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ASTRONOMY AND ASTROPHYSICS

The discovery of 96 s pulsations from the variable X-ray source 1SAX J0544.1-710 in the Large Magellanic Cloud*

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Abstract. We report the discovery of a ~ 96 s period X-ray pulsar in the direction of the Large Magellanic Cloud (LMC). The *Beppo*SAX X-ray spectrum is well fitted by an absorbed power-law model with photon index ~ 0.5. The unabsorbed luminosity in the 2-10 keV energy range is $\sim 9\times10^{35}$ erg s^{-1}. The *Beppo*SAX position ($40''$ uncertainty radius) of 1SAX J0544.1-710 was found to be consistent with that of the *ASCA* source AX J0448-70.4 and WGACAT (*ROSAT* PSPC) source 1WGA J0544.1-710. The source was detected four times between 1991 and 1996 at luminosity levels from $\sim 3\times10^{35}$ to 9×10^{35} erg s^{-1} (2-10 keV), while during a relatively deep *ROSAT* HRI observation an extrapolated 2-10 keV luminosity upper limit of $\sim 1\times10^{35}$ erg s^{-1} was obtained. Timing analysis of the *ASCA* data confirmed the *Beppo*SAX period discovery. Long-term flux variability is evident in the *ROSAT* and *Einstein* data. We revealed a pronounced Hα activity from a bright ($V\simeq 15$) likely Be-type star within the 8$''$*ROSAT* PSPC error circle. Its optical spectrum shows it is located in the LMC. These results strongly suggest that 1SAX J0544.1-710 is a transient X-ray pulsar in a massive binary system.

Key words: stars: emission-line, Be – stars: neutron – pulsars: individual: 1SAX J0544.1-710– galaxies: Magellanic clouds – X-rays: stars

1. Introduction

The number of X-ray pulsars found in the Magellanic Clouds (MCs) is small, but recent *ROSAT*, *ASCA* and *R*XTE observations have substantially increased the sample (Hughes 1994; Dennerl et al. 1995; Schmidtke et al. 1995; Israel et al. 1997; Marshall et al. 1997; Corbet et al. 1998; Lochner et al. 1998; Marshall et al. 1998). The greatest part of them was found to be associated with massive OB spectral type stars often showing intense Hα emission lines in their optical spectrum. Compared to those in our galaxy, X-ray binaries in the MCs are usually characterised by a lower galactic column density in their direction and a better determined, though larger, distance (50 kpc and 65 kpc for the LMC and the SMC, respectively). A soft X-ray spectral component, in addition to the characteristic hard power-law with exponential cutoff spectrum, is present in a small sample of them (Marshall, White & Becker 1983; Mavromatakis & Haberl 1993; Hughes 1994; Corbet et al. 1995; Campana 1996). In this letter we report the discovery of a new X-ray pulsar with a period of ~ 96 s during a *Beppo*SAX observation in the direction of the Large Magellanic Cloud (Cusumano et al. 1998). We also report the results of the spectral and timing analysis of archival *ASCA* and *ROSAT* observations. *ASCA* data confirm the presence of coherent pulsation, while the *ROSAT* observations reveal a long-term flux variability of the X-ray pulsar. Optical follow-up observations were performed at La Silla. The brightest source ($V\simeq 15$), within the narrow X-ray error circle reported by Haberl et al. (1998), showed a strong $H\alpha$ emission line with a redshift consistent with the star being located in the LMC.

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2. BeppoSAX observation

The Large Magellanic Cloud was observed by the Narrow Field Instruments (NFIs) onboard *Beppo*SAX (Boella et al. 1997a) during the Science Verification Phase on 27-28 October 1996. The primary target was CAL 87 (sequence 10013001; see Table 1). A bright X-ray source, hereafter named 1SAX J0544.1-710, at R.A. = $5^{\rm h}\,44^{\rm m}\,6\overset{\rm s}{.}6$, Decl. = $-71^\circ\,0'\,43\overset{''}{.}4$ (equinox 2000; $40''$ uncertainty radius, 90% confidence level) was visible in the NFIs field of view, $15'$ off-axis. In our analysis we used only the imaging instruments: the LECS, operating in the 0.1-10 keV energy range (Parmar et al. 1997), and the MECS operating in the 1.5-10 keV energy range (Boella et al. 1997b). The total observation length was $T = 155852$ s, while the effective exposure time was 26138 s and 138551 s for the LECS and MECS, respectively. The source counts were extracted from a $4'$ radius circular region (corresponding to an encircled energy of ~ 80% and ~ 90% for LECS and MECS, respectively) around the X-ray position.

