Studying global dust storms on Mars using high resolution spectroscopy

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Global Dust Storms

- Planetary scale storms that lift massive amounts of dust into the atmosphere rendering it opaque to visible and IR radiation and modifying several atmospheric properties.
- Since the first one, in 1956, there have been several confirmed detections of global dust storms. Zurek R. et al. (1973) calculated the probability of there being a planet circling dust storm on any given year to be ~1/3.
- Most of the detected storms happened during Mars' perihelion season (southern summer and spring), when the insolation is up to 40% (?) greater than it is in the rest of the year which increases dust devil activity and consequently dust lifting.

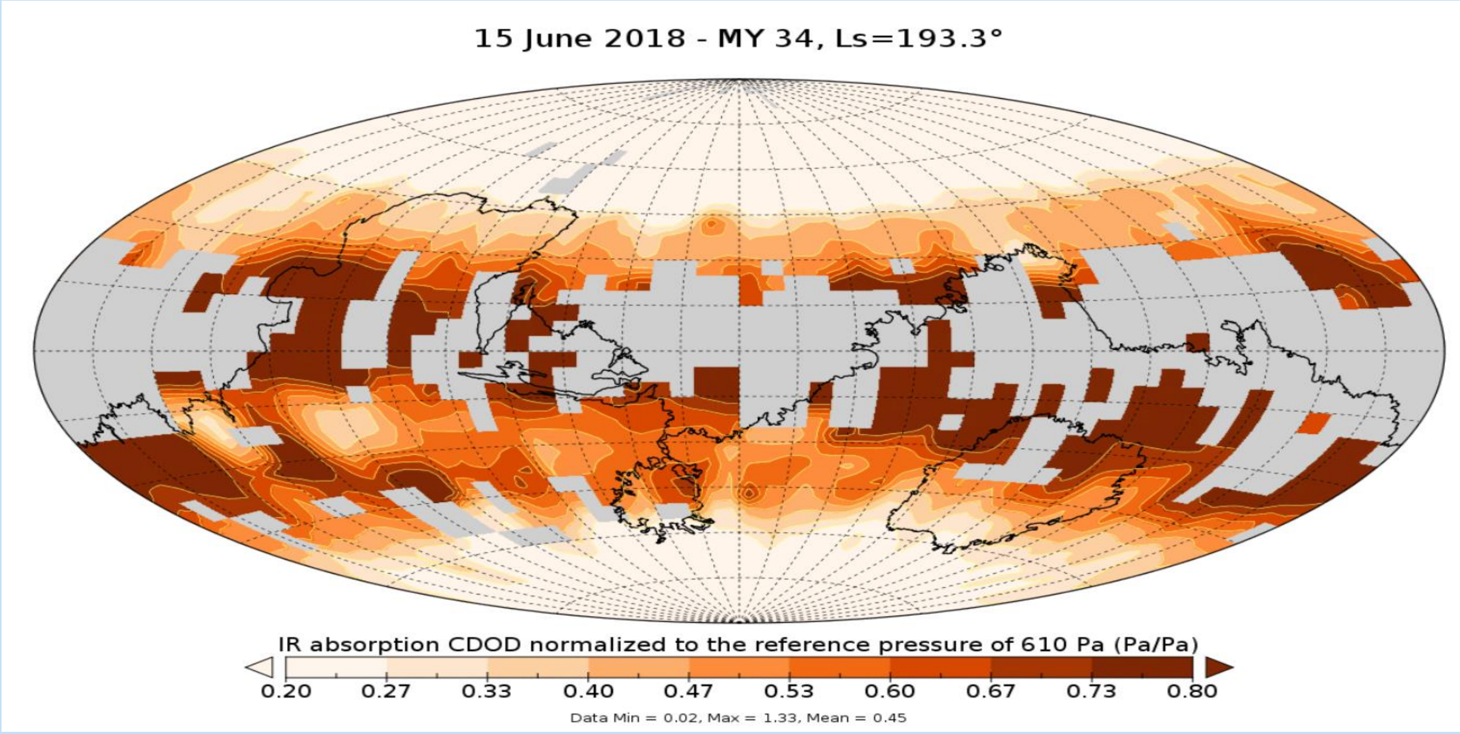

Fig 1: Infrared absorption column dust optical density of Mars in the 15th of June 2019 (Solar longitude = 193.3°) during the development of the global dust storm.

