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 2001 July 18. We detected a bright source at the position of R.A. = 17°47′02.60 and decl. = −28°52′58.9′ (J2000.0, with a 1 σ error of ~0′′7), 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 1970s. The 0.5–10 keV luminosity of the source during our observations was ~ 3 × 1033 ergs 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 on board the Rossi X-Ray Timing Explorer. After the initial 1998 outburst, two more outbursts (in 2000 and 2001) were detected with peak luminosities about 2 orders of magnitude larger than our Chandra luminosity. Our Chandra observation falls 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 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 can also exhibit bright, extended outbursts that would eliminate the need for a separate subclass 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 1035 ergs s−1, a poorly studied accretion rate regime.

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

1. INTRODUCTION

The X-ray transients are a class of X-ray binary systems that occasionally exhibit bright outbursts, during which they can display X-ray luminosities of 1036–1039 ergs s−1. Usually, those sources stay this bright for only a few weeks to, at most, a few months (see 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, where they can only be detected in X-rays at a level of 1030–1034 ergs s−1. The regime between quiescence and outburst (1034–1036 ergs s−1) has not been studied extensively, due in part to the relatively short time span the sources spent in this regime but also due to instrument limitations (e.g., lack of sensitivity) or observational constraints.

The neutron star sources that 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 that 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 can also exhibit long periods of low-level activity, which occurs either after a bright outburst or as an isolated event (Bradt et al. 2000; Simon 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 its 2000 outburst. They found a source that was active at a low level (below a few times 1035 ergs s−1) for several months. During this period, the source exhibited violent variability on different timescales. Within a few days, the source decreased from a luminosity of a few times 1035 to ~1034 ergs s−1 (Wijnands et al. 2002; Wijnands 2002), but a few days later it had increased again to 1035 ergs 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 whether 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 (Heise et al. 1999; in ’t Zand 2001) that have a rather low peak luminosity (a few times 1036 ergs s−1) compared to the bright transient sources that have peak luminosities above 1037 ergs 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 subclass 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 that have evolved beyond their minimum orbital periods of ~80 minutes and have extremely low-mass com-
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son of these dim X-ray transients and is the best-studied example of this possible subclass of transients. Cumming, Zweibel, & Bildsten (2001) suggested that the low inferred time-averaged mass accretion rate for SAX J1808.4–3658 might be a result of this source being a millisecond X-ray pulsar. For those systems that 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 rates, might also exhibit millisecond X-ray pulsations (Cumming et al. 2001).

Beside those faint X-ray transients, another, different group of neutron star X-ray binaries has been identified, members of which were seen only during type I X-ray bursts and with an accretion luminosity typically below 10^{36} \text{ergs s}^{-1}, which was undetectable by the instruments used. Coccchi et al. (2001) discussed the possibility that those systems are a separate subclass of neutron star systems that have persistent luminosities of the order of 10^{34}–10^{35} \text{ergs s}^{-1} (called 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. 2002b) at a level of \sim 10^{34}–10^{35} \text{ergs s}^{-1}. Cornelisse et al. (2002b) elaborated on the possibility of this extra subclass 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 be seen only at luminosities below a few times 10^{32} \text{ergs s}^{-1} (Cornelisse et al. 2002a), 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 subluminous (10^{34}–10^{35} \text{ergs s}^{-1}) outburst episodes, possibly with durations of years (see the discussion in Cornelisse et al. 2002a). Clearly, the behavior of X-ray binaries at luminosities below 10^{36} \text{ergs s}^{-1} is rather complex, and our knowledge of the basic observational properties is very limited.

In 1998 March, new X-ray transients were discovered by in’t Zand et al. (1998) using observations of the Galactic center region with the wide-field cameras (WFCs) on board 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 1970s (Proctor, Skinner, & Willmore 1978). From the detection of type I X-ray bursts (in’t Zand et al. 1998), it is 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) on BeppoSAX on several occasions. Using these NFI observations, both Sidoli et al. (1998) and Natalucci et al. (2000) found a source for which the 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} \text{ergs s}^{-1} (Barret et al. 2000), similar to the luminosity observed for SAX J1747.0–2853. From the observed type I bursts, a distance of \sim 9 \text{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 2000 March, SAX J1747.0–2853 could be detected again using the Proportional Counter Array (PCA) on the Rossi X-Ray Timing Explorer (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 2001 July of the region including SAX J1747.0–2853.

