

# The nature of RX J0052.1-7319

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**Abstract.** The nature of the X-ray source RX J0052.1-7319 is discussed from observational data obtained from ROSAT observations performed in 1995 and 1996. An accurate position is derived from ROSAT HRI observations of the source performed in 1995. The 6'' error circle contains two OGLE microlensing optical variables of which one has previously been identified with a 14.5 mag Be-type star in the Small Magellanic Cloud. During the October 1996 observation RX J0052.1-7319 was found to be extremely bright (with a count rate of  $\sim 1.1 \pm 0.1 \text{ s}^{-1}$ ) and 15.3 $\pm$ 0.1 second X-ray pulsations have been discovered during this observation. This would indicate for a high-mass X-ray binary nature of the source. During the 1995 observation the X-ray source detected at the position of RX J0052.1-7319 was a factor  $\sim$ 200 fainter. The corresponding luminosity has changed from  $\sim 5.2 \times 10^{37} \text{ erg s}^{-1}$  to  $\sim 2.6 \times 10^{35} \text{ erg s}^{-1}$  assuming SMC membership of the source. It is unclear whether the so far unidentified second optical variable contributes to the X-ray flux of the source.

**Key words:** accretion, accretion disks – stars: individual: RX J0052.1-7319 – stars: magnetic fields – stars: neutron – stars: rotation – X-rays: stars

## 1. Introduction

RX J0052.1-7319 (= 1E 0050.3-7335) has been discovered during Einstein observations (e.g. Seward and Mitchell 1981). But the nature of the source has not been determined making use of these Einstein observations. The source has been found to coincide with the nebular complex DEM 70 in the SMC (Davies, Elliot & Meaburn 1976). RX J0052.1-7319 has been found as spectrally hard and highly variable X-ray source in the ROSAT PSPC X-ray survey of Kahabka & Pietsch (1996) and it is Number 84 in the ROSAT PSPC X-ray catalog of Kahabka et al. (1999).

Due to its spectral hardness and the observed time variability of the X-ray flux it has been classified as a persistent and highly variable X-ray source and a candidate X-ray binary system in the Small Magellanic Cloud by Kahabka & Pietsch (1996).

The detection of X-ray pulsations for this source have not been reported for a long time and the nature of the source re-

mained unclear. But recently 15.3 sec X-ray pulsations have been discovered during ROSAT HRI and BATSE observations performed in Nov/Dec 1996 (Lamb et al. 1999). This fact indicated for an X-ray pulsar associated with this source.

The source is contained in the catalog of X-ray sources detected with the ASCA satellite in the field of the SMC (Yokogawa et al. 1999). It has been found to be a comparatively weak X-ray source and no pulsations have been found for this source from the ASCA observations.

Searches for an optical counterpart in a 10'' error circle for the X-ray source have been performed by Israel & Stella (1999). They found a B-type star with  $R=14.54 \pm 0.03$  which shows H $\alpha$  emission indicating for a Be type nature of the star. In addition they found another object with  $R=16.05 \pm 0.05$ .

The  $R=14.5$  mag star has been found to be contained in the OGLE microlensing database towards the SMC by Udalski et al. (1999). It is a long-term variable star with quasiperiodic light variation of amplitude 0.13 mag in the I band. A possible period of  $\sim$ 600-700 days has been found for the star. But it is rather uncertain due to the comparable length of the used OGLE SMC database (of 745 days, from 1997 Jan. 17 to 1999 Feb. 1). A second variable object with  $V=15.9$  has been found in the X-ray error circle which may be identical with the object found by Israel & Stella (1999).

Here we discuss the possible nature of RX J0052.1-7319. We make use of two ROSAT HRI observations performed in 1995 and 1996 in a systematic program by the author to study the time variability of (candidate) X-ray binary systems in the Small Magellanic Cloud. First and preliminary results have been reported elsewhere (Kahabka 1999a,b).

