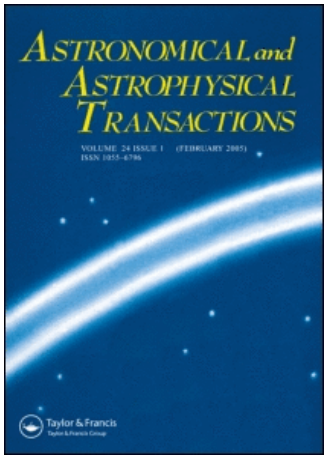

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On spectral peculiarities recorded by fast monitoring during the collision of comet SL-9 with jupiter

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ON SPECTRAL PECULIARITIES RECORDED BY FAST MONITORING DURING THE COLLISION OF COMET SL-9 WITH JUPITER

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Spectral monitoring of the impact of comet Shoemaker–Levy 9 with Jupiter was conducted in the Crimean Astrophysical Observatory from July 5 to August 30, 1994. About 2000 spectra with exposure times of tens of seconds were obtained. A preliminary statistical treatment of 323 spectra obtained during the period July 16–22 was made. Spectral variability at the temporal scale of tens of seconds was registered in the spectral regions of atomic lines of metal (Ca, Fe, Na, Li) and molecular bands and lines of the atmosphere of Jupiter (NH_3, CH_4, H_2 and H). Repeated variability was recorded in the region of the resonance line of Na at 5890–5896Å. The doppler shift of this line was up to thousands of km s^{-1} and more in several cases. This is evidence of the high energy of the exiting agent. The analysis of the disc zone spectra of Jupiter obtained on July 20 revealed that sodium emission was located in the region at about 100 000 km or more and was connected with Q fragments. The distance of the sodium line radiation region from Jupiter was evaluated as 3 radii. V. V. Prokof'eva and V. P. Tarashchuk supposed that sodium exited by high – energy electrons of the internal magnetosphere of Jupiter.

KEY WORDS Comet Shoemaker–Levy 9, Jupiter, impacts, sodium emission

1 OBSERVATIONS

Spectral monitoring of different zones on Jupiter was carried out at the Crimean Astrophysical Observatory from July 5 to August 30, 1994 in the spectral region 5500–7500Å (Abramenko *et al.*, 1996). The 0.5-m meniscus telescope and highly sensitive digital television complex were used. The original TV spectrograph allowed us to observe the disc image of Jupiter on the TV screen with very faint guiding of the telescope. The spectral resolution was about 20Å until July 27 and 7Å after this date. The exposure time 6 up to 26 s was selected so that the signal-to-noise ratio would be about 100. The accuracy of the intensity measurements in each original digital recorder of spectra was about 1%.

The aims of the spectral monitoring of the disc of Jupiter were: (1) to obtain digital data with high time resolution about physical processes in the jovian atmosphere and surrounding space; (2) to investigate fast spectral variability in the comet impact fragment sites both at the moment of impact and during various stages of outburst sequence development.

Every night, besides spectra of new spots or plumes formed by the fall of the comet SL-9 secondary nuclei, spectra of the centre, the eastern and western edges of the disc of Jupiter in the equatorial region and in the region of the central meridian at latitude of about +45° were also obtained.

2 FAST SPECTRAL VARIABILITY

The observations taken during July 16–22, 1994 were the most interesting and we have done a preliminary treatment of 323 spectra (Churyumov *et al.*, 1995; Prokof'eva and Tarashchuk, 1996). The digital observational data were transformed to relative intensities with the help of a special computer program and mean square errors versus wavelengths were obtained. An atlas of 92 pages has been prepared in which averaged original spectral records and the spectral relations of m.s.e. are presented. The date and time UT are listed on each graph. Some pages of the atlas are shown in Figures 1–4. When variability is absent, the value of m.s.e. is small and practically constant at all wavelengths (Figure 1). Figure 2 illustrates the variability of radiation in the lines of metal (Fe, Ca, Na) and probably in lines of C, N, CO. The times of metal line appearances were very short. The powerful variations of the sodium line at 5890–5896Å are demonstrated in Figure 3. The variation of Li emission was recorded also. The variability at 6100Å is not identified. The possibility of the existence C_2 and CO bands is not excluded. The quadruple line of molecule H_2 was registered when the impact site from fragment H crossed the central meridian of Jupiter after 1.3 revolutions of the latter. Figure 4 illustrates variations in lines of H_2 and H_α. The variable band of methane and probably the shifted lines of sodium also are presented.

