Chandra Observations of the Bursting X-Ray Transient SAX J1747.0–2853 during Low-Level Accretion Activity

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Accepted for publication in ApJ, 11 July, 2002

Chandra observations of the bursting X-ray transient SAX J1747.0–2853 during low-level accretion activity

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ABSTRACT

We present *Chandra*/ACIS observations of the bursting X-ray transient SAX J1747.0–2853 performed on 18 July 2001. We detected a bright source at the position of R.A = 17^h 47^m 02.60^s and Dec. = –28° 52′ 58.9″ (J2000.0; with a 1σ error of ∼0.7 arcseconds), consistent with the *BeppoSAX* and *ASCA* positions of SAX J1747.0–2853 and with the *Ariel V* position of the transient GX +0.2,–0.2, which was active during the 1970's. The 0.5–10 keV luminosity of the source during our observations was $\sim 3 \times 10^{35}$ erg s^{-1} (assuming a distance of 9 kpc) demonstrating that the source was in a low-level accretion state. We also report on the long-term light curve of the source as observed with the all sky monitor aboard the *Rossi X-ray Timing Explorer*. After the initial 1998 outburst, two more outbursts (in 2000 and 2001) were detected with peak luminosities about two orders of magnitude larger than our *Chandra* luminosity. Our *Chandra* observation falls in-between those two outbursts, making the outburst history for SAX J1747.0–2853 complex. Those bright 2000 and 2001 outbursts combined with the likely extended period of low level activity in-between those outbursts strongly suggest that the classification of SAX J1747.0–2853 as a faint X-ray transient was premature. It might be possible that the other faint X-ray transients also can exhibit bright, extended outbursts which would eliminate the need for a separate sub-class of X-ray transients. We discuss our results also in the context of the behavior of X-ray binaries accreting at low levels with luminosities around 10^{35} erg s^{-1}, a poorly studied accretion rate regime.

Subject headings: accretion, accretion disks — stars: individual (SAX J1747.0–2853) — stars: neutron — X-rays: stars

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1. Introduction

The X-ray transients are a class of X-ray binary systems which occasionally exhibit bright outbursts during which they can display X-ray luminosities of 10^{36} to 10^{39} erg s^{-1}. Usually, those sources stay this bright for only a few weeks to at most a few months (see, e.g., Chen, Shrader, & Livio 1997; Bradt et al. 2000), although some can be active for several years. After the bright outbursts, the X-ray transients slowly transit back into quiescence during which they can only be detected in X-rays at a level of 10^{30} to 10^{34} erg s^{-1}. The regime in-between quiescence and outburst (10^{34} to 10^{36} erg s^{-1}) has not been studied extensively, partly due to the relatively short time span the sources spent in this regime but also due to the instrument limitations (e.g., lack of sensitivity or observational constraints).

The neutron star sources which have been studied best in this regime are Aql X-1 and the accretion-driven millisecond X-ray pulsar SAX J1808.4–3658. Campana et al. (1998b) used *BeppoSAX* data to study the decay of Aql X-1 after one of its outbursts. They found a source which decreased steadily in luminosity until it reached quiescent levels. Its spectrum hardened during the decay, although a soft component below a few keV became more prominent. However, unlike most X-ray transients, Aql X-1 also can exhibit long periods of activity at a low level, which either occurs after a bright outbursts or as a stand-alone event (Bradt et al. 2000; Šimon 2002). Such long episodes of low-level accretion have been observed for only a few other systems, such as the black-hole system 4U 1630–47 (Kuulkers et al. 1997) or the neutron star systems 4U 1608–52 (Bradt et al. 2000; Wachter et al. 2002) and SAX J1808.4–3658. This latter source was studied intensively by Wijnands et al. (2001) using data obtained with the *Rossi X-ray Timing Explorer* (*RXTE*) during the 2000 outburst of this source. They found a source which was active at a low level (below a few times 10^{35} erg s^{-1}) for several months. During this period, the source exhibited violent variability on different time scales. Within only a few days, the source decreased from a luminosity of a few times 10^{35} erg s^{-1} to $\sim 10^{32}$ erg s^{-1} (Wijnands et al. 2002; Wijnands 2002), but a few days later it had increased again to 10^{35} erg s^{-1}. On several occasions, the source also exhibited strong flaring behavior with a repetition frequency of ~ 1 Hz (van der Klis et al. 2000; Wijnands et al. 2000). The physical mechanisms producing these violent fluctuations are not understood. Presently, it is not known if other transients can display similar behavior at such low luminosities, or if SAX J1808.4–3658 is unique in this sense (e.g., due to its likely higher magnetic field strength compared to the other transients).

Recently, a group of neutron star X-ray transients has been recognized (e.g., Heise et al. 1999; in 't Zand 2001), which have a rather low peak luminosity (a few times 10^{36} erg s^{-1}) compared to the bright transient sources (which have peak luminosities above 10^{37} erg s^{-1}) and relatively short duration (e-folding time of less than a week). Observations of such dim transients are still sparse and it is still unclear if they form a separate sub-class of transients (see the discussion in In 't Zand 2001). King (2000) argued that they are different from the bright systems and that they are neutron star X-ray binaries which have evolved beyond their minimum orbital periods of ~ 80 minutes and have extremely low-mass companion stars. The above-mentioned millisecond X-ray pulsar is one of these dim X-ray transients and is the best studied example of this possible sub-class of transients. Cumming, Zweibel, & Bildsten (2001) suggested that the low inferred time averaged mass accretion rate for SAX J1808.4–3658 might be related to this source being a millisecond X-ray pulsar. For those systems which have high time averaged accretion rates, the accreted matter will screen the magnetic field, inhibiting the X-ray pulsation mechanism in those systems. This suggests that the other dim neutron star X-ray transients, which presumably have similar low time averaged accretion rate, might also exhibit millisecond X-ray pulsations (e.g., Cumming et al. 2001).

