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The role of anisotropic thermal conduction in a collisionless magnetized hot accretion flow

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Abstract

We study the importance and the effects of anisotropic thermal conduction in a collisionless magnetized advection dominated accretion flow in the presence of discontinuity of mass, angular momentum and energy between inflow and outflow. In this paper, we have considered that the thermal conduction is a heating mechanism like viscosity and leads to an increase in the temperature of the gas. A set of self -similar solutions are used for steady state and axisymmetric structure of such hot accretion disc to solve the MHD equations in our model. Based on these solutions, we have found that the anisotropic thermal conduction can be effective in the parameter space of specific energy of outflow, toroidal and vertical components of magnetic field according to a physical constraint $t_{infall} \geq t_{\perp,conduction}$.

Introduction

In this paper we try to answer this question: How does thermal conduction with tangled magnetic field affect the structure of accretion flow and the inflow rate?

The estimated observational documents of hot optically thin accretion flow around compact objects show that they are in the weakly-collisional regime. That means the mean free path of particles (electrons and protons) becomes comparable to the scale height and the local radius R (the gas capture radius). Thermal conductivity means the transfer of heat by the collision of electrons from a microscope point of view but in the collisionless regime, the thermal conduction and viscosity can be modelled as a diffusion process.

We have studied the hot accretion disc with it's the weakly collisional nature. The observation documents confirm the collisionless properties of ADAFs especially in the hot gas surrounding Sgr A* (in the center of our galaxy) (Tanaka & Menou 2006). The weakly collisional nature of ADAFs means that the accretion timescale is shorter than the collision timescale between electrons and ions, so the transport of heat flux by particles can be important in the flow. In the hot turbulent flow with magnetic field (toroidal and vertical components), thermal conduction is anisotropic and has two parts: parallel and perpendicular. The main purpose of our present work is highlighting the importance and effects of anisotropic perpendicular thermal conduction in a steady state, axisymmetric, non-relativity hot flow by using the self-similar method in the presence of interchange of mass, momentum and energy between inflow and outflow. Also the perpendicular component of anisotropic thermal conduction is formulated like viscosity as a diffusion process and the parallel component of anisotropic thermal flux is similar to the saturated form (Cowie & McKee (1977)). The thermal conduction is considered as a heating mechanism like viscosity in our model and causes increase in the temperature of the flow.

The Basic Equations

We can write the 1.5 dimensional MHD equations of our system (the conservation of mass, momentum and energy) by considering of the effects of anisotropic thermal conduction, outflow, and magnetic field by following the Bu et al. (2009) and Ghasemnezhad (2017) in the cylindrical coordinates (r, φ,z) by using the self simillar solutions, the technique and assumptions of Bu et al. (2009).

The perpendicular thermal conduction timescale and the local infall timescale can be stated respectively as:

$$t_{\perp,conducction} = \frac{r^2}{\alpha_c C_s H} \quad (1)$$

$$t_{in} = \frac{r}{v_r} \quad (2)$$

By substituting the self- similar solutions (Bu et al. 2009, Akizuki & Fukue 2006, Ghasemnezhad 2017) and by using the inverse rotation frequency at the outer radius of the disc, $\Omega_{out} = \sqrt[2]{GM/_{r^3}}$, we can write these two dimensionless timescales

$$t_{\perp,conduction}\Omega_{out} = \frac{1}{\alpha_c x_3\sqrt{1+\beta_1}}\frac{r}{r_{out}}^{\frac{3}{2}} \quad (3)$$

$$t_{infall}\Omega_{out} = \frac{1}{\alpha x_1}\frac{r}{r_{out}}^{\frac{3}{2}} \quad (4)$$

where β_1 is the ratio of azimuthal magnetic pressure to gas pressure, α_c, α are the perpendicular conduction viscosity and kinematic viscosity coefficient and x_3, x_1 are the dimensionless velocities of inflow. So the ratio of the parallel component of thermal conduction to its perpendicular component is as follows:

$$\frac{q_{\parallel,conduction}}{q_{\perp,conduction}} = \frac{5\Phi_s \rho C_s{}^3}{-\alpha_c C_s H \rho \frac{dC_s{}^2}{dr}} \quad (5)$$

by substituting the above self-similar solutions into this relation, this ratio can be obtained:

$$\frac{q_{\parallel,conduction}}{q_{\perp,conduction}} = \frac{5\Phi_s\left[(s-0.5)+\frac{1}{\sqrt{1+\beta_1}}\right]}{-\alpha_c\left[(s-0.5)\sqrt{x_3(1+\beta_1)}+1\right]} \quad (6)$$

Where Φ_s , s are the parallel conduction coefficient and wind parameter.

