Iranian Journal of Astronomy and Astrophysics
Vol. 2, No. 1, 2015
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Iranian Journal of Astronomy and Astrophysics

The study of Hydrodynamical wind on the observational properties of magnetized accretion flow with thermal conduction

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Abstract. In this paper, we examine the effect of a hydrodynamical wind on the observational properties of supercritical accretion discs (slim discs) with thermal conduction in the presence of magnetic field under a self similar treatment. The disk gas is assumed to be isothermal. In this flow, the mass-accretion rate $\dot{M}$ decreases with radius r as $\dot{M} \propto r^{(s+\frac{1}{2})}$, where s is an arbitrary constant and indication of the effect of wind. Cooling effects of outflows or winds are noticeable in luminosity and effective temperature of advection dominated accretion flows. We apply this model to black-hole X-ray binary LMC X-3, which is supposed to be under critical accretion rate. Increasing the effect of wind decreases the disc's temperature, luminosity and radiation flux of the disc, because of energy flux which is taken away by winds. The effect of thermal conduction is similar to the effect of wind in the disc's temperature, luminosity and radiation flux of the disc, but the influence of wind on the observational properties is bigger than the effect of thermal conduction.

Keywords: accretion, accretion flow, Thermal conduction, stars: winds, outflows

1 Introduction

Accretion disc, a disc-like flow of gas, or particles like free electrons and various types of ions around any gravitational object (like black hole) in which the material orbits in the gravitational field of the object, loses energy and angular momentum because of turbulence and viscosity or shear and magnetic fields as it spirals inward slowly. The gravitational energy of the gaseous matter is converted to heat. A fraction of heat is converted to radiation. The formation of stars and planets, the powerful emissions from quasars and X-ray binaries all involve accretion discs. Accretion disc physics is governed by a non-linear combination of many processes, including gravity, viscosity, radiation, magnetic fields and other parameters like thermal conduction or wind or outflow. Luminosity and observed flux are the observable physical quantity of radiation produced in accretion discs. There is a maximum possible luminosity at which gravity is able to balance the outward pressure of radiation. The limit for a steady, spherically symmetric accretion flow is given by the Eddington luminosity (Kato et al. 2008).

There are five models for accretion disc depending on their geometry (vertically thick versus thin), mass accretion rate (sub versus supper Eddington accretion rate) and optical depth (opaque versus transparent disc). These models named Shakura & Sunyaev disc, ADAF, slim disc, Polish doughnuts and ion tori (Abramowicze et al. 2010). Thin discs ($\frac{H}{r} < 1$) consist of Shakura & Sunyaev discs, ADAF, slim disc models and thick discs ($\frac{H}{r} > 1$) include Polish doughnuts and ion tori models. Each of these models have their own characteristics that have been studied in details by many researchers (e.g., Shakura, Sunyaev 1973, Narayan, Yi

1994 & 1995, Abramowicz et al. 1988 and Abramowicz et al. 1978). Following the article by Ghasemnezhad et al. 2013 (hear after GKA13), we are interested to study the effect of wind on the observational properties of LMC X-3 that is a black hole (BH) binary system ($7M_{\odot} \leq M_{BH} \leq 14M_{\odot}$) in the large magelanic cloud at a distance of $48.1kpc$(Orosz et al. 2009, Cowley et al. 1983). LMC X-3 shows soft spectra and has a high luminosity. Also, this object has a low absorption column density along the line of sight. These properties make LMC X-3 an ideal laboratory for testing our understanding of accretion disc physics. Slim disc model describes accretion discs at high luminosity, while becoming to the Shakura & Sunyaev standard disc in the low luminosity limit (or low mass accretion rate). Slim disc model can explain the spectral behavior of several black hole binaries (like LMC X-3) which cannot be explained by the standard model (Straub et al. 2011). In the slim discs, the optical depth is very high and the radiation generated by viscosity can be trapped within the disc. Cooling processes in the slim disc model are Advection and blackbody radiation but in ADAF model are Advection, bremsstrahlung and Compton scattering. The structure and spectral properties of the slim disc model have been studied by many authors (e.g., Ghasemnezhad et al. 2013, Mineshige et al. 2000, Fukue 2000).