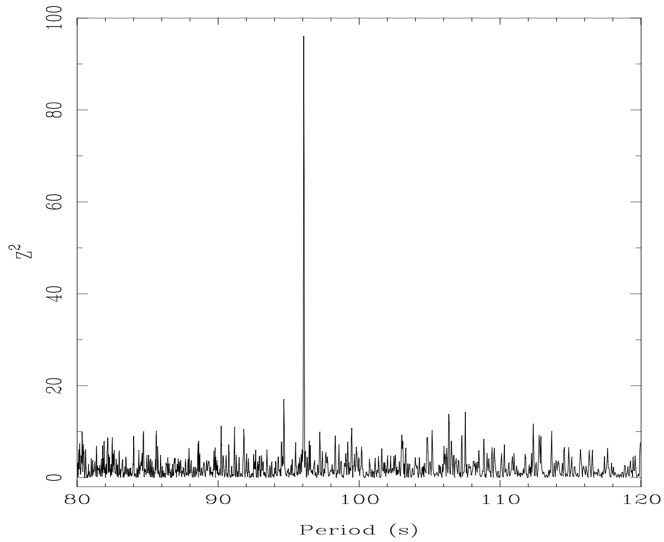

Fig. 1. Z^2 periodogram for the 2.0-10.0 keV *Beppo*SAX MECS light curve. Only periods between 80 s to 120 s are shown.

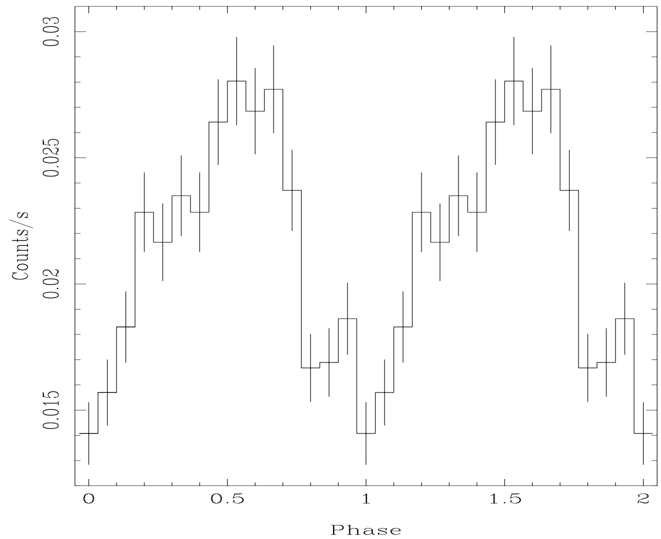

Fig. 2. 2-10 keV *Beppo*SAX MECS light curve of 1SAX J0544.1-710 folded using the best pulse period (96.079 s).

The local background was measured from a region of the image far from the detected field sources and compared with the background of archival blank fields. We did not find significant differences between the two and the latter was used in our analysis. The detected source counts, after background subtraction, were 132 and 2858 for the LECS and MECS, respectively.

2.1. Timing analysis

The LECS and MECS photon arrival times were converted to the barycenter of the solar system. A Z^2 test (Buccheri & de Jager 1989) was applied to the MECS data to search for coherent signals in the period interval between 0.010 s and 10000 s. A highly significant (7.8 σ) peak is present in the MECS data at a period of 96.08 ± 0.06 s (see Fig. 1). The period uncertainty is given by the Fourier frequency resolution ($1/T$). A better evaluation of the period was obtained by dividing the observation in five time intervals and fitting the modulation phases. The scatter of the phase residuals was consistent with a periodic modulation at P = 96.079 ± 0.007 s. The arrival time of the pulse minimum (adopted as phase 0) was JD $2450384.6300600 \pm 0.0000004$. Fig. 2 shows the background subtracted folded light curve in the MECS 2-10 keV band. The profile has a nearly sinusoidal shape with a pulsed fraction (semiamplitude of modulation divided by the mean source count rate) of $\sim$ 34%.

No significant peaks near the 96 s period were found in the LECS periodogram. This is not surprising since the total number of counts is $\sim$ 4% of those in the MECS. The corresponding pulsed fraction upper limit at 99% confidence level is $\sim$ 87%.

2.2. Spectral analysis

The spectral analysis was performed by using the response matrices taking into account the off-axis source position. The energy ranges used for the LECS and MECS were respectively 0.1-4.0 keV and 1.6-10 keV. The detected counts were grouped in order to have at least 20 counts in each energy channel. Among the single component models, an absorbed power-law gave the best fit result (Fig. 3). Due to the poor statistics of the LECS, we fixed the N_H to that predicted in the direction of the observed LMC field (7.47×10^{20} cm^{-2}). The best fit ($\chi^2/dof = 84.6/97$) gave a photon index of $0.53^{+0.12}_{-0.08}$ (see Table 2). The absorbed fluxes in the 0.1-2.4 keV and 2-10 keV energy bands are respectively $(0.39 \pm 0.01) \times 10^{-12}$ erg s^{-1} cm^{-2} and $(3.24 \pm 0.06) \times 10^{-12}$ erg s^{-1} cm^{-2}, corresponding to an unabsorbed X-ray luminosities of 1.3×10^{35} erg s^{-1} and 9.4×10^{35} erg s^{-1}, for an assumed distance of 49.2 kpc (Gieren et al. 1998). Uncertainties are given at 90% confidence level.

