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Detection of Compact Baroclinic Waves in Jupiter's Deep Clouds at 5-microns from the VLT

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Abstract

Hubble Space Telescope (HST) observations of Jupiter's North Equatorial Belt (NEB) in 2015 revealed the presence of a small-scale wave pattern interpreted as a baroclinic instability associated with the chain of cyclones on the northern edge of the NEB (near 16^{o}N) [1]. The waves spanned 2-3^o latitude, with a wavelength of approximately 1^o longitude. Given that such disturbances are sensitive to atmospheric stratification, we employed the VISIR mid-infrared imager on the VLT [2] and the TEXES instrument on Gemini to diagnose the thermal conditions in this region [3]. Throughout 2016 and 2017 we employed VLT 'lucky imaging' at 5 µm to reduce the effects of atmospheric seeing, stacking only the sharpest frames to yield global 5-µm images with exquisite detail, providing spatial context to Juno's close perijove encounters. We report the first detection of the compact wave pattern at 5 µm, indicating that this wave modulates aerosol opacity in the NEB at high pressures (2-3 bar), significantly deeper than expected from the HST imaging alone. The waves were observed west of a dark putatively-cyclonic vortex in December 2016 and January 2017, spanning a limited longitude range of ~50^o. They were only visible in regions of relatively uniform 5-µm emission. More turbulent regions of the NEB did not display similar features. Near-coincident HST observations also confirm the re-detection of this wave in localised regions, allowing us to compare the structure over a variety of altitudes. The ground-based data allow us to compare thermal and aerosol structures in regions with and without this compact wave pattern. Observations will be compared to those of Juno/JIRAM when available.

1. VLT/VISIR Observations

With the refurbishment of the VISIR instrument between 2012 and 2015, ESO now offers the capability for burst-mode imaging of bright targets at 5-µm using an M-band filter. Burst mode allows us to employ the 'lucky imaging' technique, selecting only the sharpest frames from a video sequence over ~2 minutes of observing time. This allows us to discard frames that are blurred by atmospheric seeing, resulting in the sharpest full-disc images of Jupiter ever obtained from Earth at 5 µm. Images were reduced using a custom IDL pipeline and stacked using Autostakkert [4]. After a first proof-of-concept observation in February 2016, this burst mode observing is now employed at least once per Juno perijove to provide wide spatial context to the close-in imaging from the spacecraft, with data acquired in December, January, February and March, with more expected in May, July and September 2017.

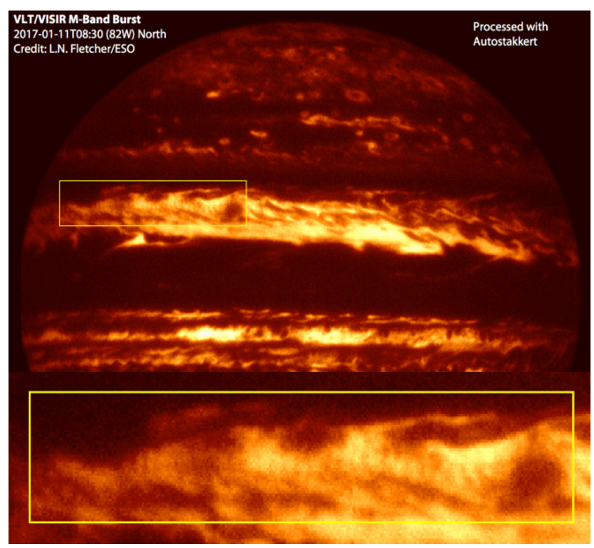

Figure 1 Example of 5-µm VISIR imaging in January 2017, with the yellow box indicating the detection of the compact wave pattern.

Fig. 1 shows the identification of the compact wave pattern in one example of a 5-µm image, confirming that this fine wave is modulating opacity at deep pressures. Observations in March 2017, along with polar projections of these maps, are shown in Fig. 2.

