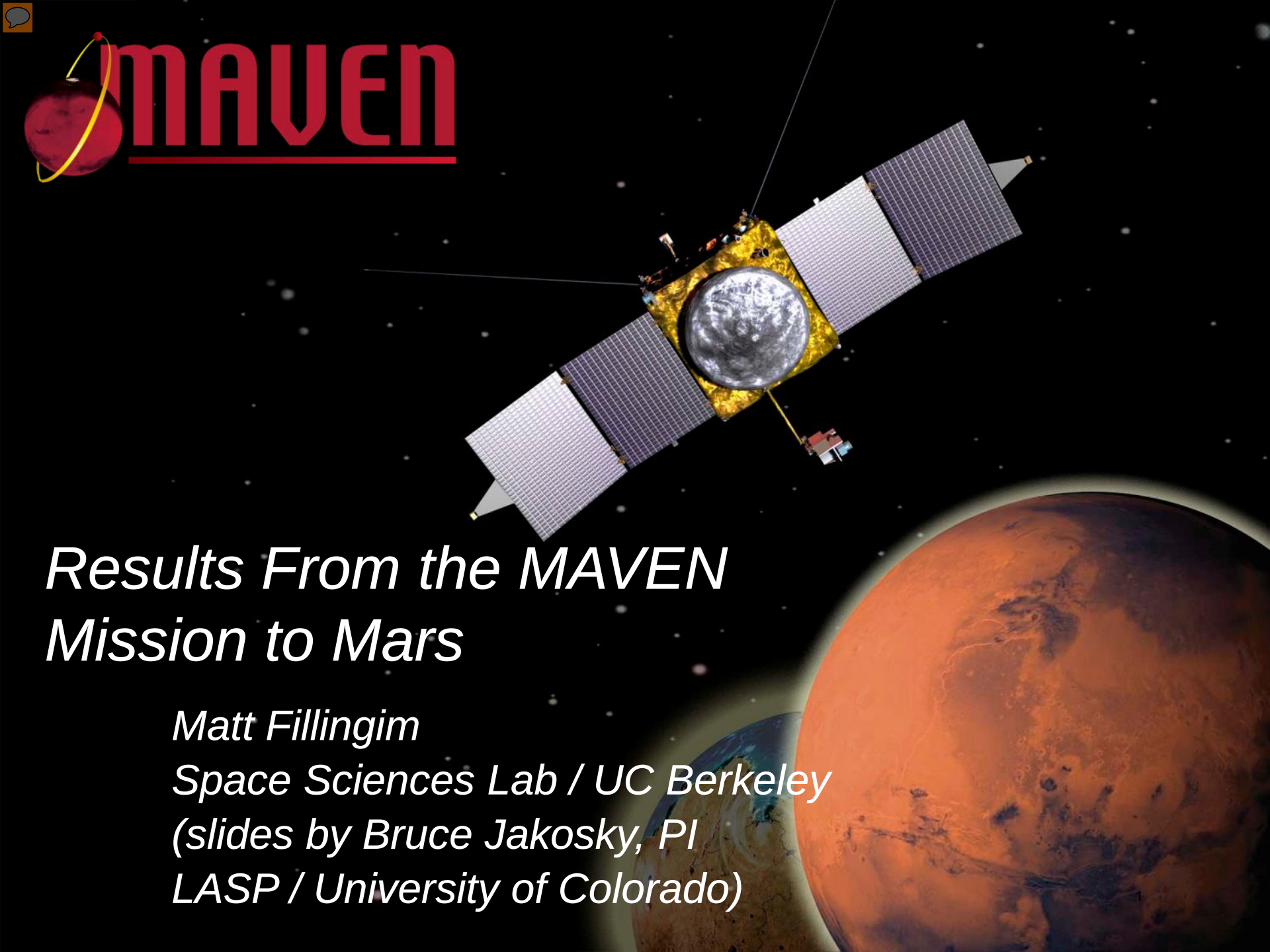


Results From the MAVEN Mission to Mars

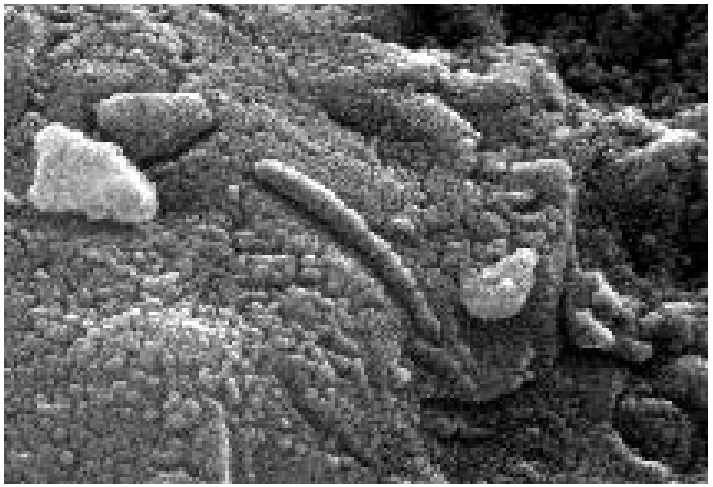
Matt Fillingim
Space Sciences Lab / UC Berkeley
(slides by Bruce Jakosky, PI
LASP / University of Colorado)

Overarching Question: Did Mars Ever Have Life?

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

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



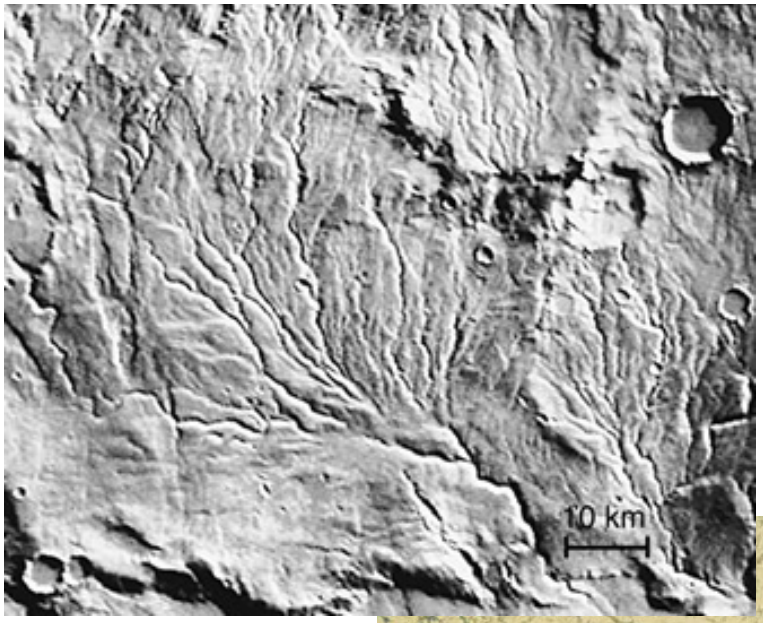
Did Mars ever have life?

How did any life interact with its planetary environment?

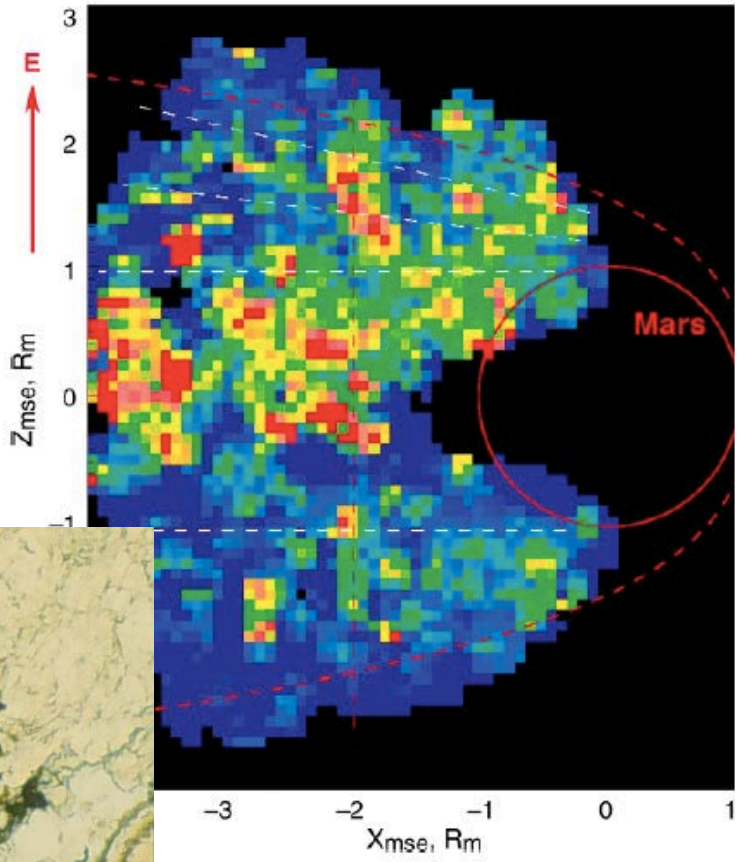
How has the habitability of Mars changed over time?

Evidence for Surface Water on Ancient Mars
Where Did the Water Go? Where Did the CO_2 Go?

Abundant evidence for ancient water

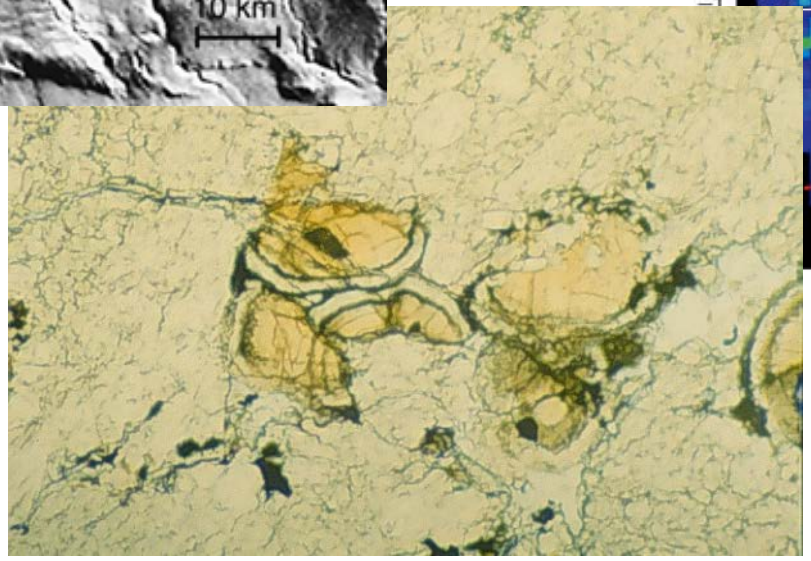


Volatiles can be lost to space



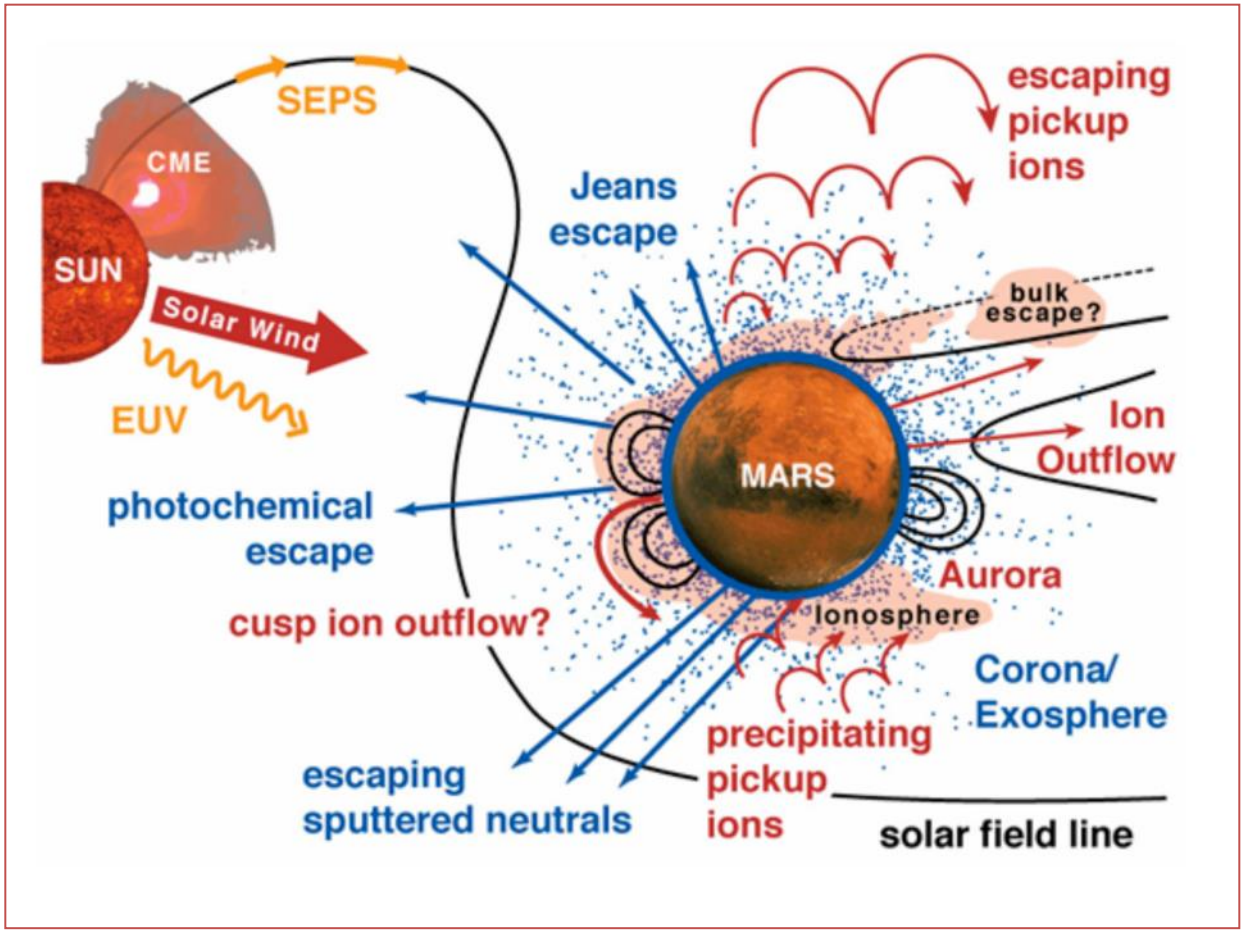
Escaping ions detected from Mars Express

