THREE TYPES OF AURORA OBSERVED BY MAVEN/IUVS: IMPLICATIONS FOR MARS' UPPER ATMOSPHERE ENERGY BUDGET

K. Connour, **N.M. Schneider, S.K. Jain**, **J.I. Deighan**, **M.S. Chaffin**, **A. Stiepen**, **C. Nasr**, **D. Brain, X. Fang**, **A.I.F. Stewart**, **M.J. Crismani**, **W.E. McClintock**, **G.M. Holsclaw**, **B. Jakosky**, *CU Boulder/LASP, Boulder CO, USA (kyle.connour@colorado.edu),* **J.T. Clarke**, **M. Mayyasi**, *Center for Space Physics, Boston MA, USA,* **J.S. Evans**, *Computational Physics Inc., Springfield VA, USA,* **J.C. Gerard**, **L. Soret**, *Laboratoire de Physique Atmosphèrique et Planètaire, Liège, Belgium,* **D. Larson**, **D.L. Mitchell**, **C.O. Lee**, **R. Lillis**, *Space Sciences Laboratory, Berkley CA, USA,* **C. Mazelle**, *Institut de Recherche en Astrophysique et Planètologie, Toulouse, France,* **J.S. Halekas**, *Univ. of Iowa, Iowa City IA, USA,* **R.V. Yelle**, **D.Y. Lo**, *Lunar and Planetary Lab, Tucson AZ, USA,* **M.H. Stevens**, *Naval Research Lab, Washington D.C., USA,* **F. Lefevre**, **F. Montmessin**, *LATMOS/IPSL, Guyancourt, France*

The Imaging Ultraviolet Spectrograph (IUVS) aboard the MAVEN spacecraft has detected three different types of auroral emission at Mars: discrete aurora (first reported by Bertaux *et al.* 2005), diffuse aurora (Schneider *et al.* 2015), and proton aurora (Deighan *et al.* 2016). The most widespread of these auroras, diffuse aurora were discovered at low altitudes and have been discovered to be coincident with the detection of highly energetic solar outbursts. Energetic electrons precipitate downward (down to ~70 km altitude), depositing their energy below the homopause. This has significant implications for the energy budget of the middle atmosphere. Discrete auroras have also been detected by IUVS near the crustal magnetic fields in Mars' southern hemisphere. These auroras are also created by the precipitation of energetic electrons but unlike diffuse aurora, which are thought to cover most of the planet for as long as the sun sustains energetic outbursts, discrete aurora are confined in space and time -- they are confined to the crustal magnetic field and have only been detected to be sustained for a few minutes. The spectroscopic signature differs significantly between diffuse and discrete aurora, indicating different physical processes involved with excitation and quenching in these auroras.

Proton aurora represent yet another type of aurora, but unlike diffuse and discrete aurora these have only been detected on the dayside of Mars and are characterized by enhanced hydrogen Lyman-α emission confined to the 120-150 km altitude range (Deighan *et al.* 2016). Detection of these aurora are characterized by a 50% increase in peak emission over the background levels, and these aurora have only been detected to last up to a few hours. Proton auroras appear to be correlated with solar wind activity. Charge exchange of solar wind protons in the Martian neutral hydrogen corona creates energetic, neutral hydrogen. The energetic hydrogen atoms enter the Mars thermosphere where they are repeatedly excited through elastic collisions, electron stripping, and charge exchange reactions, emitting Lyman alpha photons when neutral.

Understanding how these three types of aurora are created will help us better understand the interaction of Mars' upper atmosphere with solar wind, as well as the energy deposition caused by these auroras (Gérard *et al*. 2014, Gérard 2015).

IUVS measurements contain spectral information about these auroras. We will discuss the size of discrete aurora as well as duration these have been detected from IUVS. Altitudinally binned spectra will be used in order to determine the heights at which energy is deposited in Mars' atmosphere. We will also present preliminary modeling of proton aurora to better understand how Mars interacts with the solar wind.

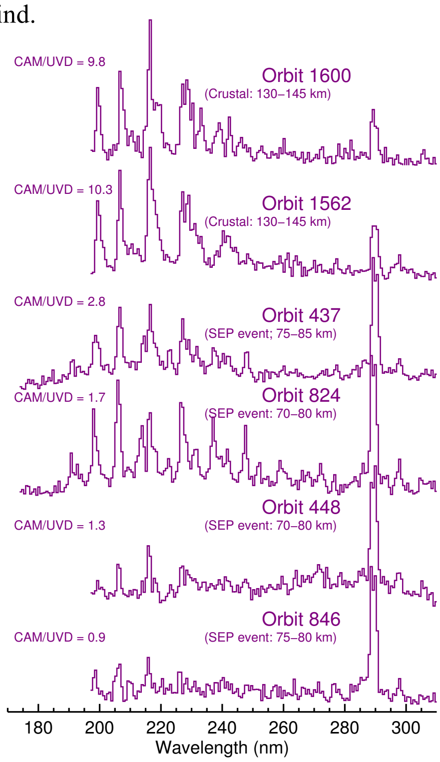

Fig. 1. Spectra at varying altitudes across different orbits. The top two spectra were obtained during discrete aurora events and the bottom four during diffuse aurora. In the discrete aurora spectra, note the higher altitude of deposition and the enhanced brightening of the Cameron bands relative to the UVD. Both are indicative of precipitation of lower-energy electrons.

References:

Bertaux, Jean-Loup, *et al.* “Discovery of an aurora on Mars.” *Nature* **435** (2005), 790-794.

Deighan. J.I., *et al.* “Discovery of proton aurora on Mars.” *49th Meeting of the AGU* (2016), P13D-01.

Gérard, Jean-Claude, *et al*. "Mars dayside temperature from airglow limb profiles: comparison with in situ measurements and models." *40th COSPAR Scientific Assembly*. Vol. 40. 2014.

Gérard, Jean-Claude. "The Mars discrete aurora: morphology, altitude and role of crustal magnetic field." (2015).

Schneider, N.M. *et al.* “Discovery of diffuse aurora on Mars.” *Science* **350** (2015) 1-5.