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Multiwavelength study of the intriguing massive star CPD–59 2629 (Tr 16-22)

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Abstract: We report preliminary results of a multi-wavelength (radio–optical–X-ray) study of the massive star CPD $-59\,2629$ (Tr 16-22) in the Carina Nebula (NGC 3372). This star has historically shown a large X-ray excess (log $L_X/L_{bol} < -6$ or even larger), which is one order of magnitude larger than expected from single massive O-type stars. A colliding wind scenario is a plausible explanation. On this subject, we searched for non-thermal radio emission and used high-resolution optical spectroscopy to check for multiplicity and investigate the nature of the stars as well as the origin and excess of the X-ray emission. We detected long-term radial-velocity and X-ray variability. Both results suggest that Tr 16-22 is a long-term massive binary system and a variable colliding wind shock scenario.

1 Introduction

Trumpler 16 is one of the most massive young open clusters in the Carina Nebula (NGC 3372). It is located at about 2250 pc (Davidson et al. 1997). Among the large population of O-type stars emitting in X-ray, CPD $-59\,2629$ (Tr 16-22) displays an unusually high X-ray luminosity in comparison with its bolometric luminosity $L_X/L_{bol} \cong -5.8$, -5.3 and -5.2 (Evans et al. 2003; Sanchawala et al. 2007; Albacete-Colombo, Méndez & Morrell 2003, respectively). Furthermore, it shows a large average absorption with an unusual characteristic beyond simple foreground reddening. The X-ray luminosity of the source seems to be variable, i.e. $L_X = 7.9 \pm 0.5 \times 10^{31}$ erg s^{-1} (Evans et al. 2003); log $L_X = 32.83$ erg s^{-1} (Sanchawala et al. 2007); log L_X = 33.30 and 32.8 erg s^{-1} (Albacete-Colombo et al. 2003, 2008; respectively), but also converts this star in one of the brightest O-type stars observed, i.e. approximately a factor of 5-20 larger than other known O8.5 V stars in massive clusters. In addition, Tr 16-22 presents a hard X-ray spectrum, that could be indicative of strong colliding stellar winds processes in a massive binary system (Corcoran 2003). All these issues make Tr 16-22 a somewhat more peculiar object, different from other known O-type stars.

2 Radio observations

The field of the massive star Tr 16-22 was observed at 4.8 and 8.64 GHz with ATCA, as part of the RMS campaigns (Lumsden et al. 2002, Urquhart et al. 2007). The field center at (FK5 J2000) = (10:45:00.90, -59:47:1) corresponds to a MSX source (G287.6393-00.7219). The synthesized beams (RA,Dec,P.A) resulted in 1.9 x 1.2, -23.9 deg (at 8.64 GHz) and 3.0 x 1.8, -21.2 deg (at 4.8 GHz). The rms attained were 0.12 mJy/beam, and 4.99 mJy/beam, at 8.64 and 4.8 GHz respectively. Unfortunately, no radio continuum source was found at the position of the star.

3 Optical observations

We compiled a set of spectrograms obtained in three different runs from CASLEO, Argentina, and LCO, Chile. From CASLEO, we obtained 5 echelle spectra ranging from 3800 Å to 6100 Å with a typical dispersion of 0.3 Å pix^{-1}. The three spectra obtained from LCO have a coverage of 3500-9800 Å and a dispersion of 0.1 Å pix^{-1}. We measured the radial velocities (RV) of He II and He I absorption lines, as well as the Na II interstellar lines and some nebular emission lines to check the stability of both echelle spectrographs. We obtained that Tr 16-22 is a radial-velocity variable. We determined a significant ($\sim$50 km s^{-1}) difference between the most extreme spectra. The mean RV obtained in each epoch could be due to a long period system. And also, some profiles suggest the presence of a secondary companion. This star is now included in the OWN survey (Barbá et al. 2010).

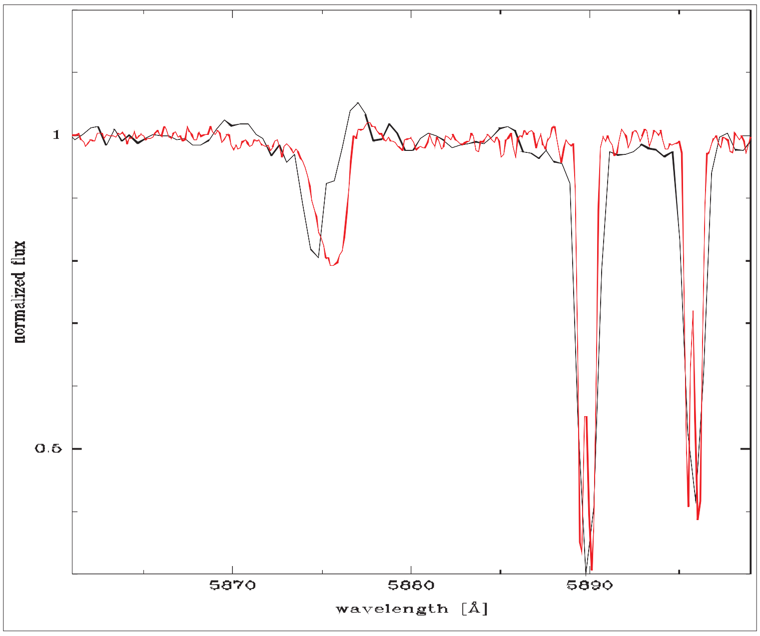

Figure 1: Two optical spectra of Tr 16-22, in the region of He I 5875 Å. Note the wavelength shift between He I absorption lines, but not between the Na I interstellar (IS) lines.