Volatiles can go into the crust



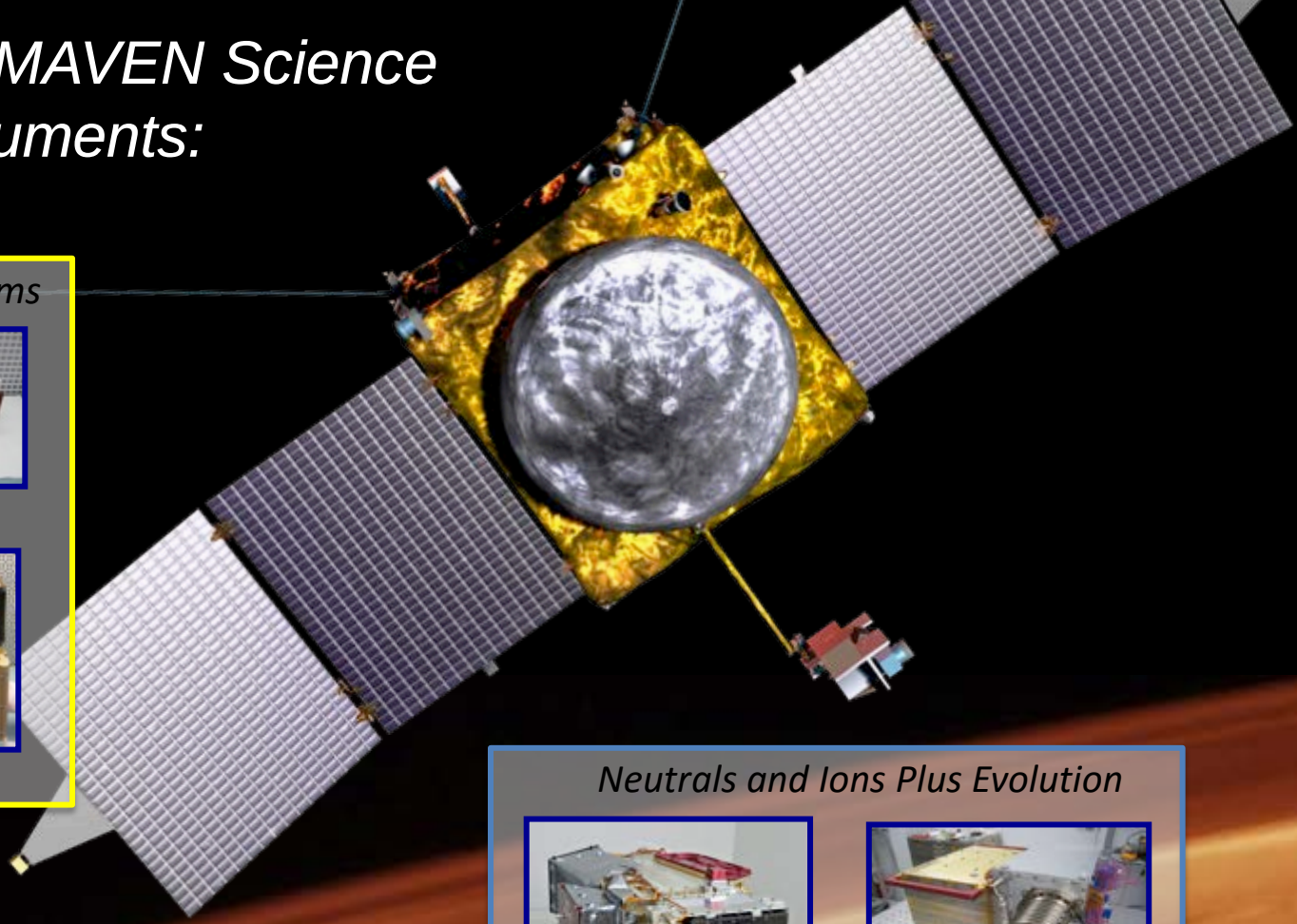
Carbonate deposits in a Martian meteorite

MAVEN Explores Escape of Atmospheric Gases to Space

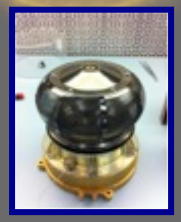


- Measure energetic drivers from the Sun, response of upper atmosphere and ionosphere, and resulting escape to space
- Understand the key processes involved, allowing extrapolation to loss over Mars history

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

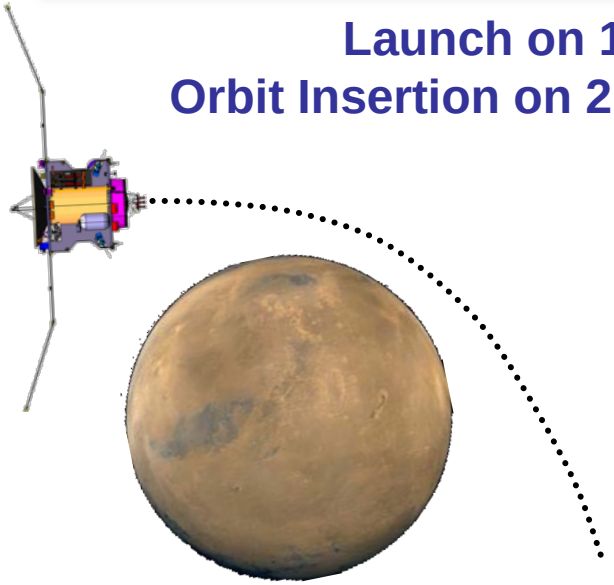
STATIC

MAG

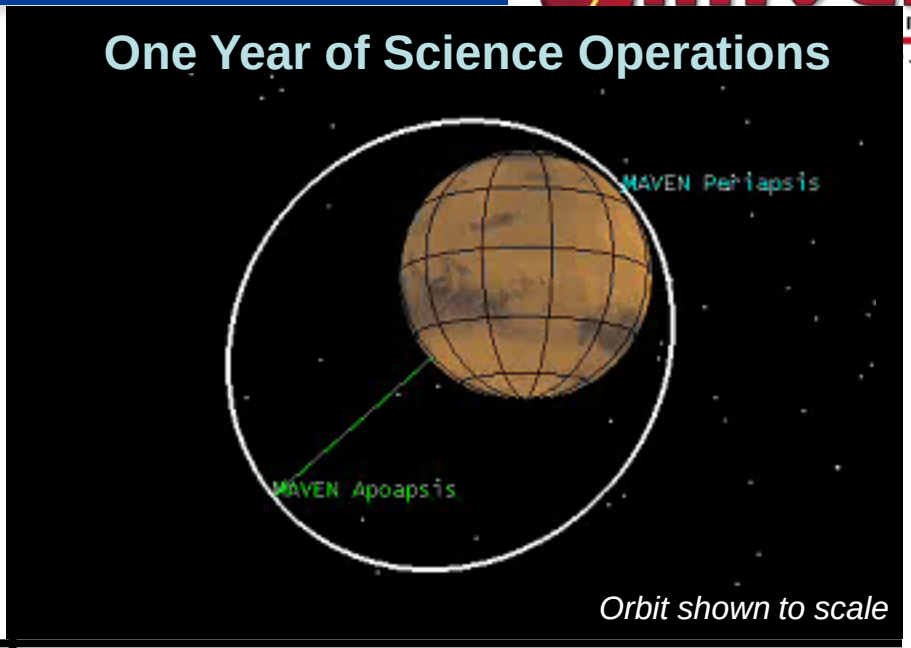
LPW

MAVEN Mission Architecture

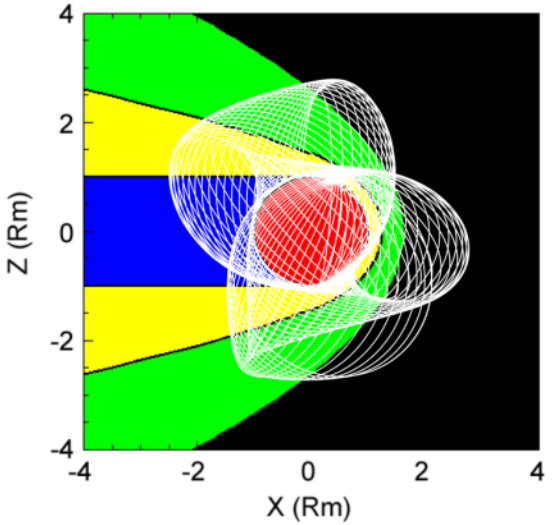
Launch on 18 Nov 2013
Orbit Insertion on 21 Sept 2014



