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Temporal correlation analysis of V 603 Aql radiation intensity

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Abstract. Results of investigation of the temporal correlation function of V 603 Aql radiation intensity are presented. It is shown that when recording the light flux passing through the polarization analyser, the temporal correlation function of intensity contains information about the period and strength of the magnetic field of the white dwarf. This information can be obtained only in an ordinary or extraordinary ray in a narrow spectral band regardless of the polarization analyser configuration. A conclusion is drawn that the detected properties of the temporal correlation function of intensity are difficult to explain within the frames of conventional models of rotating stars with a magnetic field.

Key words: stars: polarization — stars: individual: V 603 Aql — methods: numerical

1. Introduction

Calculation of the temporal intensity correlation function B(t) permits obtaining information on some physical parameters of an object. This approach becomes vital if one cannot derive information by means of traditional measurements of the average recorded flux. Such calculations assume increasing importance in present-day optics, including investigation of laser radiation. For instance, the spatial intensity correlation functions first computed by Brown & Twiss (1956) contain information on the angular diameters of stars.

At a later time, the properties of the temporal intensity correlation function of thermal light sources at different temperatures were studied. It has been shown that calculations of B(t) make it possible to determine temperatures of stars in whose spectra the energy distribution is distorted by absorption (Efremov & Naidenov, 1992). Our aim is to determine what properties the temporal intensity correlation functions of different type stars have.

The main distinguishing characteristic of our experiment, as compared to the known ones, is that we calculate B(t) after the radiation passed through the polarization analyser (for instance, Babcock's analyser) in a narrow band. It will be recalled that Babcock's polarization analyser consists of an entrance phase plate and an Island spar crystal (Babcock, 1960). To understand the results obtained below, we will describe the conventional concepts of polarized light and the properties of Zeeman components as the radiation passes through the polarization analyser.

In passing through the circular polarization analyser (parameter V is analysed), circularly polarized light follows the path of an ordinary or extraordinary ray. When passing through the crystal without the phase plate, the circularly polarized light splits into two beams. Proceeding from the above-said, it can be claimed that for any kind of polarized radiation there is a configuration of the polarization analyser with which the entering radiation runs along the two optical axes of the analyser (Born & Wolf, 1973). In analysing linearly polarized light, the angle of the polarization vector of which changes evenly, two output sinusoidal signals differing in phase by 90° will appear.

It is known that when Zeeman components of spectral lines are recorded with the aid of Babcock's analyser, in the case where the Zeeman effect is normal, one of the components is observed in the first channel of the analyser, the other in the second channel. When the magnetic field direction changes, say, as a result of star rotation, the components change the channels. It should be particularly emphasized that with variations of dynamical characteristics of polarized radiation, which arise as a consequence of rotation of a star with a magnetic field, these variations must occur in both channels of the analyser. Accordingly, the temporal intensity correlation functions must be equal in both channels of the analyser. The aim of the present paper is to describe characteristics of temporal intensity correlation functions of radiation from the binary system V 603 Aql to show their relation to the physical parameters of the star.

2. Measuring and processing techniques

The observations were carried out at the Nasmyth-1 focus of BTA using a spectropolarimeter mounted on the spectrograph SP-124 with a CCD detector. An achromatic polarization analyser was used as a polarimetric device. Measurements of circular polarization were made (parameter V was investigated). The specifications of the spectropolarimeter are described in the paper by Naidenov & Panchuk (1996). We obtained 60 Zeeman spectra of V 603 Aql in a range of 3800–5000 ÅÅ. The spectral resolution was 2–3 Å, and the time resolution — 70 s. The exposure time and the read-out were 60 s and 10 s, respectively. The spectra corresponding to the ordinary (R) and extraordinary (L) rays of the polarization analyser were exposed in one frame simultaneously. The spectrum height across the dispersion in one polarization was about 20 pixels. Each CCD frame was reduced with the standard procedures in the MIDAS environment. All the spectra were normalized to the continuous spectrum. The temporal intensity correlation functions and the power spectra were computed from the spectra for the R and L rays separately. It is known (Jenkins & Watts, 1971) that the relative error of measuring the power spectrum from the autocorrelation function is equal to 1 and does not depend on the length of realization. To increase the signal-to-noise ratio, the power spectrum was smoothed. A correlation window in the form of a Gauss function with the parameter $\sigma = 70 \times 13$ was used for the smoothing

