Suzaku Detection of an Intense X-Ray Flare from an A-Type Star, HD 161084

Junichiro MIURA,¹ Masahiro TSUIMOTO,²,* Yohko TSUBOI,¹ Yoshitomo MAEDA,³ Yasuharu SUGAWARA,¹
Katsuji KOYAMA,⁴ and Shigeo YAMAUCHI⁵

¹Department of Physics, Faculty of Science & Engineering, Chuo University, 1-13-27 Kasuga, Bunkyo, Tokyo 112-8551
²Department of Astronomy & Astrophysics, Pennsylvania State University, 525 Davey Laboratory, University Park, PA 16802, USA
³Institute of Space and Astronautical Science, Japan Aerospace Exploration Agency, 3-1-1 Yoshinodai, Sagamihara, Kanagawa 229-8510
⁴Department of Physics, Graduate School of Science, Kyoto University, Kita-shirakawa Oiwake-cho, Sakyō, Kyoto 606-8502
⁵Faculty of Humanities and Social Sciences, Iwate University, 3-18-34 Ueda, Morioka, Iwate 020-8550

miura@phys.chuo-u.ac.jp

(Received 2007 August 21; accepted 2007 November 4)

Abstract

We report on a serendipitous detection of an intense X-ray flare from the Tycho reference source on HD 161084 during a Suzaku observation of the galactic center region for ~20 ks. The X-ray Imaging Spectrometer recorded a flare from this A1-type dwarf or subgiant star with a flux of ~1.4 × 10⁻¹² erg s⁻¹ cm⁻² (0.5–10 keV) and a decay time scale of ~0.5 hr. The spectrum is hard with a prominent Fe XXV Kα emission line at 6.7 keV, which is explained by a ~5 keV thin-thermal plasma model attenuated by a ~1.4 × 10²¹ cm⁻² extinction. The low extinction, which is consistent with the optical reddening, indicates that the source is a foreground star toward the galactic center region. Based on a spectroscopic parallax distance of ~530 pc, the peak X-ray luminosity amounts to ~1 × 10³² erg s⁻¹ (0.5–10 keV). This is much larger than the X-ray luminosity of ordinary late-type main-sequence stars, and the X-ray emission is unattributable to a hidden late-type companion that comprises a wide binary system with the A star. We discuss possible nature of HD 161084, and suggest that it is most likely an interacting binary with elevated magnetic activity in the companion, such as the Algol-type system. The flux detected by Suzaku during the burst is ~100-times larger than the quiescent level measured using the archived XMM-Newton and Chandra data. The large flux amplification makes this star a unique example among sources of this class.

Key words: stars: flare — stars: individual (HD 161084) — stars: magnetic fields — X-rays: stars

1. Introduction

Main-sequence stars with intermediate (late B to early A) spectral types are considered to be intrinsically X-ray inactive. These stars have no X-ray production mechanisms, such as shocks in unstable stellar winds, causing X-ray emission in early-type stars (earlier than B2: Lucy & White 1980; Berghöfer et al. 1997), or magnetic activity as a consequence of a surface convection layer and differential rotation responsible for the X-ray emission in late-type stars. Indeed, most X-ray surveys of A-type stars in the field and in open clusters show a consistent paucity of their X-ray detections (e.g., Schmitt et al. 1985, 1990; Micela et al. 1990).

X-ray emission from A-type stars, if detected, is usually attributed to its magnetically-active late-type companion (e.g., Huélamo et al. 2000; Briggs & Pye 2003) that comprises a binary system. The idea is consistent with the following observational facts: (1) There is a lack of any correlation between the X-ray luminosity and various stellar properties of A-type stars (Simon et al. 1995; Panzera et al. 1999). (2) The X-ray emission from A-type stars is characterized by X-ray luminosities of 10²⁸–10³⁰ erg s⁻¹ with averaged soft emission, which is similar to those seen in late-type main-sequence stars.

In some high-resolution X-ray imaging studies, the position of the X-ray emission is located precisely enough to claim that the emission is from the late-type companion, and not from the A-type star, itself (Stelzer et al. 2003; Stelzer & Burwitz 2003). In some unresolved systems, too, the X-ray emission is confirmed to be from the late-type companion by an eclipsing observation (Schmitt & Kürster 1993), or by the Doppler-shift measurements of emission lines in the X-ray spectrum (Chung et al. 2004).