In this paper, we consider three important parameters in the slim disc model: magnetic field, thermal conduction and wind or outflow. The effect of magnetic field and thermal conduction on the surface temperature and observed flux of LMC X-3 were studied by GKA13. In this paper, we are interested to add the effect of wind parameter to evaluate the observational properties of slim discs.

Slim discs can explain the observed high temperature in the innermost regions (Watarai & Mineshige 2001). So, accreting materials are hot and ionized which will be affected by magnetic field. So, the magnetic field plays an crucial role in the dynamical structure and the observational properties of accretion disc. Kaburaki (2000), Abbassi et al. (2008, 2010)and Ghasemnezhad et al.(2012) studied the effect of magnetic field on optically thin advection dominated accretion flow (ADAF) in the recent years. But the magnetized slim disc model has been less studied. Numerical simulations have been developed to study the structure of slim discs (Ohsuga et al. 2005, Ohsuga & Mineshige 2011). GKA13 have studied the observational properties of the magnetized slim discs without wind parameter in two cases (LMC X-3 and narrow-line seyfert 1 galaxies). We also study the magnetized slim discs with wind parameter in LMC X-3.

Thermal conduction as a physical process has a great role in energy transport by ions or electrons in the accreting materials in a hot accretion disc where they are completely ionized. Recent observations of hot accretion disc around AGNa indicate that thermal conduction should be on collision-less regime. It seems that, it is only important for dilute (opacity is low, density is very low, mean free path of gases is very long, comparable to scale height) and accretion flows (e.g., Tanaka & Menou 2006)and is not important in the standard thin disc model (SSD) or Slim disc model. As we know, thermal conduction is the transfer of energy by ions or electrons;so, the electron thermal conduction is important at low accretion rate but ion heat conduction could be relevant at all accretion rates. We can study the importance of thermal conduction from two viewpoints: mean free pass of gases and thermal conduction time. As we know, the saturated conduction flux is $F \propto \rho c_s^3$. So, the ratio of the inflow time to the ion conduction time in a hot accretion flow (slim disc) may be as large as $\propto \frac{c_s}{V_r}$, where V_r and c_s are the radial flow velocity and the sound speed, respectively. Also, the dynamical properties of self similar solutions for the present slim disc case are the same as those for the ADAF. We used self-similar solutions for sound speed and radial velocity in section 3. We insert the numerical values for c_1 and α (used from Ghasemnezhad et et al. 2013). This ratio shows that the ion conduction time is comparable to the inflow time of the plasma. Therefore, thermal conduction can be important in slim discs. Also, Johnson &

Quataert (2007) has noted that Ion heat conduction may be important at higher accretion rates, but this is harder to assess because the ion conduction time is comparable to the inflow time.
The accretion flows lose their mass by the winds as they accrete onto the central body. Mass loss mechanism (in form of wind or outflow) is an important phenomenon in the structure and evolution of the accretion discs. Observational evidences confirm the existence of wind or outflow in various astronomical sites: in Active Galactic Nuclei(AGN), microquasars and Young Stellar Object (YSO) (Shadmehri 2009). An outflow emanating from an accretion disc can affect the energy dissipation rate and the effective temperature of the disc. As the result of the mass loss, the mass accretion rate is not constant and is dependent on radius as power law ($\dot{M} \sim r^s$ index s is an order of unity)(Blandford & Begelman 1999, Abbassi et al. 2010, 2013). Physical forces or sources that drive the discs wind, can be the thermal sources, the radiation field and the magnetic field. The name of winds in accretion disc depend on their driving forces. The wind mechanism has been investigated by many researchers (Meier 1979, Fukue 1989, Abbassi et al. 2010). We assume the wind in the disc causes the loss of angular momentum, mass and thermal energy. Recently radiation hydrodynamic (RHD) and radiation magnetohydrodynamic (RMHD) simulations, show that the strong radiation pressure force drives outflows above the slim discs (ohsuga et al. 2009, ohsuga et al. 2005). Also a mass losing accretion disc could produce spectra that will be different from that produced by standard accretion disc (Knigge 1999). Done & Davis (2008) studied the LMC X-3 spectra and concluded that the spectra of LMC X-3 could be affected by wind. Wilms et al. (2001) showed that the spectra of LMC X-3 consist of a disc black body with $KT \sim 0.8 - 1Kev$ and a soft power law. In this paper, we are interested to know how the wind parameter affect the surface temperature and radiation flux of LMC X-3.
We improved the GKA13 by adding the wind parameter and then we compare the effect of wind and thermal conduction parameters in observational properties of LMC X-3. Knigge (1999) studied the effect of mass losing (wind) on the radial structure of the accretion disc by introducing two parameters (l & η). We have used these parameters for writing the angular momentum and energy equations. We describe the effects of (l & η) in the next section.
This paper is organized as follows. In section 2, we present the equations of magnetohydrodynamics as the basic equations. self-similar solutions are presented in section 3. In section 4, we consider the radiation properties of slim discs and the results and finally, we present the summary and conclusion in section 5.

