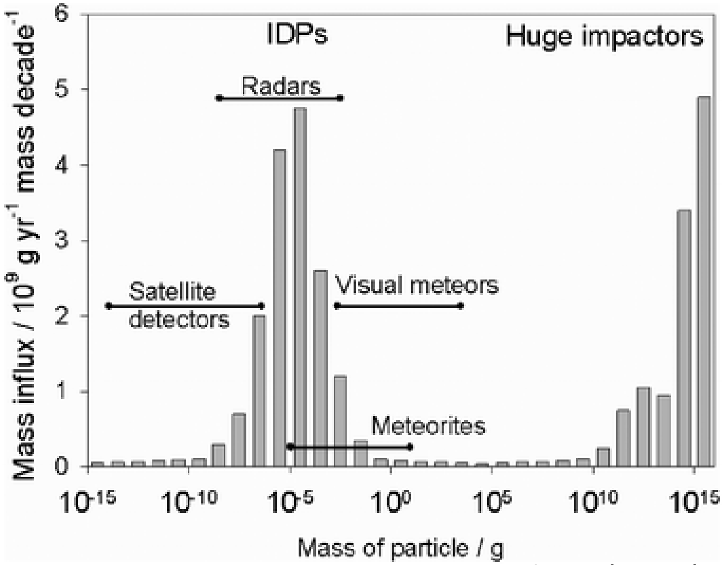
- While IUVS/MAVEN orbits Mars, the phenomena discussed herein should be considered for most planetary atmospheres

Cosmic Dust Becomes Meteors

- Cometary debris enters planetary atmospheres at orbital velocities
  – Most material is smaller than 10^{-2} g per particle (10% sand grain)

- Terrestrial Meteoric inform:
  - Interplanetary dust environment
  - Cloud nucleation
  - Effects of surface deposition
  - Perturbation of gas-phase atmospheric chemistry

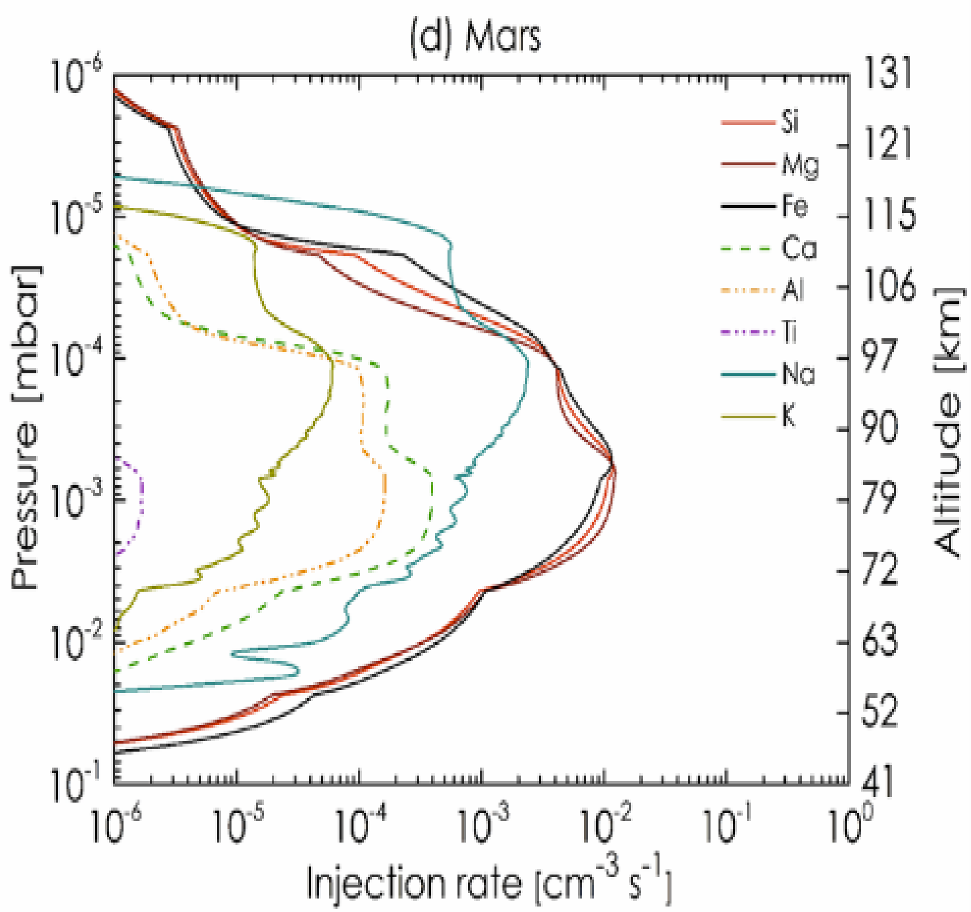




Flynn (1996)

