Towards an extension of the catalogue of particle-accelerating colliding-wind binaries

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5th May 2015 VGGRSIII, Heidelberg

Outline

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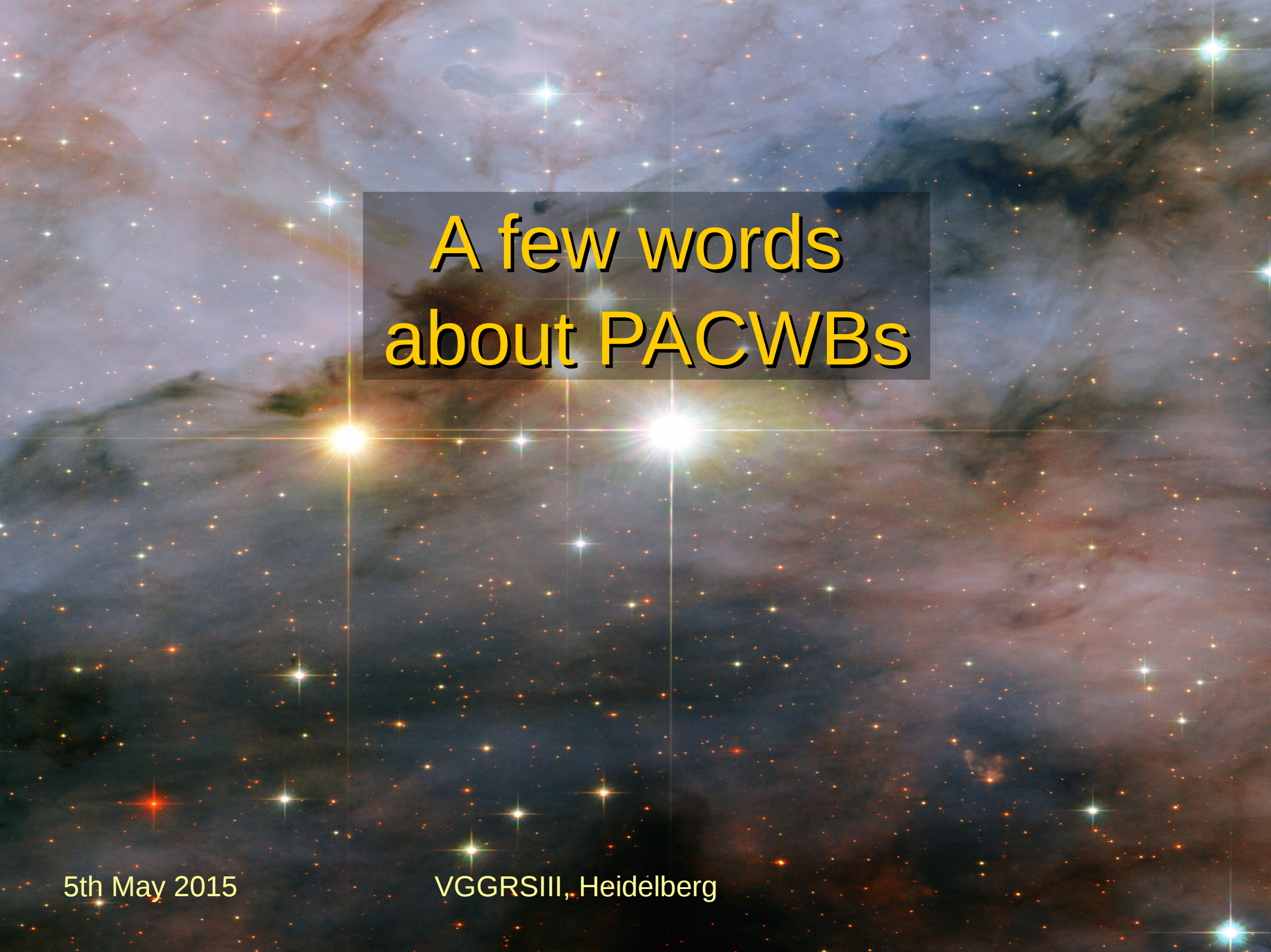

