On the ultra-compact nature of the neutron star system 1RXS J170854.4-321857: insights from X-ray spectroscopy

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ABSTRACT
The relatively small family of ultra-compact X-ray binary systems is of great interest for many areas of astrophysics. We report on a detailed X-ray spectral study of the persistent neutron star low mass X-ray binary 1RXS J170854.4-321857. We analysed two *XMM-Newton* observations obtained in late 2004 and early 2005 when, in agreement with previous studies, the system displayed an X-ray luminosity (0.5–10 keV) of $\sim 1 \times 10^{36}$erg s^{-1}. The spectrum can be described by a Comptonized emission component with $\Gamma \sim$1.9 and a distribution of seed photons with a temperature of $\sim$ 0.23 keV. A prominent residual feature is present at soft energies, which is reproduced by the absorption model if over-abundances of Ne and Fe are allowed. We discuss how similar observables, that might be attributed to the peculiar (non-solar) composition of the plasma donated by the companion star, are a common feature in confirmed and candidate ultra-compact systems. Although this interpretation is still under debate, we conclude that the detection of these features along with the persistent nature of the source at such low luminosity and the intermediate-long burst that it displayed in the past confirms 1RXS J170854.4-321857as a solid ultra-compact X-ray binary candidate.

Key words: accretion, accretion discs – stars: individuals: 1RXS J170854.4-321857 – stars: neutron – X-rays: binaries

1 INTRODUCTION

The vast majority of the known galactic population of stellar-mass black holes (BHs) and a significant fraction of the neutron stars (NS) are found in low mass X-ray binaries (LMXBs). These stellar systems have sub–solar companion stars that transfer material to the compact object via Roche lobe overflow. Among LMXBs, the population of ultra-compact X-ray binaries (UCXBs), comprised by systems with orbital periods shorter than 80 min, is of particular interest. These short periods imply small Roche lobes, in which only degenerated (hydrogen poor) donor stars can fit. UCXBs are unique laboratories to study accretion processes in hydrogen deficient environments as well as some of the fundamental stages of binary evolution (e.g., common-envelope phase, Nelemans et al. 2009; Nelemans & Jonker 2010; Tauris 2018). Last but not least, UCXBs will be primary sources for gravitational waves studies at low-frequencies by the forthcoming LISA mission (Nelemans 2018; Tauris 2018).

Although the predicted number of UCXBs in our galaxy is $\sim 10^6$ (Nelemans et al. 2009), at present only 14 systems have been confirmed (i.e. with reported orbital periods; see e.g., Strohmayer et al. 2018; Heinke et al. 2013, and references therein). One of the reasons of this scarcity is that measuring the orbital periods is not always straightforward. Standard techniques include the search for periodic eclipses/modulations for sources seen at high inclination or Doppler-delayed pulses in the case of pulsar acretors. In the optical regime, modulations due to accretion disc super-humps or triggered by irradiation of the companion star also enable to infer orbital solutions. When direct measurements are not feasible, we need to use indirect evidences to identify UCXB candidates.

in 't Zand et al. (2007) proposed a method based on the disc instability model (DIM; see Lasota 2001 for a review) that identifies systems persistently accreting at very low luminosities as potential UCXBs. Indeed, a fraction of the now confirmed UCXB population were initially candidates proposed by this method. In addition, optical spectroscopic studies have been used to test the ultra-compact nature of several systems. This is done by investigating the absence/presence of emission/absorption features in the spectra, which provide hints on the chemical composition of the accreted material, and thus, on the nature of the companion star (Nelemans et al. 2004, 2006; in 't Zand et al. 2008; Hernández Santisteban et al. 2017). Likewise, X-ray spectroscopy has been used to search for UCXB candidates. This is based on the presence of a common feature at ~0.7–1 keV, attributed to an enhanced Ne/O ratio in the plasma donated by the (white dwarf) companion star (Juett et al. 2001; Juett & Chakrabarty 2003). Despite this technique reported successfully confirmed candidates, it has to be taken with

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Table 1. *XMM-Newton* observations log.

