DEVELOPMENT ON THE BOUNDARY IN THE SYSTEM DISK-CORONA, EVOLUTION ON THE SYSTEM

Krasimira Yankova

Space Research and Technology Institute – Bulgarian Academy of Sciences
e-mail: f7@space.bas.bg

Keywords: *Accretion disc, MHD, Polarimetry*

Abstract: *This paper considers magneto-hydrodynamics of the system disk-corona. Analyze the influence of the boundary distributions over development of the flux in the corona. Discusses the significance of the type of the boundary for exchange of energy between components in the system. We will researching the structuring of the flow on the secondary component.*

РАЗВИТИЕ НА ГРАНИЦАТА В СИСТЕМАТА ДИСК-КОРОНА, ЕВОЛЮЦИЯТА НА СИСТЕМАТА

Красимира Янкова

Институт за космически изследвания и технологии – Българска академия на науките
е-мейл: f7@space.bas.bg

Ключови думи: *Акреционен диск, MHD, поляриметрия*

Резюме: *Тази статия разглежда магнито-хидродинамиката на системата диск-корона. Анализираме влиянието на граничните разпределения над развитието на потока в короната. Обсъжда се значението на вида на границата за обмена на енергия между компонентите в системата. Ще се изследва структурирането на потока в вторичния компонент.*

Introduction

Modern astronomy allowed registering quasars at the core of all known spiral galaxies, including our own: From some time, appeared a good trend to seek a unified model of AGN. Based on this idea, group with a hundred and forty authors [1] accomplished an observation program. Main conclusions are that no matter the host galaxy, a core is quasar and shows similar structure and the same mechanism of development. Differences in the observations are the result only of different levels of accretion, mass and direction monitoring. Objects, which we observe and investigate showing greatly energy efficiency: Fast variability and jet existing; Strong X-ray emission; No blackbody spectre; Light polarization; Annihilation Spectral lines.

In the theory searching to unified model to explanation of their high-energy nature starts earlier. Based on the similarity of the morphology of the object (BH + disc + corona + jets) and the spectrum of jets at different masses [3] express hypothesized that in both cases: close binary systems and active galactic nuclei's (CBS and AGNs) they result from general physical mechanism. Their idea is mathematically justified by the relationship between the emission of jets with the mass of black hole (BH) and accretion activity. The hypothesis was tested in a standard classification $1M_{☼}$ to $10^6M_{☼}$ ($1M_{☼}$ – solar masses). The measurements show a linear correlation (L_X, L_R) that may be predicted theoretically, which practically proves the hypothesis.

We created magneto-hydrodynamics model for non-stationary and non-axis-symmetrical accretion flows. Model is based on the fundamental equations of the magneto-hydrodynamics of fluids: the continuity equation (Eq. 1.1), equation of motion (Eq. 1.2), equation of the magnetic induction (Eq. 1.3), equation of heat balance (Eq. 1.4) and equation of state (1.5).

