Proceedings of the IX Bulgarian-Serbian Astronomical Conference: Astroinformatics (IX BSACA) Sofia, Bulgaria, July 2-4, 2014,
Editors: M. K. Tsvetkov, M. S. Dimitrijević, O. Kounchev, D. Jevremović and K. Tsvetkova
Publ. Astron. Soc. "Rudjer Bošković" No 15, 2015, 93-97

FLUCTUATIONS IN THE FLOW AND DEVELOPMENT OF FLARE-UPS IN COMPACT BINARY STARS

DANIELA BONEVA

Space Research and Technology Institute, Bulgarian Academy of Sciences
E-mail: danvasan@space.bas.bg

Abstract. We study the relationship between the disc's structural transformations and the burst activity, which has an effect on the light curve shape's behavior. We present several methods for investigation of flare-up events in accreting compact binaries. The theoretical modeling explains the physical properties of flow unstable processes. It shows gas-dynamical mechanisms that are considered to be the most operative for the occurrence of flares in the binary star configuration. It is pointed to the changes in mass transfer rate that could also trigger bursts activity. We analyze the observational results of quasi-periodic variability in the luminosity of white dwarf binary stars systems.

1. INTRODUCTION

Disturbances of the disc structure due to periodic movement of the dense formations, as well as due to stream - pattern interaction, can result in low amplitude oscillations manifesting as irregular variations on the light curve. Note also that the casual low-magnitude variations on the light curve (flickering) can also be a consequence of the presence of the density formation in the disc. Brush (1992) has studied mechanisms generating the flickering. He proposes four possible mechanisms responsible for the observed variations in brightness: unstable mass transfer from the L1 point and interaction with the disc edge; dissipation of magnetic loops; turbulences in the accretion disc and unstable mass accretion onto the white dwarf. Bisikalo et al. (2001) have proposed a model that explains the variations of uneclipsed parts of light curves correlated with the presence of spiral shocks. Their observations correspond to results in variations to the theoretical one. In Boneva et. al (2009) and Kononov et al. (2008) we have showed the relation between the flow's elements dynamics and the active state of SS Cyg. According to study of Zamanov et al. (2010), more of the flickering's engines are all related to the accretion process: (i) the bright spot (the region of impact of the stream of transferred matter from the mass donor star on the accretion disc); (ii) the boundary layer (between the innermost accretion disc and the white dwarf surface); (iii) inside the accretion disc itself.

In the current survey, we investigate the relationship between the disc's flow fluctuations and the burst activity, which has an effect on the light curve shape's behavior. We study the mechanisms that cause the accretion rate to be sufficiently increased and then to realize the transition from a quiescent to an active state. The results reveal the accumulation of mass that could be transferred to the surface of the white dwarf from the secondary star through an accretion disc, as well as the structure transformations, accompanied with the flow patterns formation which could trigger outbursts. We analyze the observational results of quasi-periodic variability in the luminosity of white dwarf binary stars systems. We discuss the possibility of applying the polarization modeling into the study of brighten-up events in dwarf nova stars.

2. MODELING AND METHODS

When material reaches the compact object surface through the disc, it must pass through a violent transition region. We establish a part of disc's configuration around the primary (white dwarf) star after the mass transfer being started. When investigating close components, it is necessary to include physical essence of the flow dynamics response to the interaction processes.

Further, we use as a base the model of outburst in SS Cyg, presented in Kononov et al. (2008) and Boneva et al. (2009). Here, we apply the same consequence of the proposed physical model of the bursts appearing. We modify the stage of instability processes in the disc flow adding different types of instability behavior.

Based on the observations, we suggest the following scenario for the development of an outburst. At some time, an instability and the resulting flow fluctuations develop in the disc, leading to a considerable increase in the efficiency of angular momentum transport and an increase in the rate at which matter is accreted onto the white dwarf. The growing intensity of the radiation from the white dwarf inevitably results in heating of the nearest parts of the accretion disc, and hence to an increase in the thickness of inner parts of the disc.

The gas between the toroidal shell and the accretor experiences strong heating that leads to its expansion. However, the expansion cannot be isotropic, since it is restricted in the equatorial plane by the accretor surface and the inner surface of the toroidal shell, whereas expansion orthogonal to the disc's surface is impeded only by the accretor's gravitational field. The increased velocity of the heated gas will probably be comparable to the local sound speed, which is insufficient to form a collimated jet. The expanding gas can have a low angular velocity, and is prevented from falling on the star primarily by the gas-pressure gradient rather than by the centrifugal force. This enables the gas to leave the toroidal shell and form an expanding spherical shell around the accretor. The increased size of this shell can explain the stronger emission during the development of the outburst.

