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ORIGINAL ARTICLE

The local stability of accretion disk models with considering the role of various viscosity and cooling mechanisms

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Abstract The standard thin accretion disk model can explain the soft X-ray spectra of Galactic black hole systems and AGN successfully. However, there are still a few observational documents for Radiation pressure theory in X-ray novae in black hole binary systems and AGN. The luminosity in accretion onto black holes is corresponds to $L > 0.01L_E$. According to standard thin disk model, when the accretion rate is over a small fraction of the Eddington rate, $L > 0.01L_E$, the inner region of the disk is radiation-pressure-dominated and thermally unstable. However, observations of the high/soft state of black hole X-ray binaries with luminosity within ($0.01L_E < L < 0.5L_E$) show that the disk is quite stable. Thus, this contradiction shows the objection of this model and maybe it is essential to change the standard viscosity law or one of the other basic assumptions in order to get a stable disk models. In this paper, we revisit and recalculate the thermal instability with a different models of viscosity and cooling functions and show that the choosing of an arbitrary cooling and viscosity functions can affect on the stability of a general disk model and hence maybe answer to a this problem in accretion disk theory. We choose an arbitrary functions of surface density Σ and half thickness of disk H for cooling and viscosity. Also, we discuss a general disk with thermal conduction, radial force and advection. Then, we solve the equations numerically. We obtain a fourth degree dispersions relation and discuss solutions and instability modes. This analysis shows the great sensitivity of stability of disk to the form of viscosity, so there are various effective factors to stabilize the disk. For example the exist of advection and thermal conduction can effect to stability of disks also.

Keywords ISM: accretion disks · Instability · Perturbation · Viscosity

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1 Introduction

The instability of the different regions of geometrically thin accretion disk have been studied by many groups (Shakura and Sunyaev 1973; Lightman and Erdley 1974; Lightman and Erdley 1974; Wu et al. 1996 and e.g.). The different disks models such as optically thin and optically thick models has been considered. It has been found that the innermost region in alpha disk model (geometrically thin and optically thick disks) is thermally and viscously unstable (Shakura and Sunyaev 1973; Lightman and Erdley 1974) and these are inertial acoustic unstable also (Kato 1978; Blumenthal et al. 1984). However, the previous works in optically thin disks predicted that the optically thin disks are thermally unstable and these are viscously stable. Also, in ADAF, the inner region of disks are thermally stable (Narayan and Yi 1994; Piran 1978). In 1996, Wu and Li (Wu et al. 1996) considered the local stability of accretion disks with advection and conduction. They discussed thermal, viscose and acoustic instability modes in alpha, ADAF and, slim disks. In these works, the theory showed that the radiation pressure optically thick disk should be thermally and viscously unstable.

The accretion disks around of black holes, with luminosity between $0.01L_E \preceq L \preceq 0.5L_E$, are corresponding to inner region of standard disks and the radiation pressure is dominant in these disks. According to theory, these disks should be thermally and viscously unstable (Shakura