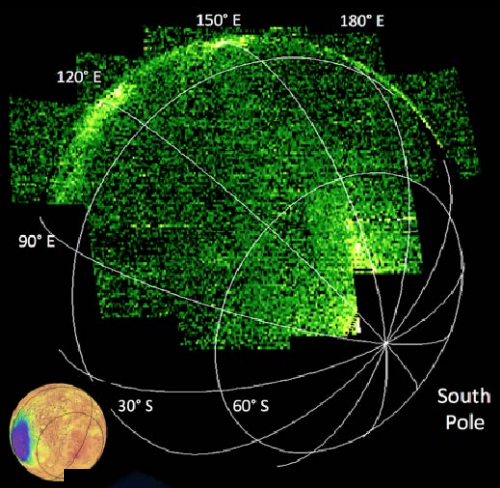
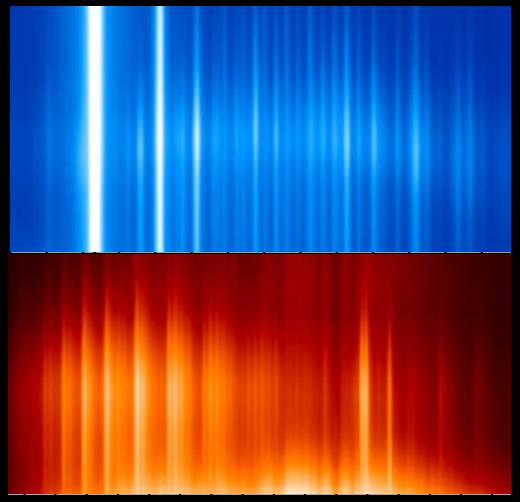
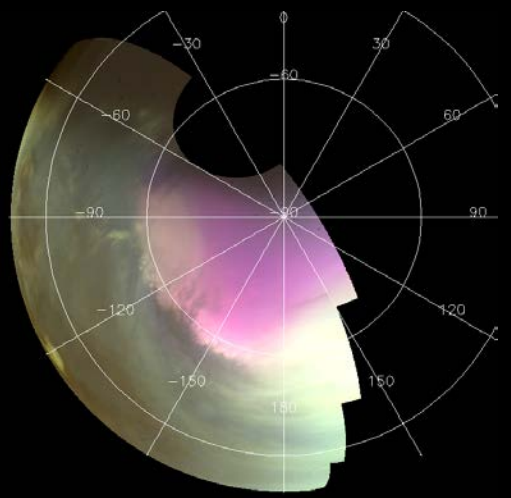
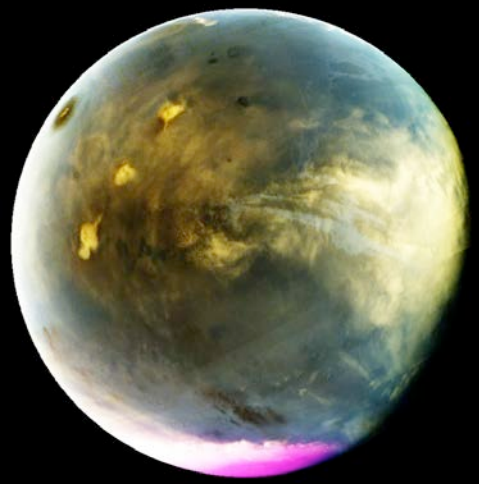
Mars Dayglow, Nightglow & Aurora

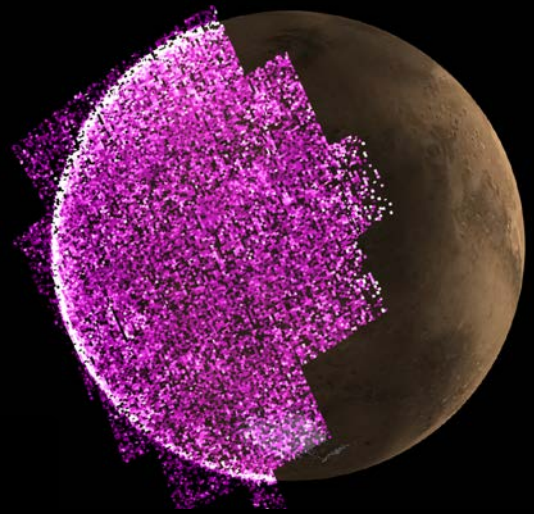
observed by MAVEN's Imaging UltraViolet Spectrograph











ESLAB Conference on Comparative Aeronomy

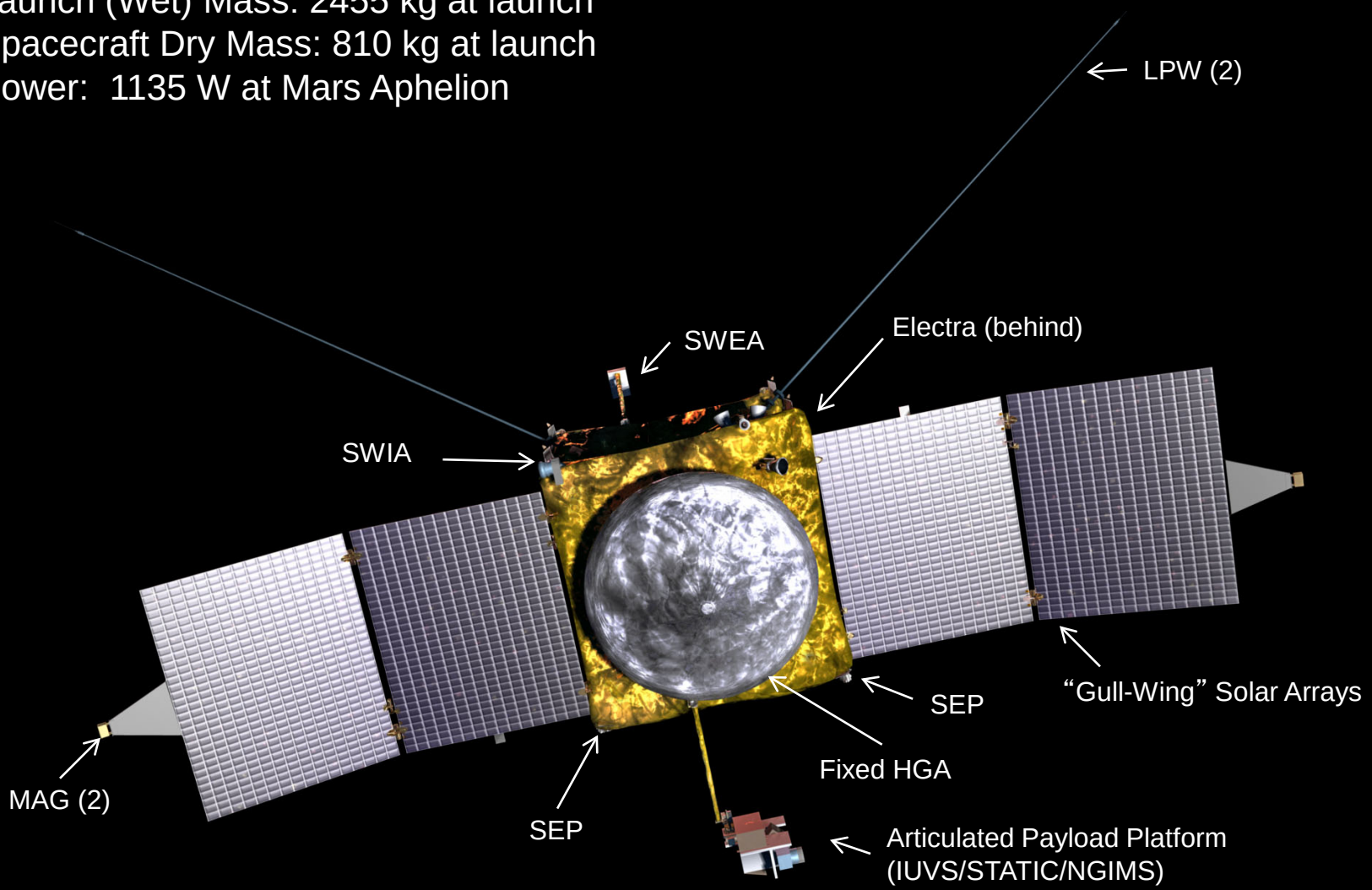
Nick Schneider, ***Matteo Crismani*** *+ the MAVEN IUVS/Remote Sensing Team*

Mars Dayglow, Nightglow & Aurora observed by MAVEN/IUVS

1. Dayglow: Response to strong flares and seasonal variation in the lower atmosphere
2. Nightglow: Revealing atmospheric circulation and tides
3. Aurora: Surprisingly common, and three distinct types

