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VERY LOW LUMINOSITIES FROM THE ACCRETION-DRIVEN MILLISECOND X-RAY PULSAR SAX J1808.4−3658 DURING QUIESCENCE

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ABSTRACT

We have observed the millisecond X-ray pulsar SAX J1808.4−3658 on three occasions during its 2000 outburst with the *BeppoSAX* satellite. The source was highly variable and erratic during this outburst, and by coincidence we obtained data only during times when the source had very low luminosities. During our observations, we detected four faint sources. The source closest to the position of SAX J1808.4−3658 is still $\sim 1\farcm6$ away. This source can be identified with SAX J1808.4−3658 only if we assume that the *BeppoSAX* positional reconstruction is not completely understood. We also reanalyzed a *BeppoSAX* observation taken in 1999 March by Stella et al. when the source was in quiescence and during which the source was thought to have been detected. Based on the similarities (position and luminosity) of this source with the above-mentioned source $\sim 1\farcm6$ away from SAX J1808.4−3658, it is possible that they are the same source. If this source is not the millisecond pulsar, then during all *BeppoSAX* observations of SAX J1808.4−3658 (the 2000 outburst ones and the 1999 quiescent one), the millisecond pulsar was not detected. A reanalysis of the *ASCA* quiescent data of SAX J1808.4−3658 recently performed by Dotani, Asai, & Wijnands confirms that during this observation the source was securely detected in quiescence. We discuss our results for SAX J1808.4−3658 in the context of the quiescent properties of low-mass X-ray binary transients.

Subject headings: accretion, accretion disks — stars: individual (SAX J1808.4−3658) — stars: neutron — X-rays: stars

1. INTRODUCTION

In 1996 September, a new X-ray transient was discovered with the Wide-Field Cameras (WFCs) on board the *BeppoSAX* satellite, and the source was designated SAX J1808.4−3658 (in 't Zand et al. 1998). Type I X-ray bursts were detected, demonstrating that the compact object in this system is a neutron star and that the source is a low-mass X-ray binary (LMXB). From the bursts, an initial distance estimate of 4 kpc was determined, but this was later revised to 2.5 kpc (in 't Zand et al. 1998, 2001). The maximum luminosity of SAX J1808.4−3658 was only approximately 10^{36} ergs s^{-1}, indicating that the source was a faint neutron star X-ray transient. The outburst lasted about 3 weeks, after which the source returned to quiescence. In 1998 April, the *Rossi X-Ray Timing Explorer* (*RXTE*) satellite scanned the region on the sky where SAX J1808.4−3658 is located using the Proportional Counter Array (PCA), and the source was found to be active again (Marshall 1998). Follow-up *RXTE*/PCA observations showed that SAX J1808.4−3658 exhibits coherent millisecond X-ray oscillations with a frequency of approximately 401 Hz (Wijnands & van der Klis 1998), making this source the first (and so far the only) accretion-powered millisecond X-ray pulsar discovered. The source was also detected in the optical (Giles, Hill, & Greenhill 1999, with an optical position of R.A. = $18^h08^m27\fs54 \pm 0\fs015$ and decl. = $-36°58'44\farcs3 \pm 0\farcs2$; all coordinates in the paper are for J2000.0) and in the radio (Gaensler, Stappers, & Getts 1999). Also, this outburst lasted only for a few weeks (e.g., Gilfanov et al. 1998).

During quiescence, SAX J1808.4−3658 was observed with the Narrow Field Instruments (NFI) on board *BeppoSAX*, and near the position of SAX J1808.4−3658 a faint (a few times 10^{32} ergs s^{-1}) X-ray source was discovered (Stella et al. 2000), which was identified with the pulsar based on presumed positional coincidence. An *ASCA* observation about half a year later resulted in a detection for SAX J1808.4−3658 in quiescence but with a luminosity at least 4 times lower than that measured with *BeppoSAX* (Dotani, Asai, & Wijnands 2000). This low luminosity makes SAX J1808.4−3658 the dimmest quiescent neutron star LMXB X-ray transient detected so far (see, e.g., Asai et al. 1996, 1998).