Nevertheless, these pieces of observational evidence do not entirely rule out the possibility of intrinsic X-ray emission from A-type stars. A-type stars with a debris disk (e.g., β Pic) may radiate thermal X-rays, fueled by accretion (Hempel et al. 2005), and those with strong magnetic activity (e.g., η Aur) may cause X-ray emission caused by magnetically confined winds (Babel & Montmerle 1997).

The long-term X-ray behavior of A-type stars is an important property to characterize their emission and to understand their origin. Monitoring observations on particular A-type stars are necessary to reveal their long-term flux and spectral variation, but the number of such studies is only a few (e.g., Briggs & Pye 2003). This is because systematic X-ray studies of A-type stars have been conducted by utilizing all-sky survey data (Simon...
et al. 1995; Panzera et al. 1999) or by snapshot observations of open clusters including A-type stars (Briggs & Pye 2003).

Here, we study the long-term X-ray behavior of an A-type star by exploiting the wealth of data obtained in the galactic center region. Every X-ray satellite has repeatedly observed this region, which contains many A-type stars as foreground objects. We surveyed the Suzaku images of the galactic center, and serendipitously found that the A-type star HD 161084 showed an intense flare during one of the mapping observations. The star is a Tycho reference center, classified as A1 V (Wright et al. 2003). In the X-ray band, the star has been soft and faint at \( \sim 10^{32} \) erg s\(^{-1}\) in the 0.5–10 keV luminosity in the archived X-ray data, but a sudden flaring made this source as bright as \( \sim 10^{35} \) erg s\(^{-1}\), which is hard to achieve by a hidden ordinary late-type companion. We report on a result obtained by the X-ray Imaging Spectrometer (XIS) aboard Suzaku, and discuss the nature of this source.

2. Observation

We conducted a Suzaku observation centered at \((\text{RA}, \text{Decl}) = (17^h44^m55.8^s, -29^d49'16")\) in the equinox J2000.0 as a part of the galactic center mapping campaign during the second announcement of opportunity observing cycle. The position is \(\sim 50'\) apart from the galactic center in the southwest direction. The observation was conducted on 2007 March 13–14 for a telescope time of \(\sim 34.5\) ks.

The Suzaku satellite (Mitsuda et al. 2007) produces simultaneous data sets taken by two instruments; one is the XIS (Koyama et al. 2007), sensitive in the energy range below \(12\) keV; the other is the Hard X-ray Detector (Kokubun et al. 2007; Takahashi et al. 2007), sensitive in the higher energy band. We used the XIS data in this paper.

XIS is equipped with four X-ray CCDs (XIS 0–3) mounted at the focal planes of the four independent X-Ray Telescopes (Serlemitsos et al. 2007) aligned to observe a \(\sim 18' \times 18'\) region. One of them (XIS 1) is a back-side illuminated (BI) CCD chip, and the remaining three (XIS 0, XIS 2, and XIS 3) are front-side illuminated (FI) chips. The BI and FI chips are composed of \(1024 \times 1024\) pixels, and are superior to each other in the soft and hard band responses, respectively. One of the FI chips (XIS 2) turned dysfunctional in 2006 November. We therefore used the data obtained by the remaining three CCDs.

The capability of XIS is subject to degradation by charged-particle radiation in the orbit. XIS employs the spaced-row charge injection (SCI) technique to rejuvenate its spectral resolution by filling the charge traps with artificially injected electrons through CCD readouts. We used the SCI mode in this observation.

The energy resolution as of the observation date is \(\sim 130\) eV in the full width half maximum at 6 keV. The radioactive sources of \(^{55}\)Fe illuminate two corners of each CCD for calibrating the absolute energy gain at an accuracy of \(\sim 10\) eV for the FI data and \(\sim 60\) eV for the BI data in the SCI mode. The imaging performance is characterized by a half power diameter of the point spread function of \(\sim 2'\), which is independent of the off-axis angle. The absolute astrometry of the XIS frame is uncertain up to \(\sim 50'\).

The observation was conducted with the normal clocking mode with a frame time of 8 s. We reduced the data using HEAsoft\(^1\) version 6.2.0. A cleaned event list was obtained from the data (processing version 1.3\(^2\)) by removing events taken during the South Atlantic Anomaly passages, the geomagnetic cut-off rigidity of \(<8\) GV, the elevation angles from the Earth rim of \(<10^\circ\) and from the sun-lit Earth rim of \(<20^\circ\), and the telemetry saturation. After filtering, the net integration time was \(\sim 19.7\) ks. The observation log is summarized in table 1.