## 2. Observations

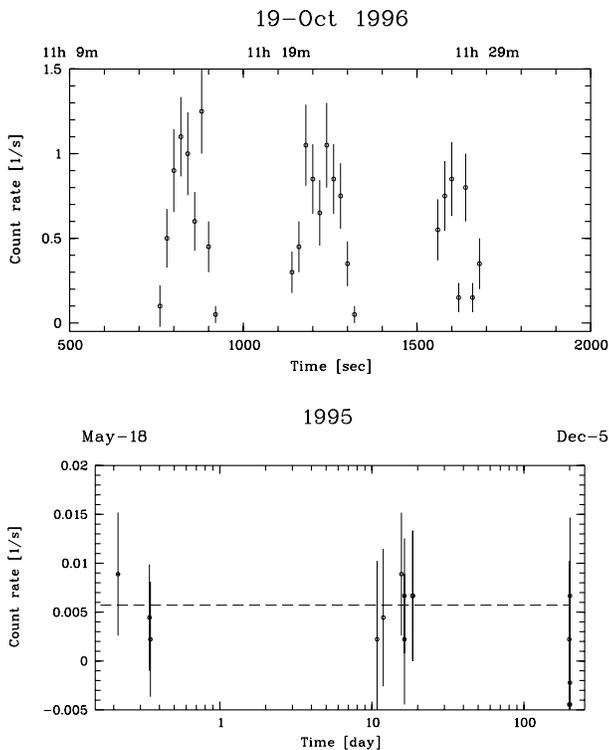
The observations discussed in this paper have been performed with the HRI detector of the ROSAT satellite (Trümper 1983) in 1995 and 1996. In Table 1 a log of these observations is given. The 1995 observation was centered on the SMC supernova remnant SNR 0049-736 = N19 (cf. Kahabka et al. 1999). The 1996 observation was centered on the supersoft X-ray source RX J0048.4-7332 (cf. Kahabka et al. 1994). The source was at an off-axis angle of 5' and 21' in the 1995 and 1996 observation respectively. It was in the 1996 observation close to the rim of the HRI detector and affected by the varying attitude of the satellite.

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**Table 1.** Data of the ROSAT HRI observations of RX J0052.1-7319 in 1995 and 1996 analysed in this work.

Obs. ID	Observation time		Exposure [ksec]	Count rate [1/s]
	[UT]	[JD - 2400000]		
wg500419h (and h-1)	18-5-1995 10:23 – 5-12-1995 11:32	49855.93285 – 50056.98065	15.6	$(5.7 \pm 2.5) \times 10^{-3}$
wg300513h	19-10-1996 11:08 – 19-10-1996 11:41	50375.96413 – 50375.98681	1.6	$1.1 \pm 0.1$



**Fig. 1.** Upper panel: Light curve of RX J0052.1-7319 for the October 1996 observation (background subtracted and corrected for off-axis vignetting). A source extraction radius of  $100''$  has been used and the bin size is 20 seconds. Three observation time intervals of  $\sim 200$  second each can clearly be seen. The large variation in count rate is due to the fact that the source is seen at the very edge of the field of view of the HRI. Due to the wobble of the detector and the variable aspect of the satellite the source was temporarily to a large degree outside of the detector. Therefore the mean count rate was low. Lower panel: Light curve of RX J0052.1-7319 for the May–Dec 1995 observation (background subtracted and corrected for vignetting). A source extraction radius of  $50''$  has been used and the bin size is 7.5 minutes.

### 3. Results

#### 3.1. The X-ray position

During the 1995 HRI observation the source had a HRI count rate of  $\sim 5.6 \pm 2.5 \times 10^{-3} \text{ s}^{-1}$  and was quite faint. It was in the central field of the detector and an accurate position could be determined. The observation extended over more than half a year (cf. Fig. 1). Three time intervals have been analyzed independently to constrain the X-ray position and to determine the positional uncertainty due to a variable satellite aspect. As there are two time variable optical counterparts in the previously reported ROSAT PSPC  $11''$  error box of RX J0052.1-7319 (Ka-

**Table 2.** X-ray position of RX J0052.1-7319 determined from ROSAT HRI observations in 1995 and 1996. The 90% confidence error radius is  $\sim 6''$  for the 1995 observations and in the range  $\sim (5-30)''$  for the 1996 observation respectively.