Doppler velocimetry using high resolution spectroscopy (UVES)

- The increased visual and ultraviolet optical depth associated with the dust storm allows the light to scatter in the lifted dust in the middle atmosphere.
- Observations with VLT's (Very Large Telescope) UVES' (Ultraviolet and visual Echelle Spectrograph) red arm allowed for the collection of the aerosol scattered light and subsequent acquisition of 80 high resolution echellogrammes.
- Each echellogramme contains 62 spectra (varying with latitude) each with several orders (16 for the MIT CCD and 23 for the EEV CCD).
- The first and last orders are generally incomplete and disposed of while the rest of the orders are concatenated to form a complete spectra.
- Data reduction was accomplished through UVES' pipeline (wavelength calibration, flat field correction and bias correction).
- By measuring the Doppler shift, induced by the moving aerosol, in the solar absorption features (common in the visual and ultraviolet wavelength range) in between two spectrums that were obtained simultaneously we can obtain latitudinal relative wind profiles.

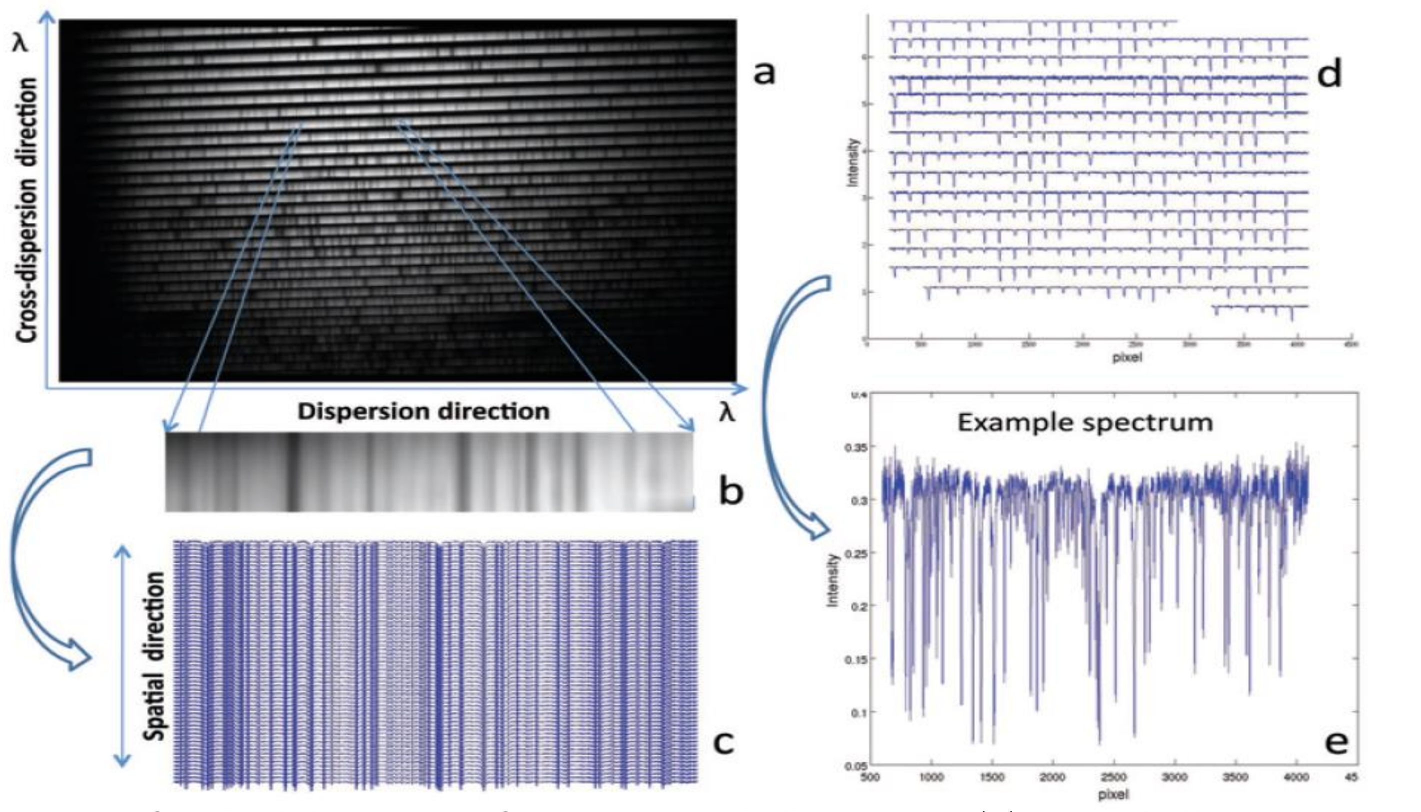

Fig 2: Steps for obtaining spectra from a UVES echellogramme. (a) Raw echellogramme showing the spectral orders for one of the detectors. (b) Magnification of part of one order, where absorption lines are visible. From each order, a stack of 64 spectra are extracted. (c) Set of 61 spectra, with each one corresponding to one pixel in the slit's active window. (d) Each spectrum is divided into 16 orders in the MIT detector and 23 orders in the EEV detector. The plot shows an example of the 16 components of an MIT spectrum, each coming from one spectral order. (e) Example spectrum from one order and one location in the Venus disk. Source: Machado, P., Dynamics of Venus' Atmosphere - Characterization of its Global Circulation with Doppler Velocimetry, Scholars' Press, 2013

Preliminary Results

- Obtained 64 spectra for each of the 80 observations.
- Retrieved preliminary Doppler velocities.

