Astronomical and Astrophysical Transactions (*AApTr*), 2013, Vol. 28, Issue 2, pp. 81–86,
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A study of variations in the 787-nm ammonia absorption band in the Jupiter atmosphere

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Received 15 February, 2013

During the last years the program of the spectrophotometric study of Jupiter included the measurements of the NH_3 absorption band 787 nm. This band is overlapped by a broader absorption band of CH_4. To detect the NH_3 band we used the ratio of Jovian spectra to the spectrum of Saturn equatorial region. It was taken into account that the ammonia absorption on Saturn is significantly weaker than on Jupiter. The results of processing the spectrograms were analyzed for the years 2007–2010. Latitudinal variations of the NH_3 band regularly show a depression of absorption at low and temperate latitudes of Jovian northern hemisphere. The equivalent width decreases approximately from 18–16 Å to 14–12 Å. A more or less symmetric and steeper decrease of absorption from the disk center to limbs was obtained for the equatorial belt of Jupiter. It may be considered as evidence of the reality of that latitudinal depression but not the instrumental errors. It should be noted that the ammonia decrease in northern hemisphere was detected also from radio observations of Jupiter.

Keywords: Jupiter; Spectra; Ammonia absorption; Seasonal changes

1 Introduction

The absorption bands of ammonia in Jupiter's spectra are much less intense than the bands of methane. Most of ammonia bands overlap with the absorption bands of methane, which complicates investigations of ammonia absorption variations across the Jovian disk. Relative abundance of ammonia on Jupiter must have spatial and temporal variation, since, unlike methane present only in the gas phase, ammonia freezes at temperatures typical of the visible cloud cover composed mainly of ammonia crystals.

Previously, the difference in latitude was revealed during the ammonia absorption across the disk of Jupiter on the basis of optical observations with the spacecraft Voyager-1 (Gierasch et al. 1986) and the Hubble Space Telescope (Edgington et al. 1998), as well as radio astronomical observations (De Pater et al. 2001; Sault et al. 2004; Showman and de Pater 2005). Using these data, the concentration of ammonia in low and middle latitudes of the northern hemisphere of Jupiter is somewhat lower.

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Although there are a large number of publications devoted to the study of ammonia in Jupiter's atmosphere, the space-time variations are poorly understood. The ammonia absorption band 787 nm in the spectrum of Jupiter has been almost unstudied earlier, also there are few laboratory measurements (Bowles et al. 2008).

The present work is devoted to research into ammonia absorption in the 787 nm band to determine its latitude-longitude variations.

2 Observations

The observations were made on the 0.6-m telescope by staff members of the Planetary Laboratory, Fessenkov Astrophysical Institute, with the diffraction spectrograph manufactured by SGS SBIG (USA) with a CCD camera ST-7XE. The dispersion of the spectrograph is 4.3 Å/pixel.

The spectrograph was set to 7.5-meter Cassegrain focus of the telescope, so that the scale of the image on the spectrograms is 0.24 arcsec/pixel. Thus, the width of the spectrogram in the equatorial angular diameter of the planet's 45″ was about 180 pixels. The spectrograms were recorded with exposure times of 10 to 60 seconds. Due to the linearity of the transfer of brightness inherent in the CCD, the accuracy of measurements that could affect only by some increase in noise and a reduction S/N ratio. However, a comparison of measurements of spectra with different exposure time showed no significant differences in the results. In 2010 it was almost invisible in the continuum southern equatorial belt of clouds (SEB) which is usually dark and broad. However, the strong absorption band of methane at 887 nm in this time has not noticeably changed. A similar situation was observed in 1989 and earlier, although this "disappearance" SEB is still a fairly rare event.

3 Processing of spectrograms

The 787 nm absorption band of ammonia is within the more intense and broad absorption bands of methane, ranging from 765 nm to 825 nm. As can be seen when comparing the spectra of Jupiter and Saturn (Fig. 1), namely the absorption of ammonia creates a difference in the band profile.

In laboratory studies, the profile of this band (Bowles et al. 2008) is somewhat broader than that obtained in the planetary spectrum, which may be due to the differences in the conditions of formation of absorption bands in the atmospheres of the planets and in the laboratory (Fig. 2).

