FIRST GLOBAL IMAGES OF MARS FUV DISCRETE AURORA FROM THE EMIRATES MARS MISSION EMUS INSTRUMENT

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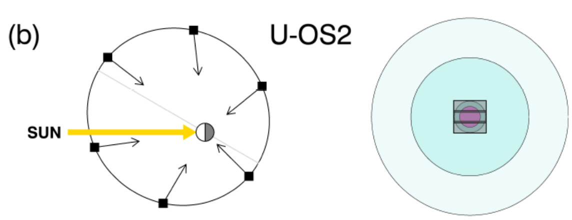
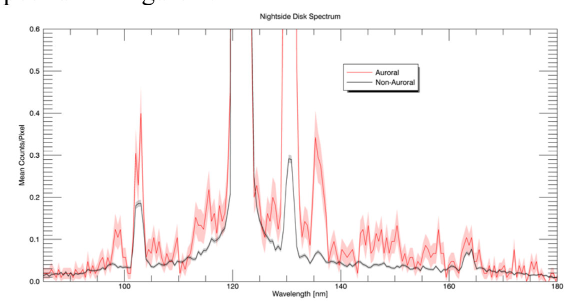
Mars Discrete Aurora: current understanding
Three major types of aurora have been discovered to occur in the Mars upper atmosphere: diffuse aurora [1], proton aurora [2], and discrete aurora [3]. The former two are produced by broad energetic charged particle precipitation during extreme solar wind disturbances and direct precipitation of solar wind protons, respectively. The latter is typified by discrete regions of ultraviolet emission from atoms and molecules electronically excited by the precipitation of accelerated electrons into the Martian thermosphere [4, 5]. It has primarily been observed from limb observations by MAVEN and Mars Express, and is most common in regions of strong, topologically open crustal magnetic fields. Aurora observations covering significant fractions of a hemisphere have been observed by MAVEN rarely and only in the mid ultraviolet (> 200 nm) [6].

Data Set: Here we report the first synoptic (or "disk") observations of Martian discrete aurora in the far ultraviolet (<200 nm). These are made by the Emirates Mars Ultraviolet Spectrograph (EMUS) on board the Emirates Mars Mission (EMM) and are well-suited to studying aurora due to a) EMM's high altitude vantage point and regular observation cadence and b) the high sensitivity of the EMUS instrument. The specific auroral observations are from the U-OS2 observation mode designed to study Mars' inner corona and includes significant coverage of the night side [7], as shown in figure 1.



From April 1 until December 31, 2021, 194 swaths provide sufficient coverage of the nightside to study discrete FUV aurora (defined as >30% of disk pixels have solar zenith angle >110°).

Spectrum: Emission is strongest at the 130.4 nm oxygen line (^{3}S decay to ground state ^{3}P), though it is also observed in oxygen features at 98.9 nm, 102.7 nm, and 135.6 nm, as well as possible emission in the CO fourth positive group bands, as shown in the typical spectrum in figure 2.



Results: overlapping swaths can be considered individually or stitched and averaged together to make a single synoptic image, as shown in figure 3. Discrete aurora show patterns broadly matching expectations (i.e. occurring more commonly in strong, open crustal field regions, as in figure 3, left). A notable exception is that the brightest aurora occurred away from crustal fields during the coronal mass ejection impact of July 21, 2021, during which discrete aurora are seen in weak crustal field regions (figure 3, right). Detectable aurora (>2 R in clear coherent patches) are detectable in approximately 55% of observations, are more common in the dusk versus dawn quadrants, and exhibit significant variability over timescales of ~20 minutes, reflecting natural variability in electron dynamics and magnetic field topology in the Mars near-space environment.

Looking forward: These synoptic images, combined with simultaneous measurements of suprathermal electrons and magnetic geometry and topology from MAVEN and Mars Express promise to elucidate the complex plasma processes driving Mars' enigmatic aurora.

References: [1] Schneider, N. M., et al. 2015, Science, 350, [2] Deighan, J., et al. 2018, Nat Astron, 2, 802, [3] Bertaux, J. L., et al. 2005, Nature, 435, 790, [4] Brain, D. A., et al. 2006, Geophysical Research Letters, 33, [5] Xu, S., et al. 2020, Geophysical Research Letters, 47, e87414, [6] Schneider, N. M., et al. 2018, Geophysical Research Letters, 45, 7391, [7] Holsclaw, G. et al. 2021, Space Science Reviews, 217, 79.

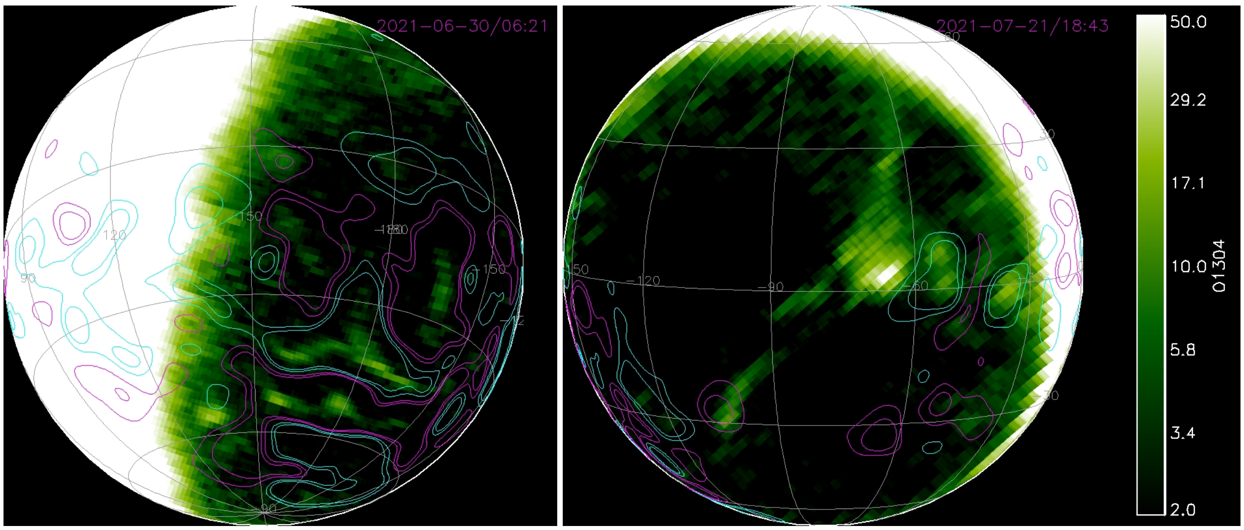


Figure 3: Examples of discrete Martian FUV aurora at 130.4 nm (emission in Rayleighs, log scale). Contours show Mars' crustal magnetic field (model from Langlais et al. [2019]) at 400 km altitude, where pink and turquoise are +10 nT and -10 nT, respectively. The left image is an example of aurora occurring in regions of strong vertical crustal magnetic field in Terra Sirenum, while the right image (the brightest seen thus far) occurred during the passage of an interplanetary Coronal Mass Ejection (ICME).