ID	Date (yyyy-mm-dd)	Exposure [ks]	EPIC Camera	Net exposure [ks]	Net count rate [counts s^{-1}]
0206990201	2004-10-01	13.4	MOS1	11.6	1.05±0.01
			MOS2	12. 1	0.98±0.01
0206991101	2005-02-19	12.9	MOS1	10.2	1.5±0.01
			MOS2	10.7	2.1±0.01
			PN	7.6	4.3±0.03

caution as the Ne/O ratio was observed to vary with luminosity in some sources (Juett & Chakrabarty 2005, see section 4)

1RXS J170854.4-321857 is a NS LMXB that has been detected by several X-ray missions since the early 70's (in 't Zand et al. 2005a, and references therein). The source has shown a persistently low unabsorbed flux of a few times 10^{-11} erg cm^{-2} s^{-1} (in 't Zand et al. 2004, 2005a), while only near-infrared upper-limits of $\gtrsim$20 mags (J, K and I bands; Revnivtsev et al. 2013) have been reported. An intermediate-long type I X-ray burst (~10 min) showed mild photospheric radius expansion, from which – assuming either a pure hydrogen or helium atmosphere – a distance of 13±2 kpc was derived (in 't Zand et al. 2005a). This translates into a persistent luminosity of L_X(0.5–10 keV)~ 1×10^{36} erg s^{-1}. This persistently low L_X, together with the aforementioned detection of the 10-min burst, which occur predominantly on UCXBs (albeit not exclusively; see e.g., Galloway & Keek 2017; in 't Zand et al. 2019) suggested that the system is an UCXB (in 't Zand et al. 2005a, 2007). In this work, we present a detailed *XMM-Newton* spectral study that provides additional support to the ultra-compact nature of 1RXS J170854.4-321857.

2 OBSERVATIONS AND DATA REDUCTION

The *XMM-Newton* observatory (Jansen et al. 2001) pointed at 1RXS J170854.4-321857 on 2004 January 1 and 2005 February 19 for ~12 ksec, respectively. Only the two Metal Oxide Semiconductor cameras (MOS1 and MOS2 Turner et al. 2001) of the European Photon Imaging Camera (EPIC) were active during the first observation, while the PN camera (Strüder et al. 2001) was also available for the second pointing (see Table 1 for the observing log). The detectors were operated in imaging (full-frame window) mode with the medium optical blocking filter during both observations. We extract calibrated events and scientific products using the Science Analysis Software (SAS, v.16.0.0). We excluded episodes of background flaring by removing data with high-energy count rates > 0.3 and > 0.5 counts s^{-1} for MOS and PN cameras, respectively. We extracted the source events using a circular region of 75 arcsec radius excising a radius of 15 arcsec (MOS1 and MOS2 for the 2004 observation), 10 arcsec (MOS1 and PN for the 2005 observation) and 5 arcsec (MOS2 of the 2005 observation) in order to mitigate pile-up effects. Background events were extracted using a circular region of 100 arcsec radius placed in a source-free region of the CCDs. We selected events with pixel pattern below 5 and 13 for PN and MOS detectors, respectively. We extracted light curves and spectra and generated response matrix files (RMFs) and ancillary response files (ARFs) following the standard analysis threads[1]. We rebinned the spectrum in order to include a minimum of 25 counts in every spectral channel and avoiding to oversample the full width at half-maximum of the energy resolution by a factor larger than 3. We used XSPEC (v.12.9.1; Arnaud 1996) to analyse the *XMM-Newton* spectra.

Finally, we also inspected and extracted the data from the Reflection Grating Spectrometers (RGS; den Herder et al. 2001), but we did not include them in the in our analysis due to their low statistics.