Phase resolved spectral analysis was performed on the MECS data. Spectra were accumulated in two phase intervals: [-0.25, +0.15] and [+0.15, +0.75], corresponding to the minimum and maximum of the pulsed emission. The best fit parameters are reported in Table 2. The X-ray emission at the phase interval around the maximum is softer than that around the minimum.

3. Previous X-ray observations

In order to confirm the presence of the $\sim$ 96 s pulsations found in the *Beppo*SAX data and to investigate the long-term behaviour of 1SAX J0544.1-710, we have searched for further observations in the databases of past X-ray missions. We found 8 pointings in the public archives: 1 obtained with *ASCA*, 5 with *ROSAT* and 2 with *Einstein* (see Table 1). Moreover the *Beppo*SAX position ($40''$ uncertainty radius) of 1SAX J0544.1-710 was found to be consistent with that of the already catalogued *ASCA* source AX J0448-70.4 and that of the WGACAT (*ROSAT* PSPC) source 1WGA J0544.1-710.

Table 1. Public X-ray observations of 1SAX J0544.1-710

Sequence (#)	Satellite	Instrument	Start Time (y M d h:m)	End Time (M d h:m)	Exposure$^\diamond$ (s)	Count rate (10^{-2} c/s)
10013001	*Beppo*SAX	MECS	1996 Oct 27 02:14	Oct 28 23:18	138551	2.06±0.05
10013001	*Beppo*SAX	LECS	1996 Oct 27 02:14	Oct 28 23:18	26138	0.51±0.04
44012000	*ASCA*	GIS	1996 Sep 06 06:00	Sep 08 08:30	69338	0.82 ±0.07
400012N00	*ROSAT*	PSPC	1991 Feb 19 04:55	Feb 19 21:33	14690	1.73±0.14
400013N00	*ROSAT*	PSPC	1991 Feb 23 08:00	Feb 25 14:42	12379	5.52±0.25
400335N00	*ROSAT*	PSPC	1993 Dec 15 21:35	Dec 16 11:10	11303	< 1.31
400655N00	*ROSAT*	HRI	1995 Jul 30 08:56	Jul 31 04:32	6004	< 0.25
300517N00	*ROSAT*	HRI	1996 Aug 13 11:49	Aug 22 00:15	13633	< 0.13
I0544S70/I0538S71	*Einstein*	IPC	1979 Apr 10 18:18	Apr 10 19:33	3030	< 1.28

$^\diamond$ Exposure times are vignetting corrected in the case of *ROSAT* PSPC observations.

Table 2. *Beppo*SAX spectral results

Parameter	LECS+MECS	MECS	
		[−0.25,+0.15]	[+0.15,+0.75]
N_H (10^{20} cm^{-2}).................	7.47 (fixed)	7.47 (fixed)	7.47 (fixed)
Photon index	$0.53^{+0.12}_{-0.08}$	$0.40^{+0.16}_{-0.13}$	$0.67^{+0.15}_{-0.10}$
F_X (10^{-12} erg cm^{-2} s^{-1})...	3.24 ±0.06	2.7 ±0.1	3.7±0.1
L_X (N_H=0; 10^{35} erg s^{-1})...	9.4	7.9	10.9
$\chi^2/(dof)$............................	84.6/(97)	58.7/(51)	44.6/(55)

Note. – The X-ray flux (absorbed) and the luminosity (unabsorbed) refer to the 2.0-10 keV energy band.

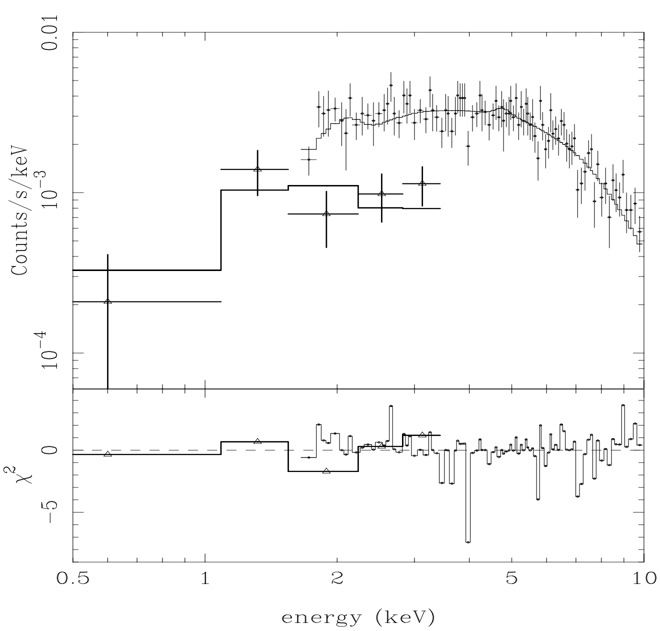

Fig. 3. *Beppo*SAX LECS and MECS energy spectrum together with the best fit model curve (top) and residuals (bottom). Note that the contribution to χ^2 is plotted + and - depending on whether the residual is positive or negative.