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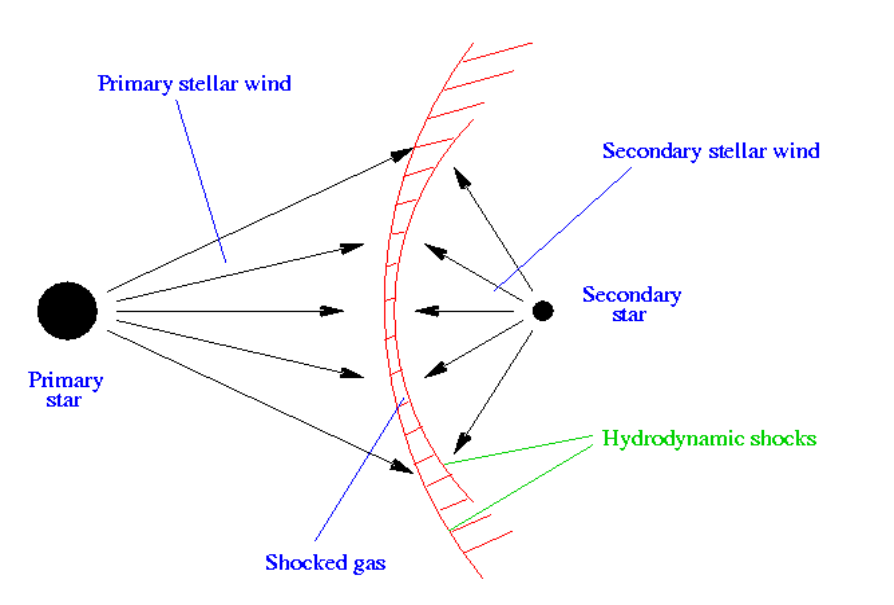
A few words about PACWBs

CWB : Binary system made of two stars belonging to the category of OB- or WR-type stars

No compact companion!

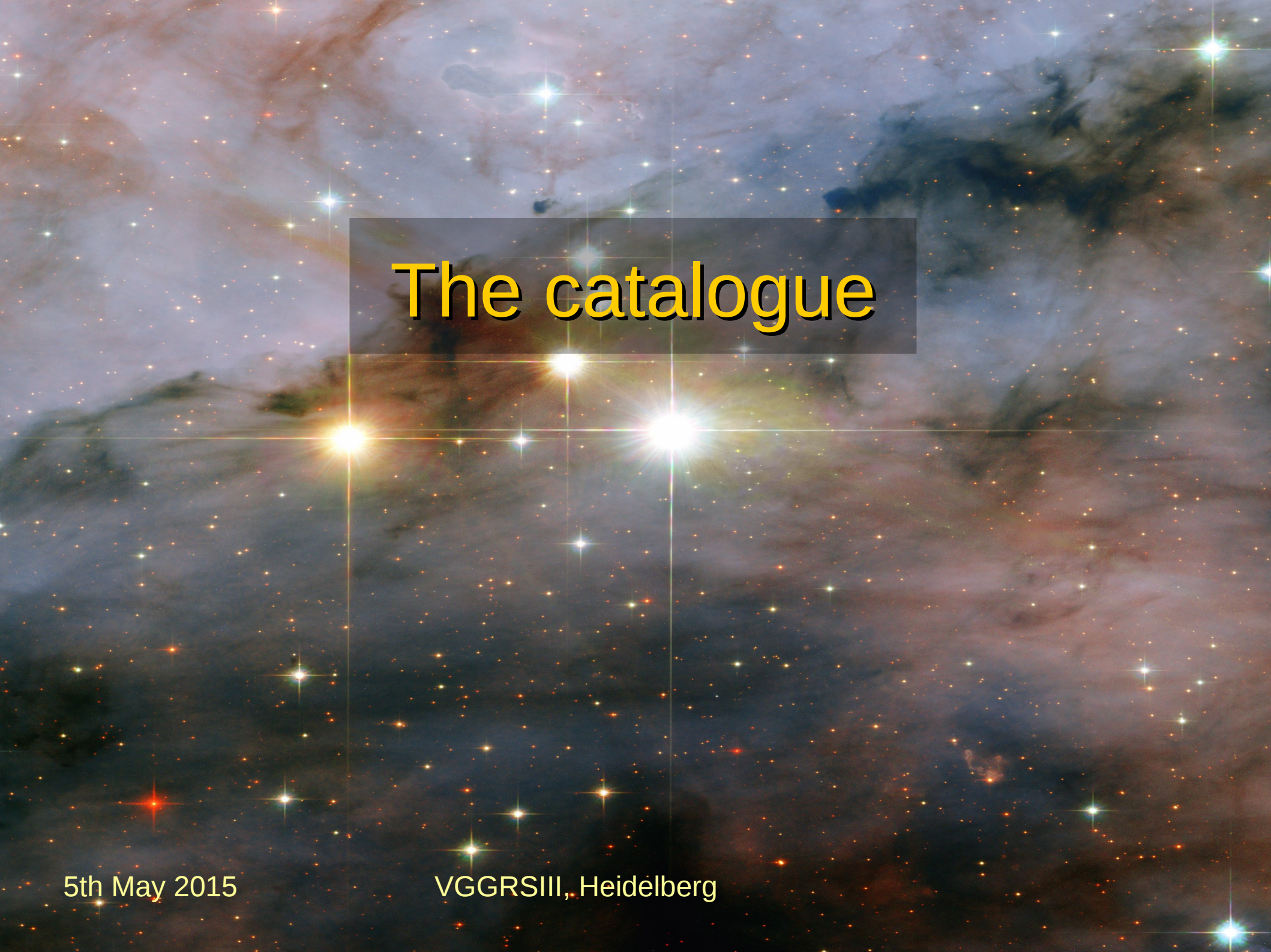
Main feature of such a system : a wind-wind interaction region

