PROCEEDINGS OF SCIENCE

Discovering the colliding wind binary HD 93129A

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HD 93129A is a binary system including an O2 If+ and probably an O3.5 V-star orbiting at a distance of about 140 AU (55 mas given the distance of 2.5 kpc), which potentially makes the system the most massive one in the Galaxy, ahead of eta-Carina. Its non-thermal radio emission was proposed to be originated by the collision between the winds of both stars. *HST*/FGS data have been reanalyzed to derive an accurate absolute position of the stars to compare them with the radio emission. The analysis of ATCA radio observations along several years reveals a power-law spectrum with an increase on the radio flux density along time. We conducted an observation with the Australian Long Baseline Array (LBA) at 2.3 GHz in 2008 to resolve the radio source and its location within the stellar system. These radio data revealed a bow-shape extended emission located between both stars, as expected in a wind collision region. The observed structure allows us to roughly estimate the mass-loss rate ratio for the two stars in the system, concluding that $\dot{M}_b \sim 0.7 \dot{M}_a$. The multiwavelength analysis points out that the detected radio emission is likely to be originated by one of the most massive collision wind binary in the Galaxy.

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1. Introduction

Massive stars consist of a category of stellar objects with spectral types ranging between O and early B-type, including also their evolved counterparts, Wolf-Rayet (WR) stars. A significant fraction of these objects are found in binary, or higher multiplicity systems (e.g. [1]). In such configurations, their powerful stellar winds are likely to collide, producing strong shocks. About 40 systems of this category are known to be non-thermal radio emitters [2]. This radio emission is believed to be synchrotron emission from relativistic electrons accelerated in shocks [3]. The current standard model for particle acceleration in massive binaries considers the Diffusive Shock Acceleration in the hydrodynamic shocks produced by the colliding winds [4, 5]. These Colliding Wind Binaries (CWB) are therefore excellent laboratories to study particle acceleration up to relativistic energies, exhibiting the same physical processes as observed in supernova remnants, but at higher mass, photon and magnetic energy densities. Beside the synchrotron emission detected in the radio domain, these objects are also expected to be non-thermal radio emitters in the high energy domain. This prediction has been confirmed as two CWBs have been reported to be non-thermal X-ray emitters (most probably due to inverse Compton scattering), and in the case of η-Car a gamma-ray emission has also been detected.

For some of these systems, the radio emission has been resolved into a bow shape, characteristic of the presence of a wind-collision region (WCR). These systems exhibit the expected bow-shaped structure around the star with the weakest wind. The main interest to exploit high angular resolution techniques is to disentangle spatially the emission from the colliding wind region from that of the individual winds of the stars in the binary system. This opportunity is highly valuable to derive the specific properties of this region, and this can only be achieved using Very Long Baseline Interferometry in the radio domain. The present project aims to apply this technique to the case of the massive binary HD 93129A.

2. The Colliding Wind Binary HD 93129A

HD 93129A is an O2 If+ star, the brightest member of the young compact cluster Trumpler 14 in the Carina nebula, with an O3.5 V companion at a distance of 55 mas (140 AU at the distance of 2.5 kpc, [6]). HD 93129A is one of the earliest, hottest and most massive O stars discovered up to now in the Galaxy.

The relative motion of the two stars has been traced by archived *HST*/FGS and *HST*/ACS observations from 1996 and 2009, but also with recent VLT and VLTI observations from [1]. These observations show that the two stars, Aa and Ab, are rapidly approaching at $\sim 2.6\ \mathrm{mas\,yr^{-1}}$ (see Fig. 1), suggesting that the HD 93128Aab may be a gravitationally bound system approaching the periastron passage. However, the orbital period, the semi-major or the semi-minor axis remain unknown up to now.

The X-ray emission of HD 93129A has been studied by [7, 8]. Although a large fraction of the X-ray emission arises from material close to the stars, there is a weak thermal X-ray component which could be originated by the wind-collision region.

At radio frequencies, we have observed HD 93129A as a strong non-thermal radio emitter, with a 1.4 GHz flux density of ~10 mJy [9].

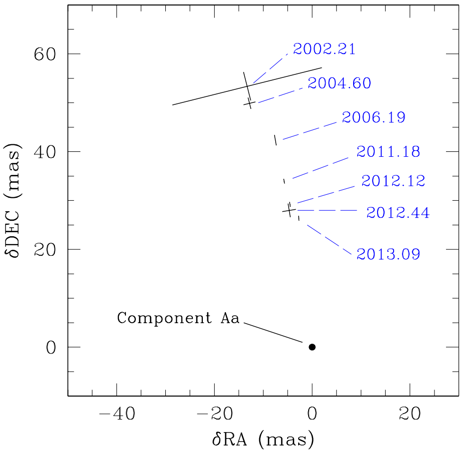

Figure 1: Relative positions of the Aa and Ab components of HD 93129A. The data have been derived from archive *HST*/FGS and ACS data and VLT/VLTI data [1].