Besides those 'faint X-ray transients', another, different group of neutron-star X-ray binaries also have been identified which members were only seen during type-I X-ray bursts and with an accretion luminosity typically below 10^{36} erg s^{-1}, which was undetectable by the instruments used. Cocchi et al. (2001) discussed the possibility that those systems are a separate subclass of neutron star systems which have persistent luminosities of order 10^{34-35} erg s^{-1} (called the 'low-persistent bursters'). This idea was supported by the detection of the possible group members 1RXS J171824.2–402934 (Kaptein et al. 2000) and SAX J1828.5–1037 (Cornelisse et al. 2002a) at a level of $\sim 10^{34-35}$ erg s^{-1}. Cornelisse et al. (2002a) elaborated on the possibility of this extra sub-class of X-ray bursters and found that their spatial distribution is consistent with the general X-ray burster distribution, but different from that of the above mentioned faint X-ray transients. This suggests that the faint X-ray transients are a different source population than the low-persistent bursters and the bright neutron star X-ray transients. However, *Chandra* follow-up observations of several potential group members showed that those sources could only be seen at a luminosity below a few times 10^{32} erg s^{-1} (Cornelisse et al. 2002b), which are similar to the quiescent luminosities observed for the bright neutron star X-ray transients. This suggests that those low-luminosity persistent sources might be genuine transients but have sub-luminous (10^{34-35} erg s^{-1}) outbursts episodes, possible with a durations of years (see the discussion in Cornelisse et al. 2002b). Clearly, the behavior of X-ray binaries at luminosities below 10^{36} erg s^{-1} is rather complex and our knowledge of the basic observational properties is very limited.

In 1998 March, a new X-ray transients was discovered by In 't Zand et al. (1998) using observations of the Galactic center region with the Wide Field Cameras (WFC) aboard *BeppoSAX*. The position of this new source (designated SAX J1747.0–2853) is consistent with that of the transient source GX +0.2,–0.2, which was observed in the 1970's (Proctor, Skinner, Willmore 1978). From the detection of type-I X-ray bursts (In 't Zand et al. 1998) is it clear that the compact object in this system is a neutron star because such events are thought to be due to thermonuclear flashes on the surface of such a star. The source was observed with the Narrow Field Instruments (NFI) aboard *BeppoSAX* on several occasions. Using these NFI observations, both Sidoli et al. (1998) and Natalucci et al. (2000) found a source whose spectrum was consistent with that of the neutron star X-ray binaries when they are at a luminosity of approximately a few times 10^{36} erg s^{-1} (e.g., Barret et al. 2000), similar to the luminosity observed for SAX J1747.0–2853. From the observed type-I bursts a distance of ~ 9 kpc was obtained (Natalucci et al. 2000). The last reported detection of the source during this outburst was on 1998 April 15 (Sidoli et al. 1998) after which the source is presumed to have become quiescent again. The low peak luminosity of the source spurred the tentative classification of the source as a faint X-ray transient (Heise et al. 1999).

Markwardt et al. (2000a) reported that in early March 2000, SAX J1747.0–2853 could be detected again using the proportional counter array aboard the *RXTE* satellite. During this outburst, the source was also detected by *ASCA* (Murakami et al. 2000) and *BeppoSAX* (Campana, Israel, & Stella 2000). Here we present *Chandra* observations performed in July 2001 of the region including SAX J1747.0–2853.

2. Observation, analysis, and results

SAX J1747.0–2853 was in the field of view of two observations performed as part of *Chandra* Galactic Center Survey (GCS; Wang, Gotthelf, & Lang 2002): observations GCS 10 and GCS 11 (see Tab. 1 for more details about those observations). The source was approximately 2.7′ and 14.3′ located from the nominal pointing direction during respectively the GCS 10 and GCS 11 observation. The ACIS-I instrument was used during these observations in combination with the S2 and S3 chips of the ACIS-S instrument. To limit the telemetry rate only those photons with energy above 1 keV were transmitted to Earth. The data were analysed using the analysis package CIAO, version 2.2.1, and the threads listed on the CIAO web pages[4].

2.1. The image and position of SAX J1747.0–2853

In Figure 1, we show the region containing SAX J1747.0–2853 as observed during observation GCS 10. We clearly detect a bright source in the various error-circles of SAX J1747.0–2853 (although at the edge of the error-circle given by Campana et al. 2000) and in that of GX +0.2,–0.2. This source was also present during the GCS 11 observation (not shown), however, the source was located at the edge of the ACIS-S2 chip and due to the large point spread function (PSF) for sources which are $\sim$ 14′ off-axis the source appears very extended and a considerable fraction of the source photons do not fall on the chip. The positional coincidence of our detected source with SAX J1747.0–2853 and GX +0.2,–0.2 makes it likely that our source can be identified with those two transients.

We used the CIAO tool WAVDETECT to obtain the coordinates of SAX J1747.0–2853: R.A $= 17^h\ 47^m\ 02.604^s$ and Dec. $= -28^\circ\ 52'\ 58.9''$ (J2000.0; with a 1σ error of $\sim$0.7 arcseconds; Aldcroft et al. 2000). Although we detected many other sources beside SAX J1747.0–2853, none of them were located in the various error-circles of SAX J1747.0–2853 and GX +0.2,–0.2. Also, none of those near-by sources could conclusively be identified with a star in either the USNO2 (Monet et

[4]Available at http://asc.harvard.edu/ciao/

al. 1996) or the second incremental data release of the 2 Micron All Sky Survey (2MASS) catalog. Therefore, we could not improve on our *Chandra* position of SAX J1747.0–2853. No USNO2 or 2MASS star is visible at the position of SAX J1747.0–2583 (Fig. 2), which is not surprising because at the time of those near-infrared observations (1998 July 5), the source was presumed to be in quiescence. In Figure 2 we present the J and $K_{\rm s}$ finding charts of SAX J1747.0–2853 obtained from the 2MASS archive.

