The MAVEN Mission, Mars' Auroras And more...

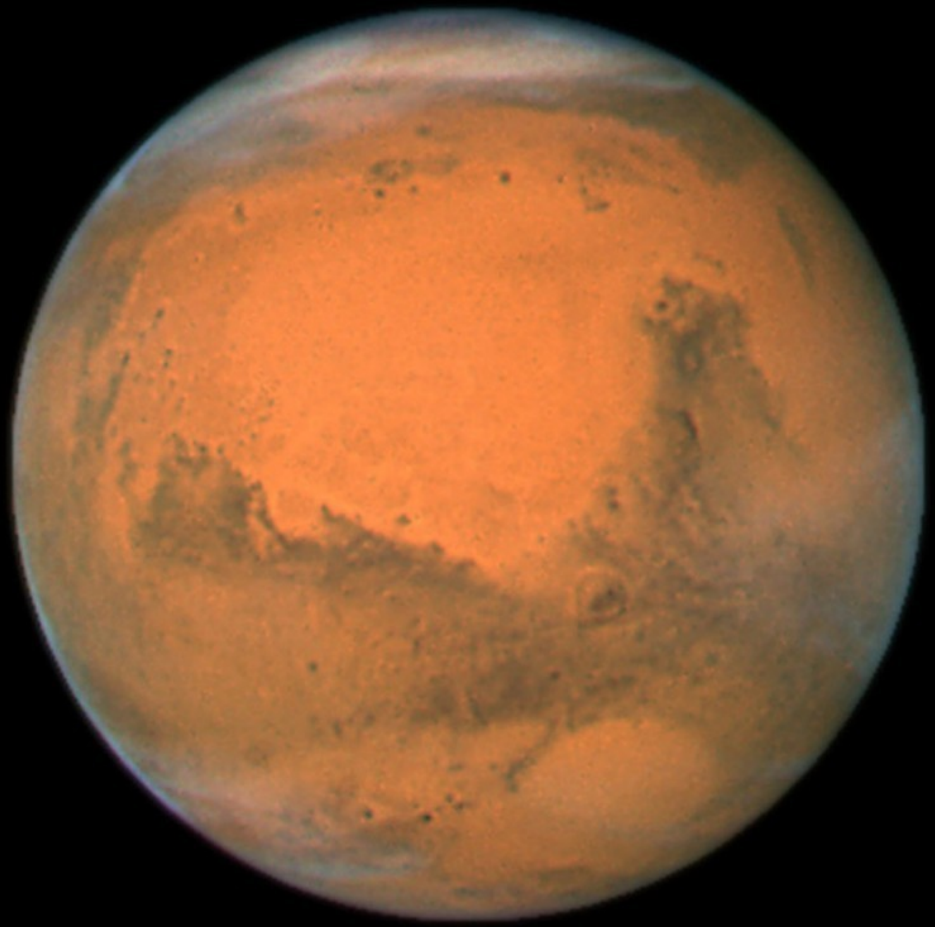
NASA Mars Science:
MAVEN Webinars
30 November 2016

Nick Schneider and the
MAVEN IUVS/Remote Sensing Team
LASP, CU/Boulder

The MAVEN Mission, Mars' Auroras, and more...

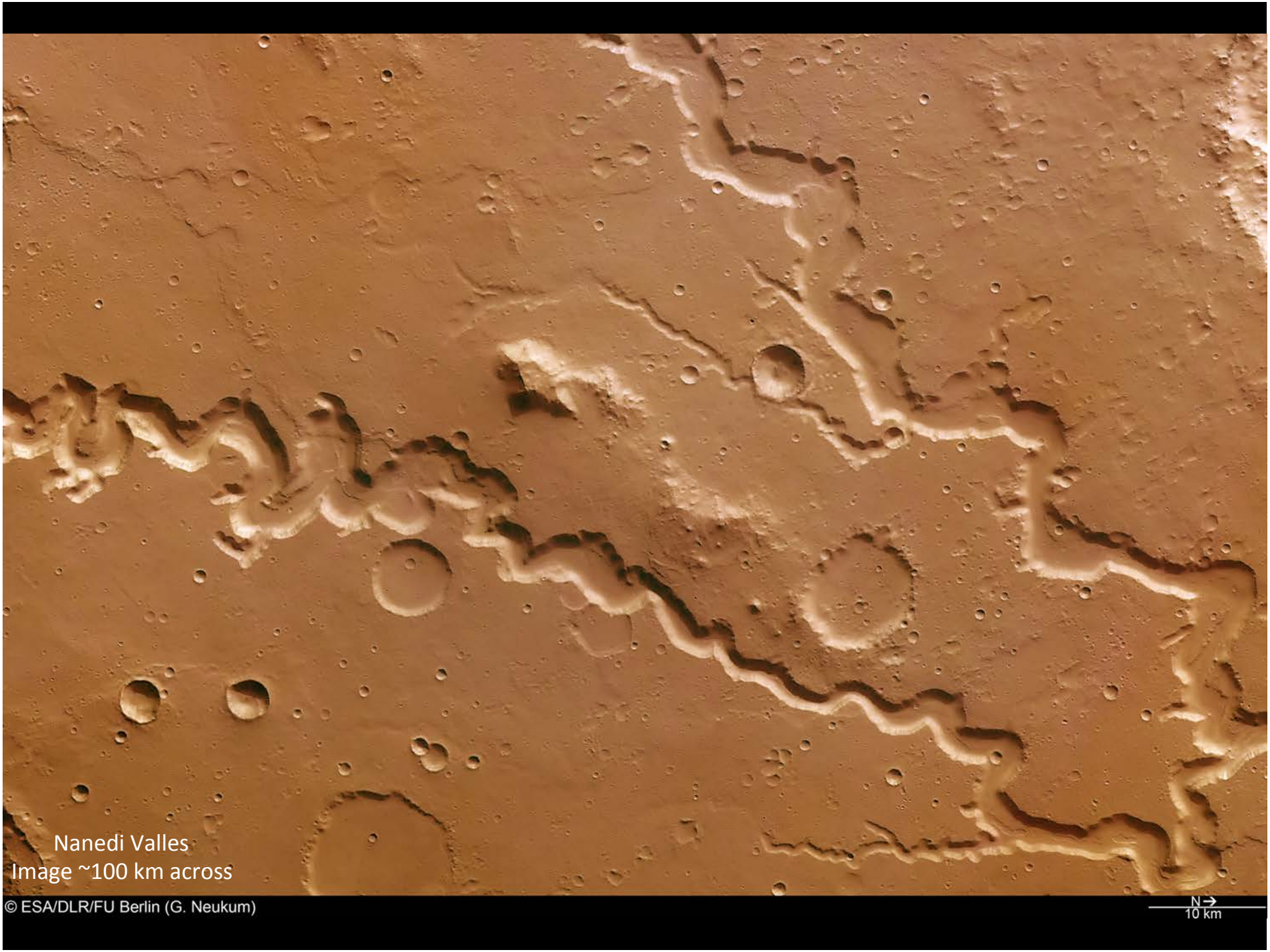
- MAVEN: The Big Picture
  - Why Mars?
  - MAVEN & IUVS' unique capabilities
- MAVEN Discoveries, ready or not!
  - Martian Meteors & Meteor Showers
  - A New Kind of Aurora on Mars
  - Did Mars Atmosphere Escape to Space?
- Sneak Peeks, Conclusions & Outlook

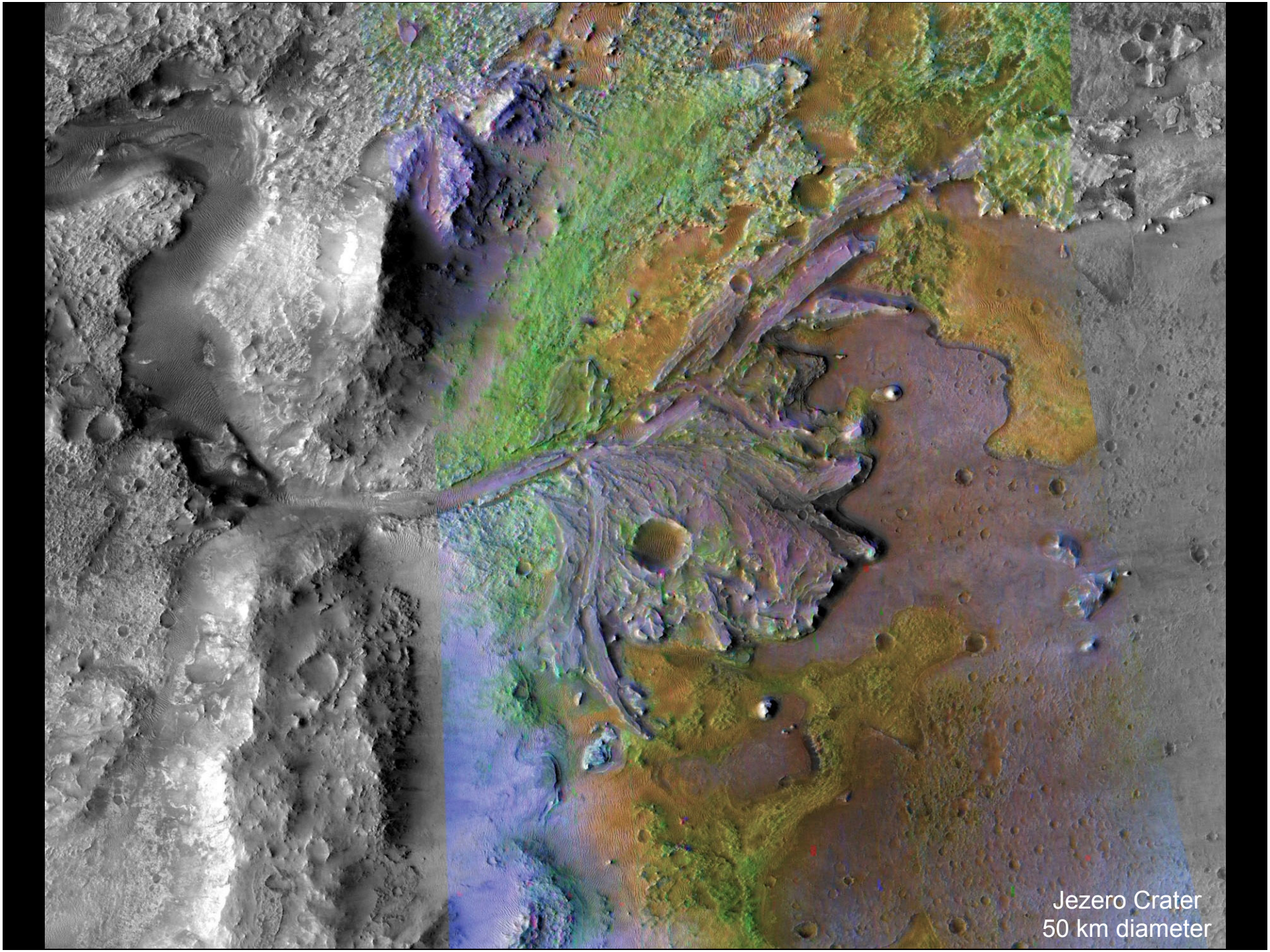
Was Mars once habitable?

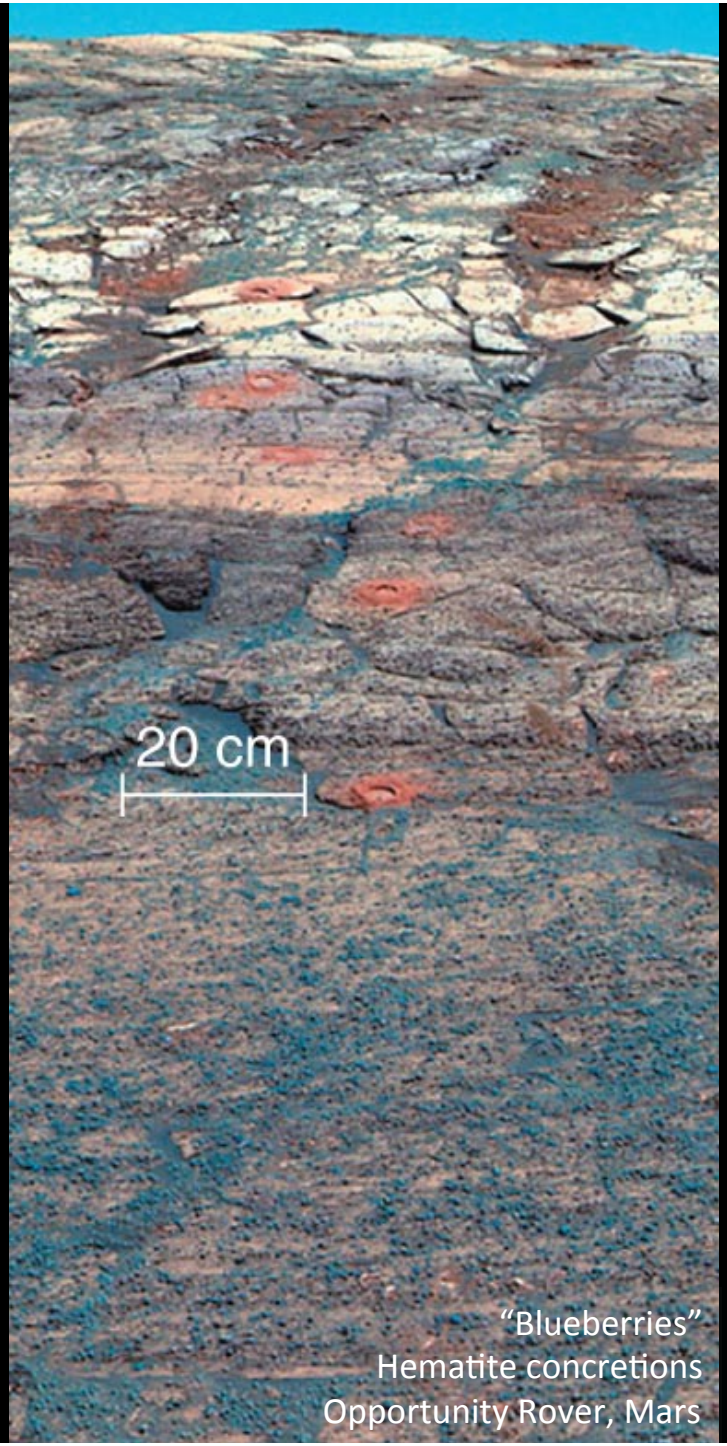


What is the surface trying to tell us?

Mars Southern Highlands
Image ~500km across


Nanedi Valles
Image ~100 km across
© ESA/DLR/FU Berlin (G. Neukum)
N
10 km

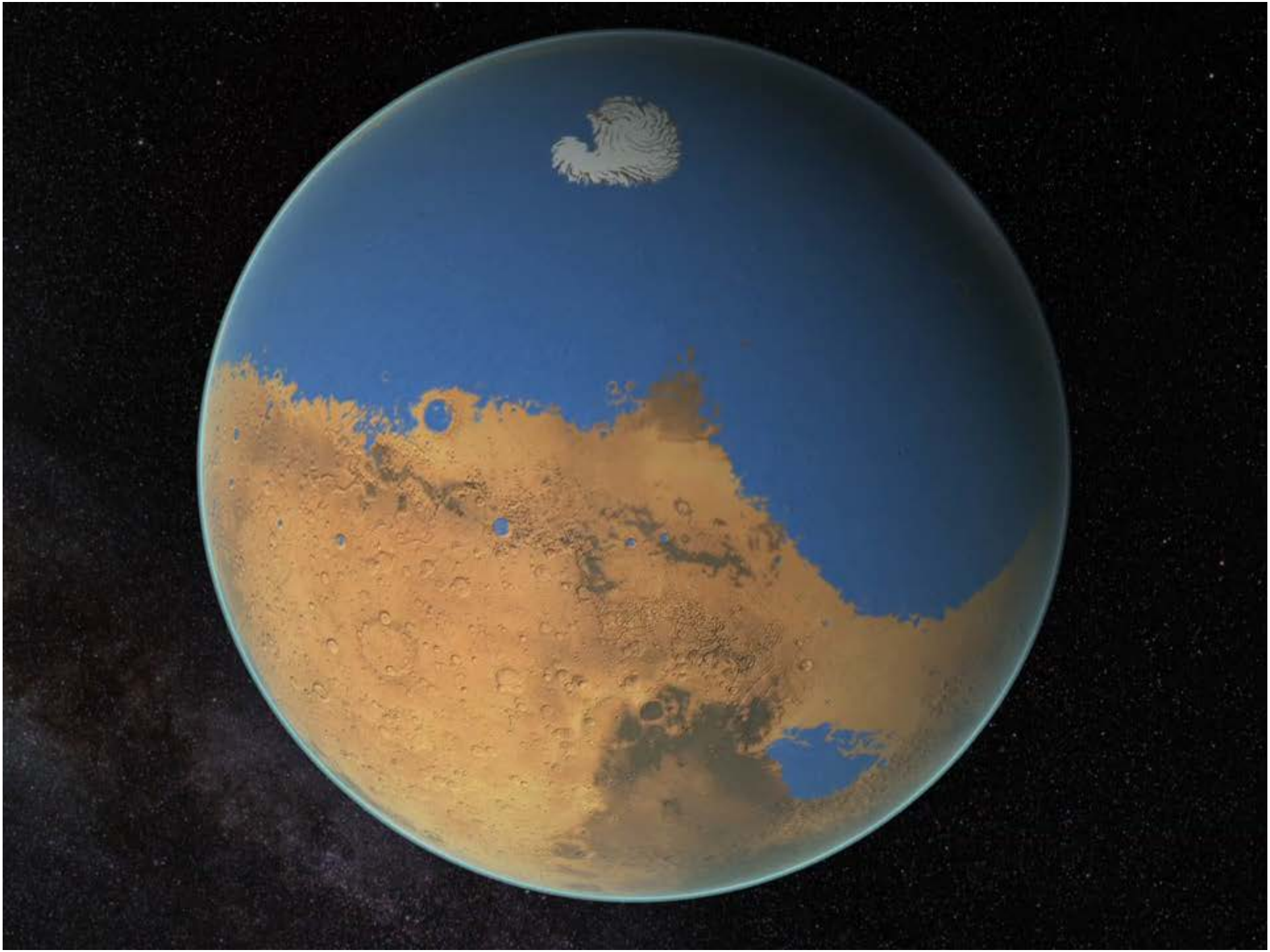

Jezero Crater
50 km diameter



"Blueberries"
Hematite concretions
Opportunity Rover, Mars

"Moqui marbles"
Navajo sandstone formation
Arizona/Utah border


Streambed deposit
Gale Crater
Curiosity Rover
Image ~1m wide

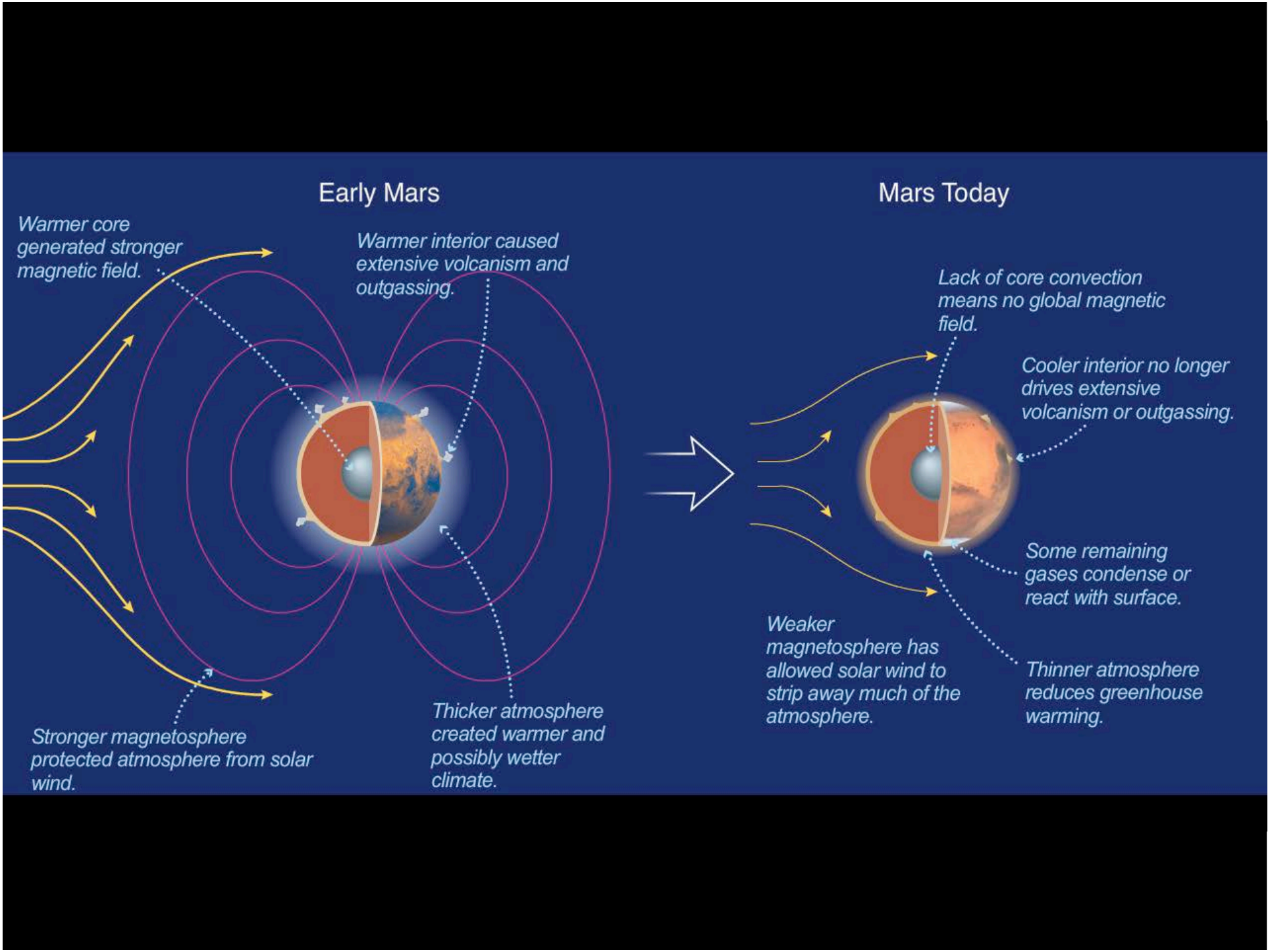


If Mars had a thick atmosphere, where it is now?
If Mars had an ocean, where is all the water now?

- Frozen at the poles?
  - Not enough!
- Locked underground?
  - Not *nearly* enough!

What other possibilities are left?