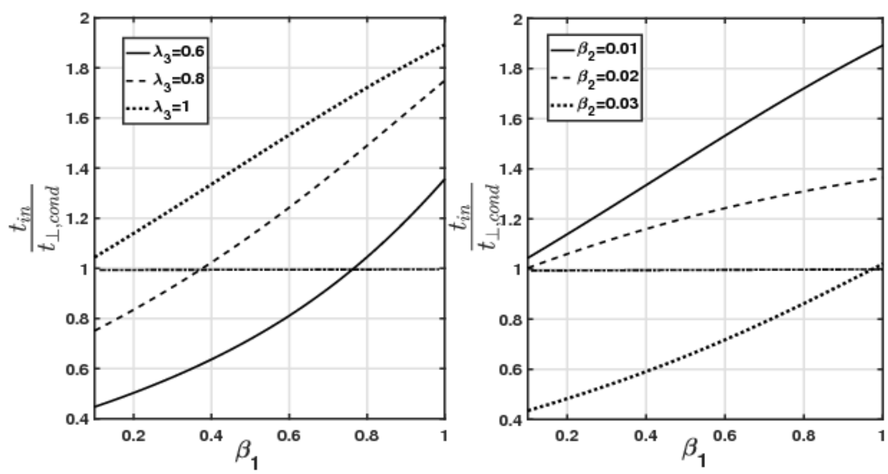

Figure1: Profile of the ratio of the infall timescale to the thermal conduction timescales. For all panels we set s=0.1, α_c =0.3, Φ_s=0.01.

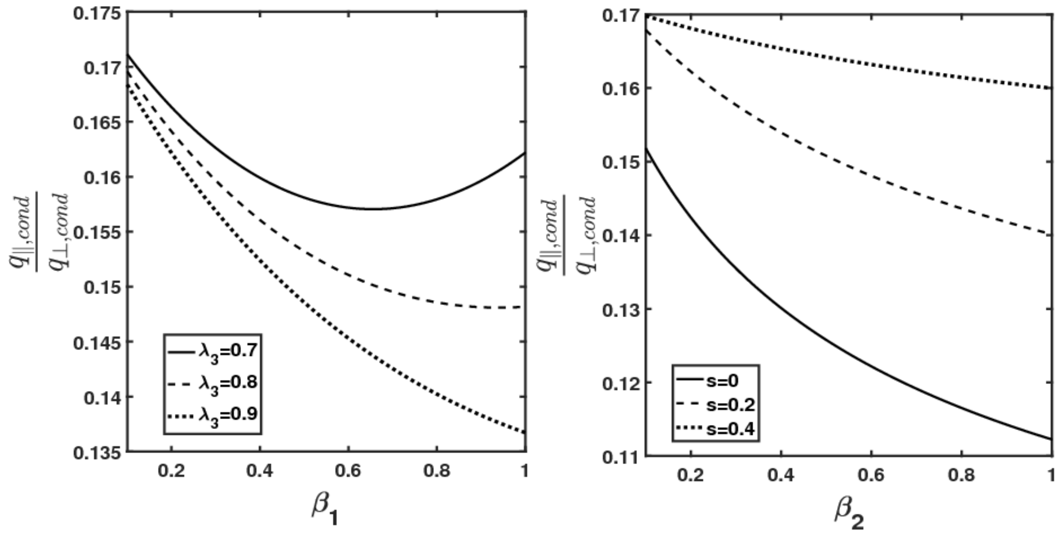

Figure2: Profile of the ratio between the conductivity along the magnetic field line to its perpendicular component. For all panels we set s=0.1, α_c =0.3, Φ_s=0.01.

Conclusion

The main conclusions of our paper are summarized as follows :

1) By defining two kinds of timescale (accretion timescale and the perpendicular component of anisotropic thermal conduction timescale) and considering the physical condition $\boldsymbol{t_{infall}} \geq \boldsymbol{t_{\perp,conduction}}$, we have found that perpendicular component of anisotropic thermal conduction can be important in a parametric space depending on the specific energy of outflow, the toroidal and vertical components of magnetic field

2) We have shown that when the large scale magnetic field (two components ($B_{\varphi,z}$) and the energy of outflow become stronger, the perpendicular component of anisotropic thermal conduction increases.

References:

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