Physical conditions : ruled by the properties of the stellar winds and by the orbital parameters



Physics of colliding wind binaries, see Julian Pittard's talk

A Particle-Accelerating Colliding-Wind Binary is a CWB with evidence for the existence of a population of relativistic particles


The catalogue

The catalogue

Catalogue of about 40 objects :
O-type, WR-type, transition objects

De Becker & Raucq 2013 A&A 558, A28

On-line version : http://www.astro.ulg.ac.be/~debecker/pacwb/

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Main tracers of particle acceleration

1. Synchrotron radio emission (all but one !)
   Spectral index, flux density, variability, resolved NT source between the stars...
2. Non-thermal X-rays (WR140 , Eta Car)
3. Gamma-rays (Eta Car)

Abbott et al. 1986 ; Bieging et al.1989 ; Benaglia et al. 2001, 2005, 2006, 2010 ; Blomme et al. 2005, 2007, 2010, 2013 ; Cappa et al. 2004 ; Chapman et al. 1999 ; De Becker et al. 2004 ; Dougherty & Pittard 2005, Dougherty et al. 2005 ; Dougherty & Williams 2000 ; Rodrigruez et al. 2009, 2012 ; Leitherer et al. 1997 ; Montes et al. 2009 Williams et al. 1990, 1994, 1997 ; And many others...

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Sugawara et al. 2011 ;
Viotti et al. 2004 ;
Sekiguchi et al. 2008

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Gamma-rays from Eta Car,
see talks by Olaf Reimer
and Victor Zabalza

Detection : Tavani et al. 2009 ;
Farnier et al. 2011
Upper limis on WR systems :
Werner et al. 2013


A few questions
and facts

A few questions and facts

Are PACWB restricted to a narrow area of stellar wind parameters ?

Are PACWB restricted to a narrow range of orbital periods ?

Do we need very high energy injection rates into the colliding-wind region to significantly detect NT emission related to relativistic particles?

Is it relevant to seek for hints for particle acceleration especially in systems with strong magnetic fields?

A few questions and facts

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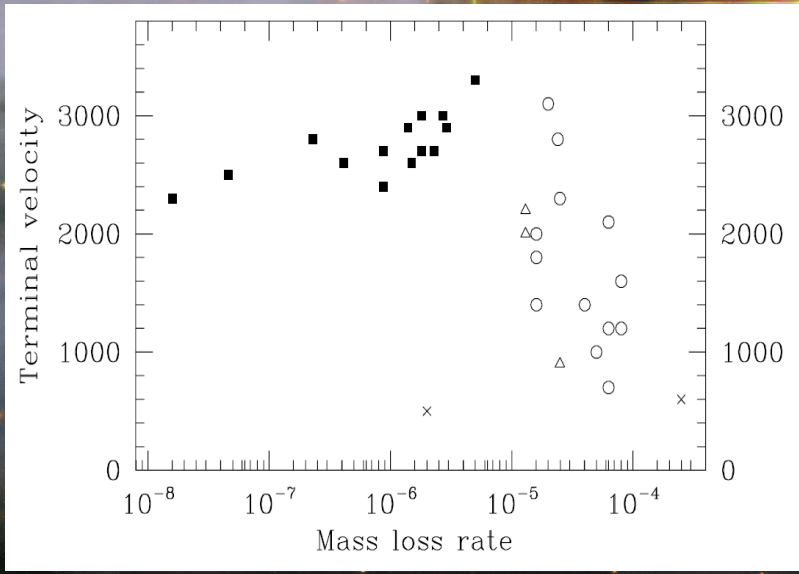


