Potential of High Resolution Mid-Infrared Heterodyne Spectroscopy to Study the Martian Atmosphere

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High resolution spectroscopy is a versatile tool to study planetary atmospheres. In the mid infrared wavelength regime the highest possible spectral resolution is provided by applying heterodyne techniques. At spectral resolution of more than 10^5 observations of fully resolved molecular features are possible allowing retrieval of many physical parameters from single lines. Due to the fact that many of the observed species are abundant also in the Earth's atmosphere, high resolution measurements allow to peak through the telluric features and lead to less ambiguity than low resolution data. In addition the high spatial resolution on the planetary disk intrinsic to infrared wavelengths enables unique ground-based studies of planetary atmospheres like Mars. A short description of the Cologne Tuneable Heterodyne Infrared Spectrometer - THIS and its specific application to the atmosphere of Mars will be presented.

Tuneable Heterodyne Infrared Spectrometer - THIS

The Cologne Tunable Heterodyne Infrared Spectrometer - THIS [1] is one of worldwide two IR heterodyne systems presently used for astronomical studies. The accessible wavelength range is between 7 and 13 μ 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 ~3000 MHz (3 dB cutoff). The spectral resolution is better than 3 x 10^7 which is not feasible with any 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 aluminum cube with a weight of approx. 80 kg (see Fig. 1). It can be attached to various telescopes (Coude, Nasmyth, Cassegrain) with different F-numbers between 10-60. The second part contains all the electronical equipment including the brick-end spectrometer an Acousto-Optical Spectrometer (AOS) and equipment for data acquisition. The entire instrument can be shipped to different telescopes and mounted within several hours.

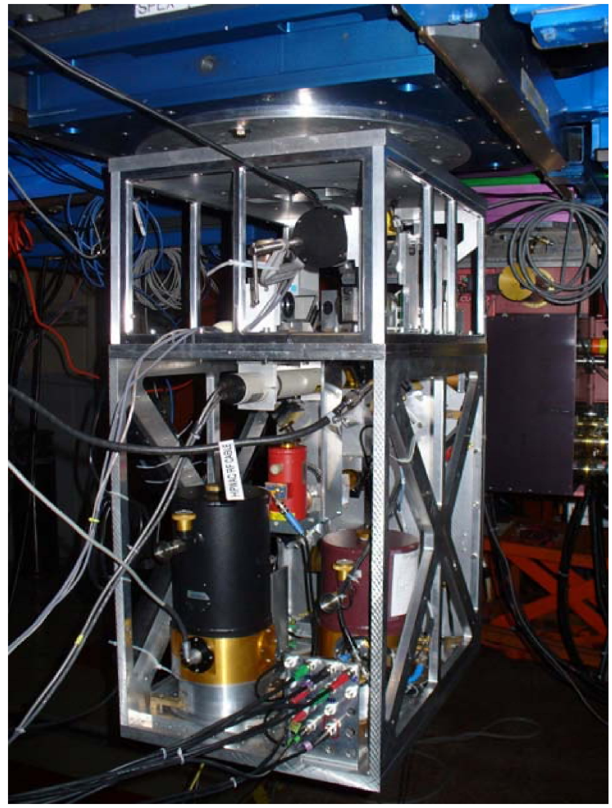

Figure 1: The Cologne Tuneable Heterodyne Receiver THIS mounted at the NASA Infrared Telescope Facility on Mauna Kea, Hawaii in March 2008.

High Spatial Resolution Mesospheric Wind Measurements

In the Martian atmospheres non-LTE processes lead to an enhanced mesospheric emission from CO_2 molecules in the 10 μm band. These very narrow emission features can be used to detect Doppler-shifts induced by winds with an accuracy down to 10 m/s. Fig. **??** shows a typical spectrum from Mars. The broad absorption features are detected in absorption vs. the surface brightness and originate at low altitudes of the Martian atmosphere (<3 mBar level). In addition non-LTE emission is contributed from the mesosphere (50-90 km altitude) creating the characteristic profiles. 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]. In case 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 $\nu/\Delta\nu \sim 10^6$ is required.

Methan Measurements

The high spectral resolution of infrared heterodyne observations provides the opportunity for detection of Martian methane lines at 7.8 μm wavelength. This capability provides the opportunity to unambiguously distinguish Martian and terrestrial absorption contributions during specific observing periods providing a high Doppler-shift between Mars and Earth of $\geq$ 15 km/s which results in a redshift of the Martian feature of 2.2 GHz. Abundances down to $\sim$ 10 ppb are detectable within $\sim$ 10 h of integration with THIS including all losses introduced by optical and electronical components. Initial measurements at the most promising line at 1277.4734 cm^{-1} were accomplished in March 2008 at NASA IRTF on Mauna Kea, Hawaii, USA, but were limited by bad weather conditions.

Detection of Variation in Surface Pressure

In addition to wind information from frequency shifts, the above mentioned CO_2 features provide information about pressure near the surface on Mars due to the shape of the line wings of the absorption feature. This opens a possibility to measure low/high pressure wave patterns similar to weather systems on Earth. First test measurements to determine the sensitivity of THIS to pressure variations were accomplished in November 2007 and March 2008.

Temperature and Photochemistry on Mars

The high spectral resolution and frequency precision of heterodyne detection enables the measurement of fully resolved absorption and emission line shapes of atmospheric species such as CO_2, O_3, CH_4, which contain information on the regions of their formation. Analysis of line shapes of well-mixed species retrieves constraints on temperature profiles. Photochemistry on Mars can be probed by direct measurement of lines of O_3, an important tracer of such processes [4].

References

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