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CHANDRA OBSERVATIONS OF THE TRANSIENT 7 s X-RAY PULSAR AX J1845.0−0258

C. R. Tam,[1] V. M. Kaspi,[1,2] B. M. Gaensler,[3,4] and E. V. Gotthelf[5]

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ABSTRACT

We present the results of *Chandra X-Ray Observatory* observations of the transient anomalous X-ray pulsar candidate AX J1845.0−0258 in apparent quiescence. Within the source's error circle, we find a point source and possible counterpart, which we designate CXOU J184454.6−025653. No coherent pulsations are detected, and no extended emission is seen. The source's spectrum is equally well described by a blackbody model of temperature $kT \sim 2.0$ keV or a power-law model with photon index $\Gamma \sim 1.0$. This is considerably harder than was seen for AX J1845.0−0258 during its period of brightening in 1993 ($kT \sim 0.6$ keV) despite being at least ∼13 times fainter. This behavior is opposite to that observed in the case of the established transient AXP, XTE J1810−197. We therefore explore the possibility that CXOU J184454.6−025653 is an unrelated source and that AX J1845.0−0258 remains undetected since 1993, with a flux 260–430 times fainter than at that epoch. If so, this would represent an unprecedented range of variability in AXPs.

Subject headings: pulsars: general — pulsars: individual (AX J1845.0−0258) — stars: neutron — X-rays: individual (CXOU J184454.6−025653)

1. INTRODUCTION

The class of neutron stars collectively known as "anomalous X-ray pulsars" (AXPs; Mereghetti & Stella 1995) has many properties that have been enigmatic since the discovery of the first example over 20 years ago (Fahlman & Gregory 1981). Foremost among puzzles was the nature of their energy source, as they show no evidence of being either accretion or rotation powered. Following extensive theoretical and observational work (see Woods & Thompson 2006 for a review), it is clear that AXPs share a common nature with another unusual class of neutron stars, the "soft gamma repeaters" (SGRs), with both best identified with young, isolated neutron stars that are powered by the decay of an enormous ($\gtrsim 10^{14}$ G) internal magnetic field. As such, they are called "magnetars" (Duncan & Thompson 1992; Thompson & Duncan 1995, 1996).

Recently, transient X-ray pulsars with properties otherwise unique to the AXPs have been discovered. The one established transient AXP (TAXP) is XTE J1810−197, a 5.5 s X-ray pulsar discovered in 2003 (Ibrahim et al. 2004) during a period of dramatic X-ray enhancement and subsequent flux decay on roughly a year timescale. The source's spectrum at the time of the outburst was soft in the 2–10 keV band, well characterized by a combined two-component spectrum (power law plus blackbody, or 2 temperature blackbody model) with parameters similar to those seen in classical, i.e., nontransient, AXPs (Ibrahim et al. 2004; Gotthelf et al. 2004). This, together with the observed secular spin-down and implied magnetar-strength magnetic field, as well as an observed X-ray luminosity in excess of the implied rotational spin-down luminosity $\dot{E}$, makes an AXP interpretation for XTE J1810−197 difficult to escape (Ibrahim et al. 2004). Yet Gotthelf et al. (2004) showed from archival X-ray data that in quiescence, the observed source flux was nearly 2 orders of magnitude fainter than at the time of the outburst and in subsequent months and was much fainter than any of the nontransient AXPs. TAXPs also open the question of how many more quiescent AXPs there are in the Galaxy. This question is particularly interesting as the magnetar birthrate could be a substantial fraction of the total neutron star birthrate, possibly even comparable to that of classical radio pulsars, whose much greater longevity makes them much more numerous in the Galaxy. On the other hand, Gaensler et al. (2005) consider the growing evidence that magnetars have unusually massive progenitors and thus argue that the magnetar birthrate is ∼10% of the total neutron star birthrate. The study of TAXPs in quiescence is important for constraining their true luminosity function and hence the size of the Galactic magnetar population.