2 The Basic Equations

We continue the paper presented by Abbassi et al. (2010) and investigate the effect of wind on the observational properties. Abbassi et al. (2010) studied the structure of magnetized accretion disc with thermal conduction and wind parameters. So, we use all the MHD equations and assumptions made by Abbassi et al. (2010). We use the cylindrical coordinates (r, φ, z) for steady state and axi-symmetric ($\frac{\partial}{\partial \phi} = \frac{\partial}{\partial t} = 0$) super critical accretion disc. We vertically integrate the flow equations; also, we suppose that all flow variables are only a function of r (radial direction). We ignore the relativistic effects and we use the Newtonian gravity in the radial direction. We adopt α -prescription for viscosity of rotating gas in accretion flow. We consider the magnetic field has just toroidal component.

The MHD equations are as the same as the equation made by Abbassi et al. (2010): The equation of continuity gives:

$$\frac{\partial}{\partial r}(r\Sigma V_r) + \frac{1}{2\pi}\frac{\partial \dot{M}_w}{\partial r} = 0 \tag{1}$$

where V_r is the accretion velocity ($V_r < 0$) and $\Sigma = 2\rho H$ is the surface density at a cylindrical radius r. H is the disc half-thickness and ρ is the density. The mass-loss rate by wind is showed by $\dot{M}_w$. So

$$\dot{M}_w = \int (4\pi r' \dot{m}_w(r') dr'), \tag{2}$$

where $\dot{m}_w(r)$ is the mass-loss per unit area from each disc face. On the other hand, we can rewrite the continuity equation as:

$$\frac{1}{r}\frac{\partial}{\partial r}(r\Sigma V_r) = 2\dot{\rho} H \tag{3}$$

where $\dot{\rho}$ is the mass loss rate per unit volume. The equation of motion in the radial direction is:

$$V_r \frac{\partial V_r}{\partial r} = \frac{V_\varphi^2}{r} - \frac{GM_*}{r^2} - \frac{1}{\Sigma}\frac{d}{dr}(\Sigma c_s^2) - \frac{c_A^2}{r}$$
$$-\frac{1}{2\Sigma}\frac{d}{dr}(\Sigma c_A^2) \tag{4}$$

where V_φ, G, c_s and c_A are the rotational velocity of the flow, the gravitational constant, sound speed and Alfven velocity of the gas respectively. The sound speed and the Alfven velocity are defined as $c_s^2 = \frac{p_{gas}}{\rho}$ and $c_A^2 = \frac{B_\varphi^2}{4\pi\rho} = \frac{2p_{mag}}{\rho}$, where B_φ, p_{gas} and p_{mag} are the toroidal component of magnetic field, the gas and magnetic pressure respectively.

