EPSC Abstracts
Vol. 13, EPSC-DPS2019-453-1, 2019
EPSC-DPS Joint Meeting 2019

EPSC
EPSC-DPS Joint Meeting 2019
15–20 September 2019 | Geneva, Switzerland

Jupiter's Ammonia-Rich Equatorial Plumes

Leigh N. Fletcher (1), Arrate Antuñano (1), Glenn S. Orton (2), Thomas Greathouse (3), Henrik Melin (1), Padraig Donnelly (1), John Rogers (4), Hans-Jörg Mettig (5), and the Juno/MWR team
(1) University of Leicester, Leicester, UK (leigh.fletcher@le.ac.uk), (2) Jet Propulsion Laboratory, Pasadena, CA, USA, (3) Southwest Research Institute, San Antonio, TX, USA, (4) British Astronomical Association, London, UK, (5) JUPOS team.

Abstract

Jupiter's equatorial plumes exhibit the coolest temperatures, highest cloud opacities, and the strongest ammonia enrichments of any location within the Equatorial Zone. They are found at 2-6^{o}N in between the cloud-depleted "hot spots", and may be responsible for Jupiter's strong equatorial ammonia enrichment. We use (i) ground-based visible/near-IR imaging to track the plumes relative to areas sensed by Juno's Microwave Radiometer (MWR); (ii) Gemini/TEXES mid-infrared spectral mapping to determine the temperature and composition of the plumes in the upper troposphere; and (iii) Juno/MWR observations in putative plume and hot spot locations to investigate deep NH_3 contrasts. We find that the plume and hot spot contrasts are challenging to detect at p>10 bar, suggesting that this is a weather-layer phenomenon, i.e., confined to lower pressures.

1. Introduction

Infrared spectroscopy of Jupiter from Voyager [1] and Cassini [2], and Saturn from Cassini [3,4], revealed that the zonally-averaged ammonia (NH_3) abundance was enriched in their equatorial upper tropospheres. On Jupiter this enrichment appeared to be localised in the adiabatically-cooled and cloudy zones between prograde zonal jets at 6.9^{o}N/7.2^{o}S. This was suggestive of a Hadley-like tropospheric circulation, with NH_3-rich air rising at the equator and descending over the NH_3-depleted belts. However, spatially-resolved mid-infrared spectral maps from Cassini and ground-based spectroscopy revealed that the NH_3 enrichment was concentrated in equatorial plumes in the 2-6^{o}N region [5]. The equatorial plumes are also dark at radio wavelengths sensed by the VLA [6]. These plumes are white and reflective in visible light [7], and are located between the prominent "hot spots" that exist on the prograde jet at 6.9^{o}N, slightly further north. The plumes are distorted by the zonal wind field, with tails extending in a southwest direction towards the equator, and bordered to east and west by dark streaks ("festoons") emanating from the southwestern corners of the hot spots. Juno's Microwave Radiometer [8] measures 1.3-50 cm emission, sensitive to the ammonia abundance from 0.7 to hundreds of bars, in narrow swaths viewed during close perijoves. Data from PJ1 (August 2016) confirmed the equatorial NH_3 enrichment, and demonstrated that the enrichment persists to great depths in the jovian troposphere [9]. An Earth-based campaign has been underway to assess, for each orbit, whether the MWR's narrow longitude track sensed an NH_3-depleted hot spot or an NH_3-enriched plume. *This work combines Juno and Earth-based observations to understand the morphology and depth of Jupiter's ammonia plumes.*

2. Plume Identification/Tracking

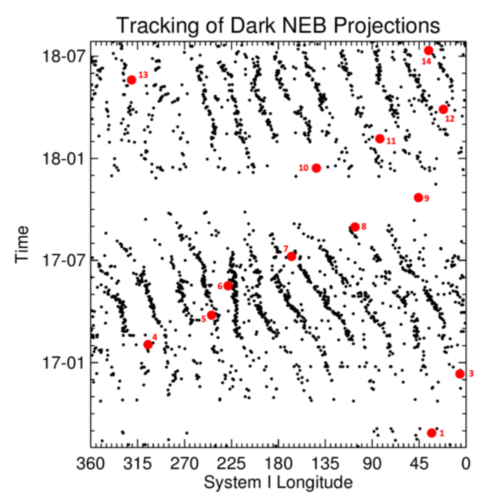

Figure 1: Tracking dark projections (hot spots) between 6-9^{o}N using the JUPOS database, compared to the System I longitudes of Juno perijoves. The y-axis is subdivided by year and month.

Amateur visible-light images, and near-infrared observations from the IRTF, are used to track the location of the plumes. Visible tracking uses measurements from the JUPOS project (jupos.org). Images at 3.8 µm show where the plumes are bright against the equatorial hazes, and images at 5.1 µm show where the hot spots appear bright due to the dearth of cloud opacity. Comparisons to the 2017 MWR “footprints” in Fig. 1 suggest that PJ4 (Feb 2) should have encountered an NH_3-rich plume, whereas PJ5 (Mar 27), PJ7 (Jul 11), and PJ8 (Sep 1) should have been close to NH_3-depleted hot spots.