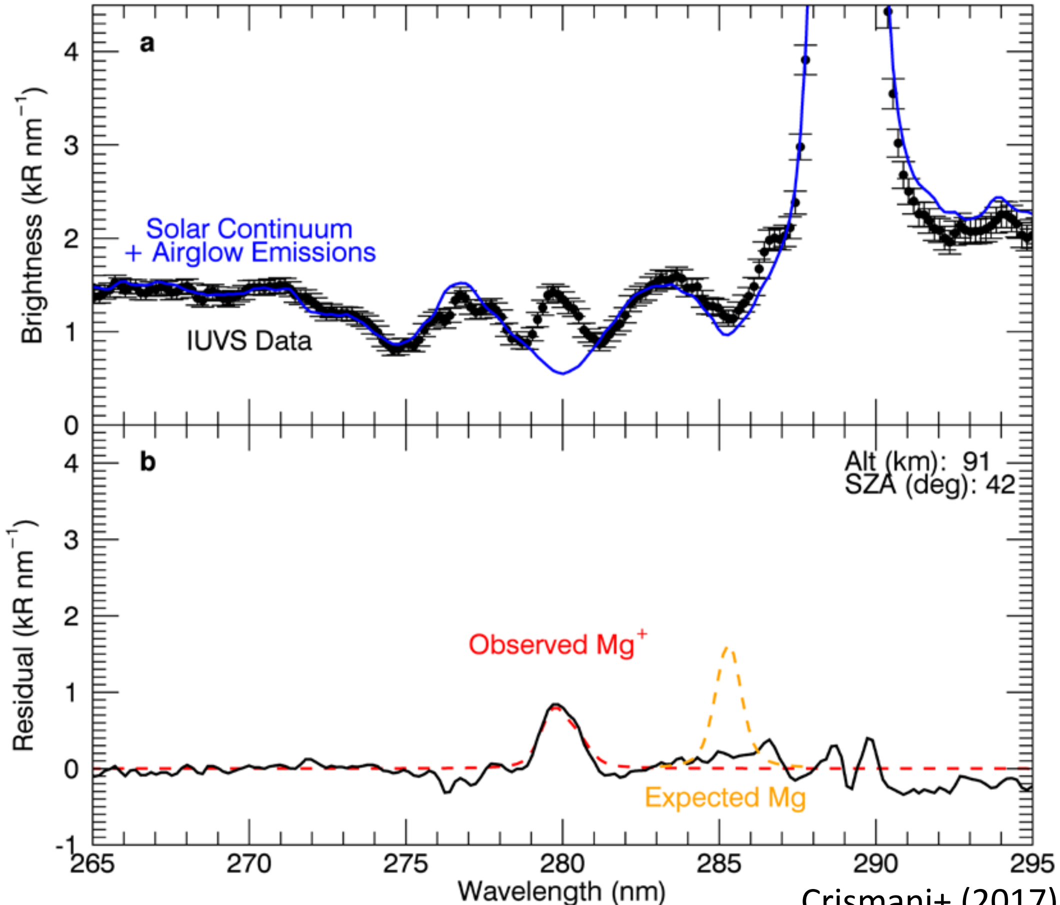
Meteoric Ablation Products

- Carbonaceous chondritic material is broken up and releases Mg, Fe, Na, etc. in the aerobraking region of the atmosphere (70-110 km)
  - Mg are 10.3% of IDP's total mass
- Mg^+ emission is most readily observed by MAVEN/IUVS in solar fluorescence
- Penetration depth anti-correlated with velocity: faster meteors ablate higher



Plane+ (2018)

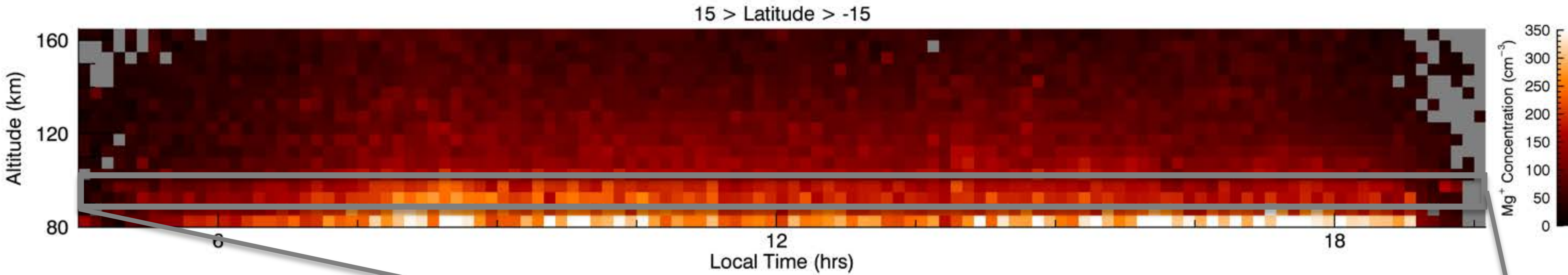
Spectrum from IUVS with Mg^+



Crismani+ (2017)

- Dayside observations of Mg^+ emission
  - Observations since Oct 2014
- Typical Mg^+ concentration of ~250 cm^{-3} at 90 km