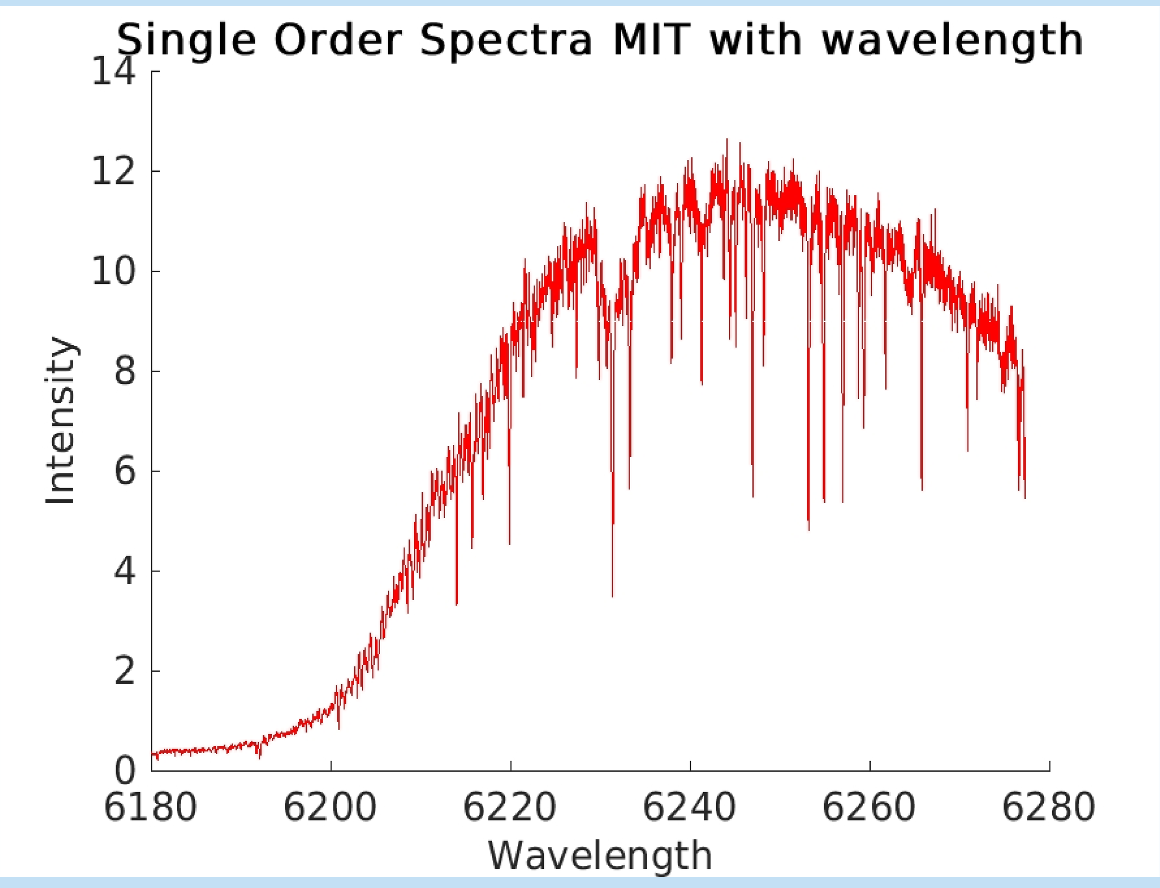

Fig 3: MIT spectra containing the 8th spectral order.