The MAVEN Spacecraft

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



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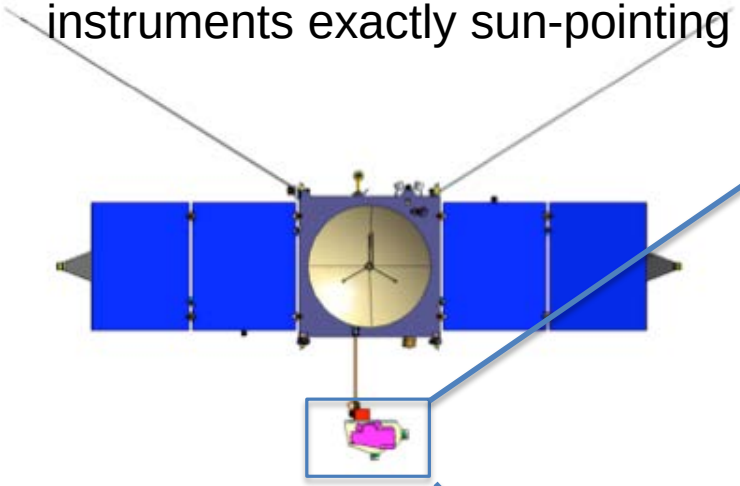
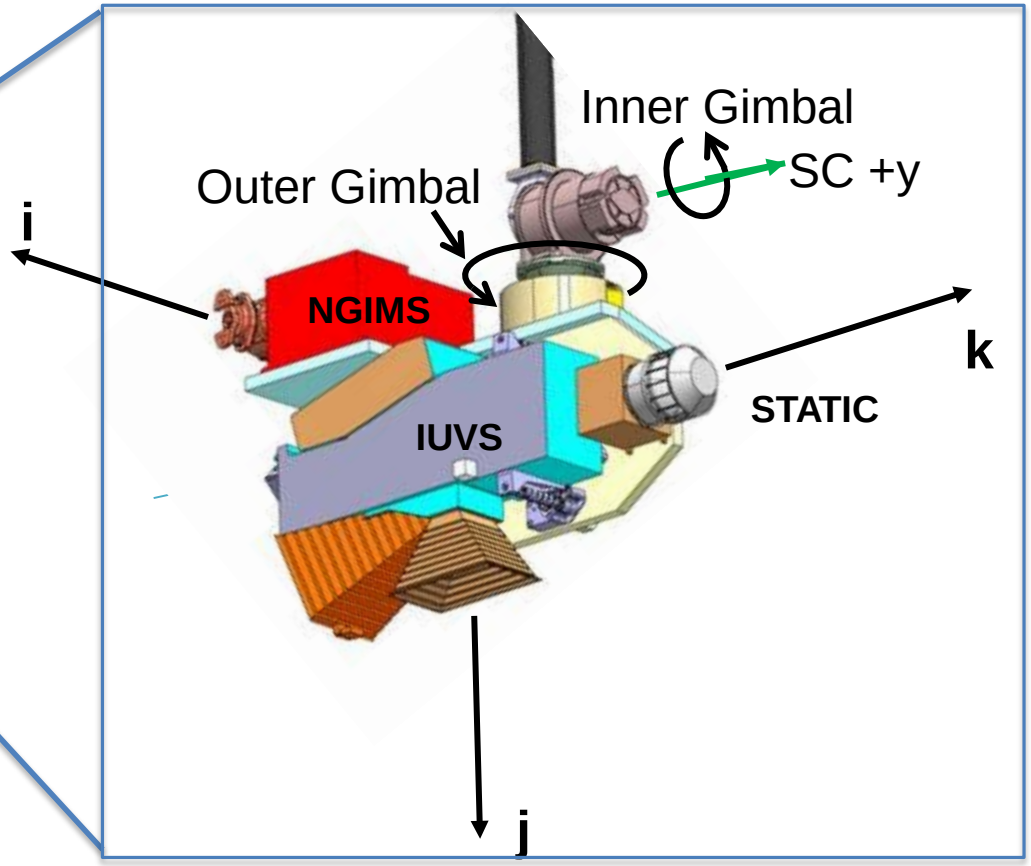
IUVS Accommodation & Pointing Capability

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

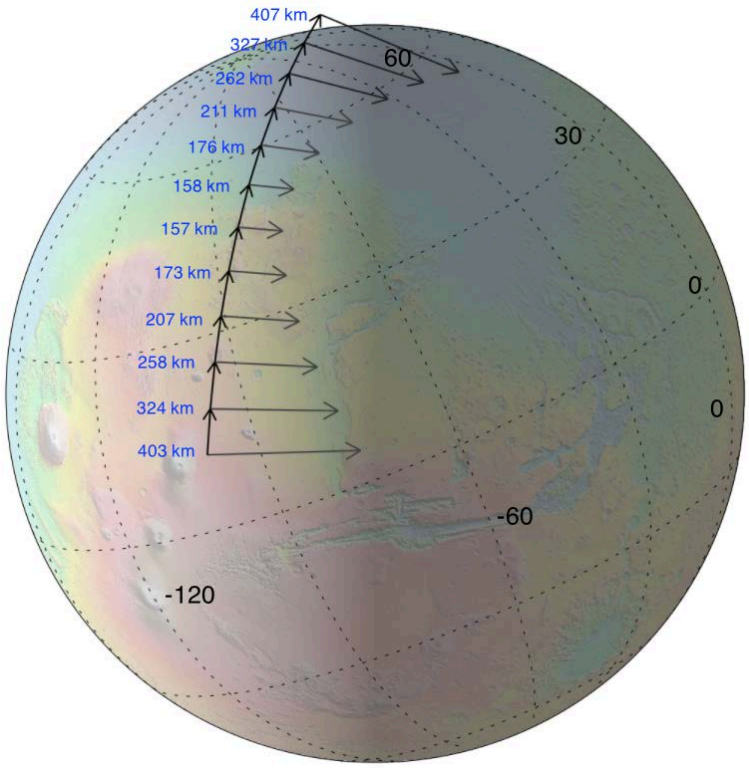


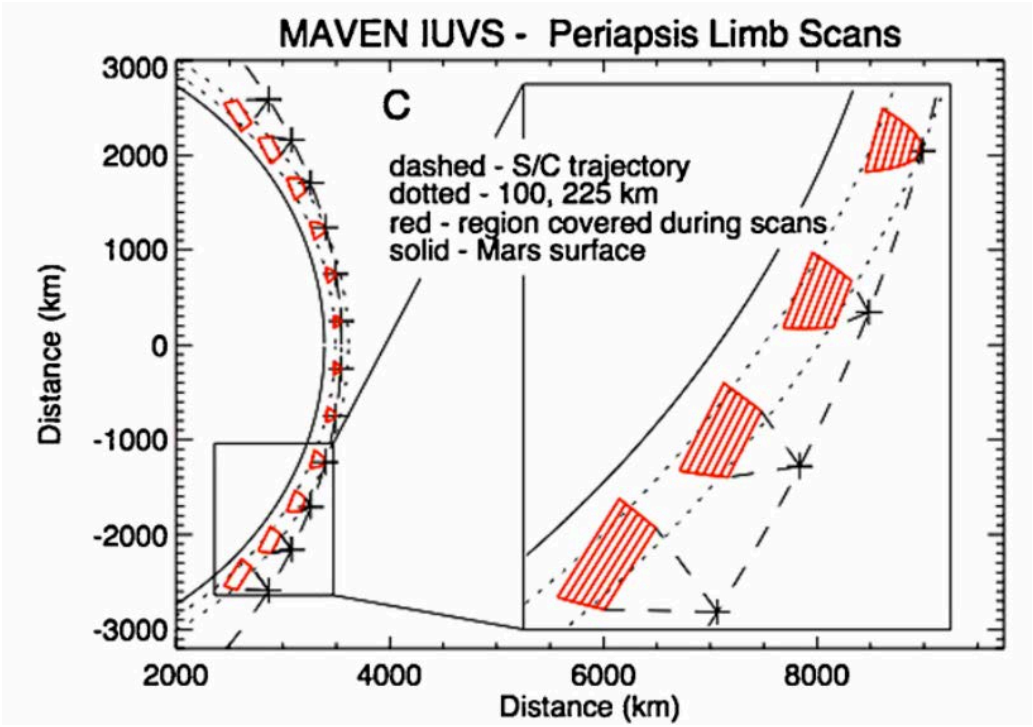
2-axis gimbals allow IUVS to observe at >50% duty cycle, obtaining limb scans, coronal scans and disk maps

IUVS Unique Characteristics

- Imaging spectroscopy via gimbals & scan mirror
- Multiple observing modes at >50% duty cycle
- 3 channels optimized for different science
- Unique orbit spans 150km to ~2 R_M altitude
- Full suite of particles & fields instruments
- Addresses issues across planetary science