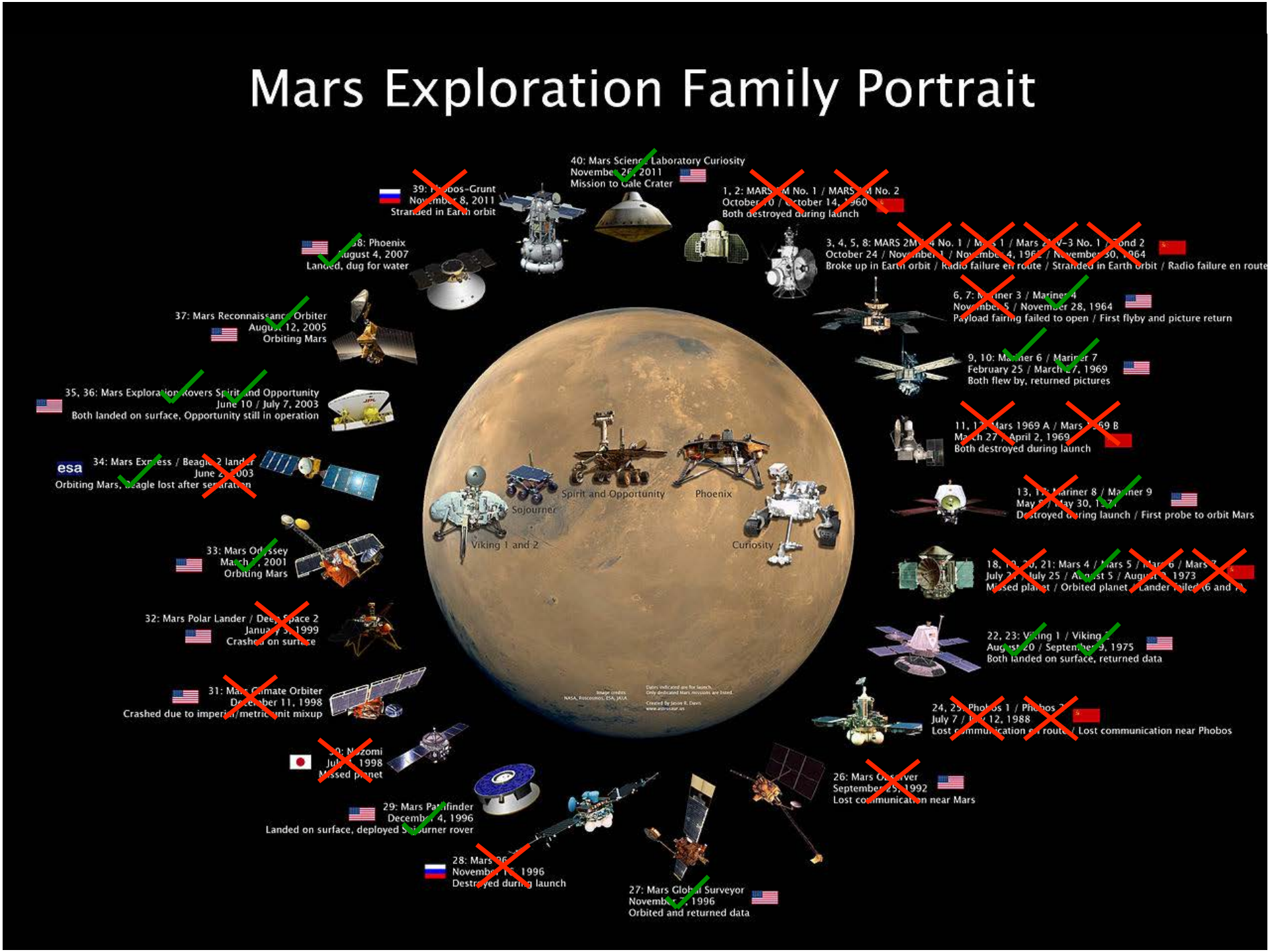
Artist's conception by Mike Carroll


Early Mars
Warmer core generated stronger magnetic field.
Warmer interior caused extensive volcanism and outgassing.
Stronger magnetosphere protected atmosphere from solar wind.
Thicker atmosphere created warmer and possibly wetter climate.
Mars Today
Lack of core convection means no global magnetic field.
Cooler interior no longer drives extensive volcanism or outgassing.
Some remaining gases condense or react with surface.
Weaker magnetosphere has allowed solar wind to strip away much of the atmosphere.
Thinner atmosphere reduces greenhouse warming.

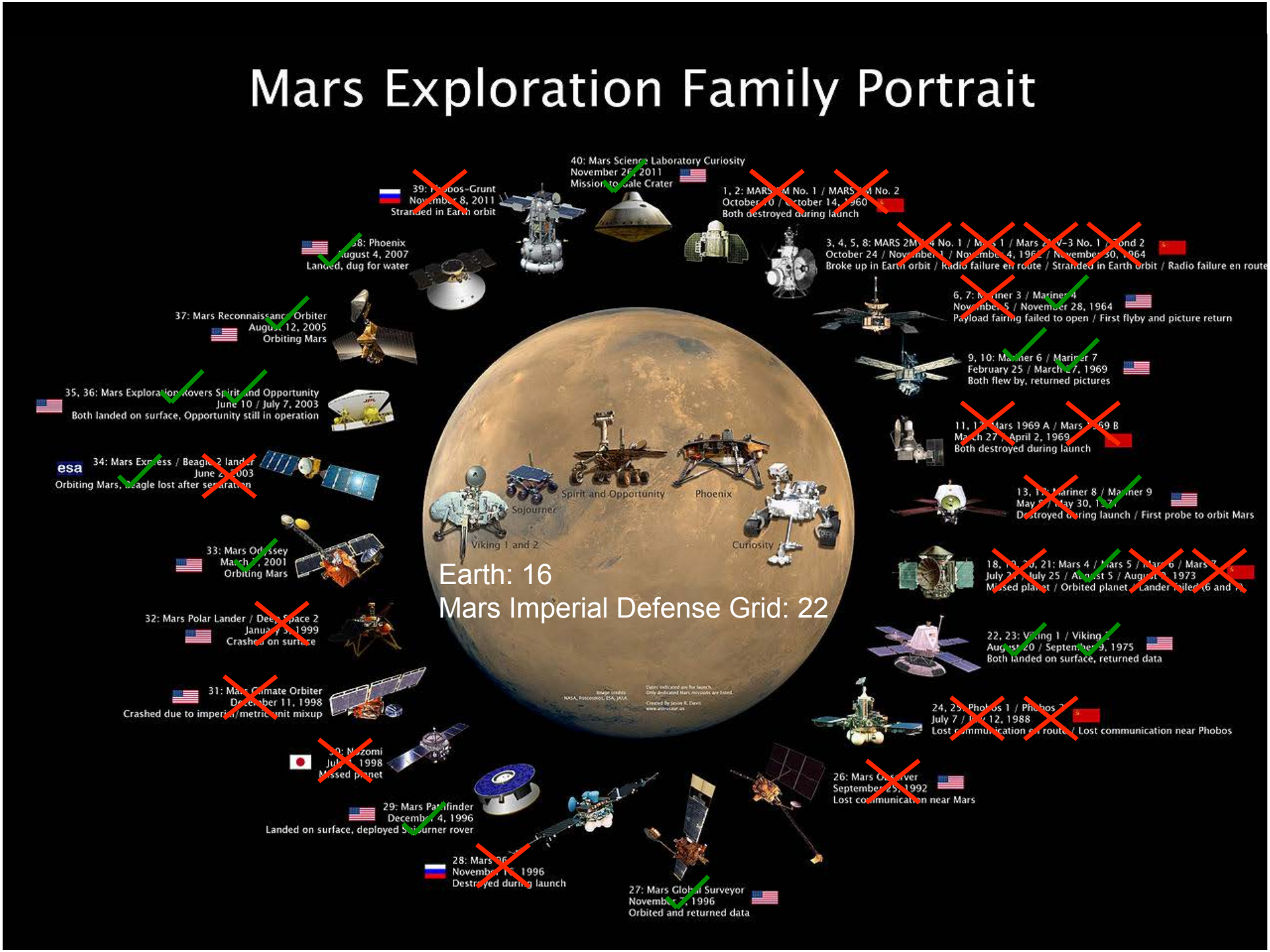
The MAVEN Spacecraft

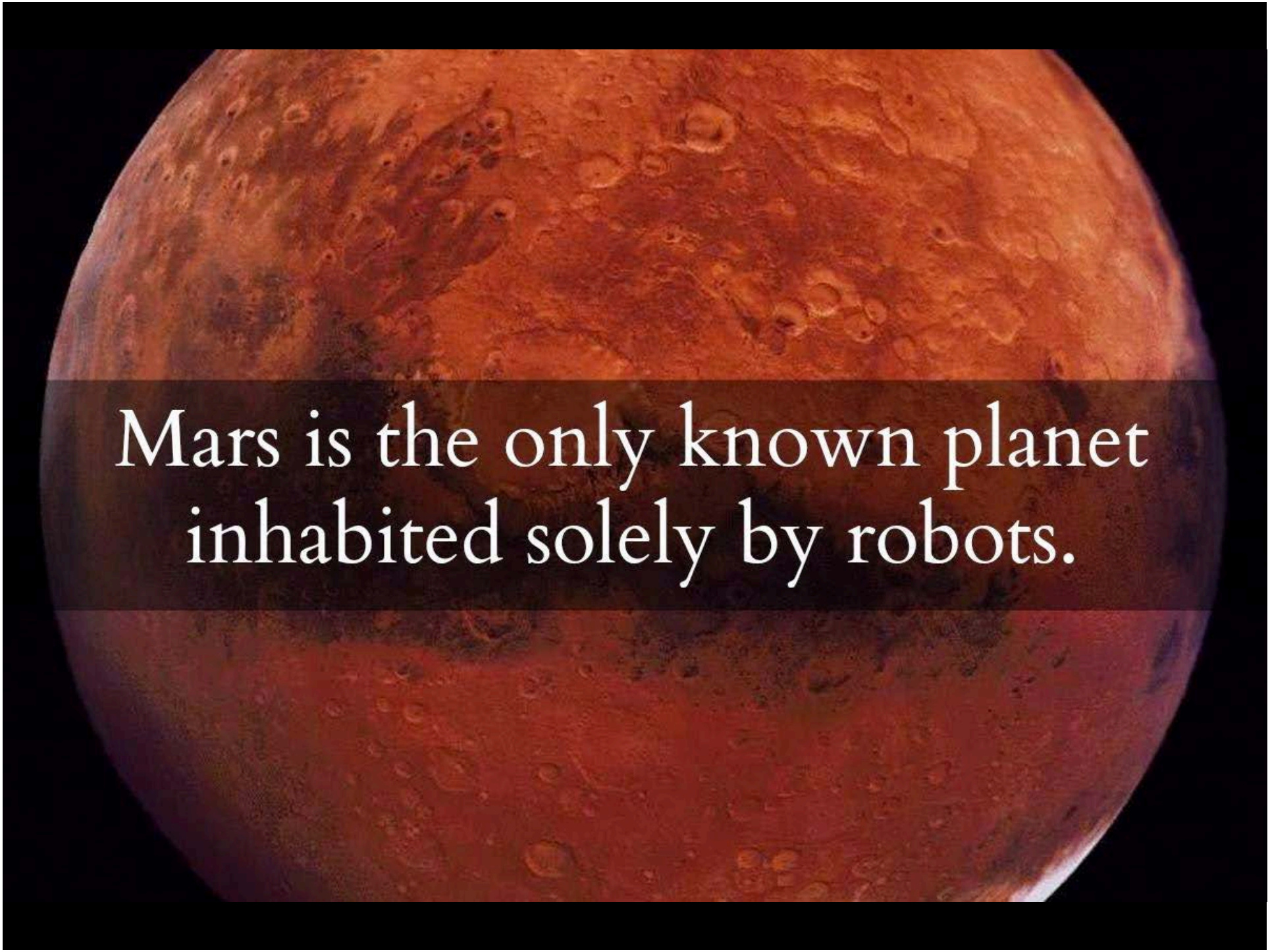
- Launch (Wet) Mass: 2455 kg at launch
- Spacecraft Dry Mass: 810 kg at launch
- Power: 1135 W at Mars Aphelion

Mars Exploration Family Portrait

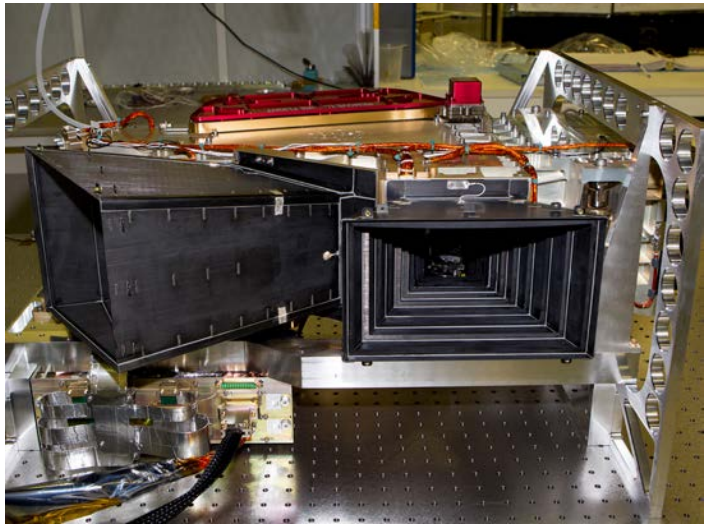


Mars Exploration Family Portrait




Mars is the only known planet
inhabited solely by robots.

MAVEN Remote Sensing



Imaging Ultraviolet Spectrograph
Wavelength range
- FUV: 110 – 190nm
- MUV: 180– 340nm
- Echelle: multi-order @ H & D Lyman α

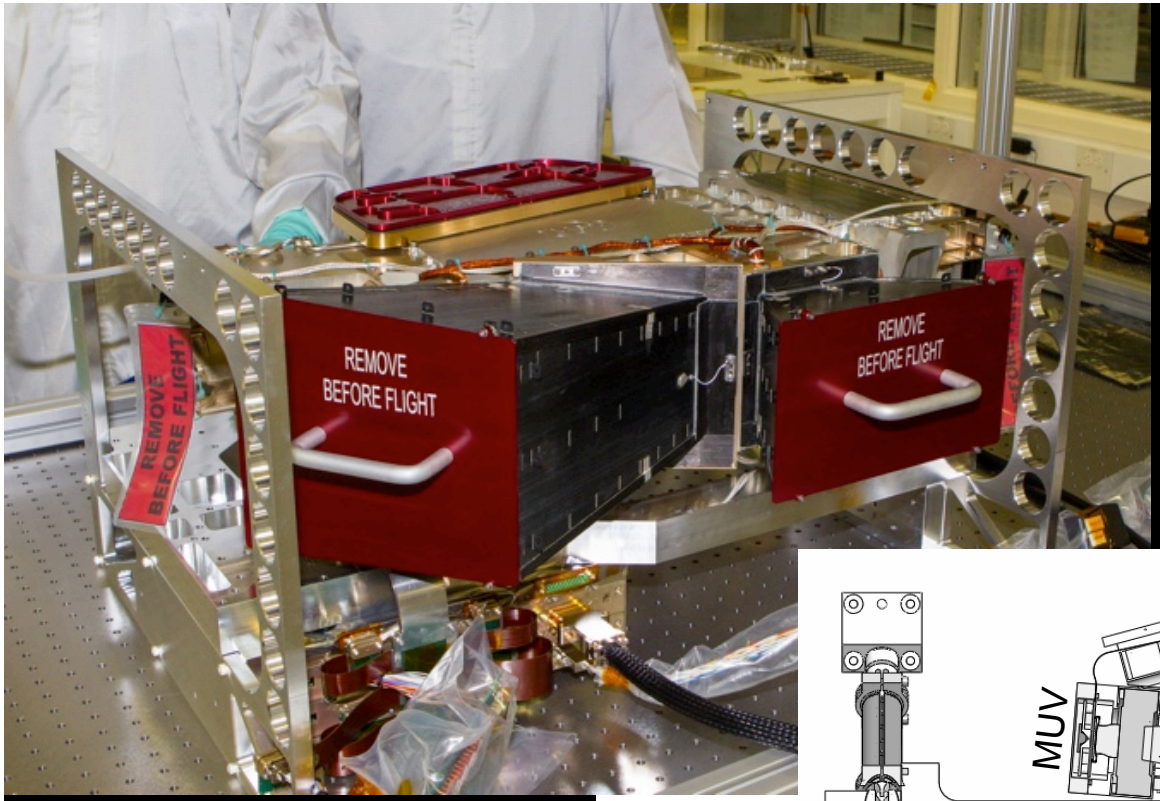
Detectors: Image-intensified 2-D active pixel sensors
Cost: $22M

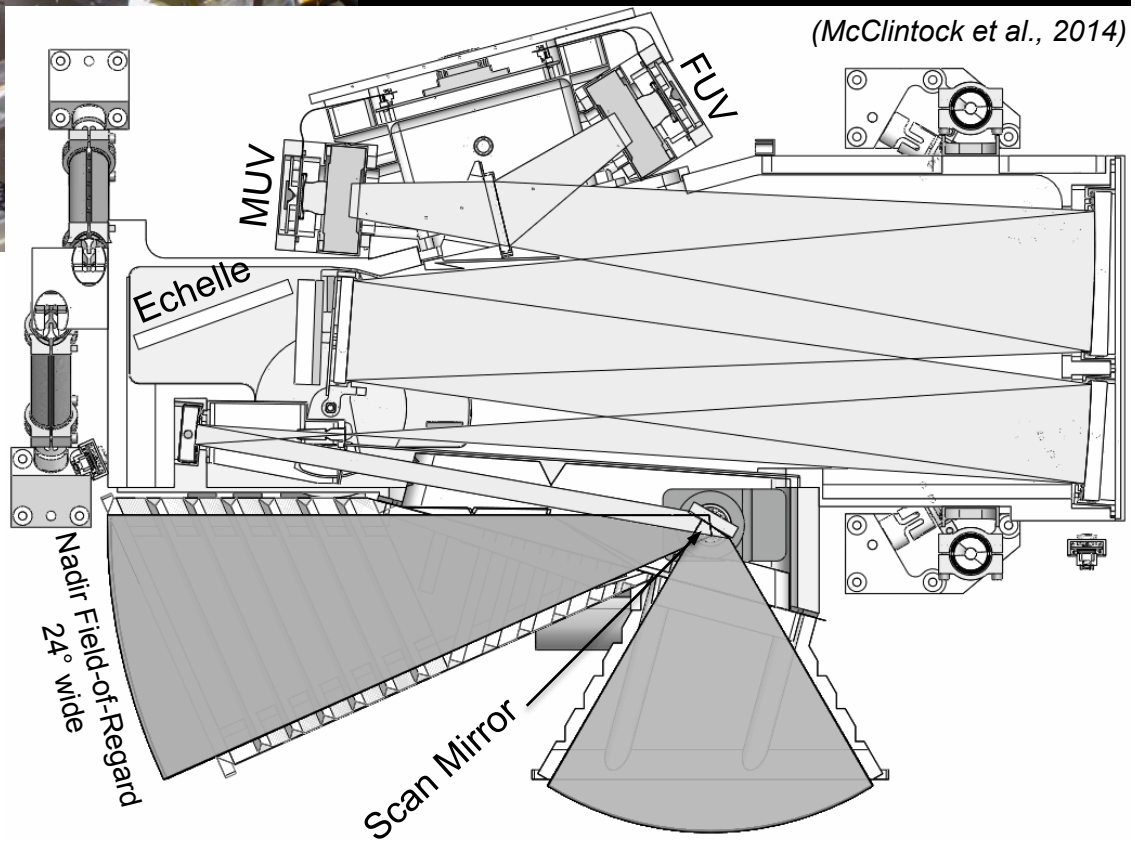
Laboratory for Atmospheric and Space Physics (LASP)
University of Colorado

Science Lead: Nicholas Schneider
Instrument Lead: William McClintock
Project Manager: Rory Barrett

Observations
- Limb scans near periapsis
- Disk maps near apoapsis
- D/H disk and corona mapping
- Hot Oxygen coronal mapping
- Stellar occultations

➢ Observing duty cycle 50%-100%





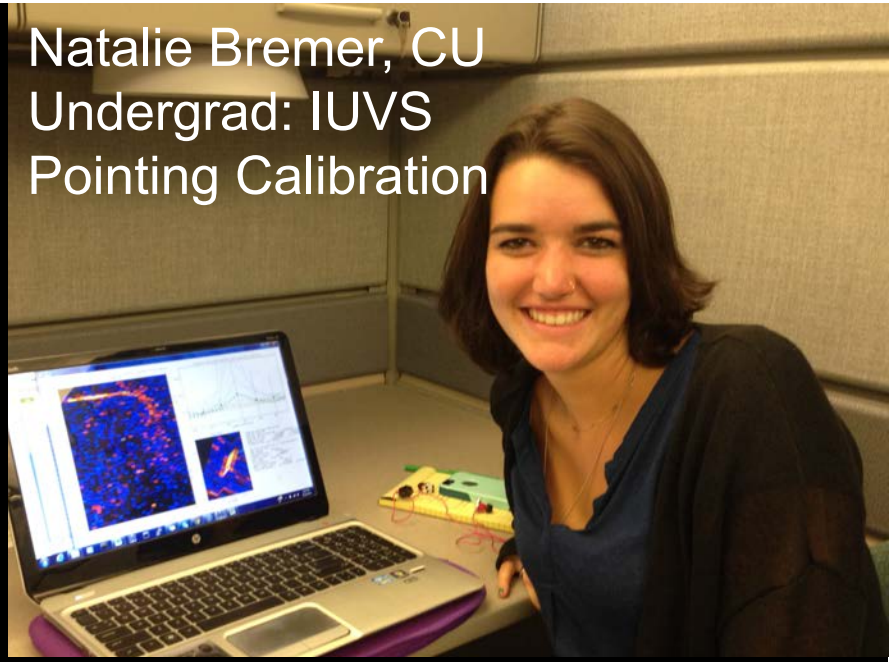
(McClintock et al., 2014)

Spectrograph
Slit: 12.5° tall

Nadir Field-of-Regard: 60° wide

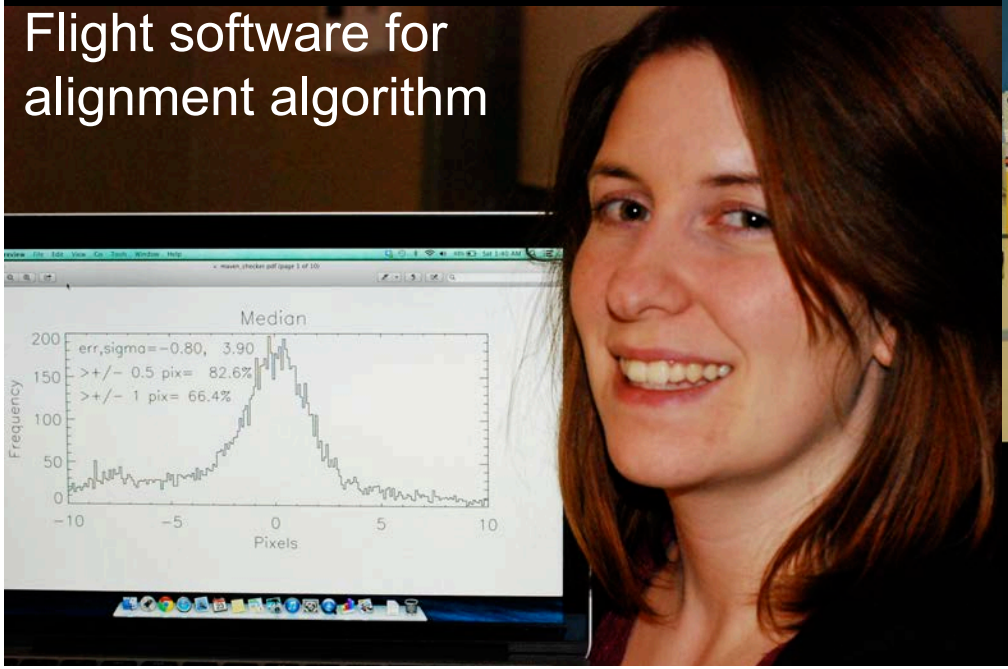

MAVEN
Mars Atmosphere and Volatile Evolution Mission
CU/LASP • GSFC • UCB/SSL • LMI • JPL

Jeremy Emmett
CU: undergrad
"Can MAVEN detect Mars Aurora?"