We employ with the next most applicable methods. Gas-dynamical numerical calculations include the "finite-difference scheme – high order", "Roe solver". We construct a "box-framed scheme" to apply it into the modeling (Boneva and Filipov 2012). Then, we make the calculations inside of the box, or frame with different measurement. This gives the possibility to configure the scheme for each problem in limited regions of all disc's areas.

We use the Doppler Tomography techniques to construct the true cart of image of the obtained data and then to derive the radiation intensity distribution in the system's velocity space, making it possible to determine the parameters of the main flow elements in which energy is released.

According to the study of many authors, the bursts and high rate of emission cause the changes in polarization state. Our interpretation of the problem shows that the polarization degree values grow during the flare-ups.

3. INDICATIONS OF FLOW'S FLUCTUATIONS AND FLARE-UPS

3.1. Density fluctuations

In the result of tidal interaction in binary star stars between out-flow from the donor star and the accretion flow, the flow changes its basic parameters values. The disturbances in the flow and mass tidal interaction give rise to the fluctuations in velocity and density. The physical essence of the flow dynamics responses to the interaction processes in binary. The disturbed flow's conditions can provoke periodic or quasi-periodic oscillations, giving rise to the light curve variations. Since the density decreases with increasing radius, approaching to the outer edge, the observed luminosities must be correlated with the distance from the inner Lagrange point L_1. In this way, the amplitude of light curve variations should be approximately corresponding to the density contrast. We have obtained the density distribution along the line connecting the centers of binary components for three runs with different orbital periods. Figure 1 shows this distribution:

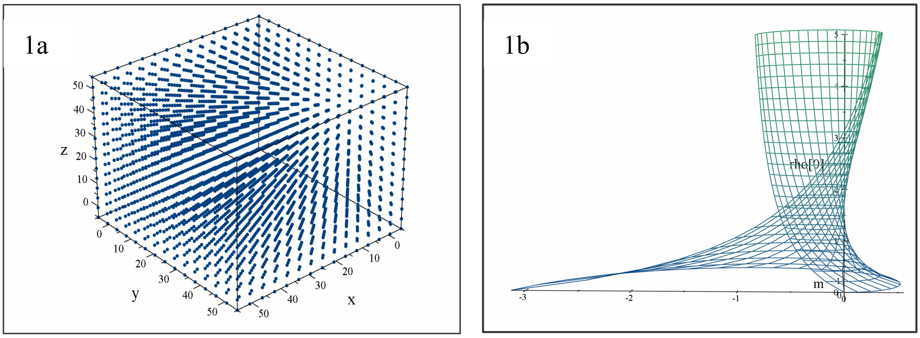

Figure 1: (a) Gradient of the density distribution in the field of calculation. It is seen the higher density areas, in the meaning of values heaping, modeled in the 3D box – framed scheme. (b) Increasing values of the density fluctuations in the disturbed mass transfer area.

We have detected the flow density fluctuations in the several type of accreting binaries, such as CV stars, Be/X stars (Kaygorodov et al. 2013), symbiotic binaries. The accretion rate is in a correlation with the level of mass transfer, which depends on density. The high accretion rate here could give rise to the X-ray luminosity and stronger emission.

3.2. Wave - patterns formation and the Disc's shape

It is clear from the previous subsection that the variations of velocity and density have significant impact on the flow's behavior. By applying the gas-dynamical numerical methods and following the conditions of Klahr Bodenheimer (2003) we have simulated the presence of two-dimensional vortical-wave patterns in the disc's flow. They are considered to be an effective mechanism of angular momentum transport (Barranco and Marcus 2005). The development of vortices is more frequently observed along the outer sides, close to the disc's edges. According to the model above, when this kind of wave patterns leave the disc zone, they could crumble and merge into the matter of the curcumdisc hallo, influenced by the conditions of low density there. It follows from the results of that the density of outer regions of the accretion disc drops substantially during an outburst.

