X-Ray Spectral Behavior in the Low/Hard States of BHCs

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We carried out systematic analysis of 8 black hole candidates (BHCs) and 1 neutron star (NS) in the low/hard states, using archival RXTE data which cover an energy range of 2−250 keV. As a result, we found that the photon index is distributed in the range of 1.2–1.8, and the cutoff energy is more than 40 keV. As the X-ray luminosity increases, both the photon index and the cutoff energy tend to become smaller. This may suggest that high energy electrons are cooled by inverse Compton scattering from soft photons. No clear differences between BHC and NS were found.

§1. Introduction

It is known that BHCs and weak magnetized NSs mainly have two spectral states: a soft/high state and a low/hard state. The low/hard state (LS) is characterized by fast time variations on a time scale of msec and a hard X-ray spectrum with a photon index of 1.4–1.7[1)] having a spectral break at $\sim$ 100 keV.[2)] This state is believed to have geometrically thick and optically thin accretion disks with a high electron temperature of $\sim$ 100 keV. However, spectral information concerning LS, such as the correlation between the photon index and the spectral break, are very poor due to insufficient observations. We carried out a systematic spectral analysis for 8 BHCs and 1 NS in the LS. Broadband coverage and a number of pointing observations of RXTE will enable us to construct a clear picture about accretion geometry in the LS.

§2. Analysis and results

From large archival data sets, we selected 103 pointing observations for 8 BHCs and 1 NS (GS 1826−238) in the LS. In our samples, 43 observations of XTE J1550−564 and 11 observations of Cygnus X−1 are included. We analyzed all the data in the standard manner for bright sources and fitted the energy spectra of PCA and HEXTE simultaneously with a power law with an exponential cutoff. We further modified this model with a smeared edge model[3)] instead of a reflection component for simplicity. From these spectral fits, we obtained three parameters: the photon index Γ, the cutoff energy $E_{\rm cut}$, and the integrated flux over 2−200 keV (F_{2-200}).

First we present νF_ν spectra of XTE J1550−564 in the left panel of Fig. 1. As the X-ray intensity decreases, the value of the spectral break increases from $\sim$50 keV to more than 100 keV, whereas photon index in the lower energy seems to change only slightly. Next, we show the correlation of F_{2-200} and $E_{\rm cut}$, limiting our consideration to the case of XTE J1550−564 in the right panel of Fig. 1. A clear correlation can be found, although these data were collected from four different outbursts.

Adding the results from 7 other BHCs and 1 NS to Fig. 1, we show the correlations of F_{2-200} and $E_{\rm cut}$ in the left panel of Fig. 2. Although the observed fluxes

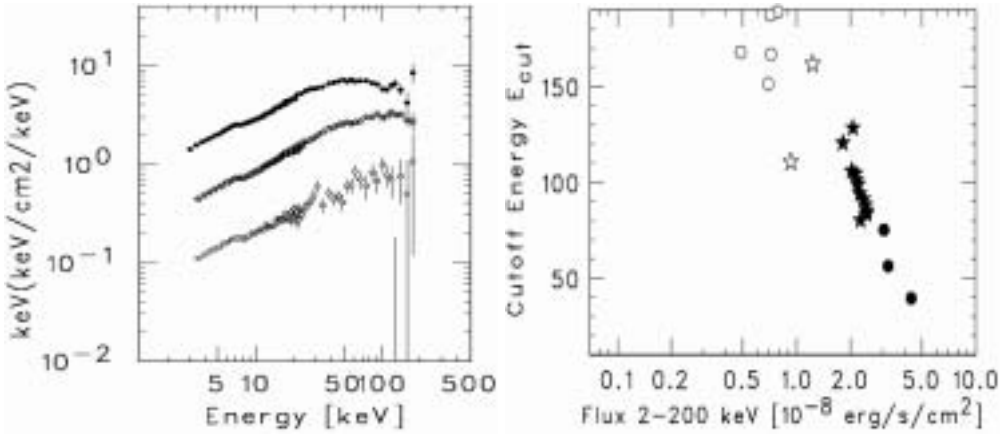

Fig. 1. Left panel: νF_ν spectrum of XTE J1550−564 in the low/hard states. Right panel: Correlation between F_{2-200} and $E_{\rm cut}$ in XTE J1550−564. The different symbols indicate that the four outbursts occurred in 1998, 2000, 2001 and 2002.

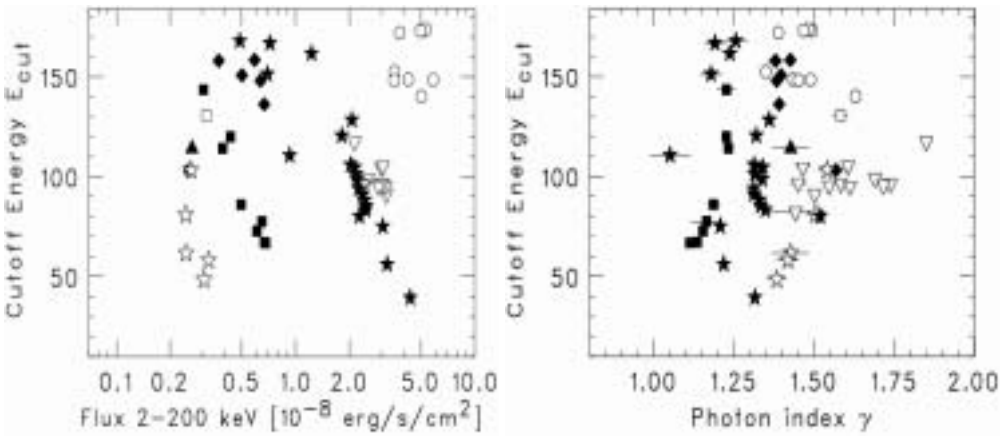

Fig. 2. Left panel: Correlation between F_{2-200} and $E_{\rm cut}$. Right panel: Correlation between Γ and $E_{\rm cut}$. The different symbols indicate the 8 BHCs and 1 NS (marked by open stars).

are different for each BHC, $E_{\rm cut}$ becomes smaller as F_{2-200} increases for any source. When $E_{\rm cut}$ decreases, the energy spectra tend to become harder, as can be seen in the right panel of Fig. 2. In addition, there are no significant differences between NS and BHCs, suggesting that the same radiation mechanisms act in the LS.

The above stated facts suggest that high energy electrons are cooled by inverse Compton scattering from soft photons; i.e. as the X-ray luminosity increases, electron temperature decreases, and the photon index increases, due to the smaller Compton y-parameter. Further studies using *Astro-E2* mission are needed.

References

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