The intensity of the Na line at 5890–5896Å was estimated on all spectra obtained on July 20. The intensity 0 was assumed when the sodium line was absent and 4 when intensity was brightest. The intensities 1, 2 and 3 determine intermediate values. Figure 5 shows the sequence of bright flashes of the sodium line during time observation UT 18:40–20:40.

Na emission showed the following peculiarities:

(1) the emission was observed not only at impact sites but also over all of the disc of Jupiter;

(2) the typical emission time was about 1 min;

(3) the doppler shift reached 1000 km s^{-1};

(4) the duration of the sequence of sodium flashes continued for about 40 min;

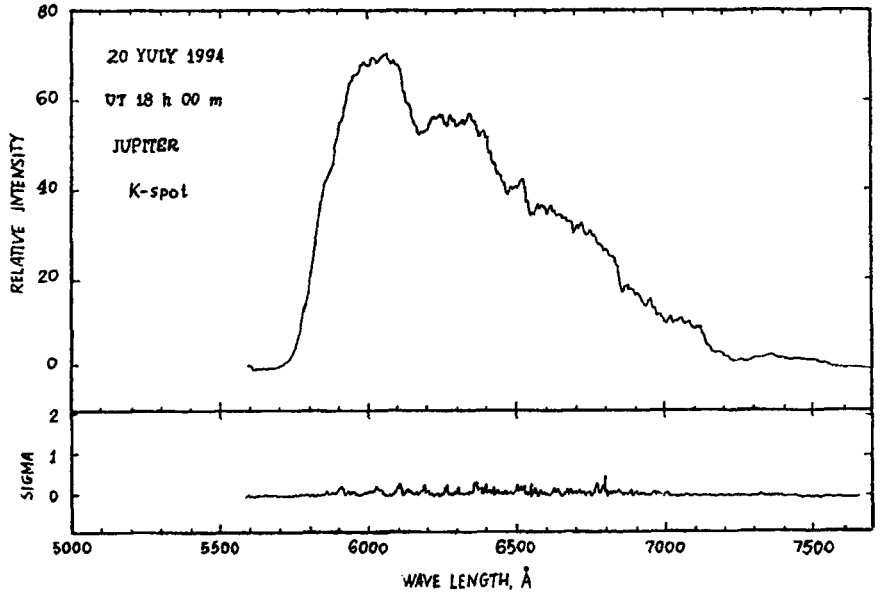

Figure 1 The spectrum of the K-spot obtained by averaging of nine records of the spectra observed one after another with an exposure time of 13 s. The precision of the intensity measurements in the spectrum is close to 0.01 and variability is practically absent.

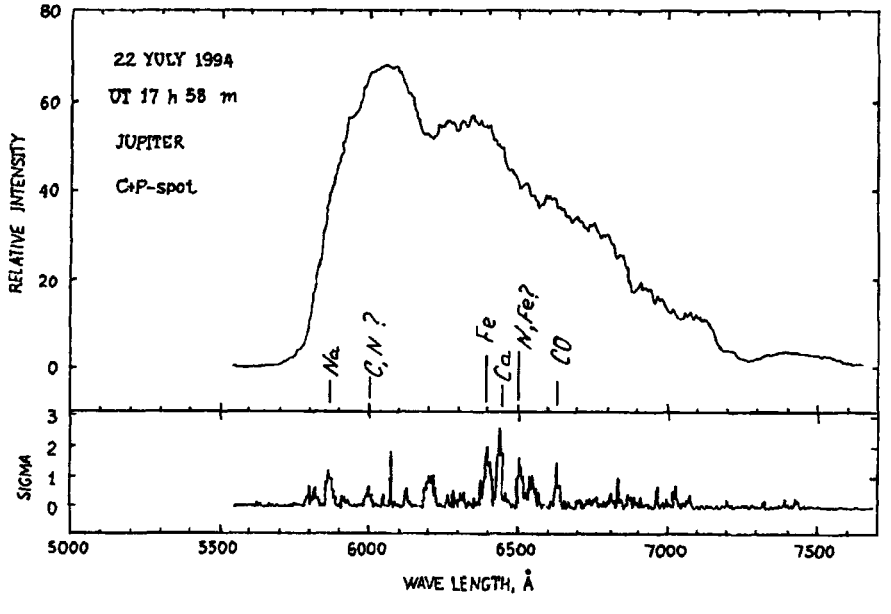

Figure 2 The spectrum obtained by averaging of three records of the spots caused by the impact of the $C + P$ nuclei. Identification of the variable details is shown. Uncertainty of identification is marked by ?.