During the GCS 10 observation, we detected 1740±42 counts (background corrected) from the source, resulting in a count rate of 0.147±0.004 counts s^{-1}. This count rate has not be corrected for pile-up, which is a serious effect for a source this bright (see also section 2.2). The exact count rate during the GCS 11 observation is difficult to estimate because the source falls only partly on the chip[5]; the number of counts is > 757 counts resulting in a count rate of > 0.065 counts s^{-1}. SAX J1747.0–2853 is known to exhibit type-I X-ray bursts (In 't Zand et al. 1998; Sidoli et al. 1998; Natalucci et al. 2000) and, therefore, we made source light curves for both observations. We did not observe any X-ray bursts.

2.2. The X-ray spectrum of SAX J1747.0–2853

We have extracted the source spectrum using a circle with a radius of 15″ on the source position. The *Chandra* PSF combined with the brightness of the source made such a large extraction region necessary to encompass most of the source photons. The background data were obtained by using an annulus on the same position with an inner radius of 30″ and an outer one of 60″. This region was chosen in order to obtain a background which did not contain any source photons. The data were rebinned using the FTOOLS routine grppha into bins with a minimum of 15 counts per bin.

We started out by fitting the obtained spectrum with XSPEC (version 11.1; Arnaud 1996). However, when fitting a power-law model to the data, we obtained a low photon index of ~ 1 and a low column density of $\sim 4 \times 10^{22}$ cm^{-2}, which was inconsistent with that observed during the *BeppoSAX*/NFI observations of SAX J1747.0–2853 (Sidoli et al. 1998; Natalucci et al. 2000). This strongly suggest that the spectrum is heavily piled-up, resulting in an artificially hard X-ray spectrum. In order to correct for the pile-up, we used the analysis package ISIS, version 0.9.81 (Houck & DeNicola 2000), and the pile-up model available there in (Davis 2001). The resulting fit parameters are listed in Table 2.

To check our results we have also extracted the spectrum of the source using an annulus around the source position of 1.5″ to 15″, thus excluding the data which were heavily affected by pile-up. The obtained spectral parameters are in good agreement with those obtained using ISIS

[5]To obtain an accurate correction factor for the number of counts detected and the observed flux of the source, one has to know accurately the PSF for a source this far off-axis, and the exact dither pattern used in order to estimate the total exposure of the source on the chip. Such detailed estimates are beyond the scope of this paper.

(see Tab. 2; note that the errors on the parameters are large due to the much lower number of photons in the spectrum). In our extraction annulus only ∼5% of the source photons are located; we have corrected our obtained flux for this, and this flux is consistent with that we have obtained from fitting the piled-up spectrum in ISIS. We also extracted the source spectrum from observation GCS 11 and fitted it in XSPEC. The extended nature of the source during this observation (due to the large PSF) makes it unlikely that the source suffers from a significant amount of pile-up and no pile-up correction was applied. Again, we obtained similar spectral parameters (Tab. 2). No flux is listed because the correction factor is unknown (see footnote 5).

We used PIMMS[6] in order to estimate the pile-up fraction in our spectrum. Using the parameter range found for our GCS 10 spectrum, we obtained a pile-up fraction between 32 and 47 % and a count rate after pile-up of 0.146 to 0.161 counts s^{-1}, which is consistent with our detected count rate of 0.147±0.004 counts s^{-1}.

We have also fitted our spectrum with different spectral models, such as a black-body model. This model resulted in a column density of $3.8^{+0.8}_{-0.7}$ or $4.4^{+1.0}_{-0.8} \times 10^{22}$ cm^{-2} and a temperature kT of 1.5±0.2 or 1.2±0.2 keV, for observation GCS 10 (using the pile-up model in ISIS) or GCS 11, respectively. The flux obtained for observation GCS 10 is 1.1×10^{-11} erg cm^{-2} s^{-1} (0.5–10 keV; unabsorbed). However, this model gave a rather low column density compared to what has been measured before with *BeppoSAX* (Sidoli et al. 1998; Natalucci et al. 2000), indicating that this might not be the correct model to fit the data. A cut-off power-law, a thermal comptonization model, or a bremsstrahlung model could also be used to fit the data accurately, however, for simplicity we only list the results of the power-law model.

2.3. Long-term behavior

To investigate the long-term behavior of the source, we have plotted the *RXTE* all sky monitor (ASM; Levine et al. 1996; available at http://xte.mit.edu/ASM_lc.html) light curve in Figure 4. The source was clearly detected during the 2000 outburst (e.g., Markwardt et al. 2000a) and it again showed a re-flare in the summer/fall of 2001. The time of our *Chandra* observations is indicated in the figure by the arrow. At the time of these observations the ASM data seem to indicate that SAX J1747.0–2853 was detected by this instrument. However, using PIMMS and the spectral results from our *Chandra* data, the predicted count rate for the ASM is ∼ 0.04 counts s^{-1}, which is below the sensitivity of the ASM. This strongly suggest that the activity detected by the ASM in-between the two outbursts is unrelated to SAX J1747.0–2583 and probably it is due to the uncertainties in the fitting process (Levine et al. 1996) and the proximity of SAX J1747.0–2853 near the Galactic center. This is consistent with the low fluxes detected for this source during the Galactic bulge scan program (Markwardt et al. 2000b) of *RXTE* as judged from the light curve of

[6] A web version is available at http://heasarc.gsfc.nasa.gov/Tools/w3pimms.html

SAX J1747.0–2853, which is presented by In 't Zand (2001) in his Figure 4.