Natalie Bremer, CU
Undergrad: IUVS
Pointing Calibration

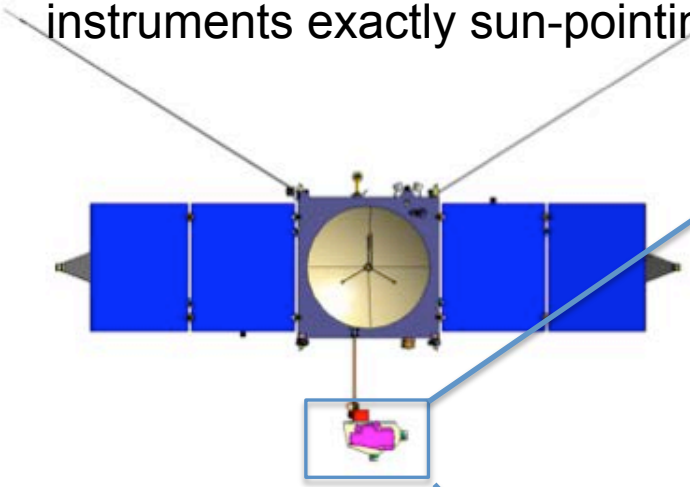
Katie Fitzgerald, CU
Undergrad
Flight software for alignment algorithm



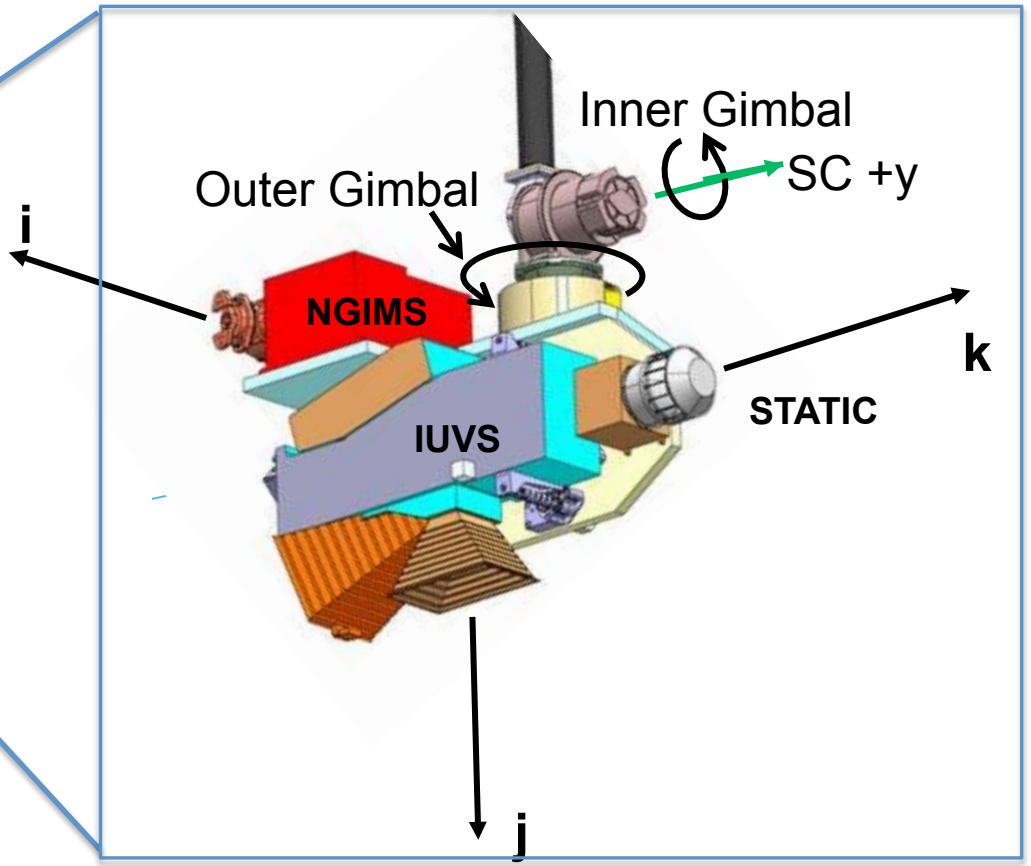
Mike Chaffin, CU Grad Student,
Mars Hydrogen Loss

IUVS Accommodation & Pointing Capability

During most normal operations, the spacecraft flies with solar arrays and body-mounted instruments exactly sun-pointing



IUVS, NGIMS and STATIC are located on the Articulated Payload Platform (APP) which uses uses two gimbals to orient one instrument axis

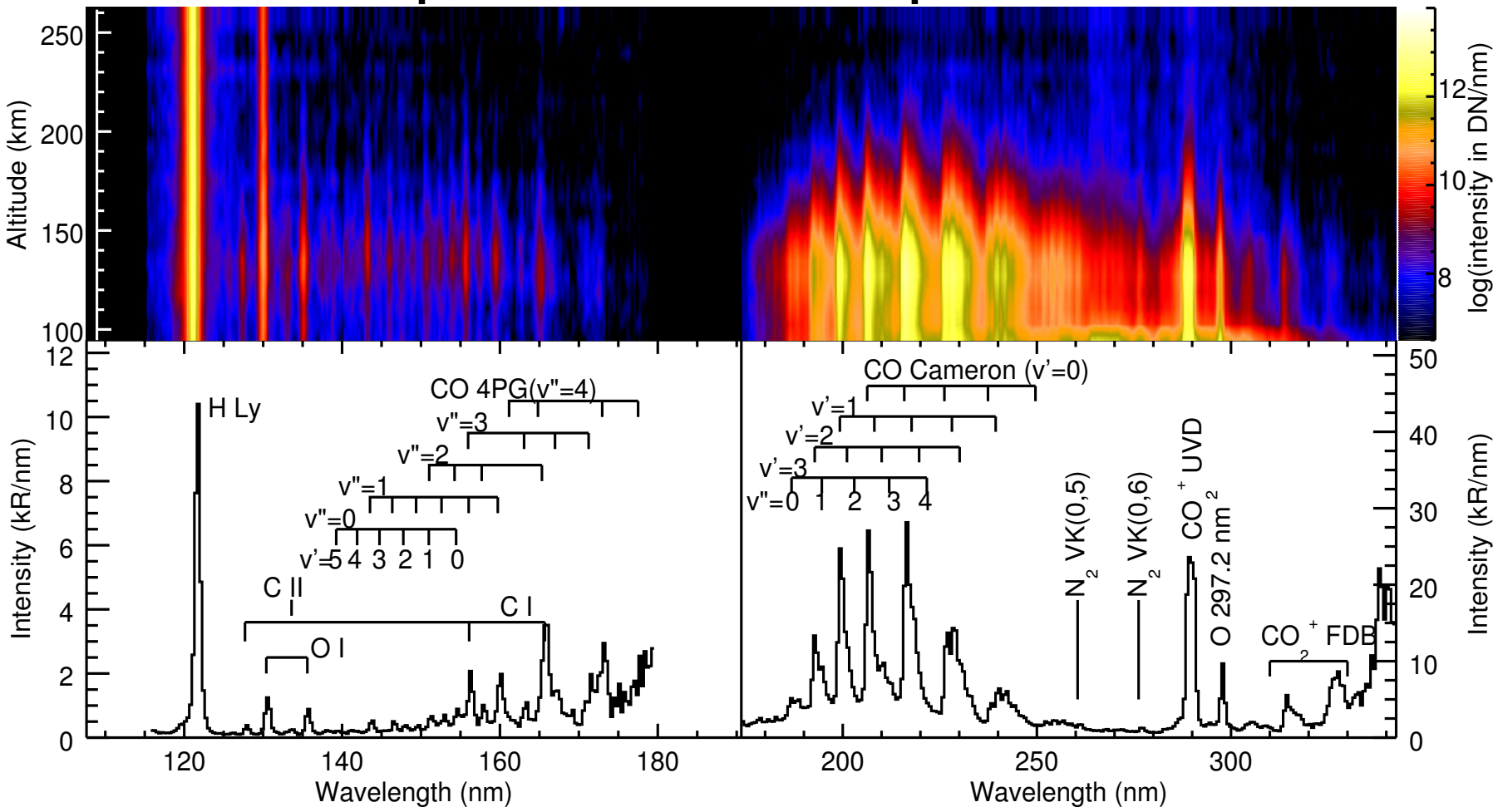


2-axis gimbals allow IUVS to observe at >50% duty cycle, obtaining limb scans, coronal scans and disk maps

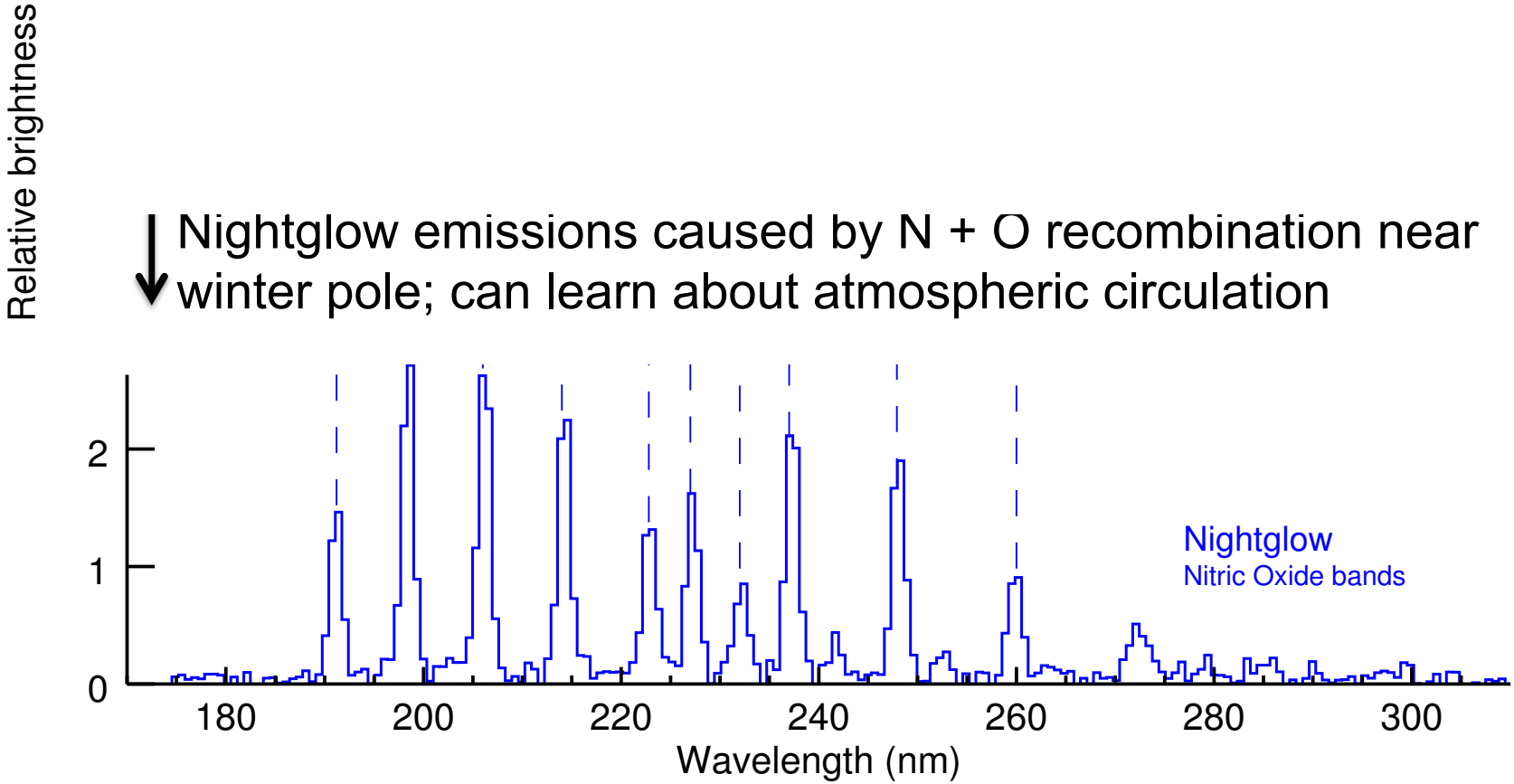
Spectroscopy

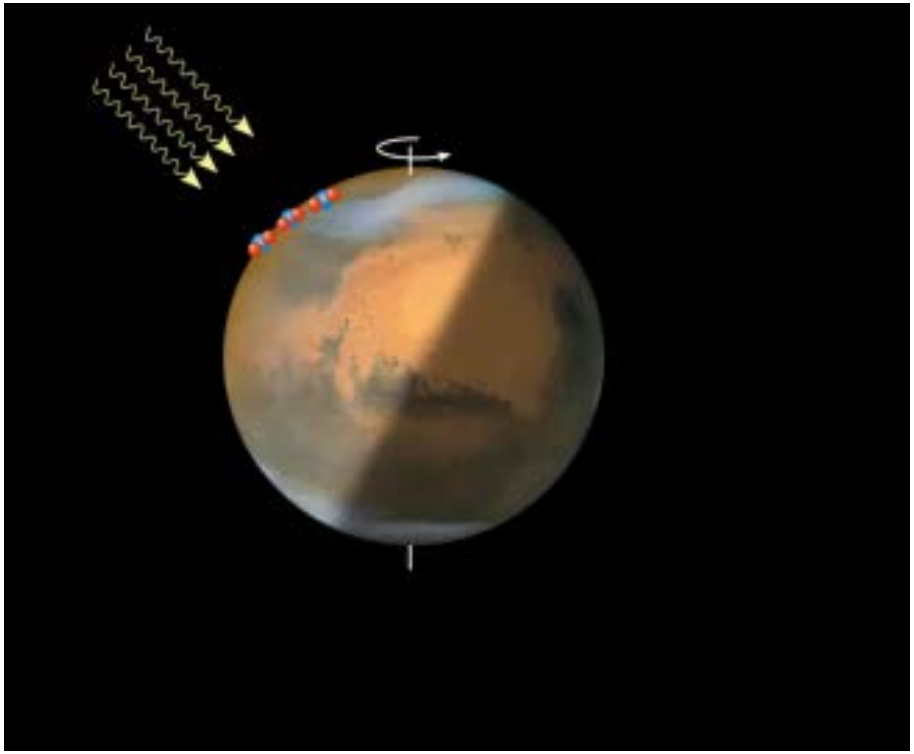
Hydrogen emission

IUVS' FUV & MUV dayglow limb scans provide excellent compositional and spatial information

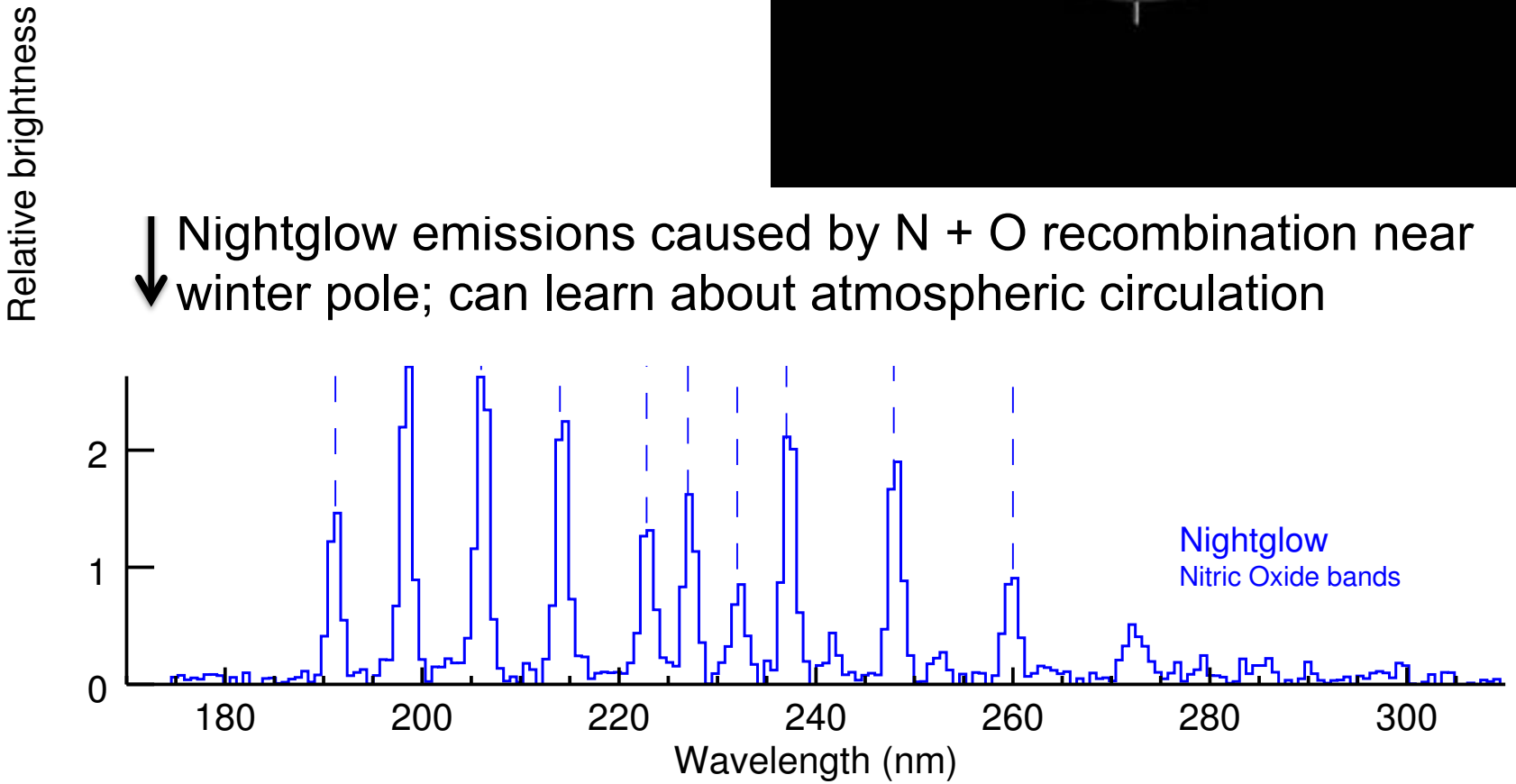


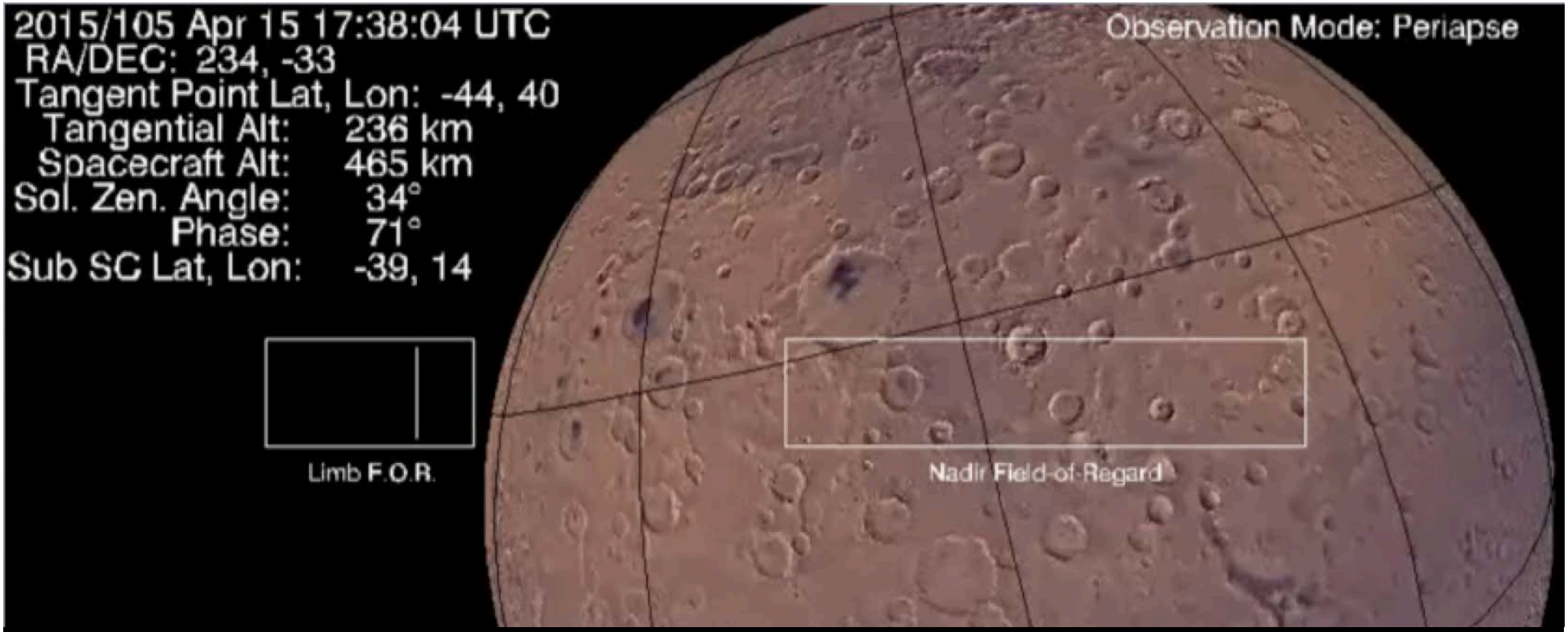
- 12 datasets like this are collected every orbit, 2.5-5x daily
- L1C data products include fitted line/band intensities
- L2 data products include retrieved densities

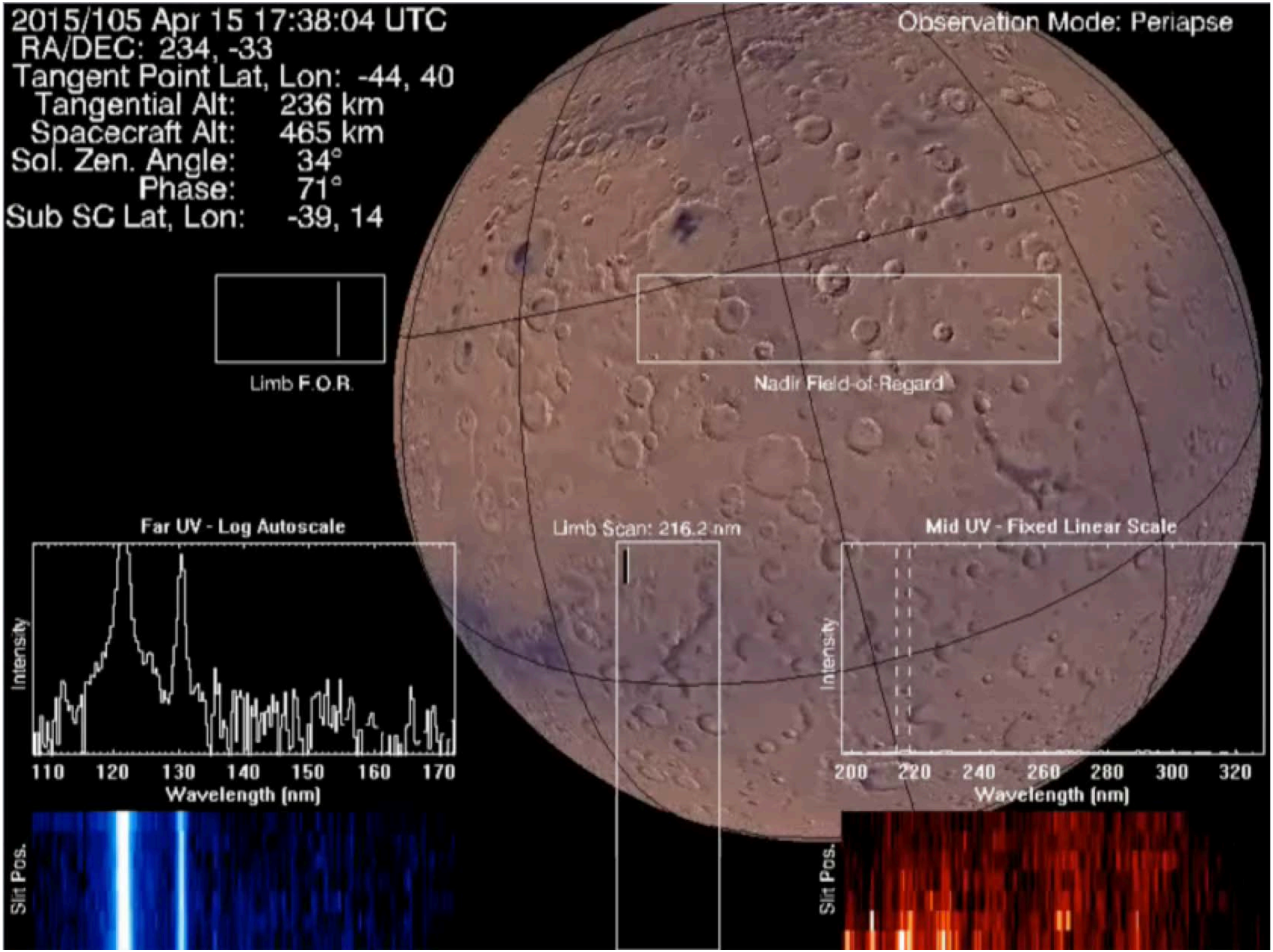

Relative brightness
Nightglow emissions caused by N + O recombination near winter pole; can learn about atmospheric circulation
2
1
0
180
200
220
240
260
280
300
Wavelength (nm)
Nightglow
Nitric Oxide bands