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

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

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

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

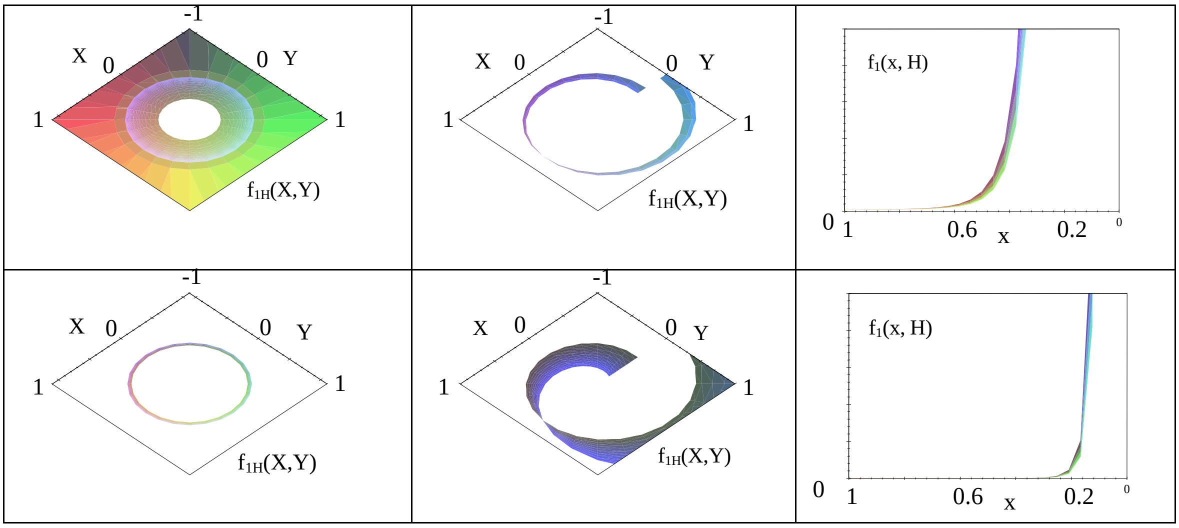
(1.5) $$p = p_r + p_g + p_m$$

Here $\boldsymbol{v} = (v_r, r\Omega, v_z)$ is velocity of flux; ρ - mass density; $\boldsymbol{B} = (B_r, B_\varphi, B_z)$ - magnetic field; p - pressure; Φ - gravitational potential; ϑ - kinematical viscosity; η - magnetic viscosity; σ - magnetic turbulent conductivity; T- temperature; S - entropy; $\dot{M}$ - accretion rate; Q_{adv} - advective term; Q^{+} - viscosity dissipation; Q_{mag} - magnetic dissipation; Q^{-} - radiative cooling; p_r – radiative pressure; p_g – gas pressure; p_m – magnetic pressure.

As we have shown in a series of articles [7,8] , he is applicable to representatives of different groups of high-energy sources: active and inactive galactic nuclei (sleeping quasars) and black holes with stellar mass (micro-quasars). We have developed the new model of the base on deformationless advective hypothesis, presented in [5,7]. It is obtained global solutions for the 2D- 3D-and local structures of accretion disk both and solution for the boundary between corona and disk. We demonstrated development interaction of field and plasma in accretion flow [4,5].

Boundary Distributions

Results from theoretical 3D-model addition for vertical structure of the disk, are used to get the correct boundary distributions for description of the processes on the boundary [6].



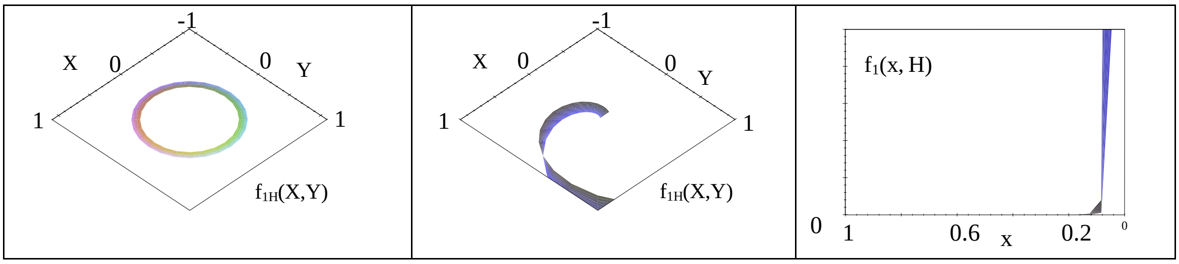


Fig. 1: Here f_1(x,H) is dimensionless functions of the boundary distribution on the mass density ρ of the flow: (a) f_{1H}(X,Y) are Cylindrical boundary contours of the function for corresponding, (b) Vertical distributions of the function for level of the increasing.

The analysis of the border distributions $f_i(x,H)$ given, that in the disk are formed the high-density and low-density areas – advective rings that provide the warming of the pad at the base of the corona (fig.1). Advective rings type determined the kind of the boundary in system corona-disk. This is especially important because into boundary is performed transfer energy between its components. Each subsystem has its own energetics, which is part of the total, but in some objects, it can be autonomous for the components.