Assuming a power-law spectrum with index of 2 and a column density of 7×10^{22} cm^{-1}, 1 ASM count corresponds to an unabsorbed 0.5–10 keV flux of 9.5×10^{-10} erg cm^{-2} s^{-1}. The peak count rate of $\sim$ 8 and $\sim$ 4 counts s^{-1} during the 2000 and 2001 outburst would results in a flux of 7.6 and 3.8×10^{-9} erg cm^{-2} s^{-1}, respectively. These fluxes are obtained using 5 day averaged count rates and the ASM dwell data indicates that at certain times the fluxes could be a factor of 2 higher. Furthermore, extra uncertainties are introduced by our assumption of a power-law spectrum for the source, but usually neutron star X-ray transients become softer when they increase in luminosities. Despite these uncertainties, these fluxes are clearly considerably larger (up to two orders of magnitude) than the fluxes we observed during our *Chandra* observations.

3. Discussion

We have detected a bright X-ray source in the various error circles of SAX J1747.0–2853 and in that of GX +0.2,–0.2, making it likely that our source can be identified with those transients. The source had a 0.5–10 keV unabsorbed X-ray flux of $\sim 3.3 \times 10^{-11}$ erg cm^{-2} s^{-1}, which for a distance of 9 kpc (Natalucci et al. 2000) results in a 0.5–10 keV luminosity of $\sim 3 \times 10^{35}$ erg s^{-1}. This luminosity is about two orders of magnitude lower than the maximum luminosity observed during the peak of the 2000 and 2001 outbursts (as observed with the *RXTE*/ASM). These high outburst luminosities are different from the low (a few times 10^{36} erg s^{-1}; 2–10 keV) luminosity observed for this source during its 1998 outburst (Sidoli et al. 1998; Natalucci et al. 2000). SAX J1747.0–2853 is in this respect similar to several other systems, such as for example the neutron star system Aql X-1 or the black-hole systems XTE J1550–564 and XTE J1859+226. Aql X-1 usually exhibits bright outbursts, but occasionally it exhibits outburst which are one order of magnitude less bright (e.g., Bradt et al. 2000; Šimon 2002). XTE J1550–564 exhibited a bright outburst in 1998/1999 (see, e.g., Sobczak et al. 2000) but after that three much weaker outbursts have been observed (Smith et al. 2000; Tomsick et al. 2001a; Swank, Smith, & Markwardt 2002). Similarly, XTE J1859+226 was detected as a bright transient in October 1999 (Wood et al. 1999; Markwardt, Marshall, & Swank 1999), but later it was found to exhibit a small re-flare (Casares et al. 2000; Miller et al. 2000). Clearly, X-ray transients can exhibit a variety of outbursts profiles and can have very bright outbursts followed by very weak ones, or vice versa.

3.1. Faint neutron-star X-ray transients

Recently, a group of faint neutron star X-ray transients was recognized (e.g., Heise et al. 1999; in 't Zand 2001), with outburst peak luminosities of only 10^{36-37} erg s^{-1} and short e-folding time scales (less than a week), implying a time-averaged accretion rate of only $\sim 10^{-11}$ M$_\odot$ yr^{-1}. Based on the characteristics of the 1998 outburst of SAX J1747.0–2853, this source was put into this class of faint transients. However, the later outbursts (especially that in 2000) demonstrate that this source can also exhibit bright outbursts with peak luminosities considerably higher than 10^{37} erg s^{-1}. In 't Zand (2001) showed that during the 2000 outburst, the source was active for at least 200 days. Moreover, our *Chandra* observations of the source were performed ~500 days after the start of the 2000 outburst and ~ 50 days before the 2001 re-flare, suggesting that in-between those outburst episodes the source might have been active at similar levels as detected during our *Chandra* observations (a few times 10^{35} erg s^{-1}). If indeed true, then the source was active for almost 600 days and possibly even longer (no information is present about the current state of this source). The bright 2000 and 2001 outbursts combined with the possible extended period of accretion are in contrast with the basic properties of the faint X-ray transient group (weak and short outbursts) making the classification of SAX J1747.0–2853 as a faint X-ray transient no longer justified (unless the classification criteria are relaxed).

A similar conclusion can be reached for the neutron star transient in the globular cluster NGC 6440. This source exhibited a faint outburst in 1998 August (In 't Zand et al. 1999), but it erupted again in 2001 August as a bright transient with a peak flux in excess of a few times 10^{37} erg s^{-1} and an outburst duration in excess of 3 months (In 't Zand et a. 2001). This behavior is remarkably similar to SAX J1747.0–2853 in that a weak, short outburst was also followed by brighter and much longer outbursts. Those similarities between the two systems raises the question if some (maybe all) of the other systems classified as faint transients, can also exhibit bright outbursts, which would cast doubts on whether those systems are indeed fundamentally different from the bright X-ray transients. Such a fundamental difference was suggested by King (2000) who argued that those faint transients are binary neutron star systems which have evolved below the period minimum, have low time-averaged mass accretion rates ($\sim 10^{-11}$ $M_\odot$ year^{-1}), have recurrence times of only a few years, and have very low-mass companion stars. The large mass accretion rates inferred for SAX J1747.0–2853 and the transient in NGC 6440 (In 't Zand et al. 2001) seem to rule-out such a system configuration for these sources. It also makes it less unlikely that they will exhibit millisecond X-ray pulsations because their relatively high inferred accretion rates will bury the magnetic field of the neutron star (Cumming et al. 2001). Note, that the most recent outbursts of NGC 6440 and SAX J1747.0–2853 might be atypical for those sources and generally they might exhibit short and dim outbursts, lowering their time-averaged accretion rate[7]. Even if true, the sources still cannot be classified as faint transients (because their outbursts can be very bright and extended). It remains to be determined if a sub-group of faint X-ray transients exists and if they are indeed post-minimum binaries.

[7]Similar arguments can also be applied to the normal (i.e., bright) neutron star X-ray transients because of the lack of knowledge about their long-term (> 1000 years) X-ray behavior.

