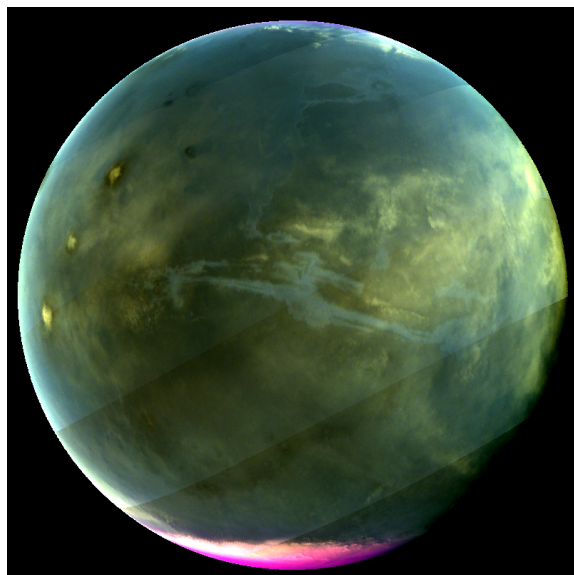


# GLOBAL UV IMAGING BY MAVEN/IUVS: DIURNAL CLOUD FORMATION, DUST STORMS AND ATMOSPHERIC SCATTERING

N.M. Schneider, J.I. Deighan, S.K. Jain, A.D. Derks, M.S. Chaffin, M. Crismani, A.I.F. Stewart, W.E. McClintock, G.M. Holsclaw, B.M. Jakosky, LASP, U. Colorado, ([nick.schneider@lasp.colorado.edu](mailto:nick.schneider@lasp.colorado.edu)), F. Lefèvre, F. Montmessin, LATMOS/CNRS, M.J. Wolff, Space Science Institute, A. Stiepen, LPAP/STAR, University of Liège, M.H. Stevens, Space Science Division, Naval Research Laboratory, J.S. Evans, Computational Physics Inc., R.V. Yelle, D.Y. Lo, Lunar and Planetary Laboratory, University of Arizona, J.T. Clarke, Center for Space Physics, Boston University

## Introduction:

A new UV spectral imaging dataset of Mars global images is being obtained by the Imaging Ultraviolet Spectrograph (IUVS) on the Mars Atmosphere and Volatile Evolution mission (MAVEN). Of particular interest for atmospheric studies are spectrally-resolved mid-UV datacubes as shown in Figure 1. Clouds, haze, dust and ozone can all be detected and quantified through image analysis and retrieval. IUVS observations are the only MAVEN data capable of probing below the spacecraft altitude, and provide an important link between the denser atmosphere and escape processes which are MAVEN's primary focus (Jakosky *et al.* 2015).



**Figure 1.** MAVEN/IUVS image on July 13, 2016 ( $L_s \sim 186^\circ$ ), when the planet appeared nearly full as viewed from the highest altitudes in the MAVEN orbit. Mid-UV colors have been scaled up into the visible range. Valles Marineris appears prominently across the middle of the image in pale blue, due to strong Rayleigh scattering deep in the atmosphere. Tharsis volcanoes appear near the left edge, dotted by white. The magenta-colored region visible at the south pole shows absorption by ozone. A hint of ozone is also visible near the north pole; more will accumulate there as winter is approaching. Diagonal striping reveals the image collection in swaths collected as the spacecraft moves of the disk. IUVS obtains images of Mars every orbit when the sunlit portion of the planet is visible from high altitude.

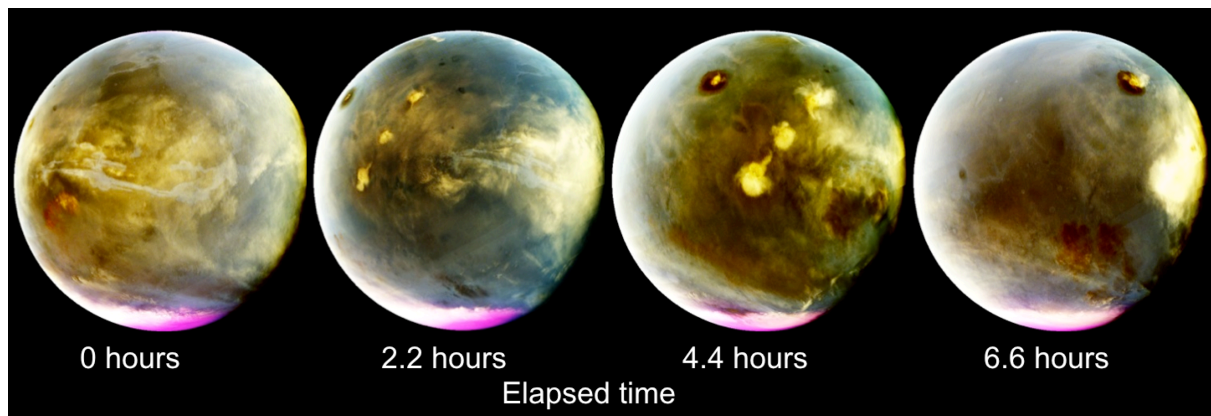
## Observations:

