SGR 0755–2933: a new high-mass X-ray binary with the wrong name

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ABSTRACT

The soft gamma-ray repeater candidate SGR 0755–2933 was discovered in 2016 by Swift/BAT, which detected a short (~30 ms), powerful burst typical of magnetars. To understand the nature of the source, we present here an analysis of follow-up observations of the tentative soft-X-ray counterpart of the source obtained with Swift/XRT, NuSTAR, and Chandra. From our analysis we conclude that, based on the observed counterpart position and properties, SGR 0755–2933 is not a soft gamma-ray repeater but rather a new high-mass X-ray binary. We suggest it be referred to as 2SXPS J075542.5–293353. We therefore conclude that the available data do not allow us to confirm existence and identify the true soft-X-ray counterpart to the burst event. The presence of a soft counterpart is nevertheless essential to unambiguously associate the burst with a magnetar flare, and we conclude that the magnetar origin of the burst and a precise burst location remain uncertain and require further investigation.

Key words. binaries: general – pulsars: individual: SGR 0755–2933 – stars: neutron

1. Introduction

A new soft gamma-ray repeater (SGR) SGR 0755–2933 candidate was discovered on Mar 16 2016 following a short (~30 ms), soft burst triggered by the Burst Alert Telescope onboard the Neil Gehrels Swift Observatory (Swift/BAT) around RA = 118.884, Dec = −29.552 (3\′ error radius, 90\% containment) and subsequently refined by Barthelmy et al. (2017) to RA = 118.8625, Dec = −29.5723 (with 3.4\′ error radius, 90\% containment). Considering that the SGRs are scarce and believed to be powered by neutron star crust fractures associated with magnetic field re-arrangements in magnetars (Thompson & Duncan 1995), this immediately triggered a follow-up campaign with multiple facilities. The tentative soft X-ray counterpart was identified at RA = 118.9270 Dec = −29.5637 (2\′ error radius, 90\% containment), minutes after the burst following an automated re-pointing of Swift/XRT (Barthelmy et al. 2016). Further monitoring of the transient with Swift/XRT showed a slow and steady fading of the source in the 0.5-10 keV band from ~8 x 10\(^{-11}\) erg cm\(^{-2}\) s\(^{-1}\) (on MJD 57463.9) to ~2 x 10\(^{-11}\) erg cm\(^{-2}\) s\(^{-1}\) (on MJD 57464.5). However, no further bursts nor X-ray pulsations in the frequency range typical for magnetars were detected (Archibald et al. 2016). Observations in the radio band from 327 and 1390 MHz (Surnis et al. 2016) to 2 GHz and 6 GHz (Harrison et al. 2017) also did not result in a significant detection of pulsations. Harrison et al. (2017) mentioned a hint of a ~300 s pulsation in the X-ray band, but no details were reported. Furthermore, the source has been observed by Chandra and NuSTAR on several occasions, but to the best of our knowledge, no results from these observations have been reported in the literature.

In this paper, we focus on Chandra, NuSTAR, and Swift/XRT observations of the suggested soft-X-ray counterpart to this event. We conclude that the position and the X-ray properties of the suggested counterpart indicate that this is not a soft-gamma repeater but rather a new Be X-ray binary (BeXRB), 2SXPS J075542.5–293353, which most likely falls within the error circle for the burst by chance. On the other hand, other X-ray sources detected within its reported error circle are too faint for the detailed analysis required to confirm the presence of a putative magnetar. The localization and classification of the burst as a soft gamma repeater therefore remain uncertain as the suggested presence of the soft counterpart was the main argument in favor of its magnetar origin.

The faintness of other potential counterparts to the burst precludes detailed analysis of their properties, and so here we focus instead on the discussion of the observed properties of the newly identified high-mass X-ray binary (HMXB), 2SXPS J075542.5–293353. We confirm the presence of ~308 s pulsations and, based on the observed long-term variability, identify the tentative orbital period of ~260 d. Considering the observed spin and orbital period of the source and the classification of the optical companion as an emission line star, we finally conclude that the system is likely a new low-luminosity BeXRB with L\(_x\) ~ 10\(^{34}\) erg s\(^{-1}\) at ~3.5 kpc. This conclusion is in line with the observed two-component broadband X-ray spectrum of the source similar to that observed in other low-luminosity BeXRBs.

