SPECTRAL EVOLUTION OF THE MICROQUASAR XTE J1550−564 OVER ITS ENTIRE 2000 OUTBURST

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ABSTRACT

We report on RXTE observations of the microquasar XTE J1550−564 during a ∼70 day outburst in 2000 April–June. We present the PCA+HEXTE 3–200 keV energy spectra of the source and study their evolution over the outburst. The spectra indicate that the source transited from an initial low hard state (LS) to an intermediate state (IS) characterized by a ∼1 crab maximum in the 1.5–12 keV band and then went back to the LS. The source shows a hysteresis effect such that the second transition occurs at a 2–200 keV flux that is half of the flux at the first transition. This behavior is similar to what is observed in other sources and favors a common origin for the state transitions in soft X-ray transients. In addition, the first transition occurs at an approximately constant 2–200 keV flux, which probably indicates a change in the relative importance of the emitting media, whereas the second transition occurs during a time when the flux gradually decreases, which probably indicates that it is driven by a drop in the mass accretion rate. In both LSs, the spectra are characterized by the presence of a strong power-law tail (Compton corona) with a variable high-energy cutoff. During the IS, the spectra show the presence of a ∼0.8 keV thermal component, which we attribute to an optically thick accretion disk. The inner disk radius as inferred from disk blackbody fits to the energy spectrum remains relatively constant throughout the IS. This suggests that the disk may be close to its last stable orbit during this period. We discuss the apparently independent evolution of the two media and show that right after the X-ray maximum on MJD 51,662 the decrease of the source luminosity is due to a decrease of the power-law luminosity, at a constant disk luminosity. The detection of radio emission with a spectrum typical of optically thin synchrotron emission soon after the X-ray peak and the sudden decrease of the power-law luminosity at the same time may suggest that the corona is ejected and further detected as a discrete radio ejection.

Subject headings: accretion, accretion disks — black hole physics — stars: individual (XTE J1550−564) — X-rays: bursts

1. INTRODUCTION

Soft X-ray transients (SXTs) are accretion-powered binary systems, hosting a compact object (either a neutron star or a black hole), that spend most of their lives in quiescence and are detected in X-rays as they undergo episodes of outburst. Their X-ray spectra are usually dominated by two components representing different physical processes acting in the close vicinity of the accreting object. The soft X-rays are likely the spectral signature of an optically thick, geometrically thin accretion disk, whereas the hard X-rays are interpreted as the inverse Compton scattering of the soft photons from the accretion disk on hot electrons present in an optically thin coronal medium. Depending on whether the electrons have a thermal velocity distribution or not, this “hard tail” can be characterized by the presence or absence of an exponential cutoff at a given threshold energy. On the basis of the shape and strength of the spectra one can distinguish between five common spectral states thought to be linked to the accretion rate of the source (see, e.g., Belloni 2001 for a recent review):

1. The quiescent state (QS) is the “off” state in which SXTs spend most of their lives. The observations of SXTs in such a state have shown that the spectrum was power law–like, with a photon index that could be either soft or hard (e.g., Kong et al. 2002). The luminosity is several orders of magnitude below that of the other states. The accretion disk is undetectable in the X-rays.

2. In the low hard state (LS), the νf_ν spectrum is peaked in the hard X-rays and characterized by a strong power law with a photon index Γ ∼ 1.5–1.9 and a cutoff around 100 keV. The disk emission remains weak, and its innermost part has a temperature kT < 0.5 keV.

3. During the intermediate state (IS) the contribution of the two spectral components to the overall luminosity is of the same order. The disk reaches a temperature of ∼1 keV, and the hard tail has a photon index of Γ ∼ 2.5.

4. In the high soft state (HS) the soft (≤10 keV) luminosity is high, and the spectrum is dominated by a thermal component in that range. The temperature of the disk is ∼1–1.5 keV. The power law is faint with a steep photon index Γ ≥ 2.5.