\section{Observation, Analysis, and Results}

SAX J1747.0–2853 was in the field of view of two observations performed as part of the Chandra Galactic Center Survey (GCS; Wang, Gotthelf, & Lang 2002) observations GCS 10 and GCS 11 (see Table 1 for more details about those observations). The source was approximately 2/7 and 14/3 located from the nominal pointing direction during the GCS 10 and GCS 11 observations, respectively. 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, those photons with energy above 1 keV only were transmitted to Earth. The data were analyzed using the analysis package CIAO version 2.2.1 and the threads listed on the CIAO Web pages.\footnote{Available at http://asc.harvard.edu/ciao/}.

\subsection{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 (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 that 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. = 17h47m02.604 and decl. = −28°52′58″.9 (J2000.0, with a 1 \sigma error of \sim 0″7; 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 nearby sources could be identified conclusively with a star in either the USNO2 (Monet et 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 J1747.0–2853 (Fig. 2), which is not surprising because at the time of those near-infrared obser-
observations (1998 July 5), the source was presumed to be in quiescence. In Figure 2, we present the $J$ and $K_s$ 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 $0.147 \pm 0.004$ counts s$^{-1}$. This count rate has not been corrected for pileup, which is a serious effect for a source this bright (see also § 2.2). The exact count rate during the GCS 11 observation is difficult to estimate because the source falls only partly on the chip: the number of counts is more than 757, resulting in a count rate of more than 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"00 from 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"00 and an outer one of 60"00. This region was chosen in order to obtain a background that did not contain any source photons. The data were rebinned using the FTOOLS routine GRPPHA into bins with a minimum of 15 counts bin$^{-1}$.

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 $2.4 \pm 1$ and a low column density of $4 \times 10^{22}$ cm$^{-2}$, which was inconsistent with that observed during the Beppo-

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**TABLE 1**

| Observed | Start Date (2001 July 18) | End Date (2001 July 18) | Exposure (ks) | Off-Axis (arcmin) | Chip | Comments |
|----------|--------------------------|-------------------------|---------------|-------------------|------|----------|
| GCS 10   | 00:48                    | 04:17                   | ~11.6         | ~2.7              | ACIS-I2 | At chip edge |
| 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.

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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.

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Fig. 1.—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.
poSAX/NFI observations of SAX J1747.0–2853 (Sidoli et al. 1998; Natalucci et al. 2000). This strongly suggests that the spectrum is heavily piled up, resulting in an artificially hard X-ray spectrum. In order to correct for the pileup, we used the analysis package ISIS, version 0.9.81 (Houck & DeNicola 2000) and the pileup model available in Davis (2001). The resulting fit parameters are listed in Table 2 and the X-ray spectrum is shown in Figure 3.

To check our results, we have also extracted the spectrum of the source using an annulus around the source position of 1.5–15″, thus excluding the data that were heavily affected by pileup. The obtained spectral parameters are in good agreement with those obtained using ISIS (see Table 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 pileup, and no pileup correction was applied. Again, we obtained similar spectral parameters (Table 2). No flux is listed because the correction factor is unknown.

We used PIMMS in order to estimate the pileup fraction in our spectrum. Using the parameter range found for our GCS 10 spectrum, we obtained a pileup fraction between 32% and 47% and a count rate after pileup 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 blackbody model. This model resulted in a column density of 3.8$^{+0.5}_{-0.3}$ or 4.4$^{+1.0}_{-0.8}$ × 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 pileup model in ISIS) or GCS 11, respectively. The flux obtained for observation GCS 10 is 1.1 × 10$^{-11}$ ergs 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).

![Finding charts for J-band (left) and Ks-band of SAX J1747.0–2853. North is up and east is left. Solid circle: Chandra error circle of SAX J1747.0–2853.](image)

### TABLE 2
Spectral Fit Results of SAX J1747.0–2853

| Observed | $N_H$ (10$^{22}$ cm$^{-2}$) | Photon Index | Flux$^a$ (10$^{-11}$ ergs cm$^{-2}$ s$^{-1}$) | Comments |
|----------|----------------------------|--------------|---------------------------------------------|----------|
| GCS 10... | 7$^{±1}$                  | 1.8$^{±0.3}_{0.4}$ | 3.3 | Pileup corrected |
| GCS 11... | 6.9$^{±1.5}$              | 2.1$^{±0.5}$ | ... | Source at edge of S2 chip |

* A Web version is available at [http://heasarc.gsfc.nasa.gov/Tools/w3pimms.html](http://heasarc.gsfc.nasa.gov/Tools/w3pimms.html).

