What is the role of the VLTI in the study of particle acceleration in massive binaries?

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Outline

A few facts...

The 'catalogue' of particle-accelerating colliding-wind binaries

The parameter space covered by these objects

The role of VLTI observations

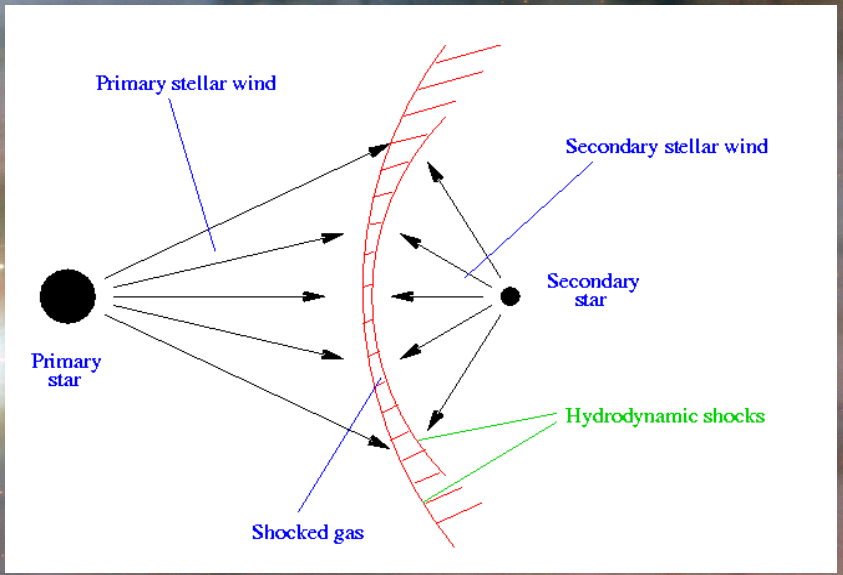
Concluding remarks

A few facts...

- At least a few tens of colliding-wind binaries are able to accelerate particles up to relativistic energies

- Most of them are identified through synchrotron radiation in the radio domain (one exception : Eta Car)

- As we are dealing with (eccentric) binary systems, a significant variability is expected (time-scale = orbital period)



- The presence of high energy particles calls upon dedicated studies in the high energy domain

- These systems are potential contributors to the population of Galactic Cosmic-Rays

The catalogue

So far, about 40 systems identified to be particle accelerators among CWBs
- O-type stars
- Wolf-Rayet stars
- a few 'transitional' objects

Now unified in only one list!

(De Becker & Raucq 2013, A&A, 558, A28)

http://www.astro.ulg.ac.be/~debecker/pacwb/

Previous censuses used to separate systems of different evolution stages, e.g. Dougherty & Williams 2000, De Becker 2007, Benaglia 2010...

→ strong need to unify these objects into a unique class, occupying a rather wide parameter space.