The 6.97 s X-ray pulsar AX J1845.0−0258 was discovered during a periodicity search for X-ray sources in the *ASCA* archive (Gotthelf & Vasisht 1998; Torii et al. 1998). Strong X-ray pulsations having a sinusoidal pulse profile were seen in data obtained in 1993 from a Galactic plane point source that was subsequently shown to be near the center of the shell supernova remnant G29.6+0.1 (Gaensler et al. 1999). The long pulse period and possible association with a young remnant strongly suggested that AX J1845.0−0258 is an AXP. Additional support for this interpretation came from the soft, highly absorbed X-ray spectrum, which was well described by the Wien tail of a blackbody having $kT \sim 0.64$ keV, similar to that seen in other AXPs (Gotthelf & Vasisht 1998; Torii et al. 1998). The pulsar was not detected in a serendipitous observation of the region obtained in 1997 as part of the *ASCA* Galactic Plane Survey (Torii et al. 1998). Interestingly, follow-up observations in 1999 revealed the source AX J184453−025640[6] in the original 3′ radius *ASCA* positional uncertainty region, whose flux was smaller by a factor of ∼10 relative to that of AX J1845.0−0258 in 1993, precluding the measurement of pulsations or spectral information

[1] Department of Physics, Rutherford Physics Building, McGill University, 3600 University Street, Montreal, QC, H3A 2T8, Canada; tamc@physics.mcgill.ca.

[2] Canada Research Chair.

[3] Harvard-Smithsonian Center for Astrophysics, 60 Garden Street, Cambridge, MA 02138.

[4] Alfred P. Sloan Research Fellow.

[5] Columbia Astrophysics Laboratory, Columbia University, 550 West 120th Street, New York, NY 10027-6601.

[6] The updated coordinate of this *ASCA* source, using the final correction for the systematic coordinate offset derived in Gotthelf et al. (2000), is $18^{h}44^{m}54\overset{s}{.}4$, $-02^{\circ}56'37\overset{''}{.}7$.

TABLE 1
Chandra Observing Characteristics

Observation ID	Start Date (MJD)	Start Time (UT)	Exposure Length (s)	Frame Time (s)	Count Rate[a] (10^{-3} counts s^{-1})
3891	52816.294593424	2003 Jun 26 07:04:12	17497	0.441	6.6 ± 0.6
3892	52817.011209629	2003 Jun 27 00:16:08	11011	0.441	6.3 ± 0.8
3893	52818.904481989	2003 Jun 28 21:42:27	11661	0.441	7.2 ± 0.8
3894	52823.081440211	2003 Jul 03 01:57:16	11018	0.441	7.6 ± 0.8
3895	52832.407594110	2003 Jul 12 09:46:56	10930	0.441	5.9 ± 0.7
3896	52852.389608127	2003 Aug 01 09:21:02	7030	0.441	7.9 ± 1.1
3897	52896.325185093	2003 Aug 14 07:48:15	11779	3.241	5.9 ± 0.7

[a] CXOU J184454.6−025653 background subtracted count rates for 2–10 keV energy range. Errors reflect 1 σ uncertainties assuming Poisson statistics.

(Vasisht et al. 2000). The rate of change of the spin frequency has therefore not been measured, rendering the source as yet unconfirmed as a bona fide AXP. It is plausible that the 1993 observation was obtained shortly after a major outburst such as that seen for XTE J1810−197 and that the source subsequently faded back to its quiescent level. X-ray observations in 2001–2003 with *BeppoSAX* MECS, *Chandra* HRC-I, and *XMM-Newton* EPIC reported by Israel et al. (2004) revealed a faint source consistent with AX J184453−025640 in position and brightness; a concurrent attempt to detect its optical/IR counterpart produced an *H*-band upper limit of 21 mag.

Here we report on a series of *Chandra X-Ray Observatory* observations of AX J1845.0−0258 in apparent quiescence. We attempt to redetect pulsations and hence constrain the spin-down rate in order to test the AXP interpretation for this source. We characterize the behavior of this candidate TAXP in a low flux state by determining its spectral properties and by searching for low-level flux variability on a variety of timescales. Finally, we discuss the likelihood and implications for a nondetection of the AXP counterpart.

2. OBSERVATIONS AND ANALYSIS

Seven observations with *Chandra* ACIS-S were obtained between 2003 June 26 and September 14 in timed exposure mode. Table 1 summarizes the observing characteristics. The first six observations were taken in 1/8 subarray mode on the chip ACIS-S3 with a time resolution of 0.441 s, sufficient to resolve the pulsar signal. The subarray's small field of view does not cover the full 3′ radius *ASCA* error circle. Therefore, we used as the aim point the position of the counterpart supplied to us from *Chandra* HRC observations ($18^h44^m54^s.6$, $-02^\circ56'53''$ (J2000); G. Israel, private communication). The seventh observation was in ACIS-S full-frame mode for which the time resolution was 3.241 s. The total exposure length at the above position was ∼80 ks.