By integration along z of the azimuthal equation of motion gives:

$$r\Sigma V_r \frac{d}{dr}(rV_\varphi) = \frac{d}{dr}(r^3 \nu \Sigma \frac{d\Omega}{dr}) - \frac{\Omega (lr)^2}{2\pi}\frac{d\dot{M}_w}{dr} \tag{5}$$

where ν is the kinematic viscosity coefficient. α-prescription (Shakura & Sunyaev 1973)for viscosity was assumed as:

$$\nu = \alpha c_s H \tag{6}$$

where α is a constant less than unity. $\Omega (= \frac{V_\varphi}{r})$ is the angular speed and $\Omega_k$is the Keplerian angular speed. To write the angular momentum equation , we have considered the role of wind in transferring the angular momentum. The wind material moving along a steam line originating at radius r in the disc was assummed to co-rotate with the disc out to a radial distance lr. The wind material ejected at radius r on the disc and carries away specific angular momentum $(lr)^2\Omega$,where Ω related to a radial distance lr. Knigge (1999) define the l parameter as the lenght of the rotational lever arm that allows many types of accretoin disc winds models. The parameter $l = 0$ corresponds to a non-rotating wind, and the angular momentum is not extracted by the wind and the disc losses only mass because of the wind while $l = 1$ represents outflowing materials that carry away the angular momentum $(r^2\Omega)$, and radiation driven disc winds are corresponding to the $l = 1$ case (e.g. Murray & Chiang (1996)). $l > 1$ corresponds to wind material that can remove a lot of angular momentum from the disc. Centrifugally driven MHD disc winds are corresponding to $l > 1$ (e.g. Blandford & Payne (1982)). In this case, the lenght of the lever arm is $l = \frac{r_A}{r}$ where r_A is the Alfen radius. Also, thermally driven outflows belong to this class (Piram 1977).

By integrating along z of the hydrostatic balance, we have:

$$\frac{GM}{r^3}H^2 = c_s^2[1 + \frac{1}{2}(\frac{c_A}{c_s})^2] = (1+\beta)c_s^2 \tag{7}$$

where $\beta = \frac{p_{mag}}{p_{gas}} = \frac{1}{2}(\frac{c_A}{c_s})^2$ which indicates the importance of magnetic field pressure as compare to gas pressure.
Now, we can write the energy equation considering cooling and heating processes in an ADAF. We assume the generated energy due to viscous dissipation and the thermal conducted are balanced by the advection cooling and energy loss of outflow/wind. Thus,

$$\frac{\Sigma V_r}{\gamma - 1}\frac{dc_s^2}{dr} - 2HV_r c_s^2 \frac{d\rho}{dr} = \frac{f\alpha\Sigma c_s^2}{\Omega_k} r^2 (\frac{d\Omega}{dr})^2 - \frac{2H}{r}\frac{d}{dr}(rF_s)$$
$$-\frac{1}{2}\eta\dot{m}_w(r)V_k^2(r) \tag{8}$$

where γ and f are adiabatic index and the advection parameter, respectively. In writing the energy equation, we have used the η parameter that defined by Knigge (1999). If a wind is driven from the surface of the optically thick disc, some of the dissipated accretion energy is converted to the wind energy. Strictly speaking, the fractions (η) of the wind 's binding energy and the wind's kinetic energy are provided by dissipation accretion energy. We have two models for the parameter (η) when $\eta = 0$ and $\eta = 1$. If $\eta = 0$, the effect of wind is minimized in this model, the wind is powered by the disc and the central star; but, in the maximal model $\eta = 1$, the effect of wind is maximized and the disc alone is responsible for powering the outflow (Knigge 1999).

So the last term on the right hand side of the energy equation is the energy loss due to the wind or outflow (Knigge 1999). So, η is a free and dimensionless parameter. In other words, the large η corresponds to more energy extraction from the disc because of the wind (Knigge 1999). Also, the second term on right hand side represents energy transfer due to the thermal conduction and $F_s = 5\Phi_s\rho c_s^3$ is the saturated conduction flux (Cowie & Makee 1977). Dimensionless coefficient Φ_s is less than unity. Finally, since we consider the toroidal component for the global magnetic field of central stars, the induction equation with field escape can be written as:

$$\frac{d}{dr}(V_r B_\varphi) = \dot{B_\varphi} \tag{9}$$

where $\dot{B_\varphi}$ is the field scaping/creating rate due to magnetic instability or dynamo effect.

