N_2 IN THE MARTIAN UPPER ATMOSPHERE IDENTIFIED USING DAYGLOW OBSERVATIONS FROM THE IMAGING ULTRAVIOLET SPECTROGRAPH ON MAVEN. M. H. Stevens[1], J.S. Evans[2], N.M. Schneider[3], A.I. Stewart[3], J. Deighan[3], S.K. Jain[3], W. E.. McClintock[3], G.M. Holsclaw[3], J.T. Clarke[4] and B.M. Jakosky[3]

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Introduction: Although the molecular nitrogen (N_2) mixing ratio is less than 10% in the upper atmosphere of Mars, isotopic evidence indicates that its primordial concentration was likely much higher [1,2]. A self-consistent explanation of N_2 loss over time must necessarily include the current N_2 mixing ratio. However, N_2 mixing ratios determined in recent observational and modeling studies disagree by up to a factor of three in the upper atmosphere [3-5]. Here we identify the N_2 Vegard-Kaplan (VK) bands in the mid-UV by the Imaging Ultraviolet Spectrugraph (IUVS) on NASA's Mars Atmosphere and Volatile Evolution (MAVEN) mission. These observations can be used to determine the N_2 abundance between 100-200 km.

The Observations: The MAVEN satellite is in an elliptical orbit with apoapsis near 6,000 km altitude and periapsis near 150 km. IUVS periapsis limb scans are herein used to obtain UV limb radiance profiles of the Martian dayglow, providing a vertical resolution of about 10 km in the 100-200 km region.

IUVS carries two detectors: one measuring the FUV airglow (110-190 nm) and one measuring the MUV airglow (180-340 nm) [6]. The MUV channel has a spectral resolution of ~1.1 nm, which is high enough to identify the relatively weak N_2 VK bands in the spectrally complex Martian dayglow [7]. The detector records images containing spectra in one dimension and spatial variations along the slit in the other dimension. To maximize the signal to noise ratio of the data used in this analysis, the spectra are averaged over the slit in the spatial dimension for each limb scan.

In October 2014 the solar zenith angles were low during the periapse passes (<60°), yielding relatively bright Martian dayglow observations. Figure 1 illustrates that the MUV spectrum is dominated by the bright CO Cameron bands as well as the CO_2^+ Ultraviolet Doublet (UVD) near 278 nm. Figure 1 also shows that the N_2 VK bands are much less prominent and require more detailed spectral analysis and retrieval methods for analysis.

Spectral Analysis: Quantifying the relatively weak N_2 VK emission requires precise knowledge of the instrument's point spread function, the underlying structure of the bright CO Cameron bands and the vibrational distribution of the VK bands.

The point spread function is determined using an IUVS measurement of the prominent H Lyman-α feature from the sunlit disk of Mars. The spectral width of this measurement is adjusted so that the observed shape of discrete features in the MUV observed near periapsis are reproduced (see Figure 1). The IUVS MUV wavelength scale is similarly defined to fit the known spectral positions of the observed features.

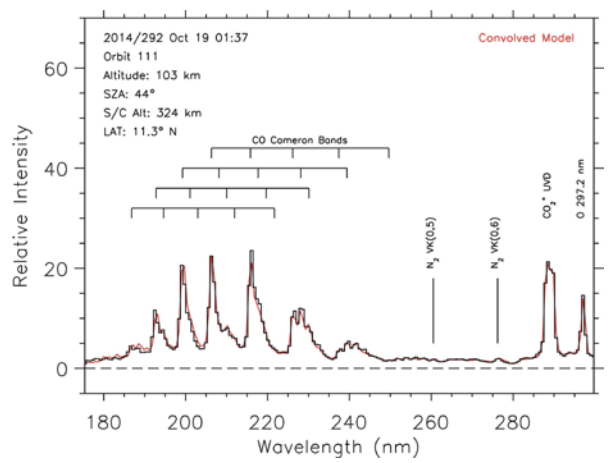

Figure 1.*Example of a mid-UV dayglow spectrum observed by IUVS on MAVEN (black histogram). The model spectrum convolved with the IUVS point spread function is overplotted in red. The CO Cameron bands are prominent while the weak N_2 VK (0,5) and (0,6) bands are weak but present near 260 and 276 nm. The orbit number, tangent altitude, solar zenith angle, spacecraft altitude and latitude are all indicated.*

The CO Cameron bands are produced primarily from photodissociation and electron impact dissociation of CO_2 [8]. However, the excited CO molecules have energy distributions that are not characteristic of the ambient Martian atmosphere. We use the upper state vibrational populations and branching ratios to the lower state reported by Conway [9]. Following the approach of Conway we derive a two temperature dis-

tribution to the Cameron bands to fit the IUVS observations. The synthetic spectrum containing the Cameron bands is smoothed and fit to the observed MUV data in Figure 1.