The catalogue

#	Usual ID	Status	Sp. type(s)	P
1	HD 15558	B (T?)	O5.5III(f) + O7V	442 d
2	δOri A	T	(O9.5II + B0.5III) + B?	5.733 d/>100 yr
3	σOri AB	M	O9.5V + B0.5V (+ OBs?)	?
4	15 Mon	B	O7V(f) + O9.5Vn	25.3 yr
5	WR 8	B	WN7 + WC(?)	38 d, 115 d
6	WR 11	B	WC8 + O7.5	78.53 d
7	WR 14	B?	WC7	?
8	CD–47 4551	U	O5If	–
9	WR 21a	B	O3f*/WN6ha + O4	32.673 d
10	HD 93129A	B	O2If* + O3.5V?	?
11	HD 93250	B	O4III + O4III	>100 d
12	η Car	B	? + ?	2022.7 d
13	WR 39	B?	WC7	?
14	WR 48	T	(WC5 + O6-7V) + OI?	19.138 d/?
15	HD 124314	B?	O6V(n)((f))	?
16	HD 150136	T	(O3-3.5V((f*)) + O5.5-6V((f))) + O6.5-7V((f))	2.675 d/8.2 yr
17	HD 151804	U	O8Iaf	–
18	WR 78	U	WN7h	–
19	WR 79a	B	WN9ha + ?	many years
20	HD 152623	T	(O7V((f)) + OB?) + OB?	3.9 d/?
21	WR 89	B	WN8h + OB	?
22	WR 90	U	WC7	–
23	WR 98	B	WN7/WC + O8-9	48.7 d
24	WR 98a	B	WC9 + OB?	565 d
25	WR 104	B	WC9 + B0.5V	220 d
26	WR 105	U	WN9h	–
27	9 Sgr	B	O3.5V((f*)) + O5V	~8.6 yr
28	WR 112	B?	WC9 + ?	?
29	HD 167971	T	(O6-7V + O6-7V) + O8I	3.321 d/~20 yr
30	HD 168112	B?	O5.5III(f*) (+ OB?)	>1 yr
31	CEN 1a	B	O4 + ?	?
32	CEN 1b	B	O4 + ?	?
33	WR 125	B	WC7 + O9III	>15 yr, ~20–22 yr
34	HD 190603	U	B1.5Ia	–
35	WR 133	B	WN5 + O9I	112.4 d
36	WR 137	B	WC7 + O9V-III	13.05 yr
37	WR 140	B	WC7 + O5	7.9 yr
38	Cyg OB2 #5	Q	(Ofpe/WN9 + O6–7Ia) + OB? + B0V	6.598 d/6.7 yr/>9000 yr
39	Cyg OB2 #9	B	O5I + O6-7I	2.35 yr
40	Cyg OB2 #8A	B	O6If + O5.5III(f)	21.908 d
41	Cyg OB2-335	B	O7V + O9V	a few days(?)
42	WR 146	B (T?)	WC6 + O8?	many years ?
43	WR 147	B	WN8 + B0.5V	many years ?

So far, about
among CWBs
- O-type stars
- Wolf-Rayet
- a few 'trans

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& Raucq 2013,
A28)

pacwb/

Previous cen
stages, e.g. D
2010...

evolution
Benaglia

→ strong nee
a rather wide

occupying

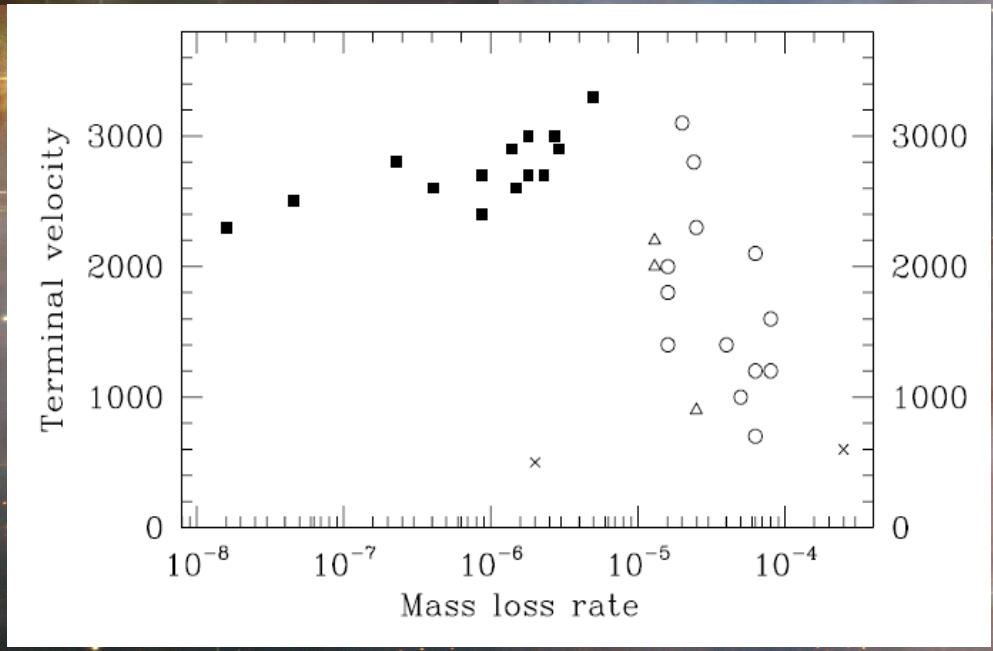
The parameter space

What do they have in common ?
Strong stellar winds & High wind velocities

Positions of the star with the strongest wind of each system, in the wind parameter space (mass loss rate in solar mass/ year, and terminal velocity in km/s)