↓ Nightglow emissions caused by N + O recombination near winter pole; can learn about atmospheric circulation




2015/105 Apr 15 17:38:04 UTC
RA/DEC: 234, -33
Tangent Point Lat, Lon: -44, 40
Tangential Alt: 236 km
Spacecraft Alt: 465 km
Sol. Zen. Angle: 34°
Phase: 71°
Sub SC Lat, Lon: -39, 14
Observation Mode: Periapse
Limb F.O.R.
Nadir Field-of-Regard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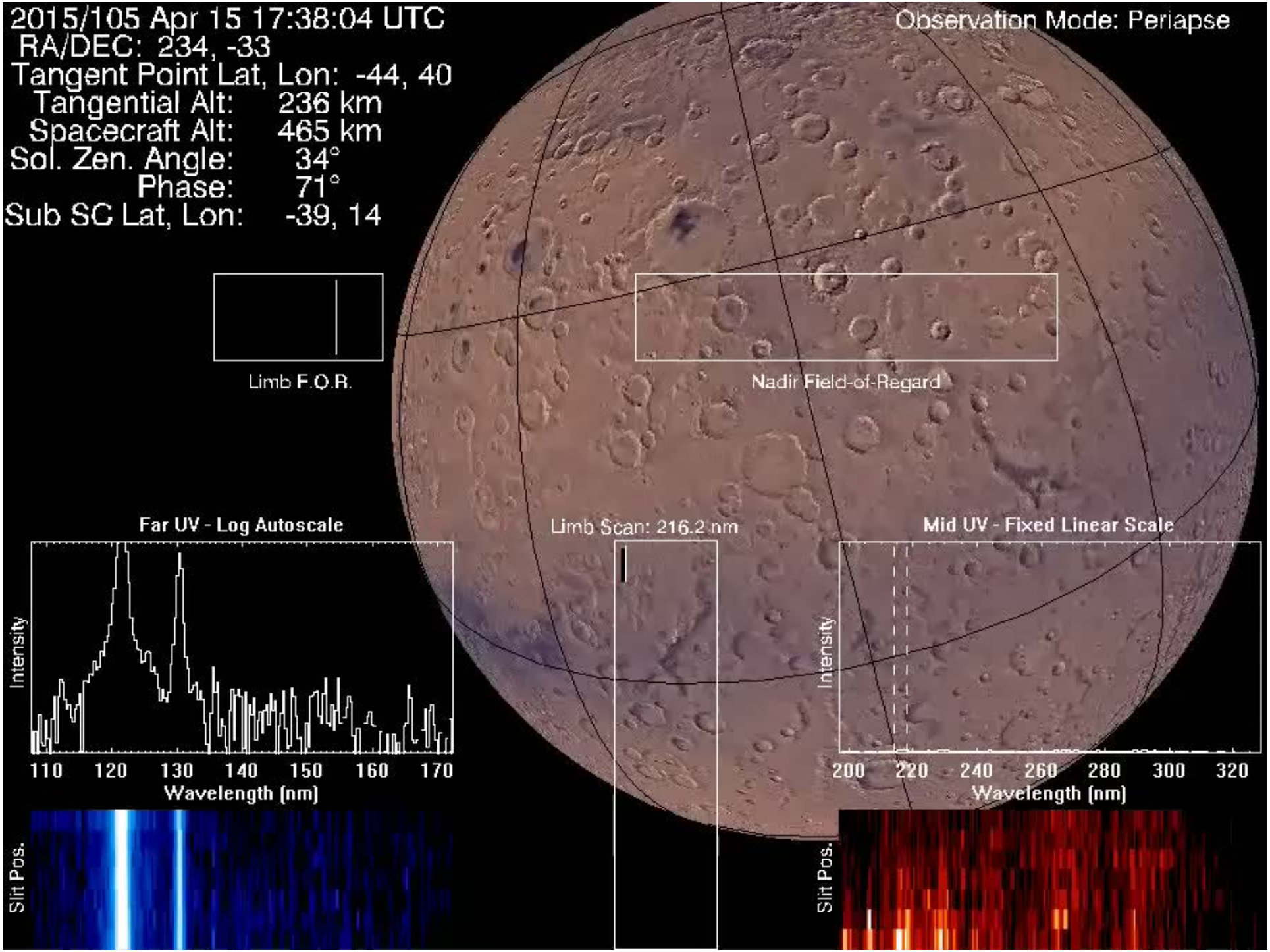
Observation Mode: Periapse
Limb F.O.R.
Nadir Field-of-Regard
Limb Scan: 216.2 nm
Far UV - Log Autoscale
Intensity
110 120 130 140 150 160 170
Wavelength (nm)
Slit Pos.
Mid UV - Fixed Linear Scale
Intensity
200 220 240 260 280 300 320
Wavelength (nm)
Slit Pos.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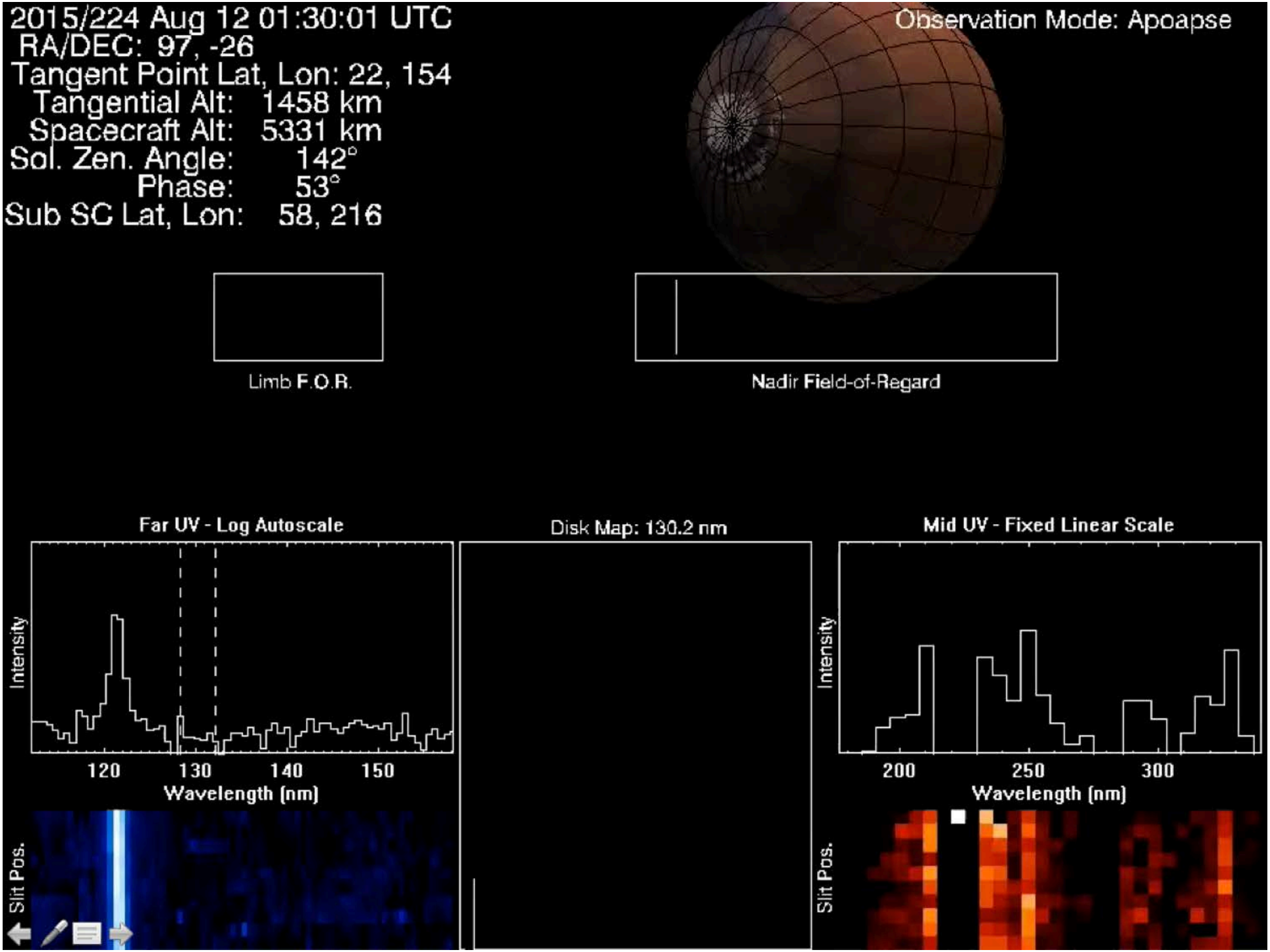
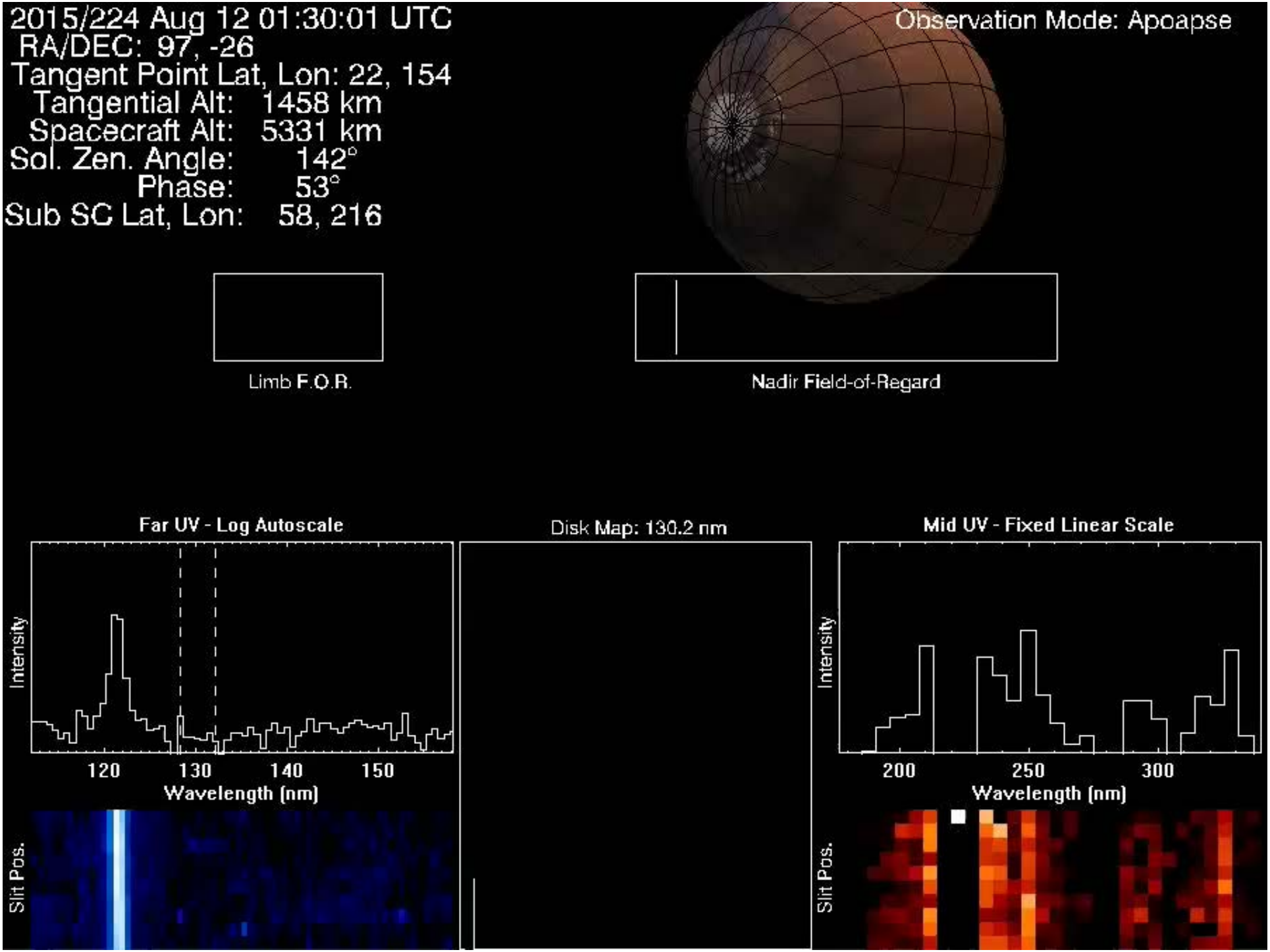
Slit Pos.


2015/224 Aug 12 01:30:01 UTC
RA/DEC: 97, -26
Tangent Point Lat, Lon: 22, 154
Tangential Alt: 1458 km
Spacecraft Alt: 5331 km
Sol. Zen. Angle: 142°
Phase: 53°
Sub SC Lat, Lon: 58, 216
Observation Mode: Apoapse
Limb F.O.R.
Nadir Field-of-Regard
Far UV - Log Autoscale
Intensity
120
130
140
150
Wavelength (nm)
Slit Pos.
Disk Map: 130.2 nm
Mid UV - Fixed Linear Scale
Intensity
200
250
300
Wavelength (nm)
Slit Pos.


2015/224 Aug 12 01:30:01 UTC
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Tangent Point Lat, Lon: 22, 154
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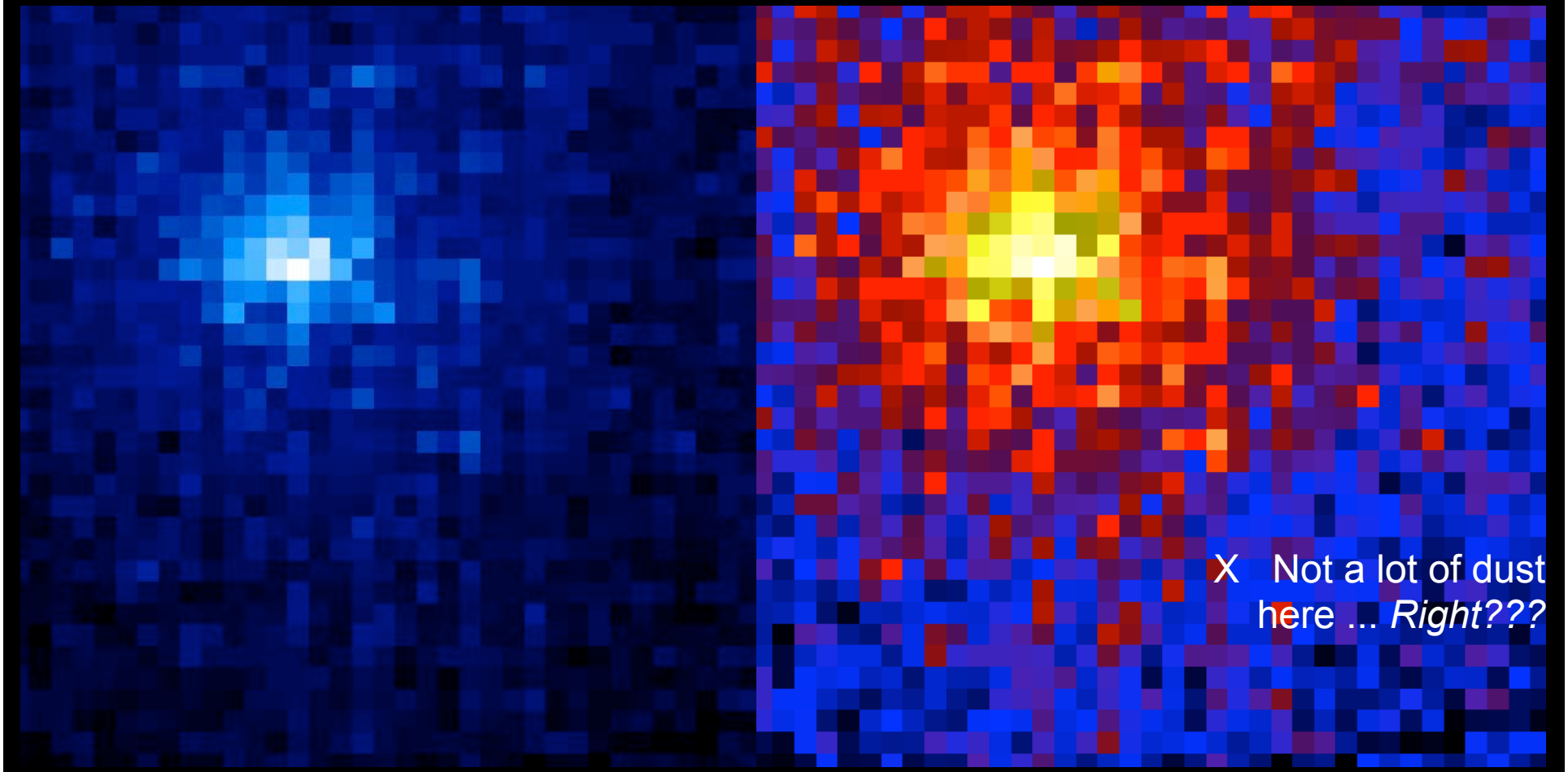
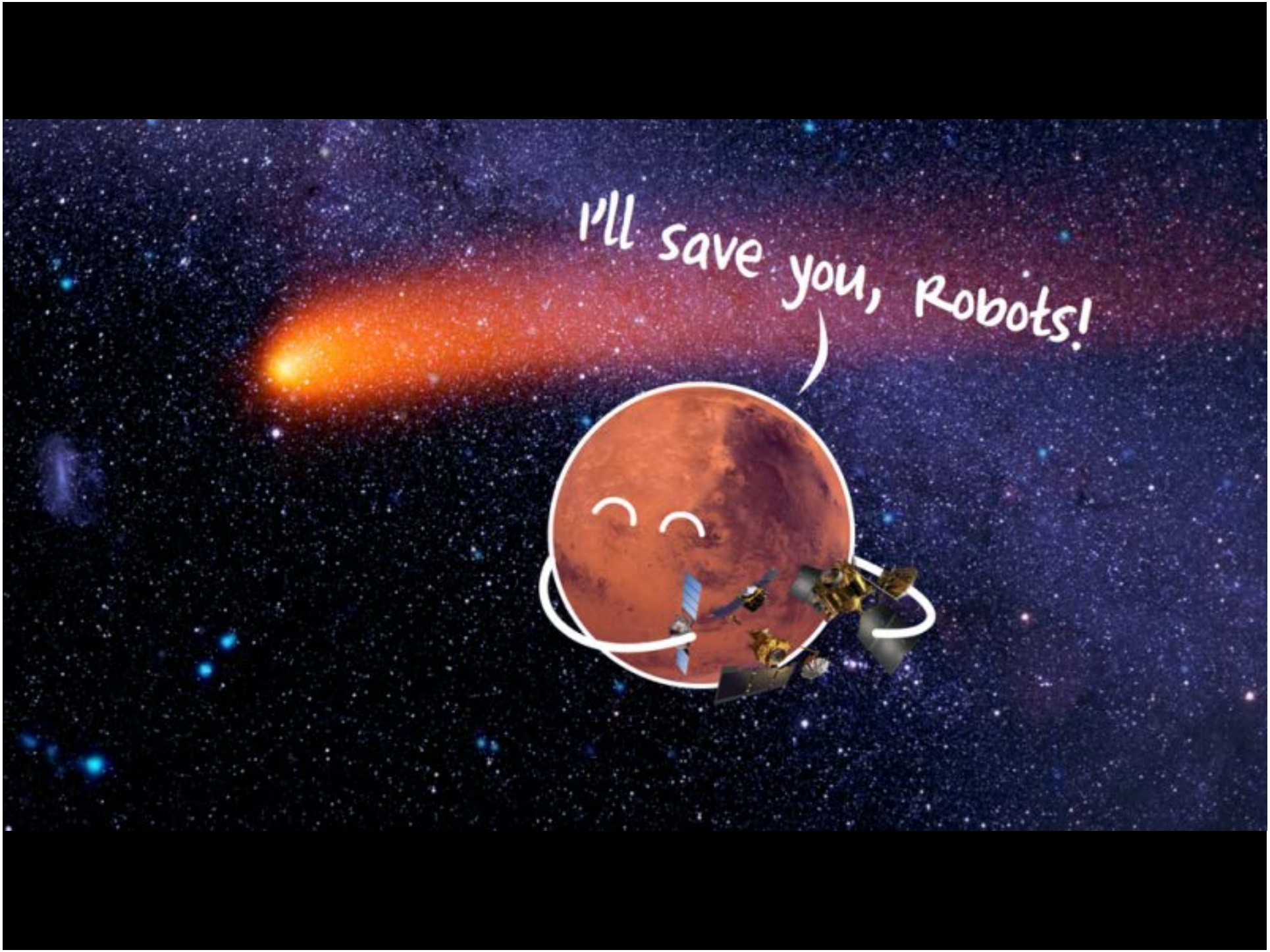
Spacecraft Alt: 5331 km
Sol. Zen. Angle: 142°
Phase: 53°
Sub SC Lat, Lon: 58, 216
Observation Mode: Apoapse
Limb F.O.R.
Nadir Field-of-Regard
Far UV - Log Autoscale
Intensity
120
130
140
150
Wavelength (nm)
Slit Pos.
Disk Map: 130.2 nm
Mid UV - Fixed Linear Scale
Intensity
200
250
300
Wavelength (nm)
Slit Pos.