Data processing was performed with CIAO 3.2.2 and CALDB 3.0.3 software packages. We reperformed some steps in the standard processing pipeline with updated calibration files, using the tool `acis_process_events`.

2.1. *Imaging*

One source at the position $18^h44^m54^s.68$, $-02^\circ56'53''.1$ (J2000) is detected in all seven observations, which we designate CXOU J184454.6−025653; this is the likely counterpart to AX J184453−025640 and the possible counterpart to AX J1845.0−0258. As seen in Figure 1, it falls within the error circles of both objects. We find no evidence of extended emission. The observations were aligned and summed using the nominal *Chandra* astrometric information. Systematic uncertainties in *Chandra* absolute positions are expected to be 0″.6 at the 90% level[7]. Although these systematic errors in general can be reduced by aligning other sources, given that some of our subarray fields contain none, the nominal astrometry must suffice. To confirm that co-addition had no adverse effects on our source's radial profile, we directly compared it to the simulated point-spread function (PSF) produced by the Chandra Ray Tracer (ChaRT) at the source chip position and found it consistent with an unresolved point source. The final position was determined from the combined image and is consistent with that measured with *Chandra* HRC.

Since the absence of pulsations precludes confirming the AXP nature of CXOU J184454.6−025653 (see § 2.2) and similarly AX J184453−025640, the true counterpart could conceivably lie anywhere in the original 3′ radius *ASCA* error circle. We searched the combined event file, unfiltered in energy, for additional point sources using `celldetect`. One source, CXOU J184507.2−025657, was found at $18^h45^m07^s.27$, $-02^\circ56'57''.3$, located 3′.1 away from CXOU J184454.6−025653, significant at the 3 σ level assuming single trial probability. Its coincidence with the near-IR source 2MASS J18450724−0256571[8] of magnitude $K = 12.7$ may suggest that CXOU J184507.2−025657 is an unlikely counterpart to AX J1845.0−0258, since a highly absorbed AXP candidate is expected to have a near-IR magnitude $K \gg 20$ (for a summary of AXP IR magnitudes and X-ray absorptions, see Durant & van Kerkwijk 2005). A considerably fainter source, CXOU J184509.7−025715, located at $18^h45^m09^s.76$, $-02^\circ57'15''.0$, was found at the 2 σ level. All of these sources are indicated in Figure 1. We also inspected an archival *XMM-Newton* observation taken 2003 March 3 (Israel et al. 2004) but found no additional significant point sources in the error region.

2.2. *Timing*

In an attempt to perform phase-coherent timing, we observed in 1/8 subarray mode to acquire high time resolution data and to identify a pulsed signal. Light curves for CXOU J184454.6−025653 were extracted from a 2″.5 radius circle in each data set at the maximum allowable time resolution (0.441 s for observations 3891–3896) in 3 energy ranges: 1–10 keV, 1–3 keV, and 3–10 keV. Event times were corrected to solar system barycenter arrival times. We performed a fast Fourier transform (FFT) on each data set; no evidence for pulsations was found in the resulting power density spectra. Using the longest of the observations (Obs. ID 3891) for the frequency range 0.0880−0.1436 Hz, we

[7] http://cxc.harvard.edu/cal/ASPECT/celmon.

[8] See http://www.ipac.caltech.edu/2mass/ for information on the 2MASS All Sky Survey.