Accurate determination of the stellar parameters of the companions is still lacking in several systems

The distribution in the plot could be interpreted in terms of kinetic power!



(De Becker & Raucq 2013, A&A, 558, A28)

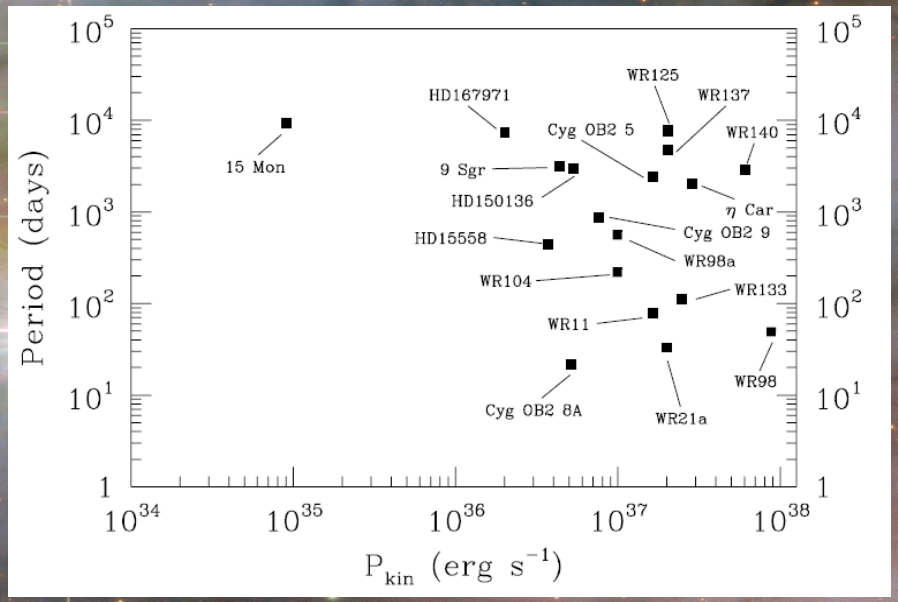
The parameter space

What about the orbital period ?

Plot of the period of the system (when available!) as a function of the kinetic power.

The lower limit on the period seems to be located at 'a few weeks'

The period distribution covers several orders of magnitude.



The multiplicity of these objects really deserves to be studied in detail to characterize the parameter space occupied by PACWBs

The parameter space

Question : are there systems occupying the 'adequate' volume of the parameter space and not yet identified as particle accelerators?

The parameter space

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→ Yes !

What is the reason for this lack of evidence for non-thermal processes ?
- an intrinsic lack of efficient particle acceleration process ?
- an observational bias?

Non-thermal radio emission (the main indicator of PA) from colliding-wind massive binaries is like a thief ! You catch it if you see it!

The role of the VLTI

Several O-type systems among the category of PACWB, and suspected to be (at least) binaries, have been resolved with the VLTI!

→ The VLTI provides important information about the members of the catalogue (fundamental parameters necessary to perform adequate modelling)