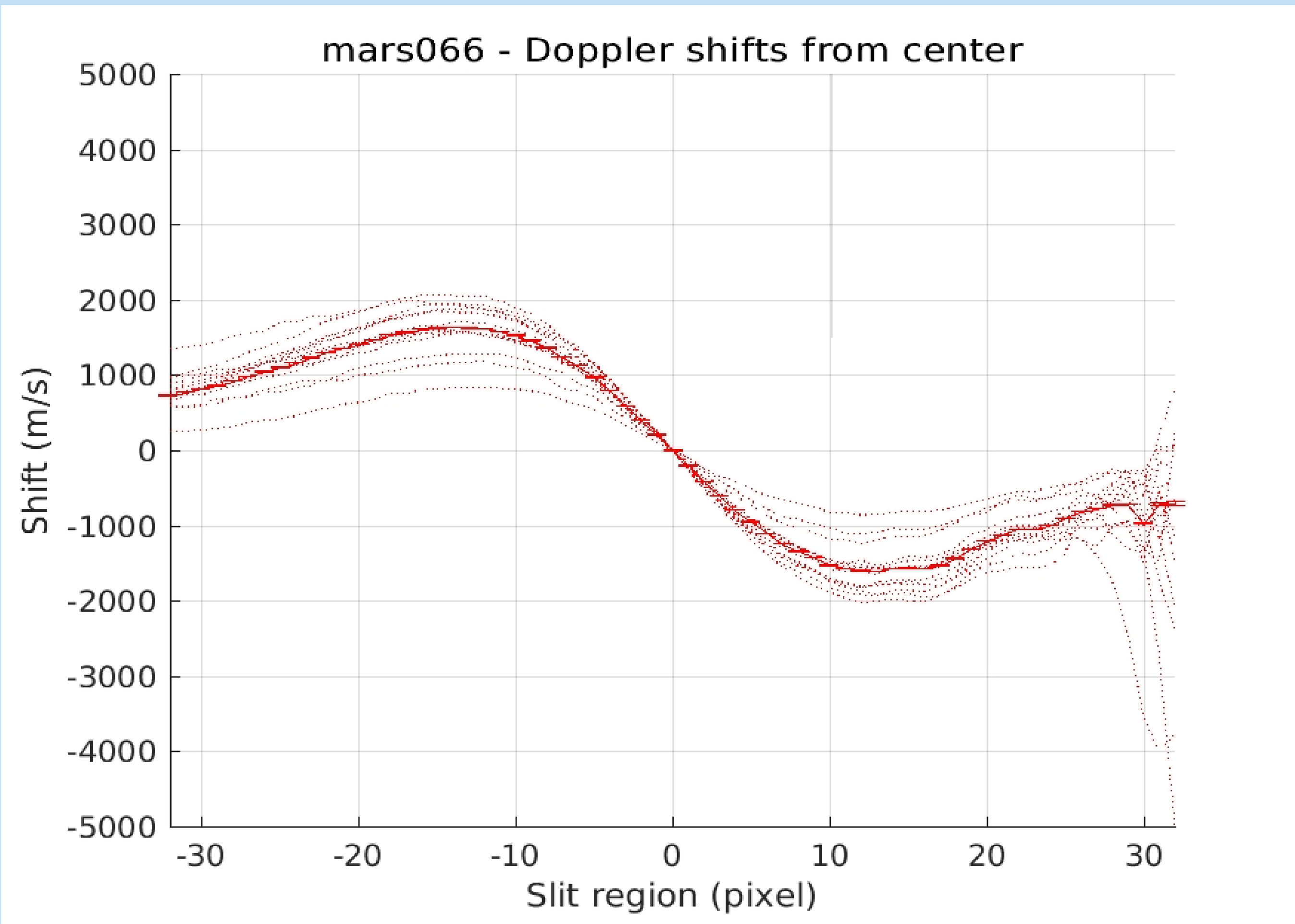

Fig 4: Measured relative (to the central pixel) Doppler shifts (meters per seconds).