3 ANALYSIS AND RESULTS

We investigated the light curves in order to search for features revealing the orbital period, such as eclipses or absorption dips (White et al. 1995). We created a 100s-bin light-curve using the PN data, from which we derive a upper limit on the mean aperiodic varibility of <5%, a constraint that it is limited by the quality of our data. A visual inspection to the (2×3 h) light-curves do not show any clear high inclination feature. In order to test this further, we performed a flux vs hardness diagram (not shown; see e.g. fig 5 in Kuulkers et al. 2013), which does not reveal any clear trend, as it would be expected for the case of variable absorption (e.g. dips). Thus, we conclude that either 1RXS J170854.4-321857 has an orbital inclination $i \lesssim 65°$ (White & Mason 1985; Cantrell et al. 2010) or that the orbital period is longer than 3.5 h. The latter scenario, given the X-ray characteristics of the source, seems unlikely.

We started our spectral study by analysing the 2005–observation, which includes the three EPIC cameras and hence has better statistics. We simultaneously fitted the 0.5–10 keV PN, MOS1 and MOS2 spectra with the parameters tied between the tree detectors. In order to account for cross-calibration uncertainties between the cameras, we included a constant factor (CONSTANT) in our models. We fix it to 1 for the PN spectrum and leave it free to vary for the MOS spectra. In our first attempt, we used a single thermally Comptonized continuum model (NTHCOMP in XSPEC; Zdziarski et al. 1996; Zycki et al. 1999) modified by photoelectric absorption which we modelled using the Tuebingen-Boulder Interstellar Medium absorption model (TBABS in XSPEC) with cross-sections of Verner et al. (1996) and abundances of Wilms et al. (2000). The corona electron temperature parameter (kT_e) typically adopts values above 10 keV in the low-hard state of LMXBs, which is beyond our 0.5–10 keV spectral coverage. Therefore, we fixed kT_e to 25 keV, which is the typical value displayed by NS systems at this low-luminous states (Burke et al. 2017). We note that variations of this value do not have an impact on the results (within errors). This simple absorbed Comptonization model was not able to reproduce our data. The fit residuals exhibited a strong feature around ~1 keV (see left plot on Fig. 1, bottom panel) with χ^2 of 661 for 416 degrees of freedom (dof) (p-value[2] of 2×10^{-13}). We added a

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[1] `https://www.cosmos.esa.int/web/xmm-newton/sas-threads`