5. In the very high state (VHS) the overall luminosity is close to the Eddington luminosity. The disk has a temperature kT ∼ 1–2 keV, and the power law is steep with Γ ∼ 2.5, although both components contribute significantly to the luminosity. It should be noted that the VHS is spectrally intermediate between the LS and the HS (Rutledge et al. 1999), thus making the IS and VHS similar states observed at different luminosities (Homan et al. 2001; see also Méndez & van der Klis 1997). A summary of the source history can be found in Rodriguez et al. (2003, hereafter Paper I). XTE J1550−564 is a
microquasar (Hannikainen et al. 2001; Corbel et al. 2002) hosting a black hole of $10.5 \pm 1.5 M_\odot$ (Orosz et al. 2002), lying at a distance of $3.2 \text{ kpc} \leq D \leq 10.8 \text{ kpc}$, with a preferred distance of $5.3 \pm 5.9 \text{ kpc}$ (Orosz et al. 2002). Extensive spectral and timing analysis of its 1998–1999 outburst has shown the need of an additional parameter beside the accretion rate $M$ to account for the X-ray state transitions (Homan et al. 2001). Renewed X-ray activity of XTE J1550–564 was reported by Smith et al. (2000). The source underwent a ~70 day outburst starting on 2000 April 6 (Paper I and references therein). Corbel et al. (2001) report the detection of a radio emission with a negative spectral index on MJD 51,665. They attribute it to optically thin synchrotron emission from a discrete ejection. The date of the ejection event is, however, hard to constrain and may correspond to the state transition occurring a few days before (Corbel et al. 2001). These authors also point out the absence of radio emission on MJD 51,670, indicating that no jet feature is present during that time, and they detect radio emission with an inverted spectrum on MJD 51,697, which they attribute to a compact jet. The outburst initiates in the IR and optical (Jain et al. 2001) ~10 days before the X-rays, and a second IR-optical maximum occurs as the source has returned to the LS around MJD 51,690. This second IR-optical peak is possibly related to the compact jet synchrotron tail (Corbel et al. 2001), as its inverted spectrum can extend up to the near-IR range (Corbel & Fender 2002). Tomsick, Corbel, & Kaaret (2001, hereafter TCK01) report spectral (RXTE/Chandra) observations during the very last part of the outburst, as XTE J1550–564 is returning to quiescence. We have studied the behavior of a low-frequency QPO in Paper I, and we focus here on the X-ray spectral behavior of XTE J1550–564 from the very beginning of the PCA+HEXTE pointed observations from MJD 51,644 until MJD 51,698, when the observations are contaminated by both the Galactic ridge diffuse emission and the close outbursting transient pulsar XTE J1543–568 (TCK01). We perform an analysis similar to that reported in TCK01 (covering MJD 51,680–51,698) and add the whole RXTE data set publicly available in the archives covering this outburst. We thus present for the first time the entire PCA+HEXTE spectral analysis of XTE J1550–564 over its 2000 outburst. The organization of the paper is as follows. We start by presenting the data reduction and analysis method used and then present the spectral evolution of the source. We discuss our results in the last part of the paper.

2. OBSERVATIONS

2.1. Data Reduction

XTE J1550–564 has been observed continuously with RXTE over all its outburst, i.e., from MJD 51,644 (April 10) to MJD 51,741 (July 16). Since the background in the Galactic ridge is difficult to estimate with a nonimaging instrument, we restrict our study to the interval between MJD 51,644 and MJD 51,698 and refer the reader to the study of TCK01 for the following period. We have reduced and analyzed the data using the LHEASOFT package version 5.2, which includes new response matrices and new background files for the PCA. We use here the maximum number of proportional counter units (PCUs) turned on over an observation and both clusters of HEXTE. We restricted ourselves to the time when the elevation angle was above 10° and the offset pointing was less than 0.02°, and we also rejected the data taken while crossing the South Atlantic Anomaly. In addition, the good time intervals were defined as when the number of PCUs turned on was constant and equal to the maximum available over a given observation; for most of them, at least three PCUs were turned on. 2000 May 12 corresponds to the abrupt loss of xenon layer in PCU 0, which renders its use for spectral analysis difficult and uncertain. We therefore extracted all the spectra from the top layer of all available PCUs except PCU 0. All spectra from individual PCUs were summed during the extraction. Background spectra were estimated using pchaskest version 3.0. The responses were generated with pspcrsp version 8.0. HEXTE spectra were extracted from both clusters in the standard mode data. We followed the “cook book” procedures for separating the ON and OFF positions before extracting the raw spectra (source and background), and then we corrected them for dead time. Responses were estimated with hxtrsp version 3.1. The PCA+HEXTE resultant spectra of a single observation were then analyzed together in XSPEC version 11.1.0. We retain in our fits the energy channels between 3 and 30 keV for the PCA and between 18 and 200 keV for the HEXTE. Furthermore, in order to accommodate the uncertainties in the PCA response matrix, we included 0.8% systematic errors from 3 to 8 keV and 0.4% from 8 to 30 keV (see TCK01).

