Proceedings of the XIII Bulgarian-Serbian Astronomical Conference
(XIII BSAC) Velingrad, Bulgaria, October 3-7, 2022
Editors: Evgeni Semkov, Milan S. Dimitrijević, Momchil Dechev and Zoran Simić
Publ. Astron. Soc. "Rudjer Bošković" No 25, 2023, 179-186

THE ACTIVE ZONE MOBILITY IN A MAGNETIZED DISK WITH ADVECTION

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Abstract. In this paper, we consider some active processes in the accretion disk of a compact object. An active zone and its construction in various objects is a consequence of the advection action in the disk. We analyses the active zone's location and its development in the disk. We estimate an alteration in the active zone's behavior, throughout the disk's outer to the inner parts, for different astrophysical sources. We discuss the similarities and differences.

1. INTRODUCTION

In series of papers (Yankova, 2007-2015) we created a new magneto-hydrodynamical model of accretion discs, based on a new specific advective hypothesis, presented in Yankova (2013, 2015a).

$$\frac{\partial \rho}{\partial t} + \nabla.(\rho v) = 0 \qquad \nabla.v = 0 \qquad \nabla.B = 0$$

$$\frac{\partial v}{\partial t} + v.\nabla v = -\frac{1}{\rho}\nabla p - \nabla\Phi + (\frac{B}{4\pi\rho}.\nabla)B + \vartheta\nabla^2 v$$

$$\frac{\partial B}{\partial t} = \nabla \times (v \times B) + \eta\nabla^2 B \qquad \eta = \frac{\eta_m}{\rho} = \frac{c^2}{4\pi\sigma}$$

$$\rho T\frac{\partial S}{\partial t} - \frac{\dot{M}}{2\pi r}T\frac{\partial S}{\partial r} = Q^+ - Q^- + Q_{mag}$$

$$p = p_r + p_g + p_m$$

Here v is velocity of the flux; ρ - mass density; B - magnetic field; Φ- gravitational potential; p-pressure; -ϑ - kinematical viscosity; -η- magnetic viscosity; Q^+ - viscosity dissipation; Q_{adv}– advective term; Q^- - radiative cooling. The unified model we built on the conception of the non-deforming advection, allows in the field of nonlinear physics to conduct an analytical study of the accretion.

The researching of the emerging because of the advective mechanism, direct and reverse connections in the disk flow, represent a solution to the global model for the radial and vertical disk structures; the local structure model and adapted model for the emerging corona. Results in detail have given in (Iankova, 2007a, b), (Iankova, 2009), (Yankova, 2012a, b), (Yankova, 2015 b, c).

Here we use our work to analyze the state of the disk active zone and we will discuss the similarities and differences in both typical cases: a micro-quasar and a symbiotic recurrent nova.

In the papers (Yankova, 2015c, 2019) the disks structures of the high-mass X-ray binary system Cyg X-1 and the symbiotic binary star RS Ophiuchi have modelled. In the next sections, we will compare the active zone behavior: its width, separation, mobility and evolution in both objects disks.

2. ACTIVE ZONE

There are usually three zones of the activity in a disk: The first is in the outermost area and is associated with the inflow from a secondary source; The real active zone, where the activity resembles that in the inner layers of a star; And the activity in the innermost regions, which is practically coronary activity (by the disk's corona or the acretor's magnetosphere).

In this paper, our attention has especially focused on the active zone in an advective disk.

Advection have directly related to an appearance, development, behavior and movement of the active zone in the accretion disk.

As we have shown in our relativistic consideration (Yankova, 2017a, b), (Yankova, 2018a, b), the Advective Operator who consists by Pure Rotation+ Pure Translation in the space-time:

$$\left(\partial_{t_i} + \boldsymbol{v}_{ij}\partial_{x_j}\right)\boldsymbol{v}_{ji} = \boldsymbol{\beta}_{ji}\partial_{t_i} + \delta_{ij}\partial_{t_j}, \tag{1}$$

Where

$$v_{ij} = \frac{\partial \chi_i}{\partial t_j}, \tag{2}$$

It naturally goes to the low-energy boundary of a non-deforming advection:

$$\frac{\partial(\rho\boldsymbol{v}_i)}{\partial \mathrm{t}} + \frac{\partial}{\partial \mathrm{x}_j}\left(\rho\boldsymbol{v}_i\boldsymbol{v}_j\right) = \rho\left(\frac{\partial \boldsymbol{v}_i}{\partial \mathrm{t}} + \boldsymbol{v}_j\frac{\partial \boldsymbol{v}_i}{\partial \mathrm{x}_j}\right) = \rho\frac{\boldsymbol{D}\boldsymbol{v}_i}{\boldsymbol{D}\mathrm{t}} \tag{3}$$

Earlier in (Yankova, 2015-2018) we have noted that incomplete modes of an advection (see radial advection Beloborodov (1998), Narayan&Yi (1994-95); or orbital advection see Fabian et al. 2012), have deformed the differential by an individual modification of one or another of its component. In this case, when the advection is a non-dominant mechanism, there are not any conditions of flow deformations. Then, a solution has transferred as a whole (eq.3).