(De Becker & Raucq 2013)

Stellar wind parameters cover a range typical of O-type and WR-type stars

Only one B star, but a transition object with enhanced mass loss

Lack of stars with weak winds

→ large parameter space to investigate, including many spectral types and classes

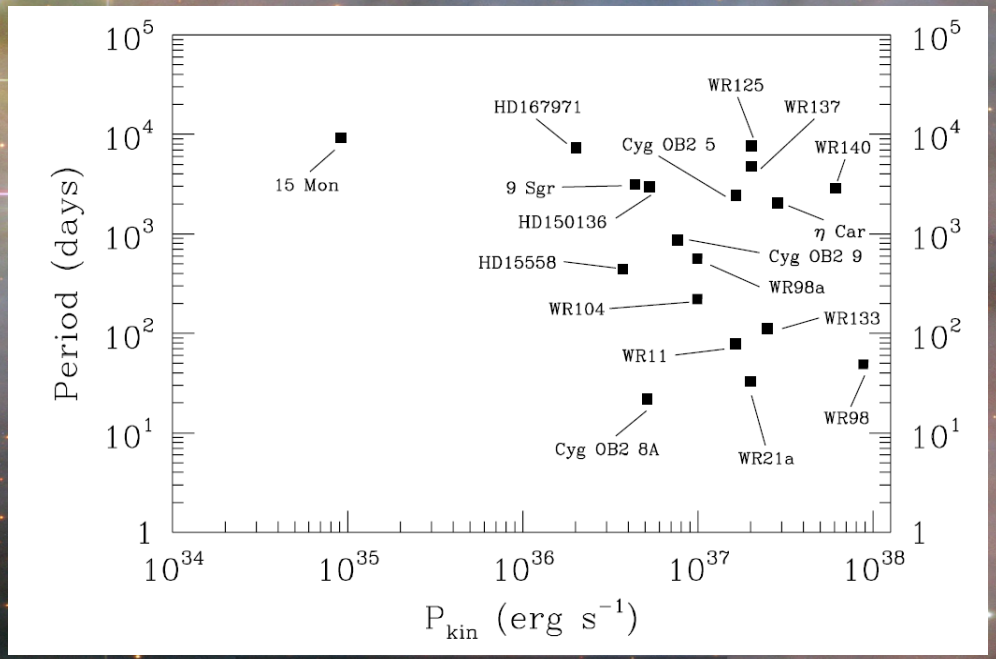
A few questions and facts

Are PACWB restricted in to narrow range of orbital periods ?

Orbital periods cover a wide range of values, from a few weeks up to many decades !

One puzzling object with a period of ~ 2 days (could be a triple system, with a third star in a wider orbit)

→ close binaries are not favored targets, but any longer period binary is worth investigating !



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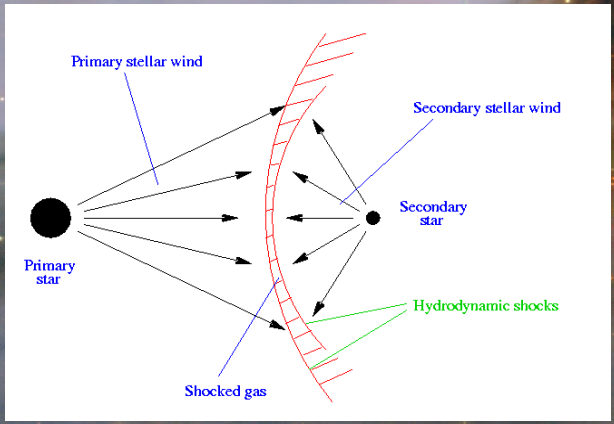

Thermal X-rays from CW depend intimately on the amount of power injected in the wind interaction zone

One may consider the particle acceleration process can be favored by a high power injection rate

However : some PACWBs present a significant non-thermal radio emission, but do not show a very bright X-ray excess attributed to the colliding-winds

