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Estimation of viscosity parameter in Accretion flows around a black hole in presence of shock waves

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Abstract. We study the hydrodynamics of steady state viscous, axisymmetric, transonic accretion flows around a Schwarzschild black hole. We adopt a viscosity parameter, α (described by Shakura and Sunyaev, 1973) and compute the highest possible value of the viscosity parameter for each pair of two inner boundary parameters (namely, specific angular momentum l_{in} at the horizon and specific energy of the flow $E(x_{in})$ at the location of the inner sonic point x_{in}, which is still capable of producing a standing shock. We find that while shocks can still form for the value of α as high as 0.3 in smaller regions of the flow parameter space, its typical value appears to be about 0.01-0.15 which is also the typical viscosity parameters achieved by magnetorotational instabilities in accretion flows.

Keywords : accretion disk – hydrodynamics – shock waves

1. Introduction

We extend the work of Chakrabarti (1996, hereafter C96) which pointed out changes of solution topologies at critical viscosity parameter α_{cr}, to include its dependence on the entire parameter space. We use model equations as presented in C96 considering the flow to be stationary, axisymmetric and in hydrostatic equilibrium in the vertical direction. The black hole is assumed to have no rotation and the space time geometry around the black hole is described using pseudo-Newtonian potential. The flow must have two physical or 'saddle type' sonic points in order to form a shock. The accretion flow originating at the companion surface with negligible radial velocity gains speed and becomes supersonic after passing through the outer sonic point. The flow then makes a discontinuous jump to the subsonic branch at a point where shock conditions

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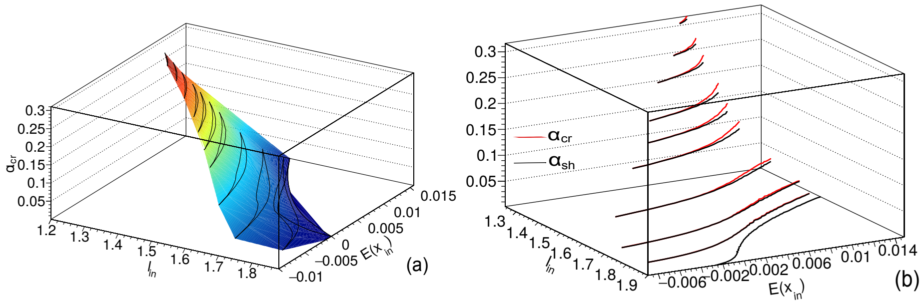

Figure 1. (a)A 3D figure representing the parameter space showing variation of l_{in}, $E(x_{in})$ and α_{cr}. (b) α_{sh}(black) and α_{cr}(red) for each pair of l_{in} and $E(x_{in})$.

are fulfilled. Subsequently, the flow becomes supersonic after passing through the inner sonic point and enters into the black hole.

We define two critical values of α, namely, α_{cr} and α_{sh}. For flows with $\alpha < \alpha_{cr}$, a flow must pass through two saddle type sonic points and can have a standing or oscillating shocks. But at $\alpha = \alpha_{cr}$, a single topology can pass through both the sonic points. For $\alpha > \alpha_{cr}$, all flow pass only through the inner sonic point. In last two cases, shocks are not possible. For any point in the parameter space, there exists a limiting value of viscosity parameter, α_{sh} above which standing shock transition is not possible. For $\alpha_{sh} < \alpha < \alpha_{cr}$ oscillating shocks are possible.

2. Results

In Fig. 1(a) we show the parameter space showing variation of l_{in}, $E(x_{in})$ and α_{cr}. Here, the contours are the boundaries for certain alpha values. Each upper boundary separates the region for which there are three sonic points. The shaded surface is the locus of all these upper boundaries. hese boundaries are similar to those drawn by Chakrabarti and Das, 2004. In Fig. 1(b) we show variation of α_{sh} and α_{cr}. Although we find that α could be as high as 0.3, the region of the parameter space allowing shock formation shrinks at high values of α and acceptable parameter space ends at $\alpha \sim 0.15$.

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References

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