1. Dayglow studies: periapse limb scans

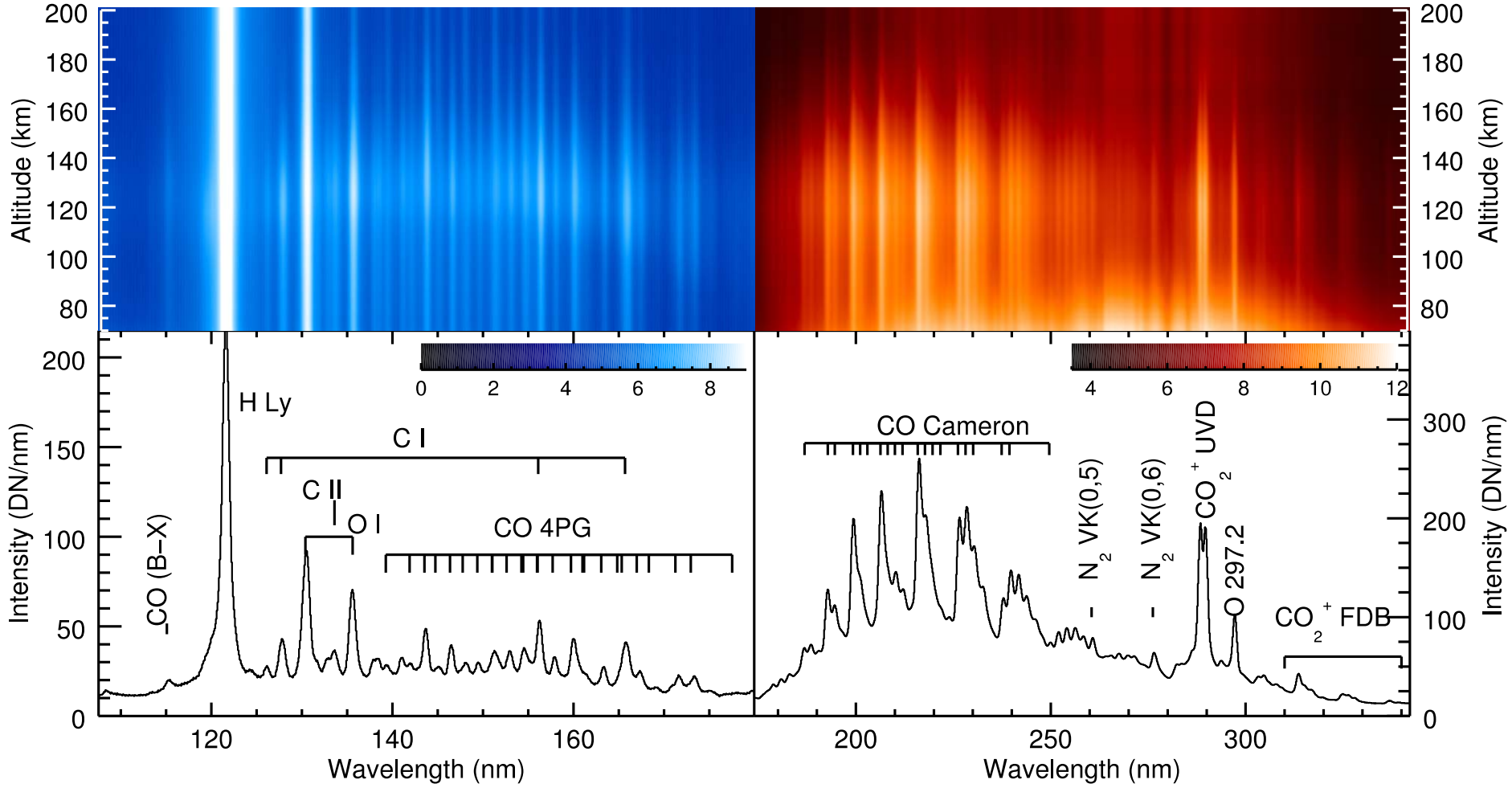




Observing geometry for Orbit 5717

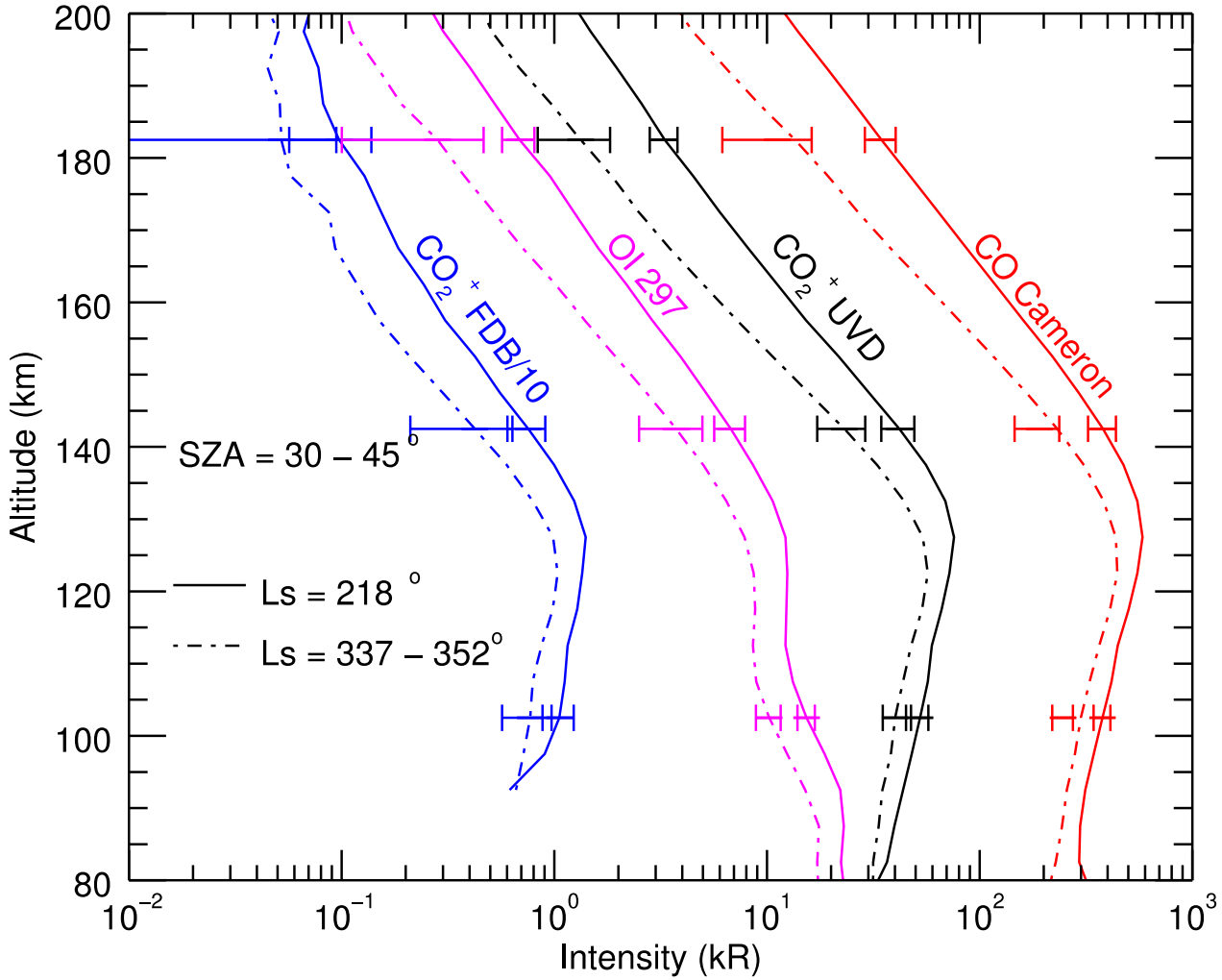
- IUVS obtains 12 vertical scans during periapse on >50% of all orbits
- Dataset now includes thousands of orbits spanning two Mars years

Mars UV Dayglow Spectrum: *not a model*



- Nearly 200 orbits, 60 hours total integration
- Most emissions from CO_2 dissociation and ionization products (Barth+ 71)

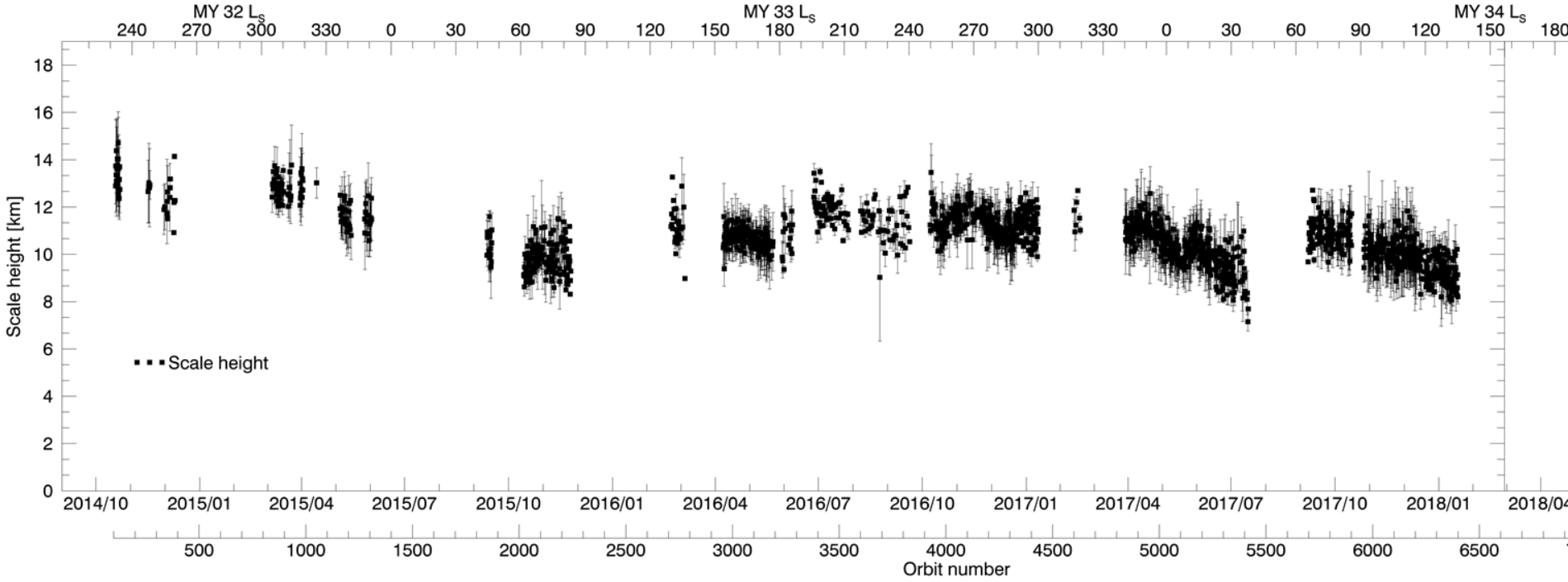
Dayglow Profiles: watching the thermosphere “breathe”



