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M-type giants as optical counterparts of X-ray sources 4U 1700+24 and 4U 1954+319⋆

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ABSTRACT

We observed with *Chandra* two peculiar galactic X-ray sources, 4U 1700+24 and 4U 1954+319, which are suspected to have a M-type giant star as optical counterpart, in order to get a high-precision astrometric position for both of them. The peculiarity of these sources lies in the fact that these are the only two cases among low-mass X-ray binaries (LMXBs), besides the confirmed case of GX 1+4, for which the companion can possibly be a M-type giant. We found that in both cases the field M-type giant star is indeed the counterpart of these X-ray sources. We also determined the distance to 4U 1954+319 to be ∼1.7 kpc. This result suggests that a number of faint ($L_X \sim 10^{32}$–10^{34} erg s^{-1}) Galactic X-ray sources are "symbiotic X-ray binaries", that is, wide-orbit LMXBs composed of a compact object, most likely a neutron star, accreting from the wind of a M-type giant.

Key words. astrometry – stars: binaries: general – X-rays: binaries – stars: neutron – stars: individuals: 4U 1700+24 – stars: individual: 4U 1954+319

1. Introduction

Low-mass X-ray Binaries (LMXBs) are interacting systems composed of an accreting compact object and a low-mass (1 $M_\odot$ or less) main-sequence or slightly evolved late-type star. However, among the more than 150 LMXBs known (Liu et al. 2001) in only one case (GX 1+4; Chakrabarty & Roche 1997) the secondary is a M-type giant. Thus, in principle, LMXBs of this kind are extremely rare. There are however two more LMXBs which might have a M-type giant as optical companion, but the X-ray position is not known with sufficiently high precision to securely confirm (or reject) the association; moreover, their optical spectra do not conclusively show the characteristic features of accreting binaries (e.g. Balmer and He II emission lines and/or a non-stellar continuum blueward of ∼5500 Å). These X-ray sources are 4U 1700+24 and 4U 1954+319.

4U 1700+24 has an X-ray flux which is variable up to a factor of 50 in the 2−10 keV band, and X-ray spectrum which shows a hardening trend with increasing X-ray flux (Dal Fiume et al. 1990; Masetti et al. 2002). The source exhibits huge X-ray aperiodic time variability: the average fractional variation in the flux during an *EXOSAT* observation was ∼50% on timescales from tens to thousands of seconds (Dal Fiume et al. 1990).

Masetti et al. (2002) presented an X-ray monitoring (performed by using data from 4 different satellites and spanning about 15 years) of this source, showing substantial long-term variability. Its X-ray spectrum is also variable in the long term. A high-resolution X-ray spectroscopy analysis of 4U 1700+24 during a phase of enhanced activity was performed with *XMM-Newton* by Tiengo et al. (2005).

Garcia et al. (1983), using the X-ray position afforded by the *HEAO-1* satellite, identified this source in the optical with a "normal" M-type giant star, HD 154791, located at ∼800 pc from Earth. Masetti et al. (2002) gave a more accurate spectral classification (M2−3 III) to this putative optical companion and, in turn, a new distance estimate (d = 420 pc). The latter authors moreover explained the absence of the features typical of accreting systems in the optical spectrum of HD 154791 as due to the fact that the luminosity of the giant star is ∼200 times larger that any possible optical emission from the accreting stream, and so the latter is overwhelmed by the former.

All of the X-ray characteristics described above are interpreted as produced by a neutron star (NS) accreting from the wind of the M-type giant.

The 1.5−12 keV *RXTE*/ASM light curve[1] of 4U 1700+24 suggests the possibility of a periodicity of around 400 days, which would be compatible with the pulsation period of a M-type giant star or with a wide orbit for the system (Masetti et al. 2002). Indeed, Galloway et al. (2002) found an optical spectroscopic period of 404 days, fully consistent with the above X-ray finding.

However, Morgan & Garcia (2001), using a *ROSAT*/HRI pointing, gave the most precise position for 4U 1700+24 available up to now, with a 90%-confidence level error radius of 2$''$.1. This localization is inconsistent, at a 3.6-σ level, with the extremely accurate position (with 90% error of 14 mas, considering also the proper motion uncertainties) of the M giant provided by *Hipparcos* (Perryman et al. 1997). This fact, if confirmed, would suggest that the actual counterpart of 4U 1700+24 is a background object, and that HD 154791 is probably an interloper along the line of sight.