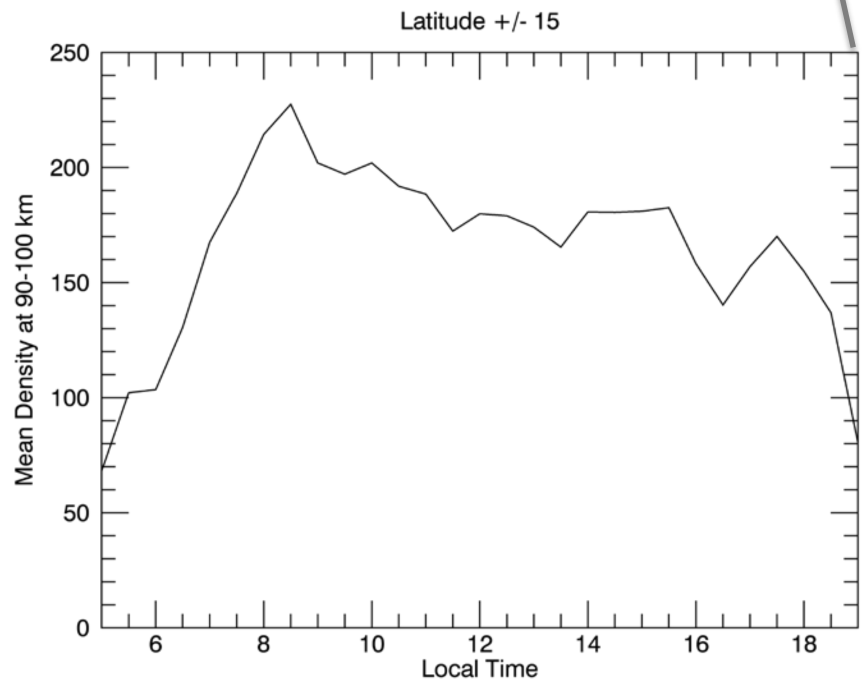
Diurnal Variation



- Ablation deposits Mg, charge exchange gives Mg^+

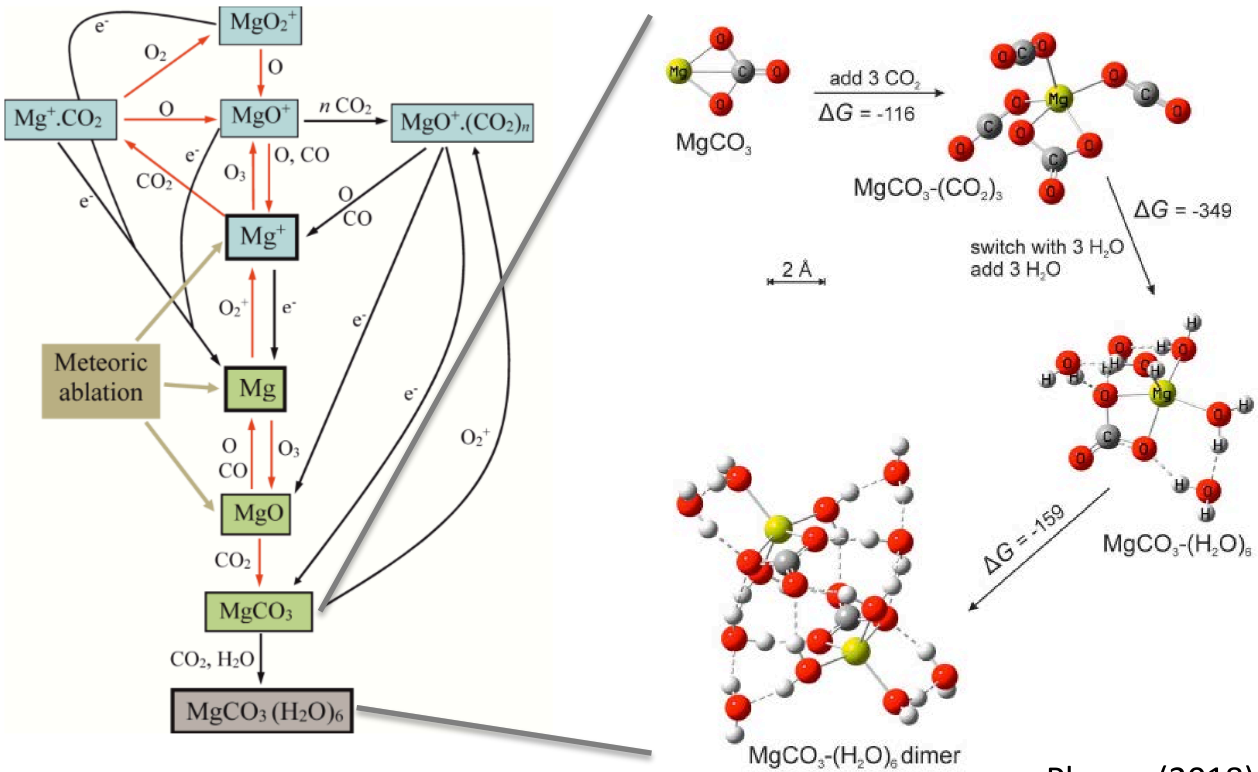
- Ionospheric variations reflected in meteoric ions
  - Sensitive to total electron content (TEC)

- Ramp and decay may give information on lifetime



Meteoric Cloud Nucleation

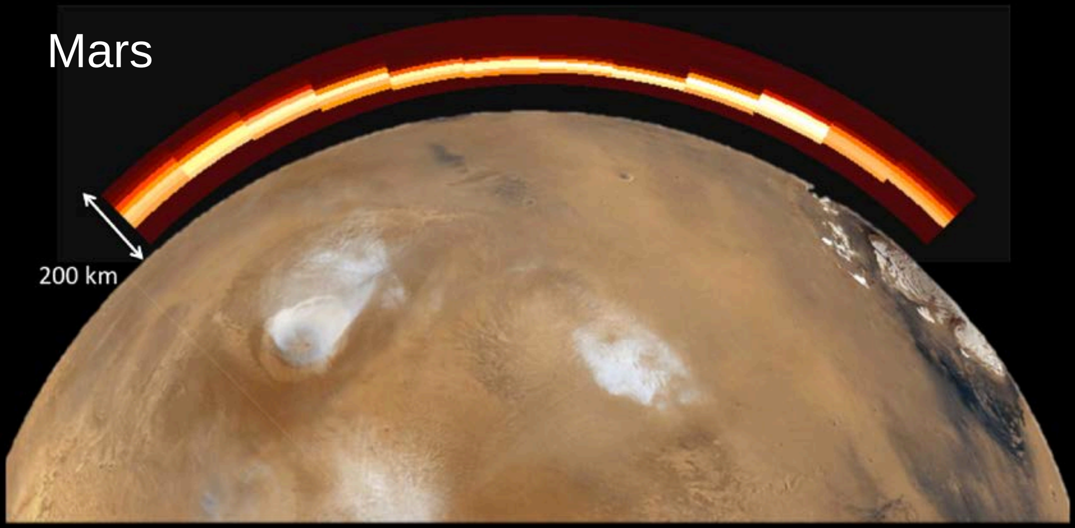
MAVEN
Mars Atmosphere and Volatile Evolution Mission
CU/LASP • GSFC • UCB/SSL • LM • JPL



Plane+ (2018)

- A novel meteoric chemistry scheme was developed to explain missing Mg emission from IUVS observations
- This leads to the formation of "dirty" ice particles which form condensation nuclei at higher T (~150 K) and high altitude

Comparing Major Meteor Showers

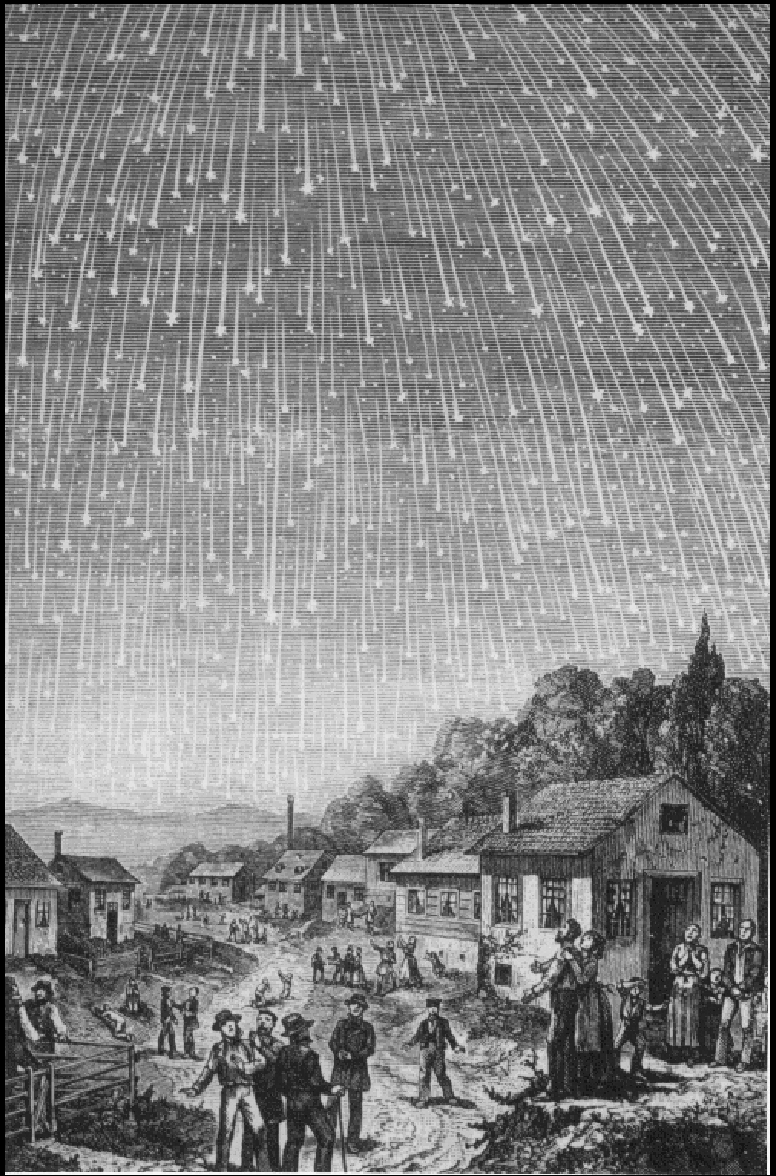


280 nm Mg^+ emission from Mars' atmosphere following the Siding Spring Meteor Shower

