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Searching for New Be/X–ray Binaries in the SMC: the case of 1SAXJ0103−7209, XTEJ0055−724, RXJ0052−7319, XTEJ0111−7317 and 2E0050−7247

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Abstract. We obtained X–ray (ROSAT, *Beppo*SAX and ASCA) and optical observations of a sample of newly discovered X–ray pulsars. We here report on the discovery of the likely optical counterpart of five of them in the Small Magellanic Cloud: 1SAXJ0103−7209, XTEJ0055−724, RXJ0052−7319, XTEJ0111−7317 and 2E0050−7247.

1. Introduction

A search for the optical counterpart of a sample of recently discovered X–ray pulsars in the Small Magellanic Cloud (SMC) has been performed by means of a variety of techniques. HRI images, if available, were analyzed using both a sliding cell and a wavelet transform–based algorithm (Lazzati et al. 1999, Campana et al. 1999) in order to precisely single out the sources and their positions on the sky. Multicolor photometry (V, R and Hα bands) have also been obtained and photometry for each stellar object in the images have been derived with aperture and profile photometry by means of DAOPHOT II (Stetson 1987) as implemented in the ESO-MIDAS package. Low resolution spectroscopy has also been performed for objects in the X–ray error circles and where the photometric conditions were adequate data have been flux calibrated.

The most likely counterparts in X–ray error circles always turned out to be Be stars whose optical properties are in agreement with X–ray findings and this sample virtually doubles the number of previous known optical counterparts of X–ray pulsars in the MCs, and allows us to compare them with the same population in our Galaxy (see Israel et al. 1999).

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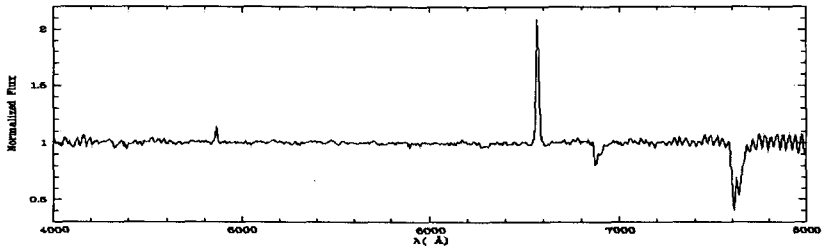

Figure 1. Low resolution spectrum for 1SAXJ0103−7209. The flux has been normalized to one.

2. 1SAXJ0103−7209

We report the discovery of a new X-ray pulsar (see also Israel et al. IAUC 6999), designated as 1SAXJ0103.2−7209, during a *Beppo*SAX observation of the SMC on 1997 July 27-28. The source showed nearly sinusoidal pulsations at a period of 345.2 ± 0.3 s. The energy spectrum is well fitted by a power law with photon index 1.0 ± 0.1, corresponding to an absorbed flux of 3×10^{-12} erg s^{-1} cm^{-2} (energy band 2-10 keV). The *Beppo*SAX source position (R.A. = $1^h03^m13^s$, Decl. = $-72°09'.3$, equinox 2000.0; estimated error radius $40''$) is consistent with the known supernova remnant SNR 0101−724 (Wang & Wu 1992) and the *Einstein* source 1E 0101.5−7225. The latter source was detected in all *Einstein*, ROSAT, and ASCA paintings since 1979 at a flux level of a few $\times 10^{-13}$ erg s^{-1} cm^{-2}, while no pulsations were detected. Multiband optical images and spectroscopy obtained with the 1.5-m Danish telescope at the ESO on 1998 July 24 show that the Be star of $m_V = 14.8$, originally suggested as the optical counterpart of the *Einstein* source (Hughes & Smith 1994), is the only star that shows strong Hα activity in the *Beppo*SAX error circle (Fig. 1).

3. XTEJ0055−724

During a *Beppo*SAX observation of the SMC on 1997 July 24-25, we detected X-ray pulsations of 58.95 ± 0.01 s from the pulsars XTEJ0055−724. The absorbed flux is about 7×10^{-12} erg s^{-1} cm^{-2} (2-10 keV). Optical spectra (1998 July 27; 1.5-m ESO telescope) obtained for the second brightest star (R.A. = $0^h54^m56^s$, Decl. = $-72°26'47''$) included in the X-ray error circle (see also Israel IAUC 6822) showed strong Hα and Hβ emission lines and we can confirm that this star is the most likely optical counterpart (see also Stevens et al. 1999). Also, a fainter star (R.A. = $0^h54^m57^s$, Decl. = $-72°26'48''$) included in the X-ray error circle showed an Hα emission line (Fig. 2).

4. RXJ0052−7319

We have identified the likely optical counterpart of RXJ0052−7319 (Lamb et al. IAUC 7081; Israel et al. IAUC 7101), a B-type star with $R = 14.54 \pm 0.03$ and $V - R = +0.08 \pm 0.04$ that is located at R.A. = $0^h52^m14^s.0$, Decl. = $-73°19'18''$

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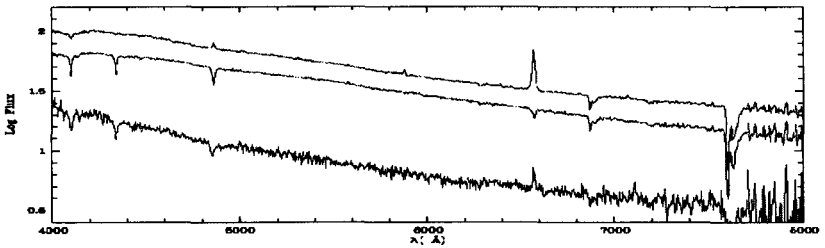

Figure 2. Low resolution spectra for three stars in the X-ray error circle of XTEJ0055−724.

