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THE GREAT RED SPOT ON JUPITER: SOME FEATURES OF THE AMMONIA ABSORPTION

Abstract. In April 2017, we carried out five cycles of spectral observations of Jupiter to study some optical features of the Great Red Spot (GRS) that is a long-lived giant anticyclonic vortex. Recording the CCD spectrograms of Jupiter's central meridian in each cycle was performing consistently for two hours in the 240^0 - 310^0 longitude ranges in steps of about 2^0 each - before, during and after passage the GRS across the CM. The main objective was to investigate the behavior of the 645 and 787 nm ammonia (NH_3) absorption bands in the GRS region, which before was studied quite a little. The measurements of the profiles and equivalent widths of these bands showed explicitly that ammonia absorption in the GRS is decreased; the decrease is even more than the NH_3 depression in the Northern Equatorial Belt (NEB) that we discovered in 2004. A comparison with the results of the studies of Jupiter in the ranges of thermal infrared and millimeter radiation allowed concluding that the causes of the ammonia absorption decrease are not the same for the NEB and GRS. In the NEB, according to the radio astronomical observations, the gaseous ammonia concentration is really lowered. In the GRS, the NH_3 absorption decrease is caused by the increased cloud volume density. As a consequence of this, the absorption equivalent optical path decreases due to multiple scattering. That is also manifested in the near infrared ammonia and methane absorption bands. Quantitative interpretation requires some further complex studies because of the multiparametric nature of the models that are will be taken.

Keywords: Jupiter, Atmosphere, Clouds, Great Red Spot, Ammonia, Methane, Molecular Absorption Bands, Spectrophotometry.

Introduction

Some important and interesting objects in the study of Jupiter's atmosphere are specific optical and dynamic properties of the Jovian Great Red Spot (GRS). A number of distinctive features of this giant long-lived anticyclonic vortex are already known quite well. The period of its rotation is about 6 terrestrial days. It is known that the GRS makes its own special speed longitude drift, and it is not always regular, and for 300 years GRS has noticeably decreased in diameter [1], which, judging by the early sketches of Jupiter, had reached 40 thousand kilometers. The GRS has specific optical features, for example, its unique red-orange color, which has not yet been explained. But the coloring of Jupiter's cloud belts is also not yet fully explained, although it is very likely that ammonium hydrosulfide (NH_4SH) plays a role in this coloring, because it forms a cloud layer at great depths, below the ammonia layer [2].

In the ranges of thermal infrared [3] and millimeter [4] radiation, the brightness temperature of the GRS is lower in comparison with the surrounding regions, and that indicates a greater opacity for radiation emerging from the deep layers of the Jovian atmosphere.

It should be noted that in spectral ranges with strong methane absorption bands, the Great Red Spot looks like the brightest, or rather abnormally bright, formation on the planet. This indicates that in the GRS region the methane absorption is strongly weakened in comparison with all other regions of the visible cloud surface of Jupiter [5]. As for the morphological and dynamic properties of the GRS, the most impressive recent results are those obtained from the space probe JUNO, approaching to Jupiter at the distance of only three thousand kilometers [6]. The properties of the GRS also show themselves in

ammonia absorption. In addition to the previous photometric and spectral observations of the GRS (for example, [7-9]), a special observational program for studying the spectral features of the GRS was carried out in 2017. Five cycles of recording the spectra of Jupiter's central meridian (CM) were carried out before, during and after a passage of the GRS across the CM. We report on results of this our research.

Observations: methods and results

From the end of March to the beginning of May 2017, a series of observation cycles of Jupiter was performed as an extension of regular long-term spectral studies of variations in the molecular absorption bands, and studying the structure of the planet's cloud cover. These observations covered almost all the longitudes of Jupiter (Figure 1), including 5 cycles destined to obtain spectra of longitudes near the GRS. At that time its longitude was 267^0 in the 2nd system. The GRS (or its core) has its own longitudinal coverage of about 12^0, apart from the peripheral light edging.

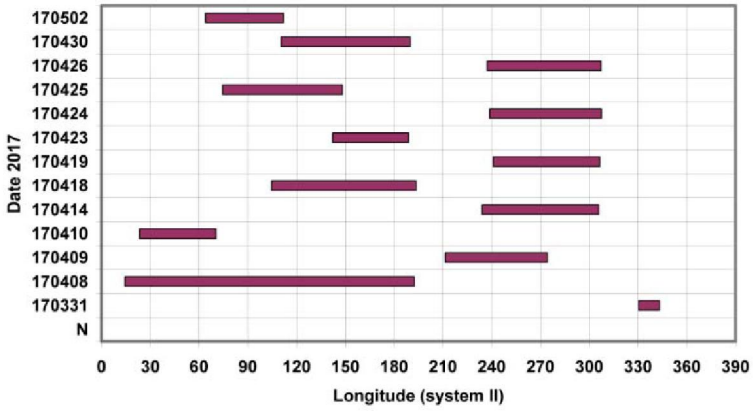

Figure 1 - Diagram of the date distribution of Jovian longitudes observed in 2017

Each cycle, timed to the GRS passage across the CM, was lasting for 2 hours. During this time, 30-32 spectra were recorded with an interval of about 4 min, which corresponded to Jupiter turn of 2.5^0. Thus, the longitudes from 240^0 to 310^0 in the second system of the Jupiter rotation were covered (Figure 2). A fragment of the map of Jupiter for April 2017, compiled by Vedovato (the site of the Association of Observers of the Moon and the planets ALPO Japan [10]), was used.

