MEASUREMENT THE POLARIZATION PARAMETERS OF HIGH - ENERGY PROCESSES IN BINARY STARS

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Keywords: *Stars: Binary stars; Accretion; polarization;*

Abstract: *We presented high-energy processes in two binary stars. Flares are detected by analysing the corresponding light curves. The energy spectrum is received for the duration of active states in these stars.*

We have studied the emission properties, as applying polarimetry methods on the high-energy events.

The results reveal significant variations in the polarization parameters of selected binaries for the period of flares activity.

ОЦЕНЯВАНЕ НА ПАРАМЕТРИТЕ НА ПОЛЯРИЗАЦИЯ ПРИ ВИСОКО ЕНЕРГЕТИЧНИ ПРОЦЕСИ В ДВОЙНИ ЗВЕЗДНИ СИСТЕМИ

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Ключови думи: *Звезди: Двойни звезди; Акреция; Поляризация;*

Резюме: *В настоящата работа представяме високо-енергетични процеси при две двойни звездни системи. След анализиране на кривите на блясъка на изучаваните двойни, се разкрива активиране на проблясъци в резултат на изхвърляния на материя. Получени са енергетичните спектри на тези звезди за периодите на активно състояние.*

Чрез прилагане на методи на поляриметрията са изследвани свойствата на излъчването на високо-енергетичните процеси.

Резултатите показват значителни изменения в поляризационните параметри по време на активиране на избухвания при двойни звезди.

Introduction

High-energy processes in astrophysical objects are associated with the phenomena, which include for example the acceleration of charged particles to very-high energies in flares or jets (from protoplanets to active galactic nuclei), or the scattering of radiation in highly aspherical distributions of matter, resulting from the effects of strong magnetic and/or gravitational fields.

Binary stars are dynamically active systems and it is related to tidally interacting processes between two stars, as well as the following mass transfer, structural transformations, flickerings and bursts. In this survey we investigate the features of flares and bursts by polarization modeling on the flares emission properties in binary stars. The flares appear ordinarily in systems with accretion discs in time scales of hours to days, with amplitudes in a range of 1 - 3 magnitudes. On the other hand, van Paradijs, van Amerongen and Kraakman [10], performed five-colour observation and demonstrated that the flares occur throughout the whole orbital period with the rise time ~ 100-200 s. AE Aqr and they found that the light curve of this CV exhibits large flares on timescales of about 10 minutes. Bruch and Grutter [3] found that the strong flares could be also phase dependent.

A repeated variability in the brightness could affect to the degree of polarization. Churazov et al. [4] proposed X-ray polarization as a mechanism to probe the flarings and the resulting, reprocessed X-ray should be polarized. The polarisation could appear as patterns in all of the above cases, as it depends mainly on the properties of radiation and geometry of the source. We investigate

the polarized emission properties of accreting binary star systems. The observational data of γCas and SS Syg are applied.

Models and methods of polarimetry

The known relations of Poincare-Stokes vectors are applied in the current calculation. Four Stokes parameters S0, S1, S2, S3 and Poincare vector P_i of polarization - characterize the intensity and polarization of the emission [4], [8], [9]. For measurement of Stokes parameters a Cartesian coordinate system (x, y, z) is used where x and y are perpendicular to the direction of light propagation z. If E_x, and E_y are the electric field components in the x and y directions, and I(φ) is the intensity of light polarized in the direction φ to the x axis (see Eqs. 1 – 4).

(1) $$I = S_0 = I\left(0^\circ\right) + I\left(90^\circ\right) = \left\langle |E_x|^2 \right\rangle + \left\langle |E_y|^2 \right\rangle$$

(2) $$Q = S_1 = I\left(0^\circ\right) - I\left(90^\circ\right) = \left\langle |E_x|^2 \right\rangle - \left\langle |E_y|^2 \right\rangle$$

(3) $$U = S_2 = I\left(45^\circ\right) - I\left(135^\circ\right) = Re\left\langle E_x E_y \right\rangle$$

(4) $$V = S_3 = I_{RHC} - I_{LHC} = Im\left\langle E_x E_y \right\rangle$$

However, the polarization state is completely determined by the three ratios S_1/S_0, S_2/S_0, S_3/S_0 which are known as the relative Stokes parameters. They have possible values between -1 and +1.