The MAVEN spacecraft orbits Mars in a highly inclined elliptical orbit, with a periapease that enters the upper atmosphere for in situ sampling and an apoapse at nearly 3 Mars radii (6200 km above the surface) for remote sensing and solar wind measurement. IUVS is an imaging spectrograph which uses a long slit and a scan mirror to obtain spectrally-resolved datacubes of the atmosphere and planet (McClintock *et al.* 2014). Separate channels record spatially-resolved spectra in the Far-UV (110-190 nm) and Mid-UV (180-340 nm). Observation sequences are tailored to different science objectives and observing geometries along different segments of the orbit. The instrument is mounted on an Articulated Payload Platform which aligns the instrument's fields-of-regard towards the planet and allows the scan mirror to the slit across the region of interest using exposures of a few seconds.

This presentation describes global images from apoapse, as shown in Figure 1. The instrument is capable of spatial resolutions of 6 km at nadir and 9 km at the limb (farther from the spacecraft). Spectral resolutions up to 0.6 nm are possible with the instrument, but data rate considerations limit the spectral resolution to  $\sim 15$  bins of 5.9 nm in the mid-UV when the highest spatial resolutions are employed. The relatively low spectral resolution is a substantial improvement over broadband filter imaging, and is fully capable of distinguishing all major spectroscopic components.

IUVS has collected global-scale images for more than one Mars year. Early in the mission, data rate allocations were low and images were obtained at coarse spatial resolution. During the recent Mars opposition, the close distance between Earth and Mars allowed higher spacecraft transmission rates and therefore the highest image resolutions listed above. Hundreds of comparable images were obtained over a period of several months. The orbit precesses on timescales of months, meaning the view from apoapse between dayside to nightside viewing and between the northern and southern hemispheres.

MAVEN's 4.5-hour elliptical orbit offers a unique observational perspective on the Mars atmosphere. While low circular orbits allow optimal resolution of the Mars surface, they do not allow global-scale imaging, and especially the wide range of local times that could be thereby sampled. From apoapse,



**Figure 2.** MAVEN/IUVS images of rapid cloud formation on Mars on July 9-10, 2016 ( $L_s \sim 183^\circ$ ). Image format as in Figure 1, with color scaling adapted for better visibility of clouds. The series interleaves two pairs of images spaced about one sol apart to show 7 hours of Mars rotation during this period. The Tharsis volcanoes, topped with white clouds, can be seen rotating across the disk. Tharsis clouds begin the day much smaller than the width of the volcanoes, but merge together in the late afternoon to span up to 2000 kilometers. Olympus Mons appears near the top of the image in frames 2-4; it appears dark because the volcano rises up above much of the scattering atmosphere. Dust storms appear as reddish-brown patches in Mars southern hemisphere.

MAVEN's vantage point allows viewing of  $\sim 9$  hours of local time, and  $\sim 4.5$  hour sampling. Furthermore, a near-commensurability between 11 orbits and two sols allows interleaving of data from adjacent sols for an effective  $\sim 2.25$  hour sampling for recurring phenomena (Figure 2).

## Results

Multicomponent spectroscopic retrievals on day-side images (Lefevre *et al.*, this conference) clearly distinguish the Mars surface, dust, clouds/ice, Rayleigh scattering, and ozone. The same features can readily be identified in the images. (Nightside imaging is capable of mapping nitric oxide nightglow (Stiepen *et al.*, this conference)). This presentation will focus on two notable phenomena visible in the IUVS images:

**Diurnal cloud formation movies.** As shown in Figure 2, IUVS images capture rapid orographic cloud formation over a span of  $\sim 7$  hours. Cloud formation studies yield critical information about circulation patterns, condensate budgets, temperature structure and other atmospheric properties (both observationally, e.g., Clancy *et al.* 2007, and through global circulation models, e.g. Forget *et al.*, 2014). Cloud formation movies will be shown for a variety of  $L_s$  values to identify stochastic variability and seasonal trends.

**Topography and dust storm analysis through Rayleigh scattering studies.** The altitude extremes of Valles Marineris and Olympus Mons can be clearly identified through the atmospheric scattering component, and additional features may be discernable (e.g., Hord *et al.*). Furthermore, high altitude dust storms can be distinguished by their low scattering spectral signature. We will report on potential uses of this aspect of the data, including seasonal variations in the features above. Spectra of these regions will be analyzed to determine whether Rayleigh scat-

tering by  $\text{CO}_2$  is a sufficient explanation or additional components such as haze or dust are required.

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