⋆ Partly based on observations collected at the Astronomical Observatory of Bologna in Loiano, Italy.

[1] Available at http://xte.mit.edu/ASM_lc.html

Table 1. Log of the *Chandra* and *XMM-Newton* observation used in this paper.

Spacecraft	Object	Start day	Start time (UT)	On-source time (ks)
XMM-Newton	4U 1700+24	11 Aug. 2002	15:38:22	5.96
XMM-Newton	4U 1700+24	07 Mar. 2003	01:08:08	5.02
XMM-Newton	4U 1700+24	09 Mar. 2003	01:03:49	8.97
XMM-Newton	4U 1700+24	13 Aug. 2003	15:23:12	13.6
Chandra	4U 1700+24	23 Apr. 2005	02:45:03	1.15
Chandra	4U 1954+319	18 Jan. 2006	20:24:30	1.18

The X-ray source 4U 1954+319 was first detected by the *Ariel* satellite at a flux of ~10 mCrab in the 2−10 keV range (Warwick et al. 1981), but the first pointed observation was that by *EXOSAT* (Cook et al. 1984). These authors showed that the source has a dramatic flaring behaviour on timescales of several minutes, with variations in intensity up to a factor of 10. This variability is still present, as demonstrated by the 1.5−12 keV *RXTE*/ASM light curve of this source.

4U 1954+319 has been subsequently observed by *Ginga* (Tweedy et al. 1989), confirming the previous *EXOSAT* results. The spectrum observed by both *EXOSAT* and *Ginga*, albeit complex below ~4 keV, is adequately described above this energy by the typical X-ray pulsar spectrum, namely a power law modified at high energy by an exponential cutoff (White et al. 1983). An in-depth X-ray spectroscopic monitoring of 4U 1954+319 will be presented in Rigon et al. (in preparation).

Both the spectral shape and the large amplitude flaring activity seen in 4U 1954+319 are typical of X-ray binary systems with a NS and a high mass companion (e.g., White et al. 1995). Anyway, a univocal identification of the optical counterpart of this source is still lacking. The two best X-ray positions (J2000) for 4U 1954+319 were provided by *ROSAT* and are: RA = $19^{\rm h}55^{\rm m}41\overset{\rm s}{.}5$, Dec = +32°05′46″ (Voges et al. 1999) and RA = $19^{\rm h}55^{\rm m}42\overset{\rm s}{.}6$, Dec = +32°06′07″ (*ROSAT* Team 2000) with 3σ error boxes of radius 9″ and 11″, respectively. These positions are however inconsistent with each other; also, in the middle of the two error boxes, and positionally inconsitent with both, a *V*-band 12th magnitude M-type giant star is present (Tweedy et al. 1989). Two more possible fainter candidates (Tweedy et al. 1989) do not show any significant H_α activity. Therefore the classification of the companion of 4U 1954+319 as a close M-type giant (Cook et al. 1984) or as a distant and reddened Be star (Tweedy et al. 1989) is still not clarified.

In order to conclusively answer, for both X-ray objects, the problem of the identification of their true optical counterpart, we performed two short ("snapshot") observations of their fields in X-rays with *Chandra*. Thanks to the superb astrometric accuracy afforded by this spacecraft, we will restrict the error box regions of 4U 1700+24 and 4U 1954+319 by a factor greater than 10 and 200 in size, respectively. Moreover, for the latter source the uncertainty between the two available X-ray positions will be solved. For 4U 1700+24 we also analyzed *XMM-Newton* archival data to further support the *Chandra* results.

As we will show in the following, this comparison will allow us to definitely confirm beyond any reasonable doubt that HD 154791 is the true optical counterpart of 4U 1700+24, and to determine that the real counterpart of 4U 1954+319 is the bright M-type giant mentioned above. The study of this latter object will be complemented by optical spectroscopy afforded in order to determine the spectral type and distance to this source.

2. The *Chandra* pointings

We observed 4U 1700+24 (obs. ID: 5455) and 4U 1954+319 (obs. ID: 5456) with the HRC-I instrument (Murray et al. 2000) onboard *Chandra* (Weisskopf et al. 2002) for ~1 ks each. The log of these observations is reported in Table 1. CIAO[2] v3.2.2 and CALDB[3] v3.1.0 were used for the data reduction. The aspect-solution 90% confidence level error radius of $0\overset{\prime\prime}{.}6$ was assumed for the positions of the X-ray sources determined from these observations.