4 X-ray observations

The field of the Carina nebula, locus of the massive star Tr 16-22, was observed, more than 20 times over 10 years, by the *Newton* X-ray Multi-Mirror Mission (*XMM*) observatory with the EPIC-PN and MOS. For this work, we use a preliminary set of seven available *XMM-Newton* observations of the region. Further analysis with the remaining available *XMM-Newton* and *Chandra* observations will be published soon. Detailed information of the observations used is given in Table 1. The data were analyzed with the XMM Science Analysis System (SAS) version 9.0.0 and the latest calibrations files.

The results show that the X-ray light curve of Tr 16-22 displays a significant variability (see Fig. 2, left panel), which covers a factor 30 over the time-scale of about 3 years. Moreover, we found time-dependent N_H variations (see Fig. 2, right panel), which confirm that the bulk of absorption comes from Tr 16-22, not the ISM. Otherwise, two thermal components are necessary to fit the X-ray spectra. While the soft component at about 0.5 keV does not show significant variations, the hard component of the spectrum varies with some dispersion between 1.5 and 2.5 keV. If it were a long-term binary as suggest our optical data, (i.e. probably an eccentric orbit), at some orbital phases, stellar winds would collide at velocities near the wind escape velocity (i.e. 2000 to 3000 km/s), which implies post-shock temperatures over 1 to 3 keV (Stevens et al. 1992). These results mean that the hard part of the X-ray spectrum would come from the colliding wind region (CWR) at the different orbital configurations of the system.

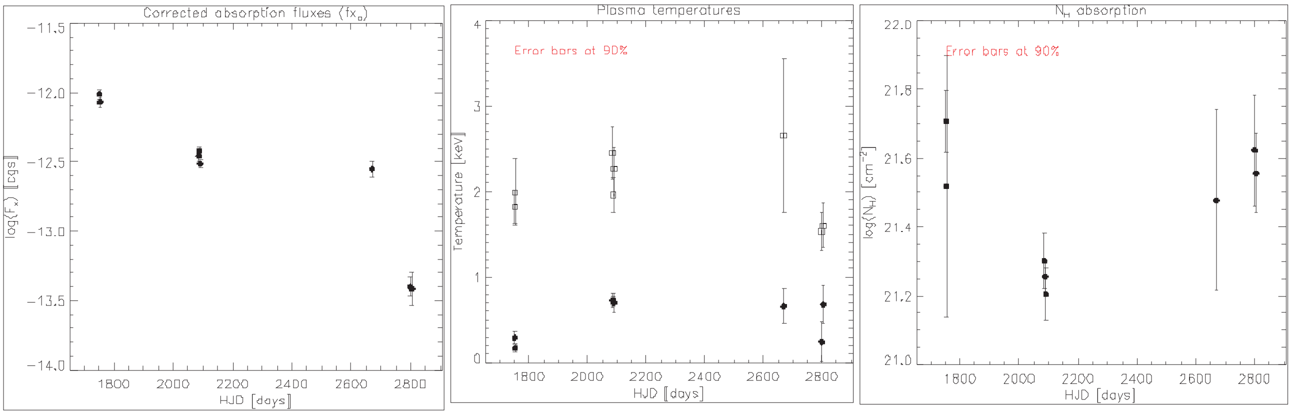

Figure 2: Left: Total absorption corrected X-ray flux as a function of time. X-ray fluxes were computed in the 0.5-8.0 keV energy band. It is clear that f_x varies over a factor 31. Center: The first and second temperature components show a slight variation in time. Right: Time-dependent N_H variations. Changes of the N_H could be due to different orbital configurations of the system. N_H^{ISM} was fixed to 5.8×10^{21} cm^{-2} (A_v=3.6; Albacete-Colombo et al. 2008.)

5 Discussion and conclusions

In massive early O-type stars, X-ray emissions are observed as a natural consequence of multiple small-scale shocks in the inner layers of their radiation-driven stellar winds (e.g. Feldmeier, Puls & Pauldrach 1997). However, in the case of O+OB binary systems, wind-wind interaction produces a hot shocked gas region with temperatures that exceed one million degrees (few keV), but also produce an increment in the observed X-ray emission from the star. Such X-ray emission is observed to be variable according to the different orbital phases, i.e. density and relative velocity of the winds of the CWR and the wind absorption along the line of sight.

Besides the observed X-ray excess of the Tr 16-22 star (e.g. Albacete-Colombo et al. 2003, 2008), its X-ray light curve shows a significant variability with time (a factor 31 in 3 years). Such a behavior cannot be explained in terms of the line-driven stellar wind shocks. The most plausible explanation of the observed flux variability and high kT values is that Tr 16-22 is an O+OB interacting wind binary system, which produces an excess X-ray emission at the CWR. Previous works suggested this

Table 1: Detailed information of the used X-ray observations

Obs-Id	Date	Exp (ks)
0112580601	2000-07-26	36509
0112560101	2001-06-25	37052
0112560201	2001-06-28	40092
0112560301	2001-06-28	37714
0160160901	2003-06-30	38352
0160160901	2003-06-13	31655
0112580701	2000-07-27	12425

scenario (e.g. Albacete Colombo et al. 2008), but this work constitutes the first report of a long-term X-ray variability in the Tr 16-22 star.

Complementary analysis of available *XMM-Newton* and *Chandra* data are in progress, and also future spectroscopic optical observations are scheduled to improve these results. These information could help to reveal more details of the interesting star Tr 16-22.

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