SAX J1808.4−3658 stayed dormant until 2000 January 23, when *RXTE* found the source to be active again (van der Klis et al. 2000). Because of solar constraints, the source was unobservable before this date (from the end of 1999 November), and it is unclear exactly when the source had become active. The source was only detected at low luminosities (up to a few times 10^{35} ergs s^{-1}), with highly variable activity lasting up to 2000 May 13 (Wijnands et al. 2000, 2001). Here, we report on *BeppoSAX*/NFI observations during this outburst.

2. THE 2000 MARCH *BeppoSAX*/NFI OBSERVATIONS

To study the 0.2–100 keV X-ray spectrum of SAX J1808.4−3658, we had *BeppoSAX*/NFI target-of-opportunity observations planned during its anticipated 2000 out-

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TABLE 1
LOG OF THE OBSERVATIONS

Satellite	Day of Observation	Source State
BeppoSAX	1999 March 17–19	Quiescence
ASCA	1999 September 17–20	Quiescence
BeppoSAX	2000 March 5–6	2000 outburst
	2000 March 8	
	2000 March 22–22	

burst. These observations were triggered, and we obtained three observations in 2000 March (for a total of 89.1 ks; see Table 1). The data were analyzed using several different approaches, but here we report only on the maximum likelihood ratio (MLR) method, which is the most sensitive one (the results of the other approaches were consistent with the results obtained from the MLR analysis). The details of this method are described in Kuiper et al. (1998) and in 't Zand et al. (2000; see also, e.g., Kuulkers et al. 2000). As already mentioned above in § 1, the source was highly variable during the 2000 outburst (see Wijnands et al. 2001), and unfortunately, all of our *BeppoSAX*/NFI observations were taken during times when the source had very low luminosities, and consequently, only the data obtained with the Medium Energy Concentrator Spectrometer (MECS) were useful.

To optimize the sensitivity toward detecting sources, we combined the data of the three observations. The resulting MLR image is shown in Figure 1. Four sources are detected in the center of this image; their coordinates are listed in Table 2 (using the latest spatial calibration; M. Perri & M. Capalbi 2001, private communication; the positions obtained by using the three observations individually varied only by ~10″). The brightest source in the field is the one closest to the position of SAX J1808.4−3658. Sufficient photons were detected from this source to extract its spec-

