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Monitoring Jovian Dynamics Using Maps of NH_3 and PH_3

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Abstract

Phosphine and ammonia are important tracers of Jovian tropospheric dynamics, but their vertical distributions are still poorly known. This information will be needed for the analysis of the radio and infrared data of the JUNO mission in 2016. We have started an observing campaign to obtain 3D maps of NH_3 and PH_3 in the 0.1-5 bar pressure range, by using TEXES/IRTF and selecting 3 spectral ranges (at 4.65, 8.9 and 10.5 microns) that probe 3 different pressure levels. The first data (Feb. 2014) allow us to map NH_3 and PH_3 at low latitudes. We plan to continue this campaign to obtain a full latitude and longitude coverage and to improve the sensitivity.

1. Introduction

For many decades, phosphine has been known to be present in the Jovian atmosphere. PH_3 is a disequilibrium species that was not expected to be found in the atmospheres of the giant planets, because, if it is in thermochemical equilibrium, it should react with water to form P_4O_6 and H_2. However, convective vertical transport in Jupiter and Saturn is strong enough for PH_3 to be transported from deep levels in the interior up to observable tropospheric levels [1]. In this region, phosphine is destroyed by solar UV photochemistry. The phosphine abundance is thus a tracer of the Jovian atmosphere, both for vertical convective motions in the deeper troposphere and for photochemistry and dynamics in the upper troposphere. The presence of ammonia, in contrast, is expected from thermochemical equilibrium. Its abundance is strongly affected by condensation at the levels of a few bars (NH_4OH, NH_4SH clouds) and 0.5 bar (NH_3 cloud) and, above it, by photochemistry [2], making it a tracer of Jovian circulation and dynamics. Thus, measuring 3D-maps of PH_3 and NH_3 simultaneously appears as an efficient tool for monitoring Jovian dynamics. Another important motivation of this study is the preparation of the Juno mission to Jupiter. One of the main scientific objectives of the Juno mission, launched in August 2011, is a measurement of the water abundance in the deep troposphere of Jupiter, using radio continuum observations at low frequencies [3]. However, the contribution of NH_3 must also be considered, as might the effect of PH_3. Determining the behavior of these species at the deepest tropospheric levels that can be sensed prior to the mission is important to anticipate any possible contribution of these species to the Juno water measurements.

Infrared signatures of NH_3 and PH_3 are found in the 5-μm region (where radiation probes the 1-5 bar level, at T = 210 – 240 K) and around 8-12 μm (where the radiation originates from higher levels, at about 0.1-0.5 bar and T = 110-140 K). From previous observations [4 - 8], there is clear evidence for a depletion of both species as a function of altitude between a few bars and a few tenths of a bar, most likely due to condensation in the case of NH_3 and photochemical destruction in the case of PH_3.

2. TEXES observations (Feb. 2014)

In February 2014, we began an observing campaign with the TEXES infrared imaging spectrometer at the NASA InfraRed Telesccope Facility (IRTF), to map PH_3 and NH_3 simultaneously at 2140-2160 cm^{-1} (4.65 μm), 1125-1135 cm^{-1} (8.9 μm) and 950-960 cm^{-1} (10.5 μm) with the medium-resolution mode (R= 15000). TEXES is the unique spectroscopic facility that allows us to probe these three spectral ranges simultaneously, and thus to achieve simultaneous 3D maps of NH_3 and PH_3. Together, the three spectral intervals give access to transitions of PH_3 and NH_3 that probe different vertical levels. At 5 and 9 μm, the CH_3D transitions are used to constrain the thermal profile. Figures 1 and 2 show preliminary results of the first run (February 2014), which demonstrate the feasibility of the study. A quick-look analysis allows us to constrain the abundances of NH_3 and PH_3 (see captions of Figs. 1 and 2).

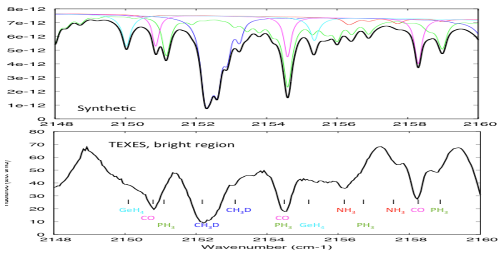

***Fig. 1**: Bottom: 5-μm TEXES spectrum (2140 - 2160 cm^{-1}) of a bright region around the NEB and the central meridian, integrated over 400 pixels, compared with synthetic spectra (top). Red: NH_3; green: PH_3; dark blue: CH_3D; pink: CO; light blue: GeH_4. The 1-5 bar region is probed. A quick comparison shows that NH_3 is stronger than in the nominal model (2.6 10^{-4} at 3 bars), and PH_3 is less than the nominal value (7 10^{-7} at 3 bars). CO and GeH_4 can also be retrieved.*

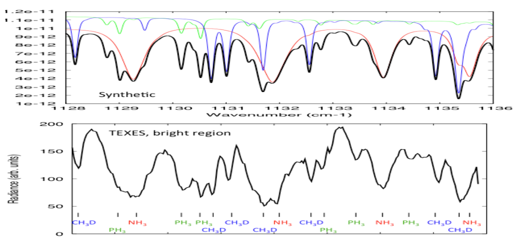

***Fig. 2**: Bottom: 9-μm TEXES spectrum (1128 - 1136 cm^{-1}) of the same region around the NEB and central meridian, integrated over 400 pixels, compared with synthetic spectra (top). Red: NH_3; green: PH_3; dark blue: CH_3D. The 0.3 – 0.5 bar region is probed. A quick comparison shows that, in this case, PH_3 is more abundant than assumed in the nominal model (1.2 10^{-7} at 0.3 bars).*

3. Future observations

We plan to repeat our observations in the fall of 2014 to accumulate more data and to increase the S/N in each pixel, and also to obtain a full longitude coverage. We also plan to add a new spectral range at 2025-2040 cm^{-1} (4.92 μm) to access stronger NH_3 transitions in the deep troposphere, which will improve the quality of the NH_3 retrieval. This program will be pursued and optimized in 2015 and later, when the Juno mission is in operation. These observations will benefit Juno's JIRAM (2-5 μm) low-resolution spectral-mapping instrument by adding sensitivity to the NH_3 and PH_3 tropospheric distributions, as well as the Microwave Radiometer (MWR) experiment that needs an upper-tropospheric boundary condition.

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