[2] The probability value (p-value) represents the probability that the devia-

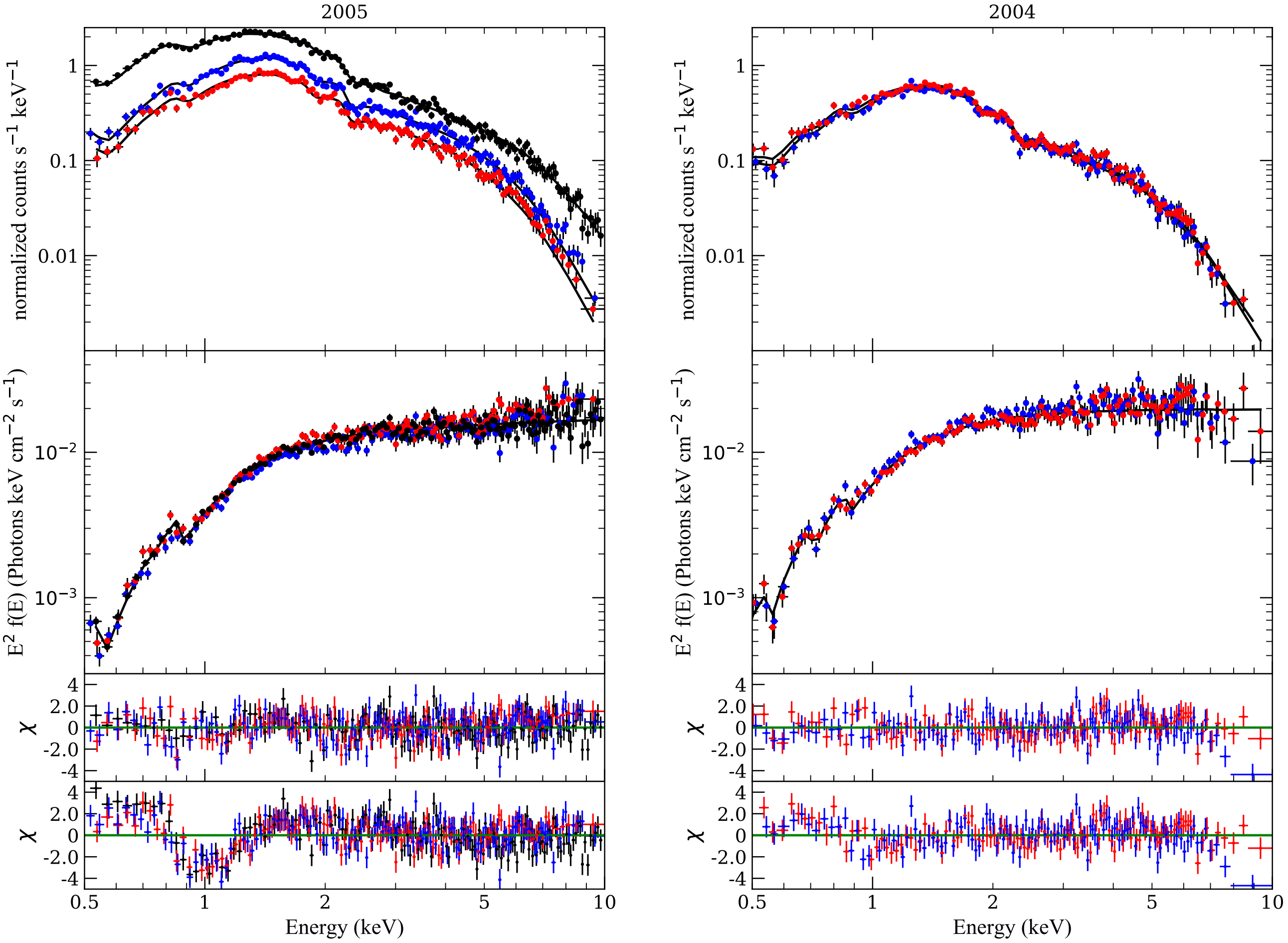

Figure 1. PN (black), MOS1 (red) and MOS2 (blue) spectra taken in 2005 (left) and 2004 (right). From top to bottom, the first panel shows the folded spectra while the second panel depicts the unfolded data. The fit using TBNEW+NTHCOMP is shown as a black solid line. The corresponding fit residuals in units of σ are shown in the third panel. The bottom panels shows the fit residuals in units of σ when using TBABS+NTHCOMP (i.e., Solar abundances).

thermal component (DISKBB or BBODYRAD) assuming that the soft residuals might be produced by emission from the accretion disc or NS surface/boundary layer, as commonly observed in NSs accreting a low luminosities (e.g. Armas Padilla et al. 2017, 2018). However, the extra thermal component does not account for the soft residuals and an evident structure remains below 2 keV.