3. Results

3.1. Image and Source Identification

Figures 1a and b show the XIS images integrated over the entire observation in the (a) soft (0.5–2.0 keV) and (b) hard (2.0–10 keV) bands. Both the FI (XIS 0 and XIS 3) and BI (XIS 1) data were summed. Two point-like sources were detected; one is conspicuous in both bands at the top right, and the other in the hard band near the center.

In order to register the XIS frame and to identify these two sources, we retrieved the archived data of other X-ray telescopes. We found that Einstein, ROSAT, ASCA, Chandra, and XMM-Newton covered this region during their observations of galactic center sources (table 1). We found that the Suzaku source near the field center was also detected in the Chandra and at the edge of the XMM-Newton images with a similar spectral hardness and brightness. The Chandra position of this source is registered using the 2MASS–Chandra counterpart matches in this region, and is named CXOGC J174445.5–295042 (Muno et al. 2006). This source is point-like and isolated, and thus serves as a good astrometric calibrator. We shifted the astrometry of the XIS image to match with the Chandra position.

Using the registered XIS frame, we measured the position of the other Suzaku source to be \((\text{RA}, \text{Decl}) = (17^h44^m45.7^s, -29^d44'46.1')\). The positional uncertainty is \(\sim 7.3\) (90% confidence range), which includes both the uncertainty of the position determination by fitting the intensity profile of the source and the uncertainty of the plate scale of the XIS image. Within the Suzaku error circle, we found a Chandra source cataloged as CXOGC J174449.7–294447 and identified as the X-ray counterpart of HD 161084 (Muno et al. 2006). We confirmed that there is no other source in the vicinity in the

---

\(^1\) See (http://heasarc.gsfc.nasa.gov/docs/software/lheasoft/) for details.

Chandra image as well as in near-infrared images obtained by SIRIUS (Simultaneous three-color InfraRed Imager for Unbiased Surveys: Nagayama et al. 2003) at the Infrared Survey Facility (private communication with S. Nishiyama and T. Nagata). We thus conclude that the Suzaku source is the X-ray counterpart of HD 161084 and is identical to CXOGC J174449.7–294447.

We also checked the XMM-Newton image obtained by the European Photon Imaging Camera (EPIC: Strüder et al. 2001; Turner et al. 2001). The profile of the astrometric calibrator is distorted at the field edge, and could not be used for the field alignment. No other sources in the image were suitable for this purpose, so we did not perform any bore-sight correction. Nonetheless, the astrometry given in the processed data\(^3\) has an uncertainty of \(\sim 3.6\) (90\% confidence range), which is sufficient to compare to the other images. Figure 2 shows a close-up view of the XMM-Newton image. A source was confirmed at the position of HD 161084, which we recognize as the XMM-Newton counterpart of HD 161084.

Although HD 161084 was detected in the Suzaku, Chandra, and XMM-Newton images, their X-ray flux is quite different; the Chandra and XMM-Newton flux is fainter than the Suzaku flux by about two orders. Actually, the source was faint and

\(^{3}\) See (http://xmm.esac.esa.int/docs/documents/CAL-TN-0018.pdf) for details.
Fig. 2. XMM-Newton 0.5–10 keV band image of the dashed square region in figure 1a. Two MOS images are combined. The pn data were unavailable. The position of the Chandra (Muno et al. 2006) and the Tycho sources are shown with a red cross and a white plus, respectively. The error circles (90% confidence range) of the position are shown for the Suzaku and XMM-Newton counterparts of HD 161084 respectively by red and white circles.

undetected in the first 10 ks (phase 1 in figure 3; see subsection 3.2) of the Suzaku observation too, which is evident in the time-sliced XIS images (figure 1) of this duration in the (c) soft and (d) hard band. This indicates that the source experienced a flux amplification during the XIS observation.

3.2. Light Curve

We constructed the X-ray light curve of HD 161084 in the 0.5–10 keV band using both the FI and BI data. The source photons were accumulated from a circular region with a radius of 1.5, while the background photons were from a circular region with a 3:0 radius (solid and dashed circles in figure 1a, respectively). The centers of the two circles are at an equal distance from CXOGC J174445.5–295042 in order to cancel a possible contamination from the source. Figure 3 shows the (a) background-subtracted light curve and (b) background light curve normalized to the extraction area.