Jain+ 2015

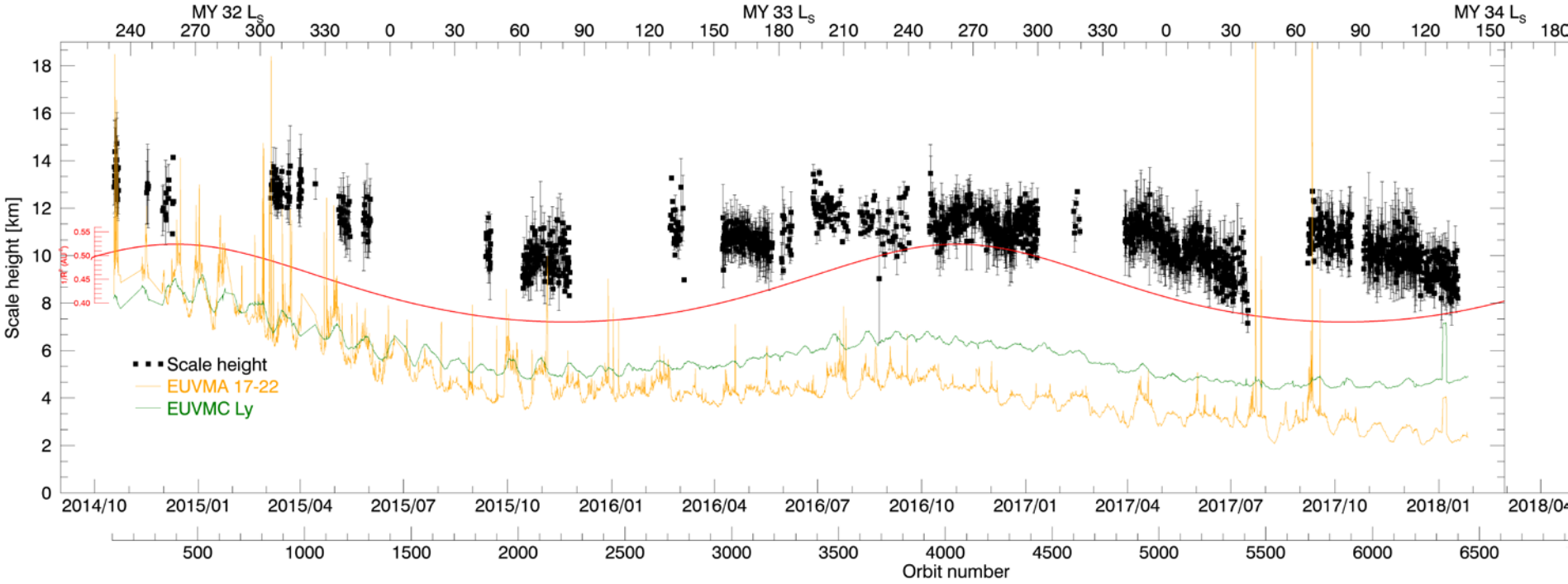
- Early observations demonstrated IUVS’s ability to document changes
- Solid curves show dayglow is brighter, higher, and more vertically extended when Mars is closer to the Sun and solar activity is higher

Two Martian Years: multiple influences reveal themselves



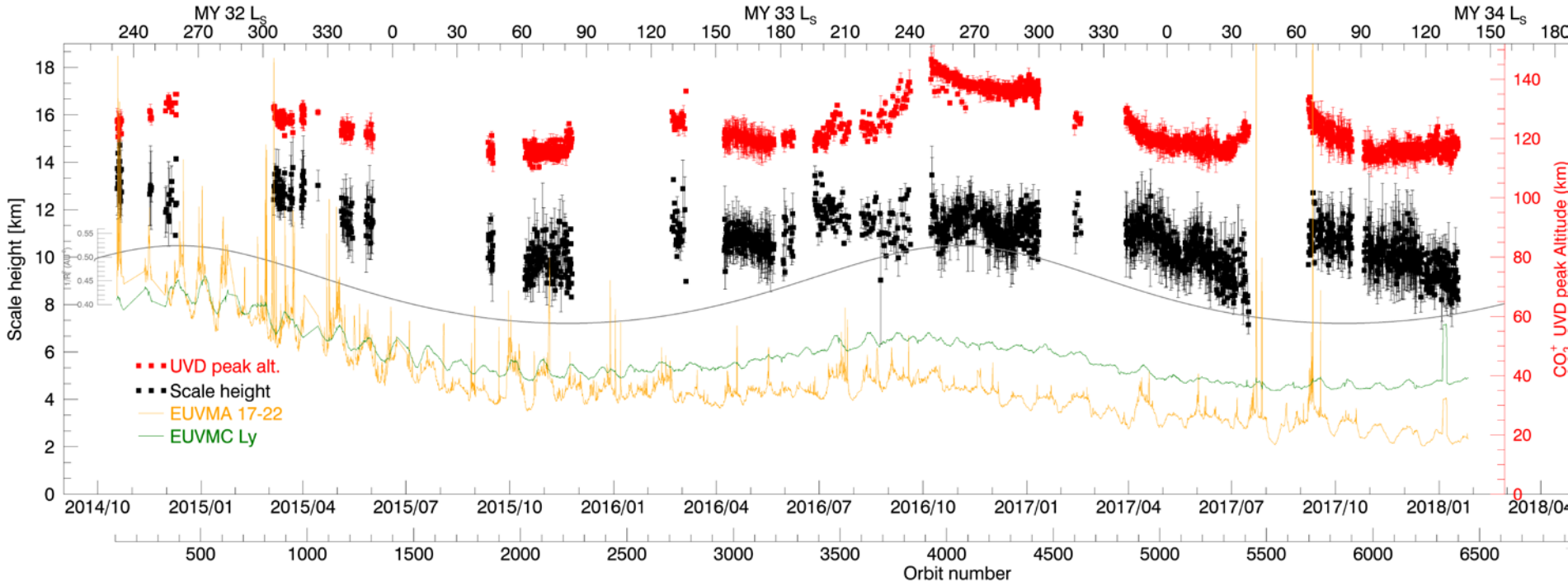
- Scale heights have varied significantly over the mission. What are the drivers?

Two Martian Years: multiple influences reveal themselves



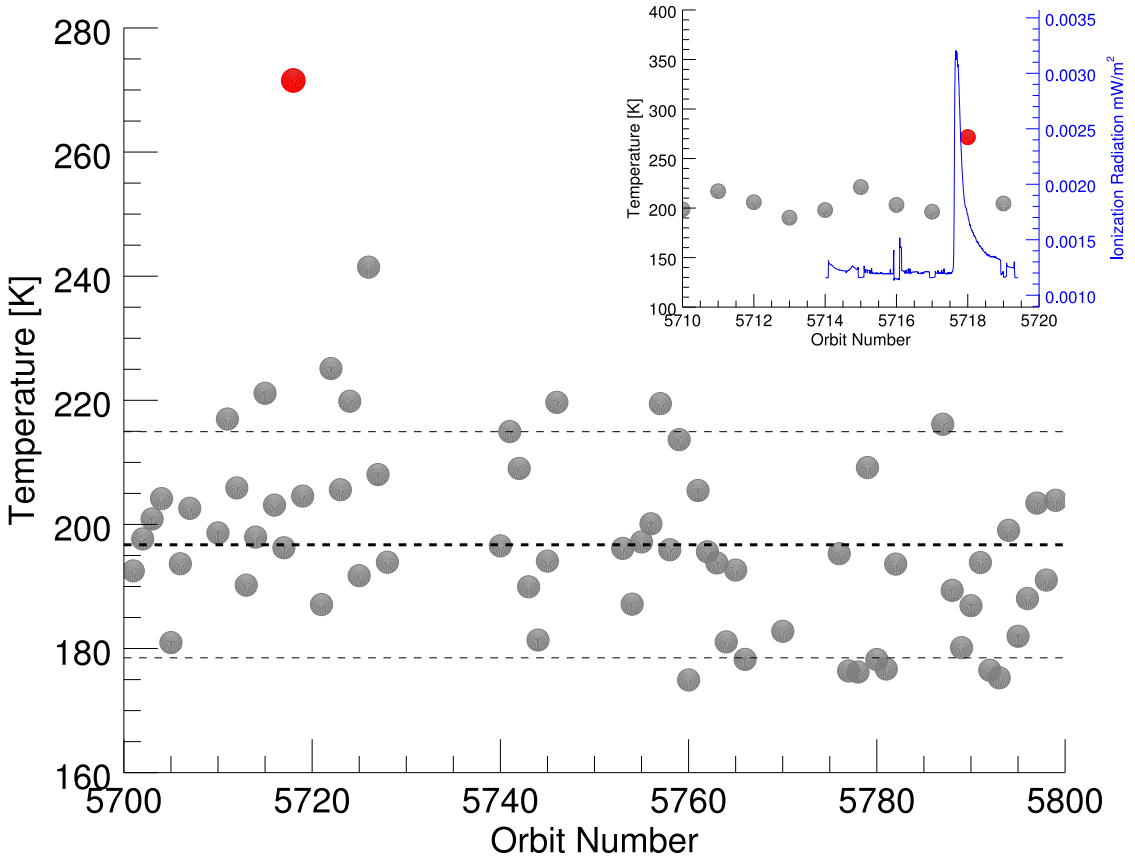
- Scale heights (black) respond to changing distance (red) and declining solar activity (green, orange)

Two Martian Years: multiple influences reveal themselves



- Peak altitude (red) tracks scale height … except around Ls~250
- Dust storm activity at that time puffed up lower atmosphere, raising the thermosphere without heating it further
- Southern hemisphere summer is when many Mars phenomena are enhanced

