Bull. Astr. Soc. India (2005) **33**, 233–236

Infrared spectroscopy of Jovian aurorae

Koshy George* and T. Chandrasekhar
Physical Research Laboratory, Ahmedabad 380 009, India

Abstract. We report on the detection at Mt.Abu of H_3^+ molecular ion emissions in the near infrared spectra of the northern auroral zone of Jupiter. These H_3^+ transitions are of rotational-vibrational origin and are due to the dynamics of Jovian auroral ionosphere located mainly at high Jovian latitudes, which confirms their magnetospheric origin. The main overtone transition at 2.093 μm and several other transitions including that of H_2 have been detected. Details are presented.

Keywords : Jovian Aurorae, Infrared spectroscopy, H_3^+, K band

1. Introduction

Aurorae are generally high latitude atmospheric emissions that result from the precipitation of energetic charged particles from the planet's magnetosphere. Aurorae on giant planets are observable over a wide range of wavelengths and provide unique and complementary information about key physical processes operating in the atmospheric and magnetospheric regions where they originate. The major features of Jovian aurorae include a main oval, with a patchy diffuse emission inside the oval. Jovian infrared aurora can be observed from ground based telescopes, and can be used to monitor the coupled magnetospheric activity on Jupiter. H_3^+ molecular ion which is abundant in the auroral region of Jupiter, consists of three protons bound by two electrons and can be thought of as a hydrogen molecule with an extra proton attached. The main overtone transition of H_3^+ at 2.093 μm acts as a good probe to monitor Jovian auroral activity. The fundamental transition of H_3^+ is at 3.94 μm in a more observationally difficult region of the infrared spectrum. Relevant transitions of H_3^+ in the 2 μm region of our observations are given in Table 1 (Bhardwaj et al., 2000, Raynaud et al., 2004)

*e-mail:koshyg@prl.ernet.in

Table 1. Spectroscopic parameters of H_3^+ line.

Wavelength(μm)	Transition	Comment
2.081	$2\upsilon_2^2$ Q (3,1)	
2.085	$2\upsilon_2^2$ Q (2,1)	Observed
2.088	$2\upsilon_2^2$ R (10,9)	
2.093	$2\upsilon_2^2$ R (6,6)	Observed
2.095	$2\upsilon_2^2$ P (3,1)	Observed
2.105	$3\upsilon_2^3 \rightarrow \upsilon_2$ R (5,6)	Observed
2.107	$2\upsilon_2^2$ P (5,2)	
2.111	$2\upsilon_2^2$ Q (6,2)	
2.113	$2\upsilon_2^2$ R (7,7)	
2.117	$2\upsilon_2^3 \rightarrow \upsilon_2$ R (6,7)	Observed
2.120	$2\upsilon_2^0$ P (7,6)	
2.122	$2\upsilon_2^2$ Q(5,2)	Blended with H2
2.127	$2\upsilon_2^0$ P (8,7)	

H_3^+ molecular ion plays a crucial role in determining the physical conditions in the Jovian ionosphere and thermosphere. In the year 1999 an electrojet was detected in the Jovian auroral oval from Doppler shifted spectral images of H_3^+ emission. (Rego et.al., 1999). It is believed that this H_3^+ electrojet produced due to highly energetic electromagnetic interactions between Jupiter and its moon Io holds the key to the mechanism, by which equatorial plasma sheet is kept in partial co rotation with Jupiter. The detection of H_3^+ molecular ion in other giant planets like Saturn and Uranus makes it a common probe to study planetary atmospheres. (Miller et al., 1990).

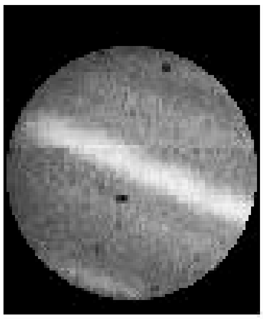

Figure 1. K' band image of Jupiter observed on 25 Dec 2003, 00:25 UT using NICMOS in imaging mode.

