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PHOTOMETRIC MODELING OF THE POLAR V808 AUR

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The light and circular polarization curves modeling for the polar V808 Aur was carried out in this work. A simple model of accretion spot on the white dwarf surface was used for Stokes parameters calculations. In addition, the modeling of eclipse light curve was performed to reconstruct the accretion stream geometry.
Keywords: AM Her type systems (polars) – Polarimetry – Eclipse mapping

1. INTRODUCTION

AM Her type systems (polars) are close binaries consisted of magnetized white dwarf (primary) and late-type main sequence star filling its Roche lobe (secondary). Strong magnetic field ($B \sim 10 - 100$ MG) of the white dwarf prevents the formation of accretion disk and the trajectory of accreting gas can be divided into two parts: ballistic and magnetic. At the ballistic trajectory the matter of secondary moves from Lagrangian point L_1 to the Alfven radius of the primary where the magnetic capture occurs. Starting from this region ionized gas moves along magnetic lines to white dwarf magnetic poles. By the interaction of falling gas with stellar surface hot ($kT \sim 10$ keV) accretion spots are formed. These spots are sources of X-ray radiation and polarized cyclotron emission in optical range.

This work is devoted to investigation of the polar V808 Aur. It is relatively bright ($V \sim 15$ mag) eclipsing polar with orbital period $P \approx 117$ min. Photopolarimetric observations [1] reveals its high circular polarization up to 14%. Spectral study of V808 Aur was performed in [2]. The analysis of X-ray data re-

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veals the existence of bright and quite faint spots on the white dwarf surface [3]. The modeling of cyclotron spectra was carried out in [4] and the obtained value of magnetic strength in primary spot is $B = 38$ MG. Numerical simulations of accretion flows in V808 Aur were performed in [5]. In this study we have analyzed photometric data of V808 Aur by simple models of accretion spot and accretion stream.

2. ACCRETION SPOT MODELING

The geometric parameters of accretion spot in V808 Aur were estimated by modeling light- and circular polarization curves which were obtained at 6m telescope BTA of Special astrophysical observatory of Russian academy of science (see [1] for details). The accretion spot was suggested to be geometrically thin and traced by magnetic lines intersected the ballistic trajectory of accreting particles as it is shown in figure 1. The ballistic trajectory was calculated solving restricted three-body problem and magnetic field of the white dwarf was supposed to be dipole. The cyclotron emission region was assumed to be temperature and density uniform. The radiative transfer solution for ordinary (+) and extraordinary (–) waves for this model is given by formula

$$I_{\pm} = B(T)(1 - \exp(-\alpha_{\pm}\Lambda)), \tag{1}$$

where B is Planck function, $\alpha_{\pm}$ — cyclotron absorption coefficients in units $\omega_p^2/\omega_c c$ (ω_p and ω_c plasma and cyclotron frequencies, respectively), $\Lambda = \omega_p l/\omega_c c$ is so-called size-parameter which is depended on geometric depth of emission region along line of sight l. Absorption coefficients $\alpha_{\pm}$ were calculated according the technique described in [6]. It should be noted that they are strongly depended on the angle between magnetic field vector and line of sight θ. Stokes parameters I and V of emitting radiation can be found as follows

$$\begin{cases} I\& = I_{+} + I_{-}, \\ V\& = 2\Big(\dfrac{I_{+}a_{+}}{1 + a_{+}^2} + \dfrac{I_{-}a_{-}}{1 + a_{-}^2}\Big). \end{cases} \tag{2}$$

Polarization coefficients $a_{\pm}$ for two polarization modes are defined as

$$a_{\pm} = \frac{2(\omega/\omega_c)\cos\theta}{-\sin^2\theta \pm (\sin^4\theta + 4(\omega/\omega_c)^2\cos^2\theta)^{1/2}}, \tag{3}$$

where $\omega \gg \omega_p$ has been assumed. Stokes parameters in photometric bands were calculated by integration of monochromatic Stokes parameters weighted on filters response function values.

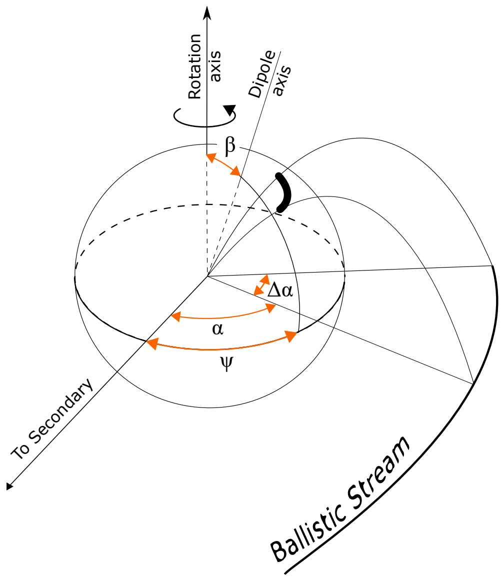

Fig. 1. The model of accreting white dwarf.

