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Thermospheric/mesospheric temperatures on Venus: comparison between ground-based high-resolution spectroscopy of CO_2 and other techniques

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Abstract

We report temperatures in Venus' upper mesosphere/lower thermosphere, deduced from analyzing very high resolution infrared spectroscopy of CO_2 emission lines acquired in 1990, 1991 and 2009. Kinetic temperatures at $\sim$ 110 km altitude (0.15 Pa) are derived from the Doppler width of fully-resolved single line profiles measured near 10.4 μm wavelength. Venus was close to inferior conjunction in all observations. Measured temperatures range from $\sim 200 - 240$ K with uncertainty typically less than 10 K. Comparisons are made to Temperatures retrieved more recently from the SOIR instrument on Venus EXpress and from ground-based sub-mm retrievals. Temperature variability appears to be high on day-to-day as well as longer timescales.

1. Introduction

On Venus as well as on Mars 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.

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 110 km for Venus and 70 km for Mars [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.

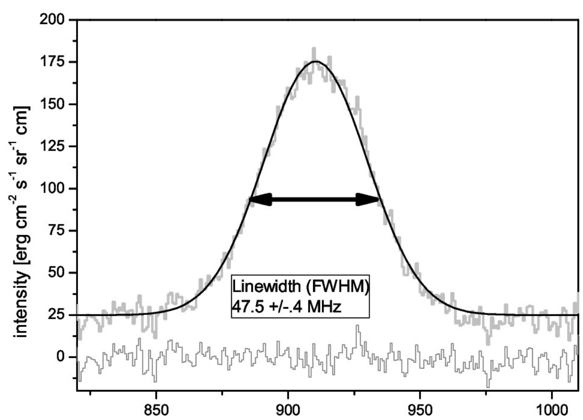

Figure 1: A typical non-LTE CO_2 emission spectrum from Venus. Plotted is the intensity vs. the intermediate frequency for the P(16) line at 947.74198 cm^{-1}. Data were taken at the equator and 45 deg offset from Venus CML. Integration time was $\sim$4 minutes. Plotted over the data is a fit to the 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 $\sim$235K [4].

2. Observations

Observations were acquired at the NASA Infrared Telescope Facility (IRTF, Mauna Kea, Hawaii, USA) in January/February 1990 and August/September 1991 using the NASA Goddard Infrared Heterodyne Spectrometer (IRHS).

Additionally, Venus was observed during three observing campaigns in 2009. Two campaigns shortly before and after inferior conjunction in March/April 2009, and one campaign at maximum western elongation in June 2009. The two campaigns in March and April were scheduled symmetrically around inferior conjunction to investigate possible asymmetries of the temperature distribution between the morning and evening limb. All three campaigns were performed at the McMath-Pierce Solar Telescope on Kitt Peak, Arizona. Observations were carried out using the Cologne receiver THIS. A detailed description of the instrument and the heterodyne technique is given in [5]. In THIS as well as in IRHS an integrated optical guide system provides accurate pointing information and allows active telescope tracking.

3. Data Analysis

The observed emission line profiles have Gaussian line shapes as the pressure at the emitting altitude is sufficiently low to neglect pressure broadening.

The kinetic temperature of the gas is retrieved from the width of the observed emission line, in which the temperature is directly proportional to the square of the line width according to the standard results of statistical mechanics for a gas in thermal equilibrium,

$$\Delta\nu_{\mathrm{D}} = \frac{\nu_0}{c}\sqrt{\frac{8k_B T_{kin}\ln(2)}{m}} \quad (1)$$

. The full width at half-maximum (FWHM) of the observed Doppler-broadened line is $\Delta\nu_{\mathrm{D}}$, ν_0 is the rest frequency of the observed transition, m is the molecular mass of CO_2, T_{kin} is the kinetic temperature in Kelvin, and the proportionality constants c and k_B are the speed of light and the Boltzmann constant, respectively.

4 Results and discussion

Measurements with IR heterodyne spectroscopy demonstrate a high variability of Venus' upper mesospheric/lower thermospheric temperatures. Short-term variations of up to 30 K at low latitudes within a few (Earth-)days were recorded. Close to the poles temperatures tend to be more stable with variability of up to 15 K. This is in agreement with other observations performed using sub-mm Earth-based and near-IR spectroscopy. This indicates a much more turbulent atmosphere at altitudes around 100-120 km than thought before. The observed variability between the campaigns has to be studied in more detail before valid conclusions can be drawn.

The temperature retrievals from different observing techniques for the given altitude of 110 km altitude agree quite well if the limitations of observational constraints are taken into account. Differences to the sub-mm values can be explained by the different FOV while disagreement to the SOIR values is due to FOV and limitation to terminator measurements. The comparison to space observations from SOIR are promising and a good example for the complementarity of ground based and space based observations.

The observed high temperature values disagree with the VIRA atmosphere model as presented by [6]. However, the authors of that work state already that the simple division into day and night time profiles without latitudinal or local time dependence for the altitude range of 100 to 150 km is due to the lack of data and that reality might be far more complex. Thus, a new reference atmosphere model is urgently needed.

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References

[1] Johnson, M. A., Betz, A. L., McLaren, R. A., Townes, C. H., & Sutton, E. C. 1976, ApJ Letters, 208, L145

[2] Deming, D., & Mumma, M. J. 1983, Icarus, 55, 356

[3] Lopez-Valverde, M., Sonnabend, G., Sornig, M., & Kroetz, P. 2011, PSS, in press

[4] Sonnabend, G., Kroetz, P., Sornig, M., & Stupar, D. 2010, GRL, 37, 11102

[5] Sonnabend, G., Sornig, M., Krötz, P., Stupar, D., & Schieder, R. 2008, JQSRT, 109, 1016

[6] Keating, G. M., Bertaux J. L. , Bougher S. W., Dickinson R. E., Cravens T. E., and Hedin A. E. (1985), Models of Venus neutral upper atmosphere - Structure and composition, Adv. Space Res., 5(11), 117-171