Soft excesses below ~1 keV have been observed in spectra of highly obscured X-ray binaries obtained in EPIC-PN Timing mode (see XMM-SOC-CAL-TN-0083 [3]). In some cases this feature has been attributed to residual uncertainties in the redistribution calibration (Hiemstra et al. 2011). However, it is unlikely that this is the cause of our residuals since (i) our spectra are taken in Imaging mode, (ii) the source is only mildly absorbed, and (iii) the structure is present in all three EPIC detectors. On the other hand, similar features have been observed in several (candidate) UCXBs (e.g. Juett et al. 2001; Juett & Chakrabarty 2003; Farinelli et al. 2003; in 't Zand et al. 2008). These are proposed to result from over-abundances in the absorbing material, generally enhanced O, Ne and Fe, which is probably intrinsic to the sources. Following the same procedure reported in the literature, we replaced the TBABS model by the absorption model TBNEW, which allows the abundances to vary (in 't Zand et al. 2008; Madej et al. 2014; van den Eijnden et al. 2018). We started again with a simple absorbed Comptonization model (i.e., TBNEW*NTHCOMP). We kept fixed all the TBnew parameters at their default values, except the equivalent hydrogen column density ($N_{\rm H}$). We tried several different fits by allowing both individual elements and combination of elements (e.g., C, O, Fe, Ne, etc) to vary. We found that soft residuals were present to some extend unless the abundances of Ne and Fe were allowed to vary freely. Indeed, this combination provided the best fit, which significantly improved previous attempts ($\Delta\chi^2$=341 for 3 dof with respect to the same model with Solar abundances). Although we are aware that the fit is still poor from a purely statistical point of view (p-value is still <0.05), we can not decrease the χ^2_ν by adding extra continuum components (e.g., DISKBB, BBODYRAD) to our model. Moreover, there is not any other feature in our residuals clearly suggesting that a component is missed. Therefore, we concluded that the impossibility of improvement might be caused by remaining uncertainties in the cross-calibration between the different detectors (Kirsch et al. 2004; XMM-SOC-CAL-TN-0052). We obtained an

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tions between the data and the model are due to chance alone. In general, a model can be rejected when the p-value is smaller than 0.05.

[3] `http://xmm.vilspa.esa.es/docs/documents/CAL-TN-0083.pdf`

Table 2. Fitting results for the 2004 and 2005 data using the TBNEW*NTCHOMP model. Uncertainties are expressed at 90 per cent confidence level.

Component	2004	2005
$C_{\rm PN}$	–	1 (fix)
$C_{\rm MOS1}$	1 (fix)	1.04±0.02
$C_{\rm MOS2}$	1.05±0.02	0.94±0.01
$N_{\rm H}$ ($\times10^{22}$ cm^{-2})	0.34 (fix)	0.34±0.4
$A_{\rm Ne}$	4.1±1	5.4±0.4
$A_{\rm Fe}$	3.5±1	2.5±0.7
Γ	1.98±0.04	1.91±0.02
$kT_{\rm e}$ (keV)	25 (fix)	25 (fix)
$kT_{\rm seed}$ (keV)	0.21±0.02	0.23±0.03
$N_{\rm nthcomp}$ ($\times10^{-2}$)	1.6±0.1	1.06±0.1
χ^2 (dof)	283(249)	522 (414)
(0.5–10 keV)		
$F_{\rm X}$ ($\times10^{-11}$erg cm^{-2} s^{-1})	8.5±0.2	6.3±0.2
$L_{\rm X}{}^{\rm a}$ ($\times10^{36}$erg s^{-1})	1.72 ±0.04	1.27±0.04

[a] X-ray luminosity assuming a distance of 13 kpc.

$N_{\rm H}$ of (3.4±0.4)$\times10^{21}$cm^{-2}(consistent with the reported value by in 't Zand et al. 2005a using *Chandra* data) and over-abundances of Ne ($A_{\rm Ne}$=5.4±0.4) and Fe ($A_{\rm Fe}$=2.5±0.7). The Comptonization asymptotic power-law photon index (Γ) is 1.91 ± 0.02 and the temperature of the up-scattered seed photons ($kT_{\rm seed}$) assuming black body geometry is 0.23±0.06 keV (consistent values are obtained assuming a disc geometry). The inferred 0.5–10 keV unabsorbed flux of (6.3±0.2)$\times10^{-11}$ erg cm^{-2} s^{-1} is implies a luminosity of $L_{\rm X}\sim$ 1.7 $\times$ 10^{36}erg s^{-1} assuming a distance of 13 kpc (in 't Zand et al. 2005a). We report best-fit results in Table 2 (see also left panel in Fig.1). Uncertainties are given at 90 per cent confidence level.