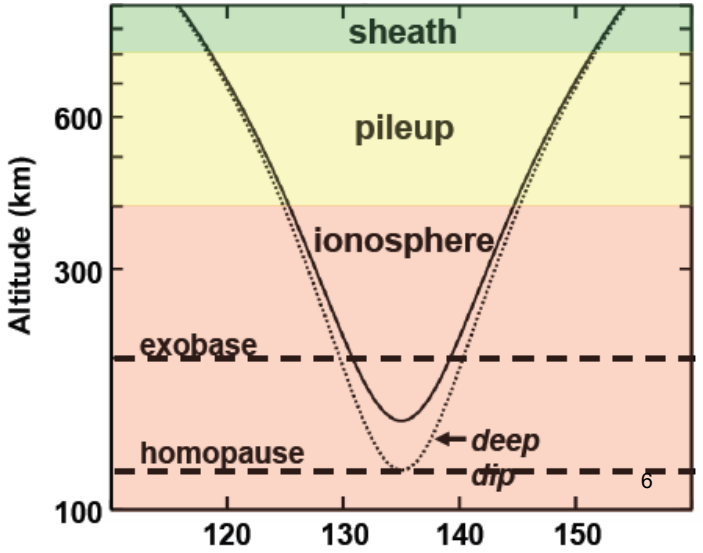
One Year of Science Operations



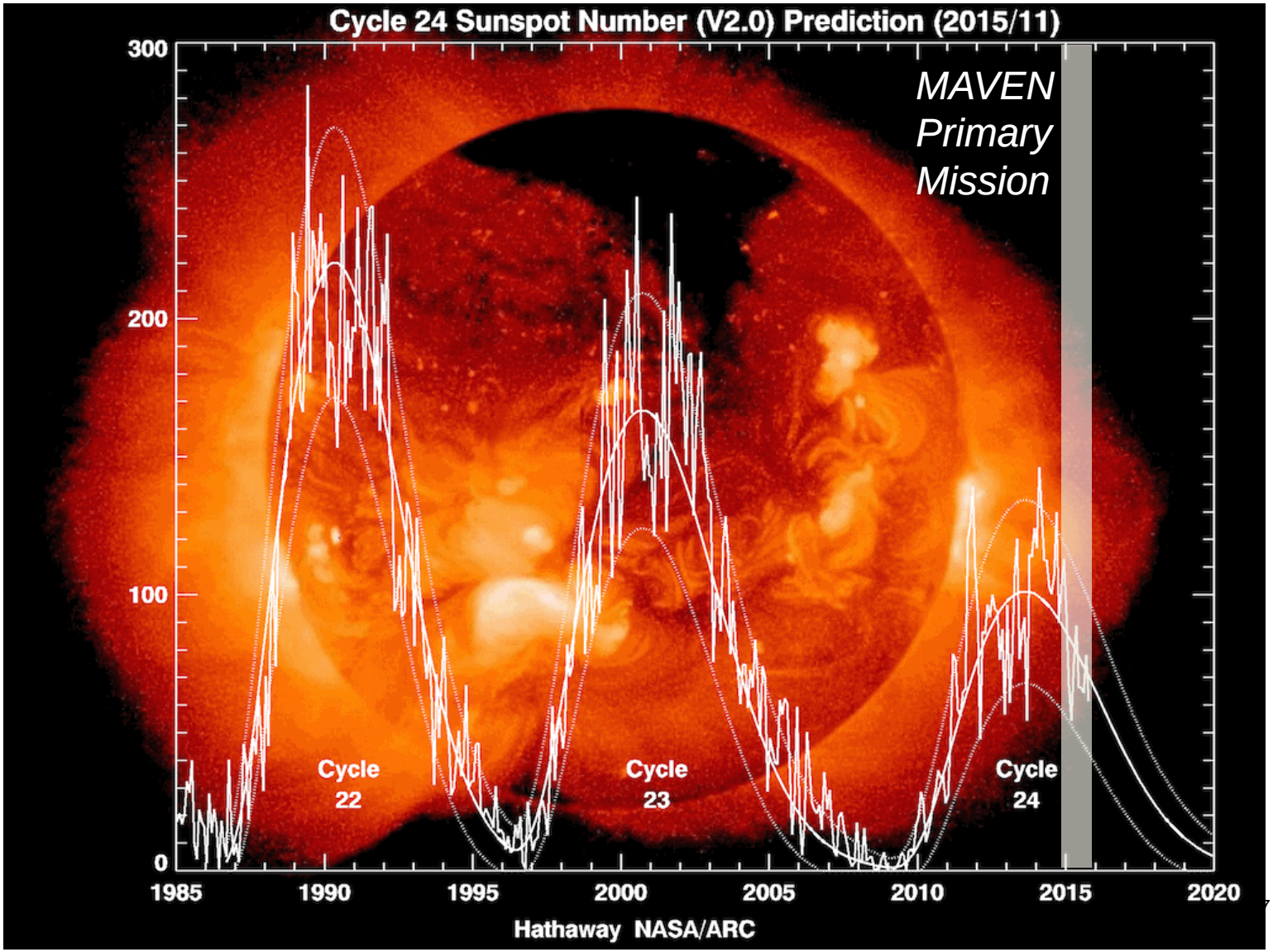
Orbit Precession Provides Coverage



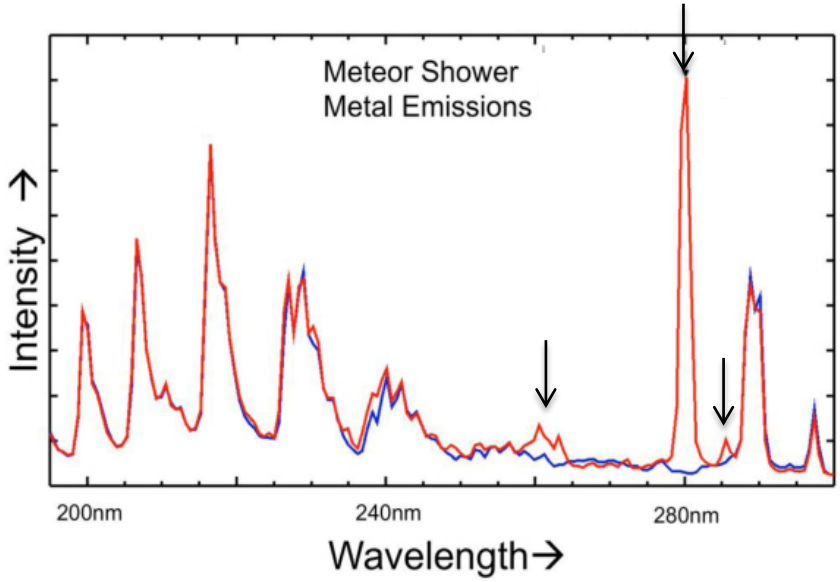
Deep Dips Cover All Altitudes



MAVEN's Primary Mission Occurs on the Declining Phase of the Solar Cycle

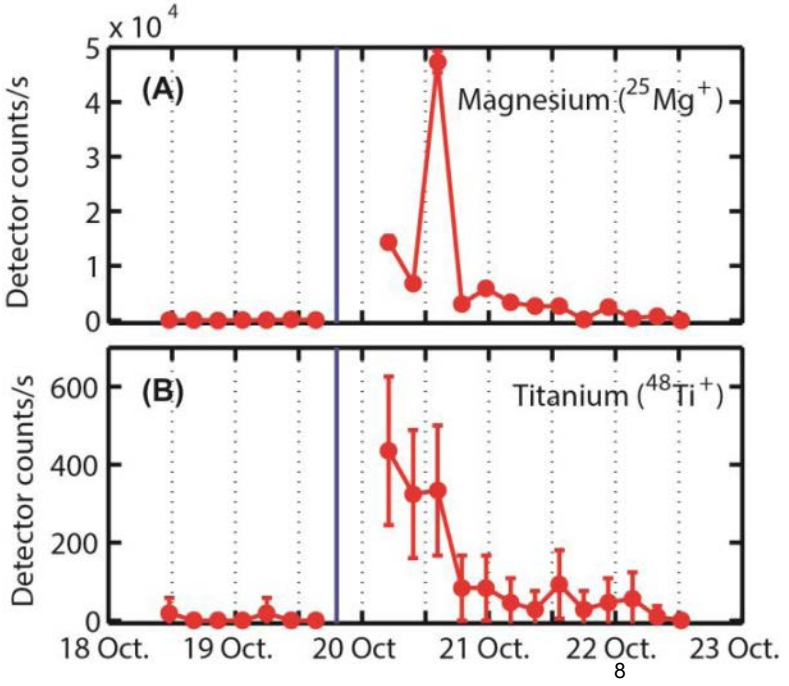


Discovery of Metal-Ion Layer Following Encounter With Comet Siding Spring



- 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

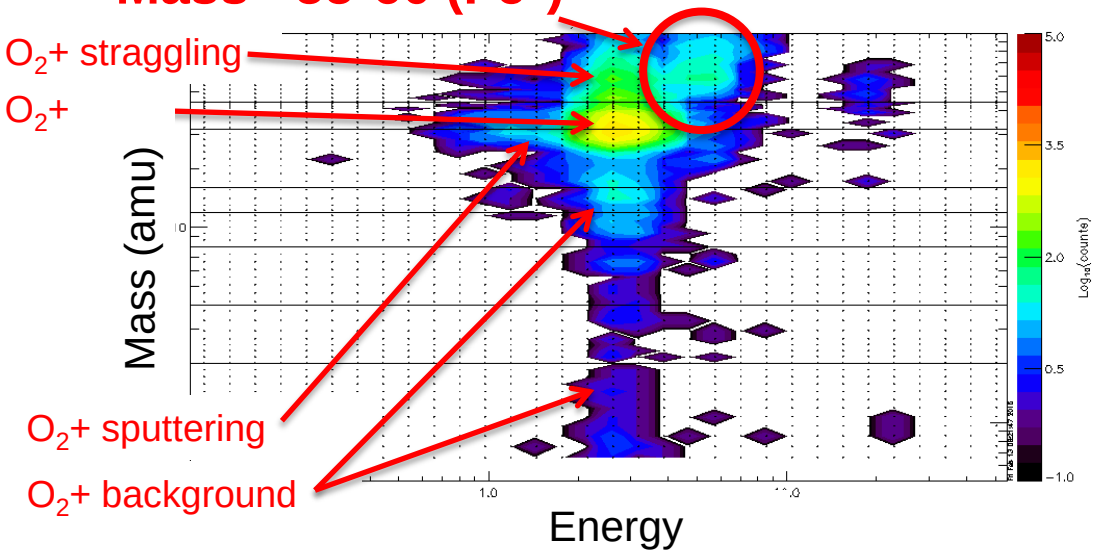


(Schneider et al. 2015, Benna et al. 2015)

Discovery of Long-Lived Metallic-Ion Layer During Deep-Dip Campaign

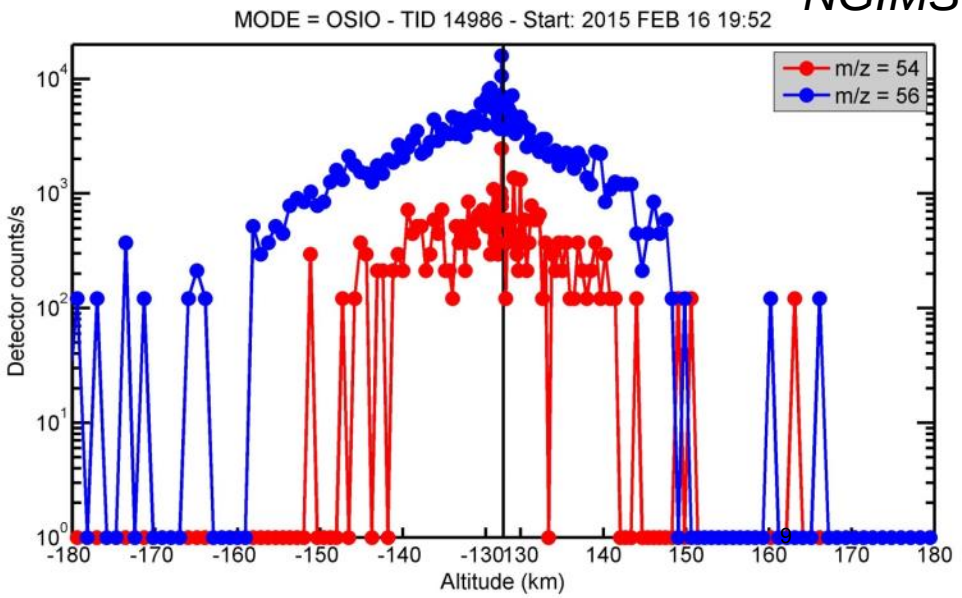
Mass ~55-60 (Fe^+)

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

NGIMS

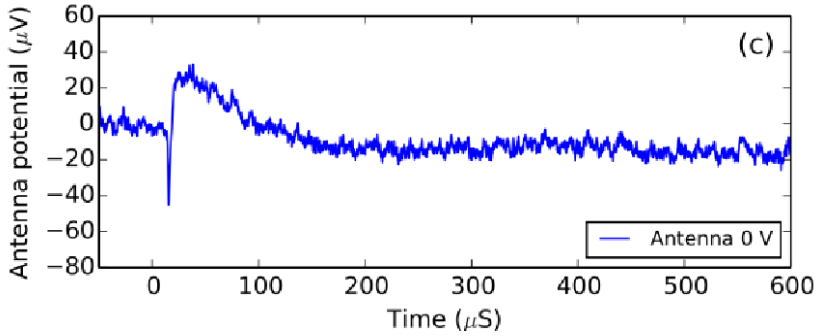


- Observed four months after Comet Siding Spring, likely no connection to it
- Previously, electron layers had been detected intermittently by *Mars Express*
- First detection of long-lived metallic-ion layer

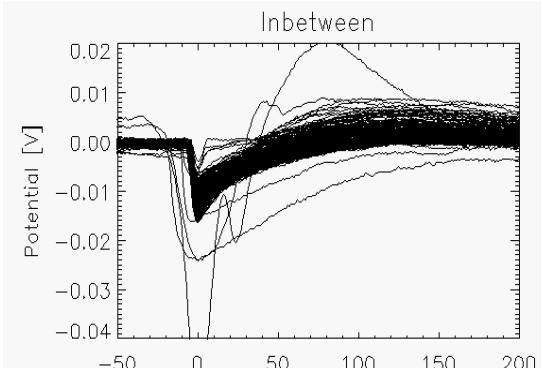
Discovery of Dust Cloud Surrounding Mars, Observed by LPW

Dust-impact signature

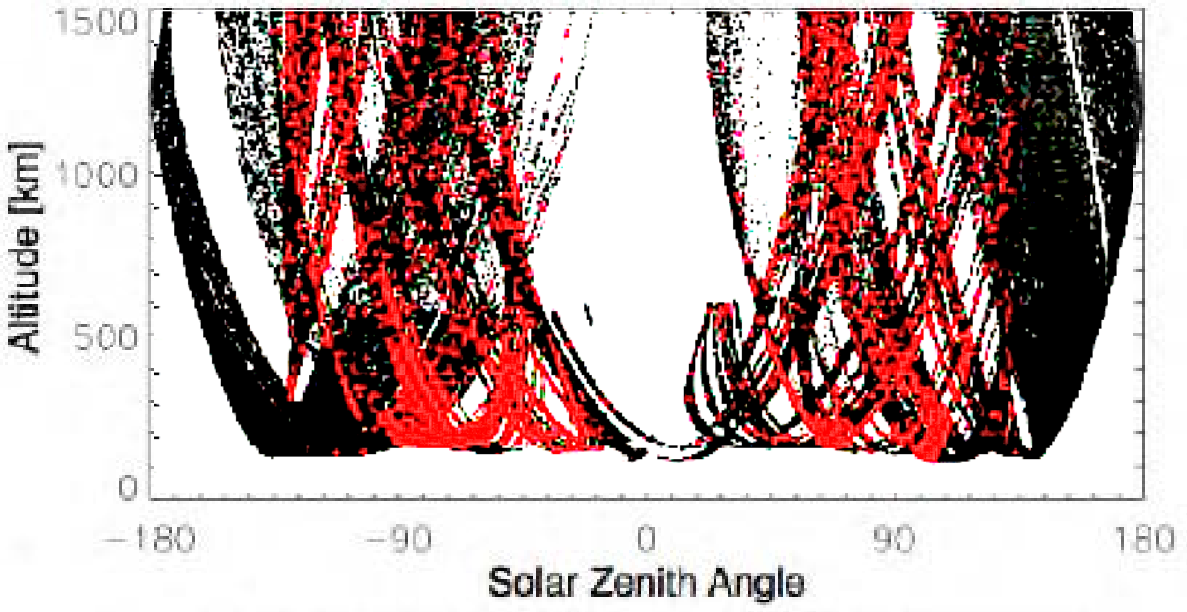
In the lab:

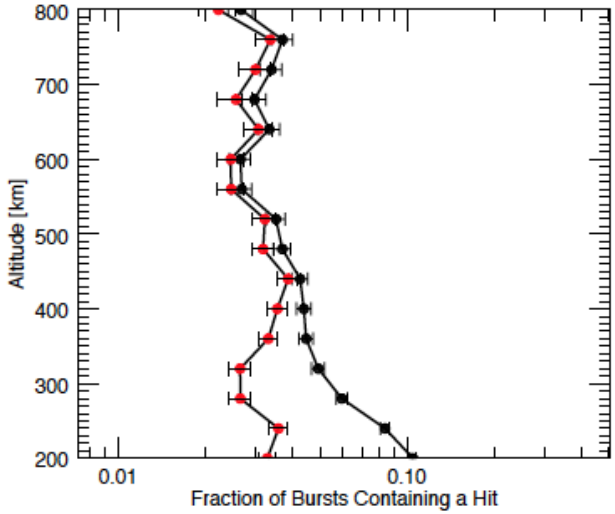


And at Mars:



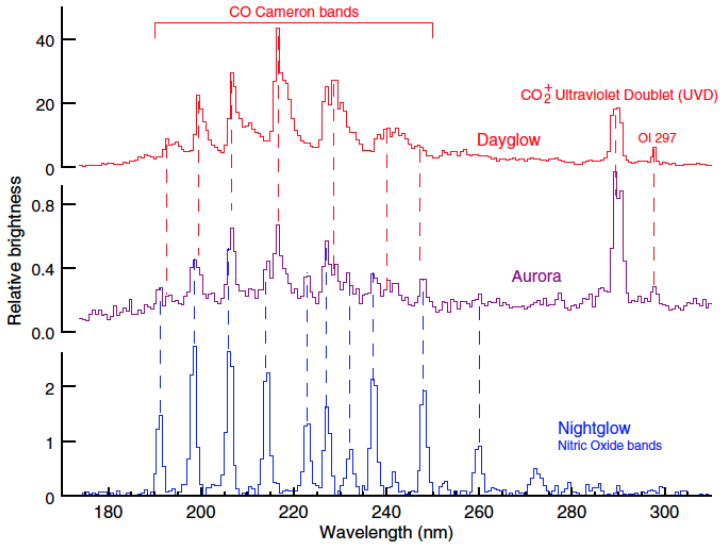
Observed distribution of dust impacts:



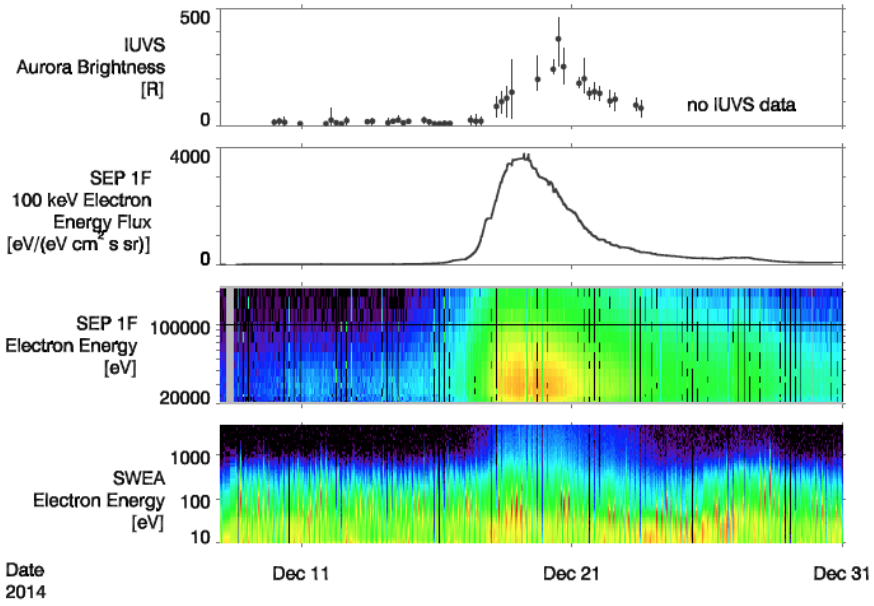


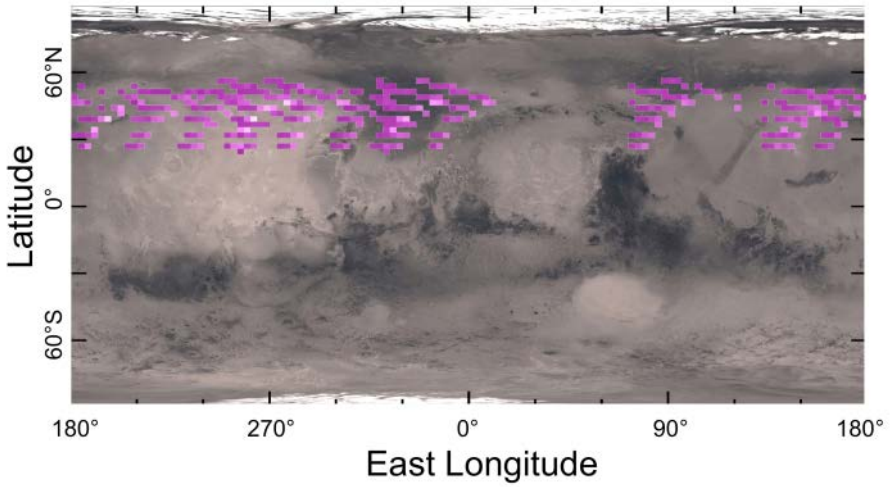
(Andersson et al. 2015)

IUVS Detection of Diffuse Aurora



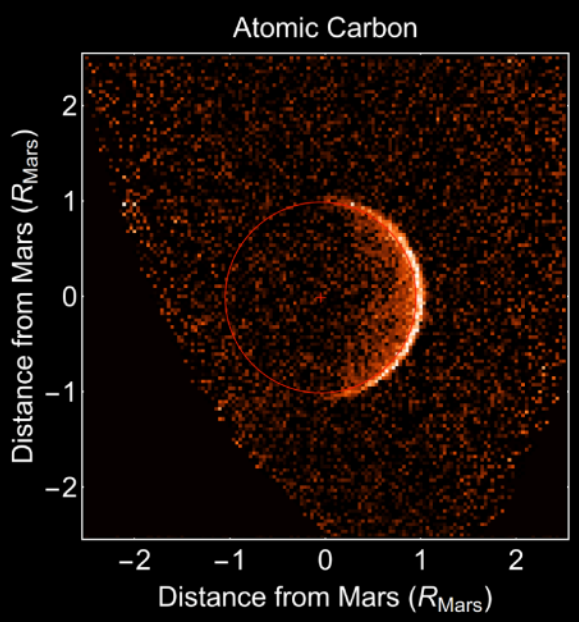
- "Christmas lights" aurora observed for five days on 18-23 December 2014
- Nightside emission at same wavelengths as dayglow; characteristic of aurora in general and of those observed by *Mars Express*
- Diffuse distribution throughout northern hemisphere; no connection to magnetic anomalies

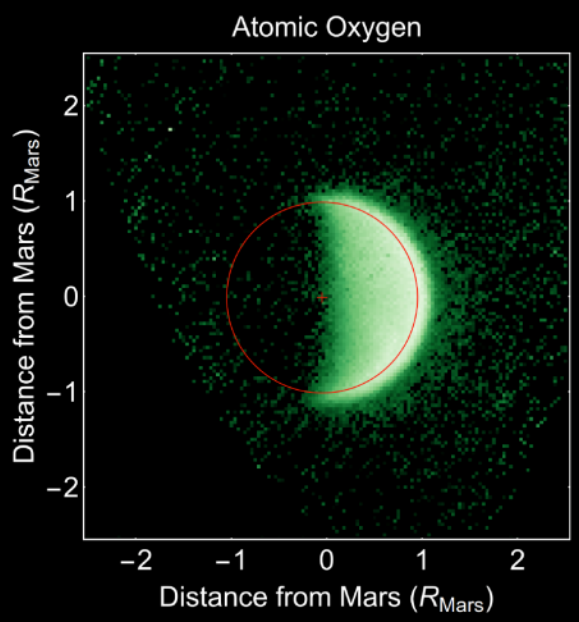


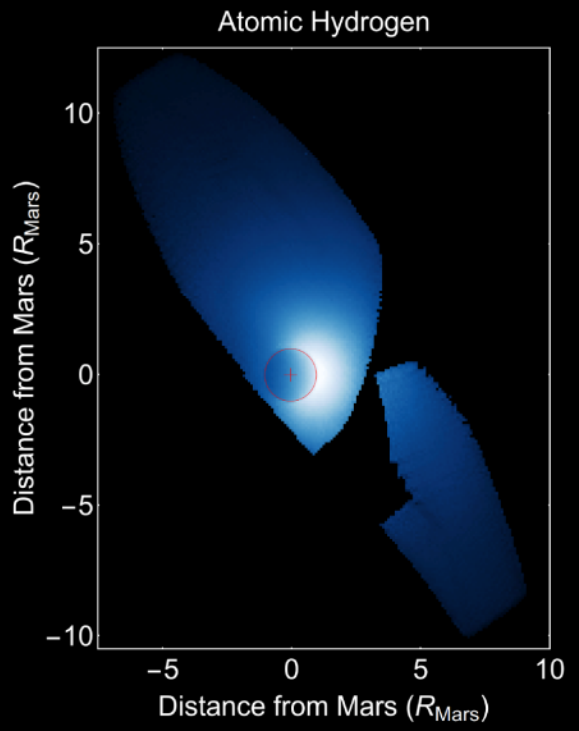


(Schneider et al. 2015)

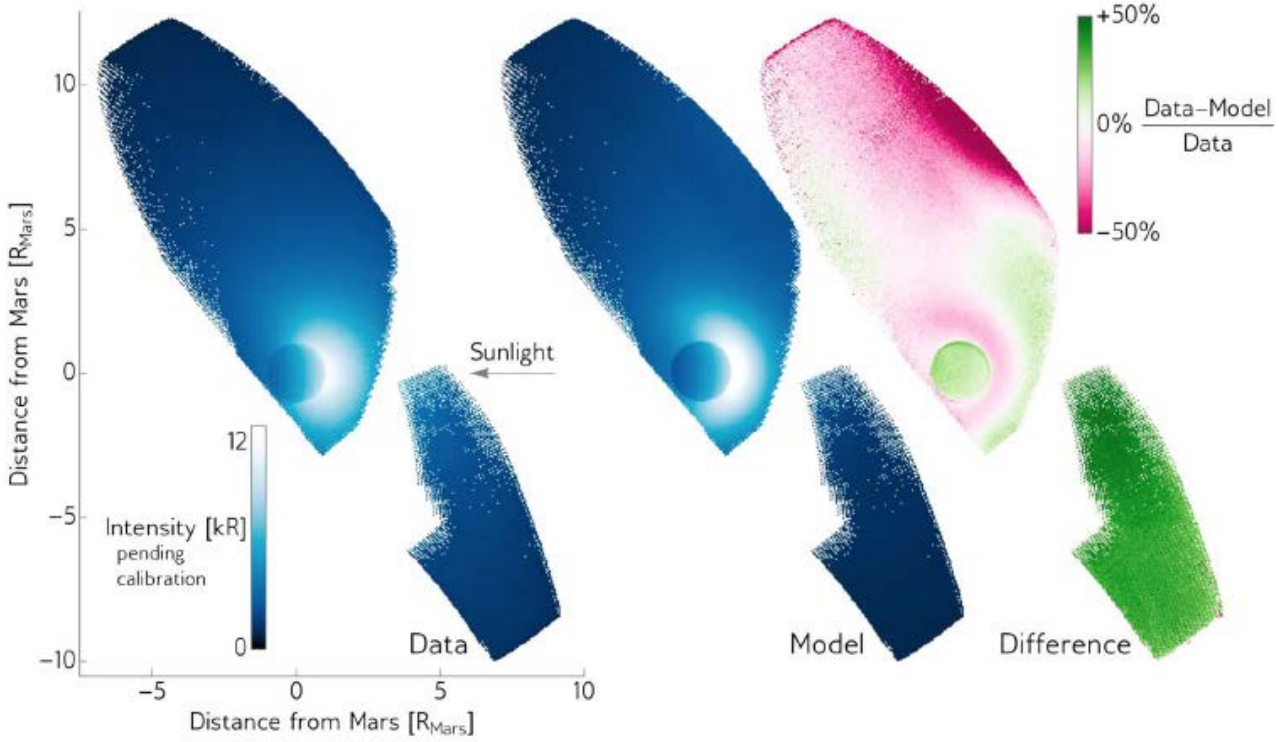
IUVS Observations of Atomic Components of H_2O and CO_2 on Their Way to Escaping