2014 (Mars)
Comet Siding Spring Meteor Shower
ZHR ~ thousands or tens of thousands meteors/hour; total mass ~16,000 kg

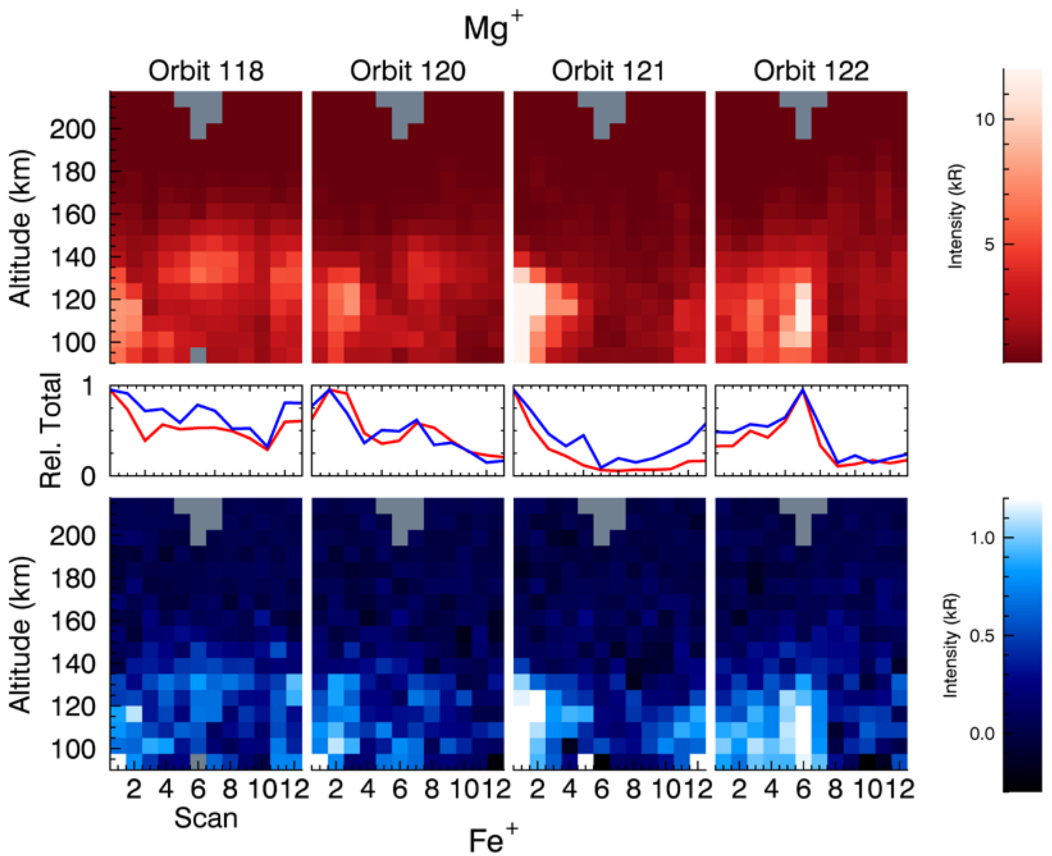
1833 (Earth)
Leonid Meteor Shower
ZHR ~ thousands or tens of thousands meteors/hour

ZHR = Zenithal hourly rate



Strange Ionospheric Dynamics

- Only Comet Siding Spring meteor shower shows an impact on meteoric layer
- This time period gives insight into strange dynamics, unassociated with the ambient ions
  - Similarly seen in NGIMS data



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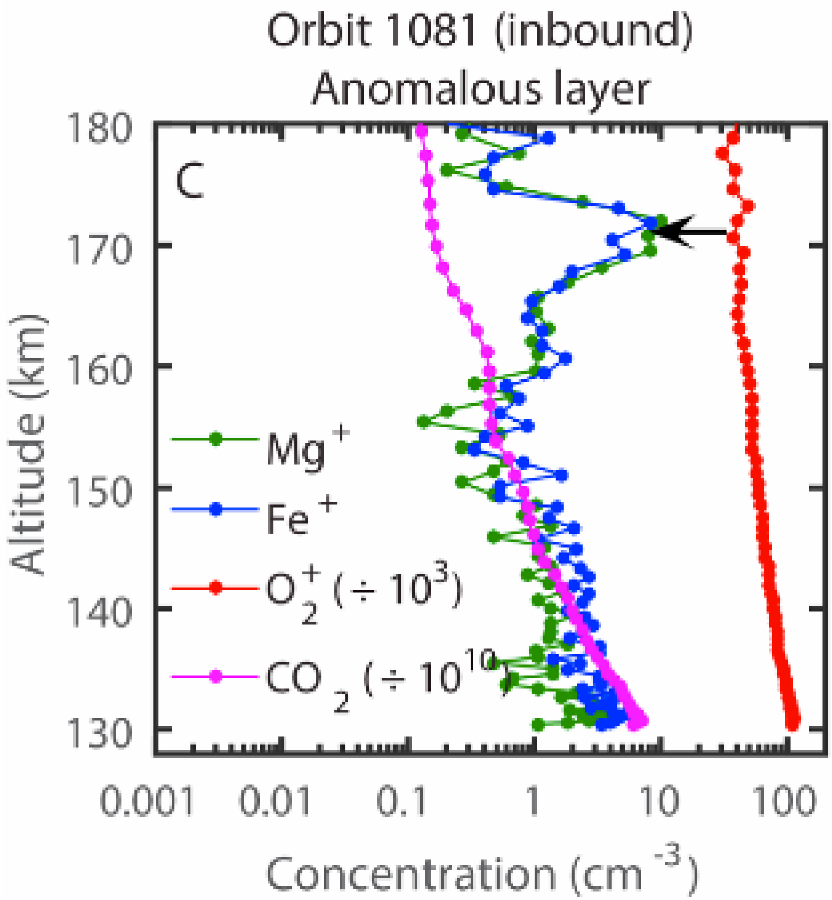