Time interval	R.A. (2000)	Decl. (2000)
1995 observation		
18-May 10:19 – 18-May 18:56	0:52:14.9	-73:19:15
29-May 06:03 – 30-May 08:43	0:52:16.1	-73:19:14
3-Jun 01:36 – 5-Jun 23:53	0:52:15.8	-73:19:11
1996 observation		
19-Oct 11:08 – 19-Oct 11:41	0:52:14.1	-73:19:16

**Table 3.** Pulse period search in the 1996 October 19 ROSAT HRI observation of RX J0052.1-7319. The effective exposure time and count rate as used in the time window for the period search are given. Only time intervals when the point-spread function was within the detector due to the wobble of the attitude have been chosen.

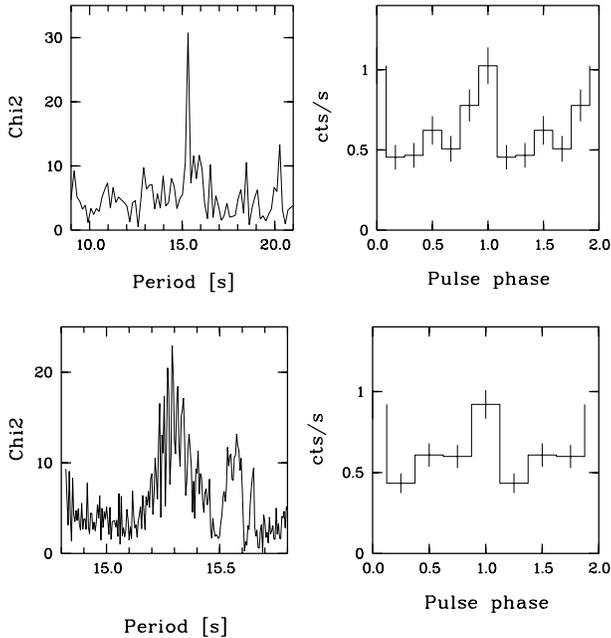
Observation date	300513h 1996 Oct 19
Effective expos. (ksec)	0.47
Pulse period (s)	15.3(1)
$\chi^2 / \text{dof}$	31/5
Effective count rate [1/s]	0.65

habka & Pietsch 1996) a more accurate HRI position may allow to determine the association of the X-ray source to either of these sources. As the nature of the optically fainter source seems not to be constrained (e.g. in terms of a stellar source or a background AGN) it is also not clear whether it is a detectable X-ray source. In principle both objects may contribute to the observed X-ray source.

From the May–June 1995 ROSAT HRI observation a mean position R.A. =  $0^{\text{h}}52^{\text{m}}15^{\text{s}}.5$ , Decl. =  $-73^{\circ}19'14''$  (equinox 2000.0;  $\pm 4''$  at 90% confidence) has been reported by Kahabka (1999a).

We derive from the three observations (cf. Table 2) an average position R.A. =  $0^{\text{h}}52^{\text{m}}15^{\text{s}}.6$ , Decl. =  $-73^{\circ}19'13''$  (equinox 2000.0) which is in agreement with the position derived by Kahabka (1999a). From the mean deviation we derive an error radius of  $\sim 4''$  (at 90% confidence). Assuming that this is the positional error due to the uncertain satellite attitude we constrain the total (statistical and systematic) positional error at 90% confidence to  $6''$ .

The source is observed during the 1996 observation at a large off-axis angle of  $21'$ . The 50% power radius of the HRI point-spread function is considerable ( $32''$ ) at such an off-axis



**Fig. 2.**  $\chi^2$  distribution for the 15.3 sec pulse period search applied to period data of RX J0052.1-7319 in October 1996. Upper panel for 6 phase bin and wider period range and lower panel for 4 phase bins and more narrow period range.

angle but the position may be more accurately determined due to the central core of the point-spread function. The statistical 90% error radius determined with a maximum likelihood analysis in EXSAS is  $\sim 5''$ . The positional uncertainty taking systematic errors into account may be between these two limits. Still the position of the source found in the 1996 observation agrees with the position of the source found in the 1995 observation. For comparison the position derived for the symbiotic nova RX J0048.4-7332 during the same observation deviates  $\sim 5''$  from the optical position (Morgan 1992).