3.2. Low-level accretion activity

We detected SAX J1747.0–2853 about 2 months before the 2001 outburst peaked (which was around 17 September 2001), demonstrating that the source was actively accreting well before the full outburst happened. It demonstrates that SAX J1747.0–2853 has a complex outburst behavior and it is possible that the source never returned to quiescence ($< 10^{34}$ erg s^{-1}) after the 2000 outburst and stayed active with typical luminosities of 10^{35} erg s^{-1}. Such long-active periods at low levels have been observed for different systems (e.g., the neutron star systems Aql X-1 and 4U 1608–52: Bradt et al. 2000; Šimon 2002; Wachter et al. 2002; or the black-hole system 4U 1630–47: Kuulkers et al. 1997). The millisecond X-ray pulsar SAX J1808.4–3658 also can exhibit episodes of long lived low-level activity. Wijnands et al. (2001) found that the source was active at a levels up to $\sim 10^{35}$ erg s^{-1} for several months during 2000. The source displayed luminosity swings up to three orders of magnitudes on timescales of only a few days. It is unclear from our observations if SAX J1747.0–2853 exhibited similar violent behavior or that it was more stable, similar to what has been observed for the other systems. Our results add to the growing evidence that the behavior of X-ray transients at low luminosity is very complex.

Several other systems have also been detected at similar low luminosities. For example, Kaptein et al. (2000) and Cornelisse et al. (2002a) detected, respectively, 1RXS J1718.2–402934 and SAX J1828.5–1037 at luminosities of 10^{34-35} erg s^{-1}. Cornelisse et al. (2002a) suggested that they are part of the X-ray burst sources which have low persistent luminosities (10^{34-35} erg s^{-1}) and might form a separate sub-class of neutron-star X-ray binaries. But *Chandra* observations of several group members showed that they could only be seen at a luminosity of a few times 10^{32} erg s^{-1} or less (Cornelisse et al. 2002b). Those low luminosities are similar to the quiescent luminosities observed for the normal neutron star X-ray transients, suggesting that those low-luminosity persistent sources might be genuine transients but could exhibit sub-luminous (10^{34-35} erg s^{-1}) outbursts episodes, possible with a durations of years (see the discussion in Cornelisse et al. 2002b). Intriguingly, SAX J1747.0–2853 likely displayed also an extended period (several hundreds of days) of low-level accretion in-between the 2000 and 2001 outbursts. The possibility exists that the physical mechanism behind this extended period of low-level activity in SAX J1747.0–2853 is related to the mechanism behind the low-level activity in the low persistent X-ray bursters. If true, it cannot be excluded that also those latter source group might exhibit outbursts (either dim or bright) in the future, similar to what has been observed for SAX J1747.0–2853. Currently, it is unclear if different sub-classes of neutron-star X-ray binaries are really needed to explain the observed differences, or that the underlining mechanisms are related to each other.

The traditional disk instability model to explain outburst light curves of X-ray transients (see Lasota 2001 for an overview) has not yet addressed the issue of the behavior of X-ray transients in this low-luminosity region. The modeling of the behavior of neutron star X-ray binaries in this regime might be complex because of the increasing influence (see Campana et al. 1998a for a discussion) of the magnetic field of the neutron star (if not buried completely by the accreted matter). The lack of our knowledge is partly due to the lack of sensitive observations in this regime.

However with current instruments, we can now obtain high quality spectra of X-ray transients when they are decaying into quiescence. SAX J1747.0–2853 was not the target of the *Chandra* observations reported here, and therefore they were not optimized for the study of this object at the detected brightness level. This resulted in relatively large uncertainties in our spectral parameters which do not allow to make strong conclusions. The spectral fit results are consistent with a constant spectral shape of the source between our observations and that of the *BeppoSAX*/NFI observations reported by Natalucci et al. (2000) when the source luminosity was approximately one order of magnitude larger. No conclusive spectral softening or hardening was observed, although we cannot exclude such spectral changes either.

3.3. Future observations

The sub-arcsecond *Chandra* position of SAX J1747.0–2853 allows for follow up studies at other wavelengths at times when the source is found to be active. Although the high column density of the source will strongly inhibit detection of the source at optical wavelengths, it might be possible to detect the source at (near-)infrared wavelengths. To this order we have presented J and K_s finding charts of SAX J1747.0–2853 in Figure 2. The excellent position of the source might also be useful for follow up X-ray observations with *Chandra* or *XMM-Newton* when the source is in quiescence. Quiescent neutron star systems have luminosities in the range of 10^{32} to 10^{33} erg s^{-1}, resulting in a flux range of 10^{-14} to 10^{-13} erg cm^{-2} s^{-1}. If the quiescent flux of SAX J1747.0–2853 is dominated by the same thermal component observed in other quiescent neutron star systems (with blackbody temperature of 0.2–0.3 keV; e.g., Bildsten & Rutledge 2002 and references therein), then it is unlikely (due to the large column density) that the source will be detectable within a reasonable amount of time (less than a few tens of kiloseconds) with either *Chandra* or *XMM-Newton*. However, if besides the thermal component, also a power-law component above 2 keV is present (as observed for several quiescent systems; e.g., Asai et al. 1996, 1998; Campana et al. 1998b) and it contributes to about half the total flux, than with a few tens of kiloseconds the source might be detectable (similarly to the recent detection of quiescent emission from the neutron star X-ray transient GRO J1744–28, which has a comparable column density; Wijnands & Wang 2002). Due to the sub-arcsecond *Chandra* position, the quiescent counterpart of SAX J1747.0–2853 can be easily identified. For other transients near the Galactic center region, the positions are usually known only to an accuracy of 1 arcminutes or worse, which increases significantly the probability that if any sources are detected in the error circles of those transients, that they are background AGNs or unrelated Galactic sources which also emit hard X-rays.

RW was supported by NASA through Chandra Postdoctoral Fellowship grant number PF9-10010 awarded by CXC, which is operated by SAO for NASA under contract NAS8-39073. WQD is supported by the CXC grant SAO-GO1-2150A. This publication makes use of data products from the Two Micron All Sky Survey, which is a joint project of the University of Massachusetts and the

Infrared Processing and Analysis Center/California Institute of Technology, funded by the National Aeronautics and Space Administration and the National Science Foundation. This publication also used the quick-look results provided by the ASM/*RXTE* team and resources provided through the HEASARC on-line service, provided by the NASA-GSFC. We thank John Houck and the CXC ISIS team for useful discusses about ISIS.