A few questions and facts

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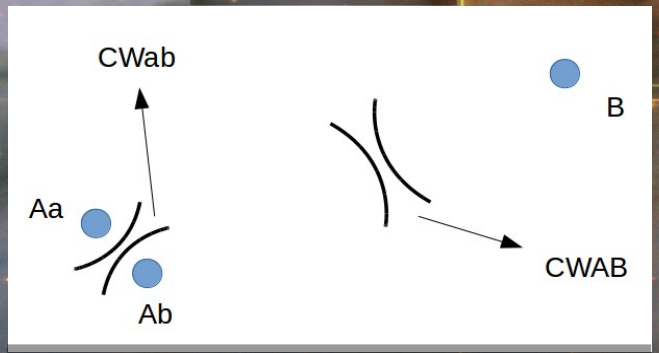
HD167971



Bright synchrotron radio emitter (phase-locked with the 21-year period)

Thermal X-rays dominated by CWab, with only a moderate contribution from CWAB

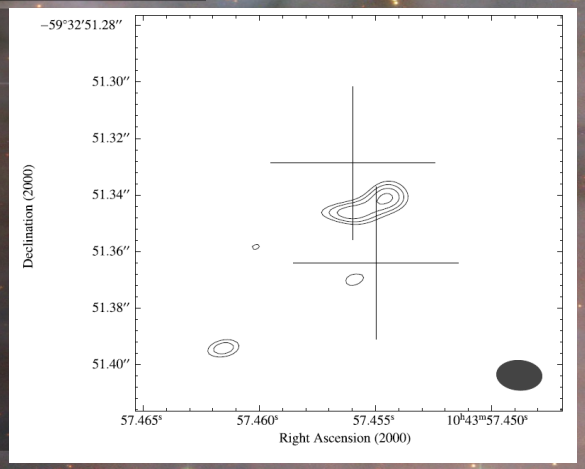
(De Becker 2015, submitted)

HD93129A

Significant NT radio emission resolved with the LBA (Benaglia et al. 2015)

The thermal X-ray spectrum does not present any hint for a spectacular emission from the colliding-winds

(Gagné et al. 2011)



→ a bright thermal X-ray spectrum strongly dominated by colliding-winds is not a criterion to select a candidate

A few questions and facts

Is it relevant to seek for hints for particle acceleration especially in systems with strong magnetic fields?

The main tracer of particle acceleration requires the presence of a magnetic field
→ one may wonder whether systems with strong magnetic fields may be good candidates !

Spectropolarimetric methods allow to measure surface magnetic field strengths down to 1 - 10 Gauss

However : Attempts to detect magnetic fields in a sample of O-type PACWBs failed to detect it

(Neiner et al. 2015)

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(Neiner et al. 2015)

In fact : models suggest that 'local' values of the magnetic field (in the wind-wind interaction region) of the order of a few mG are enough to explain the measured synchrotron radio emission in PACWBs

(Dougherty et al. 2003)

This translates into surface magnetic fields of the order of – or even significantly below – the present upper limits on the measurements

→ the selection of systems with quite strong magnetic fields is not a good criterion to identify new PACWBs

Observation strategies

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Observation strategies

Target selection

1. Categories of potential candidates include all O-type and WR-type objects (even evolved early-B type stars are relevant).

2. Systems with periods of at least a few weeks deserve to be investigated.

3. The production of a wealth of thermal X-rays from the colliding-wind region is not a requirement.

4. The detection of a surface magnetic field at the Gauss-level is not a relevant selection criterion.

→ A large fraction of massive star systems deserve to be investigated !

Observation strategies

Tool selection

Mainly : Radio observatories

- repeated observations at cm wavelengths (synchrotron emission is variable, and may no be obvious at all orbital phases)
- measurements at more than one wavelength (spectral index determination)
- potential VLBI campaigns to resolve a NT emission region coincident with the colliding-wind region

But also : High-energy observatories (hard X-rays and Gamma-rays)

- search for an inverse Compton scattering contribution in hard X-rays
- further investigations with Gamma-ray facilities are also relevant


Concluding
remarks

Concluding remarks

So far, no clear selection criterion can be established to restrict significantly the sample of candidates to be investigated
→ many systems could be studied among known massive binaries

Campaigns dedicated to the determination of the multiplicity of massive stars are very important
→ they increase the list of candidates to be investigated

Observation strategies should at first sight favor radio observations
→ such campaigns are in progress, but require a lot of telescope time

The question of the fraction of PACWBs among CWBs is an important issue, and we are still far from the answer


Thank you
for your attention !