$$\frac{1}{\sqrt{2\pi}\sigma} e^{-\frac{x^2}{2\sigma^2}} .$$

This procedure diminishes the resolution in the power spectrum, but increases the signal-to-noise ratio. The relative measurement error was 0.37. We computed the temporal intensity autocorrelation function around the spectral line H_β. In so doing, we were guided by the following considerations. From the paper by Gnedin et al. (1990), where the magnetic field estimates of the system being investigated are given, it follows that the white dwarf has a magnetic field of about 1 MG. With such a magnetic field strength, the Zeeman components are far from the centre of spectral lines (Kemic, 1974). For instance, σ^- has a wavelength of 4830 Å. This makes it possible to compute the temporal intensity autocorrelation function of this component outside the spectral line H_β, which rules out referring the time dependence of radiation to physical variations of the parameters of this spectral line.

3. Measurement results

In Fig. 1 are displayed the normalized Zeeman spectra of the star V 603 Aql in the ordinary (R) and extraordinary (L) rays (the R curve is shifted upwards by 1). One can see from the figure that there are no significant differences between the R and L specra.

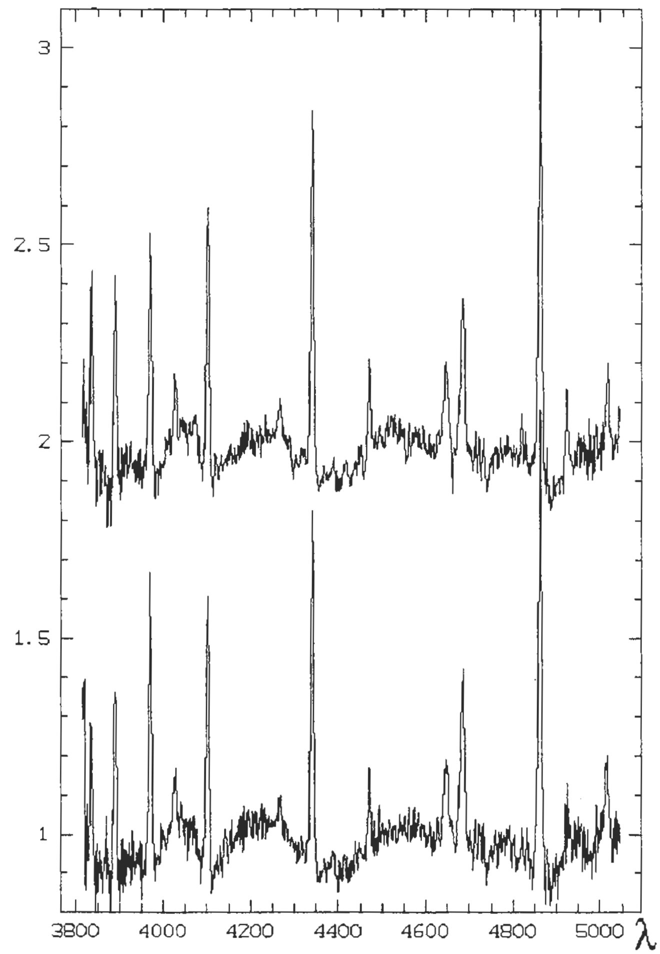

Figure 1: *Integral normalized Zeeman spectra of the star V 603 Aql in the R and L rays.*

Fig. 2 (left panel) shows the normalized intensity autocorrelation function B(t) computed from an array of Zeeman spectra of the system V 603 Aql obtained in the L ray for the wavelengths:
1 — $\lambda = 4861$ Å, $\Delta\lambda = 3$ Å;
2 — $\lambda = 4830$ Å, $\Delta\lambda = 3$ Å;
3 — $\lambda = 4835$ Å, $\Delta\lambda = 3$ Å;
4 — $\lambda = 4825$ Å, $\Delta\lambda = 3$ Å.