2. Observations and data analysis

The list of NuSTAR and Chandra observations used in this work is presented in Table 1. The data reduction was performed according to the documentation of each instrument with the help of HEASOFT v6.28 (CALDB 20200912) for NuSTAR and CIAO 4.12 (CALDB 4.9.2.1) for Chandra. Data from the two
Table 1. Dedicated NuSTAR (N) and Chandra (C) observations of the source considered in this work (grouped by observed flux).

| Instr. | Obsid     | Date (MJD) | Exp. (ks) | Group |
|--------|-----------|------------|-----------|-------|
| N      | 801021030002 | 57473.20  | 54.7      | A     |
| C      | 18014     | 57474.08  | 10        | A     |
| N      | 801021040002 | 57497.37  | 76.2      | B     |
| C      | 18015     | 57500.48  | 15        | B     |
| N      | 801021030004 | 57589.09  | 28.7      | C     |
| N      | 801021040003 | 57589.90  | 107.8     | C     |
| C      | 18016     | 57592.46  | 25        | C     |
| C      | 18017     | 57752.06  | 40        | D     |
| C      | 22454     | 58759.21  | 30        | E     |
| N      | 906013220001 | 59049.49  | 49.8      | A     |

Fig. 1. Chandra broad (0.5–7 keV) band flux image covering Swift/BAT 90% error circle for the burst as reported in Barthelmy et al. (2017) (blue circle). In addition to the originally suggested counterpart (labeled here as 2SXPS J075542.5–293353), several faint X-ray sources (red ellipses) are detected by Chandra within the BAT confidence region and just outside of it. At least two of those (labeled AC1/2) appear to have no obvious optical (Gaia DR2, blue circles) or near-infrared (2MASS, green circles, AllWise, yellow crosses) counterparts and therefore we propose that they could be true soft-X-ray counterparts to the burst detected by BAT.

Table 2. Chandra sources within Swift/BAT error circle.

| RA (J2000) | Dec (J2000) | Net (bgd) counts | signif. (σ) |
|------------|------------|------------------|-------------|
| 07 55 42.528 | −29 33 53.64 | 2442.3 (34.7) | 351.33 |
| 07 55 31.392 | −29 35 40.56 | 34.6 (8.4) | 6.62 |
| 07 55 17.664 | −29 33 06.12AC1 | 34.0 (12.0) | 7.44 |
| 07 55 28.584 | −29 33 20.88 | 28.0 (8.0) | 7.06 |
| 07 55 22.872 | −29 33 18.72 | 26.3 (7.7) | 6.74 |
| 07 55 16.224 | −29 32 25.8 | 19.4 (8.6) | 4.49 |
| 07 55 36.6 | −29 33 50.4AC2 | 9.8 (5.2) | 2.86 |
| 07 55 32.736 | −29 33 06.12 | 5.5 (1.5) | 2.20 |

Notes. Alternative candidate counterparts to SGR 0755–2933 are marked as AC1/AC2. Estimated source net and background fluxes and the detection significance are reported as estimated by wavdetect task.

a fluxed image of the field in a broad 0.5–7 keV energy range. This choice is justified by relatively low counting statistics and the fact that spectra of all known magnetars are relatively hard. Source detection was then performed as prescribed in the Chandra documentation (including the absolute astrometric correction with the 2MASS catalog as a reference). As a result, a total of 37 point sources were detected, six of which lie within the BAT error circle as shown in Fig. 1. The position of the brightest source among the six (∼2400 counts) is consistent with the XRT localization of the magnetar candidate, that is, RA = 118.9271642 Dec = −29.5648607 (07 55 42.5194, −29 33 53.4985) and ∼2′ uncertainty (at 3σ confidence level, including 1.5′′ systematic error). This is the only source for which a detailed analysis is feasible because only ∼90 counts are detected from the second brightest source and even fewer from the rest, and so below we mostly focus on an analysis of the properties of this object.