3 Self-Similar Solutions

In the last section, we introduced the basic equations for an axi-symmetric, magnetized hot accretion flow in the presence of rotating wind. The basic equations of the model are a set of partial differential equations, which have a very complicated structure. The self-similar method is one of the most useful and powerful techniques to give an approximate solutions for differential MHD equations and has a wide range of applications in astrophysics. For the first time, this technique was applied by Narayan & Yi (1994) in order to solve ADAFs dynamical equations. By adopting Narayan & Yi (1994) self-similar scaling, in fact, the radial dependencies of all physical quantities are canceled out, and all of differential equations are transformed to algebraic equations. The properties of self similar solutions for the slim disc case are the same as those for the ADAF according to Fukue (2000, 2004). Following Abbassi et al. (2010)'s solutions, we introduce the physical quantities as follows:

$$V_r(r) = -c_1 \alpha V_k(r) \tag{10}$$

$$V_\varphi(r) = c_2 V_k(r) \tag{11}$$

$$c_s^2 = c_3 V_k^2 \tag{12}$$

$$c_A^2 \frac{B_\varphi^2}{4\pi\rho} = 2\beta c_3 \frac{GM}{r} \tag{13}$$

where

$$V_k(r) = \sqrt{\frac{GM}{r}} \tag{14}$$

and constant c_1, c_2 and c_3 are determined later from the magnetohydrodynamic equations. We will obtain the disc half-thickness H as:

$$\frac{H}{r} = \sqrt{c_3(1+\beta)} = \tan\sigma \tag{15}$$

If we assume a power law form for the surface density Σ as:

$$\Sigma = \Sigma_0 r^s \tag{16}$$

where s is constant. In order to have a valid solution for the self-similar treatment, the mass-loss rate per unit volume and the field escaping rate must have the following form:

$$\dot{\rho} = \dot{\rho}_0 r^{s-\frac{5}{2}} \tag{17}$$

$$\dot{B_\varphi} = \dot{B}_0 r^{\frac{s-5}{2}} \tag{18}$$

Substituting the above self-similar transformation in the MHD equations of the system, we 'll obtain the following system of dimensionless equations, which should be solve to having c_1, c_2 and c_3:

$$\dot{\rho_0} = -(s+\frac{1}{2})\frac{c_1\alpha\Sigma_0)}{2}\sqrt{\frac{GM_*}{(1+\beta)C_3}} \tag{19}$$

$$H = \sqrt{(1+\beta)c_3}r \tag{20}$$

$$-\frac{1}{2}c_1^2\alpha^2 = c_2^2 - 1 - [s-1+\beta(s+1)]c_3 \tag{21}$$

$$c_1 = 3(s+1)c_3 + (s+\frac{1}{2})l^2\dot{m} \tag{22}$$

$$(\frac{1}{\gamma-1} - \frac{1}{2})c_1c_3 = \frac{9}{4}fc_3c_2^2 - \frac{5\Phi_s}{\alpha}(s-\frac{3}{2})c_3^{\frac{3}{2}} - \frac{1}{8}\eta\dot{m} \tag{23}$$

$$\dot{m} = 2c_1 \tag{24}$$

After algebraic manipulations, we obtain a forth order algebraic equation for c_1:

$$D^2c_1^4 + 2DBc_1^3 + (B^2 + 2D(E-1))c_1^2 + (2B(E-1) - A^2)c_1$$
$$+(E-1)^2 = 0 \tag{25}$$

where

$$D = \frac{1}{2}\alpha^2 \tag{26}$$

$$B = \frac{4}{9f}(\frac{1}{\gamma - 1} - \frac{1}{2}) - [s - 1 + \beta(s+1)][\frac{(1 - 2(s + \frac{1}{2})l^2)}{3(s+1)}] \tag{27}$$

$$A = \frac{20\Phi_s}{9f\alpha}(s - \frac{3}{2})[\frac{(1 - 2(s + \frac{1}{2})l^2)}{3(s+1)}]^{\frac{1}{2}} \tag{28}$$

