Water Vapour in the Martian Atmosphere

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1. Introduction

Although, today's Mars is cold and dry, an abundance of evidence suggests that Mars, specifically the Northern hemisphere, was once partly covered in flowing liquid water. Hence, studying the water cycle on Mars is crucial due to its importance in understanding the evolutionary history of the Martian atmosphere that once allowed for liquid water to flow and the potential for habitability on the red planet.

Currently, Mars has very little water compared to earlier in its history, despite this, water is still important and plays a key role in Mars' climate. Much of the water found on Mars today is in the regolith, with some in the atmosphere and as water ice on the surface and sub-surface. Through analysis of spacecraft measurements of water vapour, combined with global circulation models, we have slowly been able to understand the seasonal and daily water vapour variations in the Martian atmosphere. However, the vertical mixing of water vapour is still not well understood.

2. Method

Using data from the ExoMars rover and Perseverance Rover, I will be studying the water vapour in the atmosphere by imaging the solar disk during sunset to allow for a larger path length and observe a larger part of the atmosphere. [Titov et al., 1999, Tamppari et al., 2020]

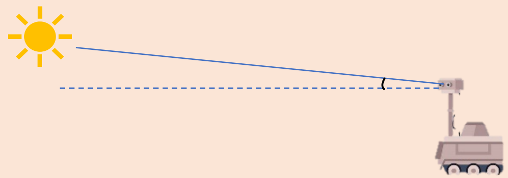

Figure 1: Schematic of rover position for image taking to detect water vapour

3. ExoMars: PanCam Instrument

The Rosalind Franklin rover on ExoMars will launch from Kazakhstan in 2022 and will land on Mars in June 2023. My project is to use the Panoramic Camera instrument, PanCam, built at the Mullard Space Science Laboratory, to study water vapour at Oxia Planum, the chosen landing site. [Vago et al., 2018] The PanCam Optical Bench (OB) contains a pair of wide-angle cameras and 1 High-Resolution camera. Each wide-angle cameras or WAC contains a filter wheel with 11 filters, a total of 22. [Coates et al., 2017] I will be working on 2 ultra-narrow band solar filters, L10 and L11, centred at 925+/- 5nm and 935 +/- 5nm to detect water vapour. Water vapour has a distinct absorption band at 936nm hence with these two filters, we can image at the band and in the continuum as shown in figure 2.

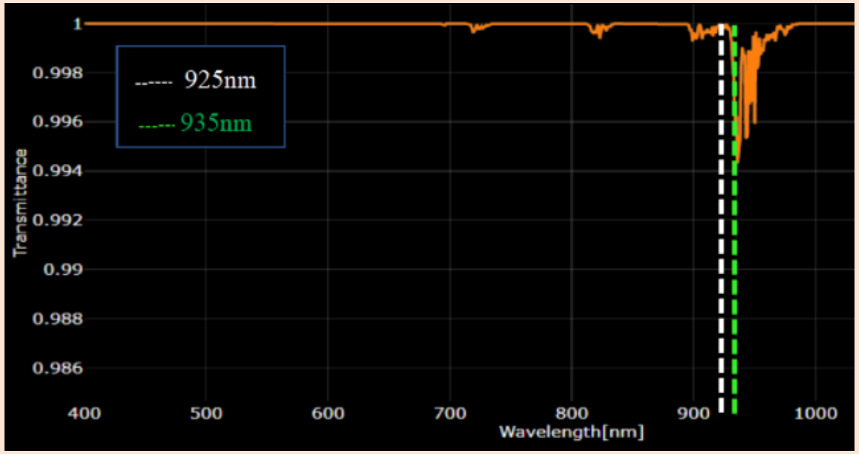

Figure 2: A figure showing how the Solar Filters on the PanCam instrument fit on the Water Vapour Spectrum generated through Planetary Spectrum Generator. The Orange is the generator spectrum of water vapour in the Martian Atmosphere, the green is the 935nm filter line and the white is the 925nm filter line. [Villanueva et al., 2018]

4. Results & Discussion

The solar filter transmissions were plotted for the L10 filter centred at 925nm as shown in the L11 filter centred at 935nm, shown in figure 3. The x-axis contains wavelengths between 900nm – 1000nm and the y-axis shows the transmission spectra.

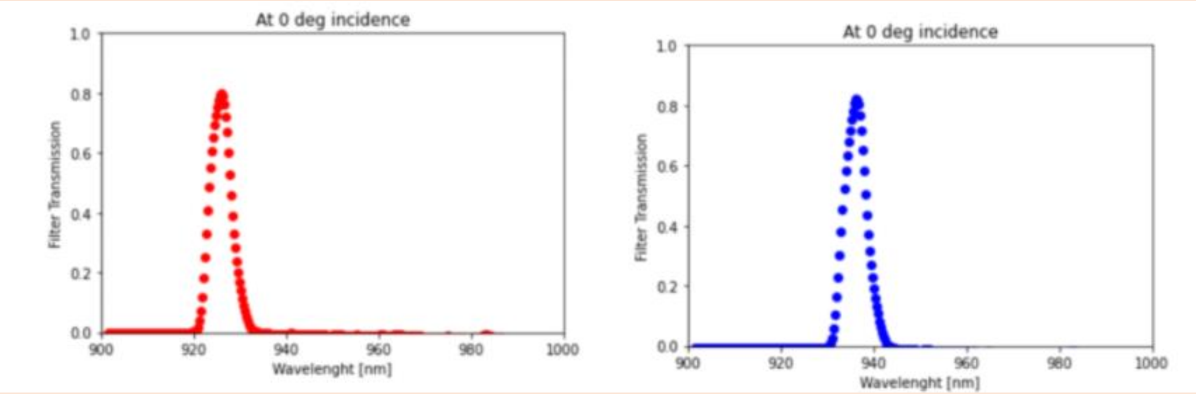

Figure 3: Graphs showing the transmission spectra for the L10 filter centred at 925nm in red on the left and the L11 filter centred at 935nm in blue on the right.