First of all, it is important to note SGR 0755–2933 has a bright infrared and optical counterpart with J ~ 9.7m, G ~ 9.94m detected at an offset of ∼0.6″ in the 2MASS and Gaia surveys. This object, CD-29 5159, is a known luminous early-type (O6) emission-line star (Stephenson & Sanduleak 1971; Reed 2003), which strongly suggests that initial classification of the corresponding X-ray source as a magnetar and SGR (SGR 0755–2933) is likely incorrect. Therefore, to avoid confusion, we refer to this source as 2SXPS J075542.5–293353 for the remainder of the manuscript. However, we emphasize that the arguments discussed by Barthelmy et al. (2016) in favor of a magnetar origin for the burst itself are still valid, and so one could still expect to detect a soft-X-ray counterpart to this event. Indeed, there are several fainter objects detected by Chandra within the Swift/BAT error circle as shown in Fig. 1 which are also listed in Table 2. All but two sources (marked AC1 and AC2) in the table appear to have potential counterparts in 2MASS and Gaia surveys and are thus likely field stars or active galactic nuclei (AGNs).

We emphasize that the absence of an obvious near-infrared or optical counterpart alone can only be viewed as a tentative indication of a possible isolated neutron star origin, and only due to the fact that other X-ray sources appear to have an optical counterpart which is not expected for a magnetar. There is therefore no strong indication that this object is indeed a magnetar, and our suggestion can only be verified through detailed analysis of X-ray properties of the source, for instance through detection of X-ray pulsations. Unfortunately, with only 10–30 net counts, and a detection significance of ∼2–7σ (estimated by wavdetect task) both objects are too faint for detailed analysis.
We therefore conclude that deeper observations both in X-ray and optical bands are required to unambiguously identify a true counterpart to the burst detected by BAT, which is beyond the scope of the current investigation. Instead, we focus exclusively on the analysis of 2SXPS J075542.5−293353 and demonstrate that it is indeed a new low-luminous HMXB.

2.2. Timing analysis

As mentioned by Harrison et al. (2017), X-ray data suggest that 2SXPS J075542.5−293353 pulsates with a period of ~308 s, which would be unprecedented for magnetars but typical of accretion-powered pulsars. To confirm the pulsing nature of the source, we extracted light curves in the 3–80 keV energy band and searched for pulsations in the range 1–1000 s in all NuSTAR observations. To extract the light curves and spectra we followed the recommendations available on the online threads for each instrument. In particular, the source and background spectra and light curves were extracted from circular regions with radii of 55′′ and 100′′ centered on the source and on a source-free region, respectively. The extraction radius was optimized to improve the signal-to-noise ratio above 20 keV as described in Vydrovov et al. (2018). For each observation, data from the two NuSTAR telescope units were analysed independently.

A strong signal with a period of around 300 s is indeed present in all cases in the Lomb-Scargle periodogram of the source (see upper panel of Fig. 2). The spin period is measured to be 307.80(4) s and 308.26(2) s for the first and last observation respectively (obsid. 80102103002 and 90601322001; the period value and uncertainties are estimated using the method described by Boldin et al. 2013). The slight increase of the spin period may indicate a spin-down trend, or may also be due to the orbital motion because the orbit of the source is not known. The observed pulse profiles in both cases exhibit a broad single peak and pulsed fraction\(^2\) of 19(2) and 22(2)/% respectively (after subtraction of the background). The statistical quality of the available data precludes a more detailed analysis as illustrated in Fig. 2. Nevertheless, we note that both pulse profile shape and pulsed fraction are similar to those observed in other pulsars accreting at low luminosities (Tsygankov et al. 2019a).