For the 2004 observation, that only includes MOS1 and MOS2 data, we fixed the constant (cross-calibration) factor to 1 for the former and leave it free to vary for MOS2. We fixed $N_{\rm H}$ to the value obtained in the best fit of our higher signal–to–noise 2005 observation ($N_{\rm H}$=3.4$\times10^{21}$cm^{-2}). As for the 2005 data, a simple absorbed Comptonization model was not able to reproduce the data. This could not be solved by adding soft thermal components ($\chi^2\cong$319 for 239 dof; p-value=4 $\times$ 10^{-4}). Although it is less evident than for the 2005 observation, some residuals below 1 keV are also present (see bottom–right panel in Fig.1). Thus, we repeated the fit using TBNEW*NTHCOMP with free Ne and Fe abundances. This produced an acceptable fit, with χ^2= 275 for 243 dof (p-value≅0.07). The fit and corresponding residuals are shown in Fig.1 (right plot). The resulting spectral values are consistent with those obtained from the 2005 observation (Table 2), albeit the system was slightly brighter in 2004.

4 DISCUSSION

1RXS J170854.4-321857 is a NS LMXB that has been detected without exception at $L_{\rm X}\sim0.01L_{\rm Edd}$ by several missions over the past decades. Within the framework of the disc instability model (Lasota 2001; Coriat et al. 2012) this persistent nature at such low luminosity implies a short orbital period, possibly within the UCXB regime (in 't Zand et al. 2005a). To investigate this further, we have carried out a detailed analysis of two archival *XMM-Newton* observations. The 0.5–10 keV X-ray luminosity during these observations was $\sim1\times10^{36}$erg s^{-1}, which is consistent with previous measurements reinforcing the persistent nature of the system (e.g., Forman et al. 1978; Markert et al. 1979; Revnivtsev et al. 2004; in 't Zand et al. 2005a). Our spectra are well described by a thermally Comptonized model with $\Gamma\cong$ 1.9 and a distribution of seed photons characterised by $kT_{\rm seed}\cong$ 0.2 keV arising from either the accretion disc or NS surface/boundary layer (possibly from both regions; see Armas Padilla et al. 2018). We do not detect direct emission from the accretion disc or NS surface as no softer thermal component was required in our analysis. NS systems accreting at luminosities $<10^{35}$erg s^{-1} usually show a soft thermal component, generally attributed to low-level accretion on to the neutron star surface (Zampieri et al. 1995; Armas Padilla et al. 2013b; Bahramian et al. 2014). This typically contributes at the ~30–50 per cent level (e.g., Degenaar et al. 2013; Armas Padilla et al. 2013a; Arnason et al. 2015; Armas Padilla et al. 2018). However, at luminosities above $\sim10^{35}$erg s^{-1} this contribution becomes lower or, in some cases, totally vanishes (Armas Padilla et al. 2013a; Allen et al. 2015; Wijnands et al. 2015). The non-detection of the thermal component together with the relatively soft photons index ($\Gamma\sim$ 1.9) concurs with the latter scenario.

Interestingly, the spectra showed a broad residual structure around ~1 keV, which we were able to account for by allowing relative abundances to vary in the absorption model. We found $N_{\rm H}$=(3.4±0.4)$\times10^{21}$cm^{-2} with enhanced Ne and Fe abundances. This $N_{\rm H}$ is consistent with the value obtained by in 't Zand et al. (2005a), albeit their abundances are in agreement with the standard interstellar value. The reason for this difference might be related to the significantly worse statistics of their spectra (with only 58 dof). We obtain Ne and Fe relative abundances of $A_{\rm Ne}$=5.4±0.4 and $A_{\rm Fe}$=2.5±0.7, while a maximum value of ~1.4 have been measured for the interstellar medium towards LMXBs (Pinto et al. 2013). Hence, the additional absorption required to fit both the 2004 and 2005 data is unlikely to have an interstellar origin, being probably intrinsic to the system. Although these over-abundances are rather high, similar values have been reported for some other UCXBs (e.g, in 't Zand et al. 2008; Madej & Jonker 2011). Nevertheless, we note that due to the relatively low spectral resolution of our data and the systematics likely involved, to derive the actual abundances and species producing the soft X-ray feature presented here is beyond the scope of the paper.

