Discovering the colliding wind binary HD 93129A

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Outline

1. Introduction on Colliding Wind Binaries
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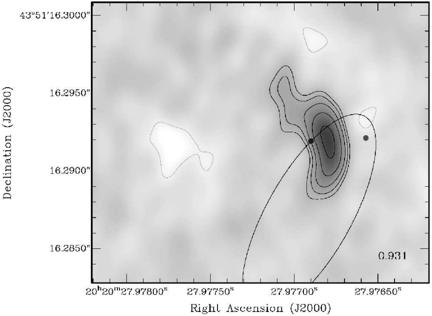
   - An introduction to the source
   - Previous observations (optical, radio, X-rays, gamma-rays)
3. Multiwavelength observations of HD 93129A
   - *HST* optical data (astrometry of stars)
   - ATCA observations
   - LBA observations
4. Results from the Colliding Wind Region
5. Conclusions

Introduction

Colliding Wind Binaries

- Binary systems composed by two massive stars are natural laboratories to study the wind-collision regions (CWRs).
- Electrons in these regions are accelerated up to relativistic energies, producing a synchrotron emission observable at radio wavelengths.
- The massive, early-type O stars present strong stellar winds, with velocities up to $\sim 3000\ \mathrm{km\,s^{-1}}$, originating powerful CWRs.



VLBA observation of WR 140 at 8.4 GHz, with the positions of the stars and the determined orbit. Dougherty et al. (2005)

HD 93129A

HD 93129A is the brightest member of the Tr 14 cluster in Carina.

One of the earliest, hottest, most massive and luminous O stars in the Galaxy.

Parameter	Values	References
Spectral Types	O2 If^{+}	Walborn et al. (2002)
Distance	2.5 kpc	
Wind terminal velocity	$3\,200 \pm 200$ km s^{-1}	Taresch et al. (1997)
System mass	200 ± 45 $M_\odot$	
Luminosity (log)	6.2 $L/L_\odot$	

The mass-lost rate $\sim 10^{-5}$ $M_\odot$ yr^{-1} is considered the highest one for an O star in the Galaxy (Benaglia & Koribalski 2004).

Multiwavelength data

Optical

An O3.5 V-star companion was detected at $\sim$50 mas (140 AU) approaching at ~ 2.6 mas yr^{-1} with *HST*/FGS data (Nelan et al. 2004).

Radio

Non-thermal radio emission has been detected by Benaglia & Koribalski (2005) with a flux density of $\sim$10 mJy at 1.4 GHz.

Multiwavelength data

X-rays

Most of the X-ray emission comes from material close to the stars. However, a weak hard component ($\sim 10\,\%$) is also detected.

Cohen et al. (2011)

$L_X / L_{\rm bol} \approx 1.4 \times 10^{-7}$ Gagne et al. (2011)

A slightly high ratio for a O2If$^+$

Evidences of the Colliding Wind Region (CWR)

Gamma rays

- Close to the Fermi source 1FGL J1045.2–5942 (0.1–100 GeV) associated with η Carinae. Very unlikely contribution from HD 93129A.
- No TeV source found at this position.

Goals of this project

The questions which should be firstly answered for HD 93129A…

- Is HD 93129A a binary system with a Colliding Wind Region?
  We only know the existence of a radio emission, a weak hard thermal X-ray component and possibly a binary system with two O-type stars.
- What is the nature of the radio emission?
- Where is located this emission?

To solve these questions, we mainly need to combine two things:

- An accurate astrometry of the two stars.
- A high resolution radio image.

Optical observations

Observations with *HST*/FGS, ACS/*HST*, VLT and VLTI from 2002 to 2013.

