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Variability of Jovian Temperatures, Aerosols and Ammonia with VLT/VISIR Imaging 2016-18

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Abstract

The VISIR mid-IR imager (5-25 µm) on the Very Large Telescope (VLT) has been providing infrared spatial and temporal support for NASA's Juno spacecraft, constraining atmospheric thermal conditions in the upper troposphere (100-700 mbar) and stratosphere (1-10 mbar). Our pre-Juno-arrival dataset (January-August 2016) demonstrated that Jupiter's North Equatorial Belt (NEB) began a northward expansion in late 2015, consistent with the 3-5 year cycle of NEB activity. We have extended this analysis to coincide with Juno's perijove encounters, once every 53.5 days. Our early 2017 data has been useful in the multi-wavelength study connecting thermal data at cloud-tops with radio observations at depth to investigate moist convection in and South Equatorial Belt (SEB) [1].

We discuss a study of the sensitivity of the VISIR imaging data to thermal, chemical and aerosol structure of Jupiter taking into account centre-to-limb brightness variations. We derive zonally-averaged temperatures, aerosols and ammonia distributions from centre-to-limb curves, and use the improved priors to assess the structure of the Great Red, the dynamics of the cold polar vortex, and provide a comparison of the upper-tropospheric aerosols and ammonia at the Equator to the findings of Juno's near-infrared and microwave observations.

1. Introduction: Variability

The VISIR observations during the Juno epoch contribute to a time-series of VLT imaging that now spans over a full Jovian year (2006-2018). Observations in eight narrow-band channels sense stratospheric temperatures (7.9 µm), tropospheric temperature (13.0, 17.6, 18.6, 19.5 µm), aerosols (8.6 µm) and ammonia (10.7 and 12.3 µm), and are inverted via our optimal estimation retrieval algorithm, NEMESIS [2]. Binning these data with respect to emission angle is significantly more constraining than previous attempts to fit these VISIR datasets, suggesting that the centre-to-limb variations contain significant information about the vertical structure.

This long time-series has allowed us to investigate thermal variability associated with fades and revivals of the South Equatorial Belt [3, 4], and the recent expansion of the NEB [5] in addition to the temperature, composition and aerosols of the Great Red Spot (GRS) and their temporal variability in the period 1995-2008 [6]. In this paper, we report on the structure of the GRS (Fig 2) and the high latitudes (Fig 1) prior to the beginning of the Juno epoch (January-August 2016) and use the data to provide cloud-top estimates of equatorial temperatures, ammonia and aerosols forming part of a time-series during the Juno epoch to compare to Juno's perijove observations.

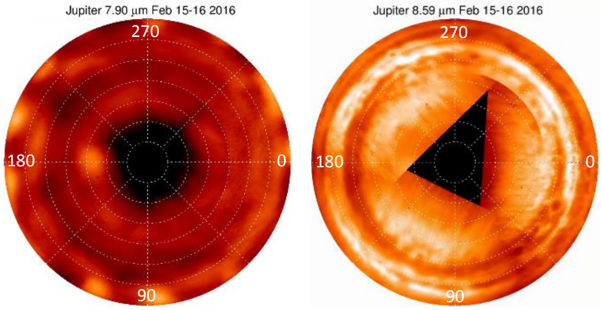

Fig. 1 – Stereographic polar projection of VISIR imaging data of Jupiter's north pole at 7.9 (sensing 6-mbar temperatures) and 8.6 µm (sensing 750-mbar aerosols). Cold polar vortex is present in stratosphere and troposphere, auroral methane emission not observed. Latitudes >20°N shown, black regions are missing data.

2. Equatorial Ammonia – Abundances and Distribution

Recent findings from Juno suggest that ammonia is strongly enhanced at Jupiter's equator, with the region over the NEB also being more depleted than SEB. This is consistent with previous thermal-IR spectroscopic analyses [7, 8], which suggest strong equatorial upwelling, but have confirmed that this zone of elevated ammonia persists to great depths below the clouds. By inverting zonal-mean VISIR observations, taking into account their dependence on emission angle, we will assess whether VISIR imaging alone is sensitive to this equatorial ammonia maximum, allowing us to map its variation with longitude (Fig 2) and with time through the full decade-long dataset.

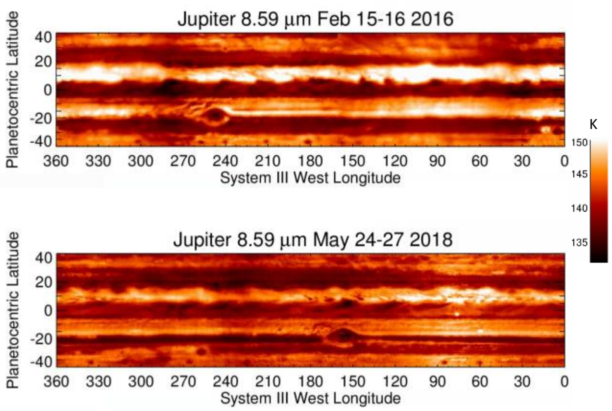

Fig. 2 – Cylindrical 8.6-µm maps of low to mid latitudes pre-Juno and at perijove-13 (May 2018) sensing cloud-top aerosols showing the variability of the banded structure of Jupiter and prominent cyclones and anti-cyclones. These and the intervening data will be used to assess long-term variability.

Summary and Conclusions

VISIR thermal imaging provides a regular source of information on the temperatures, aerosols and ammonia distributions associated with the phenomena studied by Juno. They also place the Juno epoch into the wider context of Jovian variability over a full ~12 year orbit. Future work will focus on extending the study into the long-term global variability of Jupiter (including the GRS and high latitudes) and will include the use of N-band spectroscopy to further constrain chemical abundances, and direct comparisons with deep structures observed at microwave wavelengths.

The cold polar vortex is co-located with the reflective aerosols observed in the near-IR with Juno/JunoCam, suggesting that they play a key role in the radiative cooling at the poles, and that this cooling extends from the troposphere into the stratosphere. Another notable change between 2016 and 2018 is clear difference at the equator between both panels in Fig. 2, this is related to the cloud-clearing associated with the Equatorial Zone Disturbance [9].

Acknowledgements

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