To extract our own ammonia band profile in Jovian spectra we used their ratio to Saturn's spectrum. Since in this paper we investigate the behavior of the absorption band of ammonia in different parts of the Jovian disk, it is sufficient to use only one Saturn's equator spectrum as the spectrum of comparison. The next step was to determine, for different parts of the central meridian or the equator of Jupiter, the equivalent width of the NH_3 absorption band

$$EW = \sum_{\lambda_1}^{\lambda_2} (1 - I_\lambda / I_c) \cdot \Delta\lambda \,,$$

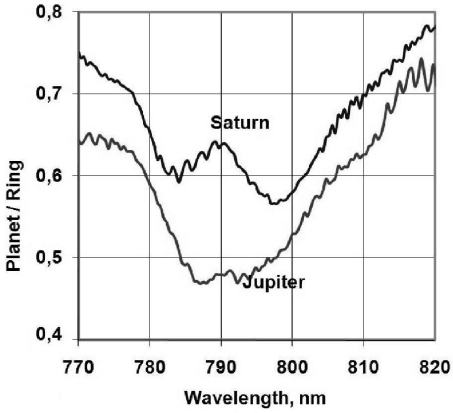


Figure 1 Comparison of the spectra of Jupiter and Saturn in CH_4 + NH_3 band 787 nm.

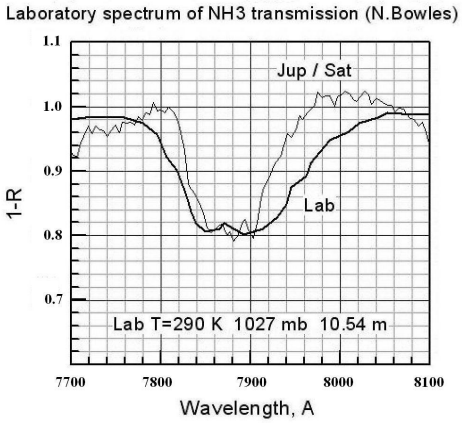


Figure 2 Comparison of observed and laboratory profile of 787 nm band of NH_3, laboratory data were obtained by N. Bowles (from V. Tejfel's personal correspondence).

where I_λ and I_c are the intensity within the band and that interpolated on a strip of continuous spectrum; $\Delta\lambda$ is the integration step (4.3 Å). The limits of integration λ_1 and λ_2 correspond to the edges of the absorption band. As a result, the EXCEL program displays a graph which shows the profile of the absorption band of ammonia, the variations of *EW* across the disk and the brightness profile in the continuum at a wavelength of 680 nm in conventional units. The longitude of the central meridian in the II system on each graph is also shown.

4 Results and conclusion

Processing of multiple spectrograms recorded in different years gives almost the same result: there is a visible depression of ammonia absorption at 787 nm in the northern

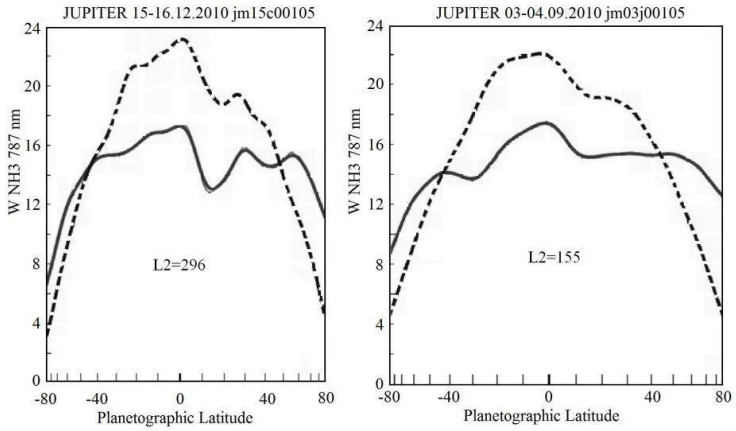


Figure 3 Variations of ammonia absorption along the central meridian of Jupiter (black line) and of the relative brightness in the continuum (dotted line).

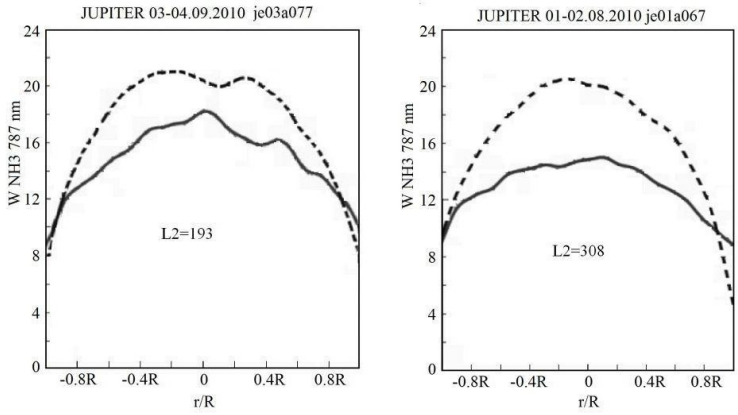


Figure 4 Variations of the NH_3 absorption band at 787 nm along Jupiter's equator (black line – ammonia absorption, dotted line – brightness in the continuum).

hemisphere of Jupiter. Within each series of the spectra the dispersion of the equivalent width estimates is very small (about 6%). Some differences are noted from series to series. They are partly due to changes in atmospheric turbulence image quality, but most likely we also have longitudinal differences because the cloud belts of Jupiter are not uniform in the structure of cloud albedo and details (Fig. 3).

