The Interplay among Black Holes, Stars and ISM in Galactic Nuclei
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Spectra from three-dimensional magneto-hydrodynamical accretion flows

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Abstract. Global three-dimensional (3D) magneto-hydrodynamical (MHD) simulations of accretion flow have been extensively performed recently. We calculate the emergent spectra from 3D MHD flows by the Monte Carlo radiative transfer simulations, and examine to what extent simulated MHD flows can account for the observed spectrum of Sagittarius A* (Sgr A*). It is found that the emergent spectrum from the inner part of the MHD flow ($r < 10r_s$) is consistent with the observations in the X-ray flaring state of Sgr A*, where r_s is the Schwarzschild radius. However, the MHD flow can not reproduce the spectrum in the quiescent state.

1. Introduction

The global 3D MHD simulations of radiatively inefficient accretion flows were first made by Matsumoto (1999), and have been extensively performed recently by several groups (see Makishima & Mineshige 2004 for a compilation of recent works). It has been revealed by the 3D MHD simulations that the flow pattern is considerably complicated and quite differs from that of the advection-dominated accretion flow (ADAF) (Hawley & Balbus 2002; Machida & Matsumoto 2003; Igumenshchev, Narayan, & Abramowicz 2003). Since the magnetic fields are fully solved, the simulated 3D MHD flows are considered to be a more realistic model for low-luminosity AGNs and low-hard state of the black hole candidates.

Test of the 3D MHD model through the direct comparison with the observed data is urgently needed but has poorly been attempted. In this paper, we, for the first time, calculate the emergent spectra based on the simulated 3D MHD flows by performing the 3D Monte Carlo radiative transfer simulations and directly compare them with observed data of Sgr A*.

2. Model and method

We take 3D data of normalized density, normalized magnetic fields, and proton temperature distribution in the accretion flows from the 3D MHD simulations (Kato, Mineshige, & Shibata 2004). We have one free parameter, ρ_0, to determine absolute values of density and magnetic fields. Assuming the electrons to have a Maxwellian distribution, we evaluate the electron temperature through the energy balance of the electrons between Coulomb collisions with ions and radiative cooling. In the present study, we suppose, for simplicity, the electron temperature to be constant in the calculating box. Since the radiative cooling rate is obtained by the Monte Carlo simulations for a given electron temperature, we thus iteratively investigate the electron temperature with the emergent spectrum so as to meet the condition.

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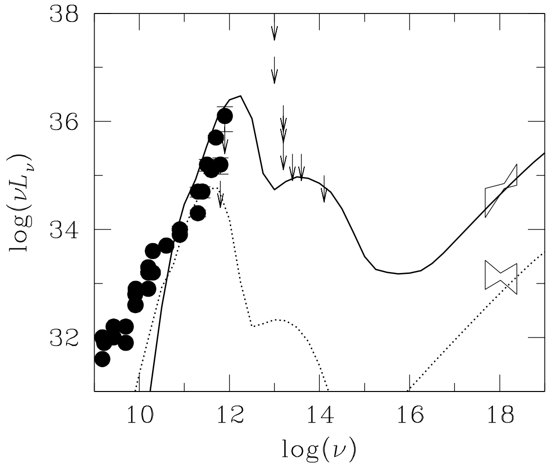

Figure 1. The resultant spectra overplotted with the observed data of Sgr A*. X-ray observations of flaring- and quiescent state are shown by the two 'bowties' (Baganoff et al. 2003). For detailed information about other observation, refer to Narayan et al. (1998). Here, the density parameters are assumed to be $\rho_0 = 1.6 \times 10^{-13}$g cm^{-3} (solid) and 0.2×10^{-13}g cm^{-3} (dotted). The calculated electron temperatures are 5.56×10^9K and 5.20×10^9K, respectively.

The emergent spectra are calculated by the Monte Carlo simulations. The method of the Monte Carlo simulation is based on Pozdnyakov, Sobol, & Sunyaev (1977). In this study, synchrotron emission/absorption, free-free emission/absorption, and Compton/inverse Compton scattering are taken into account.

3. Comparison with observed data of Sgr A*

The resultant spectra from the inner part of the flow ($r \leqslant 10r_s$) are shown in Figure 1, together with the observed data of Sgr A*. The radio peak is created because of substantial self absorption of synchrotron emission. The IR emission is due to the inverse Compton scattering of the synchrotron photons, and the free-free emission is the main mechanism of X-ray emission. As shown in Figure 1, we found that the 3D MHD model can successfully reproduce the observed spectrum in the flaring state of Sgr A* (see solid curve). On the other hand, the MHD flow can not reproduce the spectrum in the quiescent state (see dotted curve). The resultant spectrum is short of the luminosity at the radio band. The spectral slope in X-ray also differs from the observation. Our results indicate that something should lack in the simulated 3D MHD flow.

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