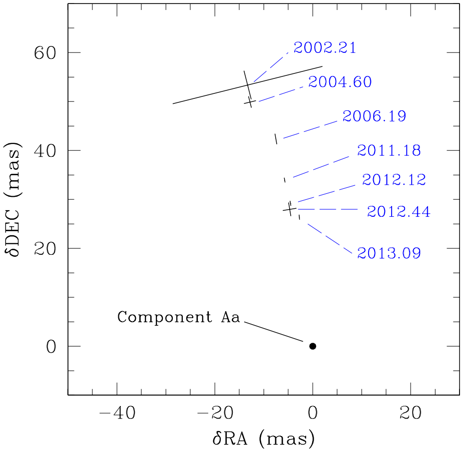
Accurate determination of the positions of the Aa and Ab stars from 8 *HST*/FGS observations from 2006 to 2009.

Precision on the absolute positions of Aa and Ab: $\sim$27 mas.

Relative positions better determined:

$D_{a\text{-}b} = 36 \pm 1$ mas,

$PA = 12 \pm 1$ deg (6 Aug. 2008)

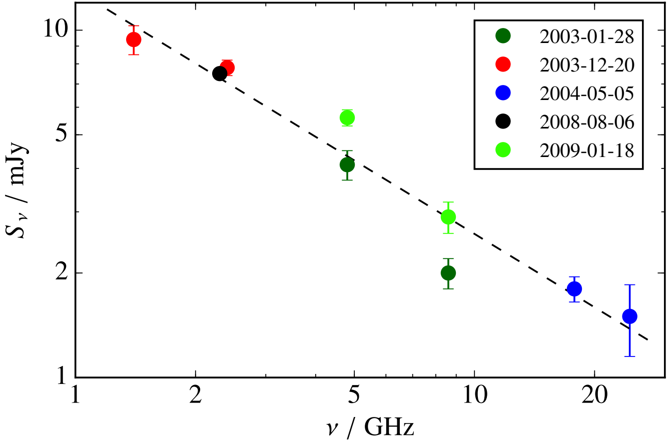


Astrometry from Sana et al. (in press)

ATCA radio observations

9 ATCA obs. (2003–2009)

Spectrum compatible with a power-law: $\alpha = -0.73 \pm 0.09$



However, we could have a steeper α ($\sim$5 GHz) with absorption at $<$2 GHz and thermal contribution at $>$15 GHz.

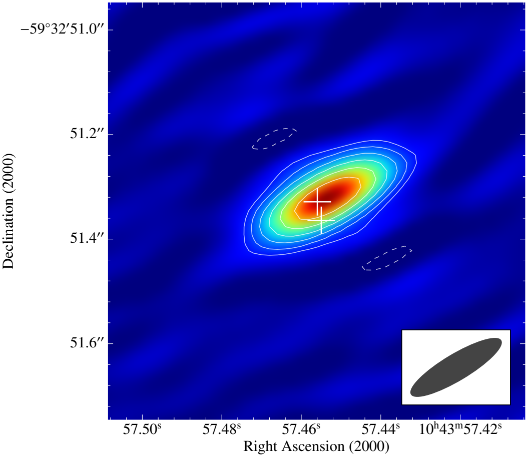
LBA radio observation in 2007

LBA obs. (22 June 2007)
Parkes, Mopra and ATCA

2.3 GHz
Time on source: 3 hours

Synthesized beam:
200×50 mas, PA $= 30.9°$

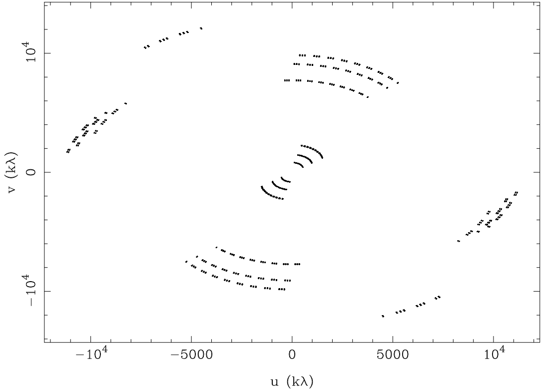
$S_\nu \sim 3$ mJy
Benaglia et al. (2010)



LBA radio observation in 2008

We observed HD 93129A on 6 August 2008 at 2.3 GHz with LBA (Parkes, Mopra, ATCA, Ceduna and Hobart) Benaglia et al. (in prep.)