Analysis of the resulting Doppler tomograms shows that the flow structure changed appreciably during the observed outburst, compared to its structure in the quiescent state (Boneva et al. 2009). The most important difference in the flow is a change in the shape of the accretion disc, from nearly circular in the quiescent state to significantly elliptical in the active state. The asymmetrical shape of the disc's projection indicates the existence of heated material in the "bow shock" area, which can be caused by the spiral density formation. Figure 2 shows the position of vortical patterns on the disc's plane and the superposition of the flow structure elements.

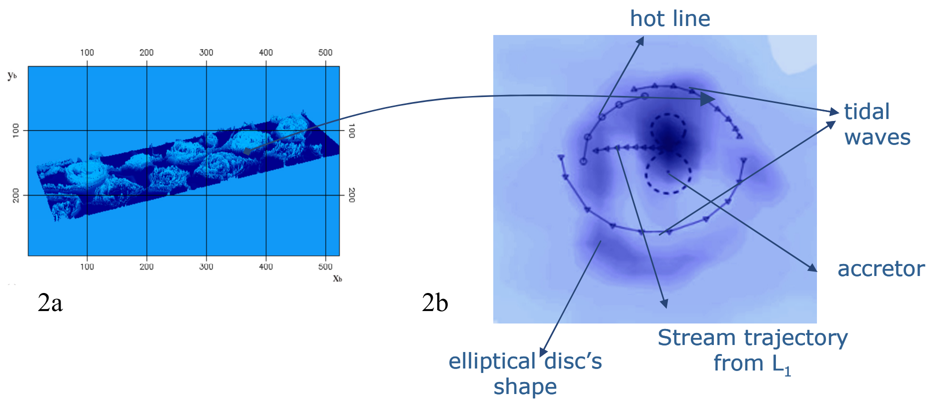

Figure 2: Vortical-like wave patterns may propagate throughout the disc, along the outer sides (a) (Boneva and Filipov 2013). The flow structure during the outburst: A result from the Doppler tomogram with superposed flow elements inferred from the numerical simulations (b) (Boneva et al. 2009).

.

4. CONCLUSION

In this survey, we present our modeling on the disc's flow morphology and its effect over the binaries' brightness variability. The model is developed on the base of increasing density and local areas with growing matter saturation. We have analyzed the flow structures during the outbursts and we indicate flow's fluctuations have been growing up in the mass transfer area. Our recent study also points to the long-lived wave patterns formation, which come rising by the tidal interaction in close binaries.

The casual low-magnitude variations on the light curve can also be a consequence of the presence of the vortical-like patterns in the disc structure.

Acknowledgments

Part of this work is supported by the Scientific Cooperation between Space Research and Technology Institute - Bulgarian Academy of Sciences and Institute of Astronomy – Russian Academy of Sciences.

References

Barranco, J. A. Marcus, P. S.: 2005, *ApJ*, **623**, 1157.

Bisikalo, D. V., Boyarchuk, A. A., Kaigorodov, P. V., Kuznetsov, O. A.: 2003, *Astron. Rep*. **47**, 809.

Boneva, D., Filipov, L.: 2013, Distribution of patterns and flow dynamics in accreting white dwarfs, *ASPCS*, **469**, 359-365.

Boneva, D., Filipov, L.: 2012, Density distribution configuration and development of vortical patterns in accreting close binary star system, http://adsabs.harvard.edu/abs/2012arXiv1210.2767B.

Boneva, D., Kaigorodov, P. V., Bisikalo, D. V., Kononov, D. A.: 2009, *Astron. Rep.,* **53**, 11, 1004–1012, http://adsabs.harvard.edu/abs/2009ARep...53.1004B.

Bruch, A.: 1992, *A&A* **266**, 237.

Klahr, H., Bodenheimer, P.: 2003, *ApJ*, **582**, 869-892.

Kyagarodov, P. V., Bisikalo, D. V., Kononov, D. A., Boneva, D. V.: 2013, *AIPC*, **1551**, 46-52.

Kononov, D. A., Kaigorodov, P. V., Bisikalo, D. V., Boyarchuk, A. A., Agafonov, M. I., Sharova, O. I., Sytov, A. Yu., Boneva, D. V.: 2008, *Astron. Rep.*, **85**, 10, 927-939, http://adsabs.harvard.edu/abs/2008ARep...52..835K.

Zamanov, R. K., Boeva, S., Bachev, R., Bode, M. F., Dimitrov, D., Stoyanov, K. A., Gomboc, A., Tsvetkova, S. V., Slavcheva-Mihova, L., Spasov, B., Koleva, K., Mihov, B.: 2010, *MNRAS*, **404**, 381.