September 2017: the thermosphere responds to an X-class flare

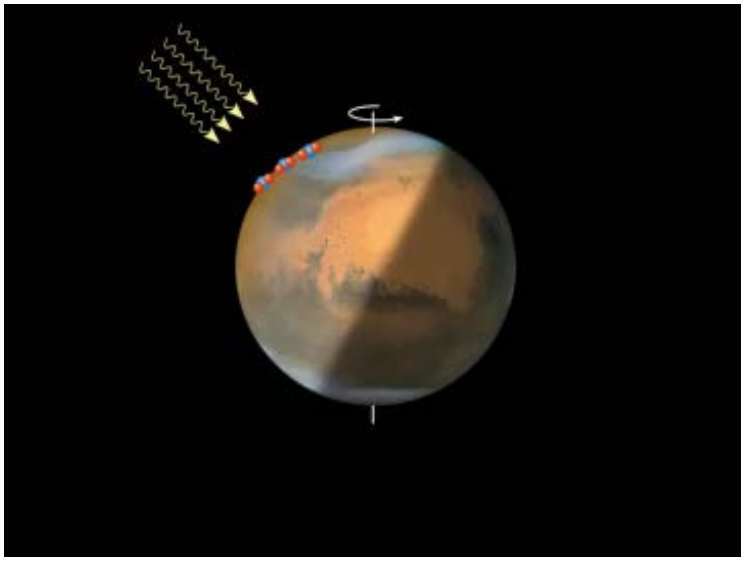


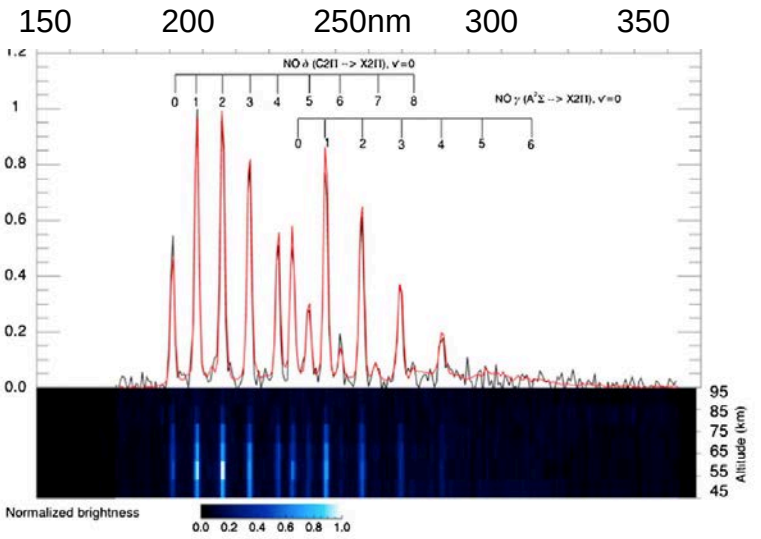
Jain+ 2018

- X-class flare observed by MAVEN/EUVM (also measured at Earth)
- Thermosphere warmed 70K during the flare, and rapidly cooled
- Flare effects from photons <10nm reached down to 90km altitude

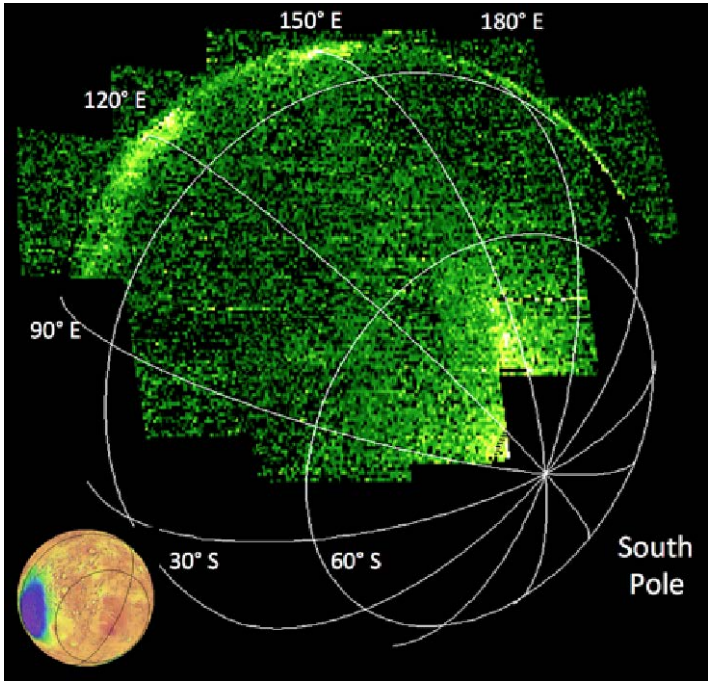
2. Nitric Oxide (NO) Nightglow at Mars

- Nightglow reveals global circulation patterns and especially their seasonal and latitudinal variations.
- N_2 and CO_2 photo-dissociated in the dayside thermosphere by EUV photons and electron impact (~140 km)
- O and N atoms travel to nightside and recombine, emitting distinct UV signal (~70km).
- NO nightglow traces inter-hemispheric transport in the thermosphere and downward fluxes in the nightside
- IUVS studies NO nightglow using limb scans and global images