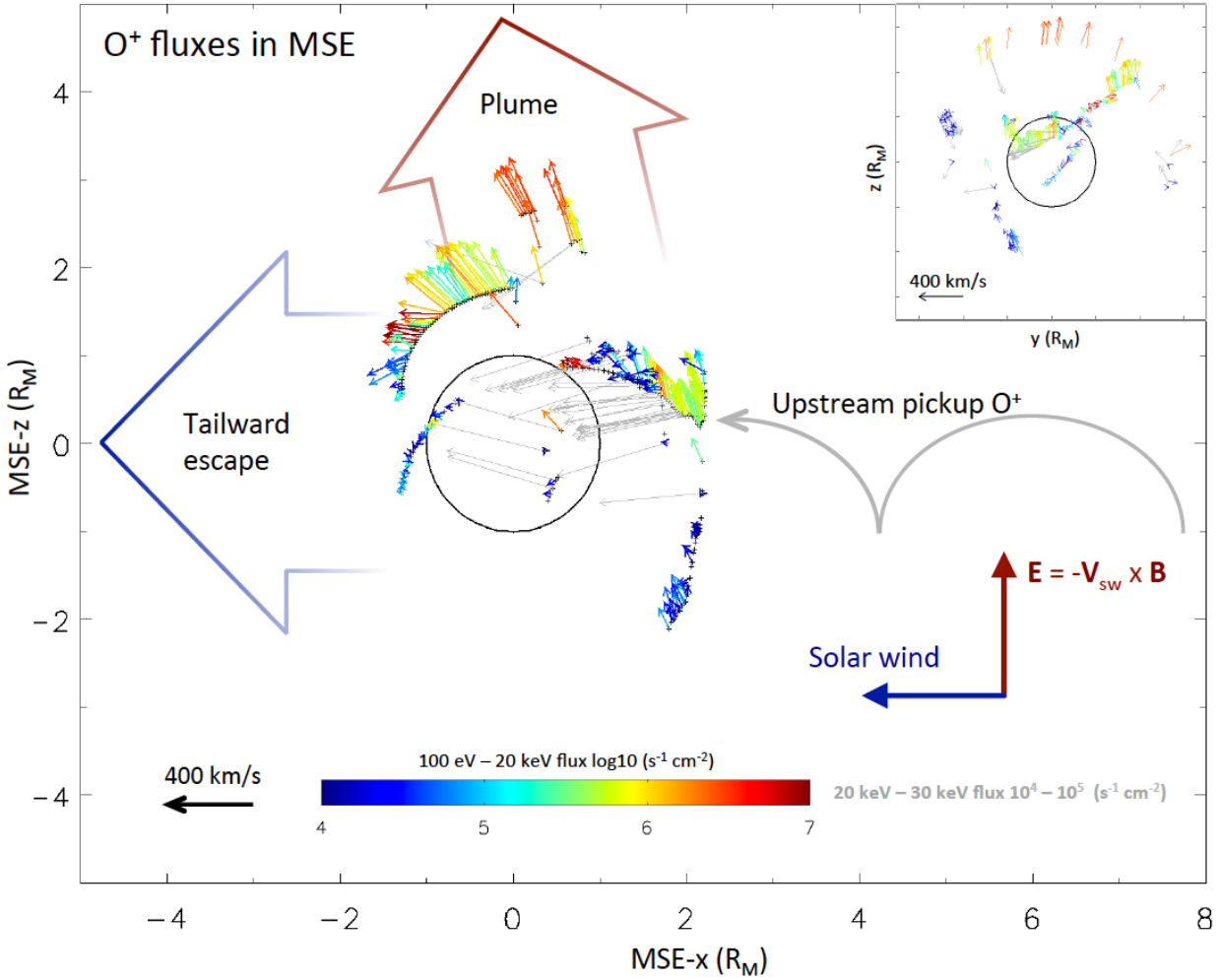
Hydrogen Distribution and Escape



- 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)

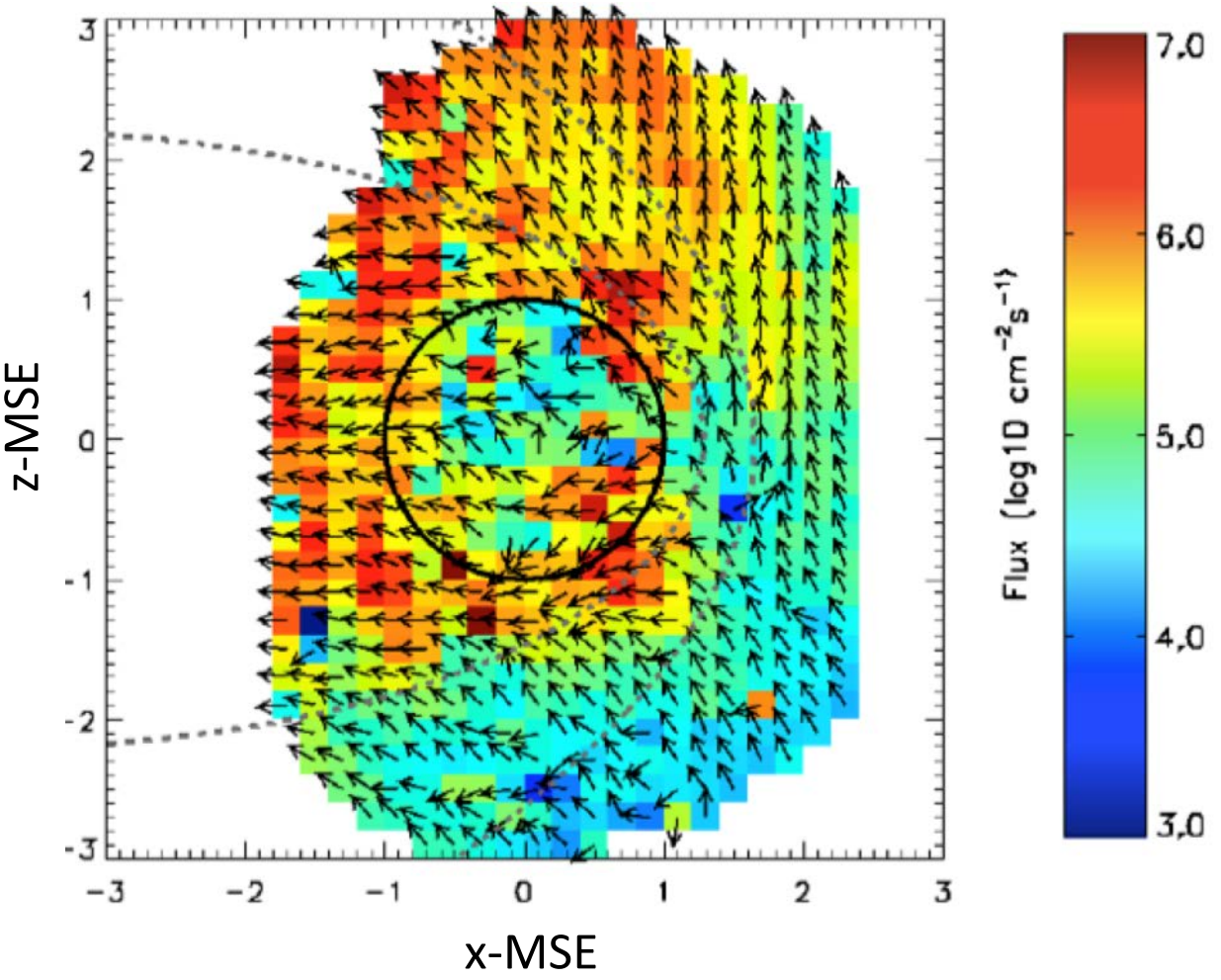


- Single orbit shows upstream pickup ions, tailward escape, and polar plume in STATIC observations

(Dong et al. 2015)

Ion Escape Driven by the Solar Wind (2 of 2)

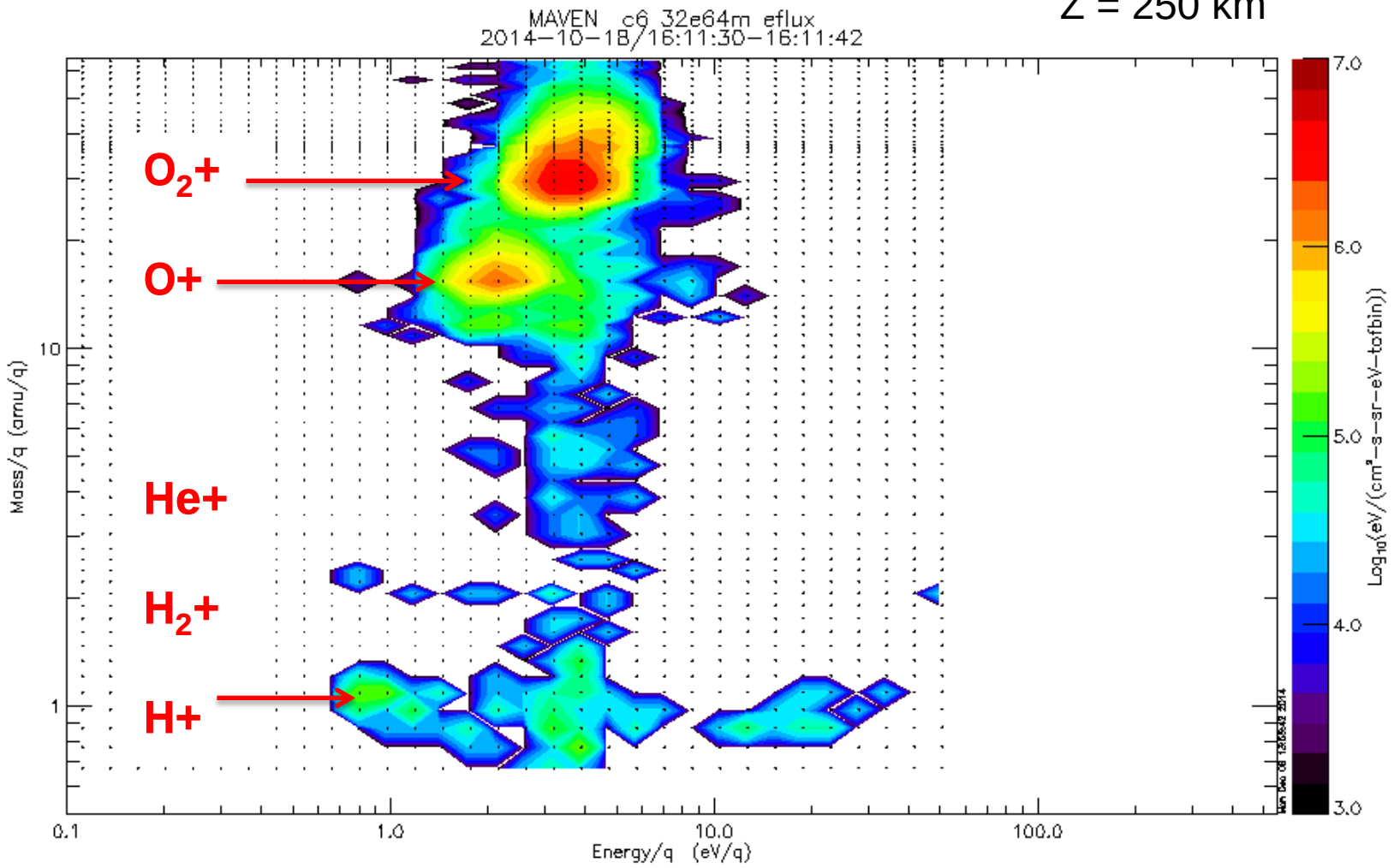
O^+ fluxes



- Accumulation of all data shows that polar plume is a substantial and stable feature
- Accounts for significant fraction of total escape

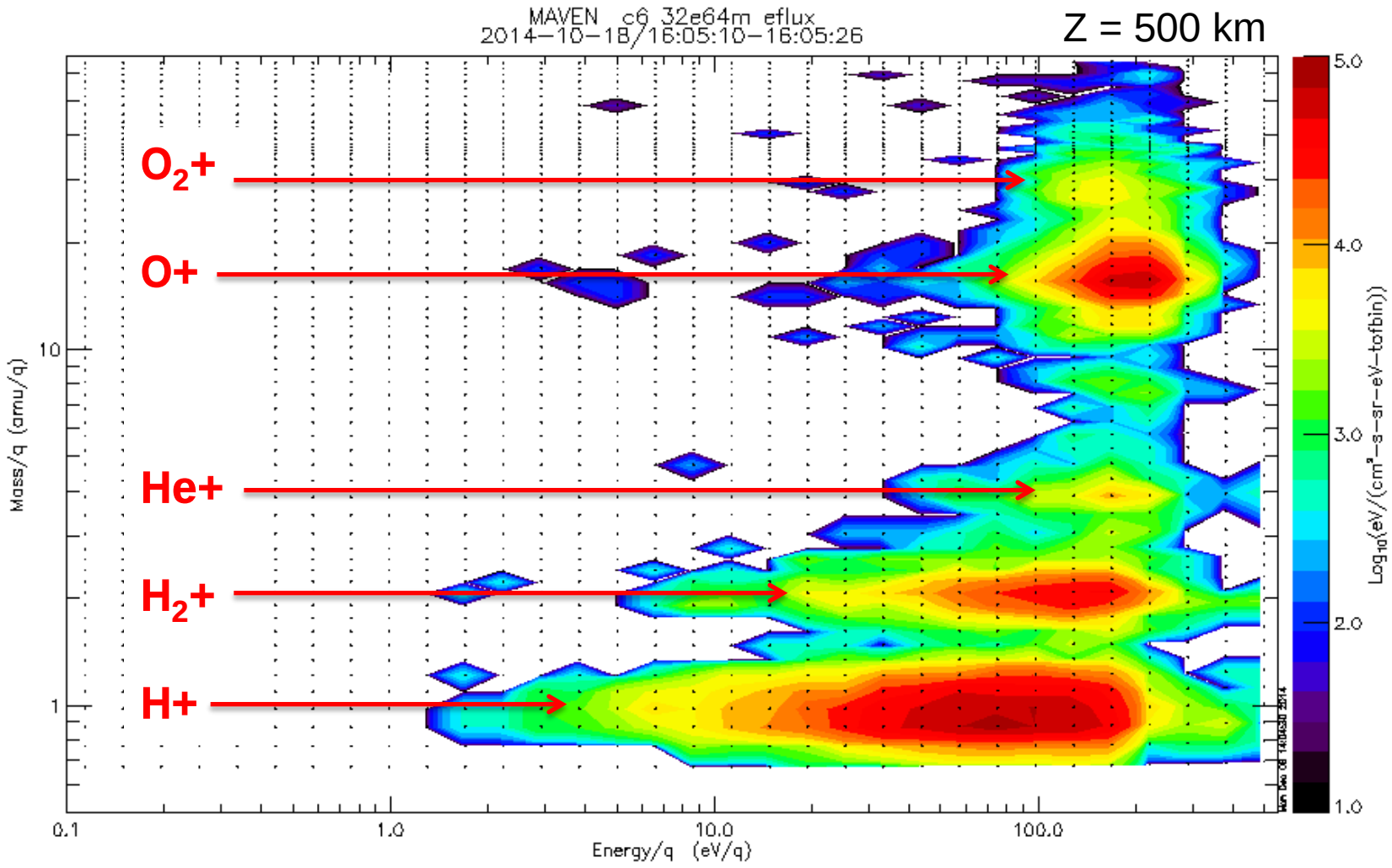
Acceleration in Polar Plume (1 of 2)