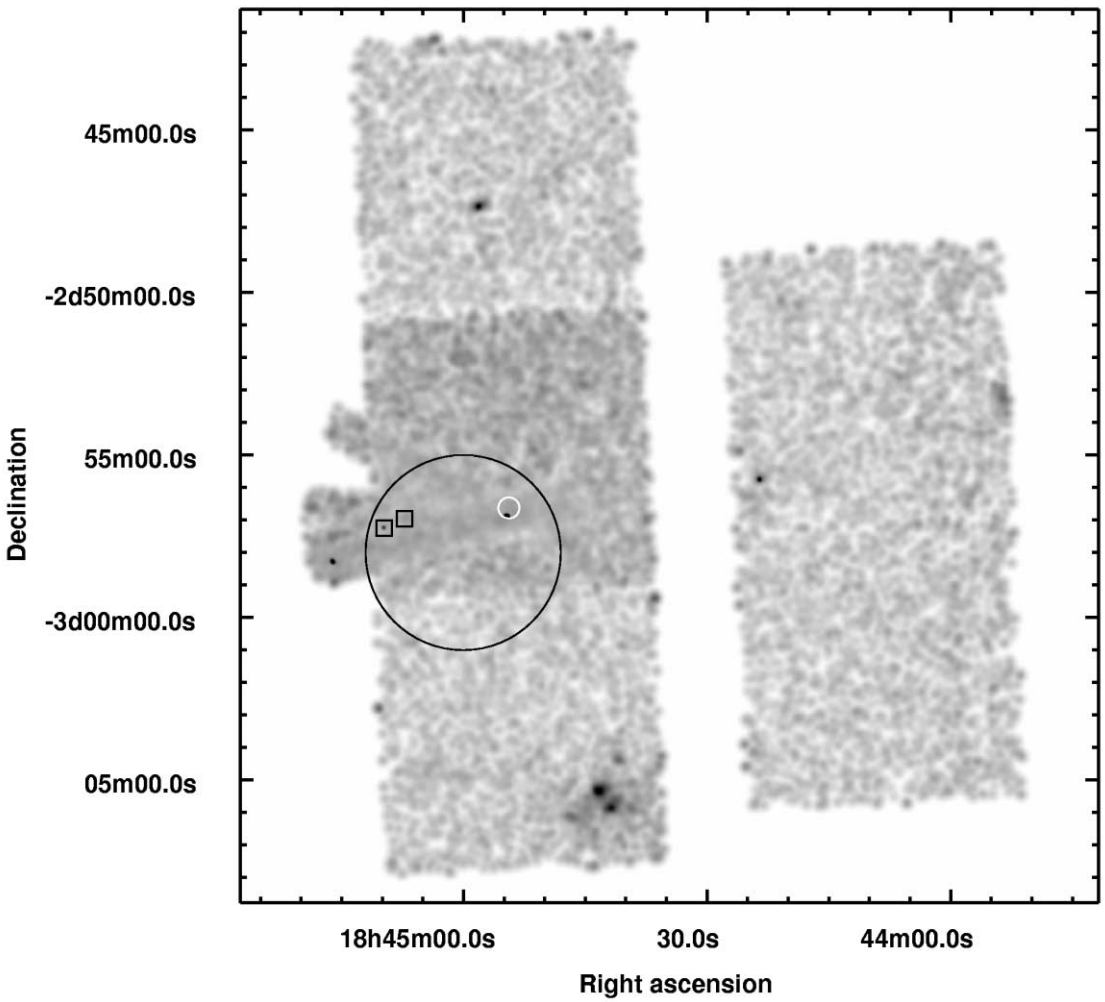


FIG. 1.—Combined *Chandra* ACIS-S image of the field surrounding AX J1845.0−0258, including chips I2–I3 and S2–S4. The image is energy-filtered (2–10 keV), binned by 4 pixels, exposure corrected, and adaptively smoothed with a (minimum) 4″ Gaussian. One observation (Obs. ID 3896) was omitted due to its effect on the appearance of the flat background. Overlaid are the positional error regions for AX J1845.0−0258 in 1993 (*black circle*; Gotthelf & Vasisht 1998) and AX J184453−025640 in 1999 (*white circle*; note that a correction has since been applied to the position in Vasisht et al. 2000). The point source encircled by both regions is CXOU J184454.6−025653, the possible counterpart to AX J1845.0−0258. Boxes indicate the locations of CXOU J184507.2−025657 (*right*; not obvious in 2–10 keV band) and CXOU J184509.7−025715 (*left*).

set a 95% confidence upper limit on the pulsed amplitude of 80% in 1–10 keV, using the method outlined in Vaughan et al. (1994). The above frequency range allows for a 10 year change in frequency corresponding to magnetic fields $\sim 10^{16}$ G and lower. Our detections of the faint point sources CXOU J184507.2−025657 and CXOU J184509.7−025715 have far too few counts ($\leq$12 in 1–10 keV) to make detecting pulsations possible.