2.2. Spectral Analysis

Several models were tested in the course of the spectral analysis. In every fit, a multiplicative constant representing the normalization between the instruments was added to the spectral model in order to take into account the uncertainties in the PCA-HEXTE cross calibration. To determine the spectral models, we first fitted PCA+HEXTE from MJD 51,646 and MJD 51,648 with a simple model consisting of interstellar absorption (wabs in XSPEC terminology) plus a power law. The resultant $\chi^2$ is poor (1191 for 142 degrees of freedom [dof]), with large residuals around 6.5 keV and a broad minimum around 10 keV. As the RXTE bandpass is not ideally suited for the determination of the interstellar absorption, we applied the equivalent hydrogen column density value $N_H$ returned from recent Chandra observations (Kaaret et al. 2003), i.e., $N_H = 0.9 \times 10^{22} \text{ cm}^{-2}$, and froze it in all our fits. Adding iron-edge absorption (smedge) improves the fits significantly with $\chi^2 = 942$ (139 dof). Following Sobczak et al. (1999) and TCK01, we froze the width of the smedge model to 10 keV. In order to accommodate for the high-energy behavior (HEXTE band), an exponential cutoff at higher energy is needed and gives satisfactory fits with $\chi^2 = 137$ (138 dof) for MJD 51,646 and 144 (138 dof) for MJD 51,648. Adding a Gaussian emission line around 6.5 keV gives only a marginal improvement to our fits. We also tentatively included a multicolor disk blackbody (Mitsuda et al. 1984), thought to represent the emission coming from the optically thick accretion disk, but our fits failed to achieve convergence, at least from MJD 51,644 to MJD 51,655. The spectral parameters returned from the fits are shown for the entire outburst in Table 1, and the spectrum of MJD 51,644 is represented in the left-hand panel of Figure 1. From MJD 51,658 a soft excess is detectable in the spectra (Fig. 1 shows the example of...
The addition of a multicolor disk blackbody model to the fits greatly improves their quality (see Table 1). Over that period, the hard X-ray contribution has significantly decreased (Fig. 2) and the photon index ranges from ±2.0 to ±2.4. The iron line may still be present, but for the same reasons as explained above we did not include it in our analysis.

Around MJD 51,683 the fits fail to converge if the blackbody component is kept in the model. From MJD 51,682 until MJD 51,688, an exponential cutoff is needed in the fits. We note, however, that for MJD 51,686, 51,687, and 51,688 above we did not include it in our analysis.

The data are significantly reduced until MJD 51,682 (it is significant at the 99.5% level using an F-test). We have checked for its presence on the following days by adding an exponential cutoff in our fits, but it gave no improvement to the fits (see Table 1). Over that period, the hard X-ray contribution has significantly decreased (Fig. 2) and the photon index ranges from ±2.0 to ±2.4. The iron line may still be present, but for the same reasons as explained above we did not include it in our analysis.

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they included a Gaussian feature in their fit, we note the relatively good agreement between their results and ours for both dates. The small differences might be due to the fact that they have used a value of $0.8 \times 10^{22}$ cm$^{-2}$ for the $N_H$ parameter and have made joint $Chandra+RXTE$ spectral fits.