3.1. ASCA *GIS*

The *ASCA* observation of the CAL 87 field which includes the position of AX J0448-70.4 was performed ∼ 50 days before that of *Beppo*SAX (sequence 44012000; see Table 1). The total observation length was $T = 82272$ s, while the effective exposure time was 69338 s.

Due to the position of the source close to the edge of the field of view, the source counts of AX J0448-70.4 were extracted from a circle of only $4'$ (corresponding at 60% of the encircled energy) around the *ASCA* best position: R.A. = $5^{\rm h}\,44^{\rm m}\,7\overset{\rm s}{.}6$, Decl. = $-71^\circ\,0'\,9\overset{''}{.}2$ (equinox 2000; $40''$ uncertainty radius at 90% confidence level). Blank sky background was used for the spectral analysis. The detected source events after background subtraction were 568.

After correcting the photon arrival times to the barycenter of the solar system, a Z^2 test was applied to the data. The search for coherent signals was performed over a period interval around that detected by *Beppo*SAX assuming a maximum $|\dot{\rm P}|$ of ~ 3 s yr^{-1} (the highest ever observed from an X-ray pulsar: GX1+4; Makishima et al. 1988). A significant peak (5.5 σ) was revealed at $P = 96.10 \pm 0.05$ s. The period is compatible, within the uncertainties, with that derived from the *Beppo*SAX observation. Fig. 4 shows the *ASCA* GIS background subtracted folded light curve in the 0.5-10 keV band. It is similar to the MECS one, with a pulsed fraction of 44%.

The *ASCA* energy spectrum was fitted by an absorbed power-law model (Fig. 5 and Table 3). Due to the poor statistics, we fixed N_H to 7.47×10^{20} cm^{-2}. The best fit gave a photon index of 0.9 ± 0.4. The absorbed flux in the 2-10 keV energy band is $(1.5 \pm 0.2) \times 10^{-12}$ erg s^{-1} cm^{-2} which converts to a luminosity of 4.3×10^{35} erg s^{-1}. We note that the photon index is consistent,

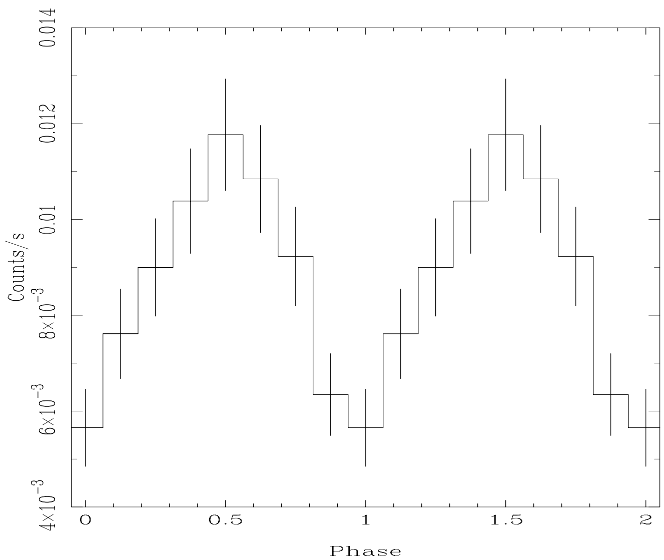

Fig. 4. 0.5-10 keV *ASCA* GIS light curve of 1SAX J0544.1-710 folded using the best pulse period.

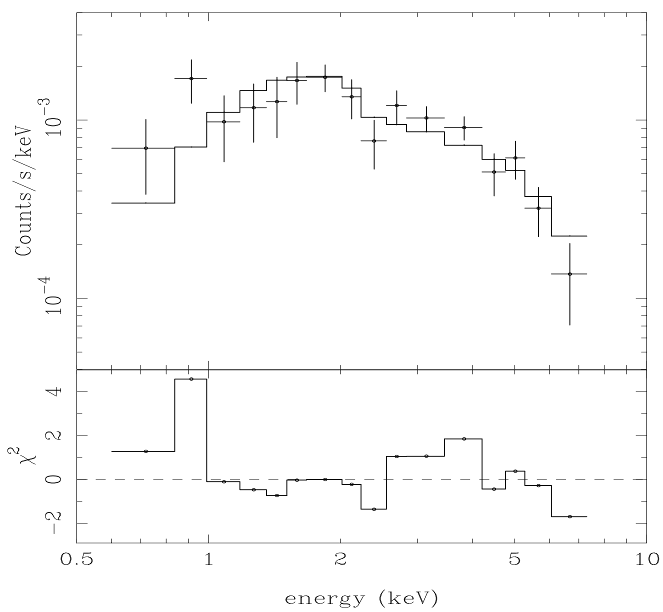

Fig. 5. *ASCA* GIS 1SAX J0544.1-710 energy spectrum together with the best fit model curve (top) and residuals (bottom). Note that the contribution to χ^2 is plotted + and - depending on whether the residual is positive or negative.

within the errors, with the *Beppo*SAX result. Keeping the photon index fixed to the *Beppo*SAX one, the fit is still good and the estimated luminosity (2-10 keV) is 5.5 $\times 10^{35}$ erg s^{-1}.