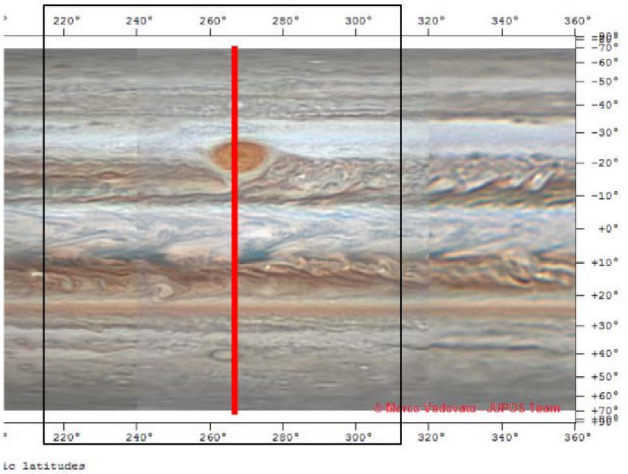

Figure 2 - Fragment of the map of Jupiter from the ALPO Japan site as of April 2017 with the area of longitude scanning

Observations were carried out using the SGS diffraction spectrograph installed in the 7.5-m Cassegrain focus of the 0.6-m RZ-600 telescope. The receiver of a spectrum image was the ST-7XE CCD camera with a matrix of 765x510 pixels. The size of one pixel is 9x9 microns and the resolving power for dispersion of 4.3 A/pixel is 8.5 A. The scale of an image on the spectrogram is 4.08 pixels /arc second. As

a rule, the exposure time of one spectrum was 20", although in some cases, it increased to 100" in order to provide a better isolation of the methane absorption band in the near-IR region (800-900 nm). In total, the extensive observational material was obtained, which can be used for different further studies, including those related to the study of temporal changes in the Jovian atmosphere during the entire period of its revolution around the Sun.

Processing spectrograms of the absorption bands

For the processing and analysis of the Jupiter's CM spectra, some corresponding programs based on spreadsheets were compiled. They could provide a quick eduction of tabular and graphical results. The main attention was paid to measurements of the two ammonia absorption bands' (645 and 787 nm NH_3) profiles and to the evaluation of their intensities. These bands are weak in intensity, especially the 645-nm band. Both bands overlap with more intense methane absorption bands, so their separations require special techniques. Therefore, their behavior in the spectra of Jupiter has not been studied in detail by anyone before, except for some researchers [11-15]. Laboratory studies of these ammonia bands are also few and not yet very definite. Their analysis is contained in [16]. The 645 nm NH_3 absorption band is located in the short-wave and relatively weak wing of the methane absorption band (λ?). Therefore, its separation is carried out simply by calculating the ratio to the interpolated smooth running of the intensity in this methane band's wing. The 787 nm NH_3 band is located in the middle of another methane band, centered at the same wavelength. Filling, its less intense central part. In this case, we use the spectrum of Saturn as a reference spectrum. In it, the ammonia absorption inside this methane band is practically absent or negligible. So, the Jupiter 787 nm NH_3 band stands out well enough in calculating the ratio of the Jupiter spectrum to the spectrum of Saturn. Figure 3 shows examples of the profiles of both ammonia bands, obtained by processing one spectrogram of Jupiter's CM for all points of the meridian (from the South Pole to the North one). As a result of measurements, we obtain estimates of the equivalent widths (W) of these absorption bands at different latitudes, including the GRS region. We note that the maximum value of W in the 645 nm band does not exceed 8A, while in the 787nm band it does not exceed 20A.

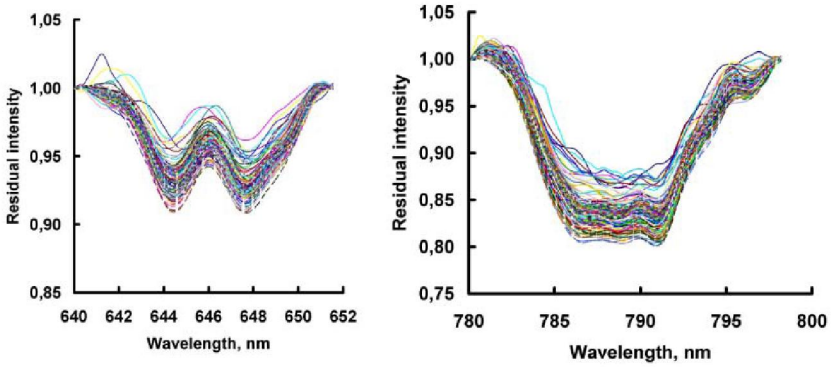

Figure 3 - The 645 and 787 nm NH_3 absorption band profiles, separated from all the lines of the Jupiter's CM spectrum

We started measurements of the 645 and 787 nm NH_3 bands in the spectrum of Jupiter in 2004. From them, we found the existence of a depression of ammonia absorption in the Northern Equatorial Belt (NEB). This depression [17, 18] is most pronounced in the 787 nm NH_3 band. In the NEB its W (W_{NEB}) is less by 2-3A in comparison with other low and moderate latitudes, where $W > W_{NEB}$ and varies within smaller limits [19]. Further observations from 2005 to 2017 (during the complete revolution of Jupiter around the Sun) have shown that this depression remains a peculiar feature of the NEB, albeit it is variable in longitudes and in time.

Ammonia absorption in the Great Red Spot

Based on the results of spectral measurements of each observational cycle during the GRS passage across the Jupiter CM, latitudinal variations in intensities of the ammonia absorption bands were plotted. The graphs plotted together for all longitudes (Figure 4) show that along with depression in the low-latitudinal NEB, the weakening of ammonia absorption in the GRS is observed. It is most pronounced in the 787 nm NH_3 band (Fig. 4).