3. SPECTRAL EVOLUTION: GLOBAL BEHAVIOR AND STATE IDENTIFICATION

The evolution of the spectral parameters are reported in Table 1, and they are plotted in Figure 2. The source spectral behavior over the outburst can be divided into two distinct states, as illustrated in Figure 2. On the basis of the spectral parameters returned from the fits (Table 1), we identify, without any ambiguities, the initial rise as a standard LS (from MJD 51,644 to MJD 51,658). The evolution of the source is rather slow here; the photon index rises from $1.49 \pm 0.01$ to $1.70 \pm 0.01$ (Fig. 2) as the 2–60 keV flux slowly rises from $1.3 \times 10^{-8}$ ergs cm$^{-2}$ s$^{-1}$ (MJD 51,644) to $2.0 \times 10^{-8}$ ergs cm$^{-2}$ s$^{-1}$ (MJD 51,658). The exponential cutoff ranges from $\approx 20$ to $\approx 36$ keV and presents no obvious correlation with the flux, whereas the folding energy decreases from $\approx 165$ keV on MJD 51,644 to $\approx 115$ keV on MJD 51,658, with an increasing soft flux. MJD 51,658 is still typical of a LS, with a photon index of less than 2, but here the spectrum has already started to soften (Fig. 2). The state transition occurs on MJD 51,660, where the hard tail steepens significantly with a photon index $\geq 2$. On MJD 51,660 and 51,662; however, a cutoff at high energy is still needed in the fits. We note that the folding energy increases up to $\approx 144$ keV on MJD 51,660 and to $\approx 422$ keV on MJD 51,662. On the basis of the spectral parameters, we can identify this new state as an intermediate/very high state. It is difficult to distinguish between these two states since both have similar spectral and temporal behaviors (and may be the same state observed at different luminosities (Homan et al. 2001; Méndez & van der Klis 1997). The presence of high-frequency QPOs (Miller et al. 2001) over the period of IS/VHS does not help much in lifting the ambiguity. It is usually assumed that the VHS has a luminosity close to $L_{Edd}$, which in our case, assuming a 10 $M_\odot$ black hole at 6 kpc (although the uncertainties are large), is $\approx 1.3 \times 10^{39}$ ergs s$^{-1}$. Here at the maximum (MJD 51,662), the bolometric disk flux is $2.1 \times 10^{-8}$ ergs cm$^{-2}$ s$^{-1}$ and the 2–500 keV (extrapolated) power-law flux is $3.35 \times 10^{-8}$ ergs cm$^{-2}$ s$^{-1}$, giving a bolometric luminosity close to $\approx 2.3 \times 10^{38}$ ergs s$^{-1}$. Given the flux and in comparison with the previous outburst (Sobczak et al. 1999), we will refer to this state as an IS. The spectral evolution from MJD 51,660 to MJD 51,662 is rather abrupt (Fig. 2) and suggests that the source has undergone dramatic evolution. Indeed, the power-law tail is now much steeper, the disk temperature is higher, and the folding energy of the cutoff has increased by a factor of $\approx 3$. The (color) radius obtained from the spectral fits (Fig. 2) varies between $\approx 32$ and $\approx 146$ km (assuming a distance of 6 kpc, for $73^\circ$ inclination). Its value remains constant around 45–55 km over 13 observations. The disk reaches its highest temperature on MJD 51,662, and from MJD 51,665 until
MJD 51,674 its color temperature is around 0.75–0.8 keV and is fairly constant (Fig. 2). After that, it starts to decrease down to \( \sim 0.5 \) keV on MJD 51,682. We note here that although the color temperature decreases, the color radius seems to decrease also. This may be due to the difficulty in determining this parameter from spectral fits starting above 3 keV at times when the source count rate starts to be low (compared to, e.g., MJD 51,658, where although the disk has a lower color temperature, the counting statistics allow a better estimate of the parameters). After MJD 51,680, the source slowly returns into a LS (see TCK01 for the spectral analysis of the observations after MJD 51,680). Although the transition to the final low state is not as sharp as in the initial stage, there is a clear evolution in terms of spectral parameters between MJD 51,680 and MJD 51,682, where the spectrum gets harder (Fig. 2) and manifests a cutoff at high energies (Table 1). From MJD 51,682 to 51,698 the source is in a LS, which first shows the presence of an exponential cutoff at high energy (MJD 51,682–MJD 51,688), while the following observations do not show any cutoff up to 200 keV. Our timing analysis (Paper I) further confirms the nature of the states. During both states, we detect low-frequency QPOs in the range 0.1–10 Hz. Two types of LFQPOs seem to be present over the outburst. The first type resembles the type C QPO (Remillard et al. 2002), and the other is more likely a type A. Interestingly, the presence of type C QPO is not related to the spectral state of the source, since it disappears after the X-ray peak on MJD 51,662 (Fig. 2), well after the first transition, and reappears after the secondary peak, on MJD 51,674, before the second transition. During the LS, however, it has a high amplitude (10%–16% rms), and during the IS it is fainter (5%) as usually observed.