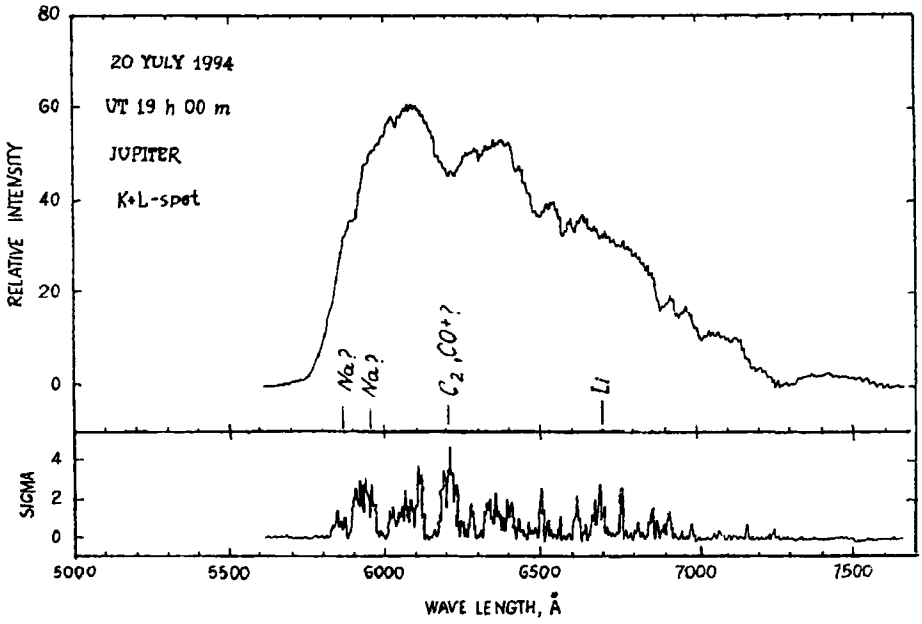

Figure 3 The spectrum of the site of nucleus K impact, averaged from three records. Variability in the region 6200Å may by connected with radiation in bands of molecules C_2 and CO^+.

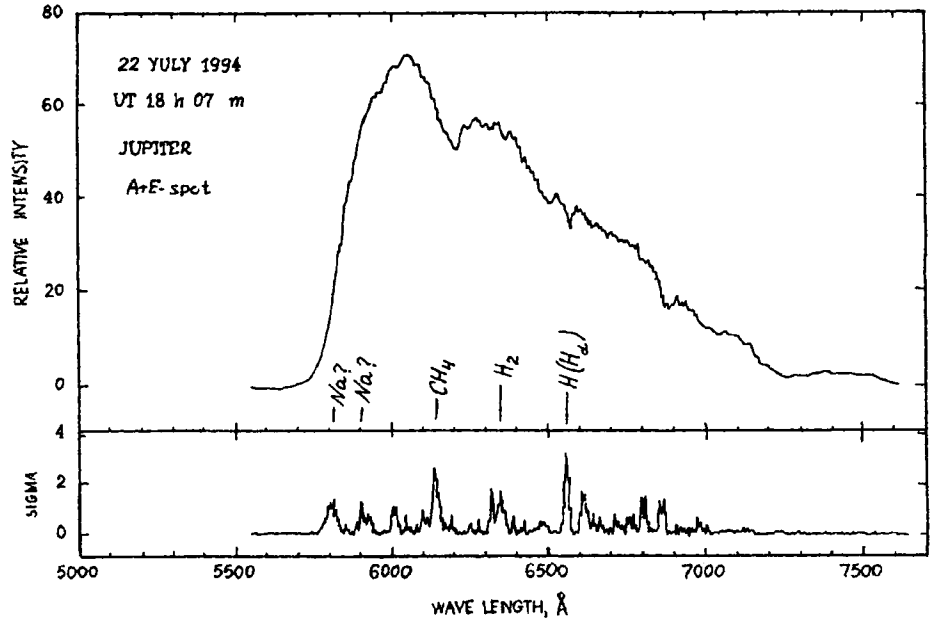

Figure 4 The average spectrum of three records showing variability in the region of the quadruple line of molecule H_2 at 6367Å registered from A and E spots.