Grebowsky+ (2017)

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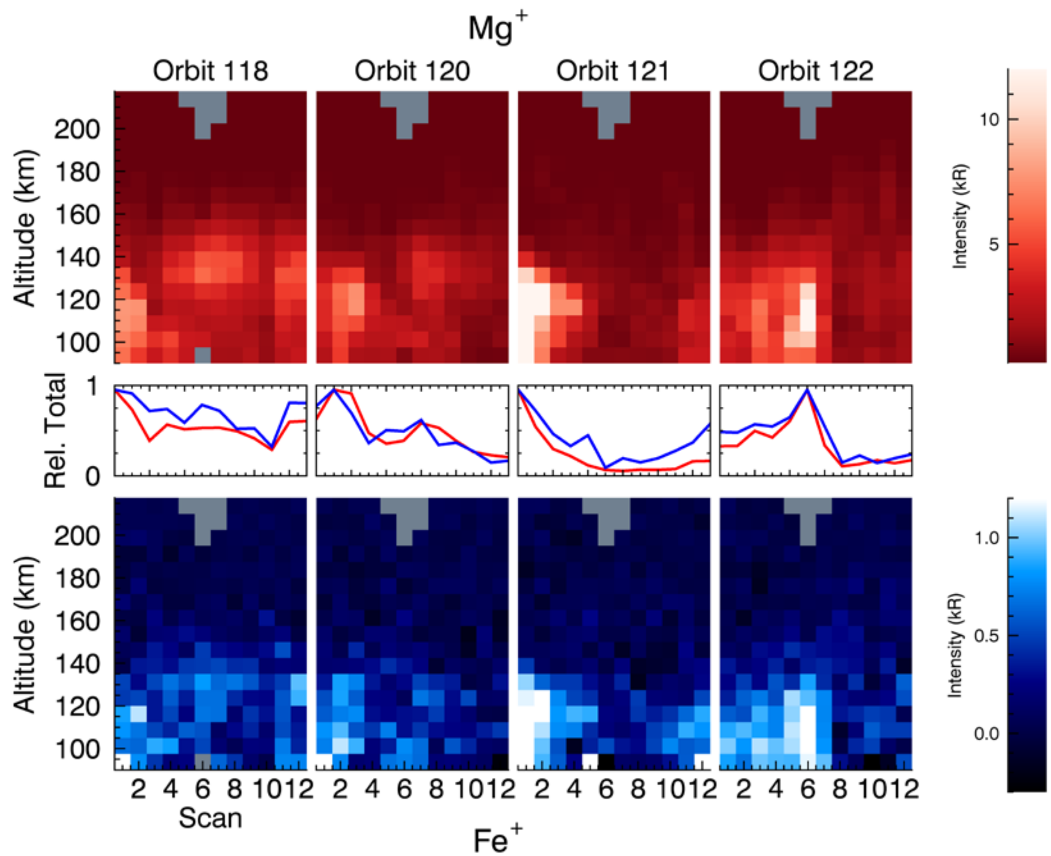


- Despite these strange features, concentrations of meteoric ions are *never* found in excess of 1000 cm^{-3}
  - After the Comet Siding Spring shower

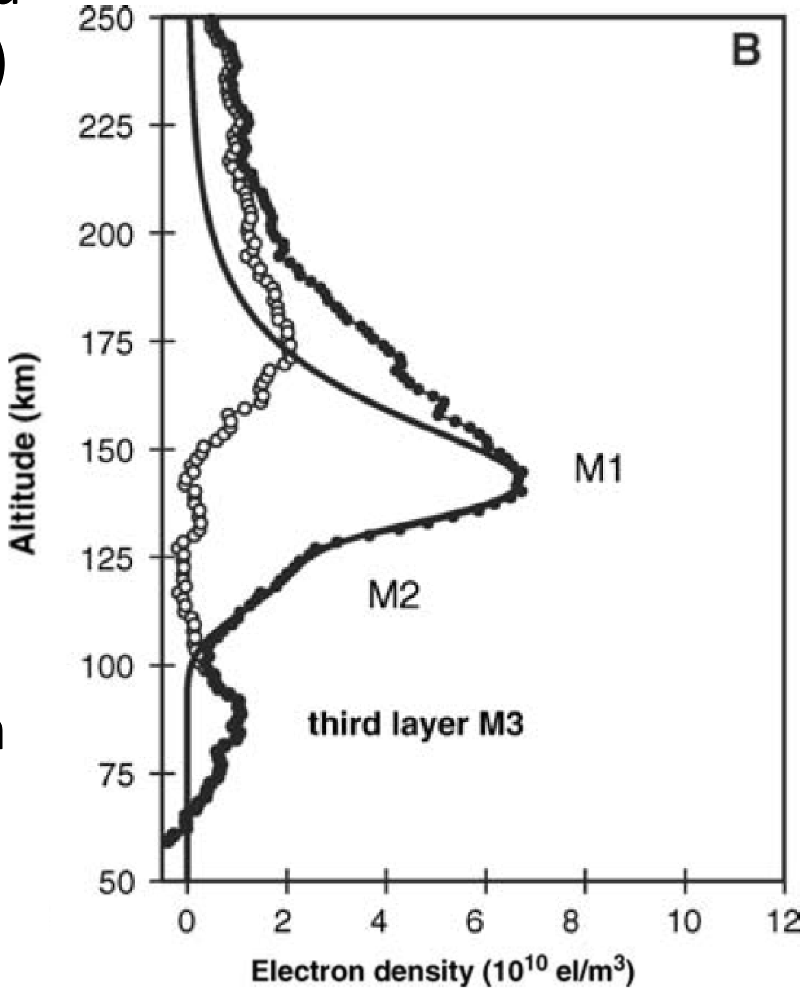
Transient Ionospheric Layer

- Radio occultations have observed transient ionospheric layers (M3) with e^- densities of 10^4 cm^{-3}
  - Composition of the ion that produces the e^- is unconstrained
  - Due to altitude of the layer, this layer is attributed to meteor ablation

- These ionospheric layers were also observed at Venus and Titan

- What are they?

