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Martian mesospheric temperatures from high-resolution infrared spectroscopy of CO_2

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Abstract

During the last decade general circulation models (GCM) for Mars have evolved to a state allowing detailed predictions of the state of the martian atmosphere. Temperatures are a key variable in the models and need to be validated by observations. Especially in the upper atmosphere temperatures are only poorly constraint by observations. Heterodyne spectroscopy of CO_2 at 10 μm wavelengths is a powerful tool to study temperatures in the upper atmospheres of the terrestrial planets. Temperatures can be calculated from fully resolved non-LTE emission lines probing an altitude of ~70 km. We will present temperature retrievals from observations between 2005 and 2010 covering an L_S range from 335-60.

1. Introduction

On Mars as well as on Venus mesospheric non-local thermodynamic equilibrium (non-LTE) emission of CO_2 can be observed, a phenomenon first discovered in 1976 [1]. Kinetic temperatures can be calculated from the width of the fully resolved emission lines. As long as stimulated emission is negligible kinetic linewidths probe the physical temperature of the emitting gas.

The altitude of the emitting region in the atmosphere is determined by the ratio of collisions induced to the probability of spontaneous emission for the excited CO_2 molecules and was found to be around 70 km for Mars and 110 km for Venus [2, 3]. Temperatures were retrieved very successfully on Venus with an accuracy of better than 10 K. A typical spectrum from Venus is shown in Fig.1.

On Mars the situation is more complicated. Due to the lower intensity of the non-LTE component of the spectrum and the higher continuum level an absorption feature of CO_2 is clearly visible in addition to the emission component (see Fig.2). Since the underlying absorption can significantly alter the apparent width of the emission component a detailed analysis and removal of the absorption is necessary.

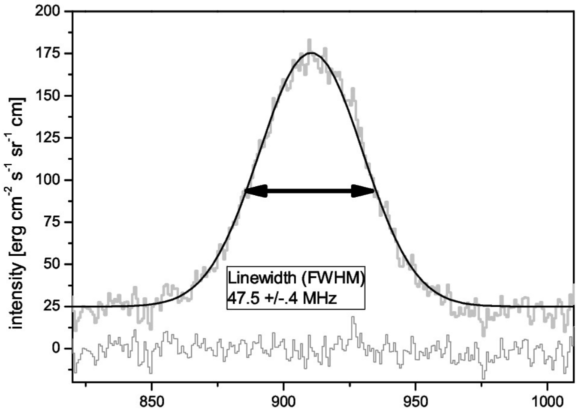

Figure 1: A typical non-LTE CO_2 emission spectrum from Venus. Plotted is the intensity vs. the intermediate frequency for the P(16) line at 947.74198 cm^{-1}. Data were taken at the equator and 45 deg offset from Venus CML. Integration time was ~4 minutes. Plotted over the data is a fit to the observed line using a radiative transport code (see text for more information). The inset plot shows the residuals. The linewidth of 47.5 MHz yields a temperature of ~235K [4].

2. Observations

Observations were carried out between 2005 and 2010 covering four seasons on Mars (L_S=335 (2005), 357 (2007), 40 (2008), 60 (2010)) using the Cologne Tuneable Heterodyne Infrared Spectrometer (THIS) [5] 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. In addition, the high spatial resolution on the planetary disk intrinsic to infrared wavelength enables unique

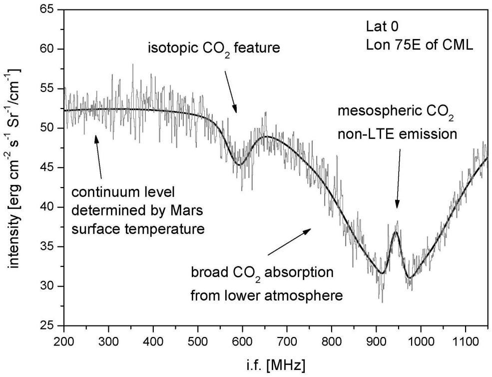

Figure 2: A typical spectrum of absorption and emission features of the P(2) CO_2 on Mars.

groundbased studies of latitudinal variations. In addition, since the altitude of the observed emission cannot be determined from the data directly we use the Granada non-LTE radiative transfer code [3] to estimate the altitude distribution of emission in our observed spectra.

3. Data Analysis

In order to successfully remove the absorption feature we need information about the temperature structure of the lower atmosphere where the absorption line is formed (<3 km). The complex observing geometry has to be taken into account. Where available we use temperature profiles from MRO/MCS. If no observational support data is available we use predicted values from the Mars Climate Database (MCD) [6]. The absorption feature is then modeled using a radiative transfer code (Codat/Beamint) developed by a group at NASA/GSFC [7] and taken out of the spectra to be analyzed. Final temperature retrievals are under way. We estimate an accuracy of up to 10 K for individual retrieved temperatures.

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