3.2. ROSAT *PSPC and HRI*

The Position Sensitive Proportional Counter (PSPC; 0.1-2.4 keV) and the High Resolution Imager (HRI; 0.1-2.4 keV) detectors onboard *ROSAT* observed the LMC several times. In particular five *ROSAT* observations including 1SAX J0544.1-710 were found in the public archive (see Table 1): three were carried out with the PSPC and two with the HRI. Moreover the *Beppo*SAX and *ASCA* error circles contain the previously catalogued *ROSAT* X-ray source 1WGA J0544.1-710 (R.A. = $5^{\rm h}\,44^{\rm m}\,7\overset{\rm s}{.}4$, Decl. = $-71^\circ\,0'\,58\overset{\prime\prime}{.}0$; equinox 2000, $20''$ of uncertainty radius, 90% confidence level; White et al. 1994) or RX J0544.1$-$7100 (R.A. = $5^{\rm h}\,44^{\rm m}\,6\overset{\rm s}{.}3$, Decl. = $-71^\circ\,0'\,50\overset{\prime\prime}{.}0$; equinox 2000, $8''$ of uncertainty radius, 90% confidence level; Haberl et al. 1998).

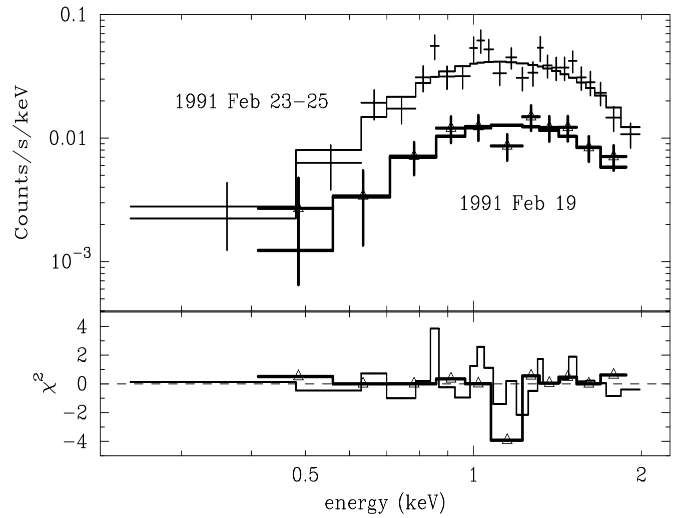

Fig. 6. *ROSAT* PSPC spectrum of 1SAX J0544.1-710 during 1991 February 19 and 23-25. The best fit power-law curve is shown, together with the corresponding residuals. The 1991 February 23-25 data and residuals are marked with thick lines and triangles. Note that the contribution to χ^2 is plotted + and - depending on whether the residual is positive or negative.

The PSPC counts were extracted from a region corresponding to an encircled energy of 95% around the X-ray position. Correction for the effective exposure map, particularly relevant near the edge of the field of view or the ribs of the detector window support structure, minimizes the effects of the satellite wobbling in the pointing direction. The vignetting correction was also taken into account.

1SAX J0544.1-710 was detected in two PSPC observations performed on 1991 February 19 and on February 23-25. During these two observations, separated by a time interval of only four days, the source count rate increased from 0.017 cts s^{-1} to 0.055 cts s^{-1}. The total counts in the extraction circles of the two pointings were $\sim$ 300 and $\sim$ 600 (60 and 50 counts are due to the background for the first and second observation, respectively).

Power spectra of the 1 s binned light curves were obtained after the correction of the arrival times to the solar system barycenter. Due to the high uncertainty of the *ASCA* derived period, no *a priori* period derivative could be assumed in the *ROSAT* data periodicity search. The search, as in the case of *ASCA*, was performed over a period interval around that detected by *Beppo*SAX and assuming a maximum $|\dot{\rm P}|$ of $\sim$ 3 s yr^{-1}. This translates into a search over an interval of $\sim$ 270 and $\sim$ 800

Table 3. *Beppo*SAX, *ASCA* and *ROSAT* spectral results.

