Swift Observations of the Ultraluminous X-ray Source Holmberg IX X–1

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Abstract

Holmberg IX X-1 is a well-known ultraluminous X-ray source with an X-ray luminosity of $\sim 10^{40}\,\mathrm{erg\,s^{-1}}$. The source has been monitored by the X-ray Telescope of *Swift* regularly. Since 2009 April, the source has been in an extended low luminosity state. We utilize the co-added spectra taken at different luminosity states to study the spectral behavior of the source. The best overall fits are provided by a dual thermal model with a cool blackbody and a warm disk blackbody. This suggests that Holmberg IX X-1 may be a stellar-mass black hole accreting at or above the Eddington limit and we are observing both the inner regions of the accretion disk and outflows from the compact object.

Key words: accretion, accretion disks – binaries: close – stars: individual: Holmberg IX X-1 – X-rays: black holes — X-rays: binaries

1. Introduction

Holmberg IX X-1 is a famous ultraluminous X-ray source (ULX) located near the galaxy M81 and it is about 2 arcmin from M81's dwarf companion, Holmberg IX. The source has been observed by all major X-ray observatories throughout the last 20 years (La Parolo et al. 2001). Apart from the X-ray flux variability, Holmberg IX X-1 is also one of the first ULXs shown to have a cool ($\sim 0.1-0.2$ keV) accretion disk, leading to a suggestion of an intermediate-mass black hole accretor (Miller et al. 2004a). It is proven that monitoring observations can reveal the physical nature of Galactic X-ray binaries by tracking their flux and spectral evolution as well as their correlation. Until now, it has been quite difficult to monitor ULXs due to their distances and crowding location. *Swift* is the first X-ray telescope with reasonable spatial resolution and sensitivity to perform such observations. In this paper, we report a *Swift* monitoring observation of the ULX, Holmberg IX X-1 with a focus on the spectral behaviors.

2. Data Analysis and Results

Holmberg IX X-1 is one of the ULXs monitored with the X-ray Telescope (XRT) of *Swift* (Kaaret & Feng 2009). The source has been observed with *Swift* regularly since 2006. In particular, there is a guest observing program for an intensive monitoring of Holmberg IX X-1 since 2008 December. Furthermore, we proposed a follow-up monitoring program in mid-April 2009 and all the data obtained after April 24, 2009 are from this new program. In this work, we focus on the data obtained in between 2008 December and 2009 August. We only used data taken in photon counting mode. For earlier data, reader can refer to Kaaret & Feng (2009) for discussion. During the period we are interested, we obtained 115 XRT observations of Holmberg IX X-1 with a total exposure time of 178.6 ks.

The X-ray long-term light curve of Holmberg IX X-1 in the 0.3-10 keV is shown in Fig. 1. Because of the low count rate for each *Swift* observation, we added all the spectra in similar state together to study the spectral behavior. We divided the light curve into two parts: 1) the "low" state with data taken after 2009 April, and 2) the "variable" state with data taken between 2008 December and 2009 early-April. We also considered a co-added spectrum from all the data. All spectra cannot be fitted satisfactorily with a power-law model or multi-color disk (MCD) blackbody model (Mitsuda et al. 1984). We next considered to apply a MCD plus power-law model that provides good fits to a sample of ULXs (e.g. Miller et al. 2004a). The additional MCD component is statistically significant for both states. For the "low" state spectrum, the addition of a disk component is significant at the $> 4\sigma$ level of confidence. In particular, the best-fitting disk temperature is very low with $kT = 0.19$ keV, which is consistent with previous observations (Miller et al. 2004b). For the "variable" state spectrum, although the additional MCD component is statistically required, the spectral parameters are completely different comparing to the "low" state spectrum. The disk temperature is much higher (2.25 keV against 0.19 keV) and the photon index is also very different (2.65 against

