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Search for evidence of Butane on Titan with new spectroscopic data

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1. Introduction

Detecting the presence of large chemical compounds is critical for understanding the photochemistry and dynamics of planetary atmospheres and in particular of Titan's organic rich atmosphere. On Titan, complex photochemical reactions lead to the formation of numerous heavier hydrocarbons, including several hydrocarbons with C_3 and C_4 frameworks.

The Composite InfraRed Spectrometer (CIRS) on-board Cassini has recorded spectra of Titan in the far and mid-infrared since 2004 with a spectral resolution up to 0.5 cm^{-1}. The Cassini mission is ending in September of 2017 and infrared observations from the ground at higher resolution are already planned. In recent years, it is in fact from remote facilities that new detections in Titan's stratosphere were obtained, including HNC (Moreno et al. 2011, using Herschel), C_2H_3CN and C_2H_5CN (Cordiner et al. 2014, 2015, using ALMA).

Yet, photochemical models for Titan, developed since the pioneering work of Yung et al. (1984) and now accounting for ion-neutral reactions (e.g. Yelle et al. 2016, Dobrijevic et al. 2016), indicate that still undetected hydrocarbons are expected to be present and observable in Titan's atmosphere. This is the case, in particular, of butane (C_4H_{10}) which is predicted to be as abundant as propane (C_3H_8), a molecule detected in Titan's atmosphere with CIRS through many vibrational bands (Nixon et al. 2009).

2. Butane

C_4H_{10} is a large molecule with two isomers, isobutane and n-butane, the latter presenting two conformers (trans and gauche). Each species has 36 vibrational modes and most of the bands are very congested. Because of this complexity, there is no plan to try a rotational analysis leading to a classical line list.

Until recently, only low resolution (0.1 cm^{-1}) and room temperature laboratory spectra of isobutane and n-butane were available in the literature. In this study we have recorded absorption cross sections of butane below 200 K to come as close as possible to the atmospheric conditions in Titan's stratosphere. Using the AILES high resolution spectrometer and the Globar light source (see Figure 1), we have recorded for the first time n-butane spectra at temperature as low as 150 K. We have observed very important variations with the temperature, in particular due to the varying relative abundance of the trans and gauche conformers. Most spectra were recorded at 0.1 cm^{-1} resolution due to the low luminosity of a Globar light source but one 12 hours' spectra could be recorded at 0.03 cm^{-1} showing very sharp features in particular for the bands centred at 733 and 966 cm^{-1}, as can be seen in figure 1.

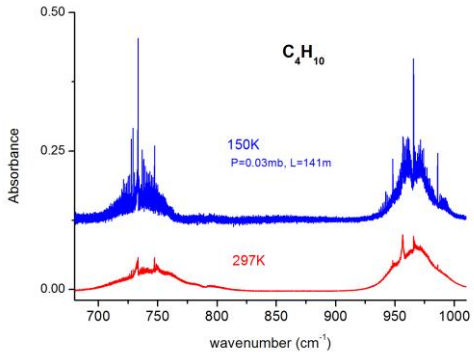

Figure 1: n-butane spectra at room and low temperature.

This means that butane can be searched in CIRS spectra of Titan with good chances due to the increase in the band contrast in low temperature conditions and with even better chances from the ground at higher resolution.

Similar measurements with the other conformer of butane, isobutane are planned. The goal is to study the detection possibilities of isobutane at low temperature as well.

References

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