Z = 250 km

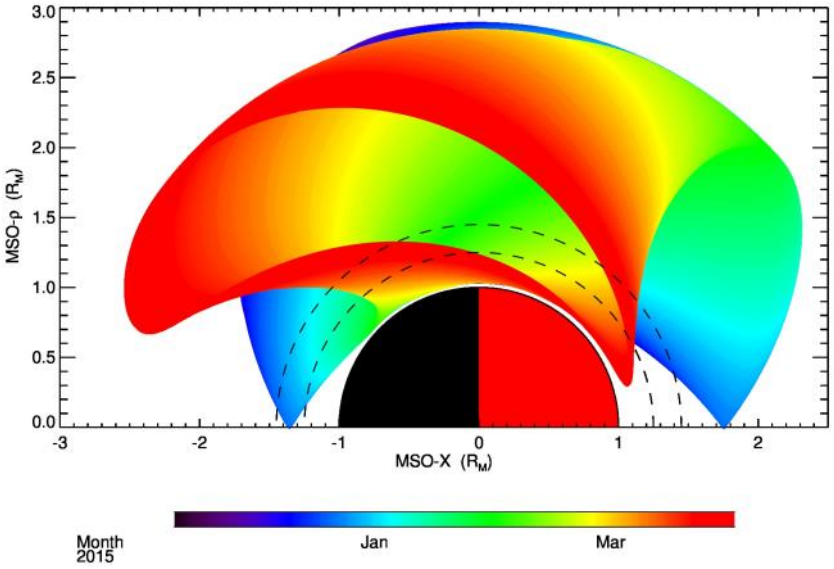


(McFadden et al. 2015)

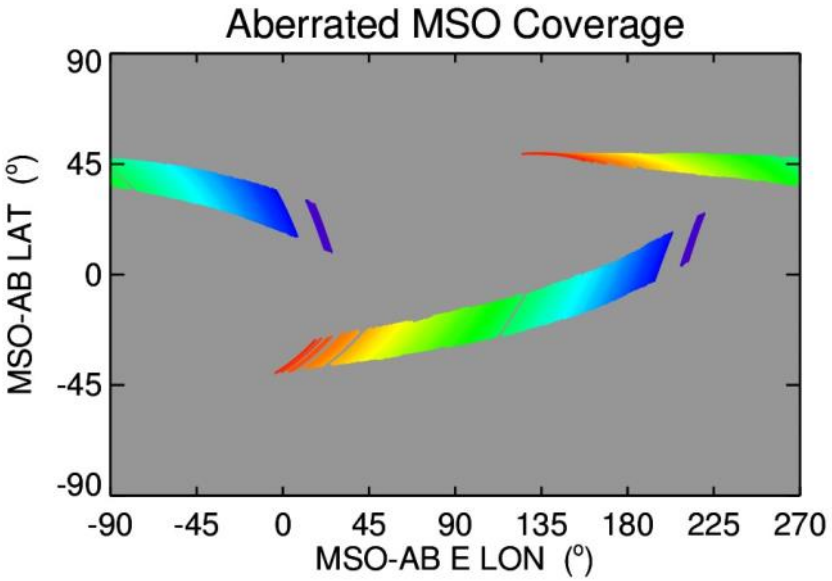
Acceleration in Polar Plume (2 of 2)

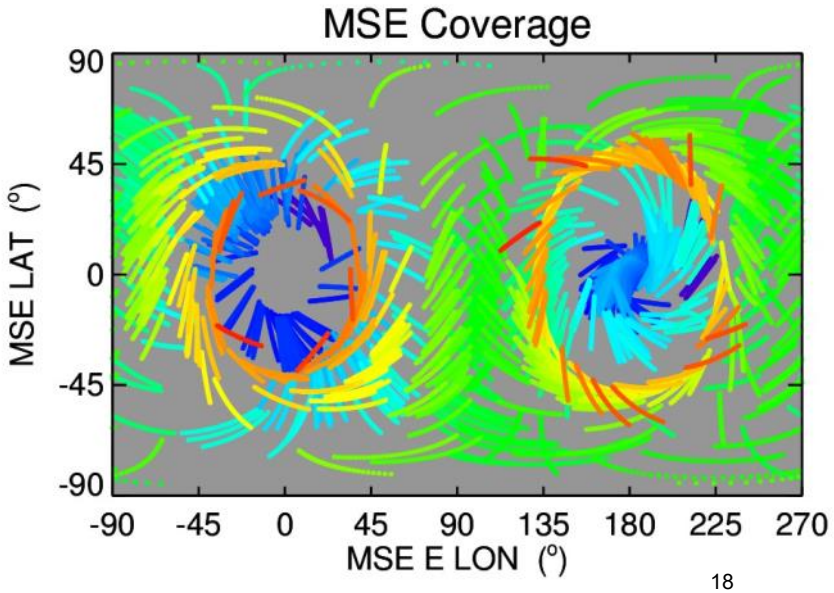


Total Escaping Flux



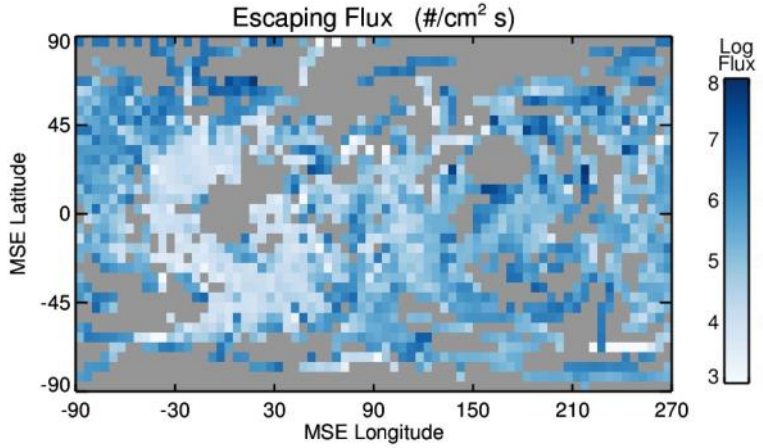
- Precessing orbit provides good geographical coverage of escaping species in all directions
- Depends on solar-wind electric field variations that fill in coverage map
- Can use this to determine total number of escaping ions

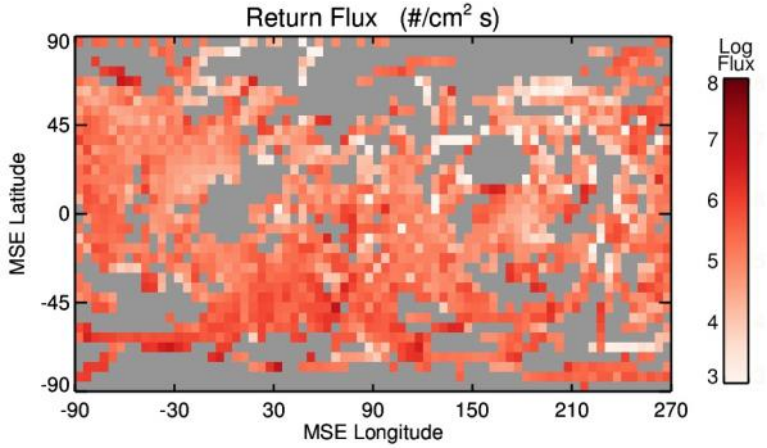


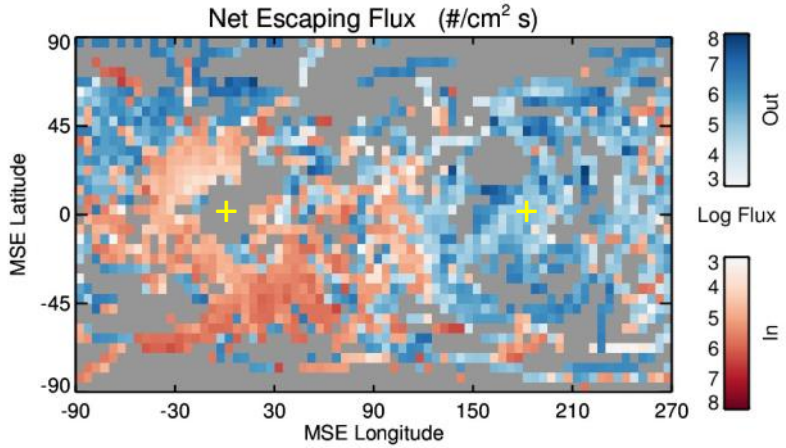


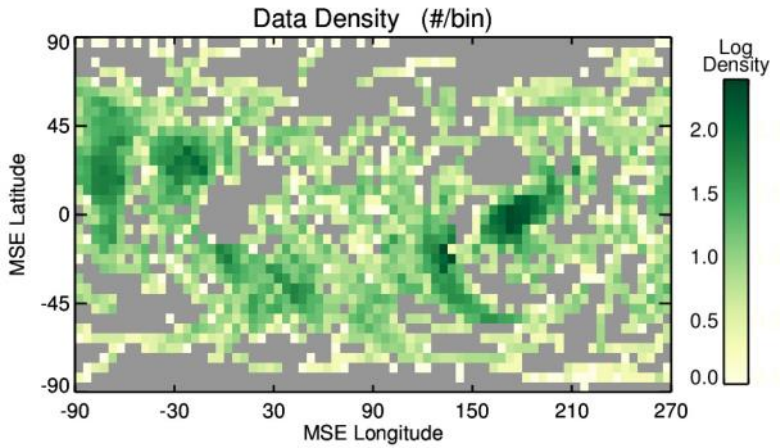
(Brain et al. 2015)

