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Examining Rotational Variability in the Upper Tropospheres and Lower Stratospheres of Uranus and Neptune from Herschel PACS OT1 Observations: Implications for the Stability of Temperature and Compositional Structure

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The power of high-resolution submillimeter spectroscopy of Uranus and Neptune was put to use to survey the rotational variability of stratospheric and tropospheric constituents of their atmospheres. These observations were motivated by the surprising discovery of as much as 12% rotational variability of emission from stratospheric constituents in the atmosphere of Uranus by the Spitzer Infrared Spectrometer and the detection of spatial variability in thermal images of Neptune's stratospheric emission (Orton et al. 2007, Astron. & Astrophys 473, L3). Our observing program consisted of three separate sequences of observations to look at the strongest lines of H_2O in the high-resolution PACS spectra of both planets, whose upwelling radiance emerges from the same vertical region as the Spitzer IRS observations of Uranus and ground-based images of Neptune, and the strongest line of CH_4 in the PACS spectrum of Neptune. We omitted measurements of CH_4 lines in Uranus, which are almost non-detectable. We added the strongest HD line in Uranus to measure variability of tropospheric temperatures that could modulate stratospheric CH_4 abundances through local cold-trapping and the strongest two HD lines in Neptune (Lellouch et al. 2010, Astron. & Astrophys. 518, L152) that determine both the tropopause temperature to limit local cold-trapping efficacy and the lower stratospheric temperature, to help differentiate between longitudinal variability of stratospheric H_2O and CH_4 abundances vs. temperatures. These were repeated over the 17-hour interval that is common to the equatorial rotation periods of both Uranus and Neptune. Although these lines had already been observed in Uranus and Neptune by PACS, no repeat measurements had ever been made to determine longitudinal variability. The observations were consistent with previous measurements, but no significant rotational variability was detected. It is possible that the absence of rotational variability in the HD and CH_4 lines is because variability is confined to very low pressures, e.g. much lower than a microbar. However, the absence of variable emission from high-altitude exogenic H_2O vapor is harder to explain, unless the variability seen in Uranus by Spitzer and in Neptune from the VLT, is not the result of variations in temperature by in the hydrocarbon abundances. Alternatively, the stratospheres of both planets are variable in time. The cause of such variability is unknown, but spatially confined outbursts have been detected in the visible and near infrared, and they may have as much influence on the stratosphere of Uranus as the great springtime storm in Saturn's northern hemisphere, creating a strong, localized "beacon" of thermal radiation (cf. Fletcher et al. 2011, Science, 332,1413) that could dominate the emission observed over the hemisphere.