The position of the X-ray sources in the *Chandra* images was obtained using the `celldetect` command. In the 4U 1700+24 data set, only a single bright source is detected at the center of the 30′ × 30′ HRC field of view. For the case of 4U 1954+319, besides the target object, a faint ($S/N \sim 3$) source was detected close to the edge of the detector. The *Chandra* PSF degradation at large offset angles[4], together with the faintness of this object, does not allow one to use it to further refine the astrometry of this pointing.

Thus, in both cases, we cannot tie the internal *Chandra* astrometry to that of optical and/or near-infrared catalogues in order to improve the positional uncertainty afforded by the HRC-I X-ray data.

3. *XMM-Newton* archival data

For the sake of completeness, we also retrived four archival *XMM-Newton* (Jansen et al. 2001) pointings (Obs. IDs: 0155960601, 0151240201, 0151240301 and 0151240401) performed on 4U 1700+24 with the EPIC instrument (Strüder et al. 2001) in "small window" mode between August 2002 and August 2003 (see Table 1). With these data we determined the average X-ray position of the source using the XMM-SAS[5] v6.5.0 software.

In this case also, due to the choice of readout mode which guaranteed a field of view not larger than 4′ × 4′, the *XMM-Newton* astrometry could not be tied to optical/near-infrared catalogues; thus, the accuracy of the *XMM-Newton* position for 4U 1700+24 is limited by the typical EPIC angular resolution, that is, 4″ (90% confidence level).

4. Optical observations

One medium-resolution optical spectrum of the red star in the field of 4U 1954+319 was acquired starting at 23:50 UT of 15 July 2004 in Loiano (Italy) with the Bologna Astronomical

[2] Available at `http://cxc.harvard.edu/ciao/`

[3] Available at `http://cxc.harvard.edu/caldb/`

[4] See the *Chandra* Proposers' Observatory Guide: `http://cxc.harvard.edu/proposer/POG/html/`

[5] Available at `http://xmm.vilspa.esa.es/sas/`

Table 2. Coordinates (equinox: J2000) and 90% confidence level errors of the positions of the X-ray source 4U 1700+24 and of the optical star HD 154791.

Source	RA (J2000)	Dec (J2000)	Error	Spacecraft and instrument	Reference
HD 154791	$17^{h}06^{m}34^{s}.5183$	+23°58′18″.554	0″.014	*Hipparcos*	Perryman et al. (1997)
4U 1700+24	$17^{h}06^{m}34^{s}.517$	+23°58′18″.66	0″.6	*Chandra*/HRC	this paper
4U 1700+24	$17^{h}06^{m}34^{s}.6$	+23°58′14″.0	2″.1	*ROSAT*/HRI	Morgan & Garcia (2001)
4U 1700+24	$17^{h}06^{m}34^{s}.6$	+23°58′17″.3	3″.5	*ROSAT*/PSPC	Morgan & Garcia (2001)
4U 1700+24	$17^{h}06^{m}34^{s}.56$	+23°58′18″.7	4″	*XMM-Newton*/EPIC	this paper