2.3. *Spectrum*

We used the `psextract` script and `mkacisrmf` tool to extract CXOU J184454.6−025653's spectra from a 2.″5 radius circle and the background spectra from a 3″ to 22″ annulus centered on the point source and computed instrumental response files. Background-subtracted count rates for the point source at each observing epoch are given in Table 1, where uncertainties assume Poisson statistics. At each epoch there were too few counts to allow a meaningful spectral fit; therefore, we combined the individual data sets into a summed spectrum containing 550 ± 24 background-subtracted counts (0.5–10 keV). We excluded channels at energies below 0.5 keV, where the effective area of ACIS-S falls off significantly, and grouped the remainder so that a minimum of 12 counts fell in each spectral bin. The spectral fitting

TABLE 2
SPECTRAL PROPERTIES OF COMBINED DATA

Model	$N_{\rm H}$ (10^{22} cm^{-2})	kT (keV) or Γ	$f_{\rm abs}$ (10^{-13} ergs s^{-1} cm^{-2})	χ^2/dof	$f_{\rm unabs}$ (10^{-13} ergs s^{-1} cm^{-2})
BB	$5.6^{+1.6}_{-1.2}$	$2.0^{+0.4}_{-0.3}$	2.6 ± 0.2	39.9/40	2.5–4.0
PL	$7.8^{+2.3}_{-1.8}$	$1.0^{+0.5}_{-0.3}$	2.8 ± 0.2	39.9/40	2.9–5.0

NOTES.—All errors reflect 90% confidence intervals. Absorbed and unabsorbed fluxes are given for 2–10 keV energy range. Uncertainties on absorbed flux reflect the fractional error on the normalization assuming the best-fit $N_{\rm H}$ and kT or Γ. Unabsorbed flux ranges are found by fixing spectral parameters at their 90% confidence boundaries.