Mars Express Radio Occultation data



Pätzold+ (2005)

Summary

- IUVS observations of Mg^+ emission have shown:
  - Meteoric ablation is occurring on Mars, and places constraints on IDP flux
  - Observations of diurnal variation are a tracer for the ionosphere
  - Meteoric smoke particles may be great cloud nuclei
  - Meteoric ions behave unexpectedly, distinct from other ions
  - Transient ionospheric layers require more consideration
- While IUVS is at Mars, these phenomena likely need to be considered for most planetary atmospheres

Invitation for Collaboration

- IUVS observations of Mg^+ emission exist over a range of conditions
  - Observations since Jan 2015, across Lat, SZA, crustal B-fields, etc.
  - If you have observations and want to compare with IUVS or MAVEN data, contact me matteo.crismani@colorado.edu

- There is lots of data and we welcome collaboration!
  - Meteoric ablation upper limits associated with meteor showers
  - Modeling of cloud nucleation from meteoric smoke particles
  - Modeling nightside ionosphere dynamics and chemistry with Mg^+
  - Undetermined physics causes anomalous gradients and scale heights
  - The source of low altitude transient ionospheric layers

Geophysical Research Letters

RESEARCH LETTER
10.1002/2015GL063863

MAVEN IUVS observations of the aftermath of the Comet Siding Spring meteor shower on Mars

N. M. Schneider[1], J. I. Deighan[1], A. I. F. Stewart[1], W. E. McClintock[1], S. K. Jain[1], M. S. Chaffin[1], A. Stiepen[1], M. Crismani[1], J. M. C. Plane[2], J. D. Carrillo-Sánchez[2], J. S. Evans[3], M. H. Stevens[4], R. V. Yelle[5], J. T. Clarke[6], G. M. Holsclaw[1], F. Montmessin[7], and B. M. Jakosky[1]

Key Points:
- MAVEN/IUVS observed bright emission from vaporized dust in Mars' atmosphere
- The dust originated in an intense

nature geoscience

ARTICLE

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Detection of a persistent meteoric metal layer in the Martian atmosphere

M. M. J. Crismani[1]*, N. M. Schneider[1], J. M. C. Plane[2], J. S. Evans[3], S. K. Jain[1], M. S. Chaffin[1], J. D. Carrillo-Sanchez[2], J. I. Deighan[1], R. V. Yelle[4], A. I. F. Stewart[1], W. McClintock[1], J. Clarke[5], G. M. Holsclaw[1], A. Stiepen[6], F. Montmessin[7] and B. M. Jakosky[1]

Space Sci Rev (2018) 214:23
https://doi.org/10.1007/s11214-017-0458-1

Impacts of Cosmic Dust on Planetary Atmospheres and Surfaces

John M.C. Plane[1] · George J. Flynn[2] · Anni Määttänen[3] · John E. Mo
Andrew R. Poppe[5] · Juan Diego Carrillo-Sanchez[1] · Constantino Listow

Geophysical Research Letters

RESEARCH LETTER
10.1002/2017GL072635

Unique, non-Earthlike, meteoritic ion behavior in upper atmosphere of Mars

J. M. Grebowsky[1], M. Benna[1,2], J. M. C. Plane[3], G. A. Collinson[1,4], P. R. Mahaffy[1], and B. M. Jakosky[5]

Key Points:
- First in situ detection of the continuous presence of several

Journal of Geophysical Research: Planets

RESEARCH ARTICLE
10.1002/2017JE005510

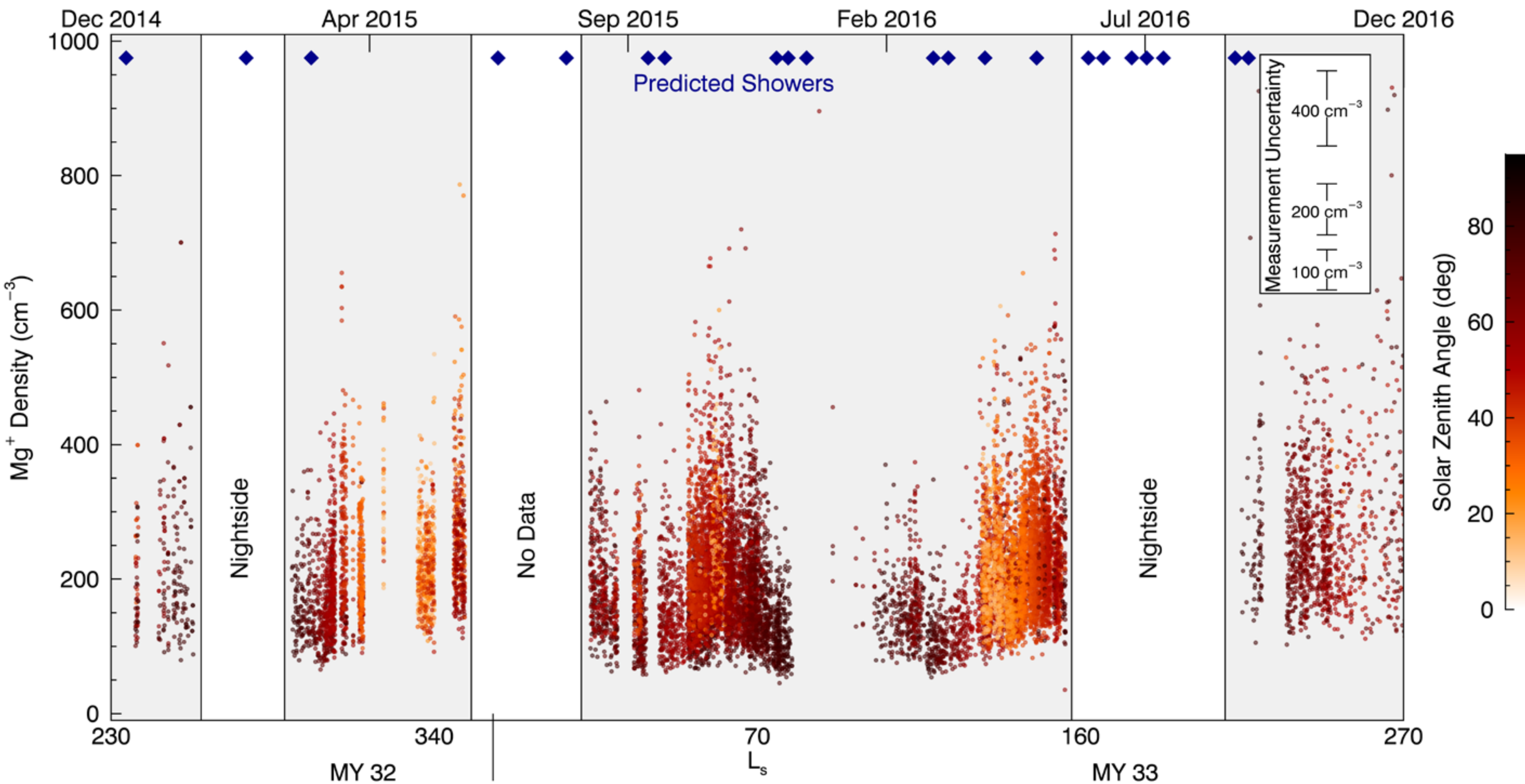
Meteoric Metal Chemistry in the Martian Atmosphere