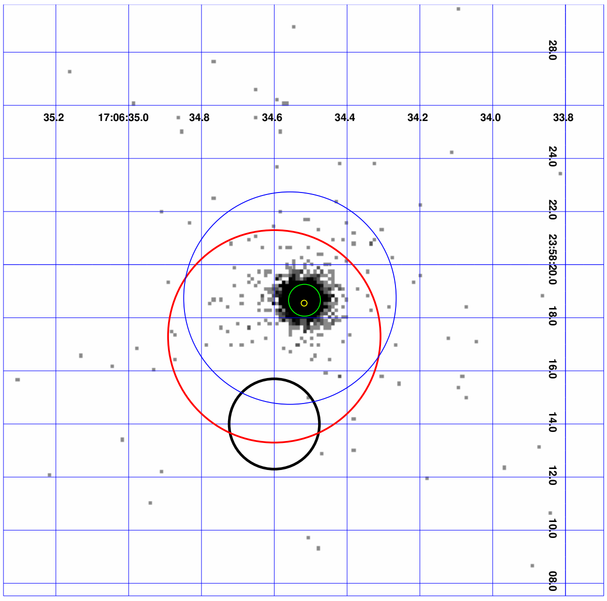

Fig. 1. *Chandra*/HRC image of 4U 1700+24 in the 0.1–10 keV band. Superimposed to the X-ray image, the following 90% confidence level error circles are drawn: *Chandra*/HRC (light circle; radius: 0″.6), *XMM-Newton*/EPIC (thin dark circle; radius: 4″), *ROSAT*/PSPC (medium dark circle; radius: 3″.5) and *ROSAT*/HRI (thick dark circle; radius: 2″.1); see Table 2 for details. The *Hipparcos* position of the optical star HD 154791 is indicated by the small light dot. North is at top, East is to the left. The field size is ~20″ × 20″.

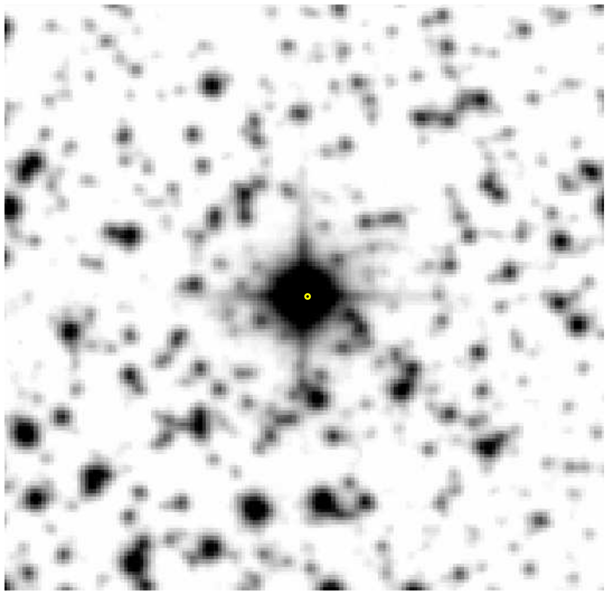

Fig. 2. DSS-II-Red image of the field of 4U 1954+319 with superimposed the 0.1–10 keV band *Chandra*/HRC X-ray position (small circle). As one can see, the HRC position falls on the bright M-type star in the 4U 1954+319 field. North is at top, East is to the left. The field size is ~2′.5 × 2′.5.

Observatory 1.52 metre "G.D. Cassini" telescope plus BFOSC. The exposure time was 1 min. The Cassini telescope is equipped with a 1300 × 1340 pixels EEV CCD. Grism #4 and a slit width of 2″ were used, providing a 3500−8700 Å nominal spectral coverage. The use of this setup secured a final spectral dispersion of 4.0 Å/pix.

The spectrum, after correction for flat-field, bias and cosmic-ray rejection, was background subtracted and optimally extracted (Horne 1986) using IRAF[6]. Wavelength calibration was performed using He-Ar lamps, while flux calibration was accomplished by using the spectrophotometric standard BD +25° 3941 (Stone 1977). Wavelength calibration uncertainty was ~0.5 Å; this was checked by using the positions of background night sky lines.

[6] IRAF is the Image Reduction and Analysis Facility made available to the astronomical community by the National Optical Astronomy Observatories, which are operated by AURA, Inc., under contract with the U.S. National Science Foundation. It is available at `http://iraf.noao.edu/`

5. Results

5.1. 4U 1700+24

The *Chandra*/HRC and *XMM-Newton*/EPIC X-ray astrometric results obtained for 4U 1700+24 are reported in Fig. 1 and in Table 2, together with all of the most accurate localizations available in the literature for this source and for the star HD 154791. As one can see from Fig. 1, the HRC error box is perfectly consistent with the position of optical star, and inconsistent at a 3.5-σ level with the *ROSAT*/HRI localization of Morgan & Garcia (2001). Moreover, HD 154791 lies within one HRC detector pixel from the PSF peak of the *Chandra* X-ray image.

The *XMM-Newton* data confirm this result, as they also are completely consistent with the more accurate *Chandra* position, whereas the consistency with the *ROSAT*/HRI position is apparently marginal.

