X-RAY FLUCTUATIONS FROM THE ADVECTION-DOMINATED ACCRETION DISK WITH A CRITICAL BEHAVIOR

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1. Introduction and Basic Physical Backgrounds

The new model for X-ray fluctuations of Cyg X-1, which is based on the fluid dynamics, is presented. The model is the optically thin and advection-dominated accretion disk model, which has a critical behavior.

The evolution of one-dimensional axisymmetric disk are considered. Basic equations are the same as Takeuchi & Mineshige (1997), which are constructed with mass conservation, momentum conservation, angular momentum conservation, and the energy equation;

$$\frac{\partial}{\partial t}(r\Sigma) + \frac{\partial}{\partial r}(r\Sigma v_{\rm r}) = 0,$$

$$\frac{\partial}{\partial t}(r\Sigma v_{\rm r}) + \frac{\partial}{\partial r}(r\Sigma v_{\rm r}^2) = -r\frac{\partial W}{\partial r} + r^2\Sigma(\Omega^2 - \Omega_{\rm K}^2) - W\frac{d\ln\Omega_{\rm K}}{d\ln r},$$

$$\frac{\partial}{\partial t}(r^2\Sigma v_\varphi) + \frac{\partial}{\partial r}(r^2\Sigma v_{\rm r} v_\varphi) = -\frac{\partial}{\partial r}(r^2\alpha W),$$

$$\frac{\partial}{\partial t}(r\Sigma e) + \frac{\partial}{\partial r}(r\Sigma e v_{\rm r}) = -\frac{\partial}{\partial r}(rWv_{\rm r}) - \frac{\partial}{\partial r}(r\alpha W v_\varphi) - rQ{\rm rad},$$

where Σ is surface density, W is vertically integrated pressure, Ω and $\Omega_{\rm K}$ are the angular frequency of the gas flow and the Keplerian angular frequency , respectively, M is the mass of the central black hole, α is the viscosity parameter, e is the internal energy of accreting gas, and $Q_{\rm rad}$ is radiative cooling rate per unit surface area due to thermal bremsstrahlung. I assign $M = 10M_\odot$. Starting from steady solution of these basic equations, I perform time evolutionary calculations using the Lax-Wendroff scheme.

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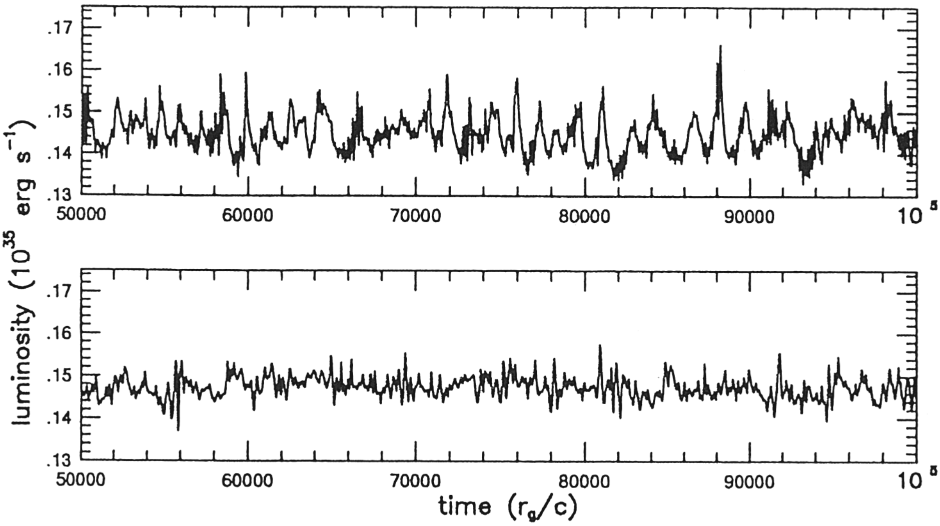

Figure 1. The obtained light curve in cases of $\eta = 0.5,\ 1.0$, from the top to the bottom, respectively. The unit of time is Schwarzschild radius per the light velocity, r_S/c.

I prescribe the critical value of the surface density, $\Sigma_{\rm crit}$, where

$$\Sigma_{\rm crit}(r) = \Sigma_{\rm steady}(r)\left(1 + \eta \frac{r - R_{\rm crit}}{r_{\rm out} - r_{\rm in}}\right).$$

Here, $\Sigma_{\rm steady}(r)$ is surface density of the steady solution, η is a free parameter representing how much $\Sigma_{\rm crit}$ deviates from $\Sigma_{\rm steady}(r)$, and the critical radius, $R_{\rm crit}$, is the radius where $\Sigma_{\rm crit} = \Sigma_{\rm steady}$. As the critical behavior, the value of α is switched as following;

$$\alpha = \begin{cases} \alpha_0 & (\Sigma \leq \Sigma_{\rm crit}) \\ \alpha_{\rm high} & (\Sigma > \Sigma_{\rm crit}). \end{cases}$$

I set $R_{\rm crit} = 30$, $\alpha_0 = 0.1$, and $\alpha_{\rm high} = 0.12$.

2. Results

In this paper, I introduce the result of $\eta = 0.5,\ 1.0$ cases. Figure 1 is the obtained light curve in cases of $\eta = 0.5,\ 1.0$, from the top to the bottom, respectively. I succeed in reproducing X-ray light curve as observed in Cyg X-1. For more details, see Takeuchi & Mineshige (1997).

References

Takeuchi, M., & Mineshige, S. (1997) X-ray Fluctuations from the Advection-Dominated Accretion Disks with A critical Behavior *ApJ*, **486**, 160–168