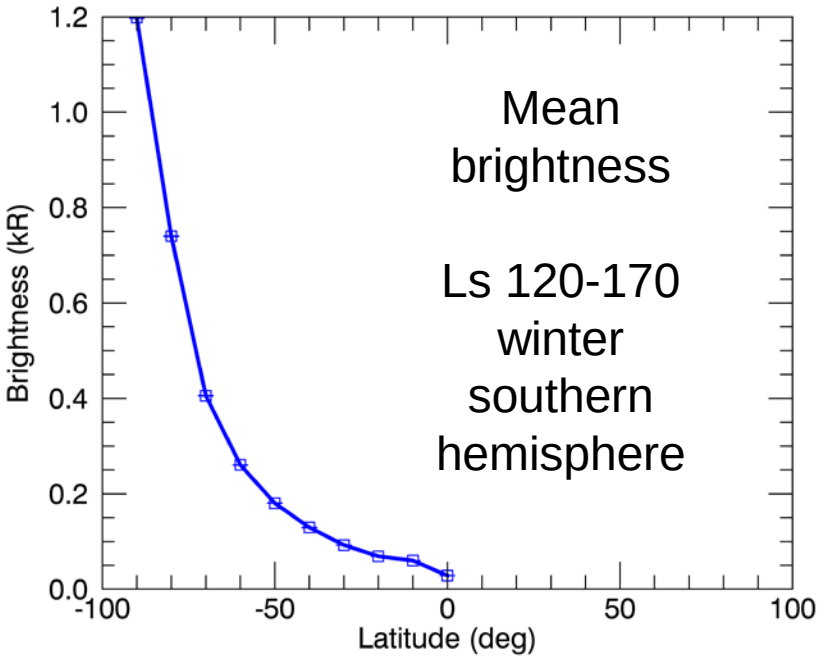




First Global Images Show Both Expected and Surprising Features

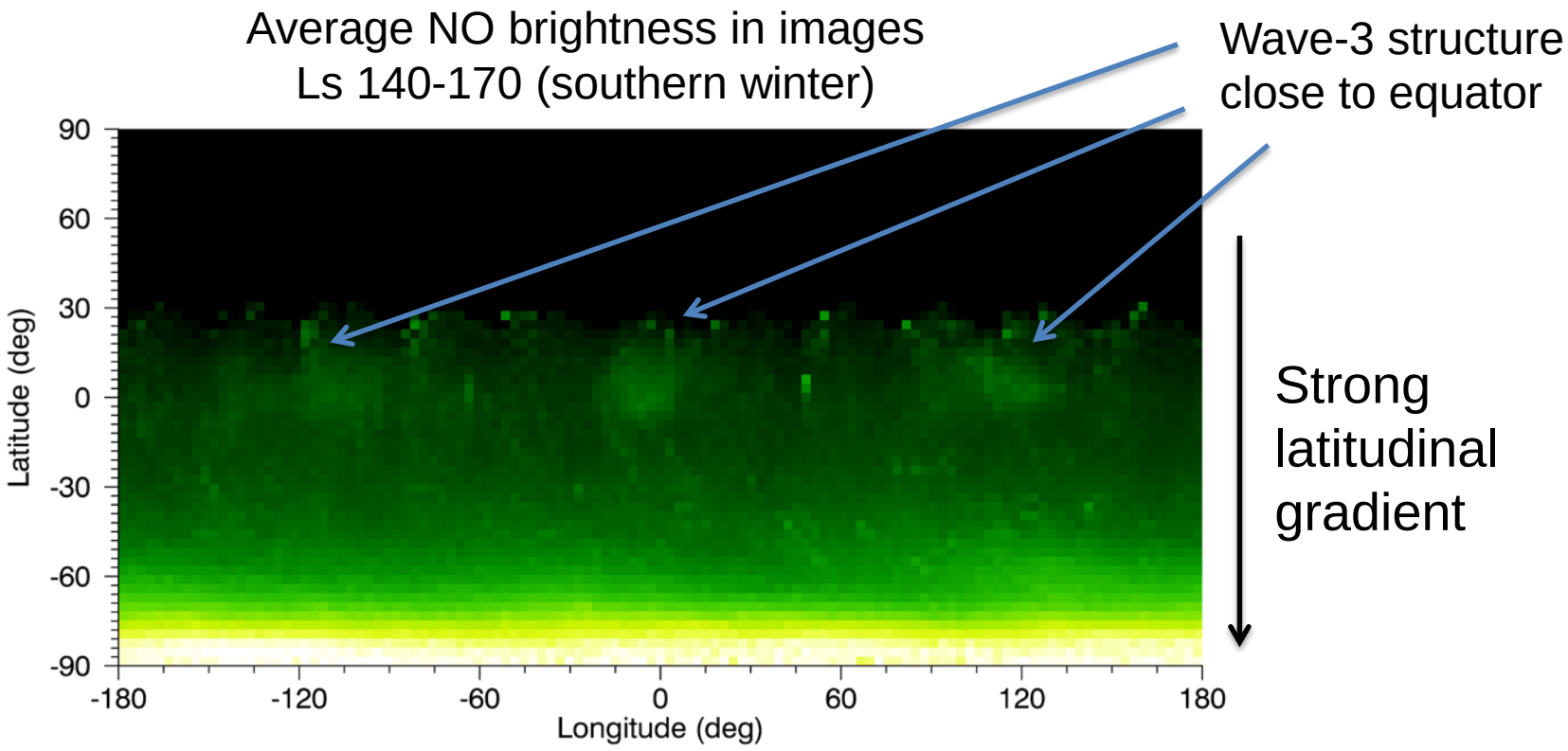


May 4, 2016 during late winter in Mars Southern Hemisphere. Orbit 3102 – Ls 147



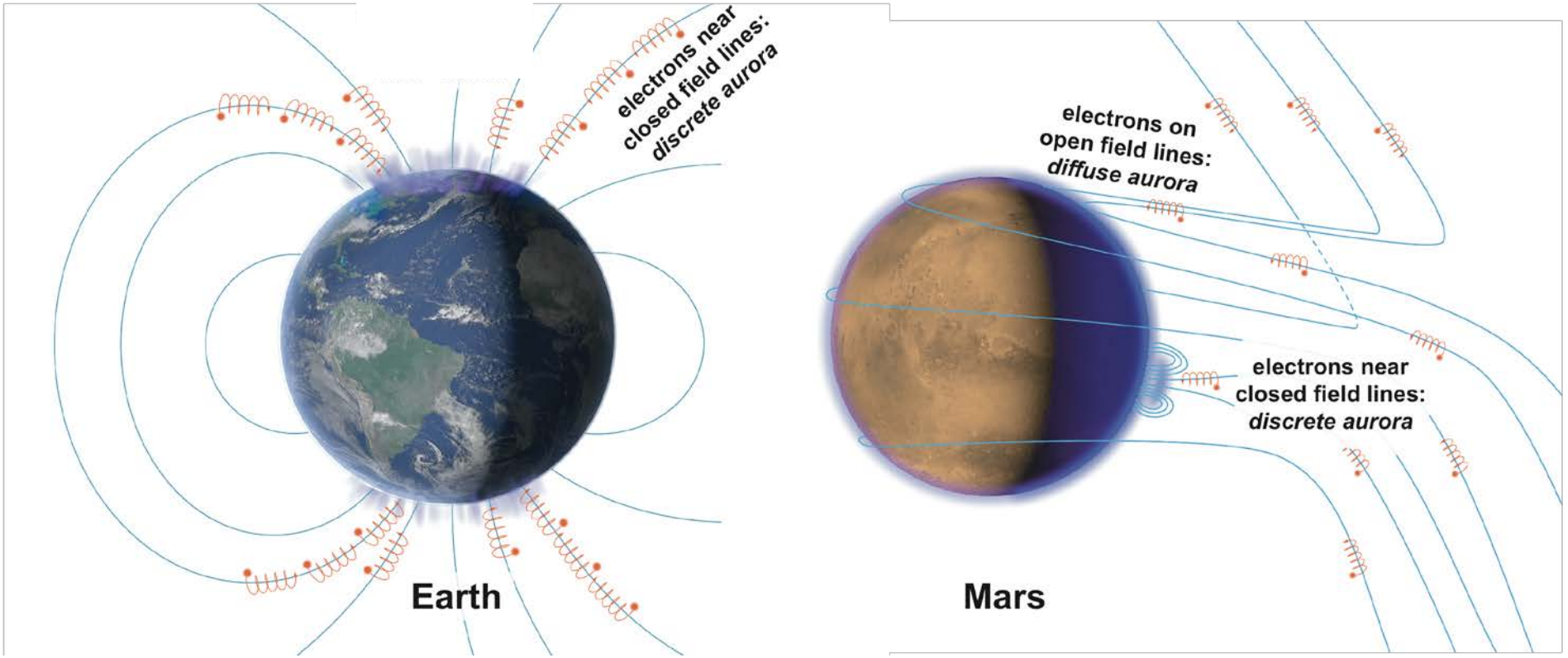
- As expected, emission is bright at the winter pole, where air descends, causing recombination
- Splotches and streaks in equatorial regions near the limb are surprisingly strong

Equatorial Wave-3 structure: stationary/non-migrating tides?



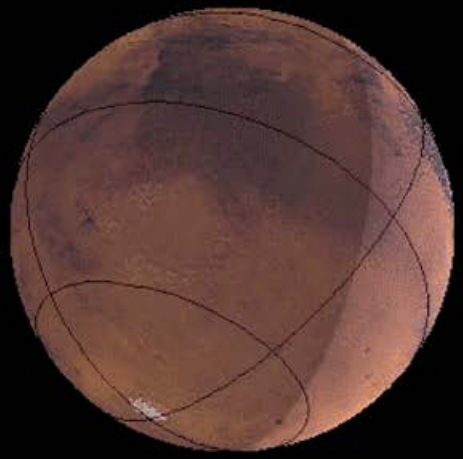
- Prominent wave-3 structure observed at equatorial latitudes in both limb-scans and global images.
- Studies of local time behavior will help identify the type of wave (e.g., stationary vs other non-migrating waves
- GCM modeling not yet matching latitudinal gradients (too strong)

3. Auroral Processes on Mars:
Comparison with Earth

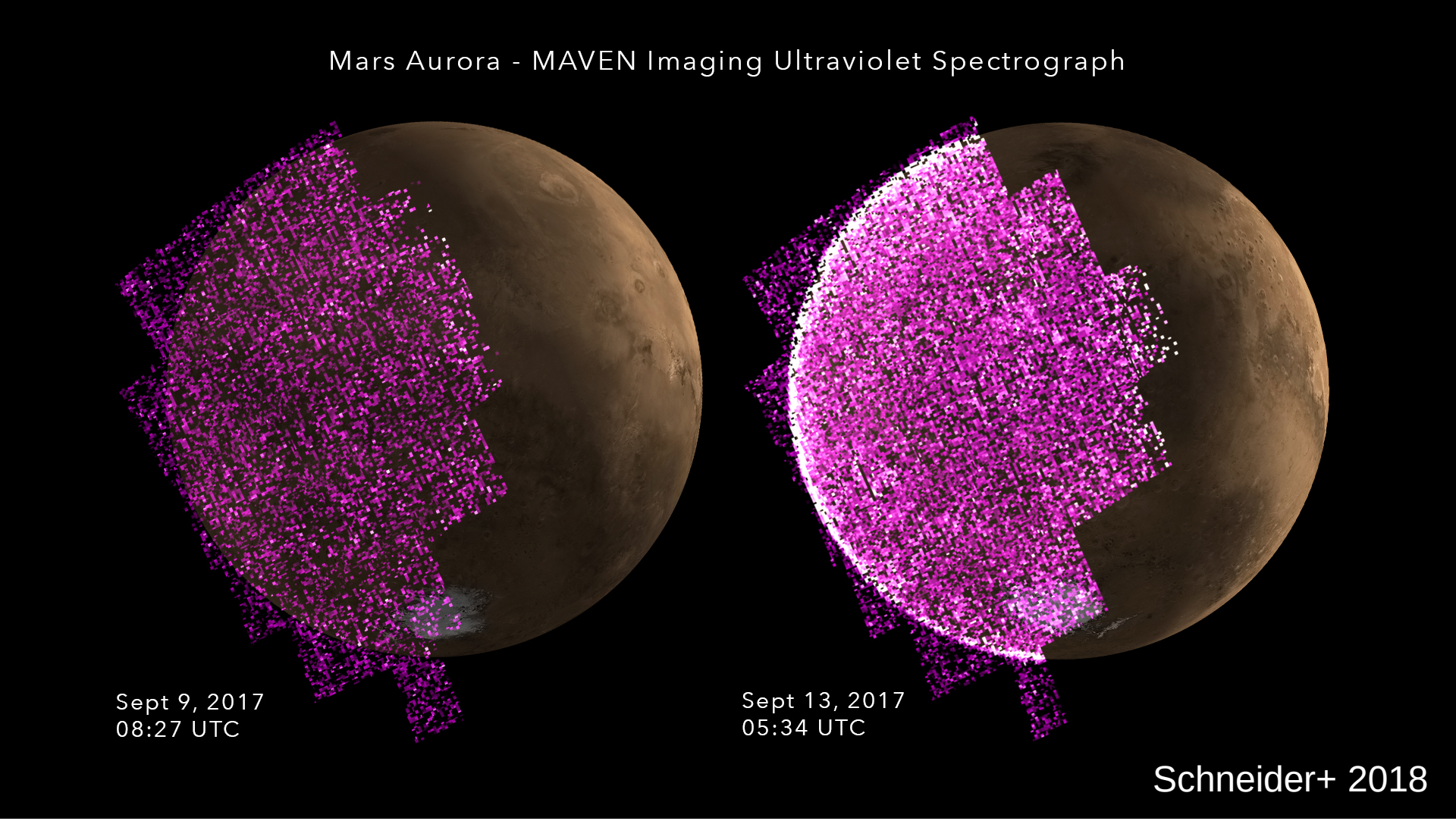


- Aurora at Mars are common, but are not like Earth's as Mars lacks a global magnetic field