J. M. C. Plane[1], J. D. Carrillo-Sanchez[1], T. P. Mangan[1], M. M. J. Crismani[2], N. M. Schneider[2], and A. Määttänen[3]

Special Section:

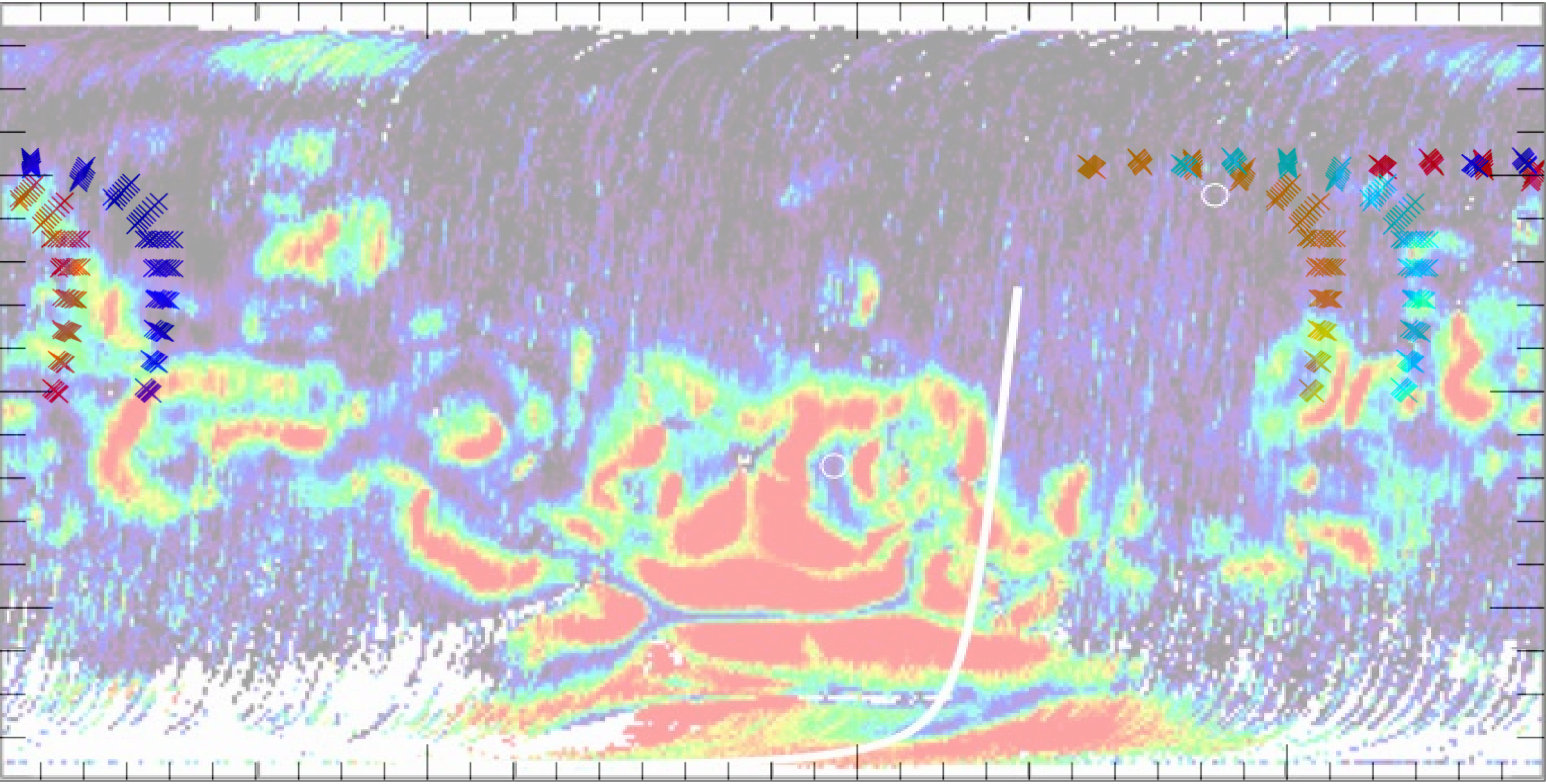
Backup Slides

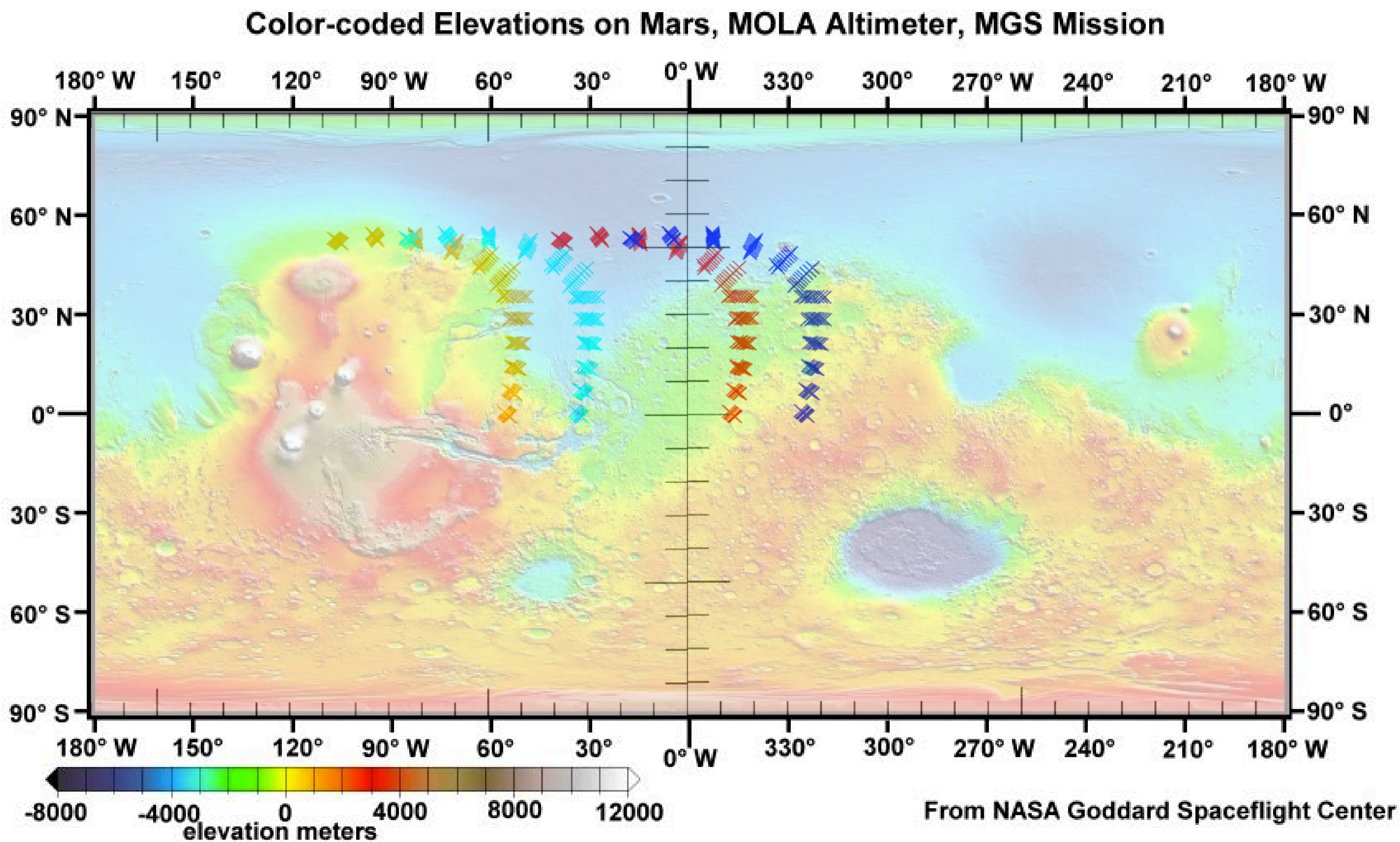
A Persistent Mg^+ Layer



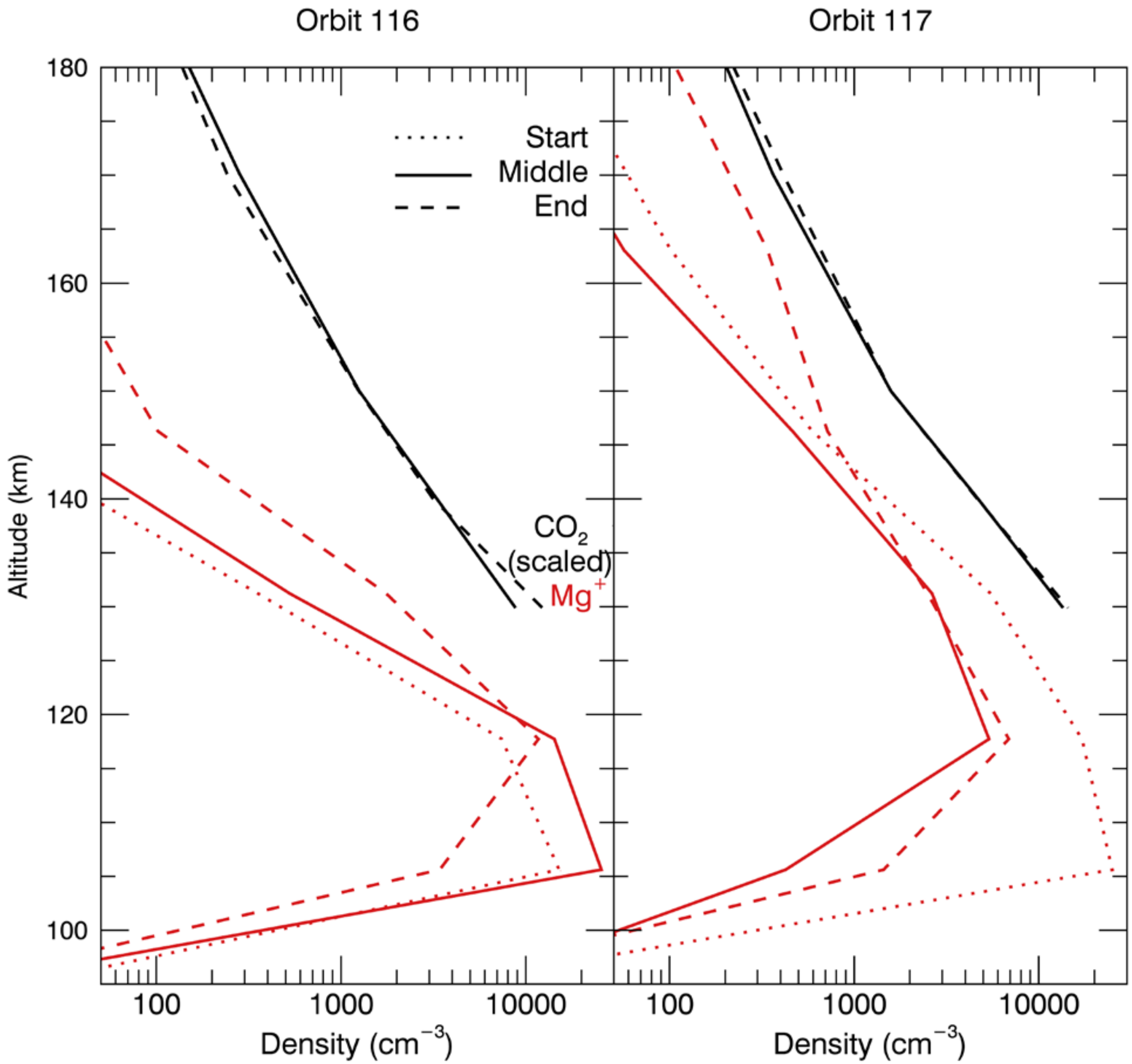
Crismani et al. 2017

Because the transient layer (M3) peaked at 10^4 electrons cm^{-3}, ablation cannot be responsible for generating the M3 layer




Color-coded Elevations on Mars, MOLA Altimeter, MGS Mission
180° W
150°
120°
90° W
60°
30°
0° W
330°
300°
270° W
240°
210°
90° N
60° N
30° N
0°
30° S
60° S
90° S
-8000
-4000
0
4000
8000
12000
elevation meters
From NASA Goddard Spaceflight Center

Independent Scale Heights



- IUVS retrieved background atmosphere doesn't vary
- NGIMS has also seen anomalous scale heights
- Not well correlated to B