Comet Siding Spring's Hydrogen Coma as seen by MAVEN's Imaging UltraViolet Spectrograph

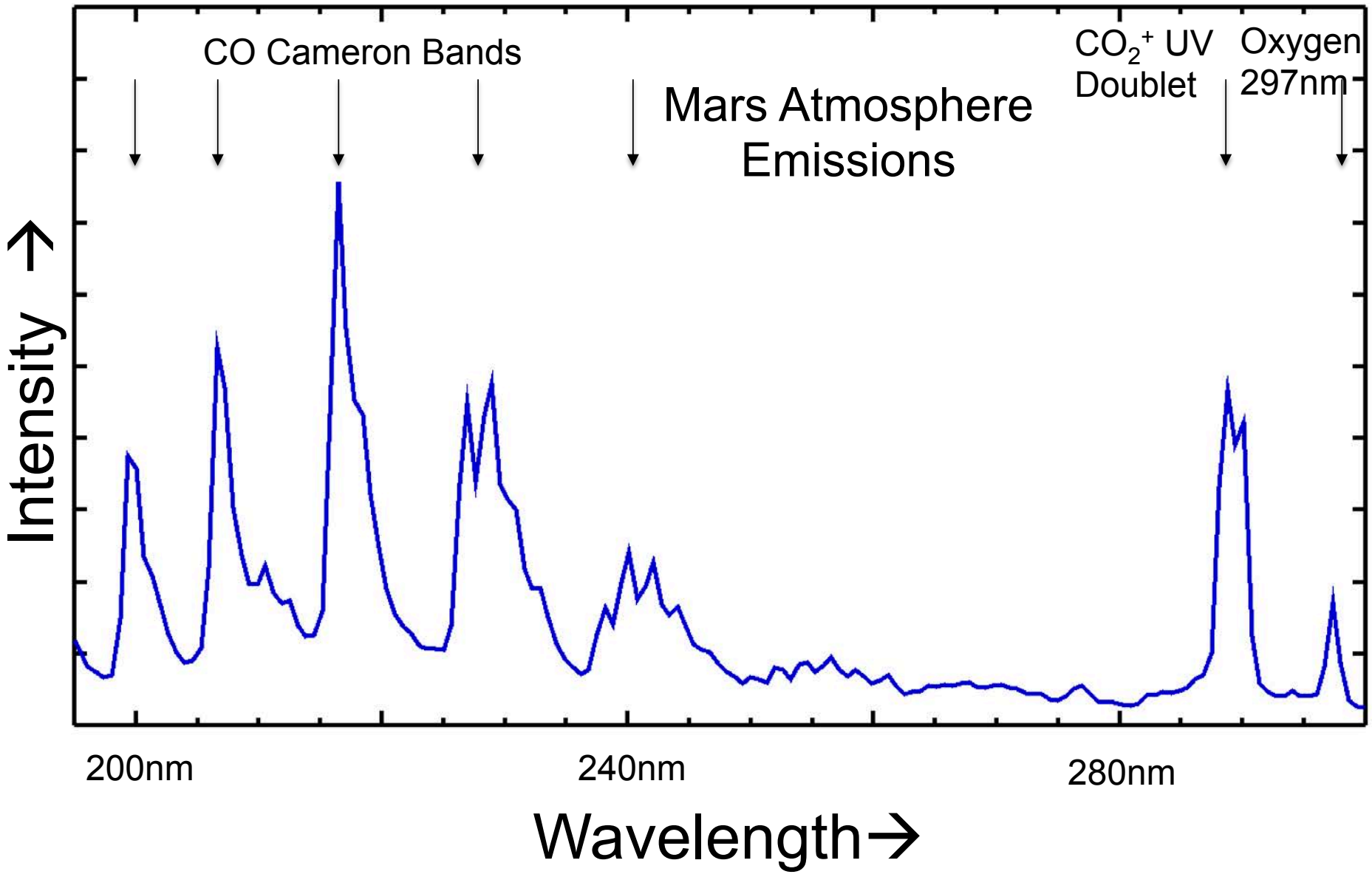


- H Lyman Alpha observations on 13 October, six days before closest approach
- Image width ~250,000 km; "miss distance" ~ 140,000 km

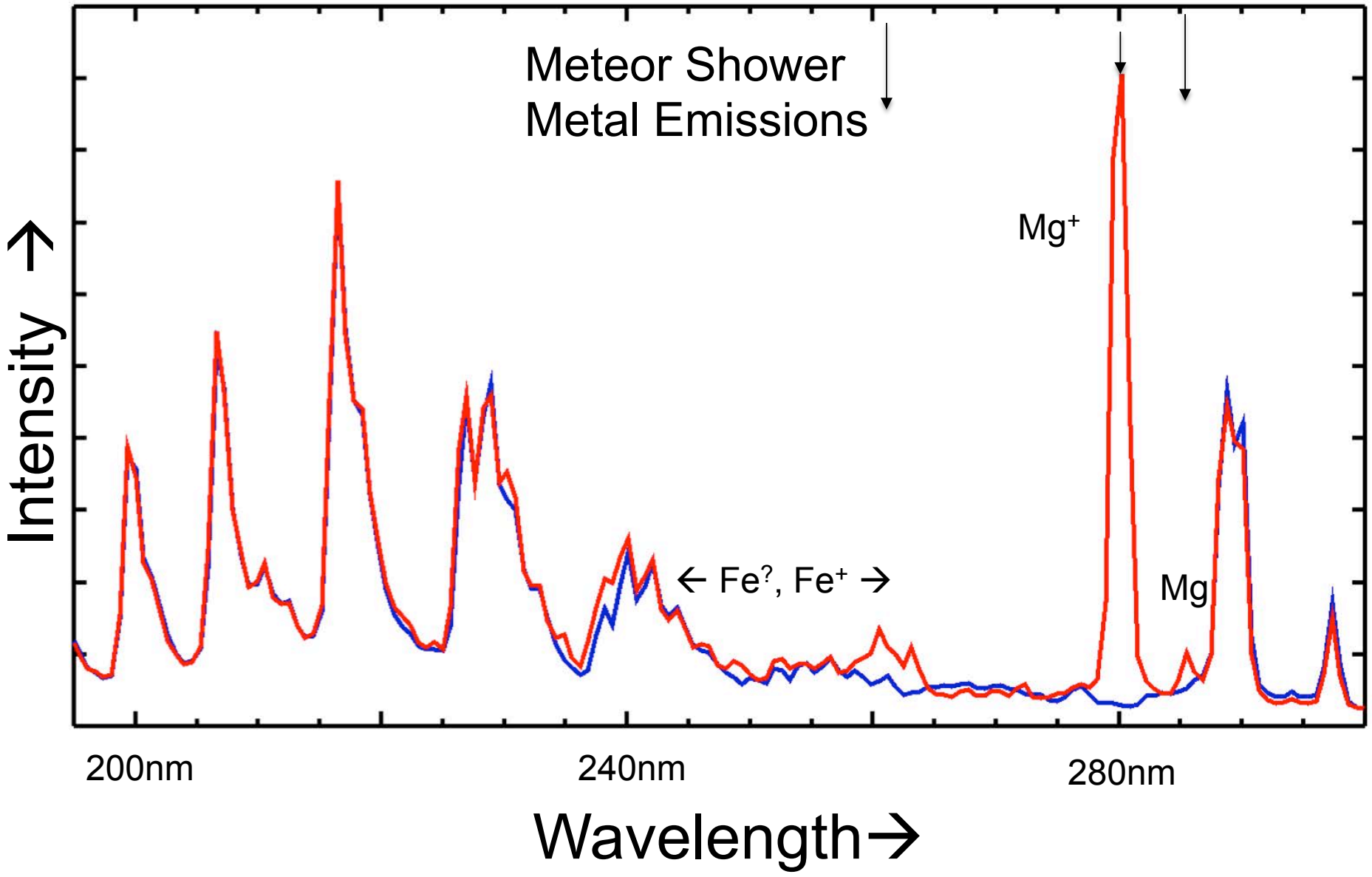
Work by Matteo Crismani

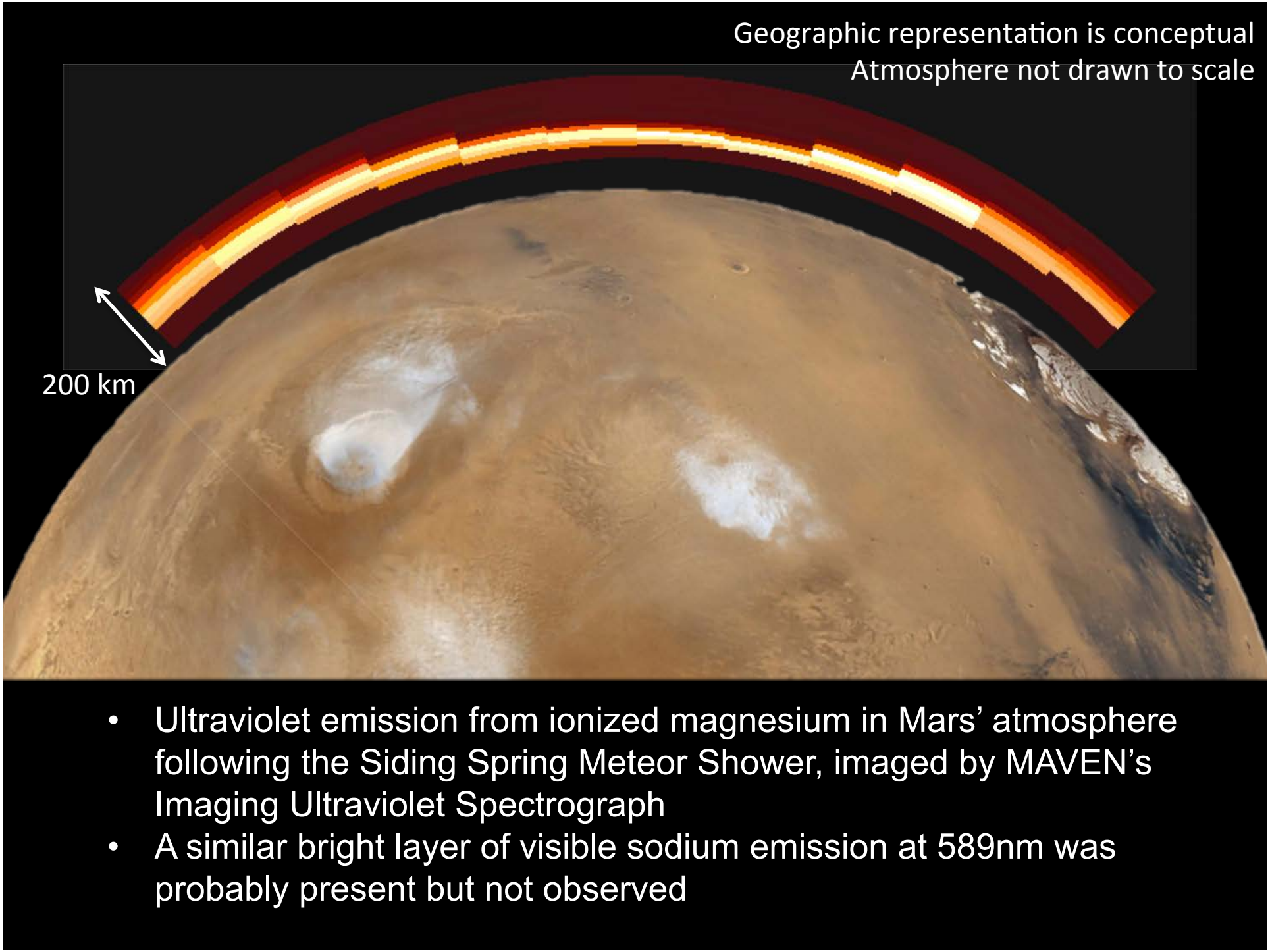

I'll save you, Robots!

MAVEN/IUVS Spectrum of Mars Atmosphere Before Comet Siding Spring



MAVEN/IUVS Spectrum of Mars Atmosphere
~6 hours after Comet Siding Spring Closest Approach





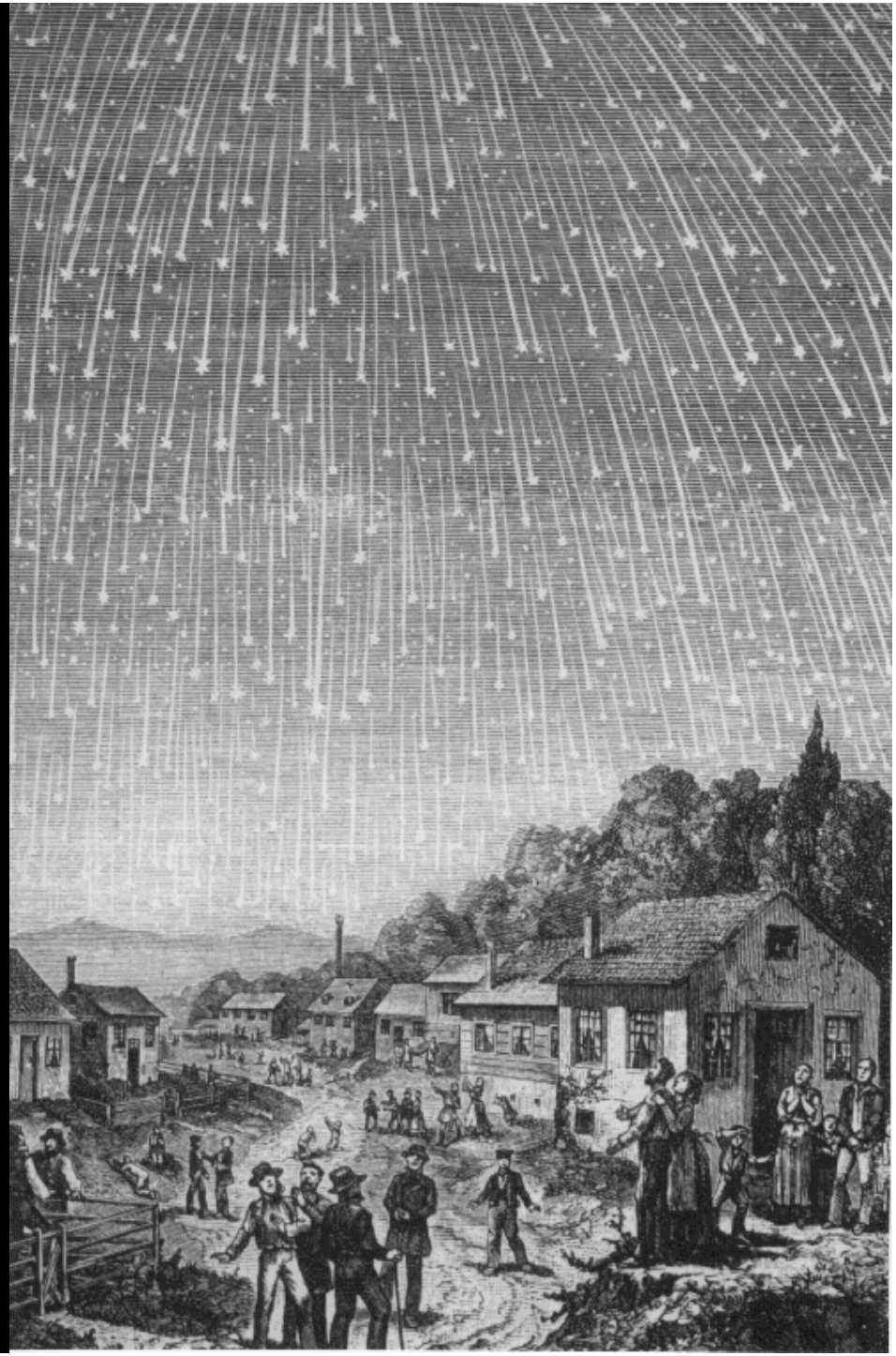
- Ultraviolet emission from ionized magnesium in Mars' atmosphere following the Siding Spring Meteor Shower, imaged by MAVEN's Imaging Ultraviolet Spectrograph
- A similar bright layer of visible sodium emission at 589nm was probably present but not observed

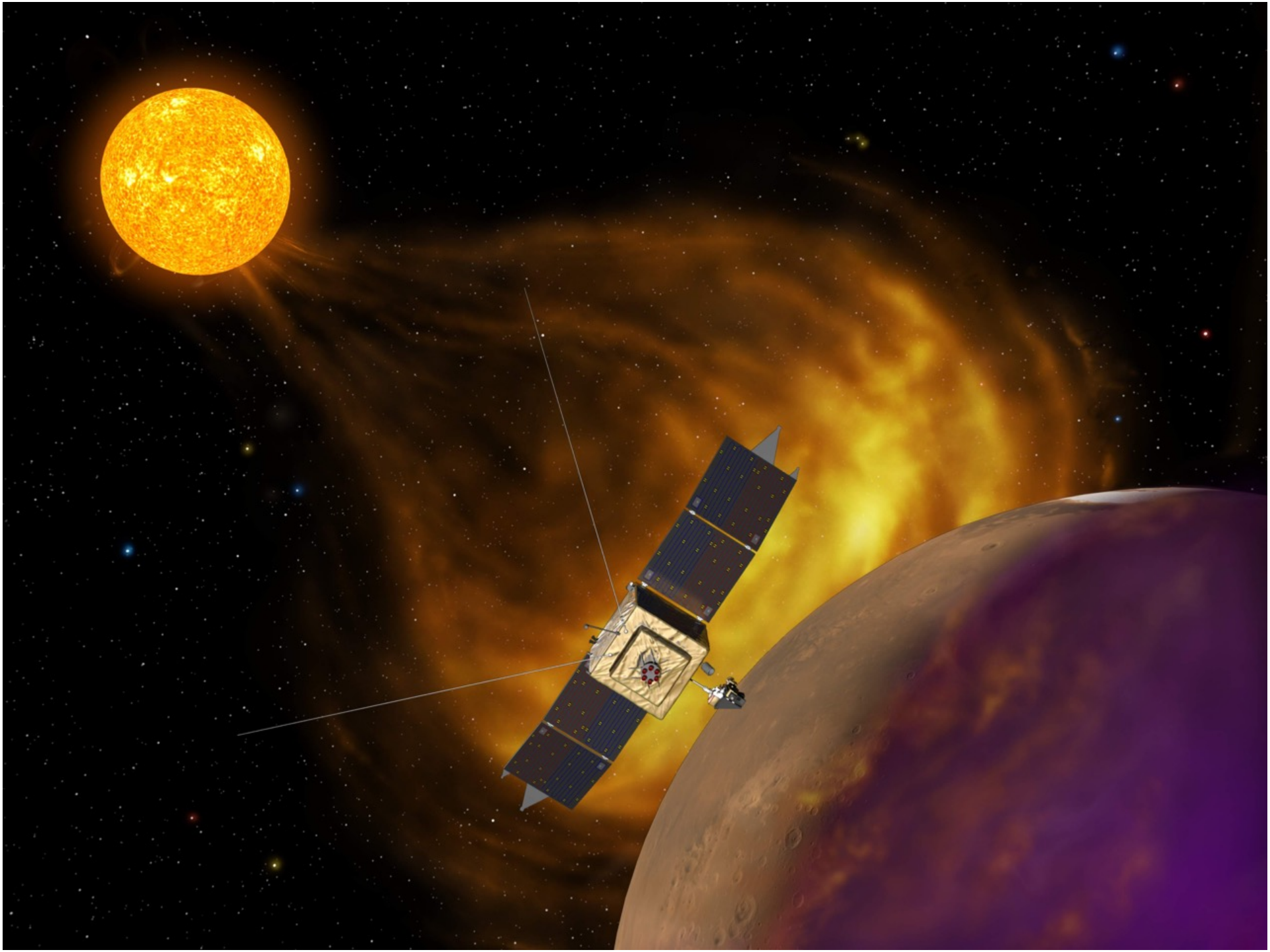
Comparing Major Meteor Showers

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

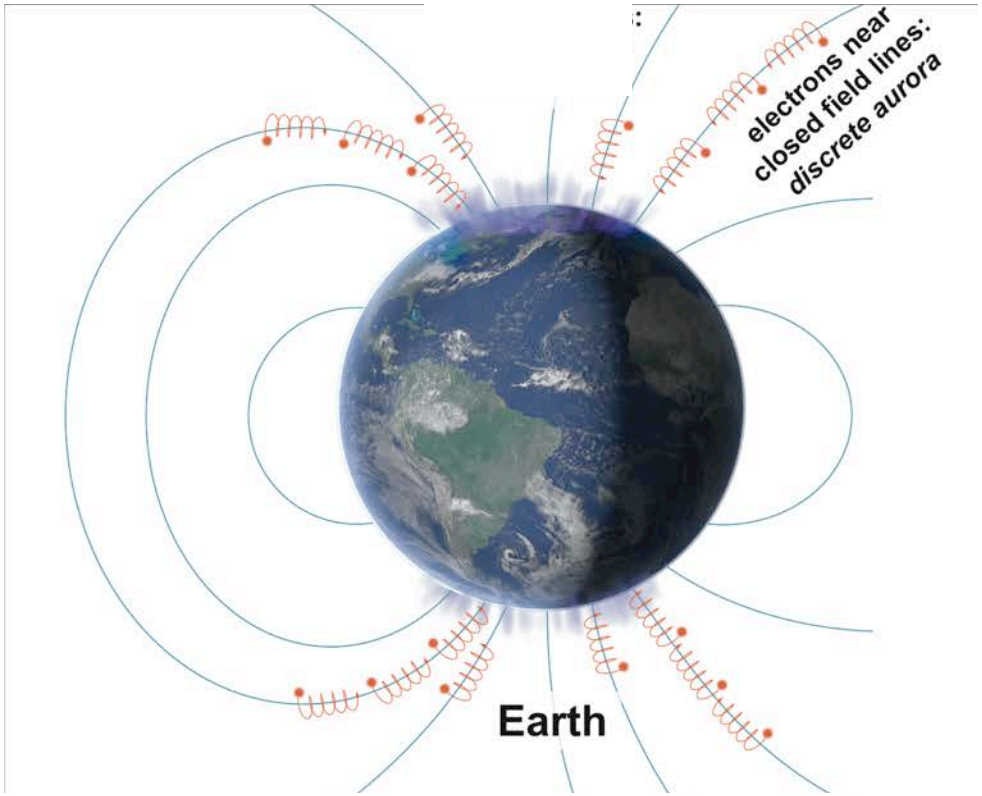
2014 (Mars)
Comet Siding Spring Meteor Shower
ZHR ~ thousands or tens of thousands meteors/hour

ZHR = Zenithal hourly rate



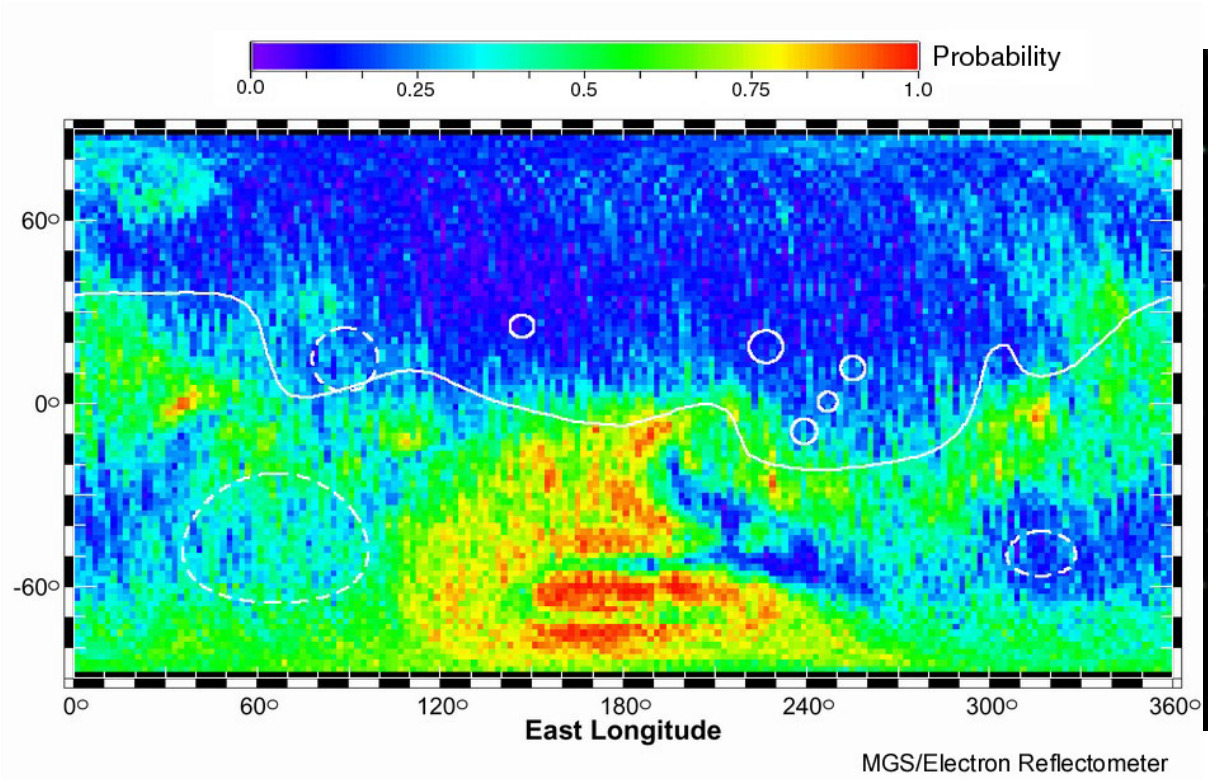


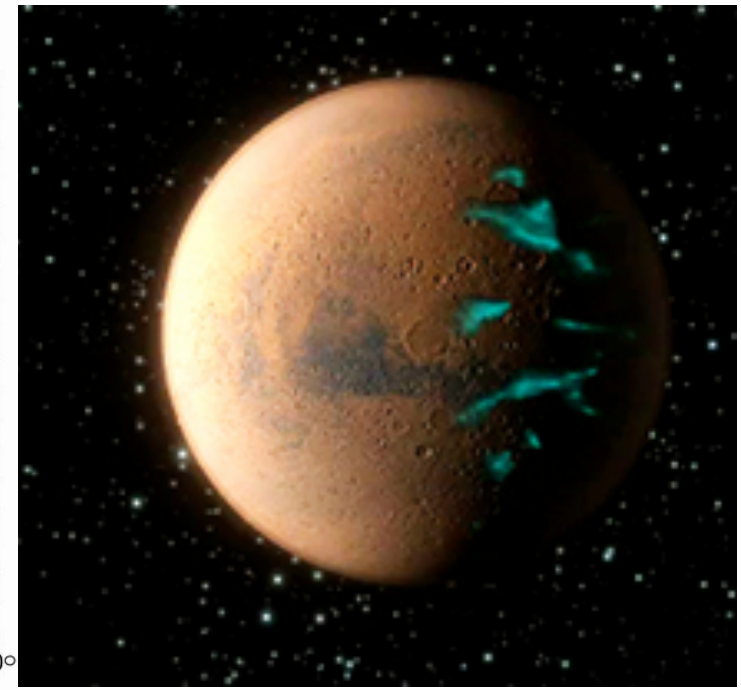
Auroral Processes at Earth



- Familiar terrestrial aurora occur near the edge of our dipole field, where interactions with the solar wind electric field can cause reconnection and energize particles within the magnetosphere

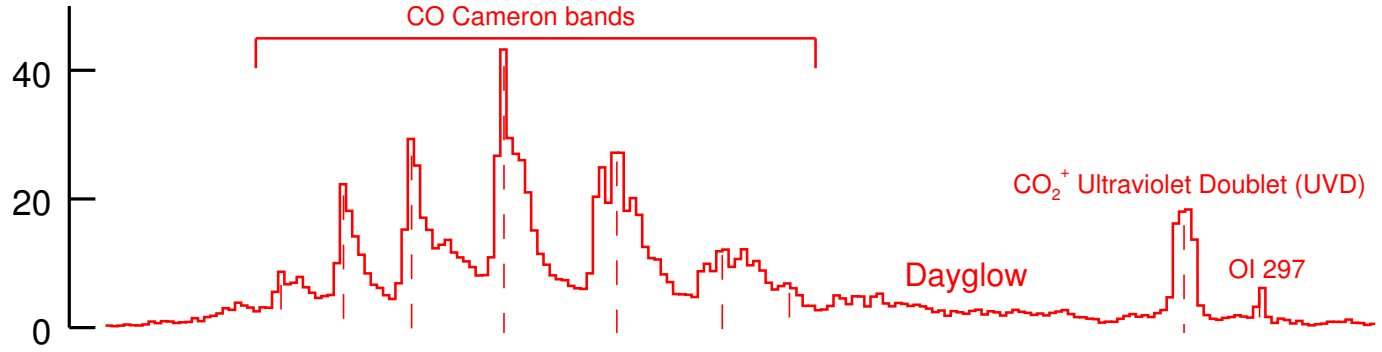
Patchy Magnetic Field, Patchy Aurora?