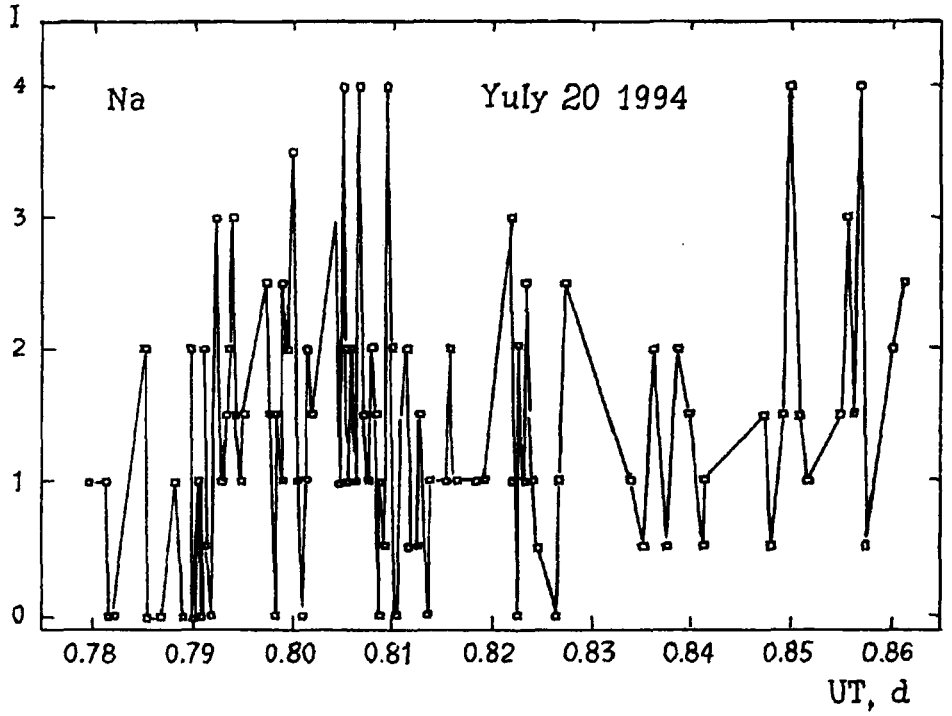

Figure 5 The temporal variation of the sodium emission intensity at 5890–5896Å observed July 20, 1994 before Q family fragment impacts.

(5) the first bright flashes took place about 40 min before the first Q fragment impact;

(6) the distance of appearance of Na luminosity was estimated as 3 radii from Jupiter.

The time of sodium observations obtained by Rose–Serote *et al.* (1995), Fitzsimmons *et al.* (1995) and Catalano *et al.* (1995) overlaps only with the end of our observation (Figure 5 UT $0^d.847$–$0^d.860$). The high time resolutions (10–20 s) of our records showed not only the sodium luminosity but its short individual flashes.

The fall of large fragments in the atmosphere of Jupiter caused powerful outbursts that led to complete evaporation of a penetrated body as well as to heating of the surrounding atmosphere. Every comet fragment was surrounded by a spacious coma containing the products of evaporation of the cometary matter, dust and a large quantity of splinters of different sizes. There is evidence that Q fragments had many small companions besides $Q1$ and $Q2$ (Prokof'eva and Tarashchuk, 1995a; Secanina, 1995a, b). Therefore the region of penetration of the cometary cloud occupied much greater space than the region of the outburst. The luminous sodium was visible over all of the disc of Jupiter and appeared before the frag-

ment outburst. Taking into account all the facts mentioned above Prokof'eva and Tarashchuk (1995b) suggested that comet sodium was exited by fast electrons in the internal Jupiter magnetosphere where small p'eces of Q fragment were evaporated.

3 CONCLUSIONS

A statistical method of observed spectral data reduction and analysis allowed us to detect a number of peculiarities in the atmospheric spectra of Jupiter which were conected with the impact of comet Shoemaker–Levy 9 fragments.

Spectral variability at a time-scale of tens of seconds was registered in the fragment impact sites for metal atomic lines (Ca, Fe, Na, Li) and molecular bands of the atmosphere of Jupiter (NH_3, CH_4, H_2 and H).

Investigation of sodium doublet line variations in spectra obtained on July 20, 1994 showed that its fast luminosity variations occurred not only at the impact site but also over the whole of the disc of Jupiter and had doppler shifts of about 1000 km. The distance of the sodium emission region from the centre of Jupiter was estimated as 3 radii. The hypothesis is suggested that sodium was excited in the jovian internal magnetosphere by fast electrons.

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