A number of confirmed (and candidate) UCXBs have exhibited similar phenomenology to that reported here, which, in most cases, has been interpreted as due to over-abundances in the absorber. This generally involves excesses in the K-edges of neutral O and Ne and the L-edge of neutral Fe, which origin have been suggested to be intrinsic to the binaries. Juett et al. (2001) first proposed the ultra-compact nature of several systems based on the detection of enhanced Ne/O ratios using X-ray spectra (see also, Juett & Chakrabarty 2003). This feature had been originally found in the confirmed UCXBs 4U 1626-67 and 4U 1850-087. In light of these findings, it was suggested that systems showing this peculiarity harbour C–O or O–Ne–Mg white dwarfs as companions. Also, a white dwarf donor was proposed for IGR J17062-6143, the last confirmed UCXB to date (Strohmayer et al. 2018). It showed a residual structure at ~1 keV, that was suggested to arise from an over-abundance of O – likely related with circumbinary material – while Ne edge abundances were consistent with the interstellar medium (van den Eijnden et al. 2018; Degenaar et al. 2017). The presence of strong emission lines of highly ionised species of Ne and O in the high resolution X-ray spectroscopy of 4U 1626-67 also suggested a C–O rich white dwarf donor (Schulz et al. 2001; Krauss et al. 2007). Optical spectroscopic studies of some of these sources support the above conclusions. The detection of C and O emission lines evidences the presence of metal–rich material in the accretion disc, consistent with C–O white dwarf donors. (Nelemans

Table 3. List of confirmed and candidate UCXBs with peculiar soft X-ray structures.

Source	Period (minutes)	P/T	Spectral data X-ray	Spectral data Optical	Interm-long burst	$N_{\rm H}$ $\times 10^{21}$cm^{-2}	$L_{\rm X}$ (Energy band) erg s^{-1} (keV)
2S 0918-549	17.4	P	Ne/O	He?	IB[a]	3.0	$\sim 3.5 \times 10^{35}$ (2–10) [b]
4U 1543-624	18.2	P	Ne/O	C/O	–	3.5	$\sim 2 - 4 \times 10^{36}$ (2–10) [b]
4U 1850-087	20.6	P	Ne/O	?	IB[a]	3.9	$\sim 1 \times 10^{36}$ (0.5–10) [c,d]
IGR J17062-6143	37.97[e]	P	O[f]	lack Hα[g]	IB[a]	2.4[h]	$\sim 2.9 \times 10^{35}$ (0.3–79) [h]
4U 1626-67	42	P	Ne/O, C, O, Ne	C/O	–	1.4	$\sim 1 \times 10^{36}$ (0.5–10) [i]
Candidates							
4U 0614+091	51?	P	Ne/O, O	C/O	IB[j]	3.0	$\sim 1 \times 10^{36}$ (0.5–10) [c]
1A 1246-588	?	P	Ne[k]	Featureless[k]	IB[a]	2.5[k]	$\sim 6 \times 10^{35}$ (0.3–10) [k]
1RXS J170854.4-321857	?	P	Ne, Fe	?	IB[l]	3.4	$\sim 1 \times 10^{36}$ (0.5–10)

