Mars Mesospheric Winds around Northern Spring Equinox from High Resolution Infrared Spectroscopy

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We present observations of mesospheric winds on Mars around northern Spring Equinox. Data was gathered using ground based ultra-high spectral resolution observations of CO_2 features around 10 μm wavelength. Observations were carried out during three seasons (L_S=335, 357, 040) using the Cologne Tuneable Heterodyne Infrared Spectrometer (THIS) at the McMath-Pierce Solar Telescope on Kitt Peak, Arizona and the NASA InfraRed Telescope Facility on Mauna Kea, Hawaii). Heterodyne techniques allow a spectral resolution of more than 10^6 and thus the observation of fully resolved molecular features and the retrieval of Doppler shifts down to $\sim$1 MHz. In the case of our observations this corresponds to an accuracy of 10 m/s. In addition the high spatial resolution on the planetary disk intrinsic to infrared wavelength enables unique ground-based studies of latitudinal variations.

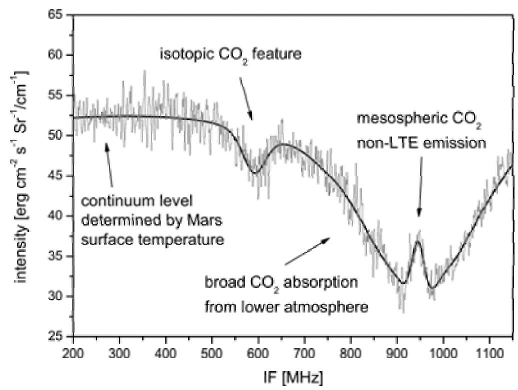

Figure 1: A typical spectrum of absorption and emission features of the P(2) CO_2 transition to retrieve Doppler-shifted wind velocities on Mars.

Tuneable Heterodyne Infrared Spectrometer - THIS

The Cologne Tunable Heterodyne Infrared Spectrometer - THIS Sonnabend et al. [1] is one of worldwide two IR heterodyne systems presently used for astronomical studies. The accessible wavelength range is between 7 and 13 μm constrained by the laser technology employed in the local oscillator and available detector/mixers. Currently tuneable Quantum Cascade Lasers are used as local oscillator and the detector is a Mercury-Cadmium-Telluride Photo Diode providing a bandwidth of $\sim$ 3000 MHz (3 dB cutoff). The spectral resolution of better than 3 x 10^7 is not accessible using direct detection method.

The instrument consist of two parts: the optical receiver contains all the optical components and is housed in (80 x 60 x 45) cm^3 aluminium cube with a weight of approx. 80 kg. Two thermal loads at known temperature provide absolute intensity calibration while a reference gas cell provides absolute spectral information. The instrument can be attached to various types of telescopes (Coude, Nasmyth, Cassegrain). All the electronical equipment inculding the back-end Acousto-Optical Spectrometer (AOS) and equipment for data aqusisiton is mounted in a standard rack. The instrument is easily transportable and has been used at various telescopes.

High Spatial Resolution Mesospheric Wind Measurements

In the atmosphere of Mars non-LTE processes lead to an enhanced mesospheric emission of CO_2 molecules in the 9 and 10 μm band [2, 3]. These narrow emission features can be used to measure Doppler-shifts induced by winds with an accuracy down to 10 m/s. The emission is embedded in a broad absorption feature originating at low altitudes of the Martian atmosphere (<3 mBar level). Fig. 1 shows a typical spectrum from Mars. The non-LTE emission is contributed from the Mesosphere (50–90 km altitude) creating the characteristic profiles shown in Fig. 1. A frequency shift between the absorption and the emission component can be directly converted to a line-of-sight velocity and, given the observational geometry, into a zonal wind shear between the two altitude regions [2, 3]. If the absolute frequency of the observation is known, independent measurements of the two velocities are possible. Due to the small line width of the emission features ($\sim$25 MHz FWHM) a high spectral resolution of $> \frac{\nu}{\Delta\nu} > 10^6$ is required.