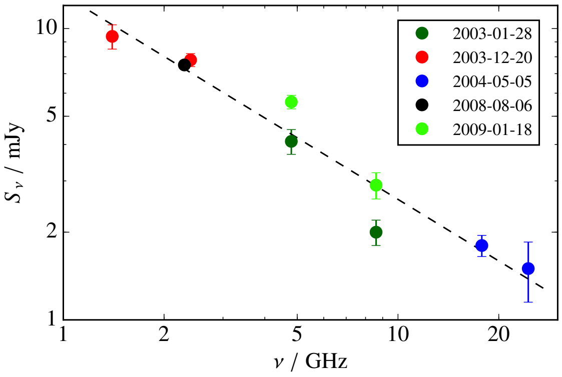

Figure 2: HD 93129A spectrum derived from the 2003–2009 ATCA observations. The average spectrum can be described by a power-law with a spectral index of $\alpha = -0.73 \pm 0.09$. We note the flux density increment observed between the 2003 and the 2009 observations for the 5–8.5 GHz range.

3. Observations and results

We combined several ATCA observations between 2003–2009 at 1.4–24.5 GHz, obtaining a power-law spectrum with an averaged spectral index of $\alpha = -0.73 \pm 0.09$. Interestingly, a flux density increment of ~ 40 % between 2003 and 2009 is reported for the 5–8.5 GHz range (see Fig. 2).

Two LBA observations of HD 93129A have been performed up to now. We firstly observed HD 93129A in 2007 as part of a eVLBI experiment to search for suitable calibrators using Parkes, Mopra, and ATCA at 2.3 GHz (project code VT11D3). The source was detected with a total flux density of ~ 3 mJy, but given the synthesized beam of $0.2'' \times 0.05''$, PA $= 30.9^\circ$ the structure of the radio source could not be resolved [10].

Later on, we conducted a 8-hr LBA observation in 2008 at the same frequency using five

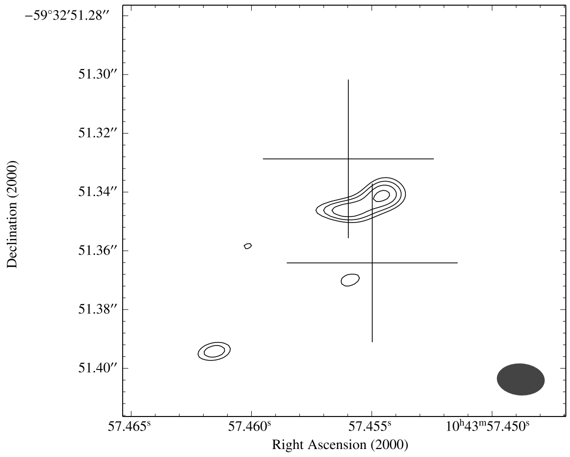

Figure 3: Image of the HD 93129A radio emission from 2008 LBA data. The synthesized beam is 15×11 mas. The crosses denote the positions of the two stars at the epoch of the radio observation. The uncertainty in the relative positions of the two stars is only 1 mas and 1° in Position Angle, although the absolute positions present a larger uncertainty of 27 mas.

antennas (ATCA, Parkes, Mopra, Ceduna and Hobart, project code V191B) to resolve and constrain the origin of the radio emission. With this configuration we reached an angular resolution of $\sim$ 15 mas. Figure 3 shows the resulting radio image of HD 93129A together with the astrometric positions infered from optical observations. Although the absolute uncertainty of these positions is 27 mas, the relative positions between the two stars is well constrained with an uncertainty of 1 mas and 1°. A bow-shaped extended emission with a flux density of 1.5 ± 0.5 mJy is detected in a position between the two stars of the system, slightly curved around the Ab component.

4. Discussion

The observed radio emission is coincident with the positions of the two stars, and together with its bow-shaped morphology, it points out the existence of a wind collision region in HD 93129A. The radio emission is clearly non-thermal (only a contribution of thermal emission is expected for the highest frequencies, 10–25 GHz). The reported flux density increment between the ATCA observations in 2003 and 2009 evidences that the WCR is becoming stronger, as expected during a periastron passage approaching. The radio emission allows us to infer a rough estimation of the wind momentum rates ratio, $\eta = (R_b/R_a)^2 \approx 0.7$, with R_i the distance between the WCR and the star i. Assuming that the winds have reached their terminal velocities, this ratio is proportional to the mass-loss rate ratio, $\eta = \dot{M}_b/\dot{M}_a$. Considering the mass-loss rates for O3 and O4 stars [11], we deduce a mass-loss rate of $\dot{M}_b \approx 1.9 \times 10^{-5}\ \mathrm{M_\odot\ yr^{-1}}$, and thus $\dot{M}_a \approx 2.7 \times 10^{-5}\ \mathrm{M_\odot\ yr^{-1}}$, consistent with the expected values for this system.

5. Conclusions

The relative motion between the two stars in the system, together with the reported radio emission, are the strongest evidence of that HD 93129A is a binary system and that its radio emission is originated by a wind-collision region. HD 93129A would be thus one of the youngest and most massive colliding wind binary in the Galaxy.

We present the first estimation of the mass-loss rate ratio for HD 93129A, although the given value should be taken with caution due to the large errors involved on its determination.

These results, more deeply detailed in [12], represent the starting point for further studies on this specially interesting member of the still scarce population of CWBs with resolved radio emission.

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