EPSC Abstracts
Vol. 6, EPSC-DPS2011-1440, 2011
EPSC-DPS Joint Meeting 2011

Improving on Titan's stratospheric trace gaseous composition of and searching for new molecules using CIRS spectra

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Abstract

Titan is one of the most interesting objects in the Solar System considering its large size and its dense nitrogenous atmosphere rich in organics. Indeed, the Cassini-Huygens mission has reported many Earth-like characteristics of Saturn largest moon verifying the Voyager 1 results 30 years ago. In this work, focusing on Titan's stratosphere, we will report the mixing ratios of traces gases in respect to previous studies and we will search for new molecules.

1. Introduction

Without doubt, the Cassini-Huygens mission has significantly advanced our perspective of the Saturnian System. The Composite Infrared Spectrometer (CIRS) [1] on board the Cassini orbiter is mapping Titan's stratospheric layers temporally and spatially during each Titan flyby by using its two interferometers to cover a spectral range of 10-600 cm^{-1}, 600-1100 cm^{-1} and 1100-1400 cm^{-1} in focal planes 1 (FP1), 3 (FP3) and 4 (FP4) respectively.

Titan's stratospheric budget has been extensively studied by using CIRS spectra and temporal variations have been derived as compared to Voyager's infrared spectrometer (V1/IRIS) results and ground-based data (Coustenis et al., in prep). However, since the Cassini/CIRS first data in 2004 and until 2017, a wealth of data is becoming available to investigate thoroughly the chemical composition, the dynamics and the seasonal evolution of its neutral atmosphere.

2. The method

We have gathered annually-averaged nadir spectral selections both in FP3 and FP4 throughout the duration of the mission from its beginnings in July 2004 up to December 2010. The averages are binned over 10° mainly centered at 50ºN, 50ºS and equatorial latitudes, while no longitudinal restriction was requested for both medium (2.5 cm^{-1}) and high (0.5 cm^{-1}) resolutions. By using the methane nu4 band at 1304 cm-1 provided by the FP4 CIRS spectra as a thermometer, we have retrieved temperature vertical profiles for each selection [2, 3]. We have used 1.48% for the methane mixing ratio as it has been derived from the recent reanalysis of the Gas Chromatograph Mass Spectrometer (GC-MS) data aboard Huygens [4]. Then, by applying the constructed temperature profile in our line-by-line radiative transfer code until the best fitting of the FP3 data was produced we infer the stratospheric trace gaseous abundances.

3. Searching for new molecules

Our radiative transfer software has been recently upgraded by adding updated spectroscopic data for all molecules and data on isotopologues as can be found in both HITRAN and GEISA (edition 2009) databases [5, 6]. The isotopic compounds have at least one atom which consists of different number of neutrons from the one of the main molecule, it exhibits different vibration states and can therefore be observed in infrared spectra. However, it seems difficult to discriminate the contribution of such molecules even at the CIRS resolution.

We can divide these isotopologues into 3 groups: hydrocarbons ($^{12}C^{13}CH_6$), nitriles ($H^{13}C_3N$, $H^{12}C^{13}C_2N$, $H^{12}C_2{}^{13}CN$, $DC^{14}N$, $H^{13}CN$) and other ($^{13}CO_2$, $C^{18}O^{16}O$). We infer also the isotopic ratios. The preliminary results for the annual mixing ratios of the weak molecules of benzene and cyanoacetylene are illustrated in Figs. 1 and 2 below. The equatorial abundances follow the same trend (Fig. 2), while the similar situation exists for the southern latitudes only after 2007 (Fig. 1).

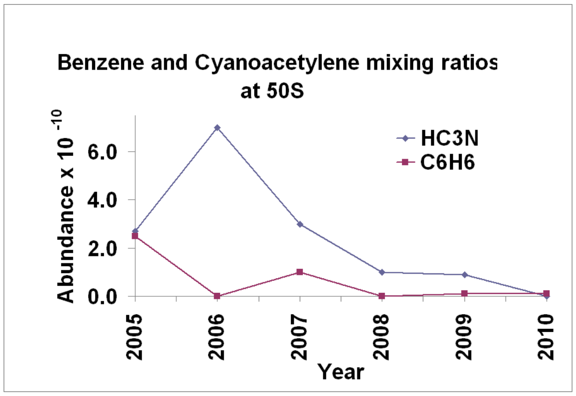

Figure 1: Plot of the annual spectral averages for both benzene and cyanoacetylene at 50ºS. CIRS nadir data were selected according to the criteria described in the text.

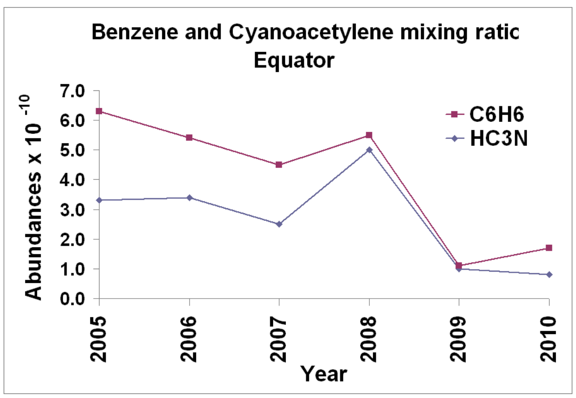

Figure 2: Plot of the annual spectral averages for both benzene and cyanoacetylene at the equator. CIRS nadir data were selected according to the criteria described in the text.

4. Conclusion

In this work, we will present the new mixing ratios of Titan's stratospheric weak species (like C_6H_6 and HC_3N) in order to compare them with previous inferences [7-12]. We will also discuss the possibility of the existence of new isotopologues and/or other molecules in our large FP3 CIRS nadir spectra. As in the work of [13] for molecules predicted but not observed, we provide new upper limits.

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