Based on data presented in van Paradijs & McClintock (1994), Nelemans et al. (2006), van Haaften et al. (2012), Heinke et al. (2013).
References: [a] in 't Zand et al. (2019), [b] Juett & Chakrabarty (2003), [c] Juett et al. (2001), [d] Juett & Chakrabarty (2005), [e] Strohmayer et al. (2018), [f] van den Eijnden et al. (2018), [g] Hernández Santisteban et al. (2017),[h] Degenaar et al. (2017), [i] Schulz et al. (2001), [j] Kuulkers et al. (2010), [k] in 't Zand et al. (2008), [l] in 't Zand et al. (2005a),

et al. 2004; Werner et al. 2006; Nelemans et al. 2006). Additionally, the lack of strong H and He emission lines, typically the strongest features in the optical spectra of LMXBs (Charles & Coe 2006; Mata Sánchez et al. 2018), supports the ultra-compact nature of some of the systems that have shown the peculiar X-ray features (e.g.; Nelemans et al. 2006; in 't Zand et al. 2008; Hernández Santisteban et al. 2017). In this context, it is important to emphasise that the Ne/O ratio was questioned as UCXB marker due to the hydrogen and helium lines found in the optical spectrum of the NS system 4U 1556-60 (Nelemans et al. 2006; Nelemans & Jonker 2010). However, 4U 1556-60 has not shown any of the X-ray features classically associated with uncommon abundances (Farinelli et al. 2003), and therefore, it was not (and has never been as far as we know) an UCXB candidate.

High resolution X-ray spectra of some UCXBs have shown, in addition to over-abundances in the absorber, the presence of a broad O vii Ly$_\alpha$ emission line (e.g. Madej et al. 2010; Schulz et al. 2010; Madej & Jonker 2011). This, together with the Fe K$_\alpha$ line, is predicted to be the most prominent fluorescent line of the reflection spectrum if X-rays are reprocessed in a oxygen-rich accretion disc. Indeed, reflection models have been modified to account for the non-solar composition of the accretion disc in order to reproduce the reflection spectra of UCXBs (Koliopanos et al. 2013; Madej et al. 2014). Moreover, Madej et al. (2014) found that better results were obtained if the ionization structure of the illuminated disc was also taken in account. Likewise, it was suggested that ionization effects might be responsible for the epoch-to-epoch variations of the Ne/O ratio found in some systems (Juett & Chakrabarty 2003, 2005; in 't Zand et al. 2008). In this scenario, changes in the continuum spectral properties would modify the ionization state of the different (absorber related) species in the accretion disc. Thus, the measured Ne/O ratio would not reflect the donor composition. However, this does not explain why the ~1 keV structure is so common in UCXBs as compared with the whole LMXB population. In Table 3 we list candidate and confirmed UCXBs that, to the best of our knowledge, have shown the soft X-ray features compatible with peculiar Ne and O abundances. Interestingly, these systems have a persistent nature, $N_{\rm H} < 5 \times 10^{21}$cm^{-2}and were accreting at $L_{\rm X} \lesssim 0.01 L_{\rm Edd}$ at the time they showed the soft feature.

Finally, numerous UCXBs have displayed intermediate-long type I X-ray burst, albeit these are not exclusively observed in UCXBs (e.g. Falanga et al. 2008). These thermonuclear explosions are thought to be associated with deep He ignitions from material accreted at very low rates ($\lesssim$ 0.01 $L_{\rm Edd}$), suggesting He-rich donors (in 't Zand et al. 2005b; Cumming et al. 2006; Falanga et al. 2008; Kuulkers et al. 2010; Galloway & Keek 2017; in 't Zand et al. 2019). As a matter of fact, in 't Zand et al. (2005b) proposed that the anomalous Ne/O ratios could result from a reduction of the O abundance due to CNO processes in helium white dwarfs. This scenario might apply to 1RXS J170854.4-321857. In this regard, the detection of a ~10 min X-ray burst, the persistently low accretion rate (~0.01 $L_{\rm Edd}$) and the apparent abundances anomalies that we have reported here agree with the above picture. Higher X-ray spectral resolution data at high signal-to-noise are required in order to further investigate the nature of 1RXS J170854.4-321857 in particular, and the physical processes behind the abundance-anomalies related features commonly observed in UCXBs.

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