Besides the long spin period, observed aperiodic variability properties can also be used to probe the origin of X-ray emission. It was recently demonstrated by Doroshenko et al. (2020) that unlike accreting objects, magnetars and other rotation-powered pulsars do not exhibit aperiodic variability. Therefore, we conducted an analysis as described in Doroshenko et al. (2020) for 2SXPS J075542.5−293353. Here, the data from two NuSTAR observations with the best counting statistics (80102103002 and 90601322001) were used. As illustrated in Fig. 3, the power spectrum of 2SXPS J075542.5−293353 indeed shows strong aperiodic variability with a broken-power-law-type power spectrum typical of accreting objects. Indeed, when modeled as a broken power law, the relative noise amplitude (i.e., the power at the break divided by amplitude of the pulsations) estimated as described in Doroshenko et al. (2020) is 35+3%5% , which is comparable to other accretors and much larger than in magnetars (≤35%). Finally, we also inspected the light curves of the source for possible short flares but did not find any. We therefore conclude that together with the long pulse period and presence of a massive optical counterpart this strongly suggests that 2SXPS J075542.5−293353 is indeed not a magnetar but rather an accreting pulsar.

2.3. Spectral analysis

Besides the already mentioned Chandra observation of the source in timed exposure imaging mode, four other observations of the source in continuous clocking (CC) mode are available. As summarized in Table 1, three of those were done quasi-simultaneously with NuSTAR, which enables broadband spectral analysis. Spectral products for NuSTAR were extracted using the same procedures as described for light curves above.

As prescribed in the instrument documentation for imaging and CC modes, to extract source and background spectra from Chandra data we used the specextract script, and circular or box-shaped regions centered on source and off-source with sizes of 2.5″ and 25″ respectively. For observations performed in CC mode, the updated source position was used to reprocess raw event files to ensure that the charge transfer inefficiency (CTI) correction is properly applied. For the observation in the imaging mode (obsid 22454), the brightness of the source was sufficient to induce significant pile-up (up to ~21% as estimated with pileup_map tool). This was accounted for by including

\(^2\) Calculated as \((F_{\text{max}} - F_{\text{min}})/(F_{\text{max}} + F_{\text{min}})\), where \(F_{\text{max}}\) and \(F_{\text{min}}\) are maximum and minimum fluxes in the pulse profile, respectively.
an additional pile-up model component (jdpileup) included in the sherpa spectral fitting package which was used to model the source spectrum for this observation (part of CIAO 4.12).

Four out of five NuSTAR observations were conducted simultaneously or quasi-simultaneously with Chandra. In all cases, Chandra operated in continuous clocking mode, and so pile-up was not an issue and was not accounted for by the model. For these observations we therefore grouped all spectra to contain at least 25 spectral counts per energy bin and used the Xspec v12.11.1 and standard $\chi^2$ statistics with default weighting to model the broadband spectra of the source. Initially we modeled all observations independently, but we found that the source flux and spectrum during the first and last observations (obsids. 80102103002 and 90601322001 respectively) were very similar, and so these observations were modeled simultaneously for the final fit to improve counting statistics. As a result, for the broadband spectral analysis, three observation groups were defined as summarized in Table 1.

The broadband continuum of the source can be described by several models used to describe spectra of other low-luminosity pulsars. In particular, as shown in Fig. 4, a two-component comptonization model (Doroshenko et al. 2012; Tsygankov et al. 2019a,b) provides a good approximation. More specifically, we used a model consisting of two CompTT components with linked seed photon temperatures and independent electron temperatures,正常化，and optical depths, for spectra of all groups A, B, and C. In addition, we included the tbabs component (Wilms et al. 2000) to account for interstellar absorption. Cross-normalization constants were included to account for minor differences in the absolute flux and energy calibration, and to account for intrinsic flux variability between individual observations that may or may not be simultaneous. Spectra are in general well described by the model. The fit results are presented in Table 3 and Fig. 4.