When is modelling the system disk - corona with total energetics, the corona is directly affected by disk's state and the heat balance is represented by an equation or a system of two closely related equations, which cannot be considered individually.

When is modelling the system disk - corona with individual energetics, this means that heat balance in the corona is influenced indirectly by the condition in disk and distributions of leading parameters on the boundary, then each component has its own heat balance, which can be considered individually.

In [8] we establish that at Cyg X-1 stratified rings type contribute to form a sharp boundary between the disc and the corona while in the disk of SgrA* cannibalism of instabilities determine other kind high-density rings and they talked about fuzzy border. Components must be considered complex there in depending on the degree of fuzziness of the border.

Model Equations of the Fluid in the Disk's Corona, for Sharp Boundary between Components

Main modification to leading perimeters of the disc is applicable even for sharp boundary between components, because of the strong physical causal connection in the system corona-disk and we can to use

(3.1) $$F_i = F_{i0}\Re_i(x = \mathbf{r}/r_0\ , Z = \mathbf{z}/r_0\ )exp[k_\varphi(x,Z)\varphi + \omega(x,Z)\,t] = F_{i0}\, f_i(x,Z)$$

for parameters in the corona. In analogy with -2D-structure of the disk, F_{i0} are their values at the outer radius of corona across the disc r_{0c}.

- Coefficient ω(r, z) indicates how often the flow deviates from its course as a result of his meeting with a structure or a spontaneous disturbance.
- Coefficient k_φ(r, z) is the sine function or central angle (in radians) between positions of such deviations on the same orbit.

There is a direct dependency of all types' instabilities with distribution the energy in the disk and respectively feedback in the developments of the characteristics of flow with the action of these instabilities in it. Feedback is an expression on the non-obvious dependence from non-linear effects. By introducing the coefficients ω(r, z) and k_φ(r, z), we define feedback in flux.

Will call ω(r, z) and k_φ(r, z) – coefficients of meeting. They correlate with wave numbers in the local model. Coefficients do not have specific relations to one concrete deviation, because they are global feedbacks. Feedbacks have a relation to general distribution of instabilities and structures in the stream as a whole.

In the disk the flow is localized in the equatorial plane. Matter can be optically thick and dominated by gas pressure. Equilibrium is maintained by rotation. Corona has optically thin flow and dominated magnetic pressure. Due to the specific nature of the almost spherical flow and weak rotation in there, kinetic viscosity drops to zero $\vartheta \to 0$, but fell restrictions on the magnetic viscous coefficient η. Also main magnetic field cannot remain in its simplest form $B_z = \frac{\mu}{r^3}$, valid for equatorial plane and take the form (see in [5]):

(3.2) $$B_z = \frac{\mu}{r^3}\frac{\sqrt{4r^2+z^2}}{\left(r^2+z^2\right)^2}$$

Now applying our modifications to adapted system in cylindrical coordinates [5] , we get:

(3.3) $$v_r \frac{\partial\rho}{\partial r} + v_z \frac{\partial\rho}{\partial z} + \rho\left(\omega + k_\varphi\Omega\right) = 0$$

(3.4) $$\frac{\partial B_r}{\partial r} = \mu z \frac{5r^2+z^2}{\left(r^2+z^2\right)^3\sqrt{4r^2+z^2}} - \frac{B_r + k_\varphi B_\varphi}{r}$$

(3.5) $$v_r \frac{\partial v_r}{\partial r} + v_z \frac{\partial v_r}{\partial z} + v_r\left(\omega + k_\varphi\Omega\right) = -\frac{\partial v_s^2}{\partial r} - \frac{v_s^2}{\rho}\frac{\partial\rho}{\partial r} + \frac{k_\varphi B_\varphi B_r}{4\pi\rho r} + \frac{B_z}{4\pi\rho}\frac{\partial B_r}{\partial z}$$