In the source light curve, we see a variation of a rapid rise and a slow decay typical of stellar flares starting at ∼12 ks after the observation started. The variation is hardly attributable to the background, because the background light curve is relatively stable. The duration of the flare is characterized by an e-folding time of ∼1.7±0.5 ks. After the flare ceases at ∼16 ks, the count rate did not settle back to the pre-flare quiescent phase, but it subsequently showed another flux amplification that lasted until the end of the observation. We defined three time slices based on this development: phase 1 for the pre-flare phase, phase 2 for the flare phase, and phase 3 for the post-flare phase.

3.3. Spectrum

We next constructed the X-ray spectrum of HD 161084. We used a provisional method4 for the spectral analysis of the SCI data. Because this method is only applicable to the FI data, we did not use the BI data in the spectral analysis. Figure 4 shows the background-subtracted spectra in the 0.5–10 keV band during the (a) phase 2 and (b) phase 3. The source and the background spectra were accumulated from the same regions for the light curves.

Both spectra are characterized by hard emission with a conspicuous emission line feature at 6.7 keV, which originates from the K line of Fe XXV. It is evident that the spectra are thermal with a plasma temperature of a few keV. We fitted the data with a thin-thermal plasma (mekal) model (Mewe et al. 1985, 1986; Kaast 1992; Liedahl et al. 1995) with an interstellar extinction (Morrison & McCammon 1983). The abundance of elements was fixed to the solar values (Anders, Grevesse 1989). Here, we generated ancillary responses using xissimarfgen (version 2006-11-26: Ishisaki et al. 2007) and the redistribution matrices using the provisional method.

The best-fit values of the plasma temperature ($k_B T$), X-ray volume emission measure ($EM$), flux ($F_X$), and luminosity ($L_X$) and the amount of extinction ($N_H$) are summarized in table 2. A statistically-acceptable fit was obtained for both spectra. Upon confirmation that the spectral shape did not change between the phases 2 and 3, we merged the two spectra and derived the best-fit parameters for the integrated spectrum (table 2). In order to examine how the best-fit parameters are affected by our choice of the background region, we repeated the same procedure for several other background regions, and found that the best-fit values were consistent with each other.

3.4. Long-Term Behavior

Using the archived data, we studied the long-term X-ray variation of this source. Out of the seven archived data sets

---

Table 2. Best-fits spectral parameters. *

<table>
<thead>
<tr>
<th>Telescope/Instrument</th>
<th>$N_H$ (10$^{22}$ cm$^{-2}$)</th>
<th>$k_B T$ (keV)</th>
<th>$EM^*$ (10$^{51}$ cm$^{-3}$)</th>
<th>$F_X^*$ (erg s$^{-1}$ cm$^{-2}$)</th>
<th>$L_X^*$ (erg s$^{-1}$)</th>
<th>$\chi^2$/d.o.f</th>
</tr>
</thead>
<tbody>
<tr>
<td>Suzaku/XIS (phase2)</td>
<td>0.22$^{+0.35}_{-0.20}$</td>
<td>5.2$^{+5.9}_{-2.0}$</td>
<td>25.3$^{+9.3}_{-6.9}$</td>
<td>13.5$^{+3.6}_{-1.6}$ 10$^{-13}$</td>
<td>4.6 $\times$ 10$^{31}$</td>
<td>18.9/18</td>
</tr>
<tr>
<td>Suzaku/XIS (phase3)</td>
<td>0.11$^{+0.14}_{-0.10}$</td>
<td>4.0$^{+2.8}_{-1.4}$</td>
<td>15.6$^{+3.3}_{-2.9}$</td>
<td>7.7$^{+1.7}_{-1.6}$ 10$^{-13}$</td>
<td>2.6 $\times$ 10$^{31}$</td>
<td>15.3/20</td>
</tr>
<tr>
<td>Suzaku/XIS (phase2+3)</td>
<td>0.14$^{+0.11}_{-0.09}$</td>
<td>4.7$^{+2.5}_{-1.3}$</td>
<td>18.0$^{+3.0}_{-2.7}$</td>
<td>9.3$^{+1.5}_{-1.2}$ 10$^{-13}$</td>
<td>3.2 $\times$ 10$^{31}$</td>
<td>22.3/20</td>
</tr>
<tr>
<td>XMM-Newton/MOS</td>
<td>0.14 (fixed)</td>
<td>0.66$^{+0.47}_{-0.35}$</td>
<td>0.19$^{+0.09}_{-0.09}$</td>
<td>1.5$^{+0.5}_{-0.7}$ 10$^{-14}$</td>
<td>4.9 $\times$ 10$^{29}$</td>
<td>8.44/10</td>
</tr>
</tbody>
</table>

* The uncertainties indicate the 90% confidence range.