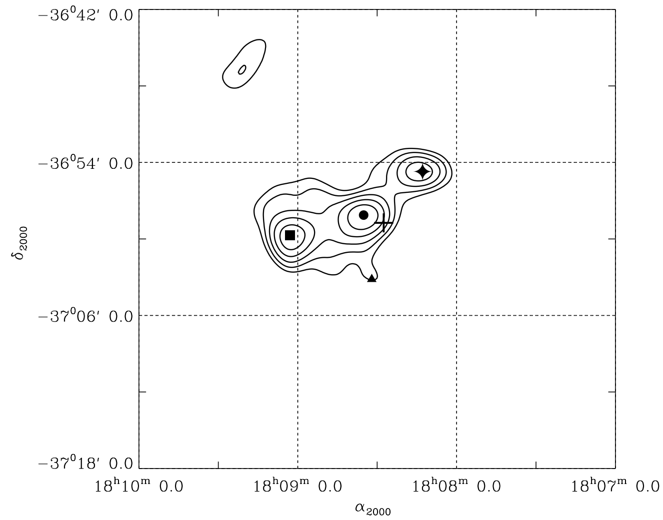

FIG. 1.—Maximum likelihood ratio image of the three 2000 March *BeppoSAX*/NFI/MECS observations combined (for 1.3–10 keV). The contour levels represent the source detection significance atop an isotropic (flat) background starting at a 5 σ significance level in steps of 1 σ (assuming 1 degree of freedom; see Kuiper et al. 1998 and in 't Zand et al. 2000 for the procedure used to generate these images). Four sources are clearly detected (greater than 5 σ) in the center of the image. The position of the millisecond X-ray pulsar is indicated with a plus. The position of the four detected *BeppoSAX* sources are indicated by the filled symbols (the *BeppoSAX* source: *circle*; SAX J1809.0−3659: *square*; SAX J1808.2−3654: *diamond*; SAX J1808.5−3703: *triangle*).

TABLE 2
SOURCES DETECTED IN THE *BeppoSAX* AND *ASCA* OBSERVATIONS

Source	Satellite	Position[a] R.A.	Decl.	Error (arcmin)	Count Rate[b] (10^{-3} counts s^{-1})
SAX J1808.4−3658	Optical	18 08 27.54	−36 58 44.3	0.2[c]	
	ASCA/SIS	18 08 26.9	−36 58 35.9	0.24	2.4 ± 0.3
					1.6 ± 0.3
	ASCA/GIS	18 08 29.8	−36 58 27.6	0.57	
BeppoSAX source	*BeppoSAX*	18 08 35.1	−36 58 07.8	0.55	1.9 ± 0.3
SAX J1809.0−3659	*BeppoSAX*	18 09 02.9	−36 59 42.3	0.56	1.9 ± 0.3
	ASCA/SIS	18 09 02.3	−36 59 39.3	0.23	2.8 ± 0.5
	ASCA/GIS	18 09 02.1	−36 59 19.5	0.53	
SAX J1808.2−3654	*BeppoSAX*	18 08 12.9	−36 54 42.7	0.59	1.6 ± 0.2
	ASCA/GIS	18 08 10.3	−36 54 11.3	0.63	1.2 ± 0.5
SAX J1808.5−3703	*BeppoSAX*	18 08 32.0	−37 03 03.1	0.73	0.8 ± 0.2
	ASCA/GIS				<1.6

[a] Source positions (J2000.0) as determined with *BeppoSAX* or *ASCA* and for SAX J1808.4−3658, also from optical observations (Giles et al. 1999). Units of right ascension are hours, minutes, and seconds, and units of declination are degrees, arcminutes, and arcseconds. The error radii on the positions are for 68% confidence levels and are composed of the direct sum of the statistical plus systematical errors. The *ASCA* positions were determined using the combined SIS-0 and SIS-1 data for SAX J1808.4−3658 and SAX J1809.0−3659 and the combined GIS-2 and GIS-3 data for SAX J1808.2−3654.

[b] Count rates for the photon energy range 1.3–10 keV (*BeppoSAX*, MECS, both active units), 0.5–5.0 keV (*ASCA*, single SIS), or 0.7–5.0 keV (*ASCA*, single GIS). The errors on the count rates are for 1 σ and the upper limit for 3 σ. For SAX J1808.4−3658, the first SIS row is for assuming a flat background distribution, and for the second row the background is modeled using the three extra point sources (see § 4). When SIS count rates are available, no GIS ones are given because the SIS ones are more reliable.

[c] Error unit for this value is arcseconds, not arcminutes.

trum, which could satisfactorily be modeled with a power law with a photon index of 1.65 ± 0.10. Assuming a column density $N_{\rm H}$ of 1.22×10^{21} cm^{-2} (using the A_v from Wang et al. 2001 and the relation between $N_{\rm H}$ and A_v from Predehl & Schmitt 1995), the unabsorbed fluxes are $1.2 \pm 0.2 \times 10^{-13}$ (0.5–5 keV) and $1.9 \pm 0.3 \times 10^{-13}$ (0.5–10 keV) ergs s^{-1} cm^{-2}. Using a blackbody, we obtained a temperature kT of 1.05 ± 0.03 keV and unabsorbed fluxes of $0.9 \pm 0.2 \times 10^{-13}$ (0.5–5 keV) and $1.2 \pm 0.2 \times 10^{-13}$ (0.5–10 keV) ergs s^{-1} cm^{-2}. However, the power-law fit is preferred over the blackbody fit (reduced χ^2 of 1.1 vs. 1.9, respectively). When fitting a two-component model (e.g., power law plus a blackbody), the fit parameters could not usefully be constrained.