### 3.2. X-ray pulsations

We have searched for the 15.3 sec pulsations reported in this source by Lamb et al. (1999) in the 1996 data. The event times have been projected from the spacecraft to the solar-system barycenter with standard EXSAS software (Zimmermann et al. 1994). In addition the photon event table has been screened by selecting the wobble phase interval (0.8,1.2) using standard EXSAS software. This procedure has been applied as the point-spread function of the source is heavily affected by the very outer edge of the detector. Due to the satellite wobble the point-spread function of the source was temporarily outside of the detector. By applying this selection we screened the data and accepted only time intervals when the point-spread function was to a large fraction within the detector. The source count rate is strongly affected by this effect. From Fig. 1 we see that the maximum effective background subtracted count rate was large, i.e.  $\sim 1.1 \pm 0.1 \text{ s}^{-1}$ . Assuming that this is the count rate when the source was to a large degree inside the detector we

conclude that the source has about this count rate. Interestingly this is about  $1.5 \times$  the count rate as reported from the ROSAT HRI observations of Lamb et al. (1999) which were performed  $\sim 1$ -2 months after our observation. Apparently the peak of the outburst occurred either during our observation or even earlier. Assuming a spectrum with an absorbing column density of  $3 \cdot 10^{21} \text{ H} - \text{atoms cm}^{-2}$ , a photon index of 1.0, a HRI count rate of  $1.1 \text{ s}^{-1}$  corresponds to a flux of  $9.6 \cdot 10^{-11} \text{ erg cm}^{-2} \text{ s}^{-1}$  and to an absorbed luminosity of  $4.1 \cdot 10^{37} \text{ erg s}^{-1}$  and to an unabsorbed luminosity of  $5.2 \cdot 10^{37} \text{ erg s}^{-1}$ .

A best period of  $15.3 \pm 0.1$  sec has been derived from the 1996 data (cf. Fig. 2). The period is not very accurately constrained as the observation was short (1.5 ksec) and additional screening of the data reduced the effective exposure time to 0.47 ksec. We used 6 and 4 phase bins respectively and the pulse profile is given in Fig. 2. The period uncertainty as determined from the relation  $\delta P = P / (T_{\text{obs}} \times N_{\text{bin}})$  (with the effective exposure time  $T_{\text{obs}}$  and the number of phase bins  $N_{\text{bin}}$ ) would be  $\sim 10^{-2}$  seconds. The significance of the period detection is  $\sim 6\sigma$ . The 1996 October 19 observation was performed about one month before the outburst reported by Lamb et al. (1999) from the ROSAT HRI and BATSE observations.

## 4. Discussion

Kahabka & Pietsch (1996) have argued that RX J0052.1-7319 may be a persistent and highly variable X-ray source as it has already been observed during Einstein observations (Seward & Mitchell 1981; Inoue et al. 1983; Wang & Wu 1992). The source has been detected in ROSAT PSPC observations performed in October 1991 and April 1992, and with the HRI performed in May to December 1995 and October 1996. The count rate was varying by a large factor  $> 100$ . The source has not always been detected during ROSAT observations. Cowley & Schmidtke (1997) report that the source was not detected during HRI observations performed in April, May, and October 1994. They derive an upper limit to the count rate of  $< 0.004 \text{ s}^{-1}$  which is still in the range of count rates derived for the 1995 observation ( $0.0057 \pm 0.0025 \text{ s}^{-1}$ ). Analysis of archival PSPC observations performed in December 1992 and May 1993 do not reveal a significant detection of the source which has been at large off-axis angles of  $44'$  and  $35'$  respectively. The  $2\sigma$  upper limit PSPC count rate is  $\sim 2 \times 10^{-3} \text{ s}^{-1}$  for the May 1993 observation and a factor of 10 lower than the PSPC count rate derived for the April 1992 observation (Kahabka & Pietsch 1996). The rise in X-ray flux (of  $\sim 0.01 \text{ counts s}^{-1} \text{ d}^{-1}$ ) during the April 1992 observation could be due to the onset of an X-ray outburst which might have happened around August 1993 and decayed till November 1993. This would give an outburst repetition time of 3.2 years (or 1200 days). This behaviour is in agreement with a High-Mass Be-type X-ray binary system which undergoes high states during periastron passage of the neutron star.