Rescaling the interloper chance probabilities computed in Morgan & Garcia (2001) using the more precise *Chandra* error box, we find that the numbers computed by these authors become smaller by a factor of ~40.

This confirms, beyond any reasonable doubt, that HD 154791 is indeed the actual optical counterpart of 4U 1700+24, and that this X-ray source is indeed a LMXB composed of a compact object (most likely a NS) orbiting a M-type

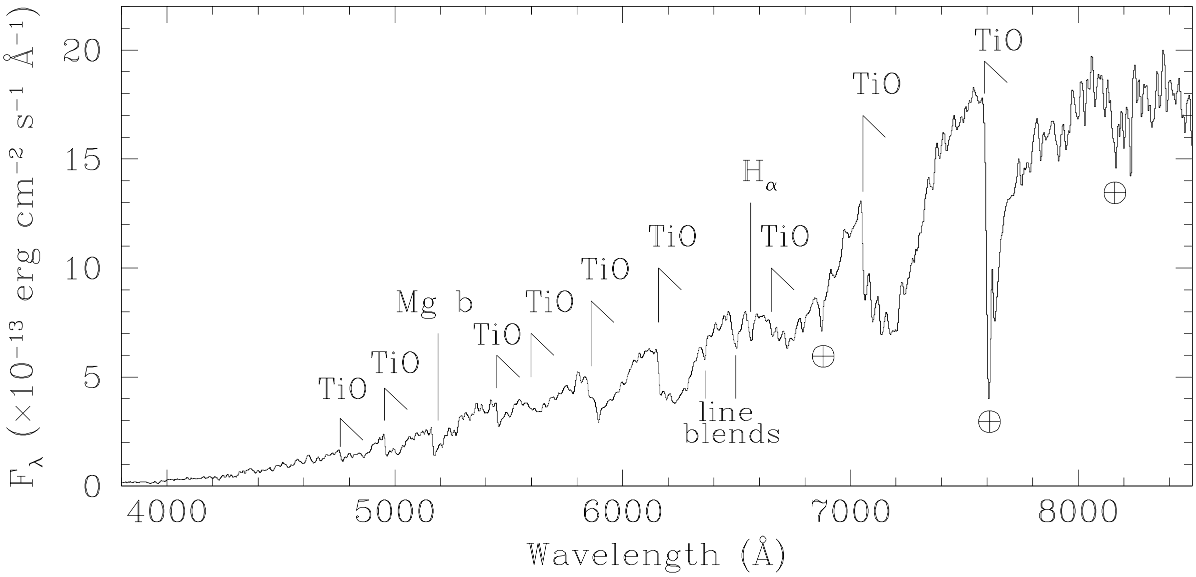

Fig. 3. 3800−8500 Å optical spectum of the optical counterpart of 4U 1954+319 obtained with the Loiano 1.52-meter telescope plus BFOSC on 15 July 2004. The spectrum is typical of a star of type M4-5 III (see text). The telluric absorption bands are marked with the symbol ⊕.

giant and located at 420 pc from Earth (Masetti et al. 2002; Galloway et al. 2002).

The HRC-I data do not contain spectral information; however, for 4U 1700+24 we determine an HRC-I 0.1−10 keV count rate of 2.33 ± 0.06 counts s^{-1}. This corresponds to a 2−10 keV flux of ~2×10^{-10} erg cm^{-2} s^{-1} assuming a Comptonization spectrum as described in Masetti et al. (2002) for the *BeppoSAX* data. This value converts into a 2−10 keV luminosity of ~4×10^{33} erg s^{-1} using the above distance estimate from Masetti et al. (2002). The comparison of this value with the long-term monitoring of this source reported in Masetti et al. (2002) indicates that 4U 1700+24 was in an intermediate X-ray activity state during the *Chandra* observation.

5.2. 4U 1954+319

The position obtained with *Chandra*/HRC for 4U 1954+319, overlaid on the relevant DSS-II-Red[7] survey image, is shown in Fig. 2. Its coordinates, RA = $19^h55^m42\overset{s}{.}272$, Dec = $+32°05'48\overset{''}{.}82$ (J2000) are consistent within the errors with the position of the USNO-A2.0[8] bright star U1200_13816030, that is, the bright red object mentioned in Tweedy et al. (1989). This star lies at RA = $19^h55^m42\overset{s}{.}33$, Dec = $+32°05'49\overset{''}{.}1$ (with an uncertainty of $0\overset{''}{.}25$: Assafin et al. 2001; Deutsch 1999), that is, $0\overset{''}{.}79$ from the X-ray position. The two positions are thus consistent with each other at a 1.8σ level, and we can confidently state that this star is the optical counterpart of 4U 1954+319.