Total Escaping Flux



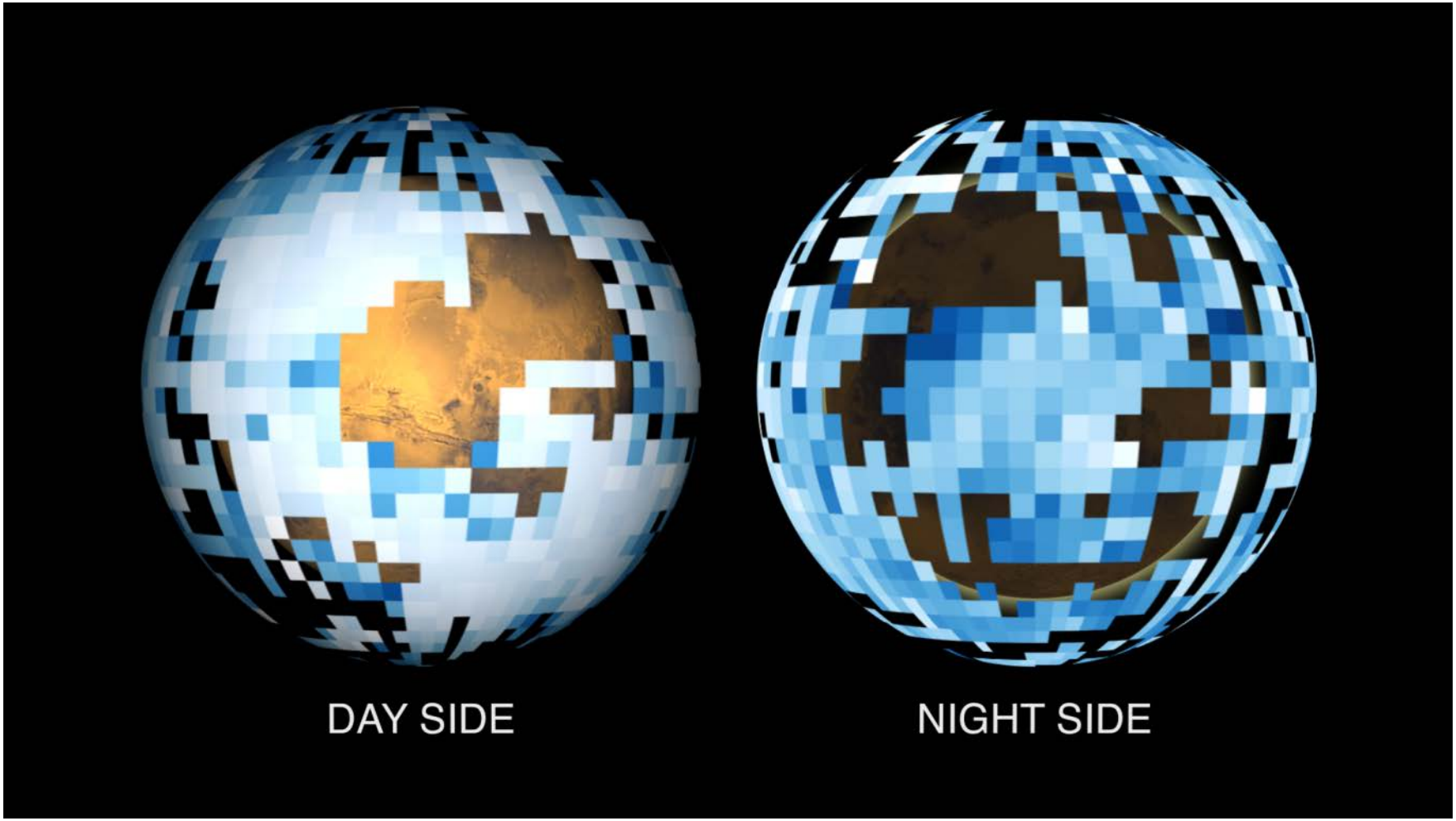






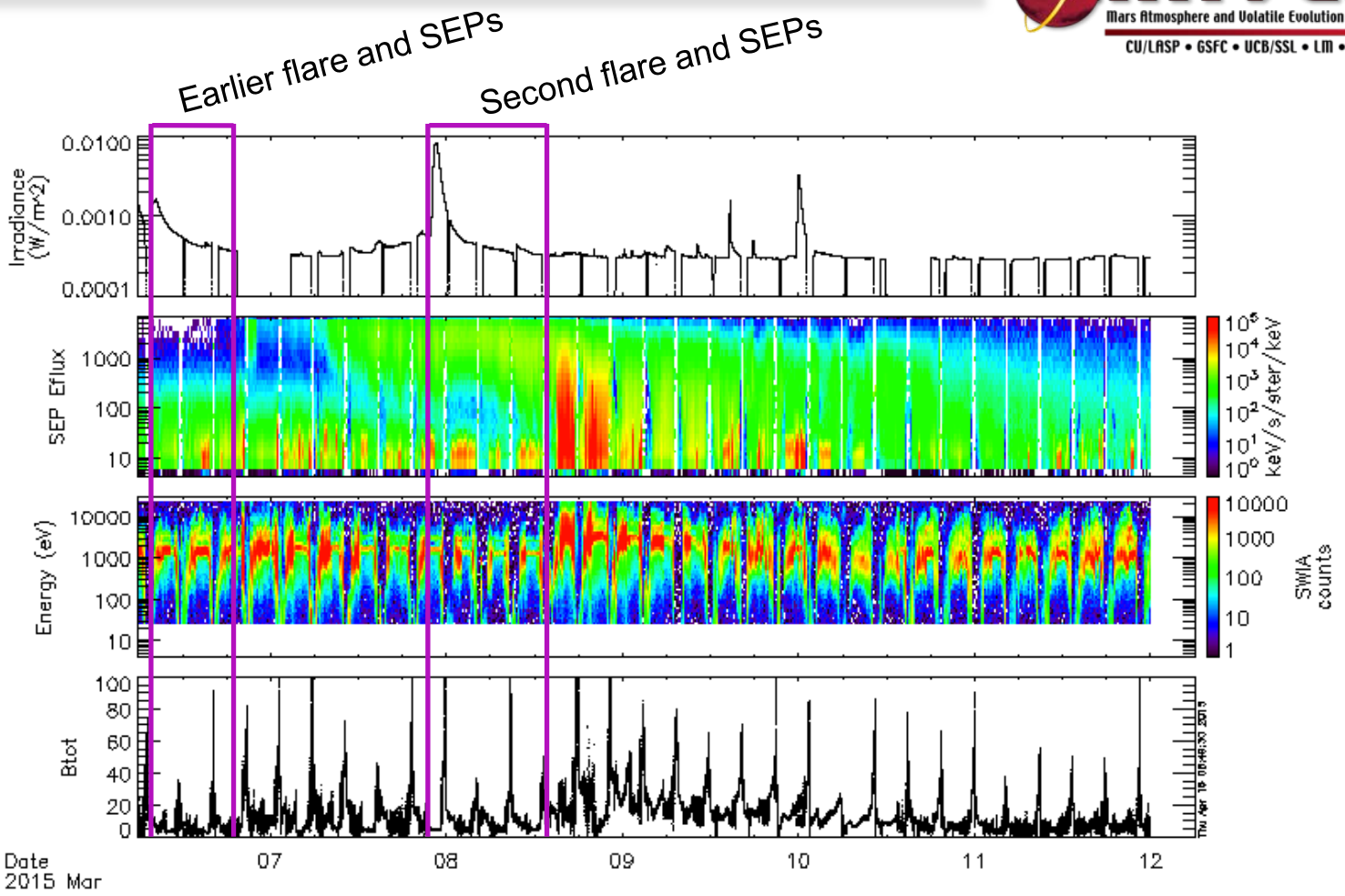
- Ion escape rate ~ 3 x 10^{24} s^{-1}, or ~100 g/s
- Not expected to be constant through time

Total Escaping Flux



- Ion escape rate ~ 3 x 10^{24} s^{-1}, or ~100 g/s
- Not expected to be constant through time

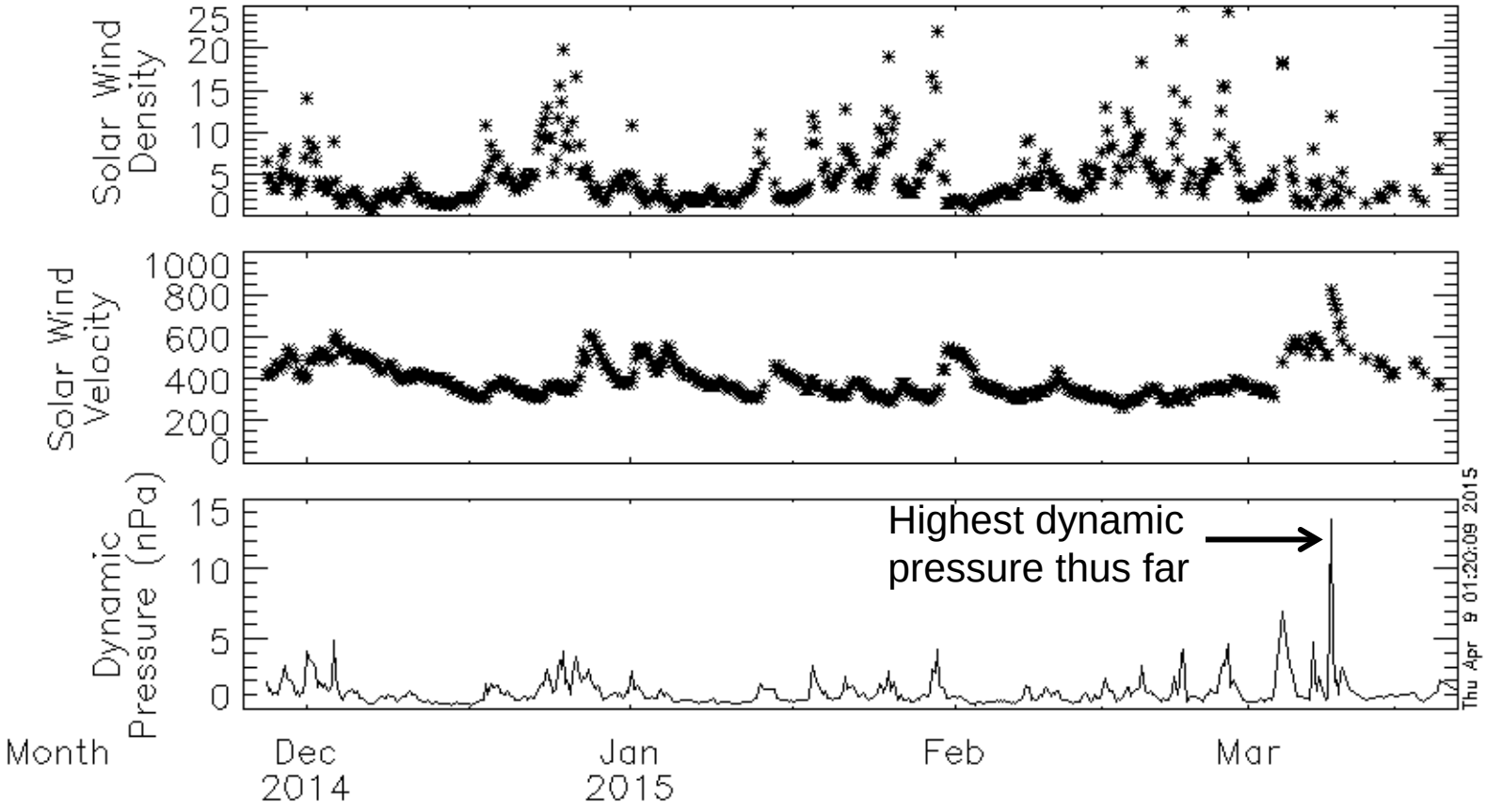
Determining the Effects of Solar Storms



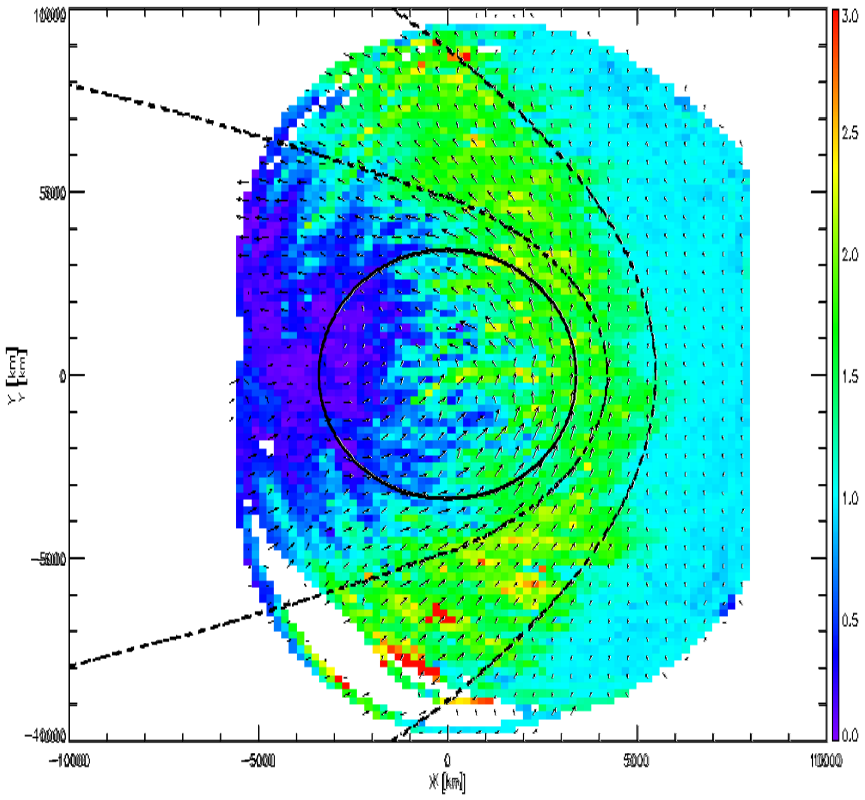
- Three solar events occurred, on March 1st, 6th, then 8th
- March 8 event was largest, but complicated by preceding events
- Flare and CME also observed by SOHO
- Examine energy input, atmospheric response

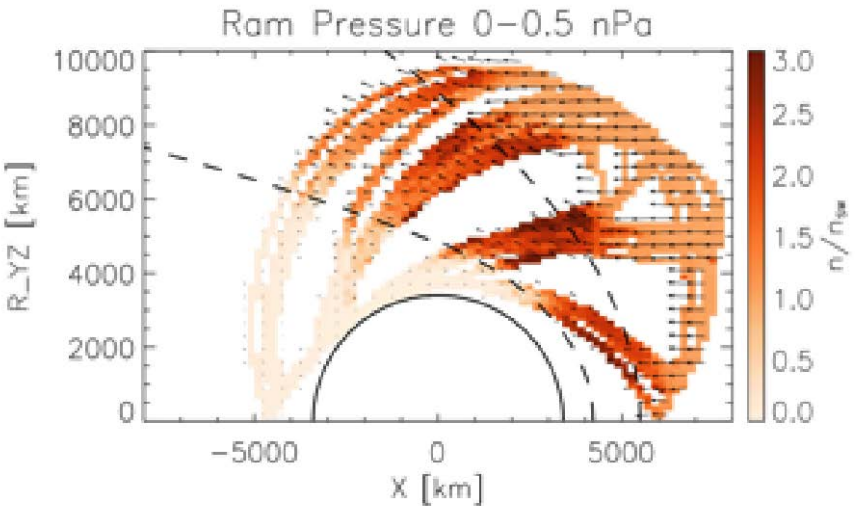
(Jakosky et al. 2015)