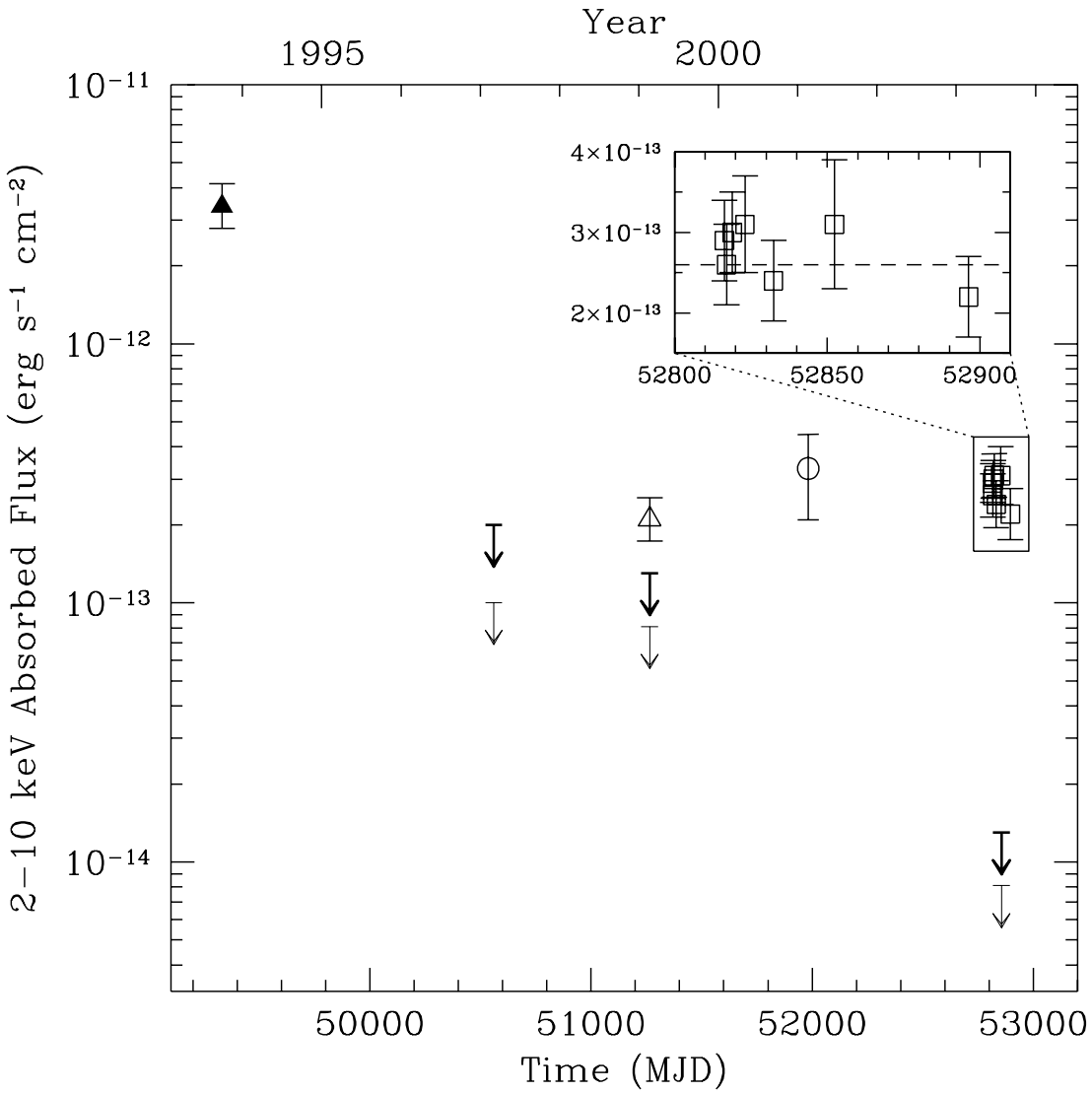


FIG. 2.—Absorbed 2–10 keV flux history of AX J1845.0−0258 spanning 10 years, given several likely spectral models. For the original *ASCA* discovery (*filled triangle*; Gotthelf & Vasisht 1998), during which pulsations were detected, and the subsequent detection of the faint source and possible counterpart AX J184453−025640 (*open triangle*; Vasisht et al. 2000), from which neither pulsations nor a spectrum were seen, we have adopted the outburst blackbody spectrum of AX J1845.0−0258 ($kT \sim 0.64$ keV). We show the blackbody flux of a possible counterpart observed with *BeppoSAX* (*circle*) as reported by Israel et al. (2004). The flux of CXOU J184454.6−025653 (*squares*) assumes the best-fit blackbody spectrum described in the text and Table 2. At some epochs, we plot upper limits in addition to detected values, in case AX J1845.0−0258's true counterpart fell below sensitivity. Two models are assumed in estimating the upper limit fluxes: the spectrum of AX J1845.0−0258 in outburst (*thick arrows*) and the spectrum of XTE J1810−197 during quiescence ($kT \sim 0.18$ keV; *thin arrows*). The 1997 upper limits were measured in an observation of the *ASCA* Galactic Plane Survey (Torii et al. 1998). The inset plot shows an enlargement of the seven *Chandra* detections and the flux derived from the combined data (*dashed line*).

package XSPEC 11.3.1 produced equally acceptable fits to single-component thermal blackbody or power-law models with photoelectric absorption; model parameters are presented in Table 2. We found a best-fit temperature of $kT = 2.0^{+0.4}_{-0.3}$ keV and an absorption of $N_{\rm H} = 5.6^{+1.6}_{-1.2} \times 10^{22}$ cm^{-2} assuming a blackbody spectrum, and a photon index of $\Gamma = 1.0^{+0.5}_{-0.3}$ and absorption $N_{\rm H} = 7.8^{+2.3}_{-1.8} \times 10^{22}$ cm^{-2} assuming a power-law spectrum (uncertainties reflect 90% confidence). The measured absorptions are consistent with the 1993 *ASCA* values within uncertainties.

Assuming that the shape of the combined spectrum is also characteristic for the spectra at each epoch, we determined those fluxes by holding the spectral parameters fixed at the values in Table 2. Since neither model is preferred based on goodness of fit, we arbitrarily chose the blackbody model for the rest of our analysis. We measured the 2–10 keV flux of the seven individual data sets by grouping spectra in the same way as for the combined spectrum, freezing $N_{\rm H}$ and kT at the above best-fit values and allowing only the normalization to vary. We found that the data are consistent with the source's flux being stable over the 12 week observing window to within statistical uncertainties: fitting to a constant flux resulted in a reduced $\chi^2 = 1.0$ for 6 degrees of freedom. The inset plot of Figure 2 shows the *Chandra* fluxes assuming the best-fit blackbody model parameters.