The source was indeed observed during the 1996 observations for about 50 days (from 1996 October 19 till December 9) in an outburst with an HRI count rate of  $0.7 - 1.2 \text{ s}^{-1}$ . If this

outburst is due to the periastron passage of the neutron star than constraints can be derived for the orbital period which has to be considerably longer.

RX J0052.1-7319 is in the OGLE SMC6 field and an about 2 year observational database exists for this source. Two OGLE detected variable stars are within the reported X-ray error circle of RX J0052.1-7319, SMC SC6 99923 and SMC SC6 99991 (Udalski 1999). The first is a long-term variable star with quasiperiodic light variation of amplitude 0.13 in the I band (the mean I magnitude is 14.5). The possible period is 600-700 days, but it is uncertain due to the length of the database. The second optical variable has an I magnitude in the range 16.1 to 15.7 with a pronounced linear rise in the I magnitude during a 200 day period. It may be identical with the object reported by Israel & Stella 1999 (IAU Circ. No. 7101), which remains so-far unidentified. No  $H\alpha$  line emission has been detected from this object. It could in principle be a background AGN. This may explain the fact that no X-ray pulsations have been detected with ASCA although an X-ray source has been detected at the position of RX J0052.1-7319. Both objects are within the 6'' HRI error circle.

It appears to be likely that RX J0052.1-7319 is associated with the 14.5 mag Be-type star and is a Be-type transient. But it cannot be excluded that the X-ray source is confused by a second near-by source, e.g. a time variable background stellar source or AGN. If it is one X-ray source then it also has to be understood why it is active in X-rays for nearly two months. If the source follows the relation between rotation period and orbital period found by Corbet for the galactic Be-type transients (Corbet 1986) then the 15.3 second rotation period would correspond to an orbital period of  $\sim 40$  days. If the duration of the 1996 outburst is indeed  $\sim 50$  days then this would argue against activity related to periastron passage for such a short orbital period.

Another possibility is that the high-mass star associated with RX J0052.1-7319 periodically undergoes "eruptions" or outbursts (of duration a few months) during which it efficiently transfers mass towards the neutron star companion (cf. Marlborough 1997). If the star settles back to its normal configuration the mass-transfer reduces. Such a scenario would still be consistent with an orbital period of  $\sim 40$  days in this system as the duration of the X-ray outburst would be determined by the duration of the outburst of the star. A Be star undergoing periodic outbursts in our Galaxy is  $\lambda$  Eri. In a recent work Mennickent et al. (1998) found for this system an outburst repetition period of 469 days (or 939 days). The duration of the outburst is  $\sim 120$  days.

The similarity of the long-period lightcurve of  $\lambda$  Eri and of the OGLE microlensing light curve of the 15.9 star SMC SC6 99991 in the error box of RX J0052.1-7319 is striking. As it is not clear whether this object is a stellar source (in the SMC) or a time variable background AGN (cf. Kawaguchi et al. 1998) it could be related to RX J0052.1-7319. Note that the fact that no  $H\alpha$  emission is observed (Israel & Stella 1999) also refers to  $\lambda$  Eri (Mennickent et al. 1998). One problem with this identification may be that the observed 1996 X-ray outburst

occurred outside the "optical outburst" although "projecting" the SMC SC6 99991 light curve onto the  $\lambda$  Eri light curve a repetition period of  $\sim 3.5$  years would be obtained which is quite close to the X-ray outburst period of RX J0052.1-7319 estimated from the X-ray observations.

## 5. Summary

For RX J0052.1-7319 15.3 sec pulsations have been detected in ROSAT HRI X-ray observations performed in October 1996. The count rate of  $1.1 \pm 0.1 \text{ s}^{-1}$  observed during this observation is the highest reported so far for this source. The corresponding X-ray luminosity is  $\sim 5 \times 10^{37} \text{ erg s}^{-1}$  for SMC distance. The position of the X-ray source coincides with a 14.5 mag Be-type star in the SMC and a fainter  $\sim 15.9$  mag object which remains so-far unidentified. Both objects have been found to be variable with a timescale of a few hundred days and are contained in the OGLE microlensing database. It is unclear which is the optical counterpart of RX J0052.1-7319 or if even both objects contribute to the observed X-ray flux.

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