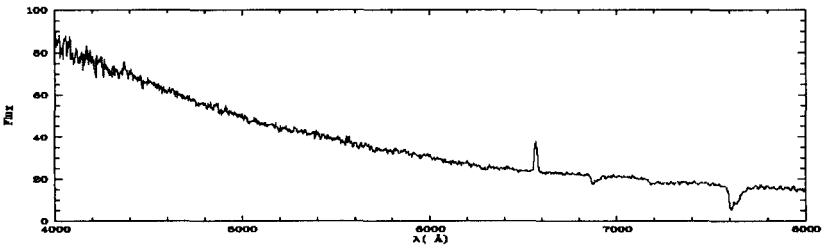

Figure 3. Low resolution spectrum for the counterpart of RXJ0052−7319.

(equinox 2000.0; estimated uncertainty 1″). A 1000 s optical spectrum taken on 1999 January 19 (range 350-900 nm, resolution 1.1 nm) shows an Hα emission line (EW = 1.2 nm, Fig. 3), clearly indicating the Be nature of the star. Within the 10″-radius X-ray error circle, there is another object ($R = 16.05 \pm 0.05$) that does not show any emission lines.

5. XTEJ0111−7317

The field of XTEJ0111−7317 (Chakrabarty et al. IAUC 7048) was observed with the 1.5m ESO Danish telescope on 1999 January 19, revealing two bright stars within the 30″ error circle (Chakrabarty et al. IAUC 7062); the fainter one is a B-type star ($R = 15.29 \pm 0.03$, $V - R = +0.06 \pm 0.04$), located at R.A. = $1^h11^m08^s.4$, Decl. = −73°16′46″ (1″ uncertainty). A 1000 s spectrum (range 350-900 nm, resolution 1.4 nm) revealed strong Hα and Hβ emission lines (EW = 2.1 and 0.1 nm, respectively), indicating that this source is the likely counterpart of the X-ray transient. The brighter star ($R = 14.30 \pm 0.03$) does not show any emission lines (Fig. 4). No other objects brighter than $R = 17.3$ are found within the error circle. Another B-type star ($R = 14.55 \pm 0.03$, $V - R = +0.05 \pm 0.04$), located at R.A. = $1^h11^m25^s.9$, Decl. = −73°17′27″ (30″ outside the X-ray error circle), shows strong Hα and Hβ emission lines (EW = 3.6 and 0.3 nm).

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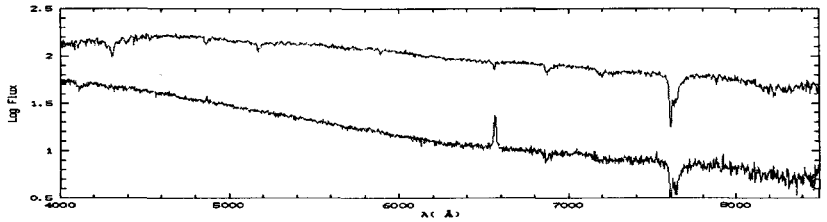

Figure 4. Low resolution spectra for the two brightest stars in the error circle of XTEJ0111−7317.

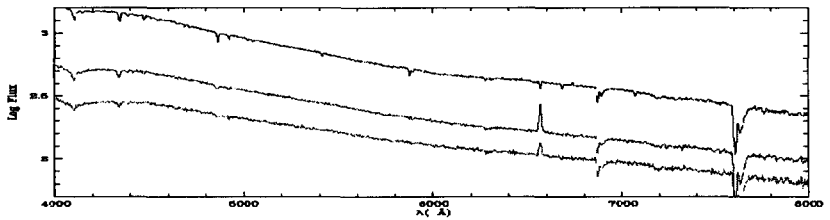

Figure 5. Low resolution spectra for the two Be stars and a comparison star in the X–ray error circle of 2E0050−7247.

6. 2E0050−7247

During a systematic search for periodic signals in a sample of ROSAT PSPC light curves, we discovered ~ 8.9 s X–ray pulsations in 2E0050−7247, a variable X–ray source in the SMC. The source was detected several times between 1979 and 1993 at luminosity levels ranging from $\sim 5\times10^{34}$ erg s^{-1} to 1.4×10^{36} erg s^{-1} with both the *Einstein* IPC and ROSAT PSPC. The X–ray energy spectrum is consistent with a power-law spectrum that steepens as the source luminosity decreases. Optical imaging and spectroscopy performed with the 90cm Dutch, 1.5m and 1.5m Danish ESO telescopes from 1996 to 1999 (Israel et al. 1997) revealed a pronounced Hα activity from at least two B stars in the X-ray error circles (Fig. 5, see also Stevens et al. 1999). These results strongly suggest that the X–ray pulsar is in a Be-type massive binary.

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