The VK rotational and vibrational structure is synthesized based on laboratory and terrestrial airglow observations. The N_2 VK band upper state vibrational populations are from Strickland *et al*. [10], which include the effects of cascade from higher lying vibrational states. Branching ratios to the lower states are from Piper [11]. The resultant synthetic VK spectrum is smoothed with the IUVS point spread function, sampled according to the derived IUVS dispersion relation and included in the fit to the MUV data in Figure 1.

All other known dayglow emissions on Mars [6,7] are similarly smoothed and included in the fit to the IUVS observations in Figure 1. A linear regression is used to identify the contribution from all the different MUV emissions. In this way, the spectral shape of each contribution is used to extract its intensity.

Figure 2 shows the spectrum resulting from the removal of all emissions from the IUVS spectrum except for the VK bands. The good agreement with the model spectrum in wavelength, spectral shape and relative intensity of the VK (0,5) and (0,6) bands indicates that N_2 is unambiguously identified in the dayglow data at Mars. Nearby VK features corresponding to the (2,6), (2,7) and (1,7) bands are also indicated.

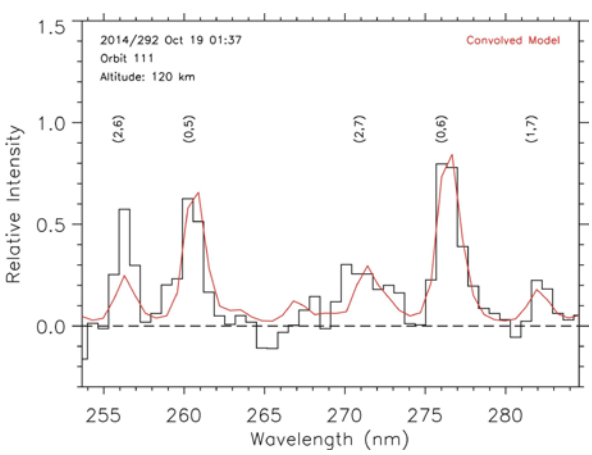

Figure 2. *Same data as in Figure 1 except that all contributions to the observed spectrum aside from N_2 VK have been removed. The best fit synthetic VK spectrum is overplotted in red. The VK (0,5) and (0,6) bands are clearly identified. Features corresponding to the neighboring (2,6), (2,7) and (1,7) bands are also present.*

Results and Future Work: The spectral analysis is applied to all altitudes in order to obtain an intensity profile of the N_2 VK emission (Figure 3). At the lower altitudes a small contribution for solar scattered light is identified and removed using a mid-UV solar spectrum. VK uncertainties from the multiple linear regression are overplotted in Figure 3. The shape of the profile and the location of the peak near 120 km are consistent with previous work [3, 5] and provide additional evidence that N_2 is identified in the IUVS data.

The VK bands are produced from photoelectron excitation of N_2 [12]. Quantitative understanding of the relevant emission cross sections and XUV solar irradiance producing the photoelectrons allow for N_2 retrievals in the Martian upper atmosphere. Future work includes the retrieval of N_2 number densities from the VK bands. Simultaneous MUV observations of the CO_2^+ UVD feature allow for the retrieval of CO_2 densities so that the N_2 mixing ratio profiles can be derived.

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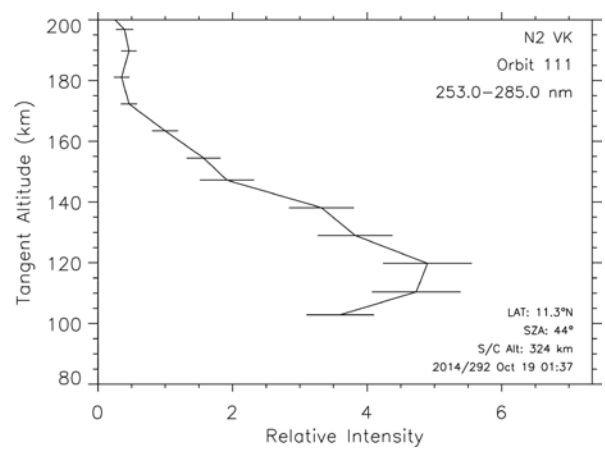

Figure 3. *N_2 VK intensity profile from MAVEN Orbit 111.*

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