The position of this brightest source, however, is located 1$'$.63 from the position of the optical counterpart of the millisecond X-ray pulsar, which is considerably larger than the 0$'$.55 error radius (68% confidence level [1 σ]; conservatively calculated as the direct sum of the statistical [18$''$] and systematic [15$''$] 1 σ errors) on the source position. The millisecond X-ray pulsar is located at the 3 σ location contour of this brightest *BeppoSAX* source, and the probability that this source can still be identified with the millisecond X-ray pulsar is $\sim$0.0029. Although this would indicate that it is unlikely that this source can be identified with the millisecond pulsar, it is possible that the systematics in the position reconstruction for *BeppoSAX* are not fully understood, and we cannot completely rule out the possibility that this source is indeed SAX J1808.4−3658. Until it is conclusively demonstrated that this source is the pulsar or not, we will refer to this source as "the *BeppoSAX* source."

3. THE 1999 MARCH *BeppoSAX*/NFI OBSERVATION

We have reanalyzed the 1999 March 17–19 *BeppoSAX*/NFI quiescent observation of SAX J1808.4−3658. We confirm the presence of the source reported by Stella et al. (2000); however, the position of this source (R.A. = $18^{\rm h}08^{\rm m}32^{\rm s}.9$, decl. = $-36°58'07''.5$; error radius 0$'$.95, 68% confidence level) and its count rates ($2.0 \pm 0.5 \times 10^{-3}$ counts s^{-1}; 1.3–10.0 keV; see also Stella et al. 2000, who obtained very similar coordinates and count rates) are almost identical to those obtained for the *BeppoSAX* source during the combined 2000 March observations, suggesting that it is the same source (the detected source is $\sim$1$'$.2 away from the position of the pulsar). If this source cannot be identified with the pulsar, then during all the *BeppoSAX*/NFI observations (both the 1999 quiescent observation and the 2000 outburst ones), the millisecond X-ray pulsar was not detected.

4. THE 1999 SEPTEMBER *ASCA* OBSERVATION

We have reanalyzed the quiescent *ASCA* data of SAX J1808.4−3658 (Dotani et al. 2000; see ourTable 1) to investigate whether the four detected *BeppoSAX* sources are also detected with *ASCA*. We used two different methods to analyze the *ASCA* data: the method applied by Dotani et al. (2000; hereafter referred to as the standard method) and also the MLR method. The morphology of the *ASCA*/Solid-State Imaging Spectrometer (SIS) images obtained with both methods (see Fig. 2 for the MLR image and Dotani et al. 2000 for the image obtained with the standard method) are very similar to each other, and a source was detected in the center of the images (at $\sim$8 σ significance, using the MLR method), and its position is consistent with the position of SAX J1808.4−3658 (using an updated spatial calibration of *ASCA*; Gotthelf et al. 2000; see Table 2; we only list the positions obtained with the MLR method). We also applied the MLR method to the combined Gas Imaging Spectrometer (GIS-2 and GIS-3) data. Although the coarse image binning and relatively high background prevented us from applying the standard analysis (Dotani et al. 2000), the MLR method may be better suited to reconstruct such a noisy, coarse-rebinned image. The resulting MLR image is shown in Figure 2. We could detect the millisecond X-ray pulsar at a significance of $\sim$5 σ.