Note.—The errors on the fit parameters are for 90% confidence levels.

$^a$ The fluxes are unabsorbed and for 0.5–10 keV. The fluxes listed for the second row of GCS 10 are corrected for the annulus extraction region. No flux is listed for GCS 11 because it is unclear what the exposure correction factor is (see text).
al. 1998; Natalucci et al. 2000), indicating that this might not be the correct model to fit the data. A cutoff 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)7 light curve in Figure 4. The source was clearly detected during the 2000 outburst (Markwardt et al. 2000a) and it again showed a reflare in 2001 summer and fall. The time of our Chandra observations is indicated by the arrow in the figure. 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, which introduces a considerable amount of extra noise.

Assuming a power-law spectrum with an index of 2 and a column density of $10^{22}$ cm$^{-2}$, one ASM count corresponds to an unabsorbed 0.5–10 keV flux of $9 \times 10^{-11}$ ergs cm$^{-2}$ s$^{-1}$. The peak count rate of 8 and 4 counts s$^{-1}$ during the 2000 and 2001 outburst would result in fluxes of $7.6 \times 10^{-10}$ and $3.8 \times 10^{-9}$ ergs cm$^{-2}$ s$^{-1}$, respectively. These fluxes are obtained using 5 day averaged count rates, and the ASM dwell data indicate 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 neutron star X-ray transients usually become softer when they increase in luminosity. Despite these uncertainties, these fluxes are clearly considerably larger (up to 2 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 these transients. The source had a 0.5–10 keV unabsorbed X-ray flux of $3.3 \times 10^{-11}$ ergs cm$^{-2}$ s$^{-1}$, which for a distance of 9 kpc (Natalucci et al. 2000) results in a 0.5–10 keV luminosity of $3 \times 10^{35}$ ergs s$^{-1}$. This luminosity is about 2 orders of magnitude lower than the maximum luminosity of SAX J1747.0–2853, and it is probably 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 SAX J1747.0–2853, which is presented by in ’t Zand (2001) in his Figure 4.

Assuming a power-law spectrum with an index of 2 and a column density of $7 \times 10^{21}$ cm$^{-2}$, one ASM count corresponds to an unabsorbed 0.5–10 keV flux of $9 \times 10^{-12}$ ergs cm$^{-2}$ s$^{-1}$. The peak count rate of 8 and 4 counts s$^{-1}$ during the 2000 and 2001 outburst would result in fluxes of $7.6 \times 10^{-11}$ and $3.8 \times 10^{-10}$ ergs cm$^{-2}$ s$^{-1}$, respectively. These fluxes are obtained using 5 day averaged count rates, and the ASM dwell data indicate 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 neutron star X-ray transients usually become softer when they increase in luminosity. Despite these uncertainties, these fluxes are clearly considerably larger (up to 2 orders of magnitude) than the fluxes we observed during our Chandra observations.