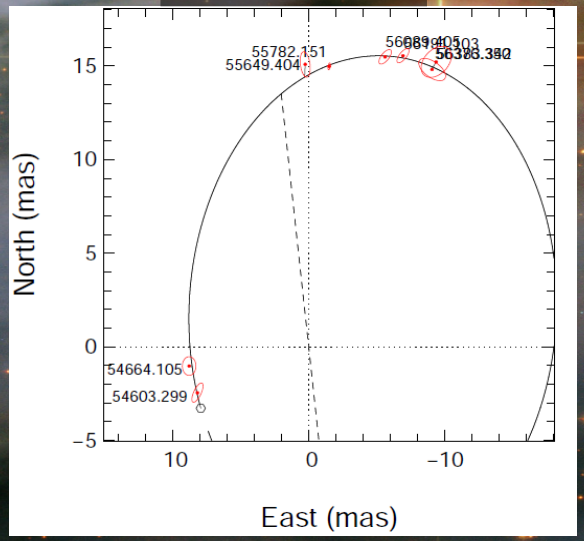
- a few results already published (Sana et al. 2011, De Becker et al.2012, Sana et al. 2013)

- a lot of additional results for several systems have been obtained (work still in progress)

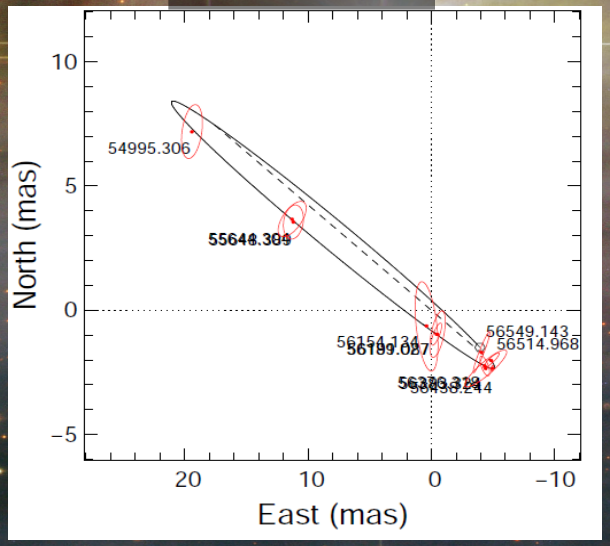
The role of the VLTI

A few examples of preliminary orbits, obtained in the context of a long term campaing including severals runs executed in VISA Belgian GTO

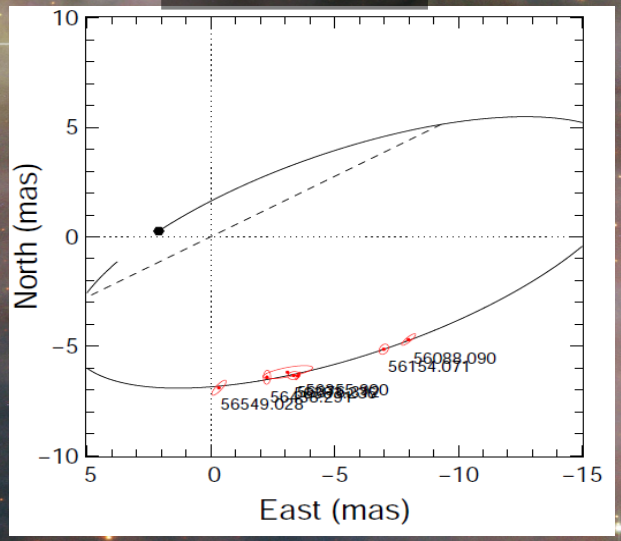
HD167971



HD164794



HD150136



The role of the VLTI

Long-term objective : investigate the parameter space of PACWBs, and identify new members of the catalogue.

→ multiplicity investigation of colliding-wind binaries NOT known to be particle accelerators

→ determine their orbit with a high accuracy

→ refine observation strategies, notably in the radio domain, to optimize the capability to identify synchrotron radio emission

→ upgrade the catalogue and improve our estimate of the frequency of PA among CWBs

Concluding remarks

The most important idea :

The study of PACWBs is now switching to a new regime. From a few individual studies of massive binaries, one can now consider the study of a real class of objects.

The role of the VLTI is highly important :

- determination of the orbital parameters
- determination of the nature of the companion(s)
(Important for modelling purpose!)

→ starting point for defining future observation strategies to
(i) improve our knowledge of identified PACWBs
(ii) to upgrade the catalogue


Thank you !