H_3^+ emission in the near infrared at 2 μm provides a ready means of ground based monitoring of Jovian plasma. At PRL using the NICMOS spectrometer and the 1.2m

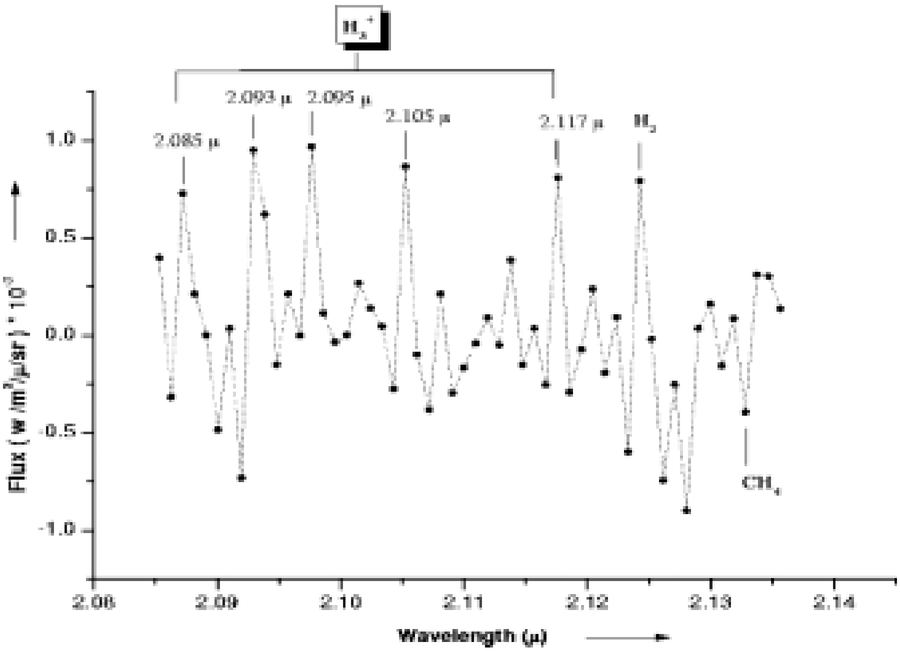

Figure 2. Figure shows a portion of the K' band spectrum of Jupiter taken in the northern auroral zone 306 deg long on 25 Dec 2003 at 23:00 UT. A continuum has been subtracted from the spectra which was then ratioed with a nearby standard star spectrum (θ Leonis, A2 type) to remove terrestrial atmospheric absorption. Line flux calibration has been done using 2MASS K magnitude of the star and a blackbody temperature of 9380 K.

telescope at Gurushikar, Mt Abu we have initiated the study on spatio-temporal variations of H_3^+ molecular ion in Jovian auroral region.

2. Observations and results

The Jovian auroral region was observed spectroscopically during the winter of 2003/ 2004 at the Cassegrain focus of the 1.2m telescope of PRL using the NICMOS imager/spec-spectrometer (Table 2). The slit of the spectrometer was positioned on the central meridian of Jupiter in system III coordinates, defined on the basis of rotation period of Jovian magnetic field. (see Fig.1) The observations consisted of several sets of 5minute exposures (multiple frame mode 3sx100) in K' band at a spectral resolution of R=1000. The analysis was carried out with the spectral reduction task of IRAF package using which cosmic ray, telluric/atmospheric absorption features were removed and wavelength/flux calibration were done.. The Jovian auroral infrared spectrum is dominated by a strong background continuum, which arises mainly due to the scattering of solar radiation, by polar aerosol haze layer. (Wong et al., 2003).

Table 2. Observations Details

Date yy/mm/dd	UT hr:min:sec	Airmass	Position Angle of North pole (Deg)	North pole angular distance from centre (Arc sec)	Angular size of Jupiter (Arc sec)	Central Meridian Longitude (Degrees) System III
2003/12/25	23:01:30	1.30	25.26	-18.19	38.90	306
2004/02/19	21:14:15	1.10	25.05	-20.68	44.30	120
2004/12/23	23:18:00	1.53	24.27	-16.42	35.16	3
2004/12/25	00:30:10	1.60	24.25	-16.47	35.26	187

The continuum subtracted auroral spectrum is shown in Fig.2. It can be seen that the H_3^+ overtone transition along with H_2 quadrupole transition at 2.122 μm is clearly detected. Methane absorption is also noted beyond 2.13 μm. The production mechanism for H_3^+ and H_2 are entirely different, the former being mainly auroral in origin where as H_2 emissions are more widespread. Further observations are ongoing to study the spatio-temporal variations of H_3^+ molecular ion in Jovian aurorae.

References

Bhardwaj et al., 2000, *Rev. Geophys.*, **38**, 295.
Miller et al.,1990, *ApJ,*, **360**, 55.
Raynaud et al., 2004, *Icarus,* **177,** 133.
Rego et al., 1999, *Nature*, **399**, 121.
Wong et al., 2003, *Geophys. Res. Lett.***30** 30.