$$E = \frac{\eta}{3f}(\frac{s+1}{1 - 2(s + \frac{1}{2})l^2}) \tag{29}$$

For the case $s = -\frac{1}{2}$, we have $\dot{\rho}_0 = 0$ which is correspond to no mass loss or wind in the hot magnetized flow (Abbassi et al. 2008). In this work, we focus on the wind case ($s > -\frac{1}{2}$). As we mentioned in introduction, the observation evidence shows that the outflow can exist in ADAF (like $sgrA^{\star}$) and slim disc (like LMC X-3). The outflow will affect the dynamics and the radiative flux of the accretion disc (Ohsuga et al. 2005,2009). As we know, c_1 determines the behaviour of the radial flow and it depends on the input parameter of the fluid such as α, Φ_s, β and f. Other flow's quantity such as c_2 and c_3 can be obtained easily from c_1:

$$c_2^2 = \frac{4c_1}{9f}[\frac{1}{\gamma - 1} - \frac{1}{2}] + \frac{20\Phi_s}{9f\alpha}(s - \frac{3}{2})[\frac{1 - 2(s + \frac{1}{2})l^2}{3(s+1)}]^{\frac{1}{2}} c_1^{\frac{1}{2}} + \frac{\eta}{3f}(\frac{s+1}{1 - 2(s + \frac{1}{2})l^2}) \tag{30}$$

$$c_3 = c_1(\frac{1 - 2(s + \frac{1}{2})l^2}{3(s+1)}) \tag{31}$$

Abbassi et al. (2010) studied the structure of a magnetized ADAFs with thermal conduction and wind parameter by solving the above equations (c_1, c_2 and c_3). We use their results specially c_3 for studying the surface temperature and radiation flux of LMC X-3 as a slim disc in the next section.

4 radiation properties and results

As we know, ADAFs occur in two regimes depending on their mass accretion rate and optical depth. In optically thin ADAFs, the cooling time of accretion flow is longer than the accretion time scale. The generated heat by viscosity remains mostly in the accretion disc. The discs can not radiate their energy efficiently. So, the gas pressure dominates the optically thin ADAFs.
Also, it is not easy to calculate the radiative spectrum of optically thin ADAFs. This model of AFAFs do not radiate away like a black body radiation. The cooling process in the optically thin ADAFs are Bremsstrahlung, Synchrotron and Compton cooling. These process have possible roles to reproduce emission spectra.
In the optically thick ADAFs or slim disc models, the mass accretion rate and the optical depth is very high. So, the radiation generated by accretion disc can be trapped within the disc. The radiation pressure dominates the optically thick ADAFs and sound speed is related to radiation pressure. This model radiates away locally like a black body radiation (Remillard & McClintock 2006).

The averaged flux F is:

$$\Pi = \Pi_{rad} = \frac{1}{3}aT_c^4 2H = \frac{8H}{3c}\sigma T_c^4 \tag{32}$$

$$F=\sigma T_c^4=\frac{3c}{8H}\Pi=\frac{3}{8}c\Sigma_0\sqrt{\frac{c_3}{1+\beta}}GMr^{s-2}, \tag{33}$$

where Π, T_c, c , σ is the height-integrated gas pressure, the disc central temperature, light speed and the Stefan-Boltzman constant. The optical thickness of the disc in the vertical direction is:

$$\tau=\frac{1}{2}\kappa\Sigma=\frac{1}{2}\kappa\Sigma_0 r^s \tag{34}$$

where κ is the electron-scattering opacity. Hence, the effective temperature of the disc surface becomes.

$$\sigma T_{eff}^4=-\frac{16\sigma T^4}{3\kappa\rho}\frac{\partial T}{\partial z}\approx\frac{4\sigma}{3\tau}T^4 \tag{35}$$

$$\sigma T_{eff}^4=\frac{\sigma T_c^4}{\tau}=\frac{3c}{4\kappa}\sqrt{\frac{c_3}{1+\beta}}\frac{GM}{r^2}=\frac{3}{4}\sqrt{\frac{c_3}{1+\beta}}\frac{L_E}{4\pi r^2} \tag{36}$$

$$T_{eff}=(\frac{3L_E}{16\pi\sigma}\sqrt{\frac{c_3}{1+\beta}})^{\frac{1}{4}}r^{\frac{-1}{2}} \tag{37}$$