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Table 1. *Chandra* observations of SAX J1747.0–2853

Obs-ID	Start date (2001 July 18)	End date (2001 July 18)	Exposure (ksec)	Off-axis[a] (′)	Chip[b]	Comments
GCS 10	00:48	04:17	~11.6	~2.7	ACIS-I2	
GCS 11	04:17	07:45	~11.6	~14.3	ACIS-S2	At chip edge

[a]The distance of the source to the pointing direction.

[b]The chip on which the source was located.

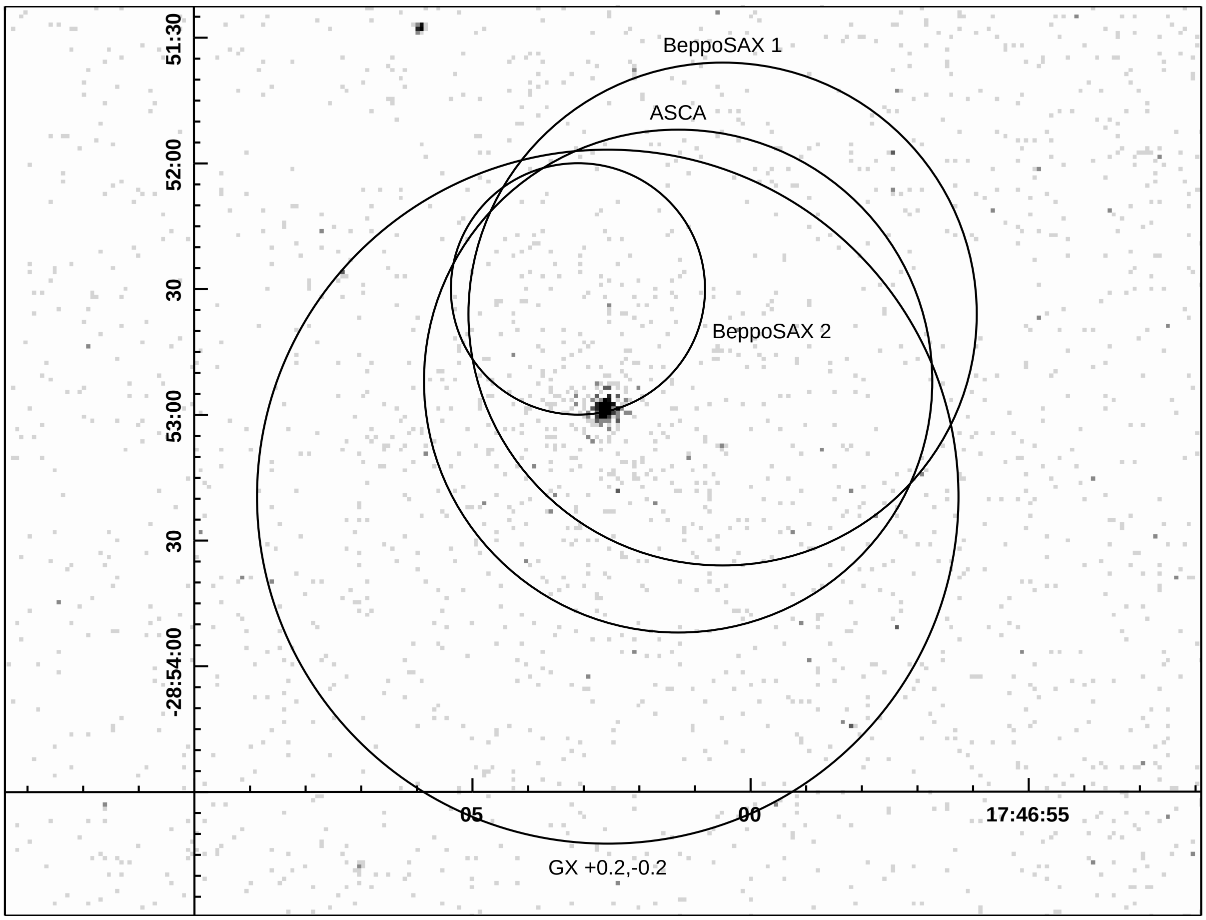

Fig. 1.— The *Chandra*/ACIS-I image (for photons with energy of 1 keV or higher) of SAX J1747.0–2853 during observation GCS 10. The coordinates are for epoch J2000.0. Shown are the *BeppoSAX* (1: Sidoli et al. 1998; 2: Campana et al. 2000) and the *ASCA* (Murakami et al. 2000) error circles on the position of SAX J1747.0–2853. Furthermore, the *Ariel V* error circle of GX +0.2,–0.2 (Proctor et al. 1978) is also displayed. The detected source is consistent with all positions of SAX J1747.0–2853 and with the position of GX +0.2,–0.2.