The September 2017 Space Weather Event: Brightest Mars aurora on record



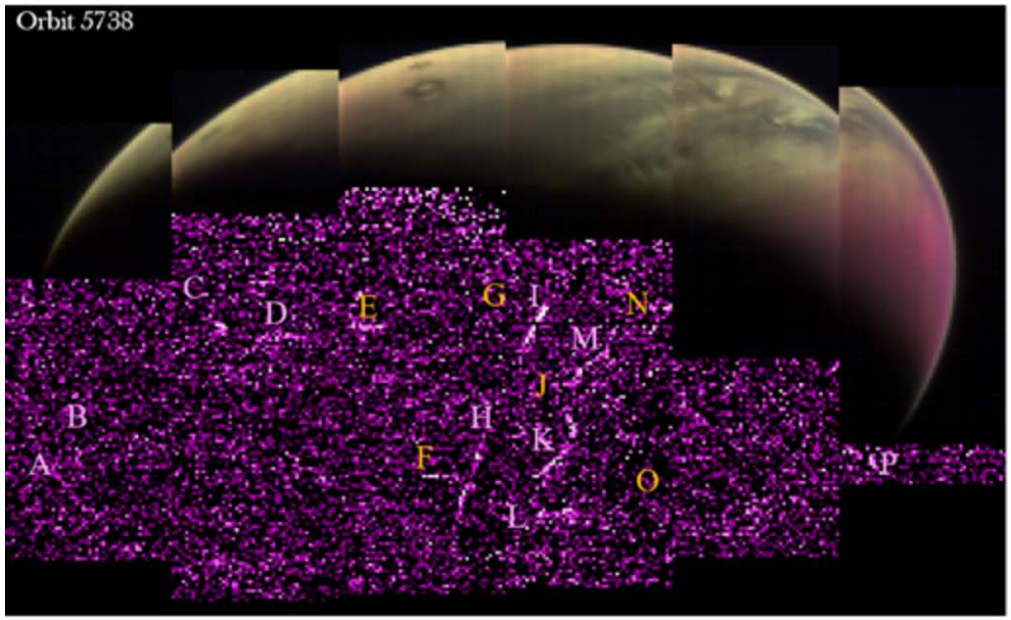
12 Sept 02:58

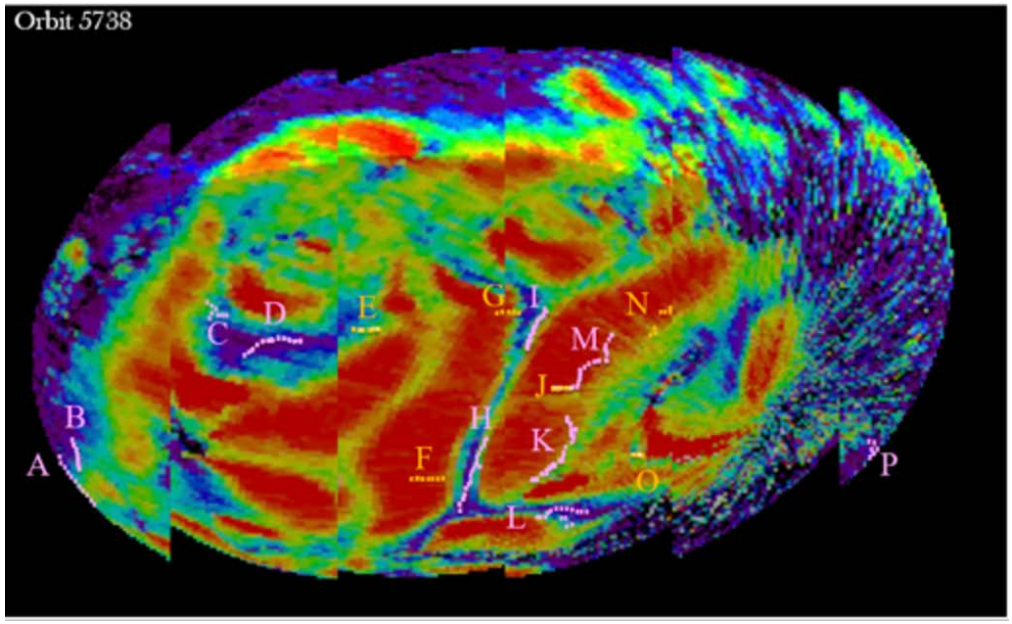


Diffuse aurora 25x brighter than any past event, enabling first images.

- Aurora effectively global, as “expected” for unmagnetized planet
- Caused by solar energetic protons or electrons (can’t tell)
- Emission peaks at 60 km – energy deposited very deep!

First Imaging of Mars Discrete Aurora



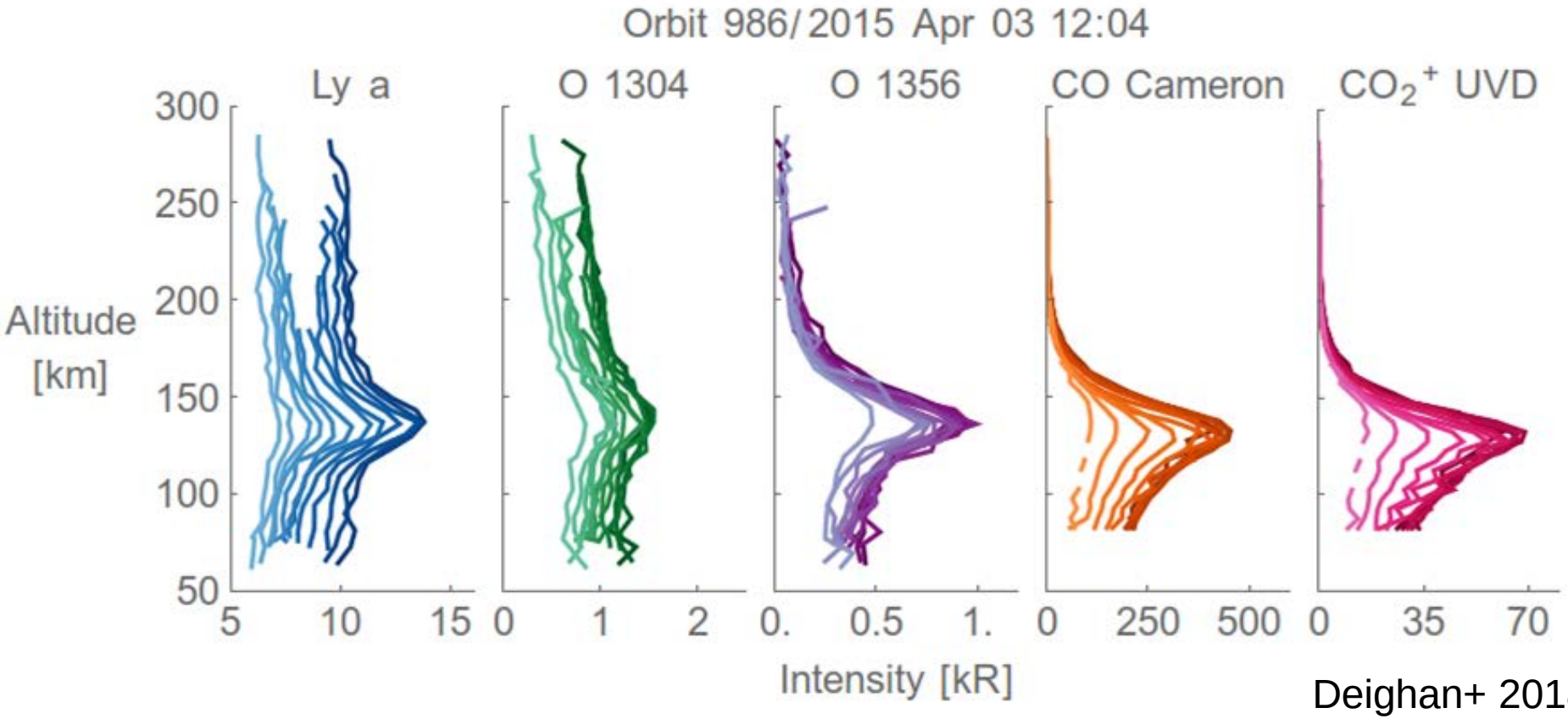


- Spectra examine pixel by pixel: purple letters indicate aurora; orange indicates noise or artifact
- Most auroral features line up with gaps between closed field lines
- Many other orbits had favorable viewing of crustal fields but no significant emissions
- Confirms discrete aurora behavior discovered by MEX/ SPICAM
- Observed only in the declining phase of the solar event, also confirming SPICAM results

Red indicates high probability of closed field line at 400km based on MGS pitch angle data (Brain 2007).