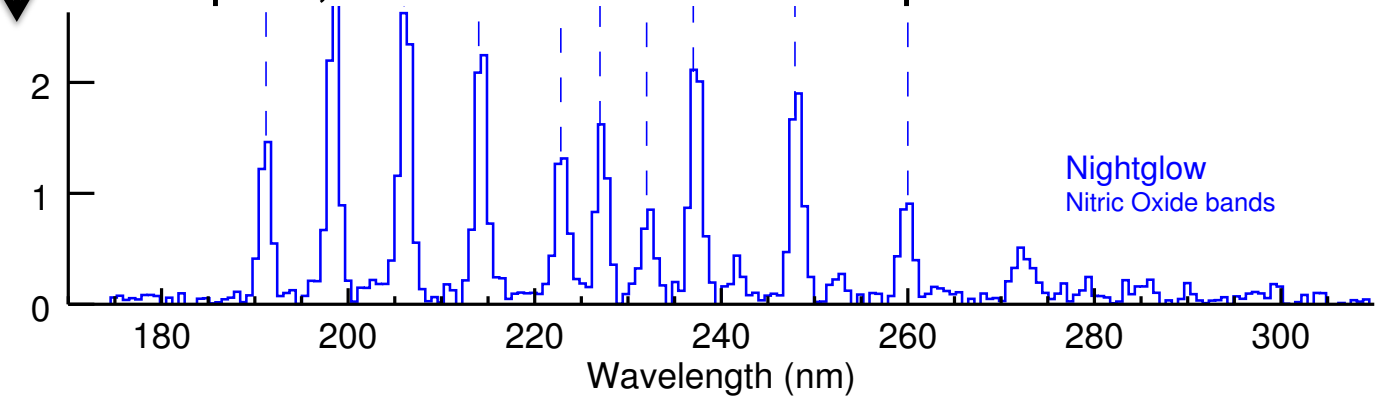
- SPICAM UV Spectrograph on ESA's Mars Express mission detected transient, small-scale *discrete* aurora
- Confirmed scenario that aurora occur at the edges of a planet's magnetic field

IUVS Discovery of Diffuse Aurora

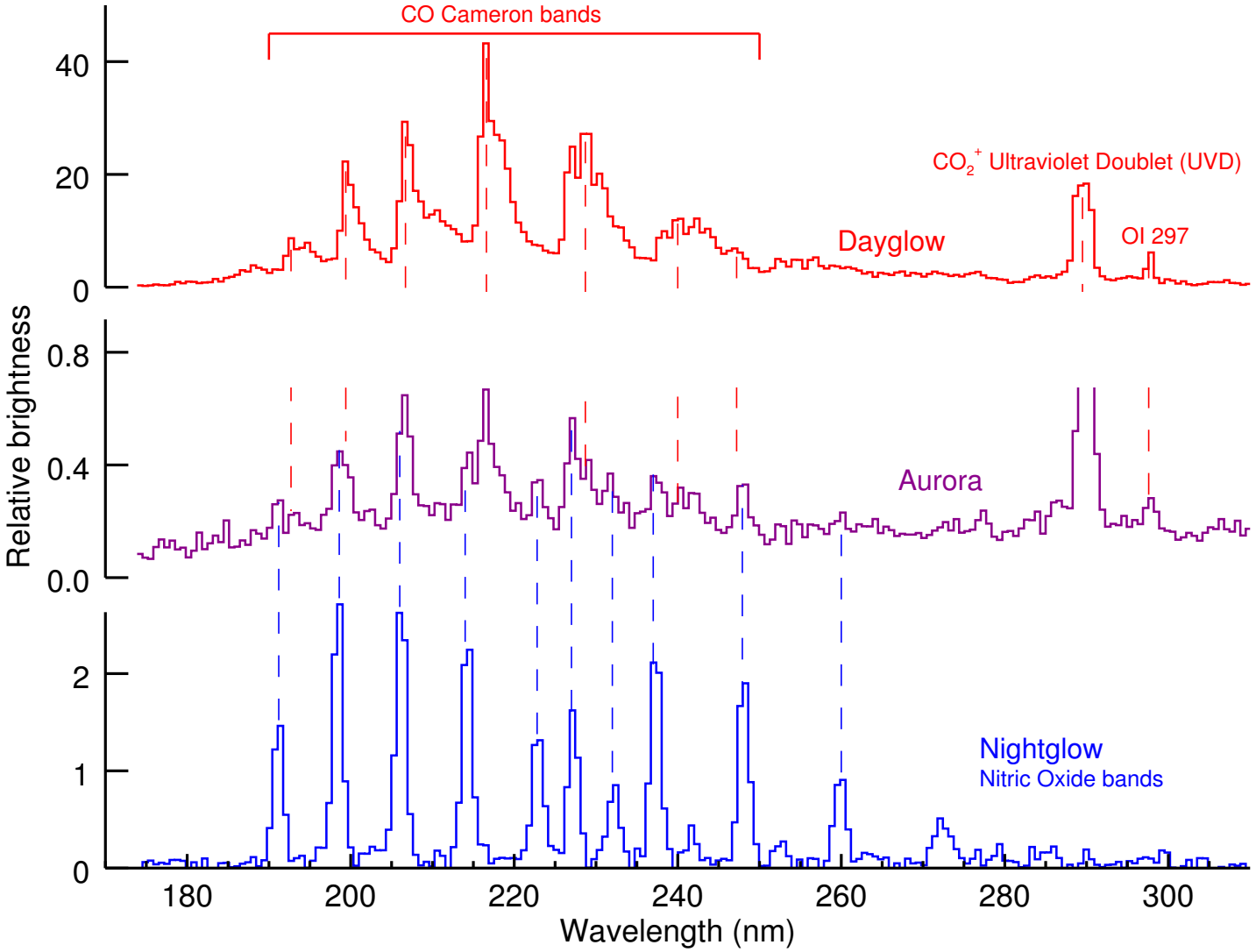


↑ Dayglow emissions caused by EUV photons & photo-electrons; can learn about composition & energy deposition

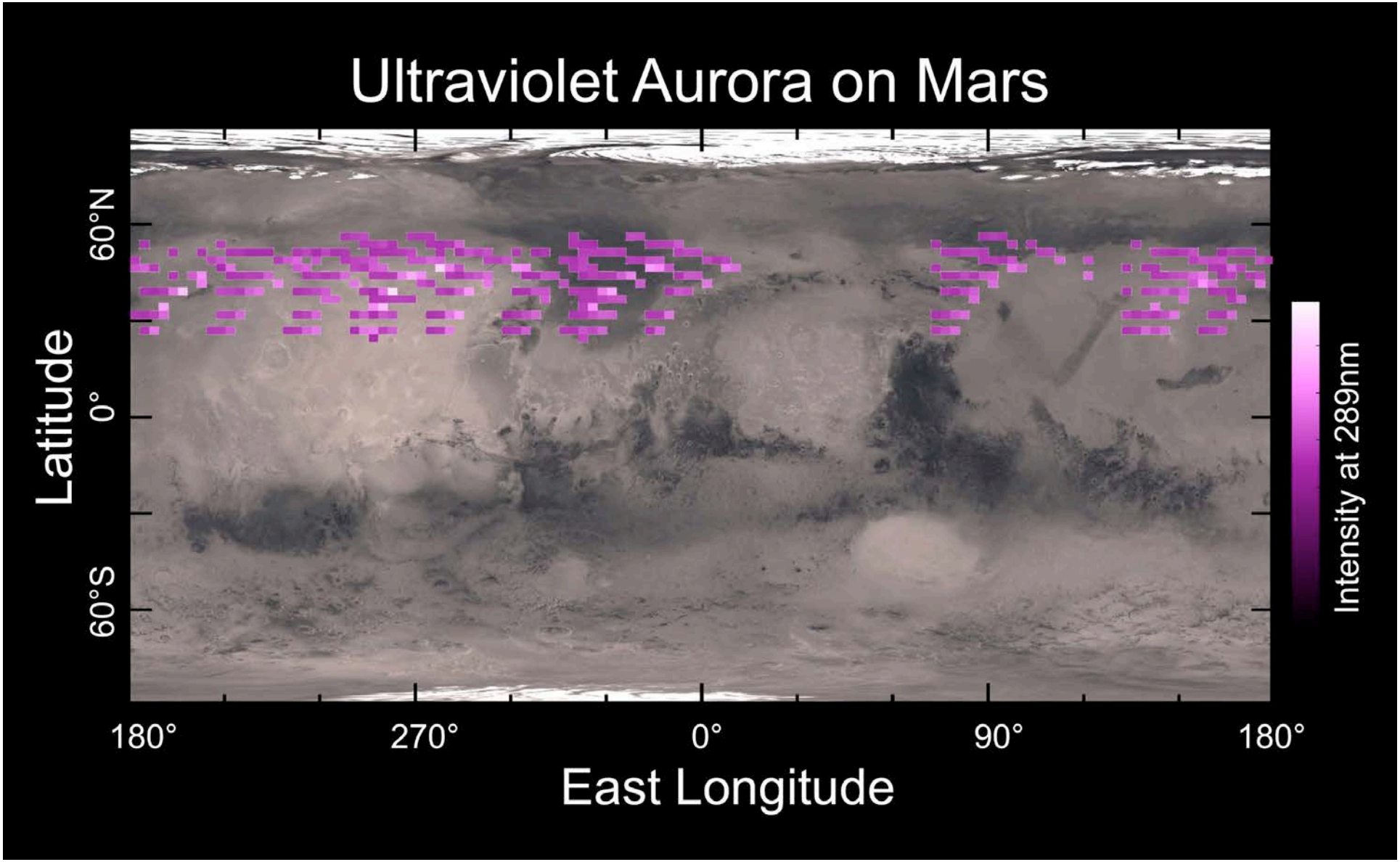
↓ Nightglow emissions caused by N + O recombination near winter pole; can learn about atmospheric circulation



IUVS Discovery of Diffuse Aurora



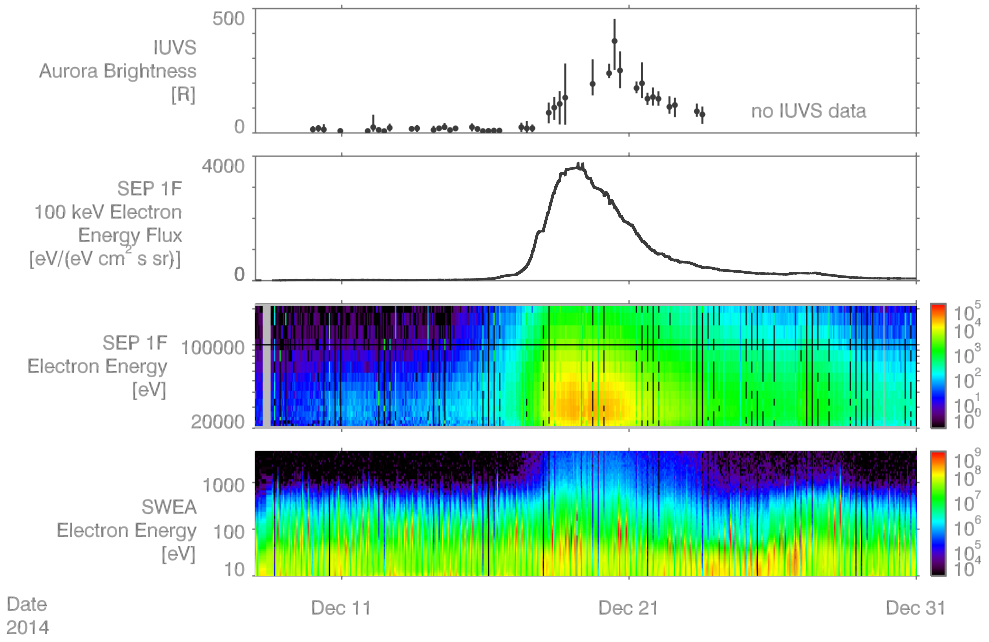
- "Christmas lights" aurora observed for five days on 18-23 December 2014
- Nightside emission at same wavelengths as dayglow; characteristic of aurora in general and of those observed by *Mars Express*

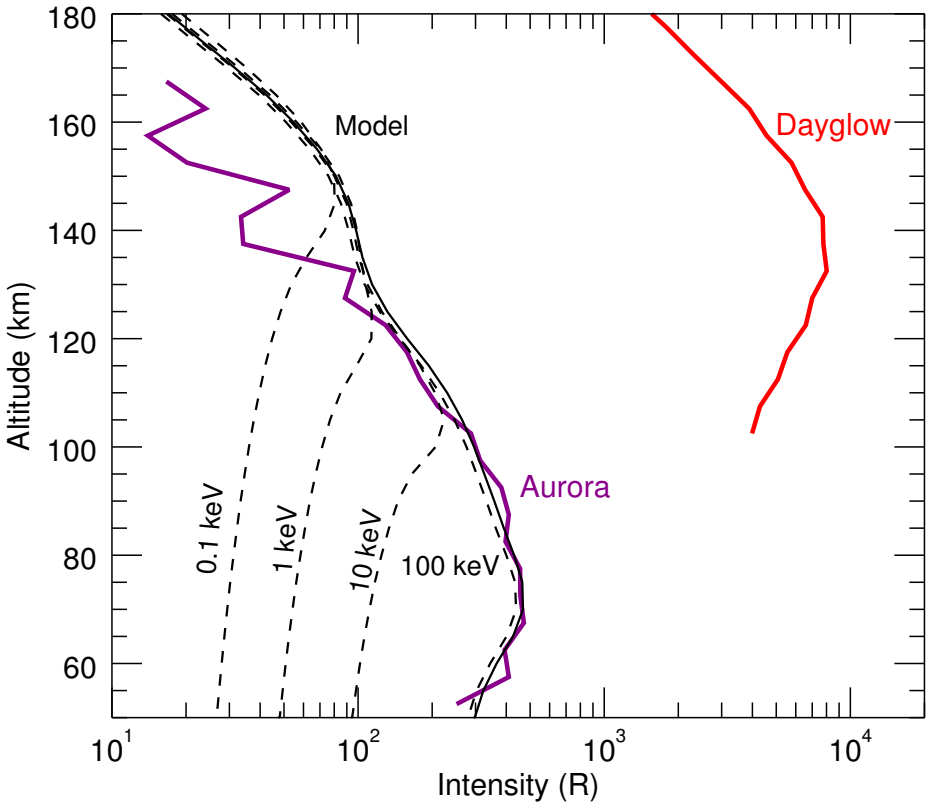


Points show geographic distribution, but data obtained along same latitude/local time path

Work by Arnaud Stiepen and Sonal Jain

Aurora – captured in light and particles

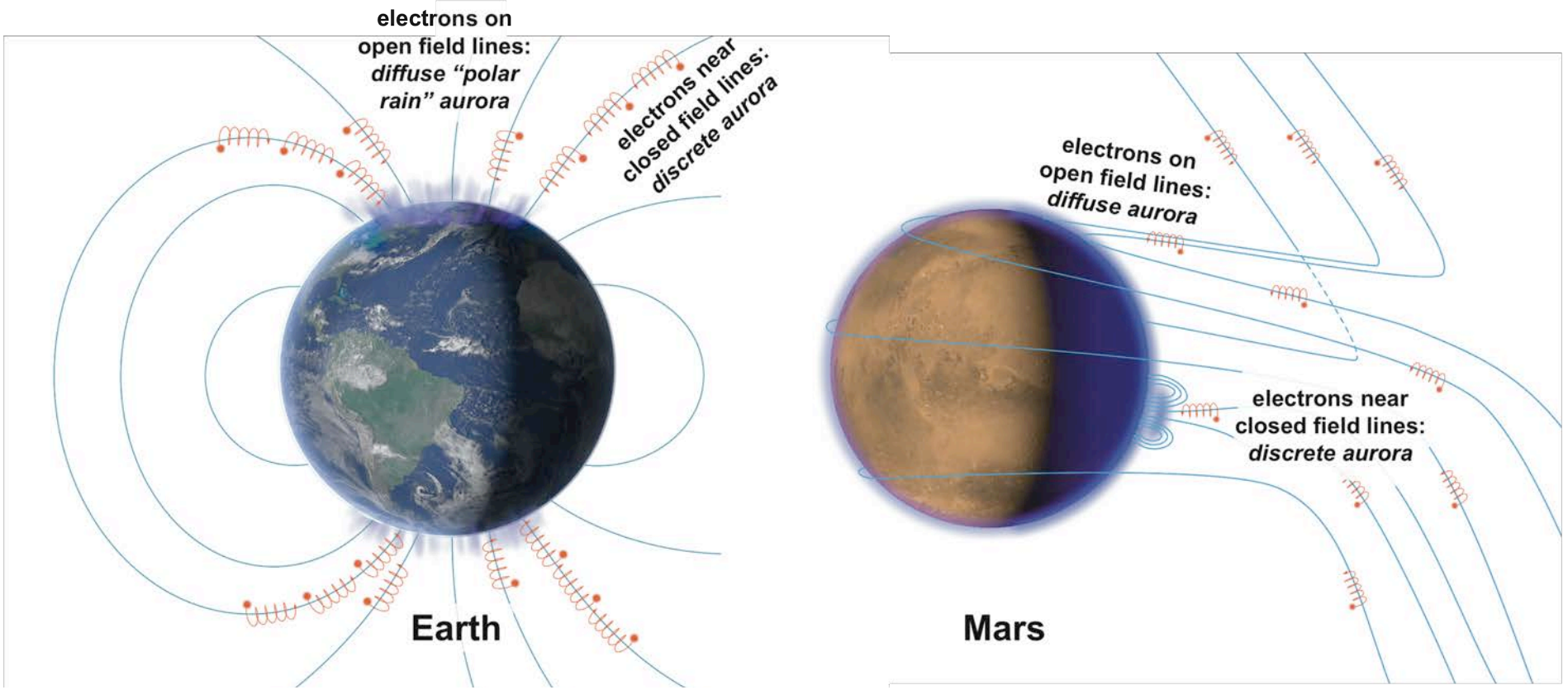




- Solar energetic-electron storm is the likely driver – arrived at Mars at the same time, seen by MAVEN's particle instruments
- Similar correlated events seen >4 times

- Occurs deep in upper atmosphere; requires extremely energetic electron flux (100 keV) as observed by MAVEN's particle instruments

Auroral Processes at Earth and Mars



- Mars *discrete* aurora are caused by electrons moving on or near closed field lines associated with crustal fields in the south
- Mars *diffuse* aurora must be a new process, with energetic solar electrons directly penetrating the atmosphere

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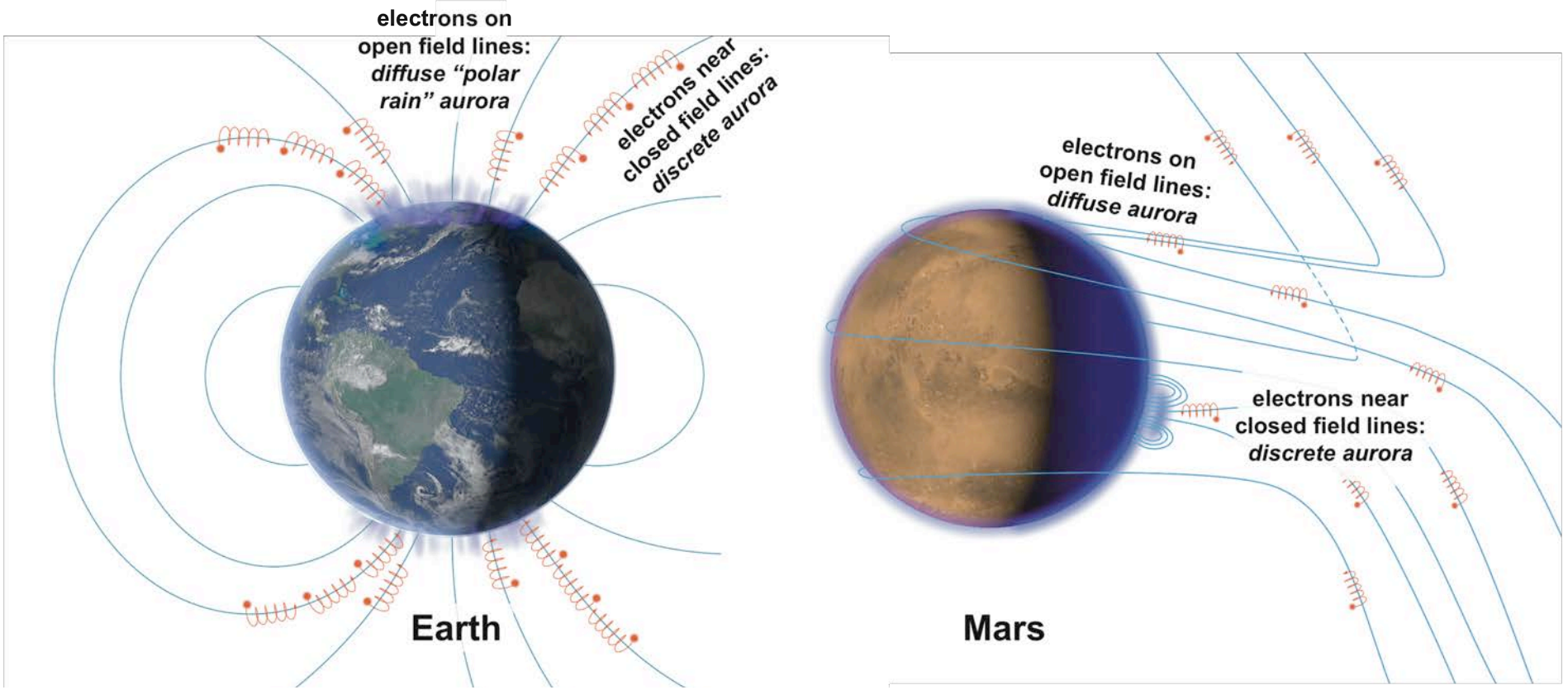
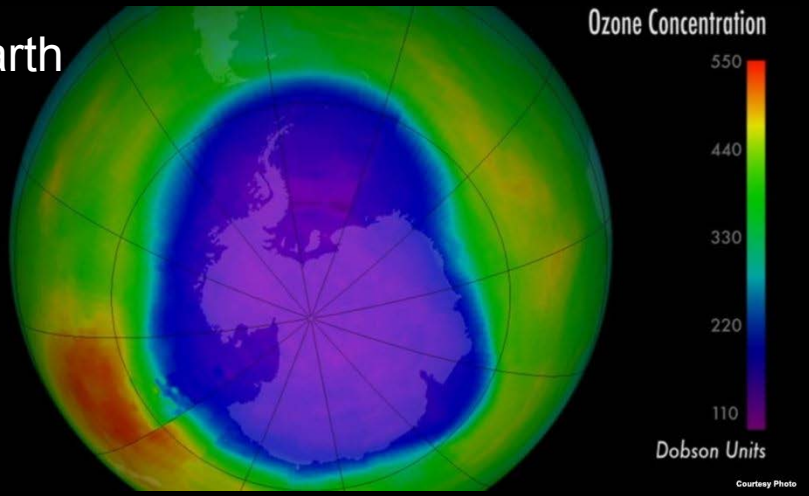