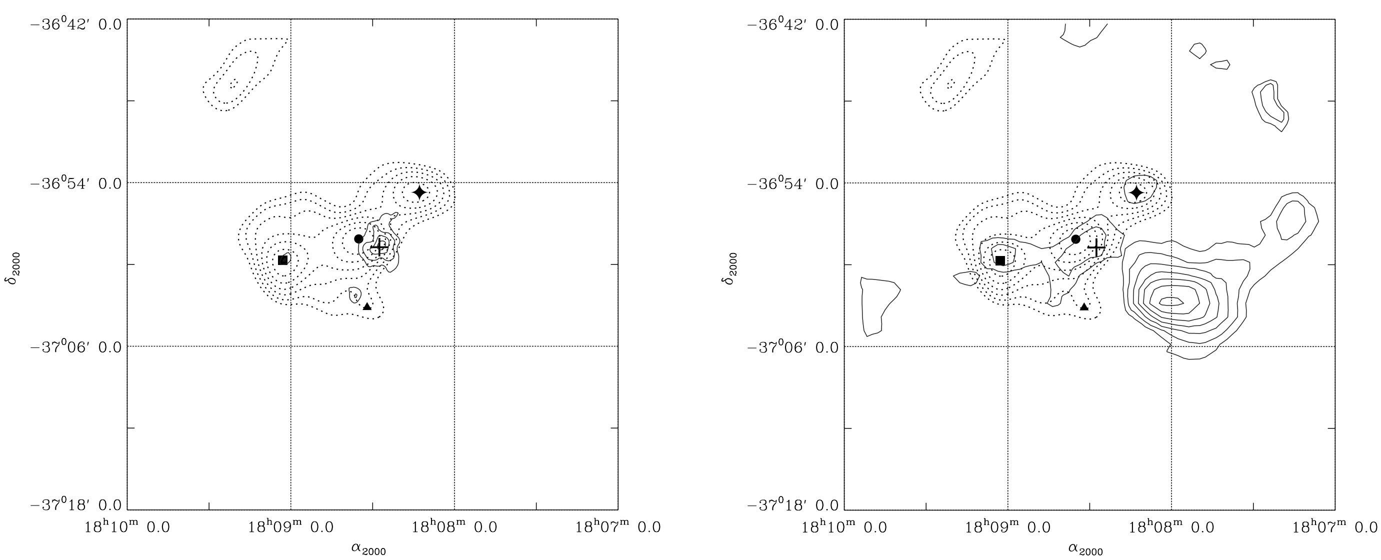

FIG. 2.—Maximum likelihood ratio images of the *ASCA* data (*solid lines*; SIS: *left* panel; 1.3–10 keV; GIS: *right* panel; no energy selection) overplotted on the 1.3–10 keV *BeppoSAX* data (*dashed lines*; see also Fig. 1). The contour levels represent the source detection significance atop an isotropic (flat) background starting at a 4 σ level (for *BeppoSAX*/MECS and *ASCA*/SIS; 3 σ for *ASCA*/GIS) in steps of 1 σ assuming 1 degree of freedom. For the symbols, see Fig. 1.

The *ASCA*/SIS count rate (0.5–5.0 keV) obtained using the MLR method is $2.4 \pm 0.3 \times 10^{-3}$ counts s^{-1}, which is significantly higher than the one we obtained using the standard method ($1.1 \pm 0.4 \times 10^{-3}$ counts s^{-1}). However, for faint sources it is important to correctly estimate the local background level at the source position, which is not trivial because of the extended *ASCA* point-spread function. To investigate the effect of a more structured background on the source count rate, we modeled the background near the pulsar in terms of including three extra point sources at "hot" positions in the MLR image, which are defined as the positions of remaining excesses in a residual MLR image after the detected sources were modeled out. Using this background model, the count rate of the millisecond X-ray pulsar decreases to $1.6 \pm 0.3 \times 10^{-3}$ counts s^{-1}. This count rate is still $\sim$50% higher than that obtained with the standard method, but the error bars are such that the count rates are consistent with each other. Clearly, to obtain the correct *ASCA*/SIS count rates for SAX J1808.4−3658, it is very important to understand the local background level.