The combined 2–10 keV flux of CXOU J184454.6−025653, assuming the blackbody spectrum, is $2.6 \pm 0.2 \times 10^{-13}$ ergs s^{-1} cm^{-2}. Although subject to large uncertainties on the measurement of $N_{\rm H}$, we estimate that the unabsorbed flux is $(2.5–4.0) \times 10^{-13}$ erg s^{-1} cm^{-2}. See Table 2 for an explanation of the uncertainties. If the source is indeed the counterpart to AX J1845.0−0258, this implies that the flux in 2003 is a factor of $\sim$13 fainter than that measured in 1993 with *ASCA* GIS (Gotthelf & Vasisht 1998).

What if CXOU J184454.6−025653 is unrelated to AX J1845.0−0258? We next looked at the two fainter point sources coincident with the error region as possible counterparts. We extracted spectra for CXOU J184507.2−025657 from a 4″ radius circle, using the same background area used earlier. This source, which was visible in only 3 of the 7 observations, produced 37 background-subtracted counts (0.5–10 keV) in its combined spectrum, insufficient to adequately fit a spectral model. However, we observed that the majority of counts fell below 2 keV, contrary to what one would expect from a highly absorbed source such as AX J1845.0−0258 that previously exhibited $N_{\rm H} \gtrsim 6 \times 10^{22}$ cm^{-2}. This evidence, combined with the probable 2MASS association we mentioned earlier, strongly suggests that CXOU J184507.2−025657 is unrelated to AX J1845.0−0258. From CXOU J184509.7−025715, which appeared in 4 of 7 observations, we extracted counts from a 4.″4 radius circle; this gave a combined spectrum containing 20 background-subtracted counts (0.5–10 keV). Again, the paucity of counts prevented us from drawing any conclusive results about the spectrum of this source.

Finally, we considered the case that AX J1845.0−0258 was not at all redetected and determined the 3 σ upper limit on the absorbed flux for a hypothetical point source. We measured the background count rate from our only full-frame data set (Obs. ID 3897), which was the only observation whose field was large enough to contain the full 3′ *ASCA* error circle. The range $\sim(8–13) \times 10^{-15}$ ergs s^{-1} cm^{-2} (2–10 keV) encompasses results assuming several likely models based on the outburst spectrum of AX J1845.0−0258 and the spectrum of XTE J1810−197 in quiescence (see Fig. 2). If the true counterpart were off-axis by 3′, the difference in effective area and PSF would not dramatically affect our ability to detect a point source unless it were at the limiting flux.

3. DISCUSSION

Our observations reveal that CXOU J184454.6−025653, whether the counterpart or not, is significantly fainter than was AX J1845.0−0258 in 1993 (Gotthelf & Vasisht 1998) by a factor of ∼13. If CXOU J184454.6−025653 is not the AXP counterpart, this factor increases significantly: AX J1845.0−0258 must now be at least 260–430 times fainter than it was in 1993. This would be an unprecedented range of variability in AXPs. CXOU J184454.6−025653's flux is consistent with that of AX J184453−025640 in 1999 (Vasisht et al. 2000); therefore, we may well have detected the same source. Figure 2 summarizes the flux history of AX J1845.0−0258.

Such variability on long timescales, seen here and in XTE J1810−197, presents a challenge to the magnetar model, which posits that the decay of the internal field is continual during the source's youth. This decay results in continual internal heating and crustal stresses. Thus, the behavior exhibited by TAXPs raises the following important question: if they are magnetars, what causes the dramatic difference in intrinsic brightness between active and quiescent states? Estimates of the crustal temperatures heated by internal magnetic dissipation predict X-ray luminosities such as those observed for nontransient AXPs (Thompson & Duncan 1996). Those same estimates are consistent with the expected stresses that result in the crustal yields that produce bursts such as that seen in XTE J1810−197 and also in the nontransient AXP 1E 2259+586 (Kaspi et al. 2003; Woods et al. 2005). Thus TAXPs and nontransients have much in common physically, but they are apparently sufficiently dissimilar that their quiescent X-ray luminosities differ by orders of magnitude.