(3.6) $$v_r \frac{\partial}{\partial r}(\Omega r^2) + v_z \frac{\partial}{\partial z}(\Omega r^2) + (\Omega r^2)\omega = \frac{B_r}{4\pi\rho r}\frac{\partial}{\partial r}(r^2 B_\varphi) + \frac{B_z r}{4\pi\rho}\frac{\partial B_\varphi}{\partial z}$$

(3.7) $$v_r \frac{\partial v_z}{\partial r} + v_z \frac{\partial v_z}{\partial z} + v_z\left(\omega + k_\varphi\Omega\right) = -\frac{\partial v_s^2}{\partial z} - \frac{v_s^2}{\rho}\frac{\partial\rho}{\partial z} - \frac{\partial\Phi}{\partial z} + \frac{\mu B_r}{2\pi\rho r}\frac{z^4+5z^2r^2-2r^4}{\left(r^2+z^2\right)^3\sqrt{4r^2+z^2}}$$

(3.8) $$\frac{\partial v_r}{\partial r} + \frac{v_r}{r} + \frac{\partial v_z}{\partial z} = 0$$

(3.9) $$\frac{aT^4}{3\rho} = v_s^2 - v_a^2/2 - RT$$

(3.10)
$$B_r(\omega + \frac{\eta}{r^2} + \frac{\eta k_\varphi}{r^2} - \frac{2\eta k_\varphi^2}{r^2} + k_\varphi\Omega) = (\frac{k_\varphi v_r}{r} - \frac{\eta k_\varphi^2}{r^2} - \frac{2k_\varphi\eta}{r^2})B_\varphi -$$
$$-\left(\frac{\eta}{r} + \frac{\eta k_\varphi}{r} - v_r\right)\frac{\mu z(5r^2+z^2)}{(r^2+z^2)^3\sqrt{4r^2+z^2}} + B_z\frac{\partial v_r}{\partial z} - v_z\frac{\partial B_r}{\partial z} - B_r\frac{\partial v_z}{\partial z} + \frac{B_r + B_z}{r}\eta\frac{\partial k_\varphi}{\partial r} +$$
$$+\eta\frac{\partial^2 B_r}{\partial r^2} + \eta\frac{\partial^2 B_r}{\partial z^2} + \frac{\partial\eta}{\partial z}\left[\frac{\partial B_r}{\partial z} - \frac{2\mu}{r}\frac{z^4+5z^2r^2-2r^4}{\left(r^2+z^2\right)^3\sqrt{4r^2+z^2}}\right]$$

(3.11)
$$B_\varphi(\omega - \frac{\eta}{r^2} - \frac{v_r}{r} + k_\varphi\Omega) = (\frac{3\Omega r}{2\left(r - r_g\right)} - \frac{2k_\varphi\eta}{r^2})B_r + \frac{\eta k_\varphi \mu z(5r^2+z^2)}{r(r^2+z^2)^3\sqrt{4r^2+z^2}} +$$
$$+\Omega B_z + rB_z\frac{\partial\Omega}{\partial z} + (\frac{2\eta}{r} + \frac{\eta k_\varphi}{r} - v_r)\frac{\partial B_\varphi}{\partial r} - v_z\frac{\partial B_\varphi}{\partial z} + \frac{\partial\eta}{\partial z}\frac{\partial B_\varphi}{\partial z} +$$
$$+\eta\frac{\partial^2 B_\varphi}{\partial r^2} + \eta\frac{\partial^2 B_\varphi}{\partial z^2} + \frac{\partial\eta}{\partial r}\left[\frac{B_\varphi - k_\varphi B_r}{r} + \frac{\partial B_\varphi}{\partial r}\right]$$

(3.12) $$v_r B_z + rB_z \frac{\partial v_r}{\partial r} + \left[2\mu v_r + \frac{2\mu\eta}{r^2} + \frac{2\mu}{r}\frac{\partial \eta}{\partial r}\right]\frac{z^4 + 5z^2r^2 - 2r^4}{\left(r^2+z^2\right)^3\sqrt{4r^2+z^2}} - v_z B_r - rB_r\frac{\partial v_z}{\partial r} - rv_z\frac{\partial B_r}{\partial r} - $$
$$- k_\varphi v_z B_\varphi - \frac{9\eta B_z}{r} - \frac{\eta}{r}\frac{\partial B_r}{\partial z} - \frac{\partial \eta}{\partial r}\frac{\partial B_r}{\partial z} + \frac{\eta k_\varphi}{r}\frac{\partial B_\varphi}{\partial z} = 0$$

