Evidence of pure ammonia clouds from Juno/JIRAM infrared spectral data

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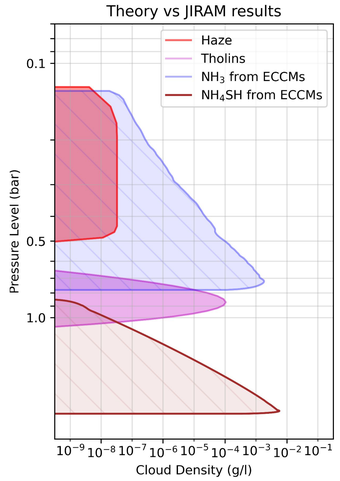
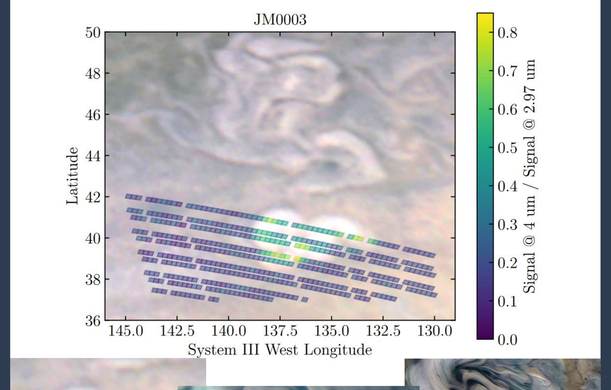
Introduction

- Equilibrium Chemistry Condensation Models (ECCMs) predicts the existence of three main cloud decks on Jupiter: NH_3 (0.6-0.7 bar), NH_4SH (1.2-1.4 bar), and H_2O (> 4 bar) (Atreya+1999).
- However, measurements from Galileo/VIMS showed that ammonia ice clouds spectral features (expected at 2 and 3 microns) are rare and not ubiquitous, and connected to small regions (<2 % of the globe) related to convective uplifting events (Baines+2002).
- The rarity of ammonia clouds was confirmed also by the LEISA instrument on NASA New Horizons mission (Sromovsky & Fry 2018), while the ISO full disk spectra indicate that the main cloud deck of Jupiter should be composed by a material in-between NH_3 and NH_4SH
- In turn, Juno/JIRAM image spectrometer data, observing in reflected light (2.5-3 micron), can be fitted only when a pure reflecting haze and a main tholin cloud are both invoked (Imanaka+2012; N.B. tholins are used as an approximation for the unknown material composing jovian clouds; Sindoni+2017 ; Grassi+2021)

What is observed is not predicted at all by models !!!
This is really important also for exoplanets

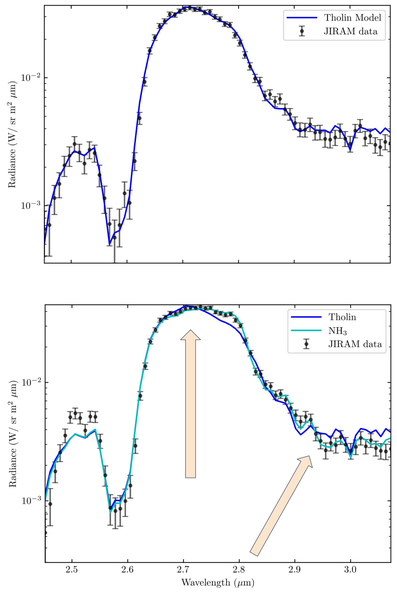


Methodology



- Thanks to its unique orbit, the Juno mission discovered that the region between the belts and zone structures and the polar caps is rich in storms and vortexes that may bring fresh ammonia in the upper troposphere
- JIRAM observed one of these structures in PJ1 (together with JunoCam !). The spectra inside the vortex are different form the ones on the outside as it is possible to observe from the ratio between the signal at 4 and 3 microns.
- Using the Planetary Spectrum Generator (Villanueva+2018), adapted to Jupiter science, and the PyOE package (Maahn+2021; Rogers+2000) we tried to perform multiple scattering atmospheric retrievals of the JIRAM spectra considering different main cloud compositions: tholin, pure ammonia, and tholin coated with ammonia.
- The retrieval considered H_2, He, and CH_4 vmr as fixed, while fitted for the gaseous NH_3 deep vmr and relative humidity.
  The other parameters of the fit are the levels, effective radii and densities of the tropospheric haze and the main cloud.

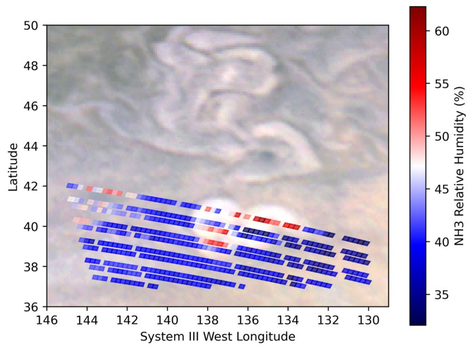
Results



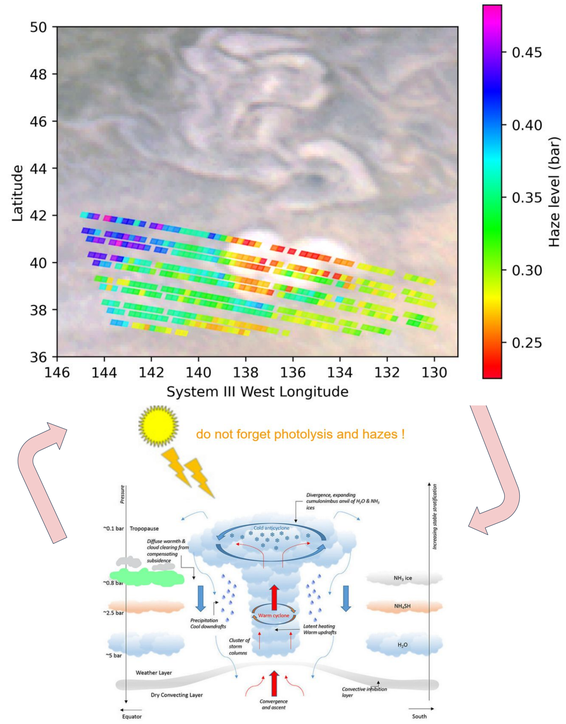
Outside the Vortex

Inside the Vortex

- The tholin clouds can fit very well the outside of the vortex region but NOT the spectra inside. In fact, the spectra inside present a shifted reflectance peak, which due to low gas absorption is totally caused by the main cloud deck. Using pure ammonia or tholins coated at 50 %, greatly improves the retrieval quality.
- The retrieval showed that the NH_3 relative humidity, the haze's and main cloud's pressure levels, and the main cloud's particles radii are very well constrained. The haze radii and densities are strongly correlated.



Conclusion



- This work detected the presence of about 38 SIACs (Spectrally Identifiable Ammonia Clouds) thanks to the Juno mission data.
- In the vortex we observed: higher hazes, higher clouds and higher relative humidity values.
- This indicates that the vortex is the result of an uplifting event that brought fresh ammonia in the upper troposphere that rapidly condensed or became a coating for the tholins.
- This work indicates that the composition of the typical jovian clouds is still unknown and that NH_3 ice clouds form only in rare occasions.

Acknowledgements

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