Mapping of CO and HCN in Neptune's stratosphere

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Structure of CO and HCN in Neptune's upper atmosphere

**CO**

- Abundance \( \sim 1 \text{ ppm} \) in upper troposphere and stratosphere
- Increase of abundance with altitude
- Higher abundance than expected from equilibrium with \( \text{CH}_4/\text{H}_2\text{O} \)

**HCN**

- Abundance \( \sim 1 \text{ ppb} \) in stratosphere
- Formed by \( \text{N}, \text{N}^+, \text{and methane products} \)
- Condensation cold trap at tropopause

Need for a significant supply source

Image www.nasa.gov
Sources of CO and HCN

**Internal**

- vigorous upward convection of CO and \( \text{N}_2 \).
- \( \text{N}_2 \) dissociated in the stratosphere to form HCN.

**External**

- Triton, comet impacts

Understanding the sources of CO/HCN provides indications on the global structure and chemistry of the atmosphere.
Rotational lines of CO and HCN

- mm/submm lines profile indicate temperature/abundance vertical profile (T/q)

- pressure broadened wide absorption wings from troposphere (CO)
- thermal broadened emission core from stratosphere (HCN and CO)

- emission spatially not resolved by single-dish instruments

CO(3-2) line measured by Hesman et al. (2007) at JCMT
SMA observations

- Submillimeter Array (SMA) : 8 antennas of 6 m diameter on Mauna Kea, Hawaii
- 3 nights in September 2010

- HCN(4-3) and CO(3-2) transitions (354.8 and 345.8 GHz), 0.4 MHz spectral resolution
- Spatial resolution of ~0.75” reached in extended configuration (Neptune's disk ~ 2.3”)

- Fourier-plane visibilities undergo an inverse Fourier transform to obtain maps
Continuum emission map at 354.5 GHz

- Continuum collision-induced emission from H$_2$-H$_2$ and He-H$_2$
- Sounds troposphere (~1 bar)
- Observed distribution close to continuum model, radially symmetric

Flux map (in Jy/beam) with 20 $\sigma$ contours

Sounded altitudes

North pole direction

Equator

Neptune's disk (1 bar)

SMA synthesized beam
CO(3-2) line maps

- Line integrated over 4 GHz
- Core (stratospheric) and wings (tropospheric) emission maps
- No significant spatial variations, except limb-darkening

Disk-integrated spectra (baselines average)

Wings emission map (troposphere) 20 σ contours

Core emission map (stratosphere) 10 σ contours
- Modeling assuming thermal profile (Lellouch et al., 2010)
- Data consistent with horizontally constant CO abundance
- Best results with:
  0.7 +/- 0.05 ppm for pressures above 10 mbar (troposphere)
  0.95 +/- 0.05 ppm for pressures below 10 mbar (stratosphere)
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**Abundance increase with altitude supports partial exogenic source**
HCN(4-3) line map

- Map integrated over the emission line (~ 8 MHz)
- Global ring shape
- At the limb, decrease of line emission by a factor ~2 in South East region
- Modeling with constant abundance in the upper stratosphere (above 0.3 mbar)
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- Ring shape produced by opacity increase with airmass
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- Ring shape produced by opacity increase with airmass
- Best results with $\sim 1.9+/-0.2$ ppb everywhere, except in a spatially limited region
- Impossible to further distinguish models due to limited spatial resolution
Possible interpretations

HCN emission minimum located near Southern pole region (summer), where active convection occurs, on morning side.

- Increased photolysis in the summer hemisphere?

- Seasonal transport?

- More condensation on the morning side?

Mid-IR photometry obtained by Orton et al., (2009).
Summary

- Mapping of CO and HCN lines in Neptune's troposphere and stratosphere with 0.75” spatial resolution

- **CO uniform horizontal distribution**, abundance increase from troposphere to stratosphere: supports partial exogenous source

- **HCN dip in the South East region.** Process not identified. Abundance ~1.9 ppb elsewhere.

Need for better resolved observations with ALMA (Cycle 1). Band 7, baselines ~700 m: ~0.3” resolution