- IUVS observations provide the most direct proof of the penetration of solar energetic particles deep in Mars' atmosphere
- For the first time, we can test whether these processes have a measureable effect on escape

Ozone on Earth and Mars

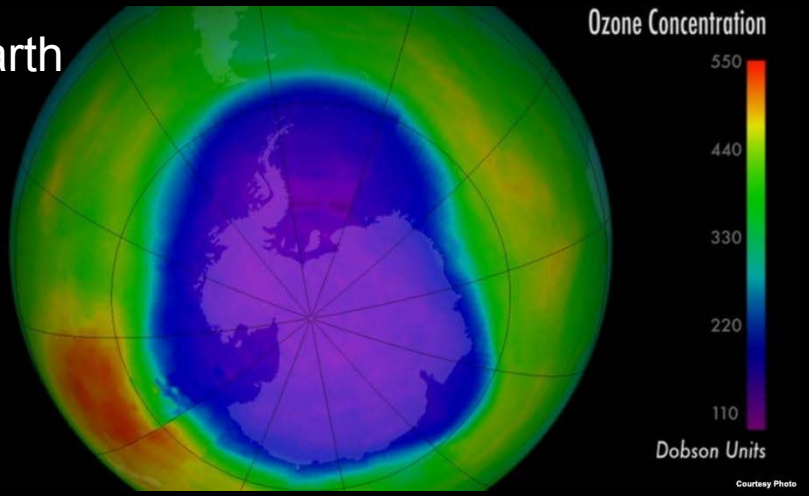
Earth



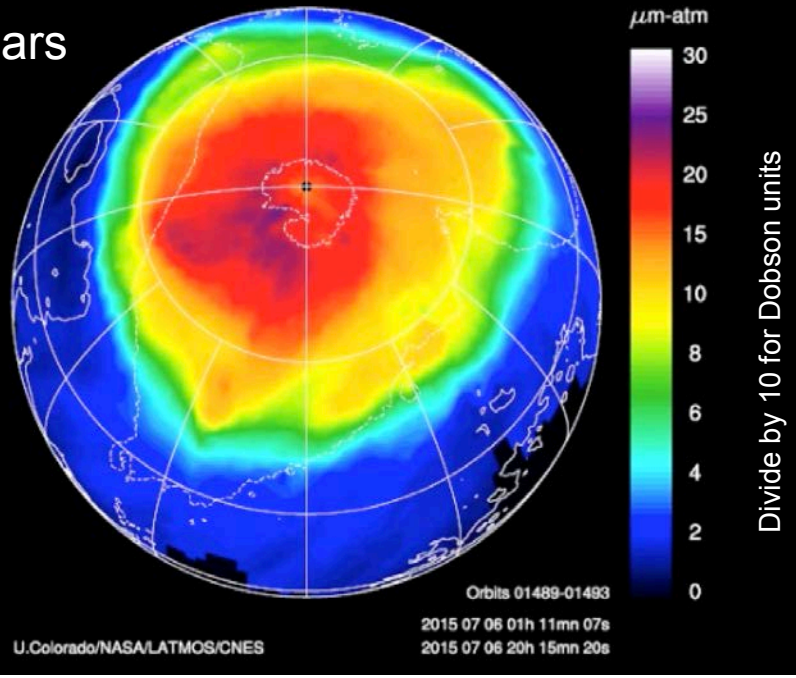
- Earth has “ozone holes” at the poles caused by reactions catalyzed by anthorpogenic chemicals (such as CFC’s) at low temperatures
- Polar vortices create boundaries in ozone distribution

Ozone on Earth and Mars

Earth

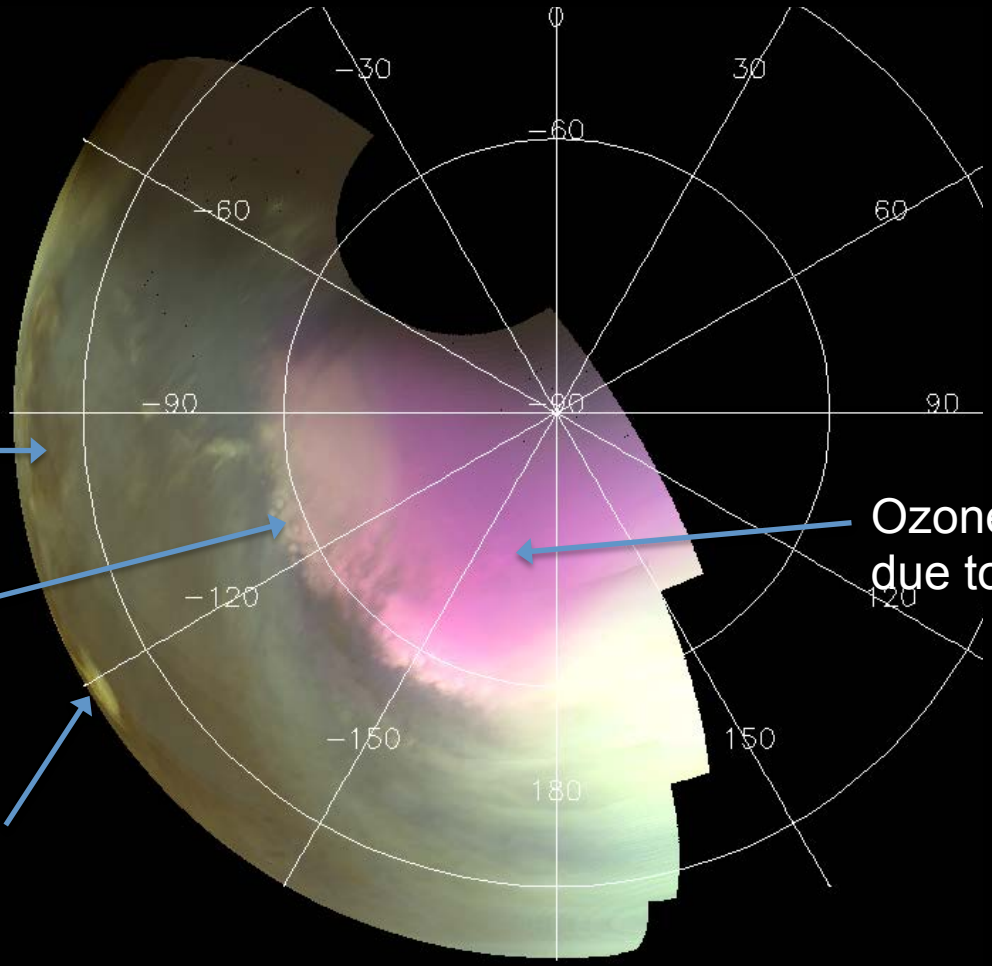


Mars



- Earth has “ozone holes” at the poles caused by reactions catalyzed by anthorpogenic chemicals (such as CFC’s) at low temperatures
- Polar vortices create boundaries in ozone distribution
- Mars has “ozone poles” because water vapor is depleted there, so its dissociation fragments cannot scavenge ozone
- Mars ozone has been extensively studied by the MEX/SPICAM, MRO/MARCI, HST and others

Mars Ozone as seen by MAVEN/IUVS



surface

CO_2 ice cap

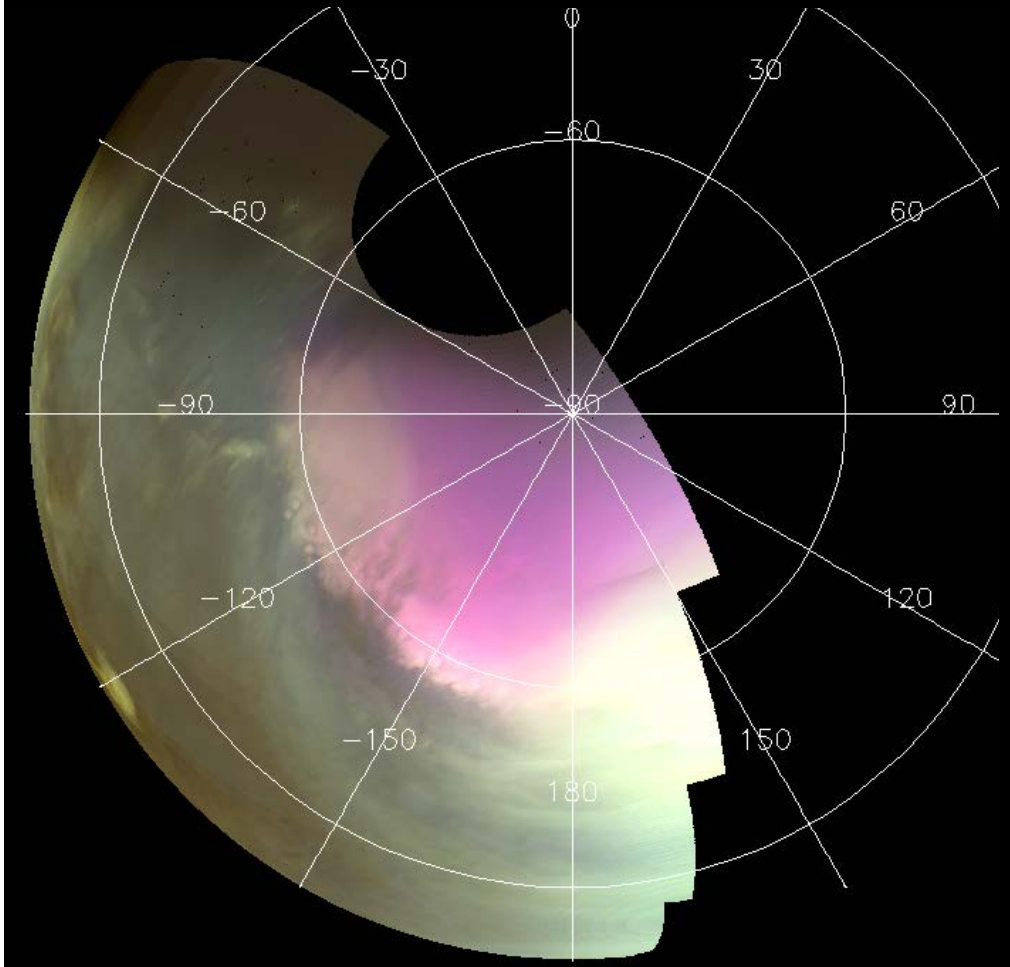
clouds

Ozone (appears magenta due to absorption)

- IUVS UV images have been polar-projected and scaled up to visible wavelengths to show what we would see with “ultraviolet eyes”
- These observations were taken in southern spring as the ice cap is retreating

with Franck Lefevre, Franck Montmessin, Justin Deighan

Mars Ozone as seen by MAVEN/IUVS



Ozone: Results

- Buildup around Mars south pole confirms global circulation models: ozone accumulates inside the polar vortex where water vapor is low
- IUVS images provide new information on the polar vortex shape and evolution; ozone breaks up sooner in spring than expected.
- Modeling and analysis will further our understanding of ozone and water vapor - a key factor in hydrogen and oxygen escape

Nightglow on Earth: [OI] 630 nm

Nightglow on Earth & Mars
(Chemo-luminescence)

- Common planetary phenomenon caused by atomic or molecular recombination
- Reactants created on dayside through ionization or dissociation
- Product left an excited state which then radiates

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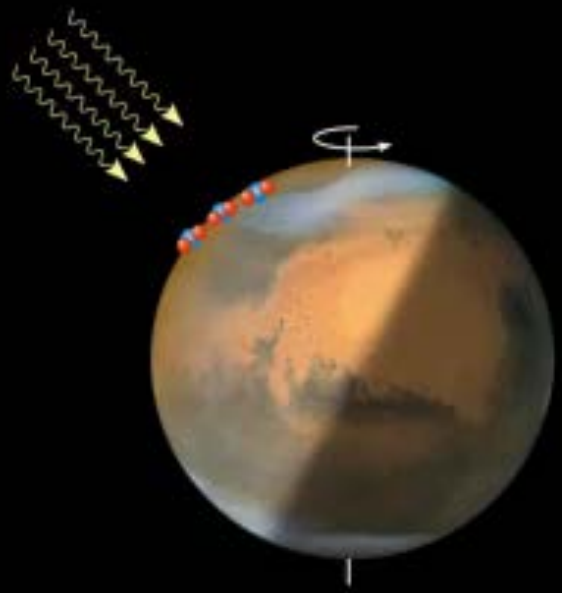
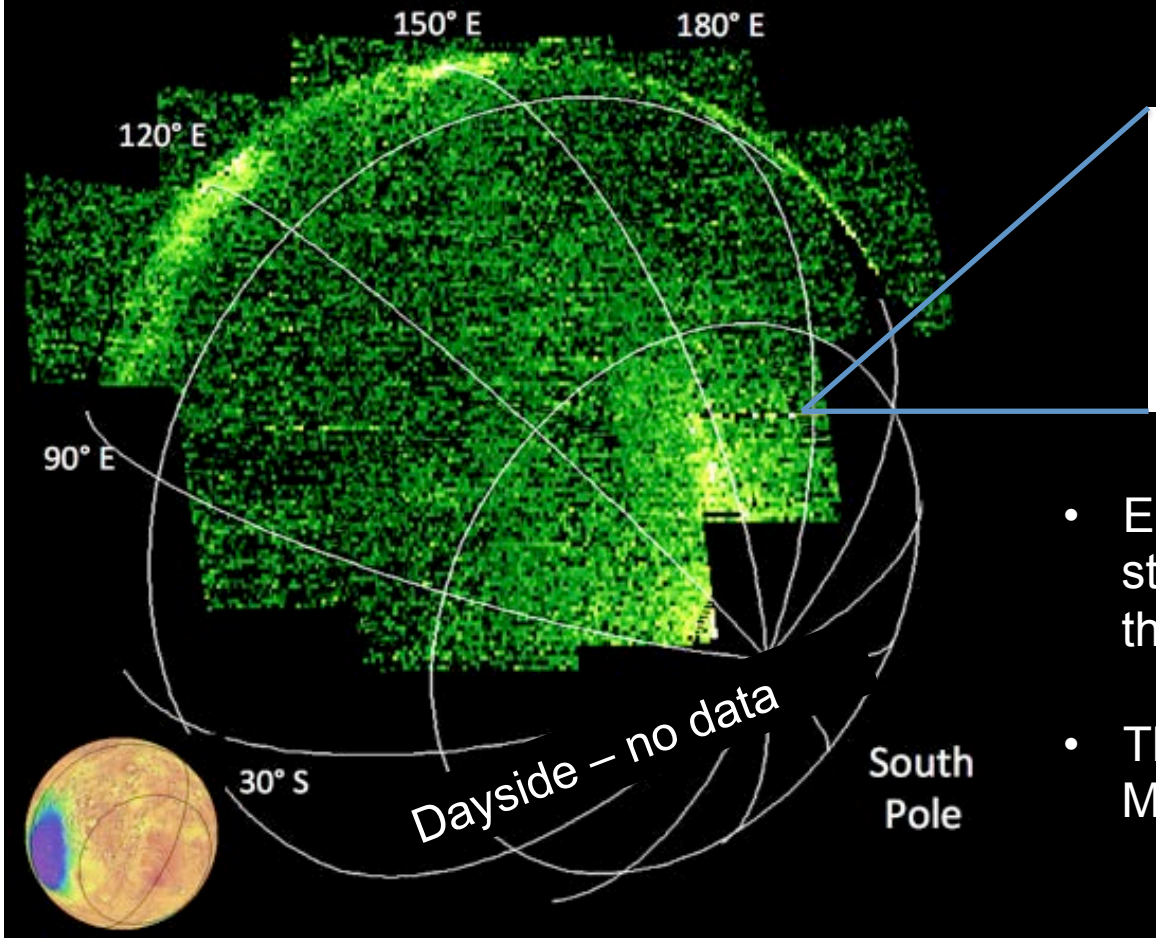
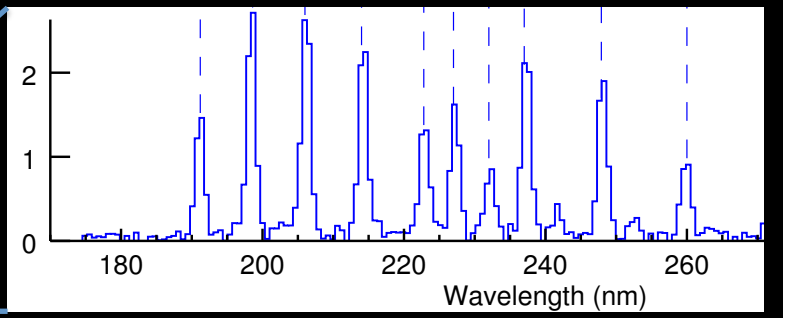
- Mars nightglow has been extensively studied by SPICAM and OMEGA on Mars Express



Animation credit: ESA/Mars Express

Mars Nitric Oxide Nightglow as seen by MAVEN/IUVS

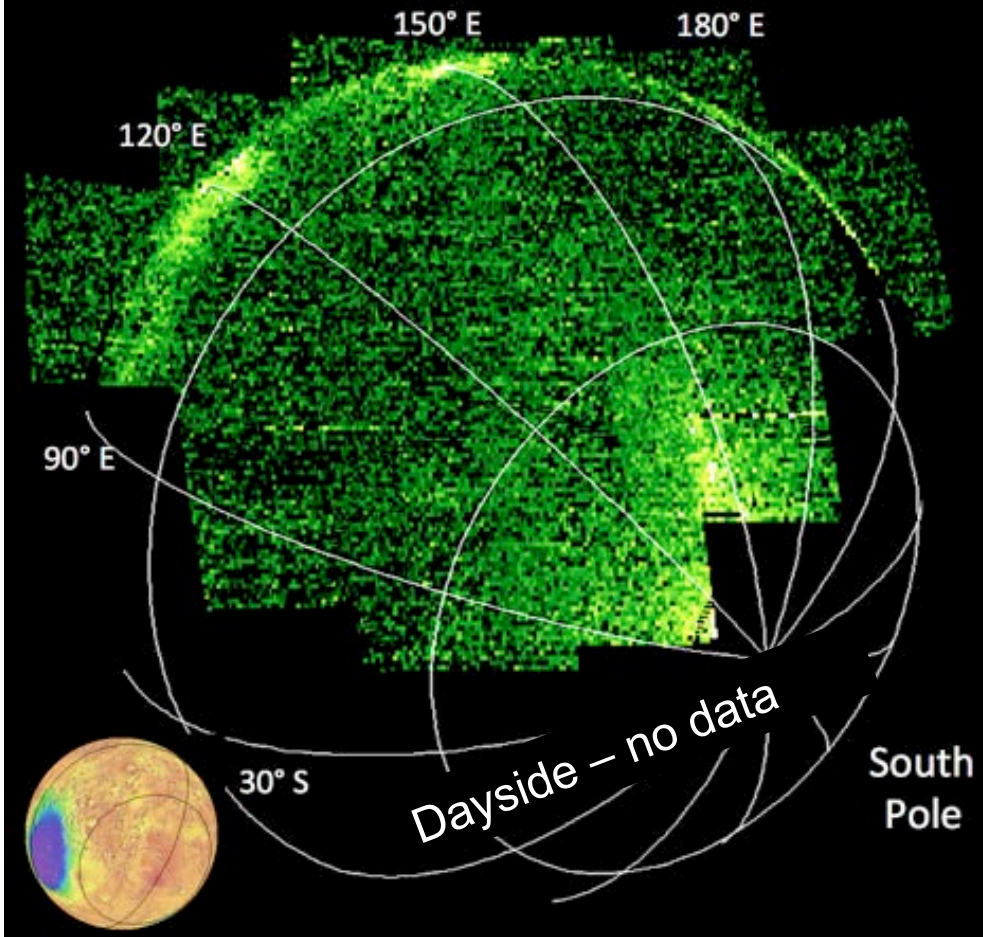




- Each pixel's brightness shows the strength of spectral signal matching the nitric oxide (NO) spectrum
- These are the first global images of Mars nightglow

with Sonal Jain, Arnaud Stiepen, Justin Deighan, Zac Milby

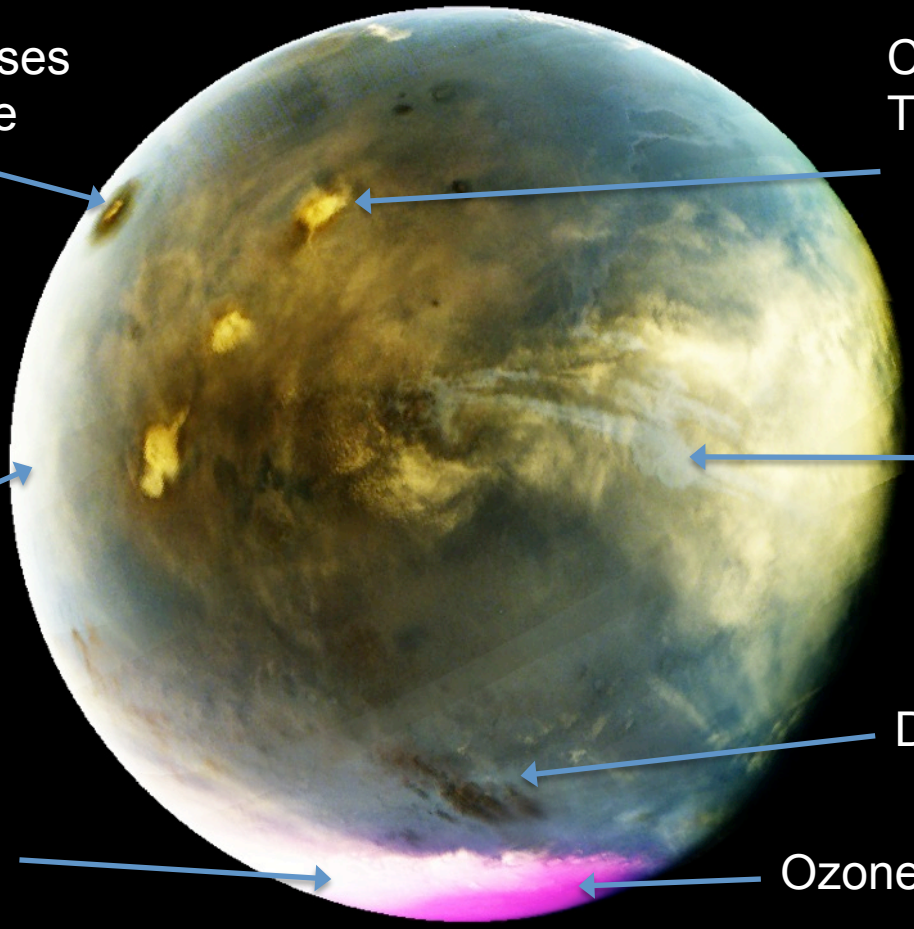
Mars Nitric Oxide Nightglow as seen by MAVEN/IUVS