The observed Stokes I and V curves with subtracted fluxes from primary and secondary are shown in figure 2. The fitting of observed data was performed by variation of dipole axis orientation (i.e. angles β and ψ) and stagnation region position determined by angles α and $\Delta\alpha$. Searching for optimal values for these parameters was carried out by least squares technique. The minimization of χ^2 was performed by genetic algorithm. The temperature of accretion spot was set at $T = 25$ keV according to [4]. The found parameters of dipole orientation are $\beta = 29°$, $\psi = 9°$ and the obtained parameters of stagnation region are $\alpha = 59°$ and $\Delta\alpha = 18°$. To reproduce the polarization peak, the size parameter $\log\Lambda = 4.8$ is required. The comparison of observed and theoretical light curves is shown in figure 2.

3. ECLIPSE MAPPING

Photometric eclipse profiles provide important information about accretion structures in polars. They reflect the geometry of accretion flows as well as the brightness distribution over accretion stream. In this work we have used a simple model of accretion stream which was used to reproduce the observed eclipse light curve of V808 Aur. We suppose that the accretion stream is geometrically thin and can be approximated by the combination of ballistic trajectory and dipole line. We set a simple distribution of brightness along the stream that divides it into a bright accretion column and a less bright remaining part.

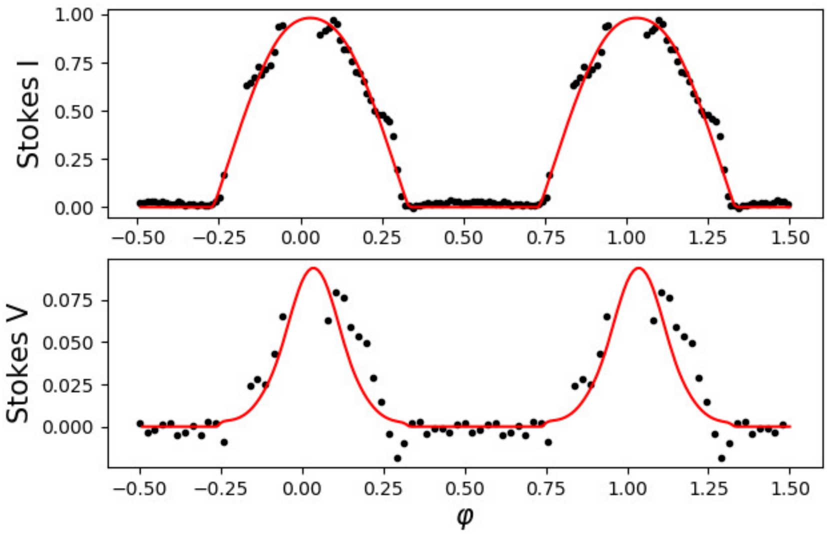

Fig. 2. The comparison of observed (dots) and theoretical (lines) Stokes curves of V808 Aur.

Photometric observations of V808 Aur during its eclipse were carried out at BTA telescope. The telescope was equipped with MPPP photometer which provides high time resolution ($\Delta t = 0.5 - 1$ sec during our observations). The obtained eclipse light curve is presented in figure 3. It can be seen that the eclipse begins with a sharp egress in brightness caused by the eclipse of a bright accretion spot. Then we can see a smooth decline in brightness where accretion stream covered by secondary and a wide valley corresponded to total eclipse of the stream.

The fitting of the observed light curve was performed by varying orbital plane inclination i, accretion column height H and the position of stagnation region defined by α angle. The optimal (in terms of χ^2-statistics) values of these parameters are: $i = 81^\circ.7 \pm 0^\circ.5$, $H = 0.2 \pm 0.15$ R_{WD} and $\alpha = 50^\circ \pm 10^\circ$.

4. CONCLUSIONS

The simple model of accreting white dwarf was proposed for interpretation the observed light and polarization curves of polars. Despite of many assumptions this model was quite sufficient in reproducing Stokes I and V curves of the polar V808 Aur. This model will be improved by including hydrodynamic calculations of the vertical structure of accretion spots.

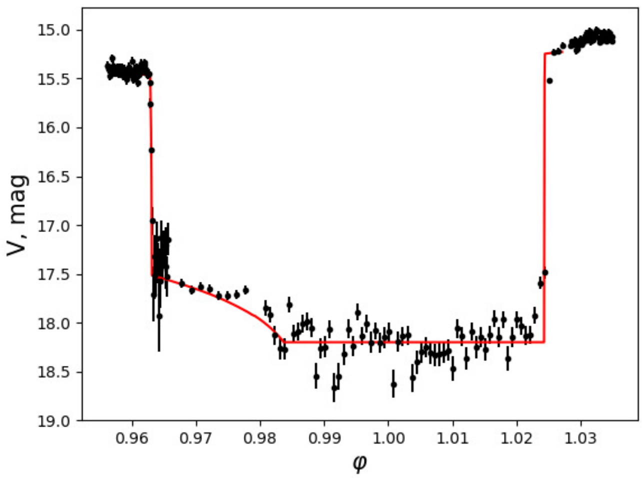

Fig. 3. The observed eclipse light curve of V808 Aur (dots) and its approximation by the found model of accretion stream (line).

In addition we have proposed a simple model of accretion stream for modeling eclipse light curves of polars. It was able qualitatively describe the light variations during eclipse in V808 Aur. For more precise analysis we plan to improve calculations of accretion stream trajectory by hydrodynamic simulations as well as add the reconstruction of brightness distribution along the stream using regularization techniques.

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