Fig. 2 (right panel) shows the normalized intensity autocorrelation function B(t) computed from an array of Zeeman spectra of the system V 603 Aql obtained in the R ray for the same wavelengths.

Analysis of the functions B(t) calculated for the wavelength $\lambda = 4861$ Å, $\Delta\lambda = 3$ Å in the R and L spectra (Fig. 2) reveals variability in the two rays. The same is true for the power spectra for this wavelength (Fig. 3).

The function B(t) for the wavelength $\lambda = 4830$ Å,

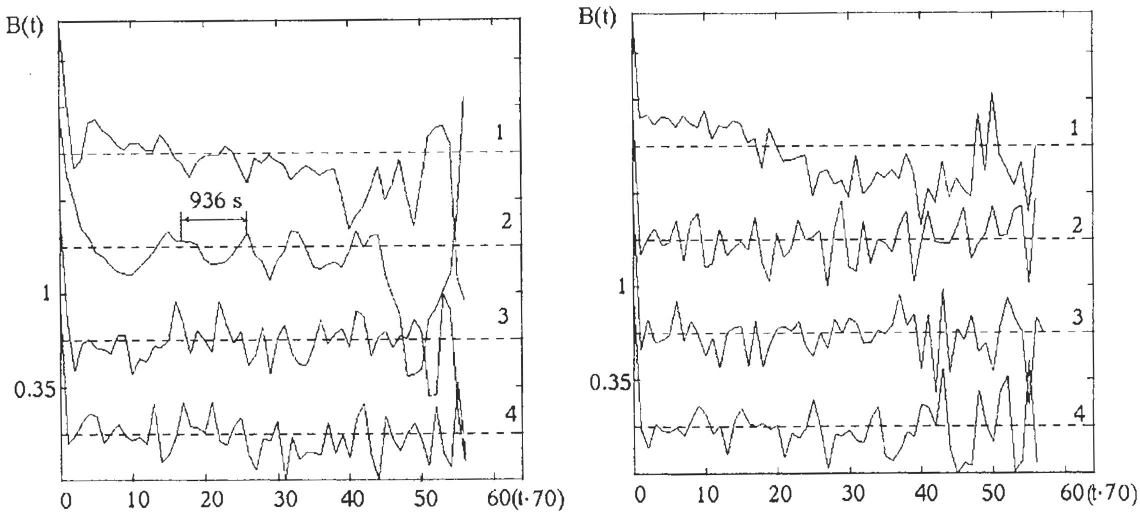

Figure 2: *Normalized intensity autocorrelation function in the L (left) and R (right) rays for the wavelengths: 1 — $\lambda = 4861\,Å$, $\Delta\lambda = 3$ Å; 2 — $\lambda = 4830\,Å$, $\Delta\lambda = 3$ Å; 3 — $\lambda = 4835\,Å$, $\Delta\lambda = 3$ Å; 4 — $\lambda = 4825\,Å$, $\Delta\lambda = 3$ Å.*

