Detection of Auroral Emissions on Jupiter at 2.2 μm with the FTS

The UV and the IR aurorae

In early January 1979, the Voyager 1 spacecraft began observations of the Jupiter system in the little explored region 500 to 1700 Å, in a closer view than ever before. The observations revealed an unexpected enhancement of atomic and molecular hydrogen emission, in Lyα and the Werner bands, in the polar regions of Jupiter (Broadfoot et al., 1979). The strong H₂ emission, only present near the poles, was interpreted as a signature of auroral emission, excited by high-energy particle precipitation along the Jovian magnetic field lines, comparable to the phenomenon observed on Earth. The UV Spectrometer on board Voyager 2 confirmed the previous detection. Subsequent observations were carried out with IUE (Skinner et al., 1984), supporting the Voyager's finding, but with poor spatial resolution (10x20 arcsec), and from the ground in the infrared, at 7.8 μm (Caldwell et al., 1980, 1983, 1988). This latter wavelength corresponds to the very intense ν₃ band of methane, which provides information about the Jovian stratosphere. In this experiment, the disk of Jupiter is mapped with a 2 arcsec aperture in a two-dimensional raster pattern. The scans revealed a brightening near both poles which were first thought to be related to auroral (i.e. nonthermal) effects.

However, with further study, significant differences appeared between the two detections. The UV emission is concentrated in zones around each magnetic pole: a) an oval known as the 'Io footprint', the locus near the surface of Jupiter where magnetic field lines through the orbit of Io intersect the atmosphere; b) an auroral arc characteristic of magnetic field lines exiting from the interior of the planet. In the infrared, the emission in both hemispheres is confined to a small spot, of about 3x6 arcsec. The northern spot is fixed, at latitude + 60°, while the southern spot moves in longitude. The position of the northern spot is found to coincide nearly with a magnetic anomaly (at 180° longitude in System III). From analysis of the infrared spectra of Voyager 1, Kim et al. (1985) reported the same localized emission in various hydrocarbon trace gases. High-resolution detection of few line profiles of hydrocarbons from ground-based observations, in C₃H₄ at 13.3 μm (Drossart et al., 1986) and in C₂H₆ at 11.6 μm (Kostiuk et al., 1987), confirmed the previous results. The most intense region, located in the northern hemisphere, is hereafter known as the Auroral Hot Spot.

To explain these striking differences, the following idea has been proposed: the aurorae in the two spectral regions, UV and thermal IR, have different source particles. A possible interpretation is a direct excitation of H₂ by the charged particles to produce the UV emission, while the infrared polar brightenings would result from an indirect excitation of the stratosphere (by secondary electrons, ions, etc.) with an intense thermal heating, resulting in a change in the photochemistry. Therefore, only the UV brightenings could be properly described as auroral signatures.

CFHT Observations: new emission lines

The auroral phenomenon and related effects has many implications for understanding the Giant Planet, for the structure of the Jovian magnetic field, the energy of the particles, the chain of reactions resulting from the precipitation of particles, the structure of the atmosphere in the polar regions and the circulation in the stratosphere. To help answering these difficult questions, the exploration of another accessible spectral window is crucial.

H₂ has vibrational transitions (quadrupole lines) in the 2.2 μm region, which have been theoretically predicted to be observable. Since the same molecule is involved in the UV emission and the 2-μm emission, the latter can give the opportunity of recovering all the information intrinsic to the ultraviolet. In addition, the solar reflected spectrum is weak (K

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On the FTS spectra, the most surprising thing was not the detection of the expected quadrupole $H_2$ line (two more are also detectable), but the discovery of many unidentified emission lines, several being more intense than the $S_1$ line of $H_2$ (Figure 10). With the kind help of the Spectroscopy Section at the Herzberg Institute of Astrophysics in Ottawa, which has a unique expertise in molecular hydrogen spectroscopy, we immediately began to identify the mysterious lines. Out of the 28 lines clearly detectable in the Jupiter spectrum and not attributed to quadrupole lines of $H_2$, 21 were found to have counterparts in a discharge emission spectrum of $H_2$ at 50 Torr, obtained by W. Majewski, containing $H_2$ Rydberg lines, $H_3$, $H_3^+$ and maybe something else.

So far, the best candidate for most of the lines is $H_3^+$ in the 2$u_2$ band, according to J. Watson. If confirmed, it would be the first detection in space of this molecule. These new observations have particular importance. They may be the first detection of real infrared aurora (i.e. nonthermal emission). The production of $H_3^+$ could be an essential link in the formation, deeper in the stratosphere, of more hydrocarbons.

More modeling and more spectroscopic work are required, as are more observations with the FTS, particularly to secure similar observations in the northern zone. The sensitivity, the high resolution and the large spectral range provided by the instrument are essential for a breakthrough in the study of the complex mechanisms of aurorae on Jupiter.

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References


Inhomogénéités dans les vents d'étoiles Wolf-Rayet

Le phénomène de vent stellaire, commun à la plupart des étoiles et particulièrement important dans le cas des étoiles lumineuses, atteint son paroxysme chez les étoiles Wolf-Rayet (W-R). Cependant, une description quantitative et non équivoque de la nature et de l'origine de ces mêmes vents reste à formuler.

La plupart des experts s'accordent à dire que les étoiles W-R sont les descendants hautement évolutés d'étoiles initialement très massives (masse initiale $\geq 40M_\odot$), de type O. Leurs raies d'émission larges et intenses, même dans le visible, indiquent une perte de masse élevée et rapide ($\geq 10^{-5}$ $M_\odot$ an$^{-1}$, avec des vitesses terminales $v_\infty \sim 1000-4000$ km s$^{-1}$).