EPSC Abstracts
Vol. 9, EPSC2014-396-1, 2014
European Planetary Science Congress 2014

Weak absorptions in high density planetary atmospheres measured by the cavity ring down technique.

M. Snels (1), S.Stefani (2) and G.Piccioni (2)
(1) Istituto di Scienze dell'Atmosfera e del Clima (ISAC)- Consiglio Nazionale delle Ricerche (CNR) , Rome, Italy,
(2) Istituto di Astrofisica e Planetologia Spaziali (IAPS)- Istituto Nazionale di AstroFisica (INAF), , Rome, Italy,
m.snels@isac.cnr.it / Fax: +39-06-49934323

Abstract

High density planetary atmospheres are characterized by a high opacity due to the strong absorbers. Howevere usually several transparency windows exist which allow to study the lower part of the atmosphere as well as the surface emission. The weak absorptions occurring in these transparency windows are mostly due to trace species and to continuum absorption of the major absorber(s). A good example is the atmosphere of Venus, where carbondioxide causes a high opacity throughout most of the infrared wavelengths, but also has some transparency spectral windows in the near infrared, allowing the study of low lying clouds , trace species such as water vapor and in some cases the surface emission. The cavity ring down (CRD) technique has shown to be a good tool for studying weak absorptions. Here we present a CRD apparatus which can be operated at high pressures (up to 40 bar) with a sensitivity which allows to measure attenuations up to 2x10^{-8} cm^{-1}. This instrument has been used to measure the carbon dioxide absorption at pressures up to 40 bar and has been also used to measure attenuation due to Rayleigh scattering at 1.18 μm.

1. Introduction

The cavity ring down technique allows to achieve effective optical paths of several kilometers by using resonant optical cavities, equipped with highly reflective mirrors, with a reflectivity typically better than 99.97 %. We use a continuous wave tunable diode laser coupled to a stable optical cavity, immersed in a high pressure container to measure weak absorption of carbon dioxide around 1180 nm. By measuring the cavity ring down times for an empty cavity and in presence of an absorber one can obtain the attenuation coefficient α which is defined as

$$\alpha = \frac{1}{c\tau} - \frac{1}{c\tau_0} \tag{1}$$

where

$$\tau = \frac{n}{c}\left(\frac{L}{1 - R + \alpha L}\right). \tag{2}$$

and

$$\tau_0 = \frac{n_0}{c}\left(\frac{L}{1 - R}\right), \tag{3}$$

Here the attenuation or extinction coefficient comprehends losses due to both absorption and scattering processes.

2. Results and discussion.

CRD measurements have been performed on pure carbon dioxide at room temperature and at pressures up to 38 bar [1] around 1180 nm. Carbon dioxide has no allowed absorption bands in the 1.18 μm window and the very weak absorption present here is due to Rayleigh scattering, collision induced bands, and far wings of nearby absorption bands. In presence of small number densities of water vapor (about 30 ppm is to be expected) also water lines can be observed. Here we choose a laser wavelength of 1180.7 nm, in order to avoid residual water vapor absorption.

The results of the CRD measurements on pure carbon dioxide at 1180.7 nm are displayed in figure 1, and have been fitted to the equation

$$\alpha = \alpha_0 + \alpha_1 \cdot D + \alpha_2 \cdot D^2, \tag{4}$$

where D is the density in mol/l, α_0 the losses in absence of gas, i.e. due to cavity mirror losses, α_1 is the attenuation coefficient due to linear absorption and Rayleigh scattering, and α_2 stands for the binary absorption coefficient, due to collision-induced phenomena.

The measurements allow to separate two contributions to the attenuation, one is linear with density and is due to Rayleigh scattering, the other one is quadratic

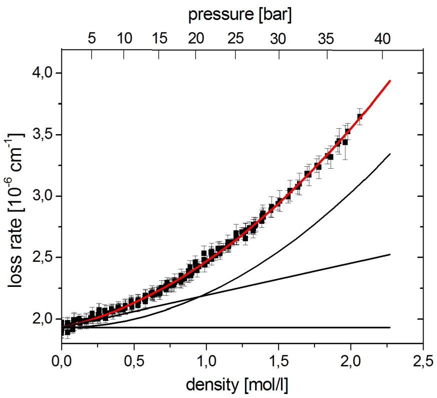

Figure 1: The square boxes represent the loss rate measured with the CRD technique, as a function of the density of the pure carbon dioxide sample at a temperature of 293 K. The bold red line indicates a least mean squares fit by a second order polynomial. The black lines indicate the constant, linear and quadratic contributions obtained from the fit. The error bars correspond with the standard deviation of the measurement. Pressure values have been indicated on the top x-axis.

with density and is due to processes involving two body collisions, including far wings and collision induced bands. We thus obtain a linear attenuation coefficient, which is in good agreement with the predicted Rayleigh scattering coefficient and a binary absorption coefficient, which compares well with the results of an analyses of SPICAV and VIRTIS spectra in the lower atmosphere of Venus [2, 3]. Presently new CRD measurements at higher temperatures are being performed in order to extrapolate the room temperature CRD data to the temperatures present in the lower atmosphere of Venus.

Acknowledgements

The authors acknowledge Angelo Boccaccini for his precious assistance in the experimental work. We also acknowledge ASI for funding part of the work (project I050/10/0) in the framework of the ASI-projects VENUS-EXPRESS and JIRAM.

References

[1] Snels, M. Stefani, S., Piccioni, J. and Bezard, B., Carbon dioxide absorption at high densities in the nightside transparency window of Venus, Journal of Quantitative Spectroscopy and Radiative Transfer 133, 464-471, 2014

[2] Bézard, B., Tsang, C., Carlson, R. ,Piccioni, G. , Marcq, E. and Drossart, P., Water vapor abundance near the surface of Venus from Venus Express/VIRTIS observations, Journal of Geophysical Research-Planets, 114, E00B39, 2009.

[3] Bézard, B., Fedorova, A. , Bertaux, J.-L. , Rodin, A. and Korablev, O. , The 1.10- and 1.18-μm nightside windows of Venus observed by SPICAV-IR aboard Venus Express, Icarus, 216, 173-183, 2011