Values in the 0.5–10 keV energy range.

---

Fig. 4. Background-subtracted XIS spectra in the (a) phase 2 and (b) phase 3 (figure 3). Data obtained by the two FI chips were merged. The top panel shows the data with crosses and the best-fit model with solid lines. The bottom panel shows the residuals to the fit.

Fig. 5. Background-subtracted EPIC spectra (black for MOS1 and red for MOS2). Other symbols follow figure 4.

Chandra observations: ObsID = 658 and 2278) or with no significant X-ray detections at all. We therefore assumed the spectral shape of the best-fit XMM-Newton model and derived the flux or its 3σ upper limit in the 0.5–10 keV band. The flux upper limit in the Suzaku phase 1 was also derived in the same manner. The long-term flux variation is shown in figure 6. During the Suzaku observation, the flux was amplified by more than two orders from the quiescent level determined by the Newton and Chandra observations. No such burst event was detected in other observations.

4. Discussion

4.1. Extinction and Distance to HD 161084

HD 161084 has been a largely ignored source, and nothing beyond the catalog information is known. We start with estimating the distance to HD 161084. From the SIMBAD database, the source has a $B$-band and $V$-band magnitudes of 10.29 mag and 10.11 mag, respectively. It is classified as a star of A1 VI or A1 V.

Assuming the source is an A1 V star, the intrinsic ($B - V$) color is $\sim 0.015$ mag (Drilling & Landolt 2000). The source is estimated to have a reddening of ($B - V$) $\sim 0.165$ mag to be compatible with the observed color, which can be converted to an extinction of $A_V \sim 0.51$ mag. This is consistent with the independent measurement of the X-ray absorption of
4.4. Nature of HD 161084

In the quiescent phase, the X-ray emission from HD 161084 appears to be attributable to an uncovered normal low-mass main-sequence companion or the intrinsic emission from an A-type star. However, the intense flare with an amplified X-ray flux and a hard spectrum makes both interpretations unlikely. The flare luminosity is beyond the reach of normal late-type stars. The X-ray emission from the debris disk and magnetic A-type stars is weak (\(~10^{32}\) erg s\(^{-1}\)), soft, and constant (Hempel et al. 2005; Cash & Snow 1982; Golub et al. 1983), which contradicts the behavior of HD 161084 during the flare.

We speculate that the X-ray emission from HD 161084 is from its hidden late-type companion, and the secondary star is exceptionally bright among stars of this type. The level of X-ray activity in late-type stars is known to be an increasing function of the rotational velocity (e.g., Pallavicini et al. 1981). This is a natural consequence that the X-ray-emitting plasma is fueled by energy release of magnetic fields generated by turbulence in the surface convection layer and differential rotation. Two major classes of late-type stars are known to rotate faster and to emit exceptionally brighter X-rays than ordinary late-type stars.

One is pre-main-sequence sources, whose faster rotation stems from the accumulation of angular momentum via accretion and contraction during their formation. These sources can be bright up to \(~10^{32}\) erg s\(^{-1}\) with hard X-ray emission (e.g., Imanishi et al. 2001). A bright and hard X-ray flare of \(~10^{31.6}\) erg s\(^{-1}\) (0.5–8.0 keV) was observed from an intermediate-type star HD 38563S (B3–B5: Yanagida et al. 2004). The X-ray emission from this source can be from a hidden late-type pre-main-sequence companion around the B star, which is quite conceivable, considering that HD 38563S is in a young star-forming region, NGC 2068. We consider that HD 161084, in contrast, is not located in a star-forming region, and thus is unlikely to have a pre-main-sequence companion. We examined the near-infrared image by SIRIUS, but no clustering of red sources was present, which would indicate star-forming regions. Moreover, the extinction toward HD 161084 is consistent with the integration of interstellar hydrogen density of 1 cm\(^{-3}\) along the line of sight. Most sources in star-forming regions suffer an additional extinction by natal molecular cloud and circumstellar matter. The lack of such extra extinction further supports that HD 161084 is a field star.

