EPSC Abstracts
Vol. 12, EPSC2018-594-1, 2018
European Planetary Science Congress 2018

Identifying the enigmatic Haystack and HASP ice clouds observed by CIRS in Titan's stratosphere

Delphine Nna-Mvondo (1, 2), Carrie M. Anderson (1), Robert E. Samuelson (1, 3)

(1) NASA GSFC, Greenbelt, MD, USA, (2) Universities Space Research Association (USRA), Columbia, MD, USA, (3) University of Maryland, College Park, MD, USA (delphine.nnamvondo@nasa.gov / Fax: +1-301-6146522)

Abstract

Stratospheric ice clouds have been repeatedly observed in Titan's atmosphere by the Cassini Composite InfraRed Spectrometer (CIRS) since the Cassini spacecraft entered into orbit around Saturn fourteen years ago. However, their chemical composition is still undetermined. For some of them, co-condensation could be a formation mechanism. We present the laboratory experiments we have conducted and the results we have obtained with the aim to identify particularly two perplexing observed stratospheric clouds, the Haystack and the High-Altitude South Polar (HASP) ice clouds.

1. Introduction

In addition to the tropospheric convective methane clouds, a second type of cloud system is observed in Titan's stratosphere. Ices clouds of crystalline cyanoacetylene (HC_3N, ν_6 band at 506 cm^{-1}) and dicyanoacetylene (C_4N_2, ν_8 band at 478 cm^{-1}) are detected in CIRS far-infrared (far-IR) spectra, at high latitudes during the northern winter [1] [2]. CIRS far-IR data also show that during mid to late northern winter on Titan, thin nitrile ice clouds extend globally from 85°N to at least 55°S. These ices exhibit several overlapping broad-emission features due to low-energy lattice vibrations [3] (Table 1). Recently, a massive stratospheric ice cloud system, called the High-Altitude South Polar (HASP) cloud, has been discovered in Titan's early southern winter stratosphere at high southern latitudes [4]. Most of Titan's stratospheric ice clouds form as a result of vapor condensation processes, composed of pure organic cyanides (like HC_3N and C_4N_2) but also of mixed nitriles and hydrocarbons. The first co-condensed nitrile ice feature dominated by a mixture of HCN and HC_3N ices, has been identified in the CIRS limb spectra, peaking at 160 cm^{-1} [3]. Most of Titan's organic vapors condense to form successive ice shells on Titan's aerosol particles as the vapors cool while descending throughout Titan's stratosphere. However, depending on the vapor abundances, local atmospheric temperatures and saturation vapor pressures, these gases enter altitude regions in Titan's stratosphere where they can simultaneously saturate, and co-condensed. During co-condensation, the ice particles mixed together and are no longer isolated into successive shells of pure ices (layered ice). The presence of other CIRS-observed stratospheric ices, such as the unidentified Haystack peaking at ~220 cm^{-1} and the HASP peaking near 200 cm^{-1} are puzzling since not any pure condensed vapor matches their emission features. In the present work, we have investigated if co-condensed mixed ices could contribute to the Haystack and HASP emission features.

Table 1: Spectral assignment of the stratospheric ice clouds detected by CIRS.

Stratospheric ices detected by CIRS	Far-IR emission features (cm^{-1})
HC_3N	506 (ν_6) crystalline
C_4N_2	478 (ν_8) crystalline
Nitrile composite ice	160 (peak)
Haystack	220 (peak)
HASP	200 (peak)

2. Experimental methodology

We have performed experiments using the SPECtroscopy of Titan-Related ice AnaLogs (SPECTRAL) high-vacuum chamber set up at NASA Goddard Space Flight Center. The SPECTRAL chamber (Fig. 1) has been designed specifically for measuring laboratory transmission spectra of thin ice films of pure and mixed ices, at Titan-appropriate temperatures (70 – 130 K) from the near to far-infrared region, i.e. from 11700 cm^{-1} to 50 cm^{-1}. The vapors were deposited at low temperatures from 30 K to 160

K, and the resulting ice thicknesses were determined, the ice phase were analysed by FTIR spectroscopy and their optical constants computed.

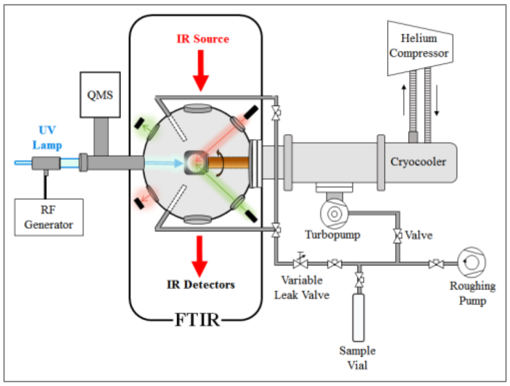
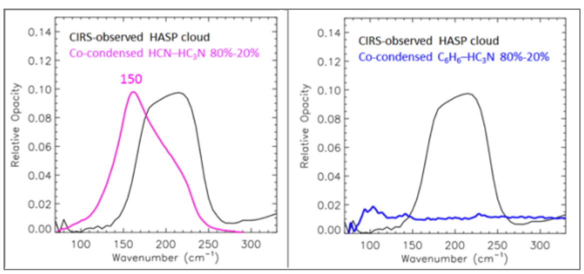


Figure 1: Schematic of the SPECTRAL high-vacuum chamber experimental setup at NASA GSFC.