Discovery of Proton Aurora at Mars

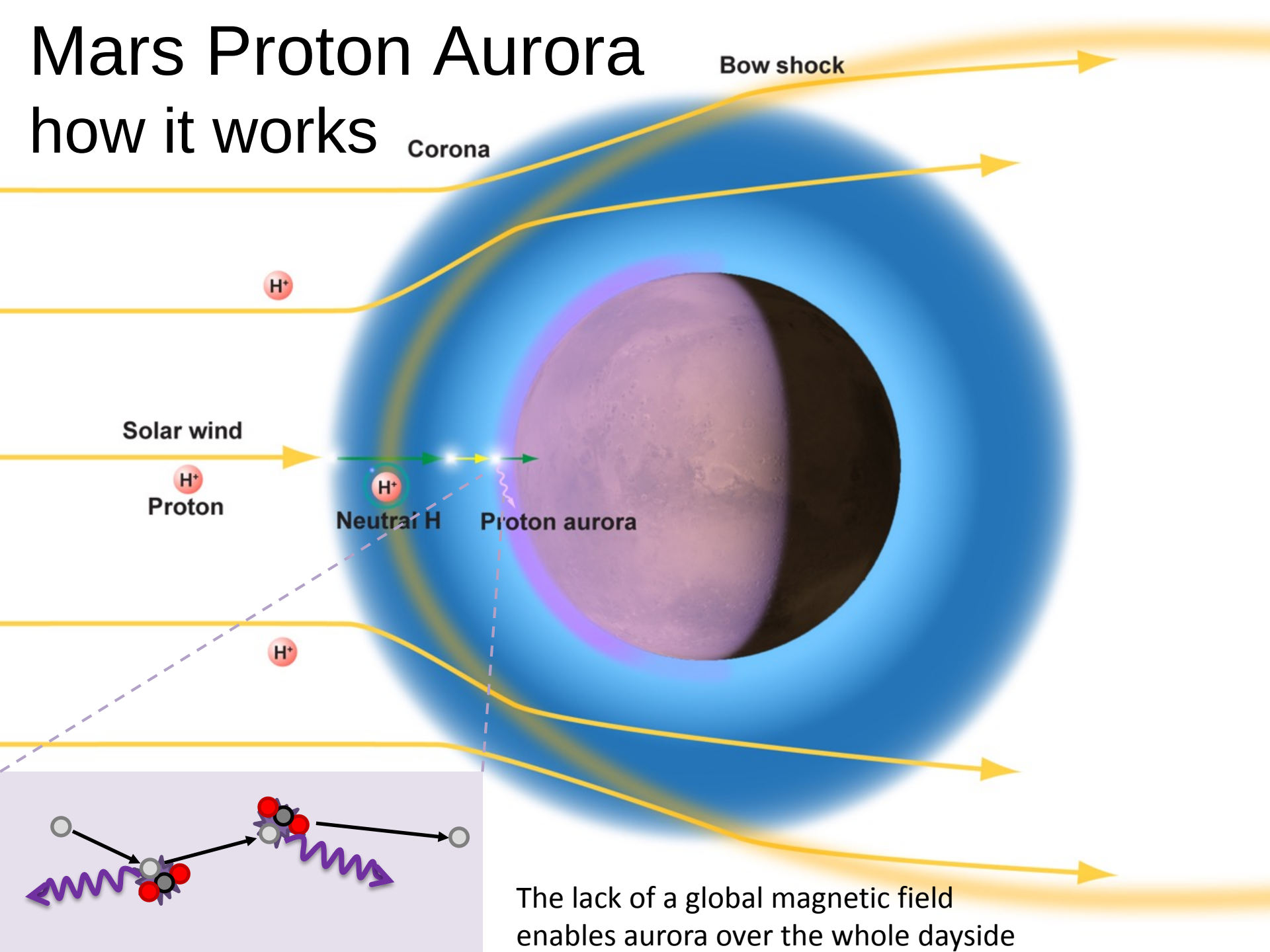
- First observation of predicted Martian proton aurora; first detection on a planet beyond Earth
- More frequent during southern hemisphere summer, probably due to enhanced H corona, escape, etc.



Deighan+ 2018

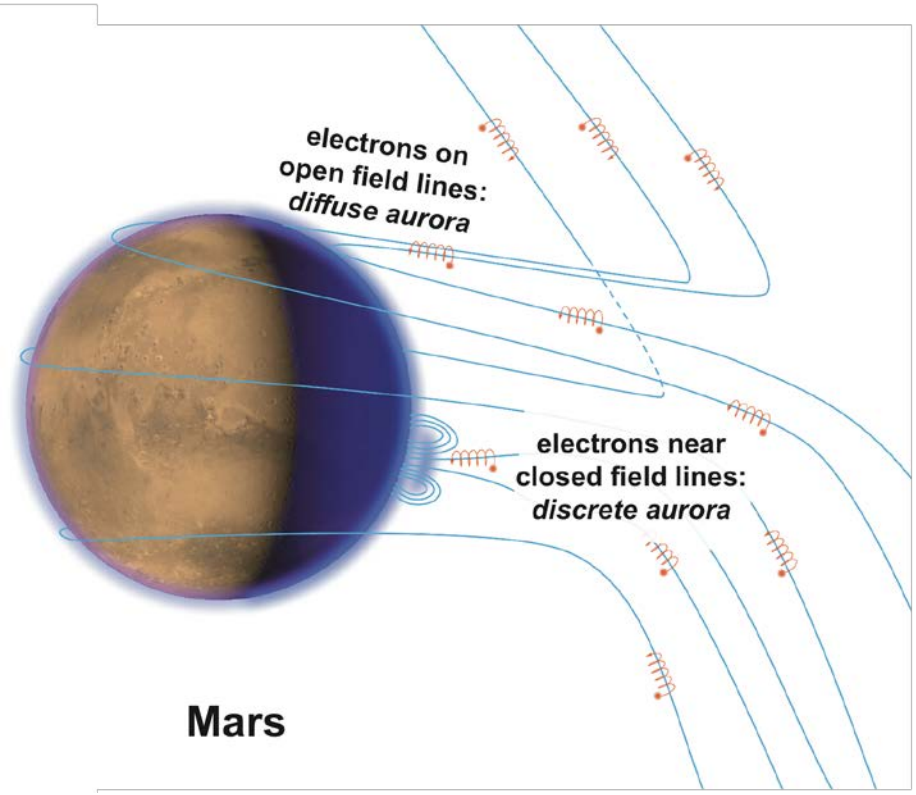
Mars Proton Aurora

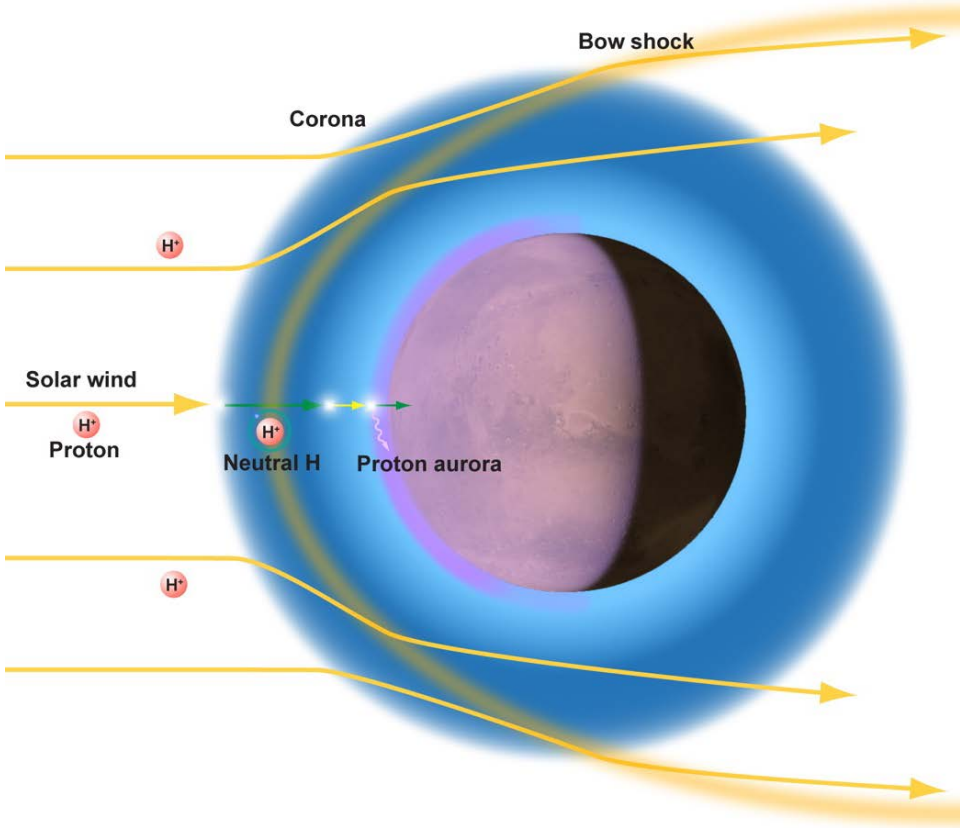
how it works



The lack of a global magnetic field enables aurora over the whole dayside

Three types of aurora at Mars





Diffuse and Discrete Aurora

Proton Aurora

- IUVS has discovered two forms of aurora (diffuse, proton) made possible by the *lack* of a global magnetic field
- Global magnetic fields should be considered both the cause and prevention of different types of aurora

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1. Dayglow: Response to strong flares and seasonal variation in the lower atmosphere
2. Nightglow: Revealing atmospheric circulation and tides
3. Aurora: Surprisingly common, and three distinct types

So many phenomena, so little time…

Limb Scan (Periapse, coronal)	Disk & coronal Scan	Apoapse Disk Imaging	Stellar Occultations
Dayglow • CO2 etc., N2, H,O • n(z), T(z) • variability • tides • meteoric metals	**H corona, O Corona** • escape • Seasonal changes	**Ozone** • polar vortex • Rossby waves • seasonal changes	**Altitude profiles** • CO2, O2 • n(z), T(z) • ozone, aerosols • day: OK, night:OK!
Nightglow (NO)		**Clouds** • nadir, limb	• Gravity waves • Standing waves
Aurora (3 types)		**Albedo, dust**	
Limb clouds (mesosphere)		**Rayleigh scattering**	**Miscellaneous**
D/H		**Nightglow** (NO)	**Misc.**
Atomic O 130nm triplet	Purple indicates other presentations at this meeting		• Past-terminator clouds
			• Rover overflights
			• Phobos