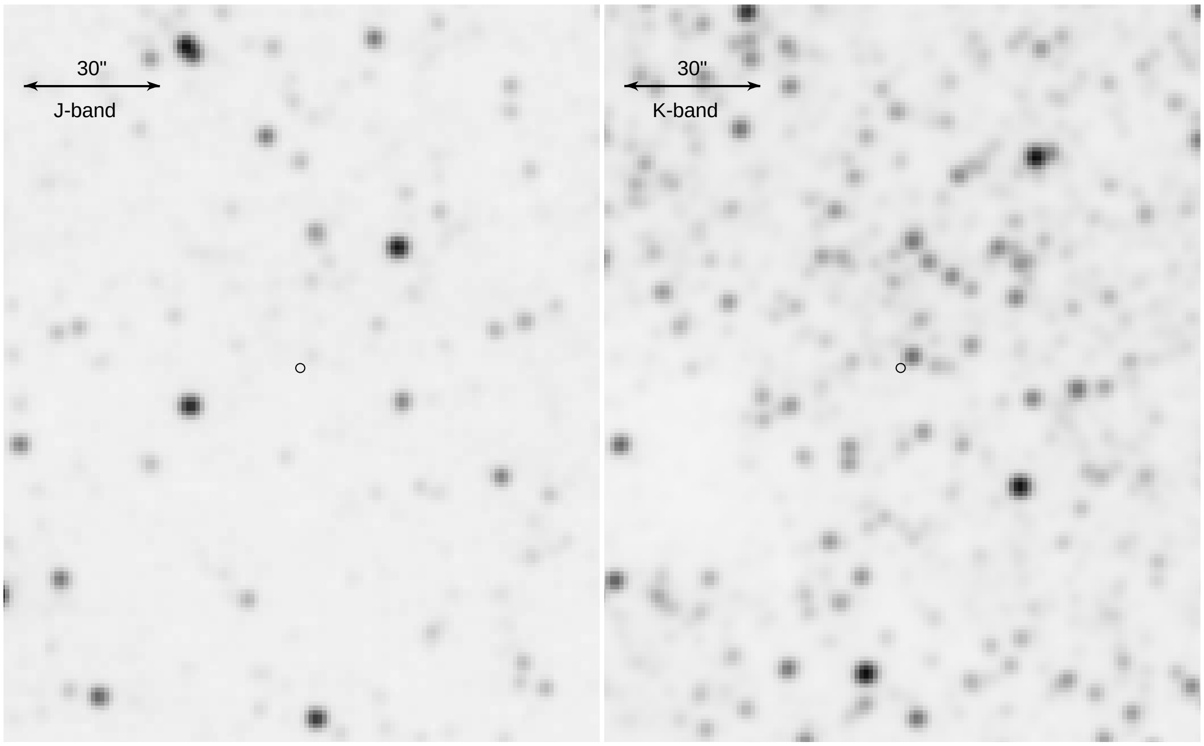

Fig. 2.— The J-band (left) and K_s-band finding charts of SAX J1747.0–2583. North is up and East is left. The solid circle is the *Chandra* error circle of SAX J1747.0–2853.

Table 2. Spectral fit results of SAX J1747.0–2853[a]

Obs-ID	$N_{\rm H}$ (10^{22} cm^{-2})	Photon index	Flux[b] (10^{-11} erg cm^{-2} s^{-1})	Comments
GCS 10	7±1	$1.8^{+0.3}_{-0.4}$	3.3	Pile-up-corrected
	7^{+3}_{-2}	$2.0^{+1.0}_{-0.8}$	3.6	Annulus extraction region
GCS 11	$6.9^{+1.5}_{-0.9}$	2.1±0.5		Source at edge of S2 chip

[a]The errors on the fit parameters are for 90% confidence levels.

[b]The fluxes are unabsorbed and for 0.5–10 keV. The fluxes listed for the second row of GCS10 are corrected for the annulus extraction region. No flux is listed for GCS11 because it is unclear what the exposure correction factor is (see text).