The advection carries the properties of flow parameters from one area of the medium to another. The mechanism transfers (transports) all disturbances without deformations.

The active zone is determined by: - an outer radius, obtained from the condition $v_a^2 \leq v_s^2$, for the radius of the disk's corona (Iankova, 2007a). Where v_s and v_a are the sound and Alfven velocities in the disk flow. – An inner radius, obtained from the critical value of the heating K > 1, where K is a measure of the disc ability to qualitative the cooling (Iankova, 2009), or the condition $\langle v_a \rangle^2 \leq (9/4)\langle v_\varphi \rangle^2$ (Iankova, 2009), where v_φ is the angular velocity; and – the disk luminosity distribution.

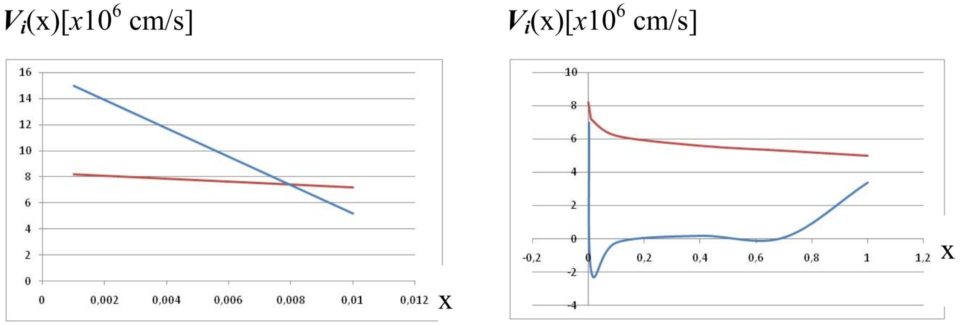
The active zone have separated into two parts: the plateau in the luminosities (see Fig.3-4) indicates the outer active zone, in which the advection conceals the activity. In the inner active zone, the activity becomes observable (Yankova, 2019).

3. RESULTS

Our model could be applied to a large variety of the real objects, to explore various aspects their evolution. Here we obtain the active zones of the studied objects at two different evolutionary moments, separated by several periods $\sim\Omega_0^{-1}$:

For RS Oph the active zone is located in the ranges ~(0.008;0.5)R_0, R_{dstr}~(0.007;0.01)R_0 (see Fig.1a) and R_{out}~0.5R_0 (see Fig.5). Here $x = r/R_0$ and $R_0 = 10^3 R^*$ is the outer radius of the disc, measured in radii of the star- accretor;

For Cyg X-1 the active zone is located in the ranges ~(0.1;0.4)R_0, R_{dstr}~0.1R_0 (see in Yankova, 2014) and R_{out} ~0.4R_0 (see Fig.2b) respectively. Here $x = r/R_0$ and $R_0 = 10^3 R_g$ is the outer radius of the disc, measured in Schwarzschild radii.



a) *b)*

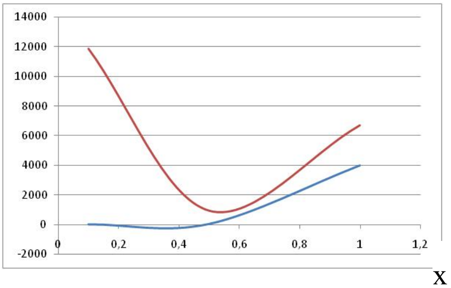
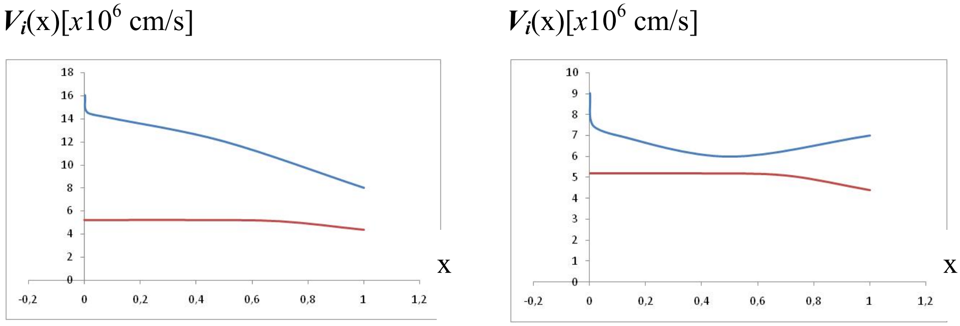