To gain a deeper understanding of the accuracy of the data we will receive from PanCam instrument, I multiplied the water vapour spectra generated from the Planetary Spectrum Generator with the filter transmission spectra. This produced the expected transmission, as a function of wavelength for both the L10 in red and L11 in blue solar filters as shown in figure 4. A strong signal is seen in the 935nm filter, hence the difference in signal in the two filters can be used to measure water vapour content in the atmosphere.

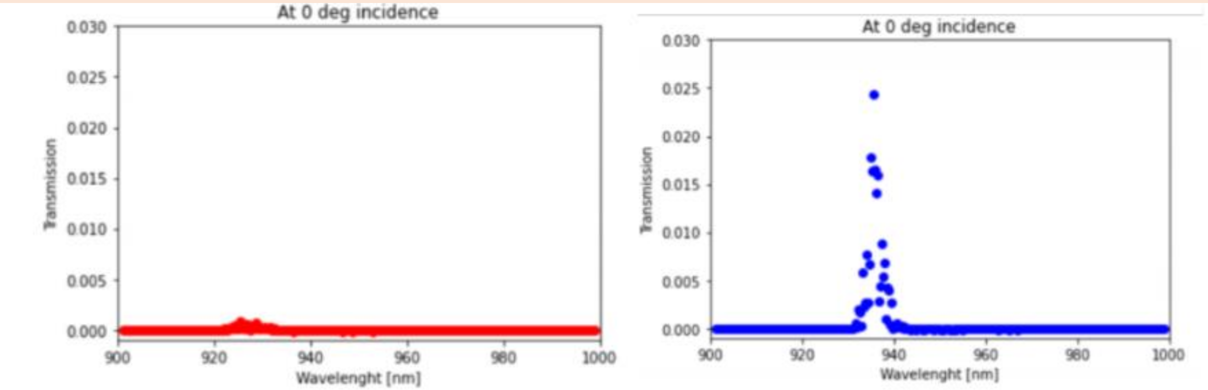

Figure 4: Graphs showing the expected transmission spectra containing water vapour signal for the L11 filter centred at 935nm in blue on the right and the transmission spectra in the 925nm solar filter on the left in red.

5. Mars2020: MastCam-Z

Similarly, the camera system onboard the Perseverance Rover can also be used to detect water vapour in the Martian atmosphere. I will be focusing on the MastCam-Z instrument, a stereoscopic imaging system and the MEDA instrument, aimed at collecting environmental data on Mars such as relative humidity. [Bell et al., 2021, Rodriguez-Manfredi et al., 2021] The filters R2, R3, R4 and R5 filters the strong water vapour absorption band and the continuum as shown in figure 5.

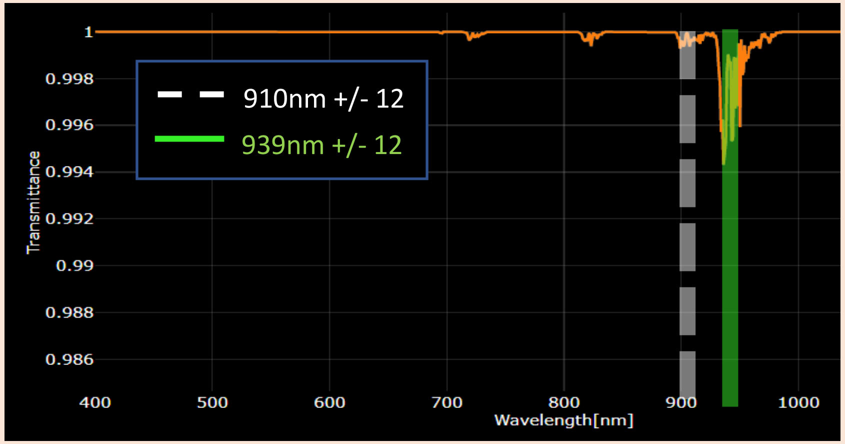

Figure 5: A figure showing how the Solar Filters on the MastCam-Z instrument fit on the Water Vapour Spectrum generated through Planetary Spectrum Generator.

6. Mars2020: MastCam-Z

- Using data from ExoMars Mars2020 rover to detect water vapour in the atmosphere

- Imaging the solar disk using the PanCam ultra-narrow band solar filters during sunset to sample a larger part of the atmosphere

- Constructing height profiles using NEMESIS retrieval tool, a general purpose correlated-K, multiple scattering radiative transfer and retrieval tool. [Irwin et al., 2008]

7. References

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