Figure 4 shows the course of ammonia absorption spectra for several Jupiter's equatorial belt processings. The absence of this characteristic meridional spectrum of the "dip" in the course of absorption indicates that the observed depression of the absorption of NH_3 to the northern hemisphere of Jupiter is not the result of any instrumental errors.

On all figures with the profiles of the absorption variations on Jupiter's disk the abscissa axis shows planetographic latitude and the ordinate shows the values of equivalent width of the NH_3 787 nm absorption band.

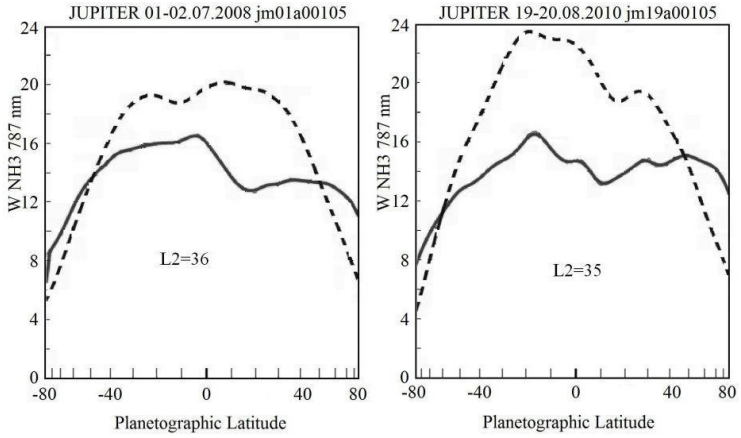


Figure 5 Comparison of the NH_3 absorption latitudinal variations in 2008 (left) and 2010 (right) (black line – ammonia absorption, dotted line – brightness in the continuum).

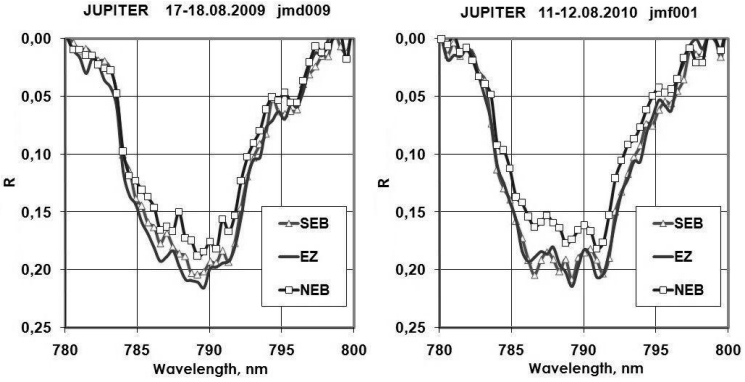


Figure 6 Profiles of the 787 nm band of NH_3 in the SEB, EZ and NEB in 2009 and 2010. In the NEB this band is noticeably weaker than in EZ and SEB (EZ – Equatorial Zone, SEB – South Equatorial Belt, NEB – North Equatorial Belt).

Figure 5 shows the course of the absorption of ammonia in 2008 and in 2010. As it was noted above there were significant changes in the zonal structure of Jupiter's cloud belts in 2010 – the SEB dark cloud band disappeared.

However, it did not affect absorption of ammonia (depression is still observed in the northern hemisphere, as seen by comparing the profiles of bands in Fig. 6) and no significant changes in absorption within the SEB were detected.

The results described above are in good agreement with the investigations of previous years (Tejfel et al. 2003; Tejfel et al. 2005). It should be noted that the measured equivalent widths may not be clear values for ammonia absorption only. Additional research into their dependence on overlapping methane absorption is planned. In any case, a further study of the detected variable effect of the South–

North asymmetry in the behavior of the 787 nm absorption band is necessary. This work will be continued to analyze the long-term ammonia absorption variations in connection and comparison with methane space-time variations on Jupiter.

References

Bowles N., Calcutta S., Irwina P., Templea J. (2008) Icarus V. 196, Issue 2, P. 612
De Pater I., Dunn D., Zahnle K., Romani P.N. (2001) Icarus, V. 149, P. 66
Edgington S.G., Atreya S.K., Trafton L.M., et al. (1998) Icarus, V. 133 P.192
Gierasch P.J., Conrath B.J., Magalhaes J.A. (1986) Icarus, V.67, P 456
Sault R.J., Chermelle E., de Pater I. (2004) Icarus, V. 168, P 336
Showman A.P., de Pater I. (2005) Icarus, V. 174, P. 192
Tejfel V.G., Vdovichenko V.D. (2003) A&AT, V. 22(2), 135
Tejfel V.G., Vdovichenko V.D., et al. (2005) A&AT, V. 24, No. 4, 359