Parameter	*Beppo*SAX LECS+MECS	*ASCA* GIS	*ROSAT* PSPC 1991 Feb 19	*ROSAT* PSPC 1991 Feb 23-25
N_H (10^{21} cm^{-2})...................................	0.747 (fixed)	0.747 (fixed)	$3.4^{+1.6}_{-2.6}$	$2.7^{+2.6}_{-2.1}$
Photon index	$0.53^{+0.12}_{-0.08}$	0.9±0.4	1.16 (fixed)	1.16 ±0.90
F_X (0.1-2.4 keV; 10^{-12} erg cm^{-2} s^{-1})...	0.39±0.01	–	0.27±0.04	0.72±0.06
F_X (2-10 keV; 10^{-12} erg cm^{-2} s^{-1}).....	3.24 ±0.06	1.5 ±0.2	–	–
L_X (0.1-2.4 keV; 10^{35} erg s^{-1})...........	1.3	–	1.6	4.5
L_X (2-10 keV; 10^{35} erg s^{-1})................	9.4	4.3	–	–
χ^2/(dof)...	84.6/(97)	15.5/(14)	8.4/(9)	23.1/(22)

Note. – the luminosity is relative to the unabsorbed flux.

Fourier frequencies centered on 0.0104 Hz for the February 19 and 23-25 observations, respectively. No significant peaks were found in any power spectrum at a 99% confidence level. Pulsed fraction upper limits are 53% and 65%, respectively. The highest peak (2.7 σ) is at $P = 96.85 \pm 0.01$ s and is present in both observations.

The PSPC spectrum was grouped in order to have energy bins with a minimum of 20 counts. The spectrum of the February 23-25 observation was well fitted by an absorbed power-law model (see Fig. 6; upper curve). The best fit ($\chi^2/dof = 23.1/22$) gave a photon index of 1.16 ± 0.90 and a column density $N_H = (2.7^{+2.6}_{-2.1}) \times 10^{21}$ cm^{-2} (see Table 3). Because of the large uncertainty, these results are in agreement with those of *Beppo*SAX. The unabsorbed 0.1-2.4 keV luminosity is $L_X \sim 4.5 \times 10^{35}$ erg s^{-1}. During the February 19 observation the number of photons (300) was too low to obtain an independent estimate of all spectral parameters. By keeping the photon index fixed to the best fit value of the February 23-25 observation, an unabsorbed X-ray luminosity of $L_X \sim 1.6 \times 10^{35}$ erg s^{-1} was derived (see Table 3 and Fig. 6).

By keeping the photon index fixed to the *Beppo*SAX value of 0.53, we obtained a good fit as well ($\chi^2/dof = 35.7/32$) for the two *ROSAT* PSPC observations together. The luminosity (0.1-2.4 keV) is only slightly different from the previous case: 1.2×10^{35} erg s^{-1} (February 19) and 3.5×10^{35} erg s^{-1} (February 23-25).

The source position is also included in three further *ROSAT* observations (see Table 1) during which only flux upper limits were obtained. In particular, it was observed by the HRI on 13-22 August 1996 (13633 s effective exposure time), only 15 days before the *ASCA* GIS detection (with pulsed emission). The extrapolated 2-10 keV luminosity upper limit of the source is 7.0×10^{34} erg s^{-1} if we use the *ROSAT* PSPC fit results, and 1.7×10^{35} erg s^{-1} if we use those obtained from the *Beppo*SAX data.

3.3. Einstein *IPC*

The 1SAX J0544.1-710 position lies within two *Einstein* Imaging Proportional Counter pointings. The total exposure time is 3030 s (see Table 1). The source was not detected. The 0.013 cts s^{-1} count rate upper limit corresponds to an X-ray luminosity of $\sim 1.3 \times 10^{35}$ erg s^{-1} (0.16-3.5 keV band).

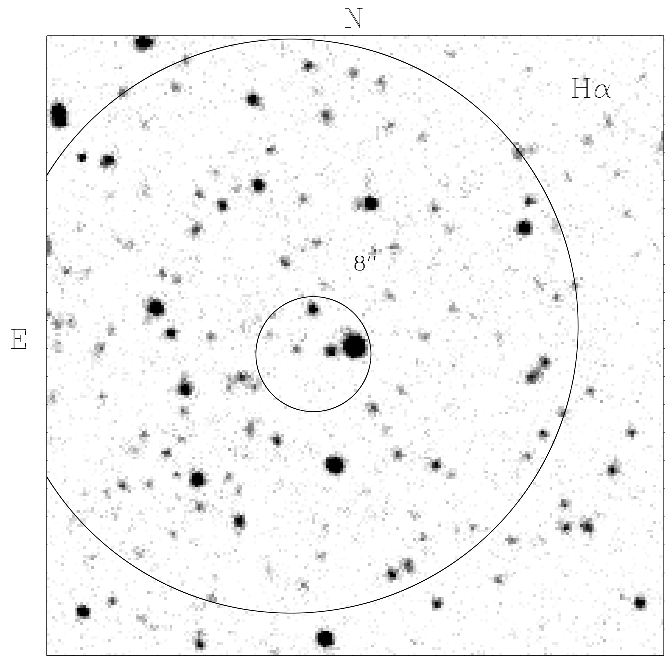

Fig. 7. $86'' \times 86''$ $H\alpha$ band image centered on the likely candidate companion of 1SAX J0544.1-710. The $8''$ radius *ROSAT* PSPC error circle is shown together with the *Beppo*SAX-MECS one.