4. DISCUSSION

4.1. Hard-Component Evolution during the Initial Hard State

Although recent studies have shown that the high-energy emission could originate in a compact jet (Markoff, Falcke, & Fender, 2001; Markoff et al. 2003), the results we present here will be discussed in the context of the standard Comptonization model involving a corona. We note, however, that the coronal geometry is unclear and that the corona could be seen as the base of the jet. In the standard Comptonization picture, the folding energy of the cutoff is close to the electron temperature. The slight decrease of the folding energy between MJD 51,644 and MJD 51,658 may indicate that the Compton cloud is cooled more efficiently. This might correspond to the approach of the accretion disk (decreasing inner radius) while its inner temperature and the soft X-ray flux increase. This interpretation is in good agreement with the state transition observed on MJD 51,660 and the presence of a thermal component in our fits from MJD 51,658. This is also in good agreement with the observation of an infrared-optical luminosity peak with a spectrum that is compatible with a thermal emission, occurring 10 day before that in the X-ray (Jain et al. 2001). In that case, the 10 day delay between the infrared/optical and the X-rays would indicate that the accretion disk fills on a viscous timescale, suggesting that it is truncated at a certain distance from the black hole. The fact that the photon index evolves from \( \Gamma = 1.57 \) on MJD 51,655 to \( \Gamma = 1.74 \) on MJD 51,658 (Fig. 2) may indicate that the state transition initiates first by a change in the Compton medium. As already suggested from the analysis of the Unconventional Stellar Aspect (USA) data (Reilly et al. 2001), the situation could be similar to the two-component accretion flow proposed in the case of other sources (Smith, Heindl, & Swank, 2002). In that case, both flows possess their own response timescale to any external perturbation (of the accretion rate). In a standard thin disk it corresponds to the viscous timescale \( t_{\text{vis}} \sim R^2/\nu \) (\( R \) being the radial distance to the black hole and \( \nu \) being the kinematic viscosity, usually parameterized with the \( \alpha \)-prescription), which is then of the order of days (Frank, King, & Raine, 1992). The coronal timescale is the free-fall timescale, which is much shorter. In this picture, any external change in the accretion rate would first occur on the corona and then on the disk. We should note here that the evolution of XTE J1550–564 during this LS is very similar to that of the 1998 outburst (Wilson & Done 2001; Wu et al. 2002). This suggests a common evolution for both outbursts, although XTE J1550–564 did not reach the same X-ray luminosity during the 2000 outburst.

4.2. State Transitions and Hysteresis Effect between the Two LSs

The first transition occurs at a total 2–200 keV flux of \( \sim 2.3 \times 10^{-8} \) erg cm\(^{-2}\) s\(^{-1}\) on MJD 51,660, and the second occurs on MJD 51,682, with a total 2–200 keV flux of \( 1.1 \times 10^{-8} \) erg cm\(^{-2}\) s\(^{-1}\). The first transition is rather abrupt and occurs at a roughly constant flux, whereas the second is smoother and occurs while the source flux is monotonically decreasing, at a flux half that of the first one. We have plotted in Figure 3 (left) the evolution of the spectral index versus the 2–200 keV flux over the outburst. The figure shows an hysteresis, similar to what is observed in other black hole sources (Miyamoto et al. 1995; Nowak, Wilms, & Dove 2002) and possibly in the neutron star Aql X-1 (Maccarone & Coppi 2003). In order to have a direct comparison with the latter source, we have plotted in Figure 3 (right) the ratio of the 2–50 keV power-law (corona) flux to the 2–50 keV disk blackbody flux versus the 2–50 keV source flux. The behavior of XTE J1550–564 is here similar to that of Aql X-1, shown in Figure 1 of Maccarone & Coppi (2003). In addition, Maccarone & Coppi (2003) have shown that the evolution of the hardness ratio versus the soft (1–12 keV) X-ray flux, i.e., the evolution of a given source in terms of spectral states versus source flux, was very similar for at least four black hole SXTs (XTE J1550–564, XTE J1859+326, XTE J2012+381, and probably XTE J1859+326) and by Nowak et al. 2002, i.e., GX 339–4, with the occurrence of a hysteresis loop. This similarity, with both black hole systems and at least one neutron star system, suggests that the state transitions and the spectral evolution of those sources over their outbursts obey similar mechanisms. The fact that the first transition occurs at constant flux is not what is expected if we assume that the increase of the luminosity is due to an increase of the accretion rate alone. This behavior more likely reflects a change in the relative importance of the emitting media, as pointed out by Zhang et al. (1997) in the case of Cyg X-1. This would further confirm the need of an additional parameter (beside the accretion rate) to model the state evolutions of LMXBs in outburst, as already pointed out by Homan et al. (2001).
4.3. The Intermediate State: Accretion-Disk Behavior

