The peculiar X-ray variations of the enigmatic massive binary WR 21a

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\textbf{Abstract}

The X-ray observations of the enigmatic W-R binary WR 21a is reported. WR 21a is one of the X-ray brightest colliding wind binaries ($\varepsilon=0.64$, $P_{\text{orb}}=31.673$ d). These masses are estimated to be $M_{\text{WR}}>87M_\odot$ (one of the most massive stars) and $M_{\text{O}}>53M_\odot$. Using Chandra/ACIS archived data, we discovered a peculiar, flare-like X-ray variability around apastron. The X-ray spectra were well-fitted with single-absorbed component at $kT\sim2$–$3$ keV, which are compatible with the thermal shocked plasma. There is the potential for a flare-like increase of the mass-loss rate. In addition, the first one-period monitoring performed by Swift/XRT in order to reveal the total variation in one period. Our observations cover 17 different epochs from 2013 October 1 to 2013 November 2 for a total exposure of about 73 ks. It is found for the first time that the flux varies roughly in inverse proportion to the separation of the two stars before the X-ray maximum but later drops rapidly toward periastron.

\textbf{Key words:} stars: Wolf-Rayet — binaries: spectroscopic — stars: WR21a

\section{1. Introduction}

From recent research, X-ray observation of massive binary is gradually becoming known to be effective tool in order to limit the wind acceleration and mass-loss rate of massive star. Massive binaries composed by a Wolf-Rayet (W-R) star and an OB star have the highest temperature plasma among early-type stars, produced by the collision of the winds. The ram pressure balance to the hypersonic winds determines the position of the colliding wind region. The shocked plasma is heated up to $10^7$–$10^8$ K. The colliding wind binary is the best testing ground for plasma shock physics, because plasma properties vary with binary separations.

WR 21a was discovered serendipitously with Einstein by Goldwurm et al. (1987). Reig (1999) presented that its X-ray emission could be explained if the star is massive, early-type star with colliding wind binary. According to its optical spectral spectrum, it was classified as a likely binary (WN5-6+O3), at a maximum distance of $d=3$ kpc (Reig 1999).

Benaglia et al. (2005) synthesized past X-ray activity of WR 21a by plotting X-ray luminosity at 1–2 keV band (figure 5 in Benaglia et al. 2005). They used all of available data obtained with Einstein, ROSAT, RXTE and ASCA. They fitted absorbed Bremsstrahlung model to all available spectra with only the luminosities free. Therefore, they assumed same column density to all spectra.

Recently, Niemela et al. (2008) executed a detailed analysis of the optical spectra of WR 21a for several epochs. Their results support the binary hypothesis, and determine the period of $P\sim31.673$ d. They obtained very high minimum masses $M_{\text{WN}}>87M_\odot$ and $M_{\text{O}}>53M_\odot$.

In this paper, we report the phase-locked X-ray variation and the one-period X-ray monitoring results for the first time.

\section{2. Observation and Data reduction}

\subsection{2.1. Chandra}

\textit{Chandra} observed WR 21a on 2008 April 27 (ObsID 9113). We analyzed archival data of ACIS. The exposure time is about 5 ksec. Data reductions were performed using the CIAO version 4.4 with the CALDB version 4.4.7. The events were extracted from a circular region of 15 arcsec surrounding the centroid position of the source. The ACIS spectrum was extracted using the CIAO tool \texttt{specextract}.

\subsection{2.2. Swift}

\textit{Swift} We requested a target of opportunity (ToO) monitoring with \textit{Swift}. Our observations cover 17 different epochs from 2013 October 1 to 2013 November 2 for a total exposure of about 73 ksec. We extracted XRT light curves by using the Swift-XRT data products generator (Evans}
et al. 2009). Only events with energy in the range 0.3–10 keV with grades 0–12 are included.

3. Results

The Chandra/ACIS spectrum was well-fitted with single-absorbed component at $kT \sim 2–3$ keV, which are compatible with the thermal shocked plasma (see figure 1). The absorption-corrected X-ray luminosity in the 0.5–10 keV band was $6.4 \times 10^{33}$ ergs s$^{-1}$. In figure 2, we show the plot for binary separation vs. X-ray luminosity of WR 21a, adding an archival Chandra data we analyzed to the data-plots in Benaglia et al. (2005). The gray dashed line shows the luminosity relation based on stellar wind acceleration $\beta = 0$. We discovered a peculiar flare-like X-ray variability around apastron, which exists in addition to the overall changing in X-ray luminosity.

X-ray flares from massive stellar binaries are only reported on Eta Carina with binary period of 5.5 years (Corcoran 2005), where one of the components is a LBV star. The flaring activity changes along with the orbital phase, but the most active phase is not apastron but periastron (Moffat and Corcoran 2009). These flares could be interpreted as a flare-like increase of the mass loss rate (Ishibashi et al 1999) or small scale (blob-like) mass loss (Moffat and Corcoran 2009), since the high activity is seen at periastron. In the case of the flares from WR 21a, this unexpected brightening around apastron may be explained the change of mass-loss rate or Large-scale Corotating Interaction.

Figure 3 shows the first one-period monitoring result with Swift/XRT. It is found for the first time that the X-ray light curve varies roughly in inverse proportion to the separation of the two stars before the X-ray maximum but later drops rapidly toward periastron. A part of the flux drop near the periastron can be explained the change of the shape of shocked plasma and occultation by W-R star.

References