where $L_E=4\pi c\frac{GM}{\kappa}$ is the Eddington luminosity.
In figures 1,2 the surface temperature (T_{eff}) is plotted as a function of the dimensionless radius ($\frac{r}{r_g}$) for LMC X-3. It is obvious that the surface temperature decreases as $\frac{r}{r_g}$ increases. Figure 1 shows the effect of wind parameter on the surface temperature. The effect of wind or outflow decreases the temperature gradient. As we can see, the slim discs become colder for the case of strong wind ($s>-\frac{1}{2}$). This is because of energy flux which is taken away by winds. We have plotted together the effects of wind parameter and thermal conduction in figure 2 and then compared them together in reducing the surface temperature. We have showed that the wind parameter is more effective than the thermal conduction in reducing the slope of the temperature gradient and reducing the surface temperature.
If the assumption that the disc is optically thick in the z-direction holds, each element of the disc face radiates roughly as a black body with temperature $T(r)$. The temperature $T(r)$ plays a similar role as the effective temperature of a stars; so, we can approximate the intensity emitted by each element of area of the discs as $I_\nu=B_\nu(T_{eff}(r))$. As we have stated above, we assume that the disc surface radiates black body radiation B_ν with temperature $T_{eff}(r)$. Then, we can equate the disc radiative flux $F(r)$ to a black body flux $\sigma T_{eff}^4(r)$ where $T_{eff}(r)$ is the surface temperature. Since $\sigma T_{eff}^4(r)=\int_0^\infty\pi B_\nu(T_{eff}(r))d\nu$ we can equate the radiative flux $F_\nu(r)=\pi B_\nu(T_{eff}(r)$. Therefore, the radiative flux depends on the surface temperature. Then, the continuum spectrum (luminosity per frequency) L_ν can be calculated (see , e.g., Kato et al. 2008) by:

$$L_\nu=\int_{r_{in}}^{r_{cr}}\pi B_\nu(r)2\pi r dr \tag{38}$$

We will integrated the luminosity in a reasonable interval: ($r_{cr}=5-50r_g$). We use the black-body function:

$$B_\nu(r)=\frac{2h}{c^2}\frac{\nu^3}{e^{\frac{h\nu}{k_B T_{eff}(r)}}-1} \tag{39}$$

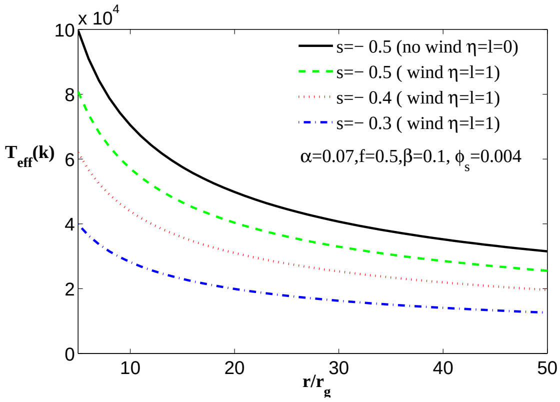

Figure 1: The surface temperature of LMC X-3 as a function of dimensionless radius ($\frac{r}{r_g}$) for two cases: no wind solutions $s = -0.5$ and with wind solutions $s > -0.5$ for a fixed thermal conduction parameter $\phi_s = 0.004$.

When the disc is seen at an angle other than face-on (from above or below the plane exactly), the circular disc appears elliptical. We study the observed flux of LMC X-3 at inclination angle $i = 60$. Observed flux from an accretion disc depends on the distance $D(= 52kpc)$ and inclination angle i as:

$$F_\nu^{obs} = \frac{L^{obs}}{\pi D^2} = \frac{\cos i L_\nu}{\pi D^2} \tag{40}$$

We plotted the observed flux of LMC X-3 for inclination angle $i = 60$ for two cases using no wind and with wind for two values of thermal conduction in figure 3. We have shown the observed flux of disc decreases by increasing the effects of wind and thermal conduction. Davis et al. (2006) plotted the spectrum of LMC X-3 for $i = 60°$, $D = 52kpc$. The observed flux is approximately $1\frac{kev}{cm^2 s}$ and the peak of the spectrum is located in $E = 1kev$. As we can see in figure 3, by adding the effect of wind parameter, the observed flux is $2\frac{kev}{cm^2 s}$; Whereas, in our previous paper (GKA13) without wind parameter, the observed flux was $4\frac{kev}{cm^2 s}$. So the presence of wind parameter causes that the observed flux to be more compatible with paper presented by Davis et al. (2006).