3. Plume Temperature/Composition

The PJ4 plume and PJ5 hotspot were both observed using the TEXES spectrometer on the Gemini telescope on 2017 Mar 10-11 (Fig. 2), allowing us to invert the 5-20 µm spectra to determine spatial distributions of tropospheric temperatures, ammonia, aerosols and phosphine in the 0.1-0.7 bar range [5]. The plumes appear dark in the TEXES maps, indicating cool, cloudy, and NH_3/PH_3-rich conditions. These atmospheric properties can be directly compared to the microwave brightness measured by Juno. Furthermore, both this plume and hot spot are identifiable a few days later in the Hubble visible-light observations on Apr 3.

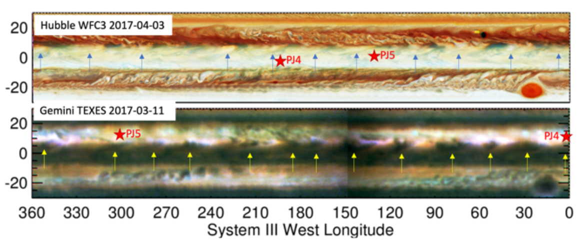

Figure 2: Hubble (top) and TEXES (bottom) maps showing plumes (blue/yellow arrows) and the PJ4/5 locations. The TEXES map is a 3-colour image from spectral windows sensing CH_3D and PH_3 near 8.6 µm.

4. Juno/MWR Plume Observations

Calibrated antenna temperatures for Juno’s 2017 perijoves were extracted from the PDS. Limb-darkening coefficients were fitted at each latitude, and the nadir antenna temperature was mapped in the equatorial region (Fig. 3). These confirm the persistent NH_3 enrichment at the equator and its bias to 2-5ºN. At 1.3 and 3.0 cm, sensing the upper troposphere at p<2 bar, PJ4 (a plume) and PJ5 (near a hot spot) are significant outliers, corroborating the NH_3 distributions determined from TEXES mid-IR spectroscopy. PJ7 and 8 may have encountered the eastern edges of NH_3-depleted hot spots, but none of these brightness temperature contrasts are as large as might be expected from previous VLA observations [6], suggesting that the MWR did not measure a fully formed hot spot in 2017. At 5.75 cm (sensing deeper ~3.5 bar), the spatial structure in Fig. 3 is still present - but lower in contrast, and it is not easy to distinguish structure at even longer wavelengths that sense p>10 bar. This suggests that the hot spots and plumes may be features of the dynamic weather layer at p<10 bar, without “deep roots” at higher pressures.

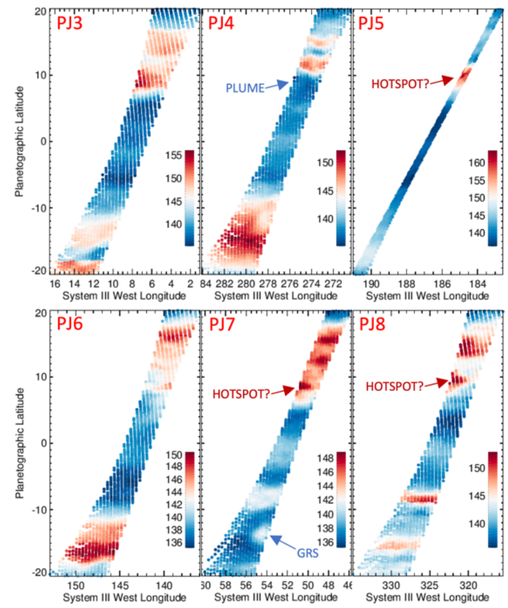

Figure 3: Calibrated MWR antenna temperatures at 1.3 cm (~700 mbar), highlighting plume regions at 2-6ºN and the edges of hot spots at 8-10ºN for 2017 perijoves. Low temperatures suggest enriched NH_3.

Acknowledgements

Fletcher was supported by a Royal Society Research Fellowship. This work was supported by a European Research Council Consolidator Grant under the European Union’s Horizon 2020 research and innovation program, grant agreement 723890.

References

[1] Gierasch et al., 1986 (10.1016/0019-1035(86)90125-9)
[2] Achterberg et al., 2006 (10.1016/j.icarus.2005.12.020)
[3] Fletcher et al., 2011 (doi:10.1016/j.icarus.2011.06.006)
[4] Janssen et al., 2013 (doi:10.1016/j.icarus.2013.06.008)
[5] Fletcher et al., 2016 (doi:10.1016/j.icarus.2016.06.008)
[6] de Pater et al. 2016 (doi:10.1126/science.aaf2210)
[7] Choi et al., 2013 (doi:10.1016/j.icarus.2013.02.001)
[8] Janssen et al. 2017 (doi:10.1007/s11214-017-0349-5)
[9] Li et al., 2017 (doi:10.1002/2017GL073159)