Using the MLR method, we were able to extract a spectrum of the source. However, the spectrum is of low statistical quality, and multiple models could be fitted to the data equally well. The spectrum can be fitted using a blackbody model (resulting in kT of $\sim$0.65 keV) or with a power-law model (with a photon index of $\sim$1.7). We have also investigated the effects of the uncertainties in the column density[7] toward SAX J1808.4−3658 by fitting the spectrum with an N_H between 0.6 and 6×10^{21} cm^{-2}. A range of fluxes was obtained, and we quote the typical unabsorbed fluxes, which include statistical errors (as due to the fit procedure) and systematic errors (i.e., the uncertainties in the background and in the column density, using different spectral shapes such as blackbody or power law): 7 ± 4 (0.5–5 keV) and $10 \pm 6 \times 10^{-14}$ ergs s^{-1} cm^{-2} (0.5–10 keV). Within these errors, those fluxes are consistent with what has been reported previously by Dotani et al. (2000).

At the position of the *BeppoSAX* source, no source could be detected, with a 3 σ upper limit on the count rate of 1.5×10^{-3} counts s^{-1} [0.5–5.0 keV; single SIS; depending on the spectral shape and the column density, this would result in an unabsorbed 0.5–10 keV flux range of $(0.3–1) \times 10^{-13}$ ergs s^{-1} cm^{-2}]. Two of the remaining three *BeppoSAX* sources were detected during the *ASCA* observation (Fig. 2). SAX J1809.0−3659 was detected in both the SIS (although at the edge of the CCD detectors; 5 σ using the MLR method) and GIS detectors (4.5 σ). SAX J1808.2−3654 was outside the field of view (FOV) of the SIS but inside that of the GIS and was detected by this instrument (3.5 σ). The positions of those two sources are consistent with those obtained using *BeppoSAX* (Table 2). SAX J1808.5−3703 was also outside the FOV of the SIS. The GIS did not detect the source. An additional source was detected with the GIS at a position of R.A. = $18^h08^m02^s.8$, decl. = $-37°02'41''.7$ (greater than 9 σ; designated AX J1808.0−3702), although it might not be a point source but an extended source (note that this causes additional systematic errors on the source position, which can be as large as 2′). No pronounced counterpart of this source is visible in the *BeppoSAX*/MECS image (Fig. 1), but it might be present at a 3 σ level.

[7] We have reanalyzed the brightest burst seen with the *BeppoSAX* Wide-Field Cameras during the 1998 outburst of SAX J1808.4−3658 (in 't Zand et al. 1998, 2001), and we determined that the column density should be less than 5×10^{21} cm^{-2}.

5. DISCUSSION

We have obtained *BeppoSAX*/NFI observations of the millisecond X-ray pulsar during its 2000 outburst. Because of the extreme variability during this outburst (see Wijnands et al. 2001), the *BeppoSAX* observations were unfortunately taken when the source had very low luminosities. We detected four field sources during our observations. One source is 1′.63 away from the position of the millisecond X-ray pulsar, considerably larger than the 1 σ error of 0′.55. This source can be identified with SAX J1808.4−3658 only if we assume that the *BeppoSAX* positional reconstruction is not completely understood. If indeed this source cannot be identified with the millisecond X-ray pulsar, then it should be designated SAX J1808.6−3658.

