HIGH RESOLUTION GROUND-BASED OBSERVATIONS OF METHANE IN THE MARTIAN ATMOSPHERE AT 7.8 MICRONS WAVELENGTH.

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We present an atmospheric study of methane (CH_4) on Mars. Data were gathered using ground based ultra-high resolution spectroscopic measurements of CH_4 absorption features around 7.8 μm wavelength. Observations were carried out from 26th April to 8th May 2010 using the Cologne Tuneable Heterodyne Infrared Spectrometer (THIS) at the McMath-Pierce Solar Telescope on Kitt Peak, Arizona.

Introduction

The detection of methane in the Martian atmosphere has been claimed by various groups since 2003 [1, 2] but only recently its presence has been undoubtedly established by Mumma et al. [3] who found strong variation of methane with season, latitude and longitude at a mixing ratio of up to 40 ppbV in late Northern summer. But all these detections were reported at 3.3 μm. The only other detection in a second wavelength range (7.8 μm) was reported by Fonti et al. [4]. However, due to the low spectral resolution of the used spectrometer (TES on MGS, 12.5 and 6.25 cm^{-1} resolution) these measurements leave room for ambiguity. Therefore a confirmation using high resolution spectroscopy is still needed. However, the question of the origin of the observed and variable amounts of CH_4 is still open. Its production by atmospheric chemistry is negligible, and its lifetime due to destruction by photochemistry is estimated to be only a few hundred years [5, 6, 7] or even shorter if strong oxidants such as peroxides are present in the surface or on airborne dust grains [8]. Thus, the presence of the now detected amounts of CH_4 require its recent release from sub-surface reservoirs or its production within the atmosphere. The ultimate origin of this CH_4 is uncertain, but it could be either abiotic or biotic [6, 9, 10]. Even more puzzling is the reported variability over the Martian year. A significant change of the methane concentration from >40 ppbV to <10 ppbV within two Martian seasons requires also a strong methane sink. What this sink could be is completely unknown. Observations of molecules related to the two processes in question (for example SO_2) as well as better understanding of the horizontal and vertical distribution of methane are necessary to draw further conclusions.

Instrumentation

High resolution spectroscopy at infrared wavelength has proven to be a powerful tool to study planetary atmospheres as many physical parameters such as composition [11, 12]. A spectral resolution of better than 10^6 allows one to fully resolve profiles of single molecular features. This is a strong advantage as the analysis of low resolution data in general requires more information about the state of the studied atmospheres which has to be provided from additional observations or models.
Heterodyning means the superimposition of the radiation to be analyzed with a reference radiation. The latter is the so called local oscillator (LO). THIS (Tuneable Heterodyne Infrared Spectrometer) [13] is one of only two IR heterodyne instruments worldwide accomplishing astronomical observations. It was designed and developed by our group at University of Cologne using tuneable quantum-cascade lasers (QCLs) as LO's, which offers the unique possibility to observe methane at 7.8 μm.

High-resolution heterodyne spectroscopy at the strong

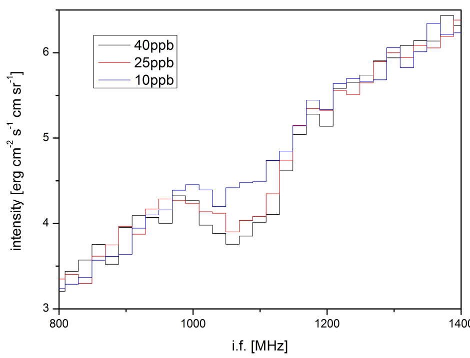

Figure 1: Simulated spectrum of methane calculated using a full radiative transfer model. Spectra are calculated for three different volume mixing ratios of methane of 10, 25 and 40 ppbV. The simulated noise represents four hours of integration time at the instrument's sensitivity at 7.8 μm and 4.2 km altitude which was established during a test observation in 2008.

methane band at 7.8 μm can lead to new insights to the vertical mixing ratio profile and can provide further independent prove of the existence and more detailed data on the abundance and distribution of methane in the atmosphere of Mars, helping to determine the location of the methane source either on or under the surface or within the atmosphere itself. The methane features are comparable in strength to the lines that fall into the usually used 3 μm window. However, at the longer wavelength reflected sunlight does not contribute significantly to the observed spectra thus analysis and interpretation of the acquired data is much easier. Our calculations (see Fig.1) show that THIS is capable of detecting volume mixing ratios of methane down to 10 ppbV. The simulated noise represents four hours of integration time at the instrument's sensitivity at 7.8 μm which was established during a test observation in 2008.