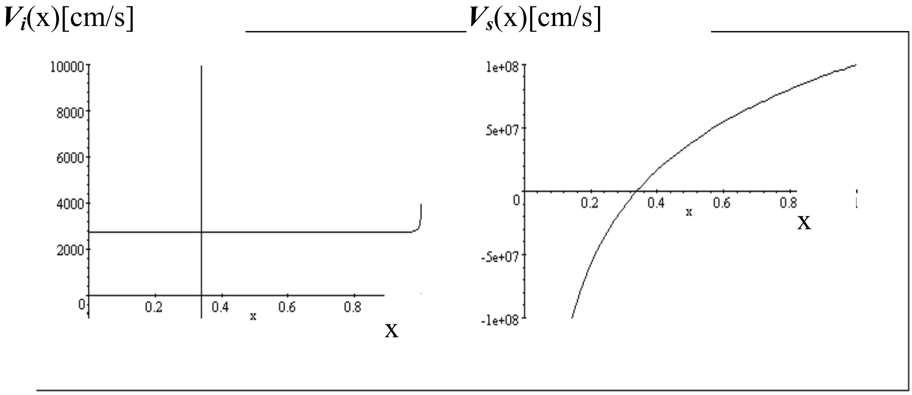
Figure 1: Distribution of the Condition $|v_a| \le |(3/2)v_\varphi|$:
(a): for RS Oph, gives a destruction radius at ~8R*, and for Cyg X-1 (see Yankova, 2014) gives a inner radius at ~100Rg,
(b), (c): at the later stage, a destruction radius for both objects is not registered.

The active zone of RS Oph spread inwards, in the ranges ~(0.005;0.5)R_0, R_{in} ~0.005R_0 (see Fig.1b, Fig.3) and R_{out}~ 0.5R_0 (see Fig.5);
While, for Cyg X-1 the active zone spread inward and outward, in the ranges ~(0.00?;0.9)R_0, R_{in} ~0.0?R_0 (see Fig.1c) and R_{out} ~0.9R_0 (see Fig.2c) respectively.



a_1) *a_2)*

Figure 2(a): at RS Oph the disc does not generate a corona



b)

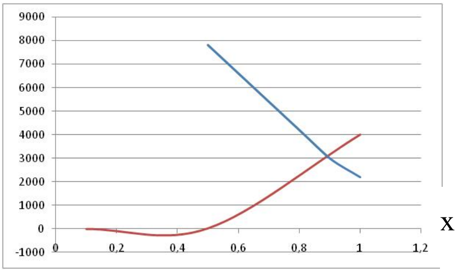


Figure 2: Distribution of the Condition $|v_a| \le |v_s|$:
(b): for Cyg X-1 (Iankova, 2007) gives an outer radius at ~340R_g,and
©: at the later stage for Cyg X-1 gives an outer radius at ~900R_g.

4. ADVECTION IN THE DISK – – THE ACTIVE ZONE BEHAVIOR

The advection controls the flow parameters in both parts the active zone. In Newtonian flux, the advective ring in the disk is the main carrier of the hidden activity. In the advective ring, a physical effect of the local heating occurs, which represents the direct connection of the instabilities with the disk's energetics. The feedback is an expression of the hidden dependence of the internal flow structure of the nonlinear effects in it (Yankova, 2012a). The active zone is densely populated with rings in which the advection is reproduced. A self-induction mode is due to interaction of the electro-magnetic field with the plasma under the conditions of a strong gravity (Iankova, 2009; Yankova, 2015a).

Two factors determine the advection in the relativism: the magnetic field topology and gravity. The self-gravity in the formations, in which advection has generated; and background potentials, determined by space-time metrics are directly interrelated to the evolving advection (Yankova, 2018; Giuseppe, 2013). The magnetic fields include and determine the feedbacks of the mechanism of a fundamental advection. With its development in relativism, the advection works even better as a mechanism. Self-gravity literally closes the rings in the beds formed by the azimuthal current in the manifold topology.

