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Tracing HCN on Titan´s atmosphere with Herschel and submillimetre ground-based telescopes

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Abstract

The aim of this study is to measure the abundance of HCN of Titan's stratosphere, derived from APEX and IRAM 30-m observations taken at 345 GHz and at 265.9 GHz on June 2010 and March 2011, respectively. We used an appropriate line-by-line radiative transfer code and the χ^2 minimisation to model the synthetic spectra of HCN and search for an optimal solution. We cross-compared the inferred abundances with the obtained from Herschel observations acquired in June, July and December 2010. Comparisons between our results and the values from Herschel show similar abundance distributions, exhibiting reliable and consistent measurements and cross-validating them.

1. Introduction

Hydrogen cyanide (HCN) is the main nitrile in Titan's atmosphere, has been firmly detected in Titan's atmosphere and their vertical profiles have been determined by spectroscopic observations. HCN is generated photochemically in Titan's atmosphere from reactions of hydrocarbon radicals with atomic nitrogen.

HCN composition in Titan's stratosphere has been investigated from a limited number of high-resolution submillimetric observations performed on June 23 and December 15, 2010 with the Herschel Space Observatory using PACS [1], and on July 16, 2010 using SPIRE [2], within the framework of the Water and related chemistry in the Solar System (HssO) project. [3]. Measured HCN vertical distributions were consistent with an increase from 40 ppb at $\sim$100 km to $\sim$4 ppm at $\sim$200 km, which is an altitude region where the HCN signatures are sensitive. In support of Herschel observations, Titan was observed from the ground using the 12-m single-dish Atacama Pathfinder Experiment (APEX) telescope in Chile. We also present complementary observations obtained at millimetre wavelengths with the Institut de radioastronomie millimétrique (IRAM) 30-m telescope in Spain. The ground and space-based observations were acquired in a time period corresponding to a very small fraction of a Titan year, we assume in the following analysis that temporal temperature variations are negligible. A quantitative link between the infered HCN abundances obtained by Herschel and ground-based observations is required to assessing the quality of the data/results and cross-validating them. We will report the ground-based observations, HCN abundances, and comparisons with the previous results with Herschel and from literature.

2. Observations and data reduction

HCN (4-3) at 345 GHz was observed at APEX and APEX-2 heterodyne receiver (SHeFI 345 GHz band) in Titan atmosphere on June 16, 2010. This receiver provides a spectral resolution of 122 kHz and a total bandwidth of 1 GHz. The telescope was used in raster scan mode. Observing conditions were not optimal, allowing an on-source integration time of 31 min. HCN (3-2) at 265.9 GHz was observed at IRAM 30-m and the Heterodyne Receiver Array (HERA) receiver on March 19, 2011. The receiver provides a spectral resolution of 4 MHz and a total bandwidth of 4 GHz. Observations were taken under good weather conditions. The telescope was used in wobbler-switch mode. The on-source integration time was 92 min. The observations were reduced using the Continuum and Line Analysis Single-dish Software (CLASS), package of the Grenoble Astrophysics Group[1].

[1] http://www.iram.fr/IRAMFR/GILDAS

3. Radiative transfer modelling and results

We used the forward model described in [4, 5, 6], which consists of a line-by-line radiative transfer model that takes into consideration a homogeneous spherically symmetric atmosphere of Titan (grid of 127 altitude points ranging from 0 to 1500 km). It calculates the synthetic spectra which best fit the observed spectra. It has been successfully applied to Venus and Mars [7, 8]. For the vertical distribution of HCN, we adopted as an initial guess the result of [9] obtained from millimetric observations at IRAM, and scaled it with a constant factor to fit the observed transitions. Both HCN lines do not reach a well defined continuum level. Afterwards, we have introduced an additional free parameter in our fitting algorithm which is the continuum scaling factor. We searched for an optimal solution for the two variables: the scaling factor for the HCN vertical profile following [9] and the continuum scaling factor for our model that provides the best fit to observation.

We performed the χ^2 minimization based on the Levenberg-Marquardt algorithm to search for an optimal solution for the two free parameters described above. We found a very good agreement between models and observations under the assumption of scaled HCN profile. Because we consider only two free parameters, we additionally calculated χ^2 map around an optimal solution and constrained confidence intervals for each of them. In both cases the continuum scaling factor is very well constrained for both lines.

4. Summary

We have carried out complementary APEX and IRAM 30-m HCN (4-3) and (3-2) line observations in Titan's atmosphere, respectively, around the Herschel/PACS and SPIRE observations. The HCN vertical profiles we inferred in this work are consistent with Herschel/PACS and SPIRE ones, and confirms the previous determination of [9]. Their preliminary comparisons yield a low standard deviation of about 0.14 ppm. Our results cross-validate the Herschel ones. They are also consistent with the observed profiles from ALMA, Cassini/CIRS and SMA (the latest ones below $\sim$230 km).

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References

[1] Rengel, M., Sagawa, H., Hartogh, P., et al.: Herschel/PACS spectroscopy of trace gases of the stratosphere of Titan, A&A, 561, A4, 2014.

[2] Courtin, R., Swinyard, B. M., Moreno, R., et al.: First results of Herschel-SPIRE observations of Titan, A&A, 536, L2, 2011.

[3] Hartogh, P., Lellouch, E., Crovisier, J., et al.: Water and related chemistry in the solar system. A guaranteed time key programme for Herschel, P&SS, 57, pp. 1596–1606, 2009.

[4] Jarchow, C., Hartogh, P: Retrieval of data from ground-based microwave sensing of the middle atmosphere: comparison of two inversion techniques, Proc. SPIE, 2586, pp. 196-205, 1995.

[5] Jarchow, C.: Bestimmung atmosphärischer Wasserdampf- und Ozonprofile mittels bodengebundener Millimeterwellen-Fernerkundung, PhD Thesis, 1998.

[6] Hartogh, P., Jarchow, C.: The microwave brightness of planetary atmospheres, preparatory modeling for GREAT and HIFI, Proceedings of the International Workshop on Critical Evaluation of mm-/submm-wave Spectroscopic Data for Atmospheric Observations, 158, pp. 75-78, 2004.

[7] Rengel, M., Hartogh, P., Jarchow, C: Mesospheric vertical thermal structure and winds on Venus from HHSMT CO spectral-line observations, P&SS, 56, pp. 1368-1384, 2008.

[8] Hartogh, P., Błecka, M. I., Jarchow, C., et al.: First results on Martian carbon monoxide from Herschel/HIFI observations, A&A, 521, L48, 2010.

[9] Marten, A., Hidayat, T., Biraud, Y., Moreno, R.: New Millimeter Heterodyne Observations of Titan: Vertical Distributions of Nitriles HCN, HC_3N, CH_3CN, and the Isotopic Ratio $^{15}N/^{14}N$ in Its Atmosphere, Icarus, 158, pp. 532-544, 2002