Observation

Observations of methane from the ground require careful selection of wavelength ranges and observing dates. Only few days timed around the maximum Earth-Mars Doppler shift are suitable to separate the Martian lines sufficiently from their telluric counterparts. Even then, the maximum expected transmission through the telluric atmosphere is 20% at 2km altitude justifying the need for two weeks of continuous observations.

On account of this we acquired observing time in the

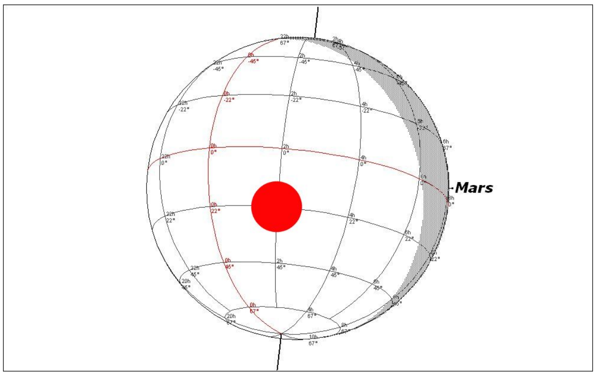

Figure 2: The observing geometry for the April 2010 run at McMath-Pierce telescope. The diameter of the apparent disk of Mars was around 7 arcsec. The size of the red cricle represents the actual FOV of the telescope relative to the apparent diameter of Mars.

end of April 2010 (Martian season of Northern summer (L_S=80)) at the McMath-Pierce telescope in Arizona. Northern summer is a season which has not been observed before but if methane is released from subsurface reservoirs as most observers believe a strong increase in the methane mixing ratio can be expected starting in Spring (L_S=0) and continuing throughout the summer. The diameter of the apparent disk of Mars was around 7 arcsec. At a diffraction limited resolution of the telescope of 1.3 arcsec at 7.8 μm we were able to resolve the planetary disk and study a specific region of Mars (see Fig.2,3).

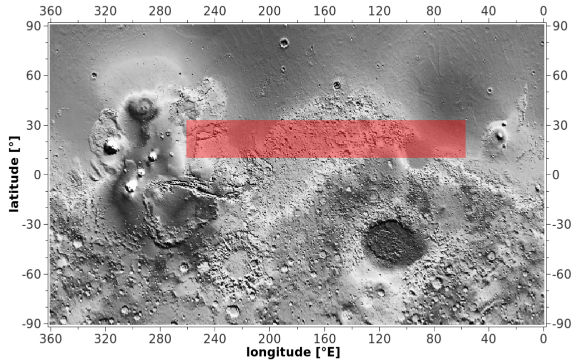

Figure 3: Overview of the observed area on Mars is highlighted in red. The background surface map of Mars was taken from "Google Mars" (http://www.google.com/mars/).

Conclusion

Fig.4 presents the measured heterodyne spectrum. Due to unfavorable weather (80% of the observing time was lost) and technical problems the signal to noise ration is worse than expected. For that reason only an upper limit of ∼100 ppbV for the methane mixing ration in the observed area (see Fig.3) can be deduced.

Another interesting fact is, that we received less signal

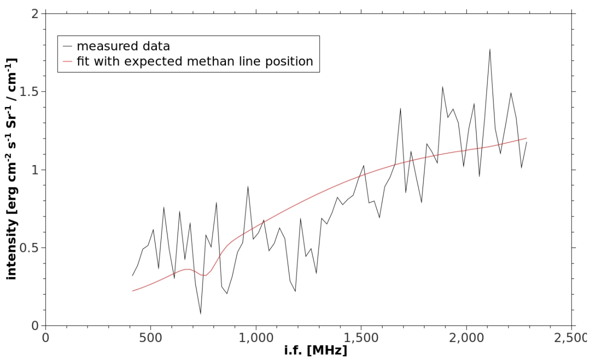

Figure 4: Heterodyne spectrum with a resolution of 25 MHz at 7.8 μm with an integration time of 29.5 houres. Red: Best fit with the expected methan line position assuming 40 ppb.

from Mars. An explanation of this could be, that the maximum transmission through the telluric atmosphere

is less than the expected 20 % at around 7.8 μm. Consequently we have to adopt our atmospheric model for future observations.
At the conference we are going to present the analyzed data from this run and show an outlook.

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