

# INFRARED OBSERVATIONS OF JUPITER'S AURORAE, ATMOSPHERE AND MOONS

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NASA's Juno mission has been observing the Jovian aurorae since 2016 from a polar, highly elliptical orbit [1–3]. From this very favorable position above the poles, Juno obtained unprecedented in-situ measurements of Jupiter magnetosphere, and unique, remote-sensing views of the polar regions, for the investigation of both atmosphere and aurorae. Juno also performed unprecedented observations of the Galilean moons of Jupiter.

Here we present results from the most significant observations performed by Juno's Infrared Imager and Spectrometer JIRAM (Jovian InfraRed Auroral Mapper) [4] during the prime mission, with particular emphasis on the most recent ones, including those acquired during Ganymede flyby.

For the atmosphere, full views of the polar atmospheric structures have been acquired for the first time during orbit 4 [5] by JIRAM. In the north polar region, Juno discovered, in 2017, the presence of an eight-cyclone structure around a single polar cyclone; in the south, a polar cyclone is surrounded by five circumpolar cyclones. The stability of these structures has been monitored for almost 5 years. Recent observations showed that the configurations of the cyclones can temporarily change: in the South the structure moved in a hexagon for a few months, before returning to its original pentagonal shape. In the north, there are significant hints that the octagonal shape may have been lost for a similar period of time. Moreover, the morphology of single cyclones is quite stable over long periods of time, with some noticeable and sudden exceptions. We find that all cyclones show a very slow, westward drift as a rigid ensemble, and, in addition, they oscillate around their rest position with similar timescales. These oscillations seem to propagate from cyclone to cyclone. Here we present the latest observation of these cyclones and we discuss the implications of their secular motion. We also integrate previous studies on the subject with dedicated velocity and vorticity maps, which show an anticyclonic vorticity field surrounding the main cyclones and acting like a stabilizer for the polar structure.

Infrared Aurora comes from electron precipitation, which produces, indirectly, H<sub>3</sub><sup>+</sup> thermal emission. Images of aurorae in this range are collected by JIRAM at each Juno perijove pass. In the main oval, the field aligned electric currents have very low densities, less than what was previously assumed to explain the intense auroral emissions. Juno observed the high energy (> 100 keV) auroral electron, but also a lower energy component (~ 1 keV), which plays a substantial role. Inside the main oval, persistent upward broadband high-energy (~ 1 MeV) electron are observed. Also, intense auroral emissions are observed in regions where little or no precipitating electron flux is detected, possibly indicating excitation from strong ionospheric electric currents. Juno also revealed a puzzling structure in the electromagnetic interactions between Jupiter and its moons [6], whose signature is the presence of auroral footprints. These are a peculiar series of emission features extending downstream of the leading one and look like a repeating pattern of swirling vortices. These multiple features have a very small scale (~ 100 km), which is not compatible with the simple paradigm of multiple Alfvén wave reflections. Other puzzling structures are observed, such as the splitting of Io's footprint tail well downstream of the leading feature, Ganymede's footprints (main and secondary), which appear as a pair of emission features instead of one, and the recent findings of small ring-shaped structures inside the main oval.

Since Juno's orbit insertion at Jupiter until today, the JIRAM spectro-imager observed Io and Ganymede several times and at different distances

and viewing angles, both with its infrared imaging subsystem and with its slit spectrometer sensitive to the 2–5  $\mu\text{m}$  spectral range. In particular, JIRAM observed Ganymede during three dedicated flybys occurred on Dec. 2019, June and July 2021.

Here we discuss the infrared images and spectra that JIRAM was able to acquire during this flyby, with an emphasis on the preliminary spectroscopic results and the distribution of the chemical species detectable in the spectra. We also present recent results from the global campaign of Io observations.

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