Stronger Greenhouse Effect on Early Mars: Collision-Induced Absorption by CO2-H2 and CO2-CH4 Complexes

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Abstract

An unanswered question in planetary science is how could the early Martian atmosphere have maintained a greenhouse effect sufficient to allow for liquid water on the surface? A recent study by Wordsworth et al. (DOI:10.1002/2016GL071766) suggested that previously unaccounted-for collision-induced absorption (CIA) by carbon dioxide (CO2) and hydrogen gas (H2), and by CO2 and methane (CH4) could provide the additional atmospheric absorption needed to trap enough radiation to raise the Martian surface temperature above freezing. However, as CIA cross-sections for CO2-H2 and CO2-CH4 complexes do not exist in the literature, the authors could only use computational methods to simulate the CIA absorption cross-sections that they themselves identify in the study as needing experimental validation. Preliminary results will be presented from experimental measurements of the CIA cross-sections for CO2-H2 and CO2-CH4 complexes performed using Fourier Transform Spectroscopy. We have obtained Beam-time at the Canadian Light Source Far-IR beamline in late October and early November which will allow us to derive Cross-sections over a spectral range of 0-3000 cm⁻¹ and a temperature range of 200-350 K. In addition to allowing us to experimentally validate the hypothesis of Wordsworth, the cross-sections so obtained can also be applied to other planetary systems with CO2-rich atmospheres, such as Venus, and will be useful to terrestrial spectroscopists.
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Introduction

- Geological evidence on Mars strongly suggests there was once liquid water on its surface.
- Most atmospheric models of ancient Mars have difficulty producing sufficient warming to raise the surface temperature above 2°C.
- A recent study by Wordsworth et al. [1] suggested that previously unaccounted-for collision-induced absorption (CIA) by carbon dioxide (CO2) and hydrogen gas (H2) could provide the additional atmospheric absorption needed to trap enough radiation to raise the Martian surface temperature above freezing.

Theory

- CIA cross-sections for CO2-H2 and CO2-CH4 complexes do not exist in the literature over the full spectral and temperature range desired; so the authors could only use computational methods to simulate the CIA absorption cross-sections that they themselves identify in the study as needing experimental validation.
- Recent work done by Turbet et al. [2], have investigated CIA of CO2-H2 and CO2-CH4 complexes at room temperature in the range of 40-640 cm⁻¹.

Experimental Details

- Experiments were performed at the FAR-IR beamline of the Canadian Light Source (CLS) Synchrotron.
- Applications for beamtime at the CLS is a highly competitive process; this project was awarded two weeks of beamtime.
- The FAR-IR beamline has a White cell that was used to detect the weak CIA absorption features.
- The White cell has a maximum pathlength of 7274.93±6 cm, and a maximum pressure of 1 atm.
- Safety protocols at the CLS limit explosive gas mixtures to maximum 20% CH4 and 8.5% H2.
- No combination of beam splitter, windows, and detector cover the full spectral range, so the experiment is divided into two optimal regimes.
- Below 600 cm⁻¹, polypropylene windows, Si bolometer detector, and mylar beam splitter are used.
- Above 600 cm⁻¹, KBW windows and beam splitter, and MCT detector are used.

Experimental Results

- Experimental measurements of CO2-CO2 CIA at three different temperatures.
- Strange signal observed around 70 cm⁻¹, unclear what caused it.
- General agreement with calculations by Gruza and Borysow [3].
- 250 K result weaker than expected.

Conclusions

- Experimental measurements of CO2-H2 CIA at three different temperatures.
- Water contamination present in the 250 K measurement.
- Agreement with Turbet et al. [2] that the experimental results are weaker than the theoretical predictions of Wordsworth et al. [1] below 600 cm⁻¹. Absorption by CO2 is causing anomalous intensity values from 550 to 1000 cm⁻¹.

References:

[2] Martin Turbet, Ha Tran, Olivier Pirali, François Forget, Christian Boulet, Jean Michel Hartmann, Far infrared measurements of the far infrared collision induced absorption spectra of gaseous CO2 (1 250 K result weaker than expected. General agreement with calculations by Gruszka and Borysow [3]. Strange signal observed around 70 cm⁻¹. Agreement with Turbet et al. [2] that the experimental results are weaker than the theoretical predictions of Wordsworth et al. [1] below 600 cm⁻¹. Absorption by CO2 is causing anomalous intensity values from 550 to 1000 cm⁻¹. Carbon Dioxide CIA

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