The concentration of the rings determines the width and thickness of the active zone, and the advective displacement have related to its mobility.

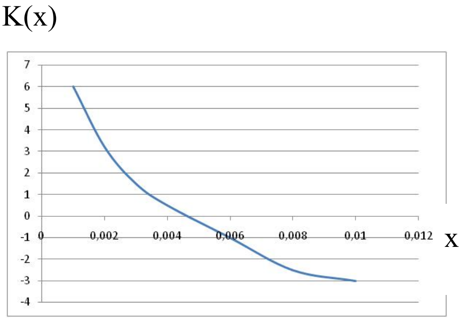


Figure 3: Distribution of the local heating in the inner regions of the RS Oph disk.

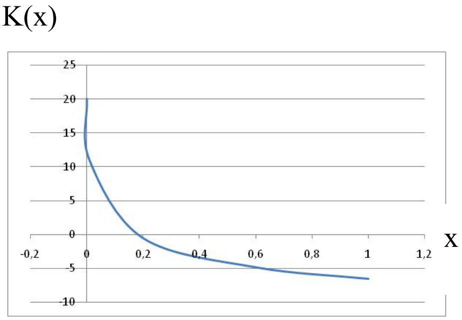


Figure 4: Distribution of the local heating in the Cyg X-1 disk.

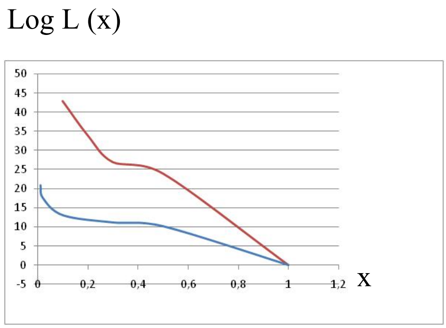


Figure 5: Luminosity distribution function of the RS Oph disk;

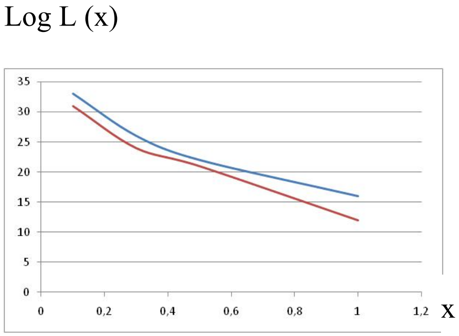


Figure 6: Luminosity distribution function of the Cyg X-1 disk

5. DISCUSSION

We can identify one main similarity and one subsequent, as well several significant differences in the active zones of our two objects:

1. The active zone consists of two separate parts – the rings in the inner and outer zone have different construction. The external ones have clearly expressed and separated from the environment. They keep in themselves the activity. While the internal rings pass one by other, they gradually fade, they blurred, which allows the activity to manifest itself.
2. In the early stages, the micro-quasar active zone is relatively narrower and heavily pulled inward to the accretor that in the disk of the other compact object.
3. In the active zone of RS Oph, however, the internal active zone is much smaller than the external one and the hidden activity is preserved in a much larger region of the disk.

The narrower and shifted in the inner regions active zone of Cyg X-1 is mainly due to the stronger background gravity of the black hole.

Weak gravity of the accretor allows the EM field in the disk more easily to hold the plasma in the rings (via partial freezing, the current efficiently guide the plasma). On this is due more than ten times longer outer active zone of RS Oph relative to the inner.

For comparison, in Cyg X-1 it is only two times larger.

4. At a later stage the active zones are extended in both objects:
5. At Cyg X-1, both active zones increase but retain location of their internal boundary.
6. At RS Oph the internal active zone increases and shortens the external active zone, equalizing approximately its width.

The pumped up by displacement activity in the inner layers is unfolding the inner zone in Cyg X-1. Here the powerful gravity plays a slightly different role, by her the accretor reacts, as unfolding and the outer zone, and thus preserving the inner boundary in the active zone.

At RS Oph the inner zone reacts in the same way, but the weaker gravity allows it to expand in both directions and to release the activity of the disk much sooner.

6. CONCLUSIONS

As the conclusion, we will note that the main structure, consequence of advection - the active zone and its construction in the various objects remain unchanged. This is a strong argument in support to the fundamental nature of the advection mechanism.

Differences in the active zones of the two disks are a result of the individual physical conditions caused by the specifics of the concrete objects and them evolution. This only confirms the functionality of our model at work with different types sources.

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