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OPTICAL INVESTIGATION OF THE CRAB PULSAR: SIMULTANEOUS UBVR LIGHT CURVES WITH TIME RESOLUTION OF 3.3 μs AND SPECTROSCOPY

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ABSTRACT

The results of the Crab pulsar observations with the photometrical MANIA (Multichannel Analysis of Nanosecond Intensity Alterations) comlex at the 6-m telescope are presented. More than 12 millions photons in UBVR-bands simultaneously with time resolution of 10^{-7}s were detected. Using the original software for search for optical pulsar period, we obtained the light curves of the object with time resolution of about 3.3 μs. Their detailed analysis gives the spectral change during pulse and subpulse, the shape of the pulse peaks, which are plateaus (with the duration of about 50 μs for the main pulse), limits for an amplitude of fine temporal (stochastic and regular) structure of pulse and subpulse and the interpulse space intensity. The results of CCD-spectroscopy of the Crab pulsar show that its summarized spectrum is flat. There are no lines, neither emission nor absorbtion ones. Upper limit for line intensity or depth is 3.5% with the confidence probability of 95%.

Key Words : pulsars: individual (PSR 0532+21) – stars: neutron

I. OBSERVATIONS AND DATA REDUCTION

The Crab pulsar was observed at the 6-m telescope in 1994 December, 6/7, with the photometric MANIA complex (Beskin et al 1982, Zhuravkov et al 1990). 11 consecutive sets of data covered 45min approximately. More than 12 millions of photons in UBVR-bands simultaneously were detected in $6''.9$ diafragm. The complex dead time is 10^{-7} s.

The value of the Crab pulsar topocentric period was obtained by the "Frenel Lense-like" method (Plokhotnichenko 1992). We chose a "test" period and built a set of consecutive light curves. We summarized the light curves with all possible phase shift values and get a set of composite light curves finally. By means of statistical methods, we found the light curve with the most significant deviation from noise (poisson) light curve. The period this curve is folded with is the closest to the true one. We used this value P_0 to find other parameters $P(t), \dot{P}(t), \ddot{P}(t)$ by means of the least squares method, i.e. by minimization of squared differences between the light curves obtained in different moments of time during our observational set. The calculated values were used to build the resulting light curves with time resolution of about 3.3 μs (Fig.1).

Spectroscopic observations of the Crab pulsar at the 6-m telescope were carried out during 4 nights in 1996 January, 13-16, with CCD maintained on the spectrograph SP-124 in Nasmyth focus. Seeings were $1''.0$ - $1''.3$ from night to night. 35 spectra with dispersion of 2.1Å/pixel were obtained in 5000-7000ÅÅ range. The exposure times varied from 3 up to 10 min for different nights, the total exposure time was 129 minutes. We used a slit of $1.''5$ width and $40''$ length oriented along "West–East" axis. To calibrate spectra in wavelengths we used the He–Ne–Ar lamp spectrum. Inhomogeneity of CCD spectral sensitivity was corrected after the spectra of stars with well-known energy distribution have been registered. For 2-D spectral images reduction (including bias correction, dividing by flat field and cosmic particles traces removing) the MIDAS context was used. The correction of instellar extinction was based on data from (Percival et al 1993).

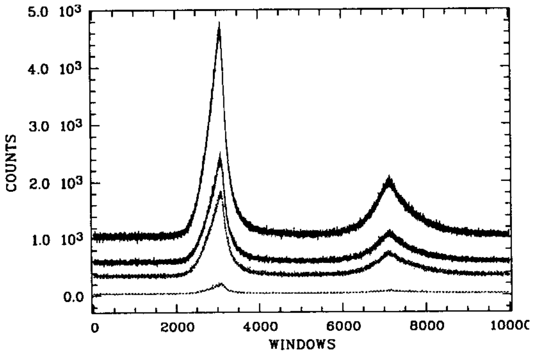

Fig. 1.— The light curves of the pulsar PSR 0532+21 with time resolution of 3.3μs in bands U+B+V+R, B, R, U (top to bottom).

II. RESULTS

The analysis of the photometric data showed the following: a fine time structure of the pulses is absent on the times from 3.3μs to 50 μs (intesity modulations have statistical origin); the top of the main pulse is plateu with the duration of about 50 μs (Fig.2); the interpulse space intensity is $\leq$ 1%; the difference of the colours between the main pulse and interpulse space is near 4% (with 10% significance level) (Fig.3).

The Crab pulsar composite spectrum is shown on Fig.4. Its spectral shape is close to flat power law with index $\alpha \sim 0$. There are no details, neither emission nor

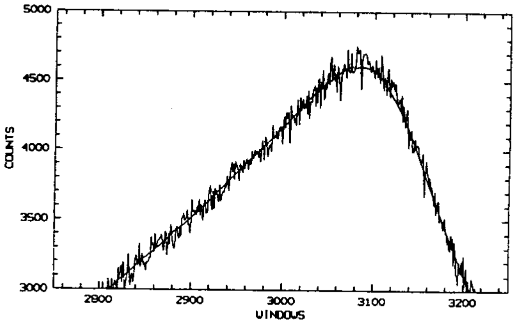

Fig. 2.— The top of the peak of the main pulse with time resolution of 3.3μs.

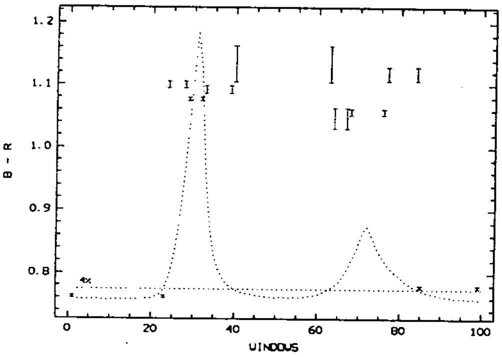

Fig. 3.— The (B-R) colour index of the Crab pulsar as a function of phase.

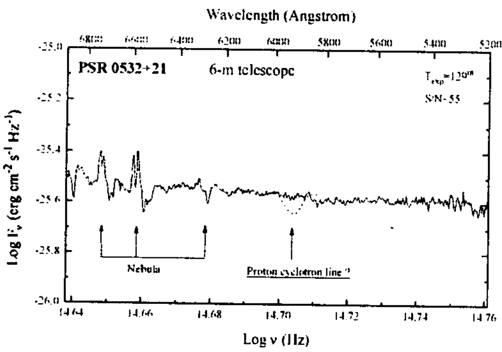

Fig. 4.— The composite spectrum of the Crab pulsar.

absorbtion lines (excepting the nebula ones). Upper limit on the line central intensities is 3.5% (with the significance level $\leq$ 5%). The wide absorption detail at λ 5900Å with depth of 15% (Nasuti et al 1996) is definitely absent. So either its detection was the result of possible calibration errors (it was mentioned by authors), or this line varies on the time scale of years.

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