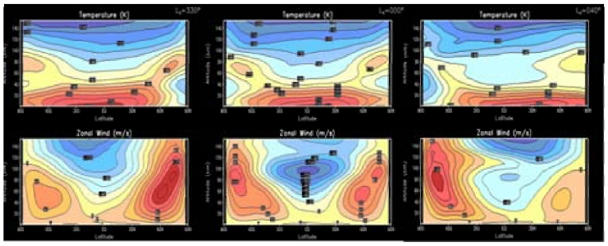

Figure 2: Model predicted temperature and zonal wind field for the Martian atmosphere for three season (L_S=330,000,040), matching the times of the conducted observations. The predicted transition from dominant northern to southern latitude jet is nicely visible.

Intention, observations and results

During the last decade general circulation models (GCM) for Mars have evolved to a state allowing detailed predictions of atmospheric dynamics. Wind speeds are a key variable in the models and need to be validated by observations. In coordination with modellers we put a focus on studying the evolution of dynamcis in the upper atmosphere of Mars around northern Spring Equinox ($L_S = 0$). As shown in Fig. 2 model calculations predict the global circulation around 50 to 100 km altitude to change from a dominant northern jet configuration during northern winter to a dominant southern jet configuration in early northern summer [4]. Season 1 (as described in Fig. 2) was observed in November 2005 and the results from that campaign are in reasonable agreement to the model predictions [3] as can be seen in Fig. 3. Two additional observing campaigns were conducted in November 2007 and March 2008 to match the seasons 2 and 3. The season 2 observations were carried out using THIS at the McMath-Pierce telescope on Kitt Peak/Arizona. The season 3 observations were carried out using THIS for the first time at the NASA IRTF on Mauna Kea/Hawaii. Data analysis for both runs is still ongoing but initial analysis shows that the quality of the acquired data is very good and thus these observations will provide the first seasonal study of zonal winds on Mars with direct comparison to model predictions.

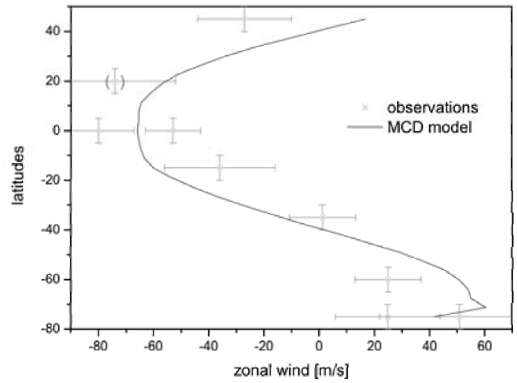

Figure 3: Comparison of retrieved wind velocities from L_S=330 to longitudinal and altitudinal averaged values from the Mars Climate Database (MCD) [4].

References

[1] G. Sonnabend, M. Sornig, P. Kroetz, D. Stupar, and R. Schieder. Ultra high spectral resolution observations of planetary atmospheres using the Cologne tuneable heterodyne infrared spectrometer. *JQSRT*, 109:1016–1029, April 2008.

[2] G. Sonnabend, D. Wirtz, V. Vetterle, and R. Schieder. High-resolution observations of Martian non-thermal CO_2 emission near 10 μm with a new tuneable heterodyne receiver. *AA*, 435:1181–1184, June 2005. doi: 10.1051/0004-6361:20042393.

[3] G. Sonnabend, M. Sornig, P. J. Kroetz, R. T. Schieder, and K. E. Fast. High spatial resolution mapping of Mars mesospheric zonal winds by infrared heterodyne spectroscopy of CO_2. *GRL*, 33:18201–+, September 2006. doi: 10.1029/2006GL026900.

[4] S. R. Lewis, M. Collins, P. L. Read, F. Forget, F. Hourdin, R. Fournier, C. Hourdin, O. Talagrand, and J.-P. Huot. A climate database for Mars. *JGR*, 104:24177–24194, October 1999. doi: 10.1029/1999JE001024.