We note that counting statistics at higher energies is not sufficient to robustly detect or exclude the presence of possible additional features such as a cyclotron resonance scattering line. The minor residuals around 30 keV are likely associated with imperfect background subtraction which contains several instrumental lines around this energy and already dominates the source flux at this energy. We therefore conclude that the continuum is well described with a two-component Comptonization model within statistical limitations of the data.

To study the long-term variability of the source, we estimated the bolometric flux in each of the 45 Swift/XRT pointed observations between MJD 57463.94 and MJD 59122.03, and in the Chandra observations. We extracted the spectra and fitted them using the same model and parameters used for the broadband NuSTAR and Chandra spectra (see next paragraph) with normalization as the only free parameter. In practice, a cflux component was added to the best-fit model for the brightest Chandra/NuSTAR joint observation. The spectra were grouped to have at least one count per energy bin and modeled using the W-statistics (Wachtler et al. 1979) in the energy ranges of 0.4–10 keV and 0.9–100 keV for PC and WT modes of XRT, respectively. The unabsorbed model flux was then calculated in the 0.5–100 keV energy range to estimate the bolometric luminosity of the source. The resulting light curve of the source is presented in Fig. 5.

Table 3. Best-fit results for broadband spectra of 2SXPS J075542.5–293353 for groups A, B, and C, and for the two-component comptonization model (with components denoted by indices 1 and 2) described in the text.

| Parameter | A | B | C |
|-----------|---|---|---|
| $N_H$, $10^{22}$ cm$^{-2}$ | $\leq 0.15$ | 0.13(9) | $\leq 0.3$ |
| $T_0$, keV | 0.75(5) | 0.64(6) | 0.6(1) |
| $kT_1$, keV | 2.1(1) | 2.1(1) | 1.6(2) |
| $\tau_1$ | 17(2) | 19(2) | 22(4) |
| $A_1/10^{-4}$ | 7.8(6) | 5.1(3) | 2.0(2) |
| $kT_2$, keV | 8.4(3) | 9.4(6) | 5.6(9) |
| $\tau_2$ | $\geq 10$ | $\geq 10$ | $\geq 10$ |
| $A_2/10^{-5}$ | 2.7$^{+2.9}_{-0.1}$ | 1.5$^{+0.5}_{-0.8}$ | 0.4$^{+2.0}_{-0.1}$ |
| $F_{12}$ | 14.4(2) | 9.6(2) | 1.5(1) |
| $\chi^2$/d.o.f. | 429.6/419 | 331.8/344 | 268.8/250 |

Notes. Observed flux (i.e., not corrected for absorption) is given in the 3–80 keV band in units of $10^{-12}$ erg cm$^{-2}$ s$^{-1}$. Uncertainties are reported at 1σ confidence level.

Fig. 3. Leaky-normalized power spectral density of 2SXPS J075542.5–293353 obtained using 3–80 keV light curves observed by NuSTAR (observations 80102103002 and 90601322001). The frequency is normalized to the spin frequency. We note the presence of strong red noise at lower frequencies modeled as a broken power law (red line) typical for accreting systems. The blue dashed line corresponds to expected white noise level.

Fig. 4. Unfolded spectrum of 2SXPS J075542.5–293353 at high flux level (spectral group A) as observed by Chandra (green) and NuSTAR (other colors) together with the residuals to the best-fit model. For comparison, the spectrum of GX 304–1 as reported in Tsygankov et al. (2019b) is also shown (in gray; arbitrarily scaled).
The remaining two Chandra observations (as there is no contemporary broadband data available) were analyzed separately, in a similar fashion to the Swift/XRT data, to estimate the bolometric flux of the source. To do that, we assumed the best-fit model obtained for group A for the broadband spectral analysis as described below and only considered normalization as a free parameter. However, we emphasize that the observed spectral shape is in fact similar for all observations despite slight differences in the best-fit parameters, and so the difference in flux estimated using the best-fit models for groups A, B, and C is less than 10%, which is lower than the statistical uncertainties of individual measurements and only affects absolute flux estimates but not the shape of the light curve.