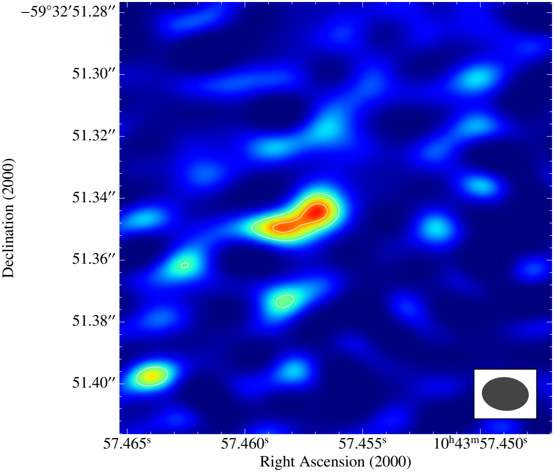
- Time on source: 3.2 hours
- Synthesized beam: 4.1×2.9 mas, PA $= 85.2°$



LBA radio observation in 2008

rms: 0.2 mJy beam^{-1}
$S_\nu = 2.9 \pm 0.5$ mJy
$S_{\rm ATCA} = 7.50 \pm 0.11$ mJy
Uncertainty in the radio position $\approx$ 3 mas

Bow-shaped extended emission
Half-opening angle $\sim$65°



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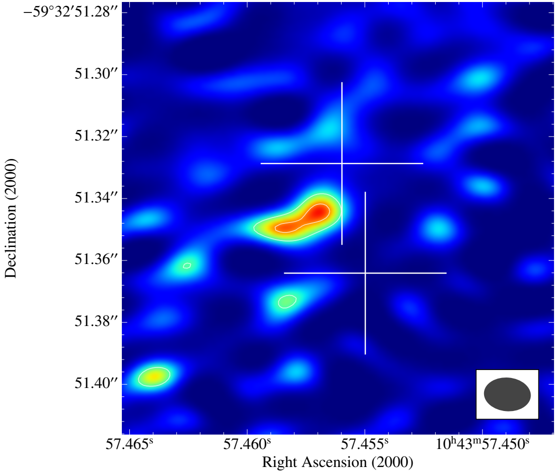

Crosses: positions of Aa and Ab stars with their uncertainties. The separation and position angle between both components have an uncertainty of $\sim$1 mas and 1°, respectively.

Results derived from the radio emission

The radio source is coincident with the positions of the two stars.
Assuming that this radio emission is centered…
the wind momentum rates ratio is

$$\eta = \left(\frac{R_b}{R_a}\right)^2 = \frac{\dot{M}_b v_b}{\dot{M}_a v_a} \approx 0.6$$

The wind velocities should be similar for both stars,
so η is a **mass-loss rate ratio**.

$$\dot{M}_b \approx 0.6\, \dot{M}_a$$

With the known values given by Muijres et al. (2012) for O3 and O4 main-sequence stars, we extrapolate to Ab (O3.5):

$$\dot{M}_a \approx 3.2 \times 10^{-6}\,\mathrm{M}_\odot\,\mathrm{yr}^{-1} \qquad \dot{M}_b \approx 1.9 \times 10^{-6}\,\mathrm{M}_\odot\,\mathrm{yr}^{-1}$$

Conclusions

- Determination of the 1.4–25 GHz spectrum of HD 93129A.
- Curved bow shaped extended emission detected between the positions of the two stars.
- Estimation of the wind momentum rate ratio, η.
- Best estimation of the mass-loss rate of HD 93129A up to now.

- Is it a gravitationally bounded system?
- Is the radio emission centered between the two stars? (better optical astrometry needed. GAIA?)
- Evolution of the radio emission during the approaching of the Ab star to Aa:
  - Spectrum from ATCA observations.
  - VLBI observations to solve the emission.

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