5 Summary and Conclusion

In this paper, we have studied the magnetized slim discs (like LMC X-3) in the presence of the thermal conduction and wind parameter. We used the self-similar method for solving the equations in the cylindrical coordinates (r, φ, z). Although the self similar solutions are too simple, they improve our understanding of the physics of the accretion discs around black hole. For simplicity, we assume an axially symmetric and static state disc with α prescription of viscosity. Also, we ignore the relativistic effects and we use the newtonian gravity in the radial direction. We have studied the effect of wind on the observational properties of LMC X-3 by following GKA13. Our results reduce to their solutions when the effect of wind is neglected. In the slim disc models, the mass accretion rate and the optical depth are very high. So, the radiation generated by accretion disc can be trapped within the disc. In optically thick ADAFs, the radiation pressure dominates. This model

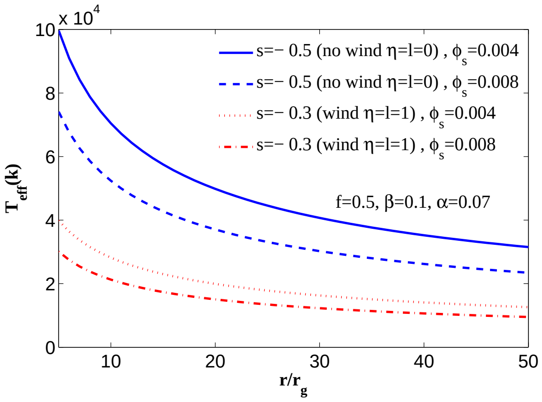

Figure 2: The comparison of the surface temperature of LMC X-3 as a function of dimensionless radius ($\frac{r}{r_g}$) for two cases: no wind solutions $s = -0.5$ for two values of thermal conduction parameter $\phi_s = 0.004, \phi_s = 0.008$ and with wind solutions $s = -0.3$ for two values of thermal conduction parameter $\phi_s = 0.004, \phi_s = 0.008$.

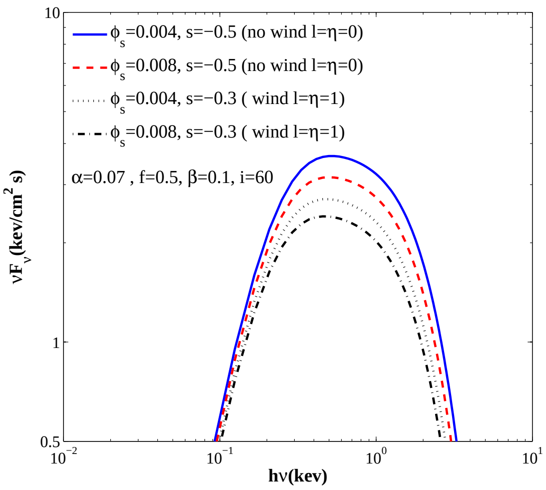

Figure 3: The observed flux of LMC X-3 with an inclination angle, $i = 60$ for two cases: no wind solutions $s = -0.5$ for two values of thermal conduction parameter $\phi_s = 0.004, \phi_s = 0.008$ and with wind solutions $s = -0.3$ for two values of thermal conduction parameter $\phi_s = 0.004, \phi_s = 0.008$.

radiates away locally like a black body radiation. We have shown the surface temperature and the observed flux of LMC X-3 decreases by increasing the effects of wind and thermal conduction. We have showed that the influence of wind on the observational properties is bigger than the effect of thermal conduction. The presence of the wind parameter causes the observed flux of LMC X-3 to be more compatible with paper presented by Davis et al. (2006). It is interesting to study the effects of convection, self gravity and global magnetic field on the radiation spectrum and the surface temperature of optically thick advection dominated accretion flows (slim discs).

The author would like to thank the referee for a number of his/her helpful and constructive comments.

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