The following equations are used for calculation the degree of polarization (the ratio of polarized to total intensity). Degree of polarization *P*:

(5) $$P = \sqrt{\left(S_1^2 + S_2^2 + S_3^2\right) / S_0}$$

Degree of circular polarization P_C:

(6) $$P_C = S_3 / S_0 ,$$

where P_C is positive for right-handed circular polarization and negative for left-handed circular polarization.

The Poincare vector of polarization is given by:

(7) $$P_i = S_i / S_0 , \text{ where } i = 1,2,3$$

We also employ the modeling and code of Goosman and Gaskell [6], and Marin et al. [8] on the estimation of polarization properties of the flares emission. Their code is based on the Monte Carlo method for modeling polarization produced by absorption, reemission and scattering in many astrophysical situations. They have studied the relation between spectral flux, polarization in percentage *P* [%] and the polarization position angle and the photon energy. They have considered those as a function of the observer's inclination and the dependence of disc inclination *i.* In the case, when the viewing angle *i* is increasing, the reflected radiation coming from perpendicular surfaces is produced by scattering. This leads to decreasing the Stokes flux for the perpendicular polarization component.

To make a clearer view, attached to the modeling, we suggest a schematic algorithm of the processes. The flares-up activity in the selected binary is in a relation with variations in the flow density level. The transformed flux structure gives rise to polarization variations in the optical and near-infrared bands and the polarization degree could change significantly.

By the initial conditions the variable polarization's states could be the result of synchrotron radiation from the forming bursts. Then an elliptical or circular polarization is established there.

In the high-energy processes the stronger emission intensity is observed. The measurement of this intensity is associated with the calculation of Stokes parameters. In the next step we can define the degree of polarization.

Results of observational and theoretical considerations.

An expression of the flow dynamics could be detected as the brightness variability of some CVs and Be/X stars. A small number of systems, including γCas, MV Lyr, SS Syg, GK Per and AE Aqr, exhibit stochastic brightness fluctuations. Flares could be detected at the light curve shapes of these binaries. The modeling prediction gives the polarization degree of the next two binaries, according to their light curves and energy spectrum.

There is strong evidence in the light curve's shape for the production of bursts in SS Cyg. SS Cyg is one of the optically brightest DN (dwarf nova). This can be the result of dynamically unstable processes in accreting flow around the primary. Its energy spectrum is expressed at (Fig.1a). During the bursts activity of this binary, the degree of polarization varies and at the higher rate of *P* this value is normalized to **1** (Fig.1b). The variations of *P* are in a relation with the maximum energy value of the burst's emission, inclination and the polarization position angle.

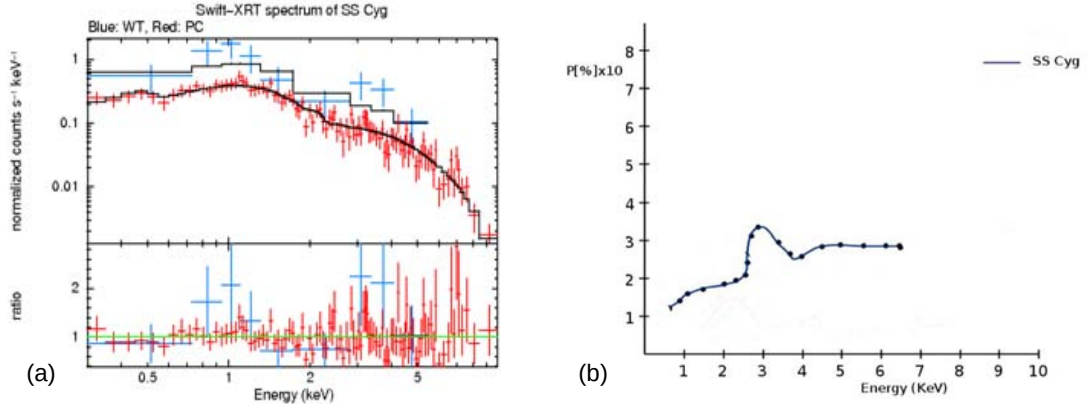

Fig. 1. Energy spectrum, PC mode of SS Cyg (Swift-XRT generator, Evans et al. 2009)) (1a). Polarization degree (***P***) during the bursts activity of SS Cyg (1b) [1].

