Three Spectral States of the Disk X-Ray Emission of the Black Hole Candidate 4U1630-47

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Recent RXTE observations have identified a very high state for several black hole candidates. Kubota et al. (2001, 2004) reported that this state can be accounted for by the inverse Compton scattering and slim disk emission. This idea is important for the purpose of obtaining a unified view of disk emission around black holes, but the sample is still poor. In addition, it has not been confirmed that the idea can be effectively applied to black hole binaries that repeat outbursts. For this reason, we analyzed the black hole candidate 4U1630-47, which is known to exhibit X-ray outbursts with a period of about 650 days, and we found it to be in a very high state in the outburst of 1998. We also found a very high state in the outburst of 1996. By considering inverse Compton scattering and slim disk emission, we found that these two very high states can be accounted as proposal by Kubota et al. It is found that 4U1630-47 is the third to exhibit three states. Three states are thought to be common among black hole binaries.

§1. Introduction

Kubota et al. (2001, 2004) reported that X-ray spectral features in a high state can be classified into three states. (1) Standard regime: the state described by the model of Shakura and Sunyaev. (2) Anomalous regime: the state in which a fraction of the disk emission is converted into hard X-rays through inverse Compton scattering. The spectrum is hard, and the inner radius appears to change. (3) Apparently standard regime: the state in which the disk thermal component is dominant and a weak hard tail is seen. When the X-ray luminosity (or disk temperature) reaches a critical value, the disk turns from (1) to (2) or (3).

§2. Data analysis and results

We analyzed PCA/HEXTE data for four outbursts during 1996−2002 obtained by RXTE. We first fitted all the spectra with the MCD plus power-law model. We fixed the column density at $9.5 \times 10^{22}$ cm$^{-2}$. As shown in Fig. 2, in Outbursts 3 and 4 and in the latter part of Outburst 2, $R_{in}$ is constant at 30−50 km (assuming a distance of 10 kpc and an inclination of $\cos \theta = 1/\sqrt{3}$). The standard disk picture is realized in these outbursts, and the spectrum is displayed in Fig. 1. For the former part of Outburst 2 (hereafter 2a), $T_{in}$ is very high, and $R_{in}$ is less than 10 km. The hard component is dominant in the spectra (Fig. 1). In Outburst 1, the X-ray luminosity is high, and the spectra is very soft (Fig. 1). Here, $R_{in}$ is somewhat small, 25 km. We considered inverse Compton scattering in Outburst 2a. In this case, $T_{in}$ becomes 1−1.3 keV, and $R_{in}$ recovers a reasonable value in the range 30−50 km, observed in the standard regime phase. In Outburst 1, the spectrum is very soft,
Fig. 1. The spectral ratio of the observational data and the values predicted by the power-law model with a photon-index of 2 in the standard regime (left), the anomalous regime (middle), the apparently standard regime (right).

Fig. 2. (a) The best-fit parameters for the MCD plus power-law model. (b) The disk luminosity \( L_{\text{disk}} \) as a function of \( T_{\text{in}} \). The data points from the standard, anomalous and apparently standard regimes are represented by the triangles, squares and circles, respectively. The solid line represents \( L_{\text{disk}} \propto T_{\text{in}}^4 \).

and the disk luminosity \( L_{\text{disk}} \) does not change significantly as \( T_{\text{in}} \) increases. The parameters tend to follow the relation \( R_{\text{in}} \propto T_{\text{in}}^{-1} \). It is thus found that a slim disk may be formed in Outburst 1, consistent with the claim of Watarai et al. (2000).

§3. Discussion

We confirmed that the accretion disk of 4U1630-47 exhibits three distinct states in the high state. In Fig. 2, we plot \( L_{\text{disk}} \) as a function of \( T_{\text{in}} \). When \( T_{\text{in}} \) is less than 1.2 keV, the standard regime appears, and the data satisfy the relation \( L_{\text{disk}} \propto T_{\text{in}}^4 \). When \( T_{\text{in}} \) exceeds 1.2 keV, this source is in the anomalous regime or the apparently standard regime. We assume here that \( R_{\text{in}} \) is 30–50 km and the black hole mass is 3.4–5.6\( \odot \). The analysis described above for several outbursts was performed for the first time. We found that the state of the accretion disk changes from outburst to outburst, depending on the luminosity (or disk temperature).

References

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2) Kubota, A. et al., Astrophys. J. 601 (2004), 428.
3) Watarai, K. et al., Publ. Astron. Soc. Jpn. 52 (2000), 133.