The presence of a cutoff in the spectra of MJD 51,660 and MJD 51,662 suggests that the coronal electrons have still a thermalized velocity distribution, although the photon index is soft. On those days also the disk starts contributing significantly to the overall luminosity. So, in the standard picture of Comptonization, as the amount of cool thermal photons increases, the coronal electron temperature should decrease because of the higher cooling rate. The observation of an increasing folding energy for the cutoff between MJD 51,658 and MJD 51,662 argues, on the contrary, for coronal heating. This behavior is similar to what is observed by TCK01, although it occurs during the decay. They suggest that this might be the signature of the onset of different emission mechanism (e.g., bulk motion Comptonization). According to Merloni et al. (2000), low values of the disk radius and flux ratio hide some failures in the basic multicolor disk blackbody model. In a previous work (Rodriguez et al. 2002b), we have retained the radius values in our analysis only when \( F_{\text{body}}/F_{\text{tot}} > 0.5 \), with the fluxes estimated between 2 and 50 keV. This criterion is more stringent than that of Merloni et al. (2000), and it has allowed us to study the disk radius behavior with high accuracy (Rodriguez et al. 2002b). On MJD 51,662, the \( \sim 2–50 \) keV disk unabsorbed flux is \( 8.4 \times 10^{-9} \) ergs cm\(^{-2}\) s\(^{-1}\), giving a \( \sim 25\% \) contribution to the total flux. It is very likely, then, that the disk parameters returned from the fit on this day are unreliable. The disk behavior over the 2000 outburst resembles that of the 1998 outburst (at least during the first part of the latter reported in Sobczak et al. 1999). Although the peak temperatures and the luminosities of the two outbursts differ significantly, there are in both cases periods of relatively constant disk parameters. During these, the temperatures are in the same ranges (0.5–0.9 keV) (Table 1 in Sobczak et al. 1999; Table 1 in the current study). Given the constancy of the disk parameters, especially the inner radius over the IS (Fig. 2), and the similarity with the huge 1998–1999 outburst, it is tempting to consider that the disk is close to the last stable orbit. The presence, over this period, of high-frequency QPOs (251–276 Hz; Miller et al. 2001), almost the highest values as yet observed in this source (285 Hz) (Remillard et al. 1999; Homan et al. 2001), may further support this assumption (see also Kalemci et al. 2001).

4.4. Ejection of the Corona?

Corbel et al. (2001) report the detection of radio emission with a flux density \( \propto \nu^{-0.46} \). The negative spectral index is indicative of optically thin synchrotron emission, which Corbel et al. (2001) attribute to a discrete ejection of material from the system. This detection of a discrete ejection, which might be associated with the state transition (Corbel et al. 2001), raises the question of the origin of the ejected material. If the ejection is associated with the
transition, this may indicate that the Comptonizing medium is the source of the ejection of the material as suggested in GRS 1915+105 (Rodriguez et al. 2002a). The ejection may also be triggered at the peak of luminosity, soon after MJD 51,662. Indeed, if we plot the 2–50 keV unabsorbed black-body flux versus the 2–50 keV unabsorbed power-law flux (Fig. 4), it appears that after the 1 crab flare (the extreme right-hand point in Fig. 4), as the total luminosity is decreasing (Fig. 2), the disk-blackbody flux remains approximately constant during an initial period, while it is the power-law flux that decreases significantly. Given the relative constancy of the photon index on those days (Figs. 2 and 3), this may suggest that there is less Compton up-scattering of the soft photons. A possible reason is that a part of the Compton medium is ejected. Given the detection of ejected material, it is tempting to consider that the Compton medium may be blown away, not, as usually assumed, the innermost part of the disk. Here again it is interesting to compare this outburst with the 1998–1999 one. During the latter outburst a discrete ejection of relativistic plasma (with apparent superluminal motion) was also detected right after the X-ray peak luminosity (Hannikainen et al. 2001). Both outbursts have very similar initial stages, starting with the LS, reaching a peak in luminosity soon after a state transition, and a discrete ejection coincident with the spike in the 1998 outburst and possibly coincident with the spike during the 2000 outburst. It is very interesting to note the similarities in the behavior of the source during both outbursts. In 1998 the huge X-ray spike it is associated with large superluminal ejection (Hannikainen et al. 2001; Corbel et al. 2002), and during the 2000 outburst the X-ray spike is associated with a discrete ejection of smaller amplitude. This may point out a strong coupling between the X-ray behavior and ejection of material in XTE J1550–564. However, the observation of Corbel et al. (2001) does not allow us to determine the date of ejection. Future multiwavelength monitoring of SXTs in outburst should allow us to study better the accretion-ejection coupling, as has been done for jet sources, e.g., GRS 1915+105 and GX 339–4. In the near future, this can be done also by including in multiwavelength studies the high-energy broadband spectra from the soft X-rays with RXTE, up to the gamma rays with INTEGRAL.

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