7 Available at http://xte.mit.edu/ASM_lc.html.
nosity 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 luminosity (a few times $10^{36} \text{ ergs s}^{-1}$; 2–10 keV) 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; 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 outbursts that are 1 order of magnitude less bright (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 were observed (Smith et al. 2000; Tomskick et al. 2001; Swank, Smith, & Markwardt 2002). Similarly, XTE J1859+226 was detected as a bright transient in 1999 October (Wood et al. 1999; Markwardt, Marshall, & Swank 2001) and, later, to be found to exhibit a small reflare (Casares et al. 2000; Miller et al. 2002). 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 (Heise et al. 1999; Šimon et al. 2001) with outburst peak luminosities of only $10^{36}$–$10^{37} \text{ ergs s}^{-1}$ and short e-folding timescales (less than a week), implying a time-averaged accretion rate of only $\sim 10^{-11} \dot{M}_\odot \text{ yr}^{-1}$. 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 $10^{37} \text{ ergs s}^{-1}$. In Šimon et al. (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 reflare, suggesting that between those outburst episodes, the source might have been active at similar levels, as detected during our Chandra observations (a few times $10^{35} \text{ ergs s}^{-1}$). If that is 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 Šimon et al. 1999), but it erupted again in 2001 August as a bright transient with a peak flux in excess of a few times $10^{37} \text{ ergs s}^{-1}$ and an outburst duration in excess of 3 months (in Šimon et al. 2001). This behavior is remarkably similar to SAX J1747.0–2853 in that a weak, short outburst was followed by brighter and much longer outbursts. Those similarities between the two systems raise the question of whether or not 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 that have evolved below the period minimum, have low time-averaged mass accretion rates ($\sim 10^{-11} \dot{M}_\odot \text{ yr}^{-1}$), 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 Šimon et al. 2001) seem to rule out such a system configuration for these sources. It also makes it less likely 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 not be atypical for those sources, and, generally, they might exhibit short and dim outbursts, lowering their time-averaged accretion rate. Even if that is true, the sources still cannot be classified as faint transients because their outbursts can be very bright and extended. It remains to be determined whether a subgroup of faint X-ray transients exists and if they are, indeed, postminimum binaries.

3.2. Low-Level Accretion Activity

We detected SAX J1747.0–2853 about 2 months before the 2001 outburst peaked around 2001 September 17, 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 ($<10^{34} \text{ ergs s}^{-1}$) after the 2000 outburst and stayed active with typical luminosities of $10^{35} \text{ ergs s}^{-1}$. 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 by Bradt et al. 2000, Šimon 2002, and Wachter et al. 2002; and the black hole system 4U 1630–47 by Kuulkers et al. 1997). The millisecond X-ray pulsar SAX J1808.4–3658 can also exhibit episodes of long-lived low-level activity. Wijnands et al. (2001) found that the source was active at a levels up to $\sim 10^{35} \text{ ergs s}^{-1}$ for several months during 2000. The source displayed luminosity swings up to 3 orders of magnitude on timescales of only a few days. It is unclear from our observations if SAX J1747.0–2853 exhibited similar violent behavior or if 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 been detected at similar low luminosities. For example, Kaptein et al. (2000) and Cornelisse et al. (2002b) detected 1RXS J1718.2–402934 and SAX J1828.5–1037, respectively, at luminosities of $10^{34}$–$10^{35} \text{ ergs s}^{-1}$. Cornelisse et al. (2002b) suggested that they are part of the X-ray burst sources that have low persistent luminosities ($10^{34}$–$10^{35} \text{ ergs s}^{-1}$) and might form a separate subclass 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 $10^{32} \text{ ergs s}^{-1}$ or less (Cornelisse et al. 2002a). Those low luminosities are similar to the quiescent luminosities observed for the normal neutron star X-ray transients, suggesting that those

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8 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 yr) X-ray behavior.
low-luminosity persistent sources might be genuine transients but could exhibit subluminous ($10^{34} - 10^{35}$ ergs s$^{-1}$) outburst episodes, possibly with durations of years (see the discussion in Cornelisse et al. 2002a). Intriguingly, SAX J1747.0–2853 displayed an extended period (several hundreds of days) of low-level accretion 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 that is true, it cannot be excluded that also those latter source groups 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 subclasses of neutron star X-ray binaries are really needed to explain the observed differences or if the underlying mechanisms are related to each other.

The traditional disk instability model used 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 due partly to the lack of sensitive observations in this regime. However, with current instruments, we can 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 that do not allow us 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 1 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 subarcsecond 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 $10^{32} - 10^{33}$ ergs s$^{-1}$, resulting in a flux range of $10^{-14} - 10^{-15}$ ergs 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; 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 in addition to the thermal component, a power-law component above 2 keV is present (as observed for several quiescent systems; Asai et al. 1996, 1998; Campana et al. 1998b) and contributes to about half the total flux, then with a few tens of kiloseconds, the source might be detectable (similar 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 subarcsecond 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 $\sim$ 1′ or worse, which increases significantly the probability that if any sources are detected in the error circles of those transients, they are background AGNs or unrelated Galactic sources that also emit hard X-rays.

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