(3.13) $$\frac{\partial S}{\partial t} + \frac{3}{2}\frac{v_r v_s v_a^2}{\Omega r^2 T} = \frac{\eta v_s}{\Omega r T}\frac{1}{4\pi\rho}\left(\frac{\partial B_r}{\partial z} - \frac{2\mu}{r}\frac{z^4+5z^2r^2-2r^4}{\left(r^2+z^2\right)^3\sqrt{4r^2+z^2}}\right)^2 - \frac{c\rho}{\pi r T}\left(v_s^2 - \frac{v_a^2}{2} - RT\right)$$

(3.14) $$\tau = \frac{\rho v_s}{\Omega}\chi$$

Here Ω is angular velocity of flux; *μ* - magnetic permeability coefficient; v_s- sound velocity; v_{ms}-magnetic sound velocity; v_a- Alfven velocity; τ-optical thickness of the flow; R - gas constant.

Have not given specific form of opacity χ =?, Ω angular velocity and η magnetic viscosity yet. In hot disks and low density, predominantly radiation pressure and finite conductivity is possible rotation to created and maintained by the resistance of the radial current [2]. This is applicable in the corona. Angular velocity decline sharply and tends to zero but remains proportionate to the

(3.15) $\Omega \approx const.\Omega_k(x, Z)$,
where *const <1*. Magnetic viscosity coefficient allows evaluating this constant magnitude.

Magnetic viscosity already included all of the components of the tensor of the magnetic stress, only that there is an important feature – the basic movement of electrons once again is φ-coordinate and the magnetic viscosity is a result of the resistance of the radial current. Therefore magnetic dissipation priority retains appearance ηj and is presented mainly by rφ- component; other components are not zeroed but compared with it are negligible and may be considered as deviations. This means that the coefficient η can be written as: $\eta = \alpha_m v_s H$

(3.16)
$$\eta = \eta_{r\varphi}\exp[k_\varphi(x,Z)\varphi + \omega(x,Z)t] = \alpha_m(x,Z)Z f_s(x,Z)\exp 2[k_\varphi(x,Z)\varphi + \omega(x,Z)t]$$

Polarimetry

Because the in the corona the prevailing massive particles are electrons, the opacity is represented by two high-energy scattering processes: U-effect Compton and synchrotron.

(3.17) $$\chi \propto \left(\frac{B}{B_0}\right)^{\frac{s+2}{2}}\left(\frac{\nu}{\nu_0}\right)^{-\frac{s+4}{2}} \qquad \sigma_k = \frac{3}{8}\sigma_T x^{-1}\left(\ln 2x + \frac{1}{2}\right) \qquad x = \frac{h\nu}{mc^2}$$

Here ***s*** is Sp-index; σ_k - Compton cross-section; σ_T - Tomson cross-section coefficient.

This naturally suggests spectro-polarimetry P (λ) ~ τ (λ), as an appropriate tool for analyzing flow-structure in the corona. Sp-polarimetry particularly effective operates with Zeeman Effect because the components of the split line have varying degrees of polarization, sometimes different kind of polarization. In the case of an external magnetic field by the Faraday rotation can be judged for the construction of plasma in it.

Changes of the polarization signal showed modify the structure of the object from which comes the polarization picture. Sp-polarimetry can appreciate even distribution and dimensions of elements (vortex particles) from the internal structure of the accretion component.

Conclusion

Model equations of the fluid in the disk and corona, for fuzzy boundary between components are subject to future consideration, like manner modelling the system disk - corona with total energetic.

Things here are simple in terms of that it will not replace heat balance and 3D- addition in this case will follow the natural spreading in corona. More correctly is remodelling in GR because such a border showed disks around SMBH.

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