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X-rays from young clusters reveal binarity of massive stars

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Abstract. We analysed the X-ray emission from massive Wolf-Rayet (WR) stars in vicinity of two young stellar clusters (Danks 1 and Danks 2) in the G305 star-forming region in the Scutum Crux arm of the Galaxy. Ten WR stars fall in the field of view of the corresponding archive *Chandra* observation. Based on the previous studies of X-ray emission from presumably single and binary WR stars, we estimate that about 60 - 66 % of the WR stars in vicinity of Danks 1 and Danks 2 are binary systems.

1. X-rays from Wolf-Rayet stars

Wolf-Rayet (WR) stars are descendants from the most massive stars in the Galaxy and are divided into three subtypes: nitrogen-rich (WN), carbon-rich (WC) and oxygen-rich (WO; see Crowther 2007 for a review on physical properties of WRs). Their X-ray properties could be summarized as follows.

Single WRs. **WN stars** are clearly detected with X-ray luminosity $L_X < 10^{33}$ ergs s^{-1} as the late WN objects (WN8-9) are faint X-ray sources (Skinner et al. 2010, Skinner et al. 2012). **WC stars** have NO X-ray detection (Oskinova et al. 2003, Skinner et al. 2006), so, they are either very faint or X-ray quiet. **WO stars**: the only pointed observation of such a star showed that they are X-ray sources (Oskinova et al. 2009, Sokal et al. 2010).

Binary WRs. Binary objects of all subtypes are X-ray sources as they are brighter than the single WR objects and their enhanced X-ray emission is assumed to originate from colliding stellar winds of the massive binary components (see Rauw & Nazé 2016 for a recent a review on X-ray emission from interacting wind massive binaries).

Guided by their X-ray properties, we propose the following *X-ray based criteria* of Single vs. Binary Wolf-Rayet object.

(i) WC stars: X-ray detection indicates a binary; non-detection indicates a single object.
(ii) WN and WO stars: objects with X-ray luminosity *larger* than 10^{33} ergs s^{-1} are binaries while others are single WRs.

2. X-rays from WRs in G305

G305 is a star-forming region in the Scutum Crux arm of the Galaxy. Near its centre, there are two compact stellar clusters Danks 1 and Danks 2 (Danks et al. 1983) with estimated age of $1.5^{+1.5}_{-0.5}$ Myr and $3.0^{+3.0}_{-1.0}$ Myr, respectively (Davies et al. 2012). More than ten WR stars have been identified in G305 (Mauerhan et al. 2011; Davies et al. 2012).

The WR stars in vicinity of the young clusters Danks 1 and Danks 2 that fell in the field of view of a *Chandra* observation (ObsID 8922; 119.5 ks exposure) are listed in Table 1. We

Table 1. Properties of the WR stars in G305

	Name (SIMBAD)	Spectral type	X-ray counts	log L_X (ergs s^{-1})	Single or Binary
(1)	[DCT2012] D1-5	WNLh	643 ± 27	33.28	B
(2)	[DCT2012] D1-1	WNLh	409 ± 21	33.68	B
(3)	[DCT2012] D1-2	WNLh	250 ± 18	33.20	B
(4)	[MVM2011b] MDM3	WN8-9	468 ± 22	33.34	B
(5)	[MVM2011b] MDM5	WN9	7 ± 5	31.59	S
(6)	[SMG2009] 845-35	WC7	(in CCD gap)	N/A	...
(7)	[DCT2012] D2-3	WC8	0 ± 3	< 31.0	S
(8)	WR 48a	WC8+WN8h	(piled up)	> 35.0	B
(9)	[SMG2009] 845-34	WC8	93 ± 10	31.53	B
(10))	MSX5C G305.4013+00.0170	WCL	0 ± 2	< 30.8	S

The spectral type is from Mauerhan et al. (2011) and Davies et al. (2012) excepting objects (7) and (8) for which is from Zhekov et al. (2014). The values of the X-ray luminosity L_X (0.5 - 10 keV) are for adopted distance of d = 4 kpc (Danks et al. 1983; Davies et al. 2012). The X-ray emission of WR 48a, the X-ray most luminous WR star in the Galaxy, is discussed in Zhekov, Gagné, & Skinner (2011; 2014).

used the CIAO 4.7.3 data analysis software to re-process the archive data and to extract all the files needed for the X-ray analysis (for details, see `http://cxc.harvard.edu/ciao/`). The spectra were re-binned to have a minimum of 10 X-ray counts per bin. We fitted the spectra with models of absorbed X-ray emission from optically thin plasma in version 12.9.2 of XSPEC (for details, see `https://heasarc.gsfc.nasa.gov/docs/xanadu/xspec/`).

3. Conclusions

Adopting the X-ray based criteria for Single vs. Binary WRs, our analysis of the X-ray emission from massive stars in G305 leads to the following conclusions.

(1) More than 60% (6 out of 9 objects) of the massive Wolf-Rayet stars in vicinity of the central young stellar clusters Danks 1 and Danks 2 in the star-forming region G305 are *binary systems* (see Table 1).

(2) Optical observations are needed to further support or rebut this conclusion.

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