Next steps

- Planetary rotation contribution subtraction is necessary as Mars's equatorial rotation velocity is not negligible (~240 m/s).
- The retrieved velocities are also affected by the geometry of the observations, they are projected to our line-of-sight and need to be de-projected.
- An evaluation of the contribution of the Young effect to the measured shifts is also warranted.
- Observation altitude constraint through coordinated ExoMars and Mars Express observations.

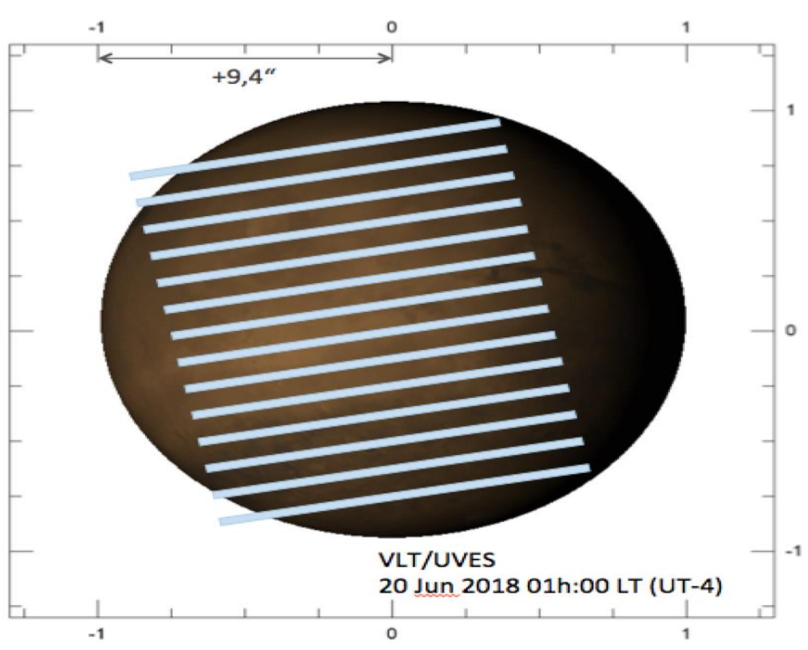

Fig 5: Observation's angular size and slit positioning (VLT/UVES). UVES slit's relative offsets perpendicular to Mars rotation axis and the UVES slit parallel to planetary rotation axis.

References

Machado, P. M., Luz, D., Widemann, T., Lellouch, E., Witasse, O. (2012), Mapping zonal winds at Venus's cloud tops from ground-based Doppler velocimetry, Icarus, Volume 221, Issue 1, p. 248-261, doi:10.1016/j.icarus.2012.07.012; Zurek, R. W., and Martin, L. J. (1993), Interannual variability of planet-encircling dust storms on Mars, J. Geophys. Res., 98(E2), 3247– 3259, doi:10.1029/92JE02936; R. M. Haberle, R. T. Clancy, F. Forget, M. D. Smith, and R. W. Zurek, Eds., "The Atmosphere and Climate of Mars," in The Atmosphere and Climate of Mars, Cambridge: Cambridge University Press, 2017, pp. i-I, doi:10.1017/9781139060172; Hans Dekker, Sandro D'Odorico, Andreas Kaufer, Bernard Delabre, and Heinz Kotzlowski "Design, construction, and performance of UVES, the echelle spectrograph for the UT2 Kueyen Telescope at the ESO Paranal Observatory", Proc. SPIE 4008, Optical and IR Telescope Instrumentation and Detectors, (16 August 2000); https://doi.org/10.1117/12.395512

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