The inspection of the optical spectrum of this object (reported in Fig. 3) clearly shows the typical features of a M-type star (Jaschek & Jaschek 1987): it is dominated by TiO absorption bands and no emission features typical of X-ray binaries are apparent. The H_α line is also detected in absorption. We also detect, among the main spectral features, the Mg "b" absorption around 5170 Å and two atomic line blends of metal intersystem lines of Fe I, Ti I, Cr I, Ba I, Ca I, Mn I, Co I and Ni I located at 6352 Å and 6497 Å (see e.g. Turnshek et al. 1985). Telluric absorption features are moreover detected at 6870 and 7600 Å.

Using the Bruzual-Persson-Gunn-Stryker[9] (Gunn & Stryker 1983) and Jacoby-Hunter-Christian[10] (Jacoby et al. 1984) spectroscopy atlases, we then compared the spectrum of star U1200_13816030 with those of several late-type stars. The best match is obtained with stars HD 110964 (M4 III) and SAO 62808 (M5 III). Thus, we classify U1200_13816030 as a star of spectral type M4-5 III.

Next, from the *R*-band magnitude information extracted from the USNO-B1.0 catalogue (Monet et al. 2003) and from the $V-R$ color index of a M4 III star (1.58; Ducati et al. 2001), we determine a V magnitude of 10.7 for the counterpart of 4U 1954+319. Assuming that a star of this spectral type has an absolute magnitude $M_V = -0.5$ (Lang 1992), we obtain a distance $d = 1.7$ kpc. We however stress that this should conservatively be considered as an upper limit to the distance to this object, as the effect of the (presently unknown) amount of the interstellar absorption along the line of sight was not accounted for.

The HRC-I 0.1–10 keV count rate for 4U 1954+319 is 0.014 ± 0.004 counts s^{-1}, indicating that the source was quite faint at the time of the *Chandra* observation. This was also confirmed by the *RXTE*/ASM data for this object. This count rate corresponds to a 2−10 keV flux of $\sim1.2\times10^{-12}$ erg cm^{-2} s^{-1} assuming a Comptonization spectrum as in Rigon et al. (in preparation). This value implies a 2−10 keV luminosity of ~4×10^{32} erg s^{-1} using the distance estimate obtained above from the optical spectroscopy.

All of the above makes 4U 1954+319 a more distant twin of the X-ray binary 4U 1700+24, both in terms of spectral type of the companion and of X-ray luminosity range. This system is therefore most likely hosting a compact object accreting from

[7] Available at http://archive.eso.org/dss/dss

[8] The USNO-A2.0 catalogue is available at http://archive.eso.org/skycat/servers/usnoa

[9] Available at: ftp://ftp.stsci.edu/cdbs/cdbs1/grid/bpgs/

[10] Available at: ftp://ftp.stsci.edu/cdbs/cdbs1/grid/jacobi/

the wind of a M-type giant star showing no spectral signatures other than those of its spectral type. The latter characteristic is due to the low X-ray luminosity when compared to the bolometric luminosity of a M4 III star ($\sim 2 \times 10^{36}$ erg s^{-1}; Lang 1992); so, reprocessing of variable X-ray emission is completely lost into the glare of the M-type giant companion. Thus, a scenario similar to that described by Masetti et al. (2002) for 4U 1700+24 may also be applicable to the system 4U 1954+319.

6. Conclusions

The positional information obtained from the *Chandra* observations presented in this paper showed that the optical counterparts of X-ray sources 4U 1700+24 and 4U 1954+319 are both M-type giant stars to a high confidence level. Besides, spectroscopy of the optical counterpart of 4U 1954+319 allowed us to determine its spectral type and its distance.

The detection of two such systems within the 4th *Uhuru* catalogue (Forman et al. 1978) indicates that a number of wide systems composed of a compact object and a giant star may be present in the Galaxy, eventually evolving (as suggested by Gaudenzi & Polcaro 1999) to a tighter configuration similar to that observed in the X-ray binary GX 1+4 (Chakrabarty & Roche 1997).