Nightglow: Results

- The brightening near Mars south pole confirms global circulation models: air flows as expected from the summer pole to the winter pole
- Splotches and streaks elsewhere are surprising, and indicate irregularities in global circulation
- Modeling and analysis are underway to explain these features and their strong variation with time

Mars Clouds as seen by MAVEN/IUVS



Olympus Mons rises above most of the scattering atmosphere

Clouds topping Tharsis volcanoes

Valles Marineris obscured by scattering from atmosphere

Scattering from atmosphere at limb

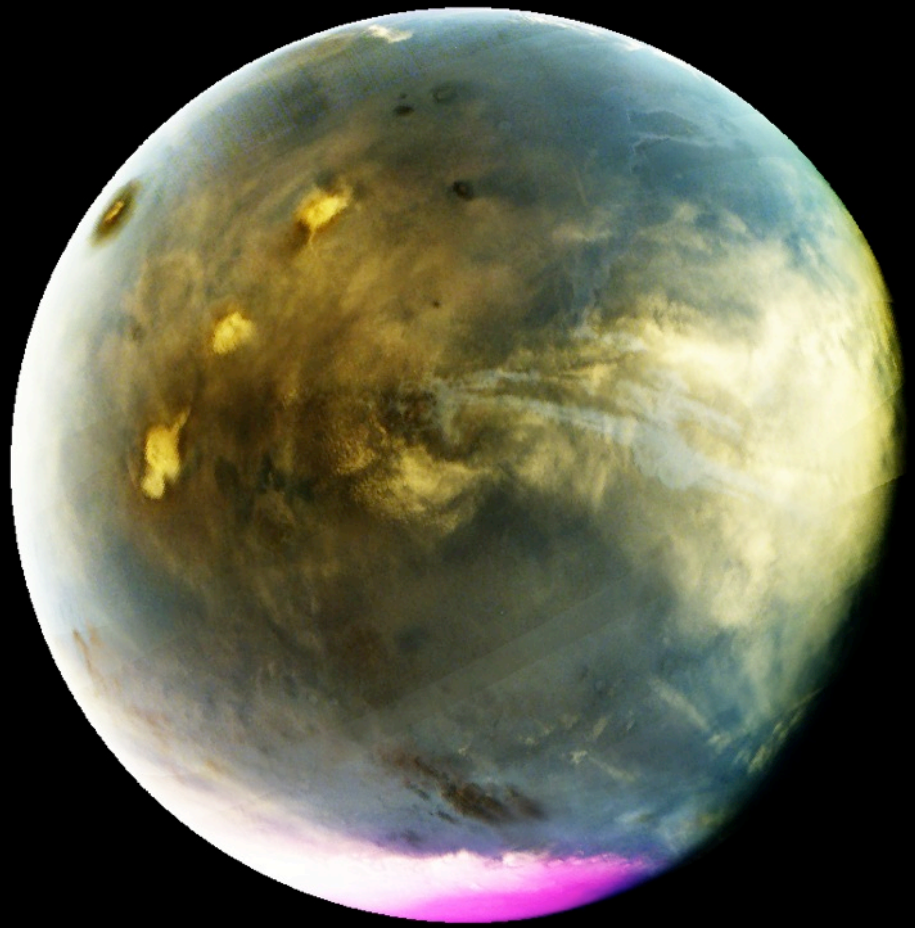
Dust storm (brown)

Clouds and CO_2 ice cap

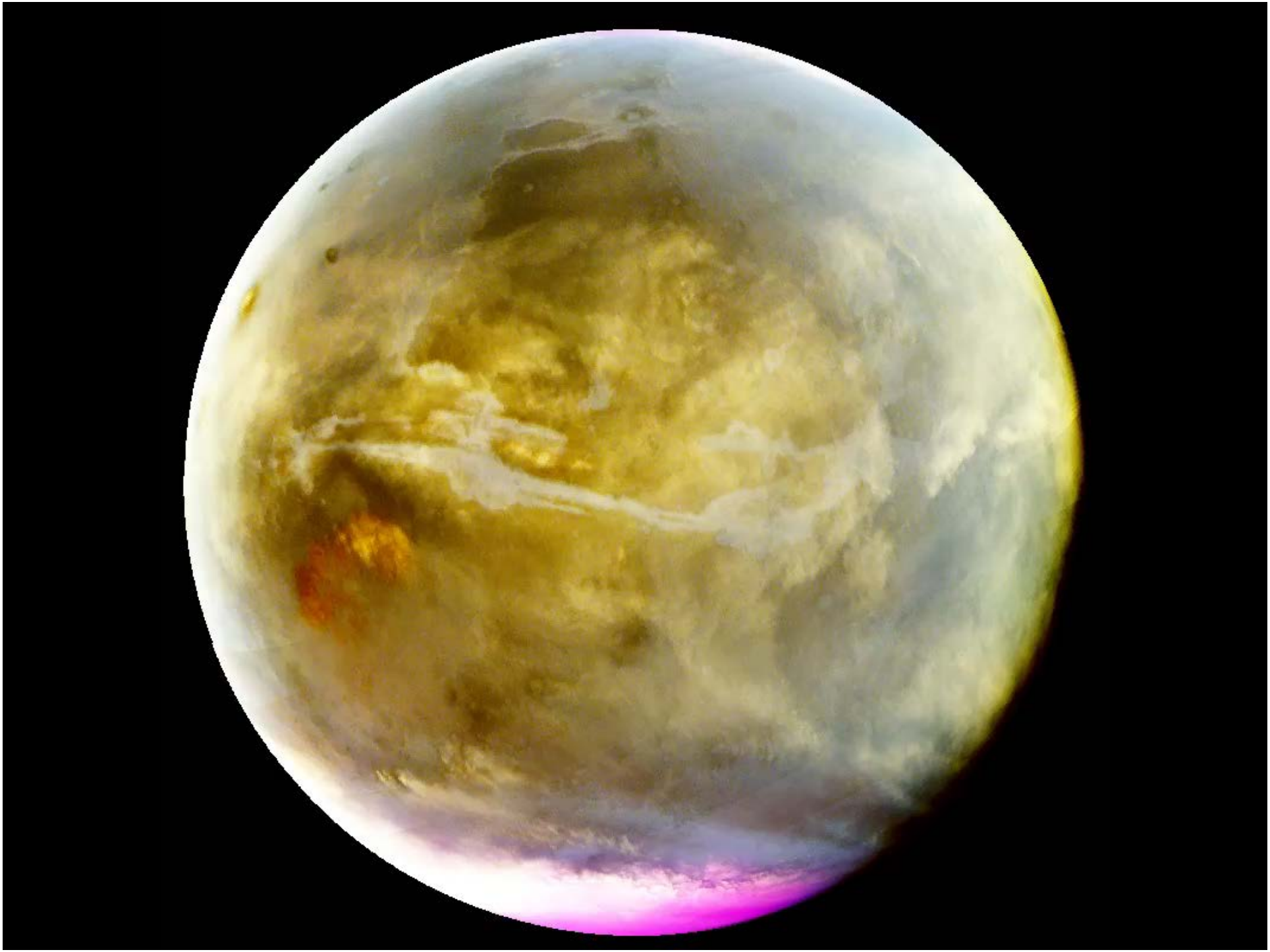
Ozone (magenta)

With Justin Deighan, Mike Wolff, Alyssa Derks

Mars Clouds as seen by MAVEN/IUVS



- Clouds composed of water ice crystals are common in the Mars atmosphere
- Clouds trace circulation patterns, affect energy balance, and provide insight on the water vapor inventory
- Mars clouds have been extensively studied by groundbased telescopes and every Mars mission
- MAVEN's unique orbit and IUVS instrumentation combine to provide a new perspective on cloud formation



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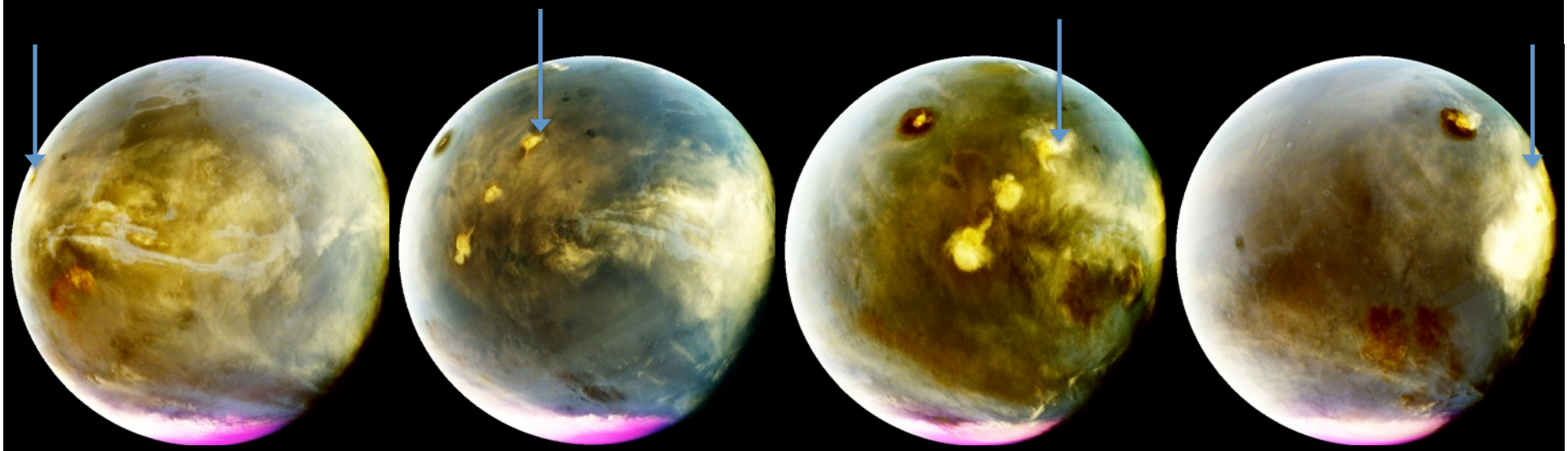
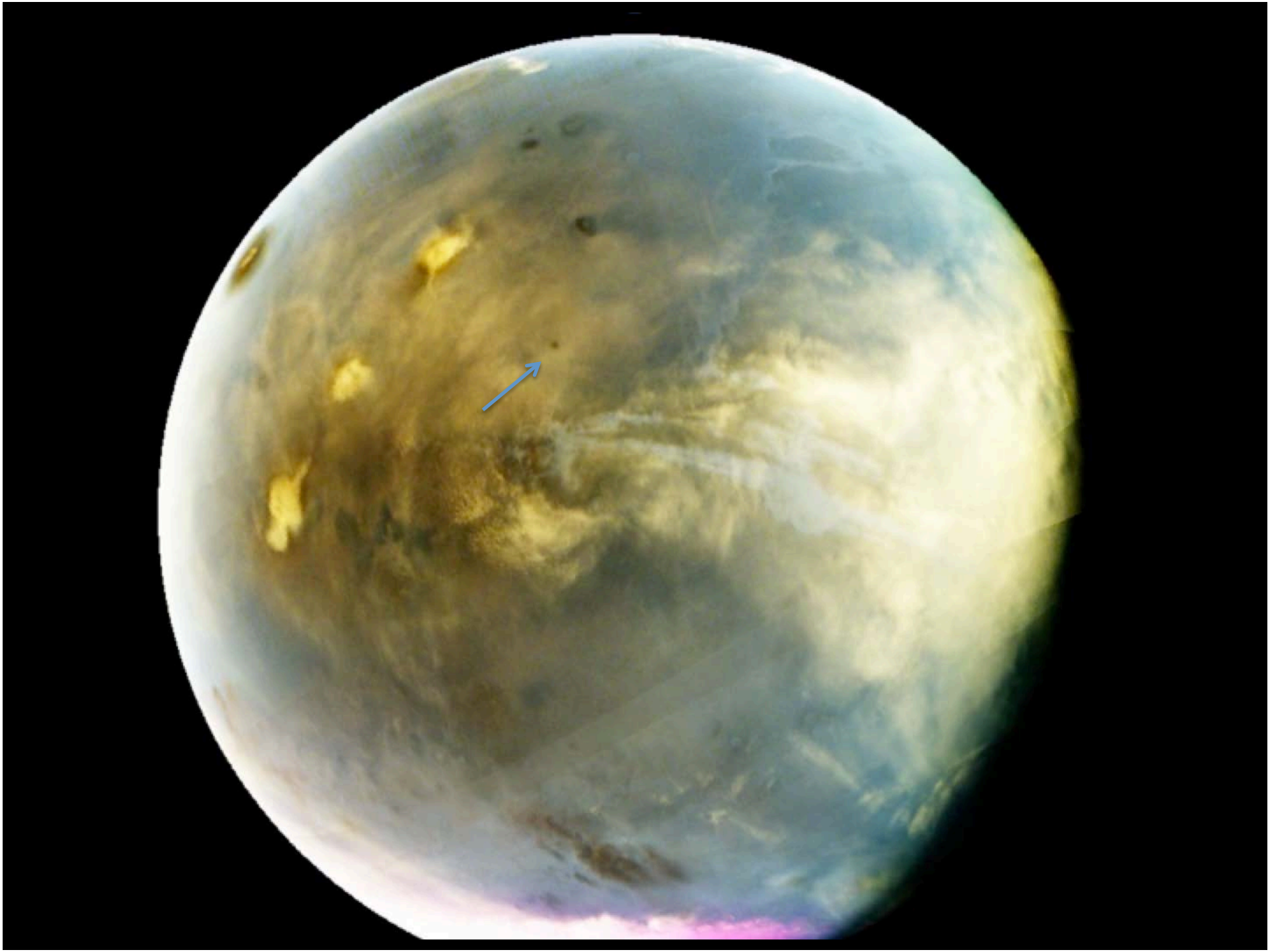
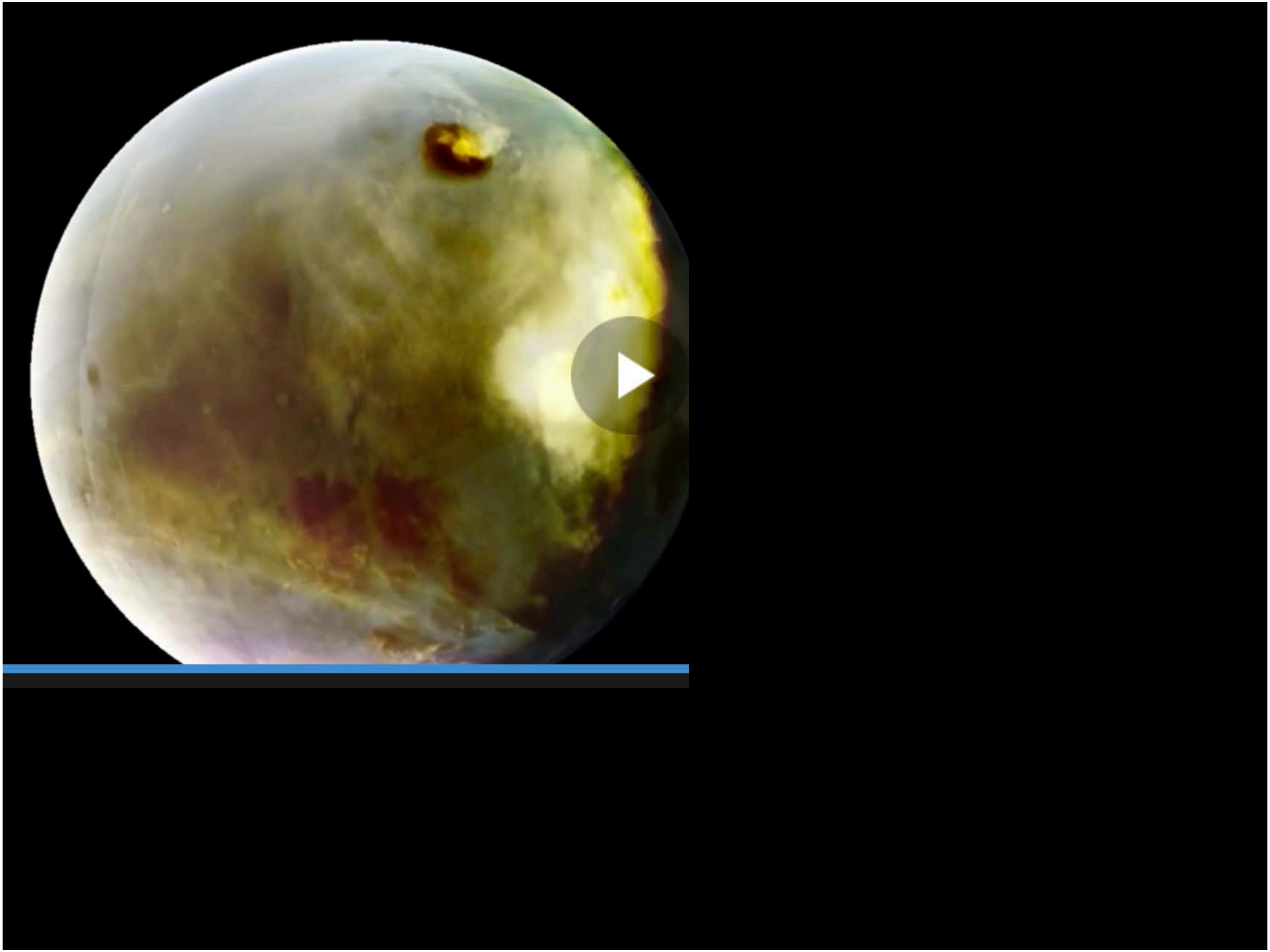


- Clouds: Results
- MAVEN's unique diurnal coverage shows 1000-mile-wide clouds forming in ~7 hours
- Rapid and extensive cloud formation presents a challenge to circulation models

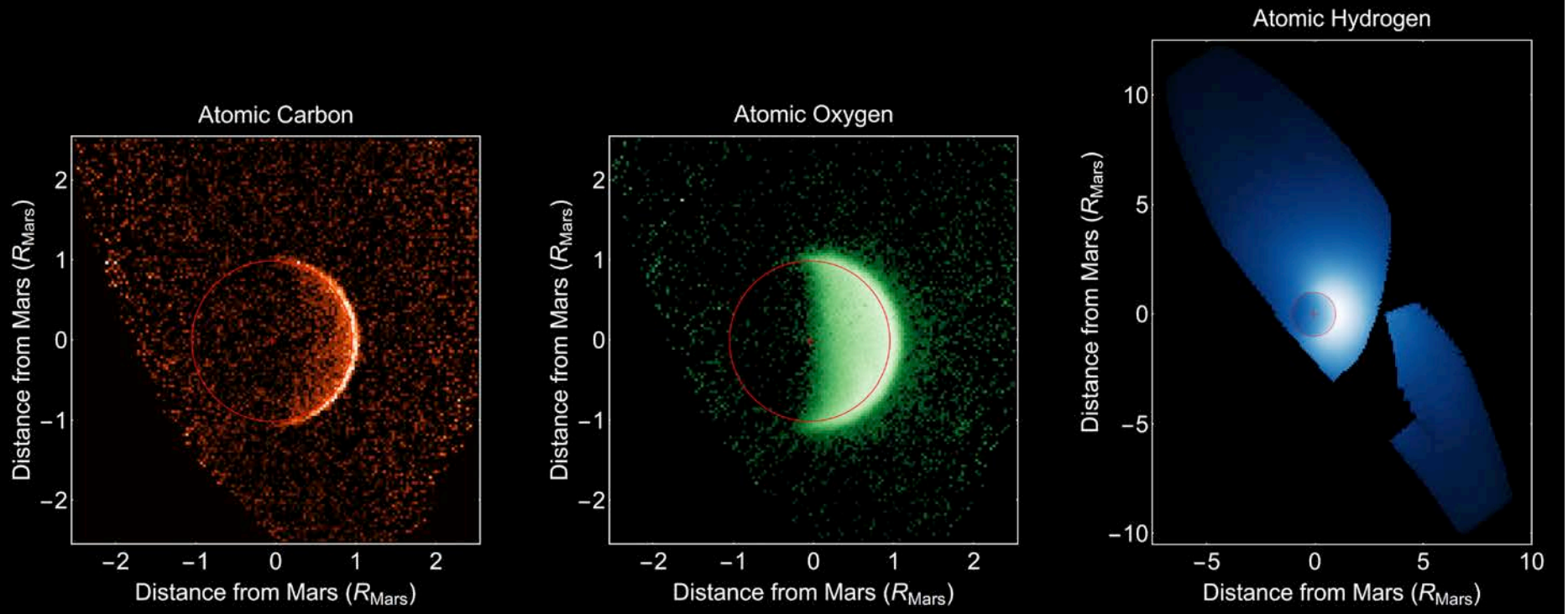





NASA
NASA SAYS IT HAS NO EXPLANATION FOR THE CLOUDS' ORIGINS
The Weather Channel

Solar Wind Stripping based on by MAVEN’s charged particle instruments

IUVS observes the atoms of H_2O and CO_2 on their way to escaping from Mars

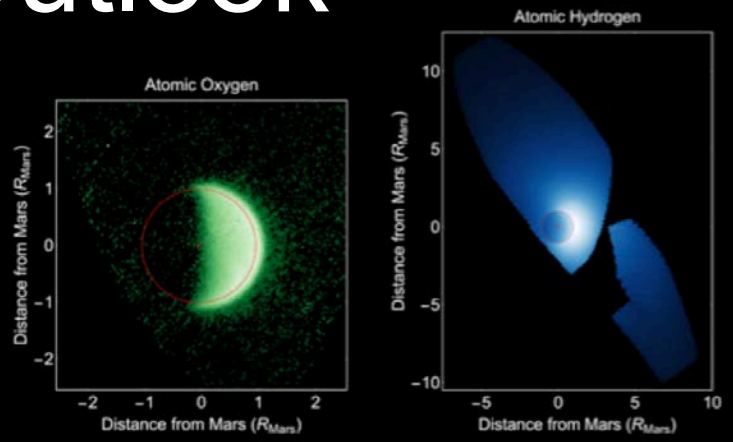


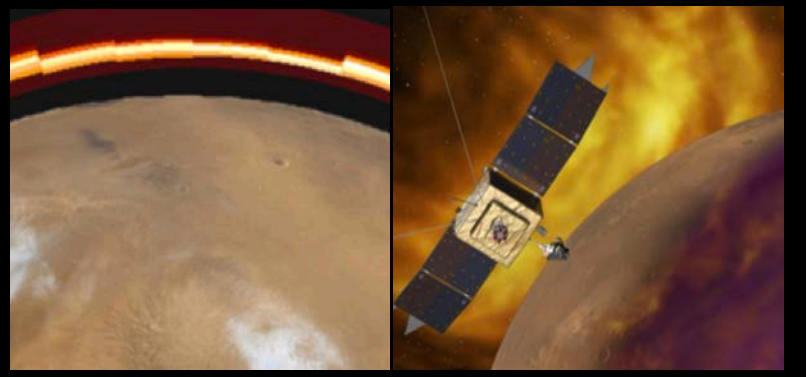
Three views of an escaping atmosphere

Work by Mike Chaffin & Justin Deighan

Summary & Outlook

- First indications support the idea that Mars lost its atmosphere (and possibly and ocean) to space
- Mars' atmosphere continues to astonish nearly fifty years after the first spacecraft visit
- Colorado's homegrown and home-flown spacecraft may continue to make discoveries for years to come





MAVEN Haiku Contest Entry

Red speck in our sky
We will fly to you to know
Blue speck in your sky

Anonymous[?]