The other class of fast rotators is interacting binaries. The tidal force and mass transfer between the two components of a close binary synchronizes the stellar rotation with the orbital motion, giving rise to a faster rotation and elevated X-ray activity in the late-type constituent. A handful of classes of such interacting binaries are known (Hall 1989; Richards & Albright 1993). Among them, the classes that may contain an intermediate-type main-sequence star are the Algol-type (semi-detached) and the W Uma-type (contact) binaries.

The Algol-type binary is a well-established class of intense X-ray emitters with an intermediate-type dwarf and late-type giants or sub-giants. The X-ray emission from Algol-type sources is attributed to a fast-rotating late-type star (White & Marshall 1983; Schmitt & Favata 1999; Chung et al. 2004).
They emit hard and luminous X-rays with occasional flares (Singh et al. 1995, 1996; Ottmann & Schneider 1996), which is comparable to those observed from HD 161084 in the flare state. We suggest that HD 161084 is an interacting binary of the Algol-type based on the observed X-ray properties.

W UMa-type stars also cause X-ray flares with a luminosity up to $\sim 10^{31}$ erg s$^{-1}$ (McGale et al. 1996; Choi & Dotani 1998). In almost all of these systems, the spectral type of the two stars are nearly equal (Maceroni & van’t Veer 1996). The secondary star of HD 161084 is thus likely to be another A1-type star. The origin of the X-ray emission boils down to the intrinsic X-ray emission from A-type stars, which we concluded to be unlikely to account for the emission from HD 161084. We thus speculate that HD 161084 is not a W UMa-type binary.

What makes this source unique among these classes is the degree of amplification of the flare flux from the quiescent flux. Both the Algol and W UMa binaries show occasional flares, but their flux increase from the quiescent state is common. A few times (Choi & Dotani 1998; Gondoin 2004a, 2004b; McGale et al. 1996; Nordon & Behar 2007; White et al. 1986). It may be the case that the X-ray emitting late-type companion in the HD 161084 system was eclipsed during all of the previous X-ray observations, except for phases 2 and 3 of the Suzaku observation. The interacting binary nature of HD 161084 is conclusively identified by established methods, such as photometric eclipse and spectroscopic monitoring. We encourage follow-up observations of this source.

5. Summary

We serendipitously detected an intense X-ray flare from the A1-type star HD 161084 during one of the Suzaku mapping observations of the galactic center region. A flux of $\sim 1.4 \times 10^{-12}$ erg s$^{-1}$ cm$^{-2}$ (0.5–10 keV) was recorded. The spectrum shows a prominent Fe XXV K$\alpha$ emission line at 6.7 keV, indicating a high-temperature plasma. The flare decay time scale is $\sim 0.5$ hr. We estimated the distance of HD 161084 as $\sim 530$ pc based on the spectroscopic parallax. The peak luminosity of the flare amounts to $\sim 10^{32}$ erg s$^{-1}$ (0.5–10 keV).

The flare emission is too luminous and too hard to explained by an intrinsic emission from A-type stars, or a hidden late-type main-sequence companion in a wide binary. We suggest that the nature of this source is most likely an interacting binary, such as the Algol-type system, in which the magnetic activity of the late-type companion is enhanced by fast rotation due to locking with the orbital motion.

The position of this source at the galactic center allowed us to study its long-term behavior by exploiting the wealth of the archived data in this region. The quiescent level was characterized by an X-ray luminosity of $\sim 10^{29.5}$ erg s$^{-1}$ and a plasma temperature of $\sim 0.7$ keV, which are distinctively different from those during the flare.

HD 161084 showed two orders of amplification in luminosity from the quiescent to the flare phase. No Algol-type sources were found with such a large amplification before, which makes HD 161084 a unique sample of these possible classes.

The authors thank Dai Takei and Masashi Hanya for their help in the archived X-ray data reduction, Shogo Nishiyama and Tetsuya Nagata for providing the SIRIUS data, and Shinya Narusawa for expertise comments on interacting binary systems. This research has made use of the SIMBAD database, operated at CDS, Strasbourg, France. Y.T., Y.M., and S.Y. acknowledge support from the Grants-in-Aid for Scientific Research (numbers 17740109, 17740126, and 18540228, respectively) provided by the Ministry of Education, Culture, Sports, Science and Technology.

References

Mitsuda, K., et al. 2007, PASJ, 59, S1