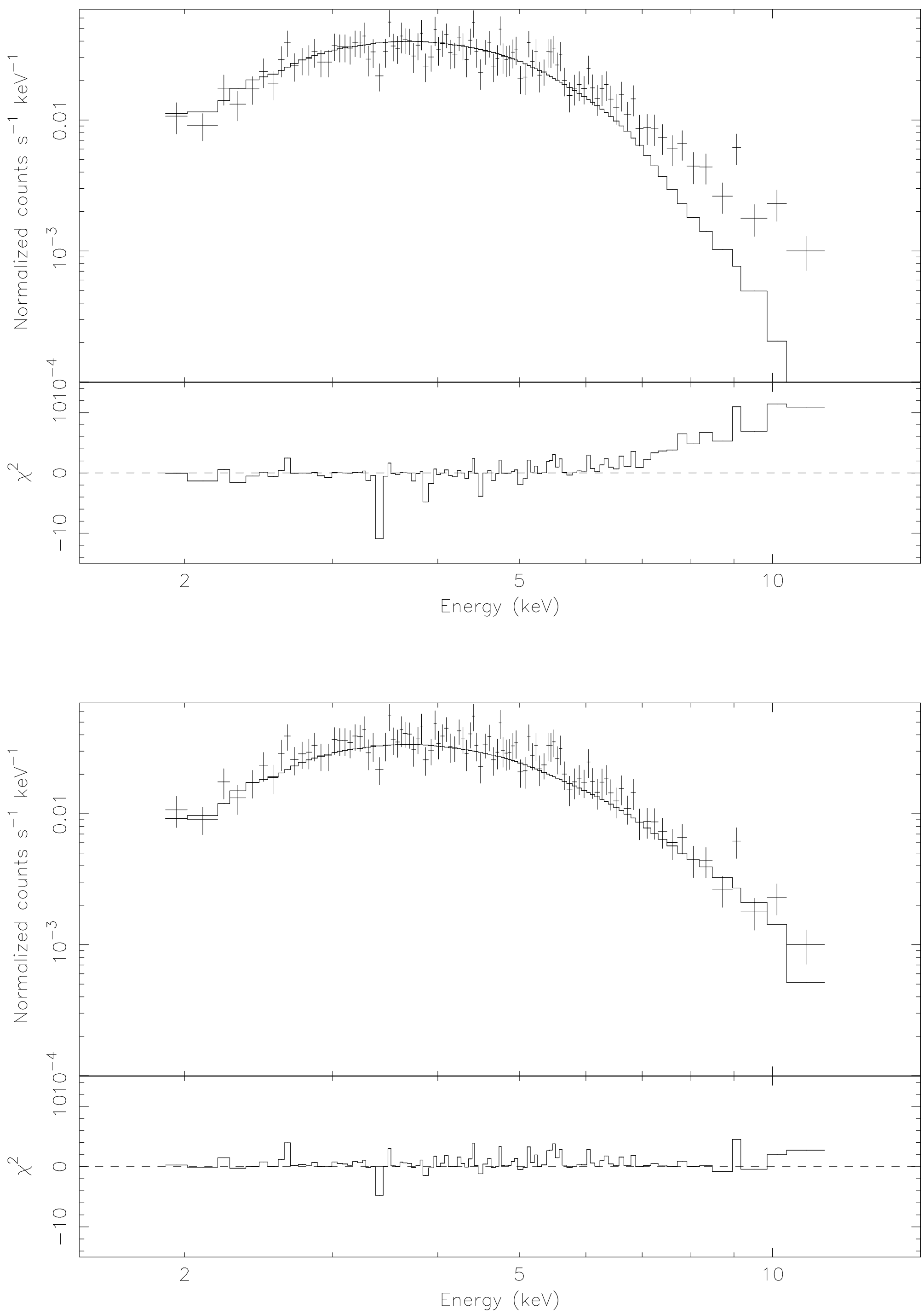

Fig. 3.— The *Chandra*/ACIS-I spectrum for SAX J1747.0–2853 as obtained during observation GCS 10. The solid line in the top panel is the best fit power-law as obtained using ISIS and the pile-up model, but no pile-up correction was applied for display purposes. Clearly, excess counts are present for photon energies above 6 keV. The solid line in the bottom panel shows the same fit, but now also the pile-up correction has been applied. Clearly, the power-law + pile-up model produces an acceptable fit to the data.

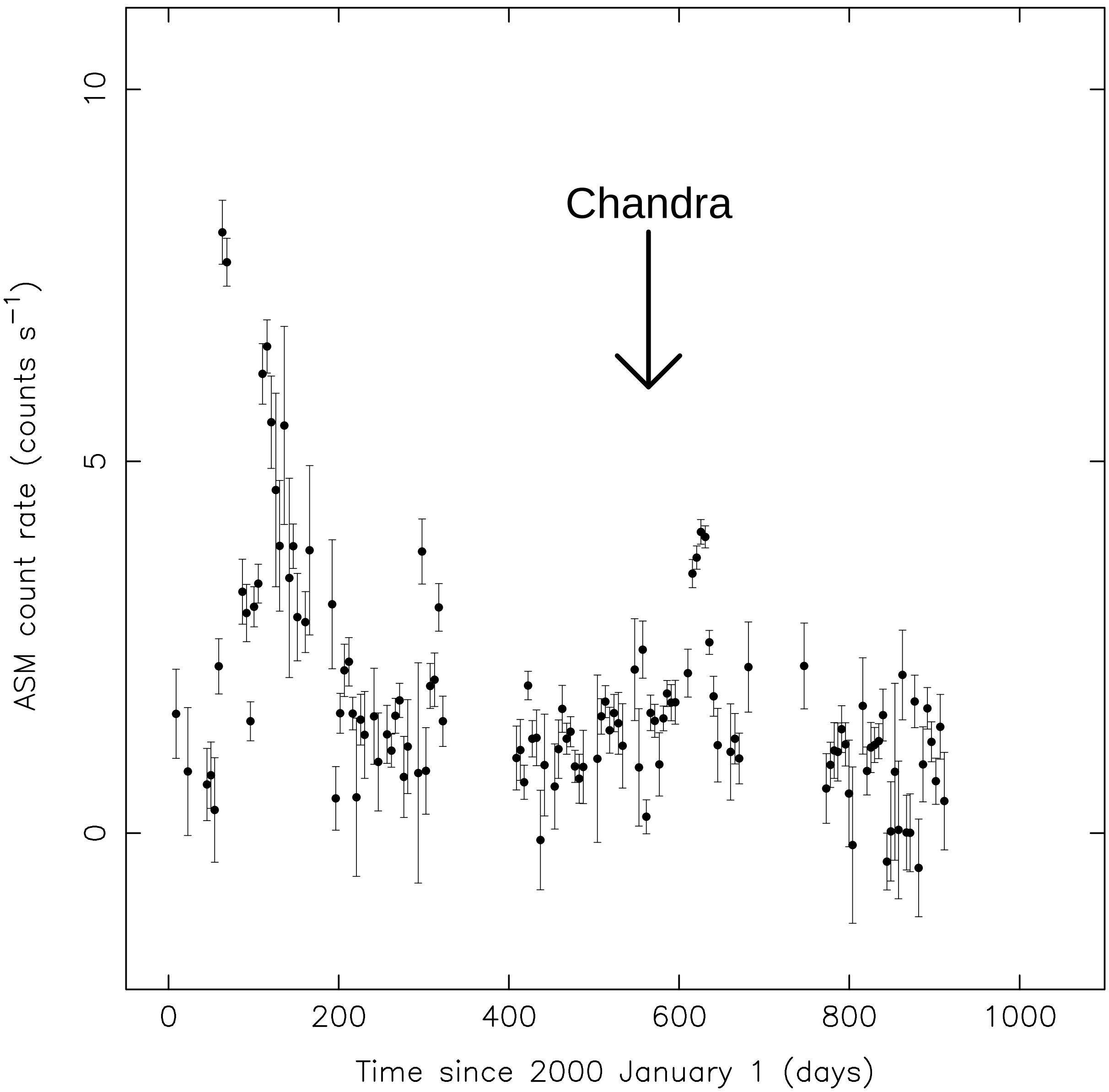

Fig. 4.— The *RXTE*/ASM light curve of SAX J1747.0–2853 since 2000 January 1 in 5 day bins. The arrow indicates at which time the *Chandra* observations were taken. Although it appears that the source was weakly detected by the *RXTE*/ASM at the time of the *Chandra* observations, this is due to the uncertainties in the fitting process to obtain the source counts (Levine et al. 1996) and the proximity of the source to the Galactic center with introduces a considerably amount of extra noise.