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ORIGINAL ARTICLE

Structure and stability of magnetized accretion disks with anomalous viscosity

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Abstract The structure and stability of a magnetized accretion disk are numerically examined with anomalous viscosity. The temperature, surface density and radial velocity all decrease with increasing radius r. The results show that the existence of the magnetic field $\boldsymbol{B}$ has an impact on the structure of the disk, which directly results in the variation of the growth rate and the damping rate of the unstable and stable modes. For Inward-moving mode, the magnetic field greatly enhances the instability at short wavelength and acts as a factor of stability at long wavelength. The growth rate of outward-moving unstable mode decreases, while the damping rate of thermally stable mode increases significantly owing to the magnetic field.

Keywords Accretion disks · Anomalous viscosity · Magnetic fields · Stability

1 Introduction

The stability of accretion disks has attracted considerable attention since the standard thin accretion disk model was first formulated in the early 1970s (Shakura and Sunyaev 1973). Based on α-viscosity and the revised form of it, many studies concerning the stabilities have been carried out. However, most of them were non-magnetized (Chen and Taam 1993; Wu and Yang 1994; Wu et al. 1994; Lin et al. 2011). In fact, magnetic field plays an important role in many fields of astrophysics. So far, there are three primary reasons for the importance of the magnetic fields in accretion disks. Firstly, the magnetic fields may serve the sole viscosity source and the magnetic turbulence significantly increases the viscosity (Shakura and Sunyaev 1973). Secondly, there are highly-collimated jets in many disks, which can be well understood when a magnetic field is present. Last but not least, the reconnection of emerging flux by buoyancy and the flux exterior to the disk may contribute to the heating corona. It is meaningful to consider models of accretion disk endowed with a magnetic field.

Li and Zhang (2002) reveled that the self-generated magnetic fields in accretion disk is modulationally unstable in the Lyapunov sense, leading to a self-similar collapse of the magnetic flux. Based on Vlasov equations and Maxwell equations, the collapsing feature of the self-generated magnetic field from transverse plasmons is investigated on rather small scales of the motion in the accretion disks. As the effects of the intermittent magnetic flux, the anomalous magnetic viscosity occurs

$$\nu_m = \frac{\eta}{\rho} = 7\times 10^{-12}\frac{c^2}{r\left|\frac{\partial\Omega(r)}{\partial r}\right|}T_0^{2/3}\left(\frac{T_e}{T_0}\right)^{2/3} \times \left(\frac{\bar{W}_0^p}{10^{-5}}\right)^{4/3}\left(\mathrm{cm}^2/\mathrm{s}\right), \quad (1)$$

where Ω is the angular velocity, T_0 the fiducial temperature of interest in the problem, T_e the local electric temperature and $\bar{W}_0^p$ the turbulence parameter of pumping waves. Using the new anomalous viscosity, we examined the structure of thin magnetized accretion disks around young stellar object (YSO) and found that large-scale magnetic fields can heat the outer parts of the disk (Zhou and Li 2004). Lin and Liu (2011) calculated numerically the stability of the thin magnetized accretion disk surrounding a YSO on the basis of the truth structure, and mentioned that the stability of a thin magnetized accretion disk for varying magnetic field should be considered.

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