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# MAPPING METHANE AND WATER DURING NORTHERN MID-WINTER AND MID-SUMMER ON MARS

**Robert Novak** (1), Michael Mumma (2) Geronimo Villanueva (3) Sara Faggi (4)
(1) Iona College, New Rochelle NY USA(rnovak@iona.edu), (2) Goddard Space Flight Center, Greenbelt MD USA (Michael.j.mumma@nasa.gov) (3) Goddard Space Flight Center, Greenbelt MD USA (geronimo.villanueva@nasa.gov, (4) Goddard Space Flight Center, Greenbelt MD USA, (sara.faggi@nasa.gov)

**Abstract:** In recent years, we have renewed our search for organic molecules (such as $CH_4$, $CH_3OH$, $H_2CO$, $C_2H_6$, $C_2H_2$, $C_2H_4$, etc.) in the atmosphere of Mars [1-3]. Here we report new detections of methane and water, and upper limits for the other molecules listed. These searches targeted Mars on 2 and 9 January 2017 (211°W to 136°W, $L_s$ ~ 293°) and 29 and 31 January 2018 (156°W to 256°W, $L_s$ ~ 122°) using the L3 setting on iSHELL (NASA-IRTF). The seasons on Mars were mid-Northern winter ($L_s$ ~ 293°) and mid-Northern summer ($L_s$ ~ 122°).

**Observations:** iSHELL is a cross-dispersed echelle-grating spectrograph (1.1 - 5.3 μm) with a resolving power of ~ 70,000. The L3 setting spans wavelengths in thirteen spectral orders ranging from 3.20 – 3.48 μm (Fig. 1). This spectral range includes absorption bands of the molecules listed above along with bands of water. On both nights in each run, the slit was positioned N/S on Mars along the central meridian and data were taken continuously as the planet rotated under the slit. We recorded data in 60 sec exposures, nodding the telescope in an ABBA sequence. Sufficient flats and darks were taken at the same spectral setting to avoid decreasing the signal to noise level after flattening. Typically, 28 minutes of accumulated Mars data were stacked, and spectral extracts were then extracted at 0.6 arc-sec interval in the latitudinal direction.

The Mars atmospheric spectrum was then isolated from the solar and terrestrial atmospheric features, and atmospheric models were generated for Mars to match the observed spectrum (Figure 2). Examples of spectral extracts from the data are located in Figure 3 for both methane detections and non-detections. Column densities were extracted for both $CH_4$ and $H_2O$ when detected. When not, and for other species, upper limits were detected. Results of these measurements will be presented and compared with results from previous observations [1].

When no $CH_4$ absorptions were observed above the noise level, an upper limit for methane was calculated to be ~ 1.0 ppb (3-σ). When detected, the column densities implied mixing ratios up to approximately 25 ppb. These detections are consistent with our previous findings [3] when we found abundances up to 35 ppb in a regions from 260° to 330°W and -30° to 50°N. That region barely intersects the region we observed in 2017 and 2018 and reported here. Data reductions taken near 270°W do show methane absorption. Further analysis is ongoing.

Several methane absorptions lines occur in orders 154 – 158. We plan to stack several of these lines. Since lines for $H_2CO$, $C_2H_6$, and $C_2H_4$ fall within the L3 setting, we will also extract column densities and/or obtain upper limits for them.

**Summary:** The observations presented here, along with our previous observations [3], indicate that methane, along with water vapor, is released in a plume from the sub-surface. After the release, the methane spreads across

the globe, providing the background methane density that has been detected. The release is seasonal, peaking in mid-summer. Several questions remain, especially why is the lifetime of methane in Mars' atmosphere so short. Further investigations, taken during different seasons of the year, are planned along with eventually mapping the entire planet to determine the location of other methane plumes.

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[1] Mumma et al., DPS 2015, [2] Villanueva et al., Icarus 2013, [3] Mumma et al., Science 2009.


Figure 1. Orders 155 and 157 from the L3 setting of iSHELL. These orders contain absorption lines of the P- and R-branches of $CH_4$ along with water. These two orders were isolated, cleaned of hot and dark pixels, and straightened.

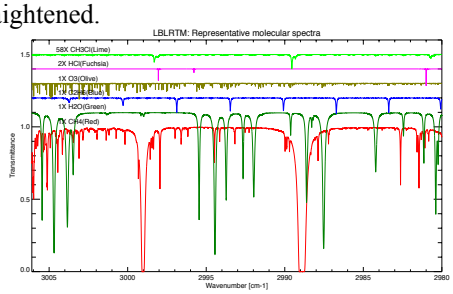


Figure 2. Atmospheric models used to analyze Mars data. Spectra from individual gases are combined to form a model atmosphere that is matched with the observed extracts. Models are constructed from the solar spectrum and the terrestrial spectrum. Once these are matched, then the Mars' spectrum results and it is further matched with a model. The values that are part of the model then become the measured values.

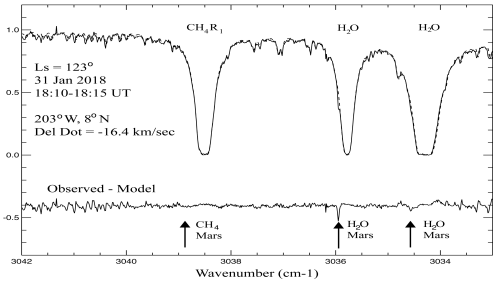


Figure 3a. A three-row spectral extract taken from the cleaned and straightened data of Figure 1. The upper trace is the total observed data. From this, the solar and terrestrial component are subtracted resulting in the reduced lower trace. This trace is used to measure the gases in Mars' atmosphere. $H_2O$ absorption are seen, but $CH_4$ absorptions are lacking.

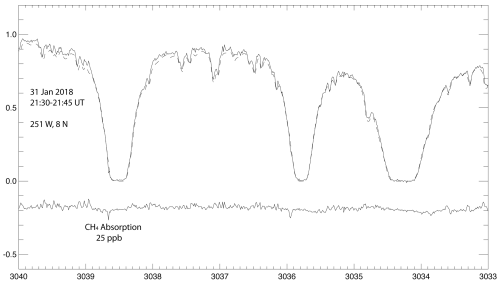


Figure 3b. A two-row extract similar to that in Figure 3a, but taken at a different location on Mars. Here, the $CH_4$ absorption is larger than the noise level (25 ppb).