3. Results

3.1 Results: HASP study

We have co-condensed vapor mixtures of HCN-HC_3N, C_6H_6-HC_3N and C_6H_6-HCN at 110 K and analysed the resulting mixed ices (Fig. 2). HCN, HC_3N, C_6H_6 are gases co-condensing at the pressures, temperatures and altitude where the HASP cloud is observed.



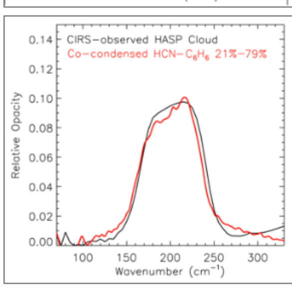


Figure 2: Laboratory Far-IR spectra of different mixed ices from co-condensed vapors com-pared to the CIRS-derived spectrum of Titan's HASP cloud (at 79°S, mid southern fall).

The spectrum of co-condensed thin ice film from mixed vapors of 20% HCN- 80% C_6H_6 deposited at 110 K is a good match for the HASP emission feature at 200 cm^{-1}. This result demonstrates that the chemical composition of the HASP cloud is consistent with a mixed C_6H_6-HCN ice, formed via co-condensation.

3.2 Results: Haystack study

Spectra of crystalline HCN ice and crystalline propionitrile (C_2H_5CN) ice obtained from pure vapors deposited at 110 K and 135 K, respectively were obtained (Fig. 3). They do not match the Haystack emission feature at 220 cm^{-1}.

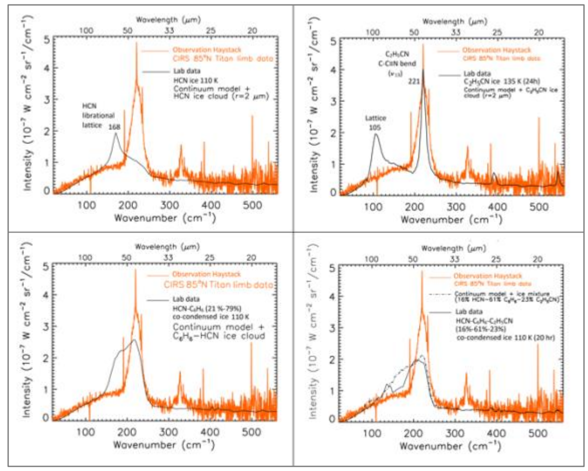


Figure 3: Laboratory Far-IR spectra of different mixed ices from co-condensed vapors compared to the CIRS-derived spectrum of Titan's Haystack cloud (at 85°N).

Comparing our laboratory spectra of different mixed ices containing HCN, C_6H_6, C_2H_5CN to the CIRS data (Fig. 3), we do not find any good match for the Haystack emission feature yet, but further experiments with other co-condensed ices are currently in progress.

Acknowledgements

D.N.-M acknowledges research funding support by the NASA Postdoctoral Program at NASA GSFC, administered by the USRA. C.M.A. and R.E.S. acknowledge funding from both the Cassini Project and the CDAP.

References

[1] Anderson, C.M., Samuelson, R.E., Bjoraker, G.L., Achterberg, R.K.: Particle size and abundance of HC_3N ice in Titan's lower stratosphere at high northern latitudes. Icarus, Vol. 207, pp. 914-922, 2010.

[2] Anderson C.M., Samuelson, R.E., Achterberg, R.K., Barnes, J.W., Flasar, F.M.: Subsidence-induced methane clouds in Titan's winter polar stratosphere and upper troposphere. Icarus, Vol. 243, pp. 129-138, 2014.

[3] Anderson C.M., Samuelson, R.E.: Titan's aerosol and stratospheric ice opacities between 18 and 500 μm: Vertical and spectral characteristics from Cassini CIRS. Icarus, Vol. 212, pp. 762-778, 2011.

[4] Anderson, C.M., Nna-Mvondo, D., Samuelson, R.E., Achterberg, R.K., Flasar, F.M., Jennings, D.E., Raulin, F.: Titan's High Altitude South Polar (HASP) Stratospheric Ice Cloud as observed by Cassini CIRS. In: AAS/DPS Meeting Abstracts, Vol. 49, p 304.10, 2017.