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Neptune's Atmospheric Structure from the Spitzer Infrared Spectrometer

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Introduction: NASA's Spitzer Infrared Spectrometer (IRS) acquired mid-infrared (5 - 37 micron) disc-averaged spectra of Neptune in May 2004, November 2004, November 2005, and May 2006. Meadows et al., (2008, doi: 10.1016/j.icarus.2008.05.023) discovered Neptune's complex hydrocarbons methylacetylene and diacetylene and derived their abundances using the May 2004 data. The rest of the Neptune data has yet to be published. The data have all been reduced using the same methodology as Rowe-Gurney et al., (2021, doi: 10.1016/j.icarus.2021.114506) used for Uranus, so that each year can be reliably compared.

We detect the same hydrocarbons seen in Meadows et al., (2008). This includes the strongest bands of methane (CH_4), acetylene (C_2H_2) and ethane (C_2H_6) as-well-as weaker but still clearly recognisable features of ethylene (C_2H_4), carbon dioxide, methyl (CH_3), methylacetylene (C_3H_4) and diacetylene (C_4H_2).

At Uranus, there was a considerable longitudinal variation in stratospheric emission detected in the Spitzer data for multiple epochs (Rowe-Gurney et al., 2021). A variation is not present at Neptune in 2005 or late 2004, when all the separate longitudes displayed the same brightness temperature. In May 2004 a stratospheric variation is present, although it is tentative due to the deviation only appearing at a single longitude and because there are larger uncertainties on this early dataset. If the variation is real then it could be caused by stratospheric methane injection associated with convective clouds or perturbations to the location of the south polar warm vortex (Orton et al., 2012, doi: 10.1016/j.pss.2011.06.013).

Optimal Estimation Retrievals: The data from 2005 have optimised exposure times, multiple observed longitudes, and therefore the lowest noise. It is this data we are using to derive the vertical structure of the temperature and composition in the stratosphere and upper troposphere (between around 1 nanobar and 2 bars of pressure). We present full optimal estimation inversions (using the NEMESIS retrieval algorithm, Irwin et al., 2008, doi: 10.1016/j.jqsrt.2007.11.006) of the globally averaged November 2005 data with the aim of constraining the temperature profile and the abundances of the stratospheric hydrocarbons. We fit both the low-resolution (R~120) and high-resolution (R~600) module data, testing multiple temperature priors derived from chemical models (Moses et al., 2018, doi: 10.1016/j.icarus.2018.02.004) and observations from AKARI (Fletcher et al., 2010, doi: 10.1051/0004-6361/200913358). Initial findings show that we are sensitive to stratospheric D/H ratio (derived from the relative abundances of CH_4 and CH_3D) and therefore we will attempt to constrain this value by finding the best fit for our model.

Conclusion: Full spectrum mid-infrared data from Neptune in 2005 taken by the Spitzer Infrared Spectrometer is to be analysed using optimal estimation retrievals for the first time. The globally-averaged stratospheric temperature structure and the abundances of stratospheric hydrocarbons will be determined along with the ratio of D/H. The disc-averaged thermal and chemical structure from Spitzer will likely be our best characterisation of Neptune's thermal structure until JWST/MIRI acquired spatially-resolved mid-infrared spectroscopy in 2022.