NUMERICAL SIMULATIONS OF PULSATIONALLY UNSTABLE ACCRETION DISKS AROUND SUPERMASSIVE BLACK HOLES

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Abstract. The innermost region of slim accretion disks with standard α viscosity is unstable against axisymmetric radial inertial acoustic perturbations under certain conditions. Numerical simulations are performed in order to demonstrate behaviors of such unstable disks. It is shown that oscillations with the period of $\sim 10^{-3}(M_{\rm BH}/M_{\odot})$ s can be excited near the inner edge of the disks, where $M_{\rm BH}$ is the mass of the central object. This kind of unstable disks is a possible origin of the periodic X-ray time variabilities with period of $\sim 10^4$s observed in a Seyfert galaxy NGC 6814.

1. Introduction

Accretion disks around a supermassive black hole are the most promising model of active galactic nuclei (AGN's). Various types of time variabilities observed from AGN's and their comparison with possible disk oscillations are important clues to diagnose the model.

Under certain conditions the innermost region of relativistic accretion disks is pulsationally unstable against axisymmetric radial oscillations, which propagate in the disk as inertial-acoustic waves (Matsumoto et al. 1988, 1989 and references therein). This paper presents briefly recent results of numerical simulations performed in order to investigate behaviors of such unsteady disks around a supermassive black hole. Detailed results will be published elsewhere (Honma et al. 1992). Similar investigations in the case of stellar mass black hole have been performed by Matsumoto et al. (1988, 1989).

2. Results

Slim, transonic disk models with standard α viscosity are used. The parameters involved in our simulations are the mass the central object, $M_{\rm BH}$, the accretion rate describing the initial steady state, $\dot{M}_{\rm init}$, and the viscosity parameter, α. Values of them are set to $M_{\rm BH} = 10^4 M_{\odot}$, $\alpha = 0.1$, and

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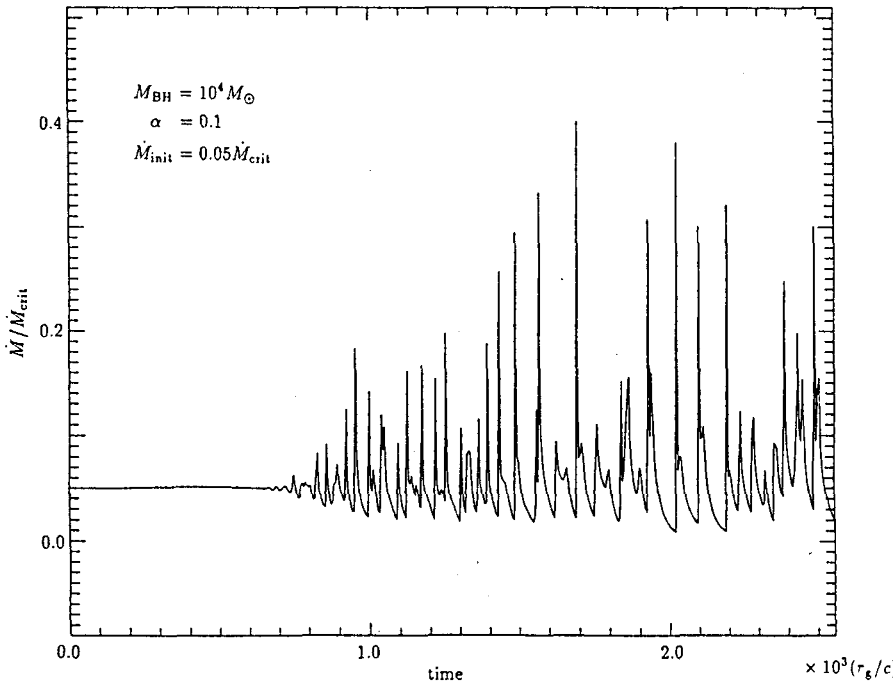

Fig. 1. Time variations of accretion rate at $\varpi = 2.8r_g$ in the simulation with $M_{BH} = 10^4 M_\odot$, $\alpha = 0.1$, and $\dot{M}_{init} = 0.05\dot{M}_{crit}$.

$\dot{M}_{init} = 0.05\dot{M}_{crit}$, where, $\dot{M}_{crit}$ is the critical accretion rate, which is defined as $\dot{M}_{crit} = 16L_{Edd}/c^2$.

The overall feature of the disk behavior is essentially the same as that obtained by Matsumoto et al. (1988, 1989) to the case of stellar mass central objects: The innermost region of the disk (radius $\sim 3r_g - 3.5r_g$) oscillates quasi-periodically and generate waves, which propagate both outwards and inwards from this region. The waves immediately grow to shock waves. Figure 1 shows the time variation of the accretion rate through the inner boundary. The period of the oscillation is $\lesssim 100(r_g/c)$.

3. Discussion

Recently, periodic variability of X-ray intensity with the period of $\sim 10^4$ s is discovered in a Seyfert galaxy NGC 6814 (Mittaz and Branduardi-Raymont 1989). This period of time variation of NGC 6814 can be explained as the oscillation of the innermost region of the accretion disk, if $M_{BH} \sim 10^7 M_\odot$ is employed.

The time variability presented here as our simulation results is not exactly periodic; quasi-periodic and somewhat chaotic. The system of equations which we treat is similar with that of stellar pulsation, although boundary conditions are different. Hence, depending on values of parameters, semi-regular and chaotic variations will be expected even in the present case of disk oscillations, as in stellar pulsation. This is interesting theoretically and also when we want to explain observations.

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