The accumulation of mass transferred to the surface of the white dwarf from the giant star through an accretion disc eventually triggers an outburst activity.

Further, we develop our study of the binary star γ Cas (Cassiopeia), which is of Be/X stars type. Typical X-ray luminosities of Be/X-stars are ~ 10^{34}÷10^{39} erg/s. The most common suggestion is that the emission comes from accretion from the Be star wind or disk [11]. In Kaygarodov et al. [7] we make an assumption that the X-ray emission is due to the accretion of matter by neutron star with mass ~ 1M◦. There the relationship between X-ray luminosity and accretion rate is determined. As we have already said in [2], the higher luminosity rate, in the result of flares could affect on the polarization degree. This suggestion is shown at Figures 2 (a,b).

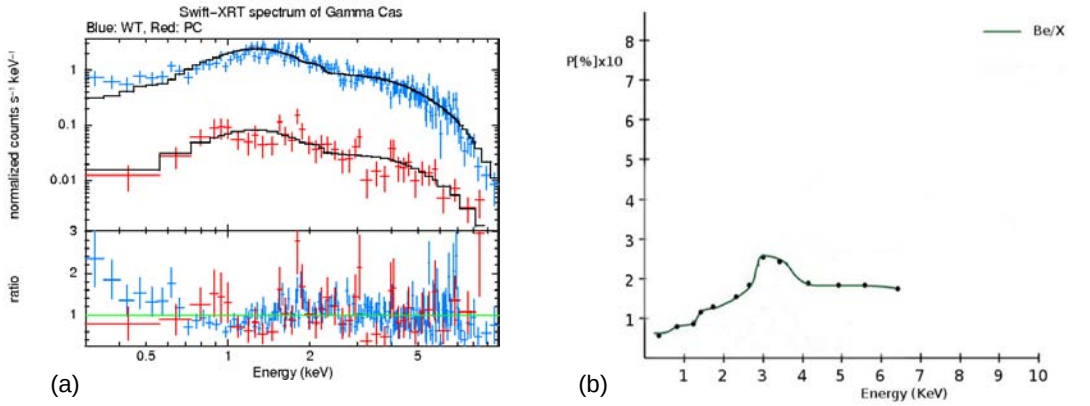

Fig. 2. Swift-XRT energy spectrum, PC mode of γ Cas (Be/X) (Swift-XRT generator, Evans et al. 2009 [5]) (2a). The high accretion rate here could give rise to the X-ray luminosity (10^{34} ÷10^{39} erg/s). Polarization degree (P) variations during the flares activity of γCas (Be/X) (2b) [1].

The high-energy peculiarities include an X-ray light curve that varies on several timescales ranging from seconds to 2–3 months. We have already shown this in [1] and [2].

Conclusion

We report observations of the flare-ups and burst activity as seen at the light curve's shape of the studied binaries. Each of the events, which we have identified as flares, has a characteristic stellar flare profile. This means a sharp rapid rise to maximum followed by a quasi - exponential decay. In these two classes of compact binaries, presented in the section "Results", some difference between the flickering is detected. The difference could be caused by physical properties of the accreting flow, as well as by the dominating flickering mechanism or their orbital periods.

The polarimetry methods to detect the active emission processes in binaries are applied. It is revealed a high polarized emission and the polarization degree variations during the high-energy processes in the studied binaries

Acknowledgments:

- Part of the results are presented at the COST action MP1104 by the COST support
- This work made use of data supplied by the UK Swift Science Data Centre at the University of Leicester.
- The authors thank the AAVSO (American Association of Variable Star Observers) to provide the data of Light Curve Generator, contributed by observers worldwide and used in this research.

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