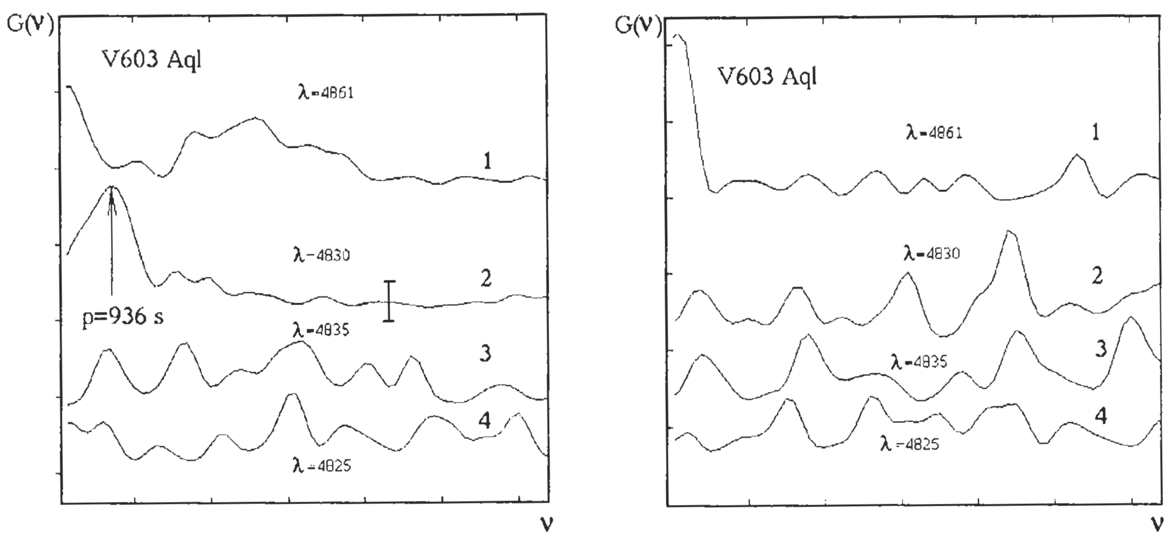

Figure 3: *Power spectrum for the L (left panel) and R (right panel) rays at the wavelengths: 1 — $\lambda = 4861\,Å$, $\Delta\lambda = 3$ Å; 2 — $\lambda = 4830\,Å$, $\Delta\lambda = 3$ Å; 3 — $\lambda = 4835\,Å$, $\Delta\lambda = 3$ Å; 4 — $\lambda = 4825\,Å$, $\Delta\lambda = 3$ Å.*

$\Delta\lambda = 3\,Å$ (curve 2 in Fig. 2), calculated in a narrow band of the spectrum for the L ray, is a curve varying with a possible spin period of the magnetic component of the system (from literature data the magnetic component spin period is 936 s). This is confirmed by the power spectrum for this wavelength (curve 2 in Fig. 3). From the data obtained a conclusion can be drawn that for the wavelength $\lambda = 4830\,Å$ the radiation intensity fluctuations become statistically dependent every 936 s. The normalized intensity autocorrelation function and power spectra computed for L and R at the wavelengths $\lambda = 4835\,Å$, $\Delta\lambda = 3\,Å$ and $\lambda = 4825\,Å$, $\Delta\lambda = 3\,Å$ show no periodicity. To exclude instrumental effects, we studied the standard magnetic star HD 215441. Spectra of HD 21541 and those of the object under investigation were obtained on the same night. No peculiarities at the indicated wavelengths were detected on its spectra.

4. Conclusions

We calculated the temporal intensity autocorrelation functions for a number of stars varied in their physical parameters. Collections of spectra of the stars EV Lac, CI Cam, GRW 708247 were processed. From the results a conclusion has been drawn that no significant differences from the adopted knowledge on polarized radiation have been detected. The system

V603 Aql is an exception. The inordinary properties of the function B(t) are apparently inherent in stars with strong magnetic fields. This inference is based on the following experimental data.

1. The period of the intensity correlation function in L is correlated with a possible period of the axial rotation of the white dwarf (Figs. 2, 3, curve 2).

2. No periodicity in the short- and long-wave regions of the continuous spectrum around the wavelength under study has been revealed (Figs. 2, 3, curves 3 and 4).

The presented evidence suffices to argue that in calculating the B(t) of the star V603 Aql, the signal having the following properties is recorded. As the beam of light passes through the polarization analyser, the temporal intensity autocorrelation function contains information on a possible rotation period of the white dwarf and its magnetic field magnitude. This information can be derived only in the ordinary and extraordinary rays in a narrow spectral band irrespective of the configuration of the polarization analyser.

It should also be noted that the detected property of the temporal intensity autocorrelation function is difficult to explain in the frames of the generally accepted models of rotating stars with a magnetic field.

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