A possible nondetection of SAX J1808.4−3658 during our *BeppoSAX* observations would result in a 3 σ upper limit on the count rate of 1.1×10^{-3} counts s^{-1} (1.3–10 keV; both MECS units active). When assuming an N_H of 1.22×10^{21} cm^{-2} and a power-law–shaped spectrum with index 2, this would result in an upper limit on the luminosity of $\sim 1 \times 10^{32}$ ergs s^{-1} (0.5–10 keV; for a distance of 2.5 kpc). In our *ASCA* observations, we could not detect a source on the best position of the *BeppoSAX* source with a range of upper limits on its X-ray flux of $0.3–1.0 \times 10^{-13}$ ergs s^{-1} cm^{-2} (0.5–10.0 keV; unabsorbed). If the column density is indeed $\sim 1.22 \times 10^{21}$ cm^{-1}, then the upper limit determined with *ASCA* (less than 0.6×10^{-13} ergs s^{-1} cm^{-2}) was lower than the flux detected during the *BeppoSAX* observations ($1.9 \pm 0.3 \times 10^{-13}$ ergs s^{-1} cm^{-2}). This discrepancy can mean that indeed the *BeppoSAX* source is the millisecond pulsar, or also that this source is variable. In the latter case, the fact that this source is detected during all *BeppoSAX*/NFI observations (including the 1999 March 17 observation) and not during the single *ASCA* observation should then be regarded as a coincidence. The *ASCA* fluxes obtained (using W3PIMMS) for the other three *BeppoSAX* sources were consistent with the values obtained from the *BeppoSAX* fluxes (taking into account the uncertainties in the spectra, the internal absorption of the sources, and in calculating the fluxes using W3PIMMS). The nature of those field sources is unknown, but they could be, e.g., active galactic nuclei.

If indeed the *BeppoSAX* source is a previously unknown source, then its proximity to the millisecond pulsar raises the question of whether all the outbursts observed from the pulsar so far are indeed due to the pulsar and not from this extra source. It is clear that the source that exhibited the 1998 and 2000 outbursts was the millisecond X-ray pulsar, because during both outbursts the 401 Hz pulsations were detected (Wijnands & van der Klis 1998; van der Klis et al. 2000). Furthermore, during both outbursts the optical counterpart increased considerably in luminosity (Giles et al. 1999; Wachter & Hoard 2000; Wachter et al. 2000; note that this secures the subarcsecond-accurate position of the pulsar). However, the *BeppoSAX*/WFC positional errors of the persistent source detected during the 1996 outburst are consistent with both the position of the millisecond pulsar and the *BeppoSAX* source. Still, there are two measurements that provide convincing evidence that the 1996 outburst was also due to the millisecond X-ray pulsar. First, the

99% error regions of the three bursts detected during that outburst are all consistent with the pulsar, while that of one burst is clearly inconsistent with the other source. We note that all three bursts were observed in a small time window during the 1996 outburst and are most likely due to the same source. Second, there is a marginal detection of a 401 Hz oscillation during one of the three bursts (in 't Zand et al. 2000).

Independent of whether the *BeppoSAX* source can be identified with the millisecond X-ray pulsar or whether it is an unrelated field source, it is clear that SAX J1808.4−3658 has very low luminosities in quiescence. As discussed in detail by Wijnands et al. (2001), the very low luminosity of SAX J1808.4−3658 during the *BeppoSAX* observations demonstrates the highly variable nature of the source during its 2000 outburst. For example, the source luminosity was below a few times 10^{32} ergs s^{-1} on 2000 March 5–6 and 8; it reached $\sim 10^{35}$ ergs s^{-1} on 2000 March 11, as observed with the *RXTE*/PCA, but the source was very dim again with *BeppoSAX*/NFI on 2000 March 22–23. Also, on several occasions after 2000 March, the source could again be detected with the *RXTE*/PCA. Therefore, although the X-ray luminosity was very low during our *BeppoSAX* observations, the clear long-term activity of the source demonstrated that these observations cannot be regarded as true quiescent observations.

