TWO-DIMENSIONAL ACCRETION DISK MODELS OF A NEUTRON STAR

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We investigate the accretion disks around compact objects with high mass accretion rates near the Eddington's critical value $\dot{M}_{\rm E}$, where radiation pressure and electron scattering are dominant. This raises next problems : (a) whether stable disks could exist in relation to the theory of thermal instabilities of the disk and (b) what characteristic features the disks have if the stable disks exist. A non-rotating neutron star with the mass $M = 1.4 M_{\odot}$, radius $R_* = 10^7$cm and the accretion rate $\dot{M}_{\rm ac} = 2.0$ and $0.5 \dot{M}_{\rm E}$ (models 1 and 2) is considered as the compact object. We assume the α-model for the viscosity and solve the set of two-dimensional time-dependent hydrodynamic equations coupled with radiation transport. The numerical method used is basically the same as one described by Kley and Hensler (1987) and Kley (1989) but we include some improvements in solving the difference equations (Okuda et al. 1997). The initial configuration consists of a cold, dense, and optically thick disk which is given by the standard α-model (Shakura and Sunyaev 1973) and a rarefied optically thin atmosphere around the disk.

Numerical results are summarized as follows.

1. After several hundreds rotational periods at the inner edge of the disk, the disk attains to a nearly steady state. The disks are optically thick, geometrically thick, and thermally stable. The disk thickness (H/r) is $\sim$ 0.5 and 0.2 for models 1 and 2, respectively. The disk has approximately homogeneous vertical structures for the density and temperature (Figs. 1 and 2). The angular velocity exterior to the boundary layer $(r \leq 0.1 R_*)$

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is nearly Keplerian in the whole disk region ($R_* \leq r \leq 10R_*$) considered here. The stable disks belong to a category of the advection dominated disks (*slim accretion disk*) proposed first by Abramowicz et al. (1988). However the disks are unstable against convection and many convective cells are formed in the disk region.

2. Due to the dominant radiation pressure force in the inner disk, the powerful winds with mass loss rates comparable to the input accretion rate $\dot{M}_{\rm ac}$ are driven and a high velocity jet with $\sim 9 \times 10^4$ km s^{-1} is formed in the polar region. These velocity fields are rather variable. Resultantly the total luminosity emitted through the disk surface becomes lower by a factor of 5 than the theoretical one corresponding to the input accretion rate $\dot{M}_{\rm ac}$.

3. The disks are surrounded by the optically thin, rarefied, and hot atmosphere.

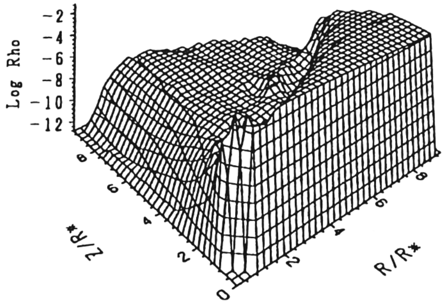

Fig. 1
The bird's-eye view of the density on the meridional plane for model 1 at $t = 10^3 P_{\rm d}$, where $P_{\rm d}$ is the Keplerian orbital period at the inner edge of the disk. The densities are expressed by the logarithm of ρ (g cm^{-3}).

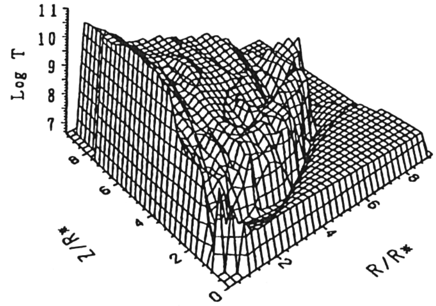

Fig. 2
The temperature distribution for model 1 at the same time as Fig. 1. The temperatures are expressed by the logarithm of T (K).

References

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