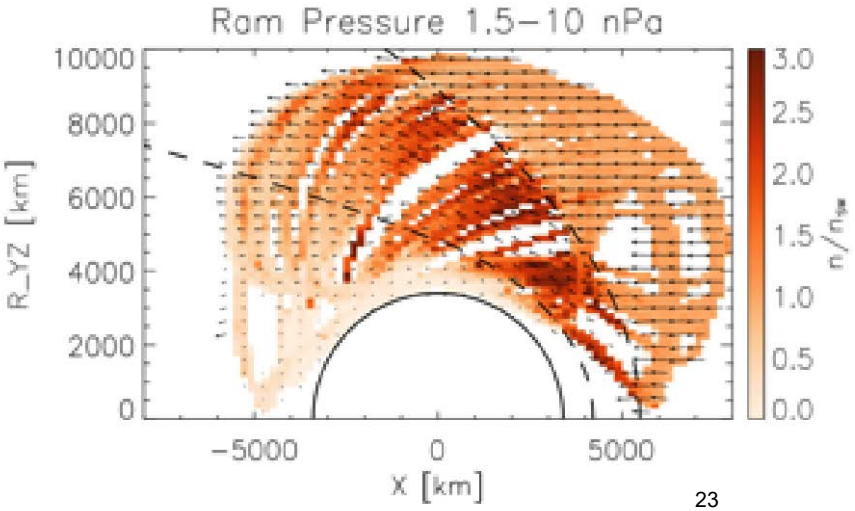
Increased Dynamic Pressure of Solar Wind



Regions of Near-Mars Space Defined by SWIA and MAG Measurements



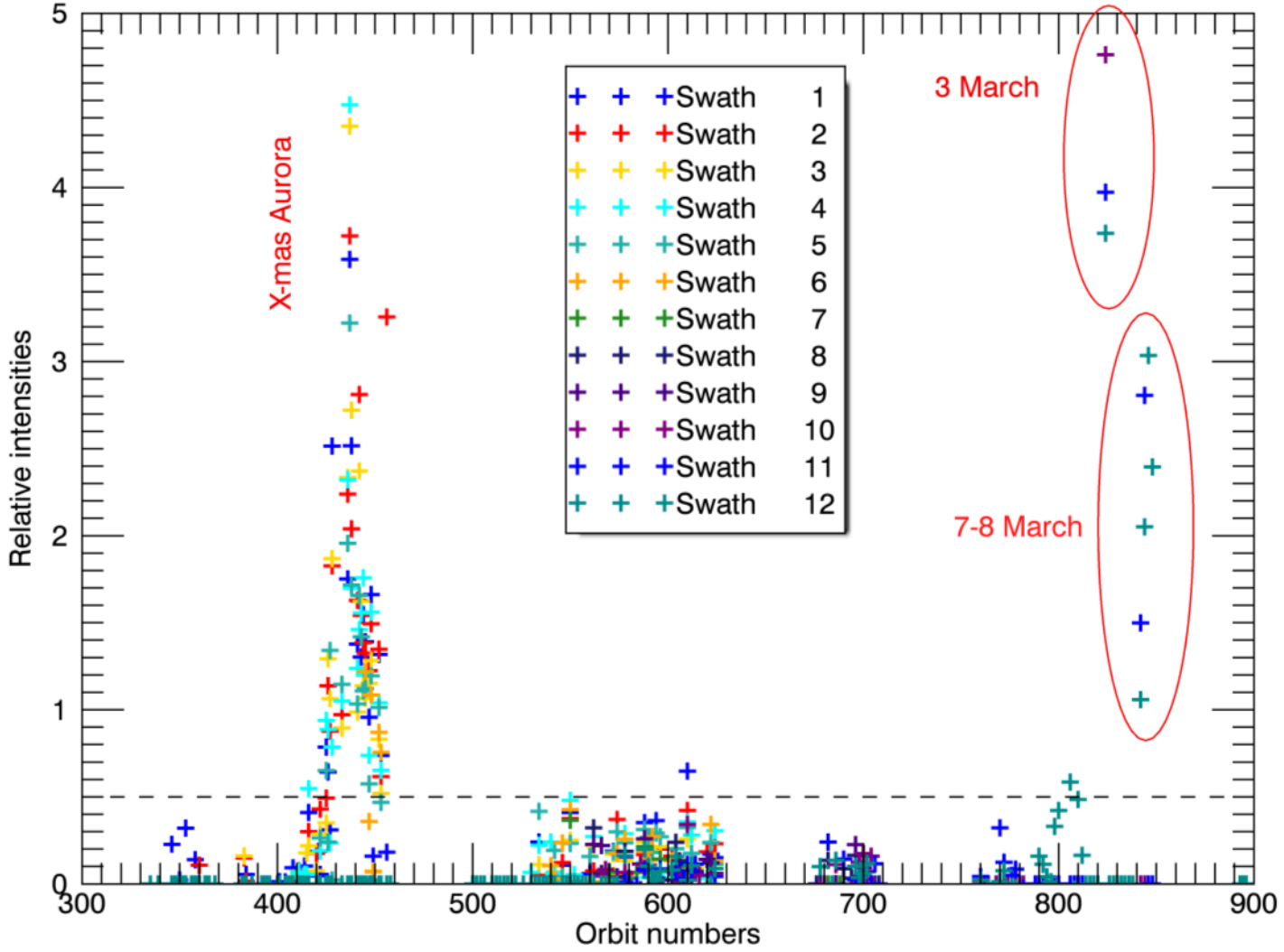




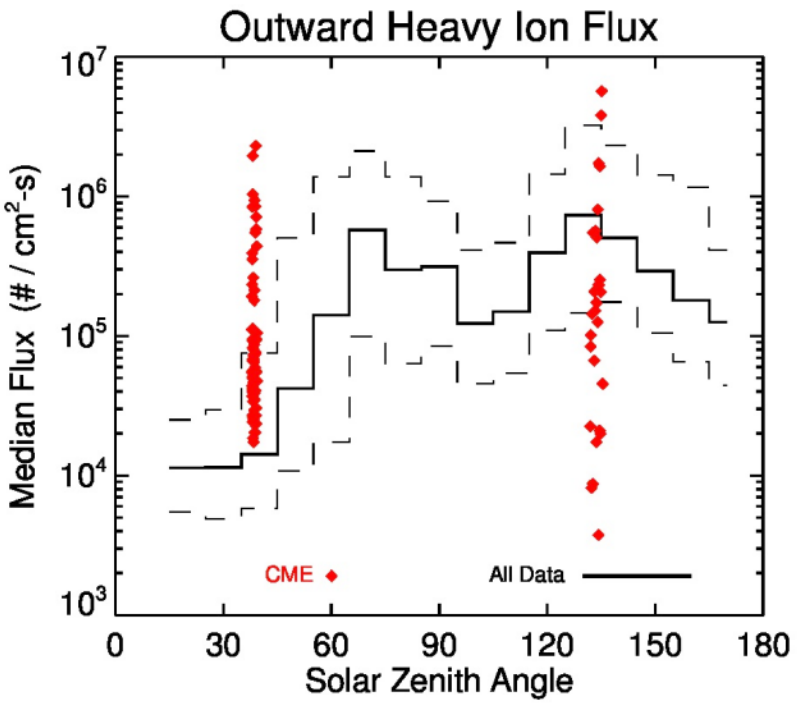
(Halekas et al. 2015)

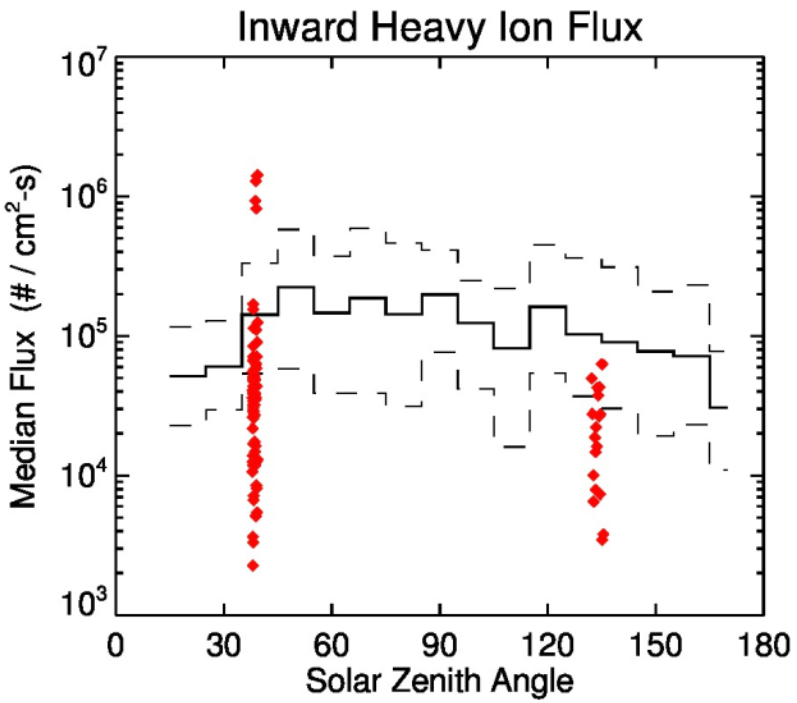
Aurora Triggered by Both Events

…and compared to the earlier "Christmas lights" aurora



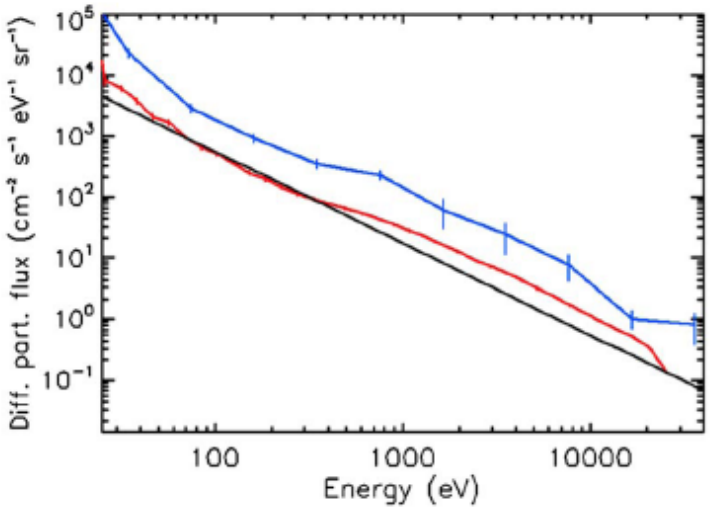
Escape Resulting From ICME



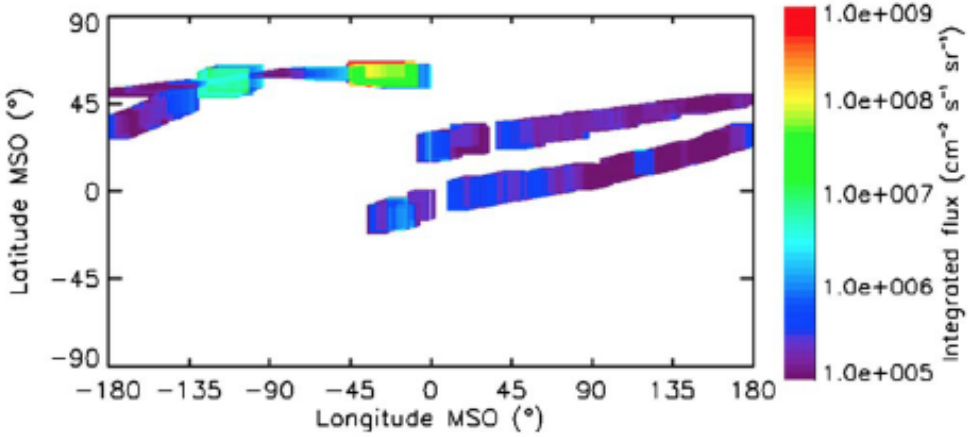


- Limited geographic coverage during ICME precludes unique determination of total escape, integrated over all angles
- Measurements indicate minimal change to tailward flux, and significant enhancement of flux on sunward side

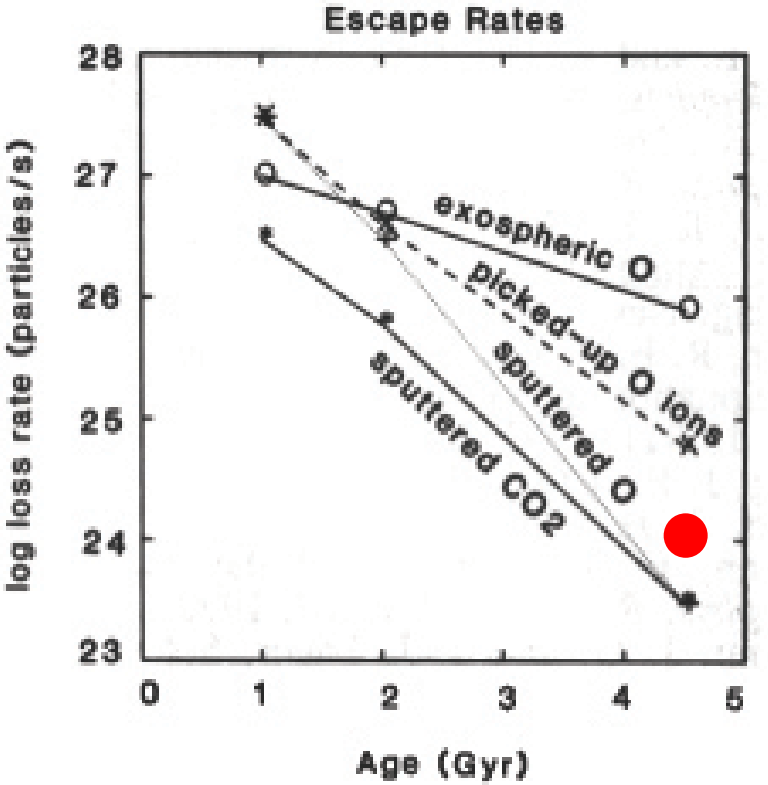
Loss Resulting From Sputtering



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



Spatial distribution of sputtered ion flux



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

(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