We reanalyzed the *ASCA* observation of SAX J1808.4−3658 reported by Dotani et al. (2000). We confirm the detection of the millisecond X-ray pulsar. Because of the uncertainties in its exact *ASCA* count rate (see § 4) and its exact spectral shape, the exact quiescent luminosity of the millisecond pulsar is difficult to constrain, but it is most likely in the range $(0.3\text{–}1) \times 10^{32}$ ergs s^{-1} (0.5–10 keV). Despite this large uncertainty in its quiescent luminosity, the source is clearly fainter than the other neutron star LMXB X-ray transients when they are in quiescence (which are larger than a few times 10^{32}–10^{33} ergs s^{-1}). If the quiescent luminosity of SAX J1808.4−3658 is indeed as low as a few times 10^{31} ergs s^{-1}, then it is unclear whether the found distinction (e.g., Garcia et al. 2001 and references therein) between the quiescent luminosity of neutron star transients and black hole transients (a few times 10^{30}–10^{31} ergs s^{-1}) can hold. If certain neutron star X-ray transients can indeed be as dim in quiescence as the black hole systems, then the reasons to invoke the presence of event horizons in the black hole systems will disappear (Garcia et al. 2001). More observations of neutron star transients in quiescence are required to assess the validity of reported quiescent luminosity difference between the two types of systems. Such observations will also give important information to assess the question of whether the millisecond X-ray pulsar is unique not only with respect to its pulsating nature but also with respect to its quiescent behavior.

Brown, Bildsten, & Rutledge (1998) proposed that the quiescent X-ray luminosities of neutron star LMXB transients depend on their time-averaged mass accretion rates. Compared with the other systems, the time-averaged accretion rate of the millisecond X-ray pulsar is low, and Brown et al. (1998) suggested that this source should have a low quiescent X-ray luminosity. Within the uncertainties of their model and our observations, the predicted quiescent luminosity is consistent with the detected one. It is also possible that this low quiescent luminosity is related to the fact that the source is so far the only accretion-driven millisecond X-ray pulsar known. For example, if this uniqueness is due to a higher neutron star magnetic field than that of the other sources, then during quiescence the so-called propeller mechanism might inhibit residual accretion onto the neutron star. Indications for residual accretion in quiescence have been found for the other neutron star systems, which is mainly inferred from the power-law tail in their quiescent X-ray spectrum and the variability of several sources in quiescence (however, see Ushomirsky & Rutledge 2001 for a discussion about X-ray variability due to deep crustal heating). However, only at most $\sim$50% of the quiescent X-ray flux of those sources is due to this power-law component, suggesting that the low quiescent luminosity of SAX J1808.4−3658 can only in part be due to the lack of residual accretion in this system.

It is very well possible that the very low quiescent luminosity is due to a combination of the two above-mentioned effects. The low time-averaged accretion rate of SAX J1808.4−3658 will not heat-up its neutron star to the same temperature as in the other systems, causing a lower thermal luminosity from its surface. Also, when residual accretion is inhibited because of its magnetic field, the power-law component is absent, and the total quiescent X-ray luminosity of SAX J1808.4−3658 could be very low compared to the other neutron star X-ray transients in quiescence. High-quality quiescent X-ray spectra (e.g., with *XMM-Newton* or *Chandra*) of SAX J1808.4−3658 will help considerably to understand its low quiescent luminosity.

Note added in manuscript.—After submission of our paper, Campana et al. (2001) reported preliminary results on their *XMM-Newton* observation of SAX J1808.4−3658 in quiescence. They detected the source at a luminosity of approximately 5×10^{31} ergs s^{-1} (0.5–10 keV), consistent with our quiescent *ASCA* luminosity. They also reported that at the position of the *BeppoSAX* source, no source could be detected. However, the *XMM-Newton* observation was not taken at the same time as our *BeppoSAX* observations during the 2000 outburst, and variability of this *BeppoSAX* source cannot be ruled out. Analysis of the Director's Discretionary Time (DDT) *XMM-Newton* observation taken on 2000 March 8 will definitely settle this issue because it was taken very close in time to our *BeppoSAX* observations.

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