4. Optical observations

Optical observations of the field containing the *Beppo*SAX error circle were performed on March 19, 1998 at La Silla (Chile) using the 1.54-m Danish telescope equipped with DFOSC (Danish Faint Object Spectrograph and Camera). Images were taken with the B, V, R and $H\alpha$ filters with exposure times of 20, 20, 10 and 350 s, respectively. Within the $80''$ error circle we identified ~ 130 objects in the R band down to a magnitude of ~ 20.6. Fig. 7 shows the $H\alpha$ image.

Fig. 8 shows the $H\alpha$ versus $(R - H\alpha)$ diagram of the identified objects. The brightest one lies at about $10''$ from the *Beppo*SAX error circle center and it is the only one showing

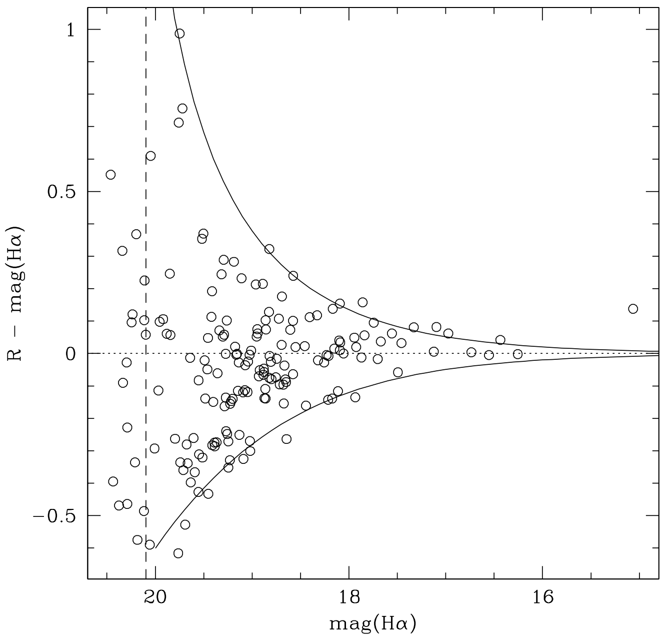

Fig. 8. $H\alpha$ versus $(R-H\alpha)$ diagram for all the optical sources within the $40''$ *Beppo*SAX error circle. The two solid lines mark the $\pm3\sigma$ error from the noise, while the dashed line corresponds to the $H\alpha$ filter 3σ detection limit. Only one object (the brightest) shows significant emission.

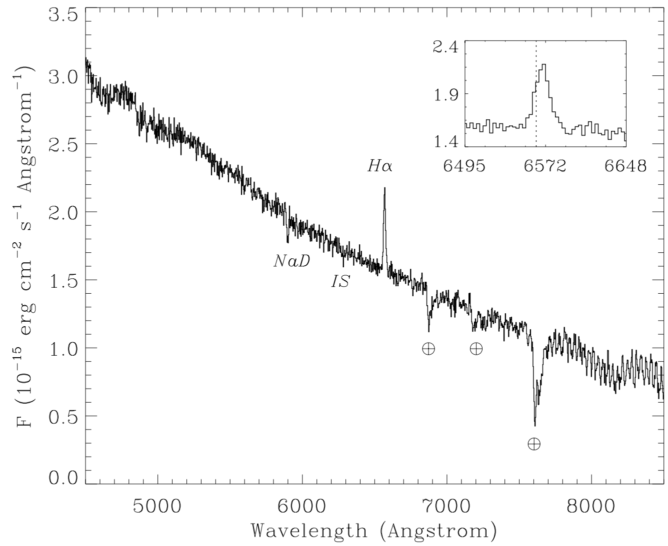

Fig. 9. Optical spectrum of MACS J0544−710#002 in the $4500-8500$ Å range. The inset shows the $H\alpha$ line with its rest position marked with a dotted line.

$H\alpha$ emission, with $(R-H\alpha)=0.14$. This object (at the center in Fig. 7) also falls inside the $8''$ radius *ROSAT* PSPC error circle (Haberl et al. 1998). Its coordinates (J2000) are R.A. = $5^{\rm h}\,44^{\rm m}\,5\overset{\rm s}{.}22$, Decl. = $-71^\circ\,0'\,50\overset{''}{.}7$; this is the same star, labelled as MACS J0544−710#002 in the Magellanic Catalogue of Stars by Tucholke et al. (1996).