The spectrum of CXOU J184454.6−025653 raises doubt that this is indeed the pulsar counterpart. For the blackbody model, the temperature of 2 keV is much higher than the 0.18 keV measured for XTE J1810−197 in quiescence (Gotthelf et al. 2004) and is in fact much higher than for any known AXP or SGR.[9] Evidence for inconsistent spectral behavior may have already been seen in 2001–2003 by Israel et al. (2004). Indeed the *Chandra* point source is much harder than was the pulsar when in outburst in 1993 (Gotthelf & Vasisht 1998; Torii et al. 1998), in stark contrast to XTE J1810−197 which greatly hardened ($kT = 0.67$ keV) when bright. Thus if CXOU J184454.6−025653 is the pulsar counterpart, its spectral properties in quiescence are puzzling. The quiescent spectrum is more in line with that seen from magnetospheric emission in rotation-powered pulsars (see Kaspi et al. 2006 for a review); however, no such object has ever shown even a small variation in its X-ray luminosity, much less orders of magnitude. Moreover, the 7 s periodicity is much longer than has been seen in any rotation-powered magnetospheric X-ray emission. The measured 80% pulsed fraction is well above that seen in other AXPs and is therefore unconstraining.

If the *Chandra* source is not the pulsar counterpart, what could it be? The source's salient properties are its hard spectrum, its approximate luminosity [$L_{\rm X} \simeq 10^{33}(d/5\ {\rm kpc})^2$], and its absence of variability on timescales of days to weeks. Given the photon index in the power-law spectral model, an active galactic nuclei (AGNs) interpretation is plausible (e.g., Watanabe et al. 2004; Nandra et al. 2005). We estimate the probability of our object being a background AGN from the predicted number density as a function of 2–10 keV flux according to *Chandra* ACIS-I deep observations of an "empty" Galactic plane region by Ebisawa et al. (2005). Coincidentally, their field of view is centered only ∼1° from our target, so it is likely that our fields share many common properties, such as absorption column. From Figure 24 of Ebisawa et al. (2005), the number of extragalactic point sources per square degree with flux greater than 3×10^{-13} erg s^{-1} cm^{-2} is ∼2. We expect ∼0.02 AGNs per circular region of radius 3′; hence, there is a ∼2% chance that this source is an AGN. Ebisawa et al. (2005) estimate JHK_s magnitudes of 21–23 mag for AGNs in their survey of the Galactic plane, where at least $A_{K_S} \sim 4$ mag of extinction may be present (Predehl & Schmitt 1995; Rieke & Lebofsky 1985). Even if we make the simple assumption that the X-ray and near-IR emission of AGNs are part of a single power-law spectrum, and that CXOU J184454.6−025653 should be 1–2 orders of magnitude brighter in the near-IR than most of their survey sample, as in the X-ray, it will still be difficult to confirm or rule out this possibility using IR observations, given its predicted faintness.

On the other hand, several types of Galactic objects could have properties similar to those of this source (see Muno et al. 2004 for a similar discussion). Winds from massive stars have similar spectral and flux properties, as do some high-mass X-ray binaries. However, these would tend to be IR-bright, in conflict with the *H*-band limit of 21 mag reported by Israel et al. (2004). A very small number of millisecond pulsars with similar X-ray luminosities are shown to possess comparably hard X-ray spectra (Kuiper & Hermsen 2004); although, until pulsations are seen from CXOU J184454.6−025653, it will be impossible to test this. One source class whose properties are similar to that of the point source in question are cataclysmic variables, specifically the class of intermediate polars. The observed near-IR emission is thought to be dominated by their dwarf companion and may be very faint given the absorption to this source. Muno et al. (2004) estimate $K \approx 22–25$ mag for sources at the Galactic

[9] See online magnetar catalog http://www.physics.mcgill.ca/∼pulsar/magnetar/main.html for a summary of AXP properties.

center, at comparable distance and suffering comparable extinction. This would be hard to detect.

Thus it seems clear that simply obtaining deeper near-IR observations will not be sufficient to determine whether this source is the counterpart. The most promising avenues for doing so therefore are either obtaining very deep X-ray observations in the hope of redetecting pulsations or else waiting patiently for the pulsar to grace us with another outburst bright enough for follow-up with other observatories.

We conclude that no matter what, AX J1845.0−0258 is interesting: if the counterpart is the detected source, then either AX J1845.0−0258 is not an AXP or AXPs can have a much wider range of spectral properties in quiescence than has been thought. If this is not the counterpart and the AXP identification is correct, then AXPs are capable of >2 order-of-magnitude flux variations, an interesting challenge to the magnetar model and also further evidence for a large, as yet undetected population.

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