3. Discussion

Based on our analysis of the Chandra flux image, we estimate the position of the initially identified soft-X-ray counterpart to the magnetar candidate SGR 0755−2933 to be RA = 118.9271642 Dec = −29.5648607 with an uncertainty of ~2″. This position appears to coincide with a bright infrared and optical source CD-29 5159 known as an early-type emission-line star (Stephenson & Sanduleak 1971). We therefore argue that this object is likely not the counterpart to the burst detected by BAT. The object is detected by Guia (DR2 source 5597252305589385984) with a significant parallax of ~0.29 (1) mas. This allows estimation of the distance to the source, giving 3.5(2) kpc (Bailer-Jones et al. 2018). Based on the distance estimate and the observed X-ray flux, the source luminosity can be estimated at $L_x \sim 10^{34}$ erg s$^{-1}$, which is significantly above expectations for stellar X-ray emission, and consistent with luminosities observed from low-luminous X-ray binaries.

Pulsations at ~308 s are significantly detected with NuSTAR. The pulse profile is characterized by a single broad peak similar to that of low-luminous accreting X-ray pulsars, such as for example X Persei. In addition, the power spectral density of 2SXPS J075542.5−293353 shows the presence at low frequencies of a strong red-noise component on top of the expected white noise. As recently shown by Doroshenko et al. (2020), aperiodic variability is a clear indicator of accretion in compact sources. We therefore suggest that 2SXPS J075542.5−293353 is a new low-luminosity X-ray pulsar. This hypothesis is in line with the observed broad-band X-ray spectrum of the source obtained with NuSTAR and Chandra, consistent with a two-component Comptonization spectrum typical for low-luminosity accreting pulsars (see Doroshenko et al. 2012; Tsygankov et al. 2019b,a; Mushtukov et al. 2020).

As already mentioned, the long-term variability of the source revealed by Swift/XRT monitoring hints at a possible orbital period of ~260 d as shown in Fig. 5. Although the sampling is sparse, the duration of each of the two periods of enhanced activity around MJD 57500 and MJD 59000, each of which lasts more than 50 days, hints at a rather long orbital period. The third re-activation of the source around MJD 57750 is also consistent with this conclusion. Of course, further monitoring of the source is required to confirm it. Nevertheless, we note that the tentative orbital period identified based on recurrent flux enhancements appears to be in line with purely phenomenological expectations. As shown in Fig. 6, the spin period (308 s) and the orbital period (260 d) suggest that the source resides in the Be X-ray binaries region of the so-called “Corbet” diagram (Corbet 1986). The observed flux enhancements around periastron are therefore in line with this classification. However, we would like to emphasize that this would also be the case for significantly shorter periods due to the large scatter of objects in the diagram, and so independent confirmation of the tentative period either through continued monitoring of X-ray flux or X-ray timing is essential.

We emphasize that until now, low-luminosity accretion has mostly been investigated in transient sources during their quiescent state. Peculiarily, 2SXPS J075542.5−293353 appears to also have rather low luminosity during outbursts which makes it only the second source of this kind known besides X Persei. We note that the majority of HMXBs are actually expected to have low luminosities (Doroshenko et al. 2014), and the discovery of 2SXPS J075542.5−293353 may mark the beginning of a series of discoveries of this population hidden from instruments like Swift/BAT. More objects like this can be expected to appear in the SRG/eRosita survey where we expect to detect several tens of low-luminosity HXMBs (Doroshenko et al. 2014).

4. Conclusions

Following the detection of a burst by Swift/BAT in March 2016, SGR 0755−2933 was classified as a new peculiar magnetar candidate. The discovery triggered a series of observations of the

Fig. 5. Bolometric long-term light curve of the source as observed by Swift/XRT (black), NuSTAR (blue), and Chandra (red). Vertical lines indicate expected outburst timing assuming 260 d orbital period.