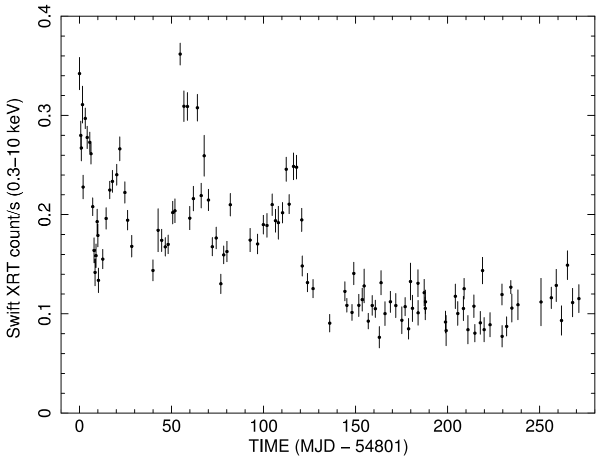

Fig. 1. *Swift* XRT 0.3–10 keV lightcurve of Holmberg IX X-1. The first data point was taken on 2008 December 1. Since 2009 April (Day 121), Holmberg IX X-1 has stayed in the "low" state.

1.68). Furthermore, this model is only marginally acceptable. Finally we consider a dual thermal model consisting of a cool blackbody continuum at low energies and a hot disk blackbody component at high energies (Stobbart et al. 2006). This model provides the best fitting for both states as well as all the data combined with very similar spectral parameters ($kT = 0.2$ keV and $kT_{in} = 2$ keV).

3. Discussion

We obtained a long-term X-ray light curve of Holmberg IX X-1 by using *Swift* XRT and found that the source transited from a "variable" state to a "low" state. The co-added spectra of both states can be best described with a dual thermal model (blackbody plus MCD). This dual thermal model is motivated by the presence of optically thick outflowing winds from a black hole accreting at or above the Eddington limit (King & Pounds 2003). When this happens, the accretion energy must be emitted from the photosphere corresponding to a certain blackbody temperature. This blackbody temperature may explain the ultrasoft (~ 0.1 keV) X-ray component of some ULXs, indicating that we may be observing both the accretion disk as well as the wind from the central black hole. In this scenario, the ULX is simply the extension of stellar-mass black hole accreting at or above the Eddington limit. Holmberg IX X-1 has been observed with *XMM-Newton* several times and indeed it is one of the first ULXs to test the cool disk model (Miller et al. 2004b). In Stobbart et al. (2006), the cool disk model provides a better fit than the dual thermal model although both are statistically acceptable. In our *Swift* monitoring observation, the dual thermal model can alway provide the best fit while the cool disk model is only acceptable in the "low" state data. If this is true, Holmberg IX X-1 may be a stellar-mass black hole accreting at or above the Eddington limit, instead of an intermediate-mass black hole. This model is also supported by a recent study of Holmberg IX X-1 using *XMM-Newton* and *ASCA* data in which the spectra can be described by a slim disk model indicating that the source is accreting near the Eddington limit (Tsunoda et al. 2006). Therefore it is likely that the source during our *Swift* monitoring as well as the *XMM-Newton* observation taken in 2001 and *ASCA* observation taken in 1999 (Tsunoda et al. 2006) is in a disk-dominant state.

The nature of the compact object of Holmberg IX X-1 is still a mystery. Previous *XMM-Newton* observations suggest that it is an intermediate-mass black hole based on a cool accretion disk model. Our study using the long-term *Swift* monitoring observations indicates that a dual thermal model can provide a better fit suggesting an extreme stellar-mass black hole accreting at or above the Eddington limit. By comparing our *Swift* monitoring observations with previous *XMM-Newton* and *ASCA* observations, there is an indication that Holmberg IX X-1 occasionally switches between a disk-dominant state and a power-law dominant state (see e.g., La Parola et al. 2001; Miller et al. 2004b; Tsunoda et al. 2006). In order to investigate if there is any spectral change and also the nature of the black hole, Holmberg IX X-1 is therefore deserved for further study using monitoring campaign.

References

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