Its magnitudes, determined with aperture photometry and calibrated using the Landolt (1992) RU149 and PG0942-029 sequences, are: $B=15.46$, $V=15.33$, $R=15.21$, $H\alpha=15.07$. The uncertainty of these measurements is 0.05 mag. The resulting $(B-V)=0.13$ and $(V-R)=0.12$ suggest that this object could be an A7 supergiant. On the other hand, from the $(B-V)$ versus $(R-H\alpha)$ diagram as reported in Grebel (1997), it falls in the Be stars region.

We then accumulated a 10 minutes spectrum of MACS J0544−710#002 using Grism 4 (range 300-900 nm) with a $2''$ slit, giving a spectral dispersion of ~ 3 Å/pixel. Wavelength and flux calibrations have been performed with He+Ne lamps and with the spectroscopic standard EG 21, respectively. The spectrum is shown in Fig. 9. Despite the wide wavelength range (~ 600 nm) covered by Grism 4, we decided to show only the spectrum between 450 and 850 nm due to the low sensitivity of the CCD below 450 nm and to the scattering at the edges of the spectrum.

A bright $H\alpha$ line is seen in the spectrum; its integrated flux is 1.01×10^{-14} erg s^{-1} cm^{-2}, with an equivalent width of 6.4 Å. The $H\alpha$ line red-shift of 6 Å we measured is consistent with the object being located within the Large Magellanic Cloud. No other major emission feature is visible. The spectrum also shows telluric bands and interstellar absorption lines. The Na doublet interstellar absorption is redshifted by 6 Å and has a total equivalent width of 1.3 Å: this indicates the presence of local interstellar matter which might redden the star. Assuming the empiric relation by Barbon et al. (1990), we find a color excess $E(B-V)=0.32$ for this star. If this value is correct, the reddening-corrected color indices for this star would be $(B-V)=-0.2$ and $(V-R)=-0.05$, which are typical of a B star. This correction has however to be taken with some degree of caution since the formula by Barbon et al. (1990) is evaluated for the interstellar reddening in the Galaxy. The different chemical composition of the interstellar medium in the LMC could originate a different relation between $E(B-V)$ and $EW_{\rm NaD}$ but we do not expect a different wavelength dependent reddening coefficients in the various optical bands (see Fig. 9 of Calzetti 1997).

5. Conclusion

During a *Beppo*SAX observation of the CAL 87 field in the Large Magellanic Cloud, we discovered ~ 96 s pulsations in the 2-10 keV flux of 1SAX J0544.1-710. The energy spectrum of the pulsar is well modeled by an absorbed power-law with photon index of ∼0.53 in the 0.1-10.0 keV energy band. The unabsorbed luminosity in the 0.1-2 keV and 2-10 keV energy band are 1.3×10^{35} erg s^{-1} and 9.4×10^{35} erg s^{-1}, respectively.

The *Beppo*SAX position of 1SAX J0544.1-710 was found to be consistent with that of the *ASCA* source AX J0448-70.4 and of the WGACAT (*ROSAT* PSPC) source 1WGA J0544.1-710. The timing analysis of the *ASCA* data confirmed the presence of significant pulsations at a period of ~ 96 s. The *ASCA* GIS 2-10 keV luminosity was 4.3×10^{35} erg s^{-1}.

Only in two, out of five, *ROSAT* observations the 96 s pulsar, previously catalogued as 1WGA J0544.1-710, was detected.

The estimated unabsorbed luminosity in the 0.1-2.4 keV energy band was 1.6×10^{35} erg s^{-1} and 4.5×10^{35} erg s^{-1} on 1991 February 19 and February 23-25, respectively. Due to the poor statistics no significant peaks (above 99% c.l.) were found in any of the performed power spectra with a pulsed fraction upper limit of the order of 60%. However, assuming the 2.7 σ signal at $P = 96.85$ s in the *ROSAT* data is real, and extrapolating to the *Beppo*SAX epoch, it would imply a period derivative $\dot{\rm P}$ = -0.14 s yr^{-1}. The *ROSAT* energy spectrum parameters of 1SAX J0544.1-710 are consistent with those of *Beppo*SAX and *ASCA*. The *ROSAT* HRI failed to detect 1SAX J0544.1-710 (2-10 keV luminosity upper limit of $\sim 1.0 \times 10^{35}$ erg s^{-1}) only 15 days before the *ASCA* detection implying a flux variability of at least a factor 10 over a time scale of 2.5 months. The relatively low peak X-ray luminosity detected from 1SAX J0544.1-710 suggests the source was observed either during the decay (or the rise) of a large outburst or during a low luminosity (possibly recurrent) one.

We performed multi-band optical observations that revealed a peculiar $H\alpha$ emitting object near the center of the X-ray error circle. Its color indices and the spectral analysis showed it is likely a Be star located in the LMC. These optical study findings together with the long-term X-ray variability of 1SAX J0544.1-710, suggest it is a transient X-ray pulsar in a high mass X-ray binary system hosting a Be-type star. Following this assumption and using the empirical relation between pulse and orbital period (Corbet 1986), an orbital period of ~ 100 days can be inferred for 1SAX J0544.1-710.

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