Fig. 6. Location of 2SXPS J075542.5−293353 in the “orbital period”−“spin period” diagram (indicated by cross) assuming a 260 d orbital period. The red and blue points correspond to transient (BeXRB) and persistent systems respectively as reported in Liu et al. (2006).
source with NuSTAR, Chandra, and Swift/XRT aimed at localizing the object, searching for the spin period of the neutron star, and characterizing the broadband spectrum of the source. Here we present an analysis of these observations.

Surprisingly, the precise localization of the source with Chandra suggests that the initially suggested soft-X-ray counterpart to the burst observed by Swift/BAT is unambiguously associated with the massive emission line star CD-29 5159. We argue that this, together with the long 308 s spin period and the associated with the massive emission line star CD-29 5159. We suggest an alternative counterpart might also, in the end, be unrelated to the burst, and as such, association of the burst with a magnetar flare and classification as a magnetar candidate SGR 0755–2933 should be considered unreliable until deeper X-ray observations are available.

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References
Abdollahi, S., Acero, F., Ackermann, M., et al. 2020, ApJS, 247, 33
Archibald, R. F., Scholz, P., & Kaspi, V. 2016, ATel, 8831, 1
Bailer-Jones, C. A. L., Rybizki, J., Fouesneau, M., Mantelet, G., & Andrae, R. 2018, AJ, 156, 58
Barthelmy, S. D., D’Elia, V., Gehrels, N., et al. 2016, ATel, 8831, 1
Barthelmy, S., Cummings, J., Gehrels, N., et al. 2017, GCN Circular, 19207, 1
Boldin, P. A., Tsygankov, S. S., & Lutovinov, A. A. 2013, Astron. Lett., 39, 375
Corbet, R. H. D. 1986, MNRAS, 220, 1047
Dhawan, V., Mioduszewski, A., & Rupen, M. 2006, VI Microquasar Workshop: Microquasars and Beyond, 52,1
Doroshenko, V., Santangelo, A., Kreykenbohm, I., & Doroshenko, R. 2012, A&A, 540, L1
Doroshenko, V., Ducci, L., Santangelo, A., & Sasaki, M. 2014, A&A, 567, A7
Doroshenko, V., Santangelo, A., Suleimanov, V. F., & Tsygankov, S. S. 2020, A&A, 643, A173
Evans, P. A., Beardmore, A. P., Page, K. L., et al. 2009, MNRAS, 397, 1177
Harrison, A., & Lynch, R. N. 2017, in American Astronomical Society Meeting Abstracts #229, Am. Astron. Soc. Meeting Abstr., 229, 431.04
Liu, Q. Z., van Paradijs, J., & van den Heuvel, E. P. J. 2006, A&A, 455, 1165
Mushtukov, A. A., Suleimanov, V. F., Tsygankov, S. S., & Portegies Zwart, S. 2020, MNRAS, submitted [arXiv: 2006.13596]
Rea, N., & Torres, D. F. 2008, ATel, 1731, 1
Reed, B. C. 2003, AJ, 125, 2531
Stephenson, C. B., & Sanduleak, N. 1971, Publ. Warner Swasey Obs., 1, 1
Surnis, M. P., Maan, Y., Joshi, B. C., & Manoharan, K. 2016, ATel, 8831, 1
Thompson, C., & Duncan, R. C. 1995, MNRAS, 275, 255
Torres, D. F., Rea, N., Esposito, P., et al. 2012, ApJ, 744, 106
Tsygankov, S. S., Doroshenko, V., Mushtukov, A. E. A., et al. 2019a, MNRAS, 487, L30
Tsygankov, S. S., Rouco Esorial, A., Suleimanov, V. F., et al. 2019b, MNRAS, 483, L144
Vynorov, V., Doroshenko, V., Staubert, R., & Santangelo, A. 2018, A&A, 610, A88
Wachter, K., Leach, R., & Kellogg, E. 1979, ApJ, 230, 274
Wilms, J., Allen, A., & McCray, R. 2000, ApJ, 542, 914