These do not show the compact wave, but reveal a chain of putatively cyclonic features at the northern edge of the NEB (remaining from the NEB expansion phase in 2015-16, [2]), and chaotic activity in the South Equatorial Belt (SEB) associated with a recent outbreak of moist-convective activity [5]. The polar projection also reveals an intensely bright band on the northern edge of Jupiter's North Temperate Belt (NTB(N)) following outbreak activity on the southern edge (NTBs) in October 2016 [6]. This narrow band was not visible in our February 2016 data, suggesting that it may have formed as a consequence of the NTBs outbreak. The polar projections show latitudinal contrasts in 5-µm emission, with a distinct change in character near 45°N and (tentatively) a band of higher opacity between 60-70°N, on the edge of the polar domain imaged by Juno. The two hemispheres are asymmetric, with the south showing brighter emission between 35-50°S and poleward of 65°S. The cause of this long-lived asymmetry in 5-µm banding remains unclear.

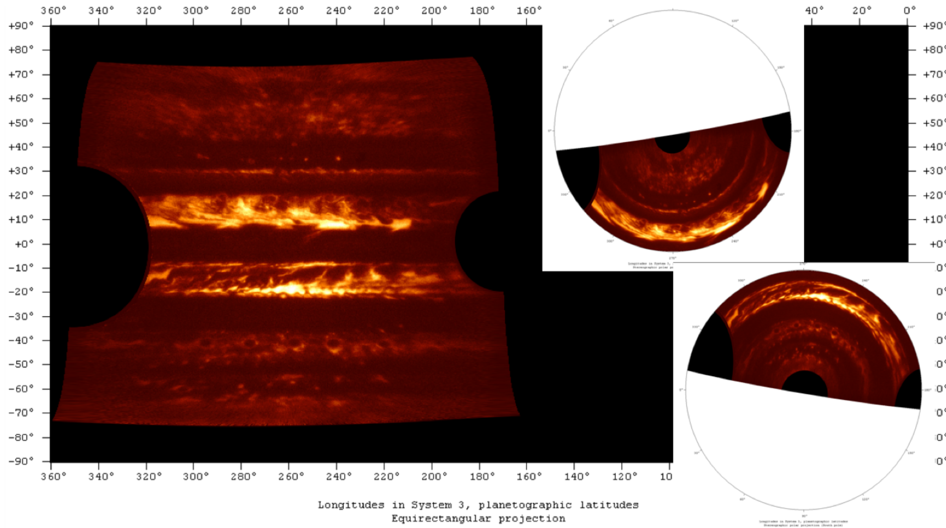

Figure 2 Maps of VISIR 5-µm observations on March 16, 2017, showing the turbulent NEB, the mid-SEB outbreak, and the bright NTB(N) band. Inset are polar projections of the north and south.

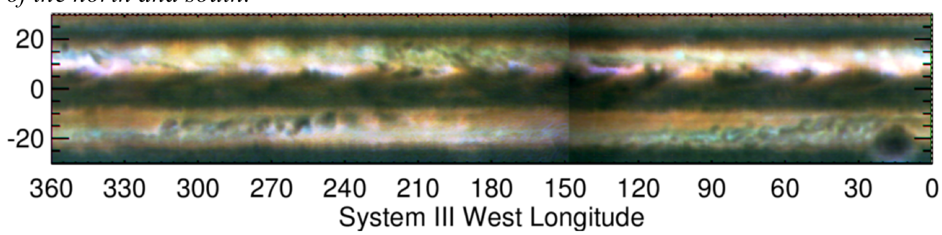

Figure 3 Three-colour map from one TEXES spectral channel near 8.6 µm (Mar 12-13, 2017), using absorptions of decreasing strength from red to green to blue.

2. Gemini/TEXES Observations

To further constrain the background environment in which these waves propagate, we moved the TEXES spectrograph from the 3-m IRTF to the 8-m diameter Gemini Observatory. Repeatedly scanning Jupiter's tropical domain over two nights in March 2017 has provided the highest-resolution mid-IR spectral map of Jupiter ever obtained. Eight spectral channels are used between 5-20 µm [3]. Fig. 3 shows a three-colour composite from just one channel near 8.6 µm, sensing temperatures, aerosols and PH_3 in the upper troposphere. These show spectral changes with longitude in the NEB, allowing us to deduce thermal and compositional contrasts in the regions hosting the compact wave train (as well as in the mid-SEB outbreak, clearly seen between 240-300°W and possessing similar conditions to the turbulent wake of the Great Red Spot). Taken together, the VLT 5-µm images and the Gemini/TEXES spectroscopic maps will provide important constraints on temperatures, clouds, ammonia and phosphine in Jupiter's upper troposphere to support Juno.

Acknowledgements

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References

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