Thus, in conclusion we suggest that many faint X-ray objects in the Galaxy may belong to this subclass of binary systems (which, by analogy with symbiotic stars in which a white dwarf accretes from the wind of a M-type giant companion, can be dubbed "symbiotic X-ray binaries") and that this may be a non-negligible evolution channel for LMXBs.

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References

Assafin, M., Andrei, A. H., Vieira Martins, R., et al. 2001, ApJ, 552, 380
Chakrabarty, D., & Roche, P. 1997, ApJ, 489, 254
Cook, M. C., Warwick, R. S., & Watson, M. G. 1984, *EXOSAT* observations of 3A1954+319, in X-ray Astronomy '84, ed. M. Oda, & R. Giacconi (Komaba: Institute of Space and Astronautical Science), 225
Dal Fiume, D., Poulsen, J. M., Frontera, F., et al. 1990, Il Nuovo Cimento, 13 C, 481
Deutsch, E. W. 1999, AJ, 118, 1882
Ducati, J. R., Bevilacqua, C. M., Rembold, S. B., & Ribeiro, D. 2001, ApJ, 558, 309
Forman, W., Jones, C., Cominsky, L., et al. 1978, ApJS, 38, 357
Galloway, D., Sokoloski, J. L., & Kenyon, S. J. 2002, ApJ, 580, 1065
Garcia, M. R., Baliunas, S. L., Doxsey, R., et al. 1983, ApJ, 267, 291
Gaudenzi, S., & Polcaro, V. F. 1999, A&A, 347, 473
Gunn, J. E., & Stryker, L. L. 1983, ApJS, 52, 121
Horne, K. 1986, PASP, 98, 609
Jacoby, G. H., Hunter, D. A., & Christian, C. A. 1984, ApJS, 56, 257
Jansen, F., Lumb, D., Altieri, B., et al. 2001, A&A, 365, L1
Jaschek, C., & Jaschek, M. 1987, The Classification of Stars (Cambridge: Cambridge Univ. Press)
Lang, K. R. 1992, Astrophysical Data: Planets and Stars (New York: Springer-Verlag)
Liu, Q. Z., van Paradijs, J., & van den Heuvel, E. P. J. 2001, A&A, 368, 1021
Masetti, N., Dal Fiume, D., Cusumano, G., et al. 2002, A&A, 382, 104
Monet, D. G., Levine, S. E., Canzian, B., et al. 2003, AJ, 125, 984
Morgan, Jr., W., & Garcia, M. R. 2001, PASP, 113, 1386
Murray, S. S., Austin, G. K., Chappell, J. H., et al. 2000, Proc. SPIE, 4012, 68
Perryman, M. A. C., Lindegren, L., Kovalevsky, J., et al. 1997, A&A, 323, L49
ROSAT Team 2000, *ROSAT* News No. 71
Stone, R. P. S. 1977, ApJ, 218, 767
Strüder, L., Briel, U., Dennerl, K., et al. 2001, A&A, 365, L18
Tiengo, A., Galloway, D. K., Di Salvo, T., et al. 2005, A&A, 441, 283
Turnshek, D. E., Turnshek, D. A., Craine, E. C., & Boeshaar, P. C. 1985, An atlas of digital spectra of cool stars (Tucson: Western Research Company)
Tweedy, R. W., Warwick, R. S., & Remillard, R. 1989, 3A1954+319: a possible supergiant X-ray binary?, in Two Topics in X-Ray Astronomy, Vol. 1: X-Ray Binaries, ed. J. Hunt, & B. Battrick, ESA SP-296, 661
Voges, W., Aschenbach, B., Boller, T., et al. 1999, A&A, 349, 389
Warwick, R. S., Marshall, N., Fraser, G. W., et al. 1981, MNRAS, 197, 865
Weisskopf, M. C., Brinkman, B., Canizares, C., et al. 2002, PASP, 114, 1
White, N. E., Swank, J. H., & Holt, S. S. 1983, ApJ, 270, 711
White, N. E., Nagase, F., & Parmar, A. N. 1995, The properties of X-ray binaries, in X-ray Binaries, ed. W. H. G. Lewin, J. van Paradijs, & E. P. J. van den Heuvel (Cambridge: Cambridge Univ. Press), 1