Recent results of radio observations on Particle-Accelerating Colliding-Wind Binaries

Michaël De Becker
Space sciences, Technologies, and Astrophysics Research
(STAR) Institute, University of Liège, Belgium

In collaboration with

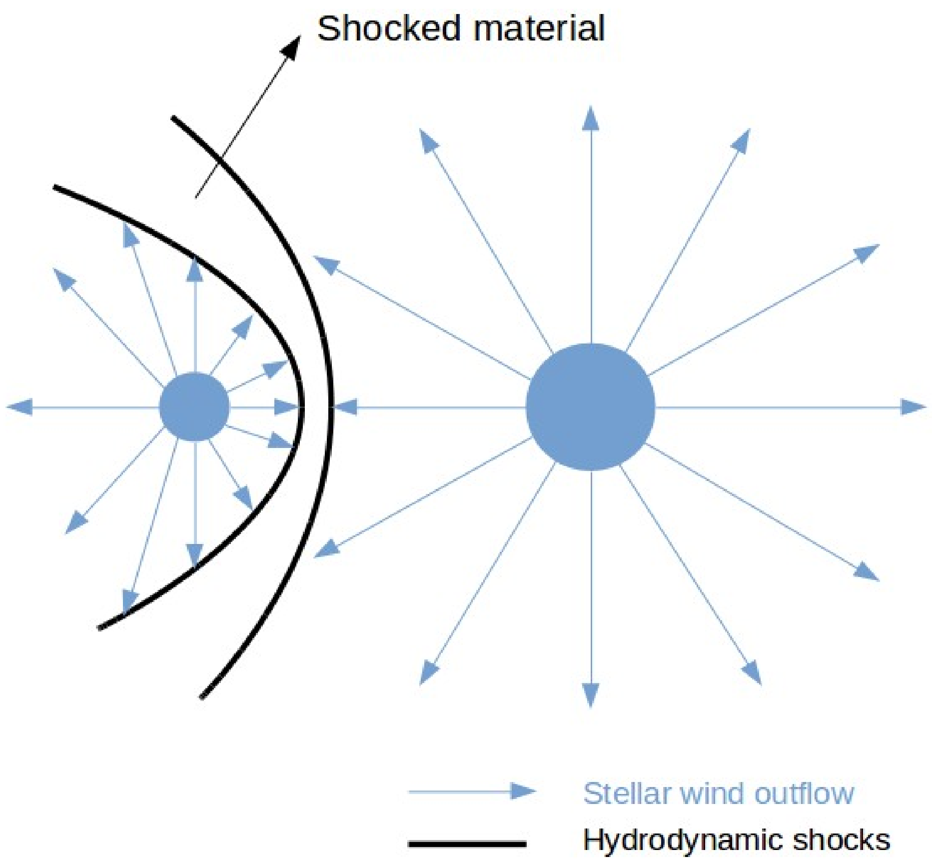
Paula Benaglia, Santiago del Palacio, Natacha L. Isequilla
Universidad Nacionale de La Plata and Instituto Argentino des Radioastronomia, Argentina

Ishwara Chandra C. H.
National Center for Radio Astronomy (NCRA) – TIFR, Pune, India

Outline

1. PACWBs and their radio emission
2. The system WR133
3. WR11 and its surroundings
4. Low frequency observations of the Cygnus region
5. Concluding remarks

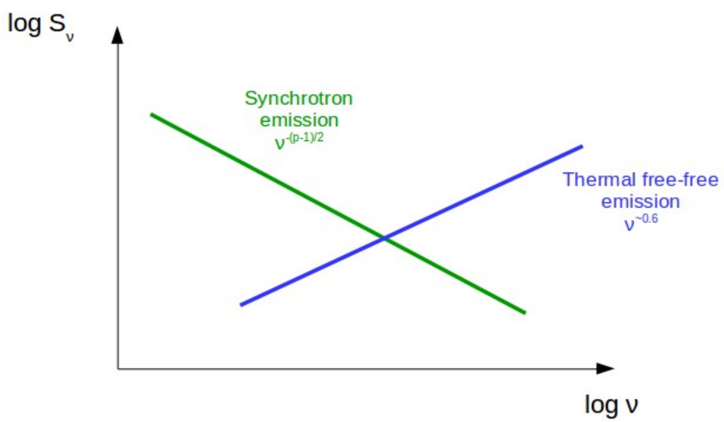
1. PACWBs and their radio emission

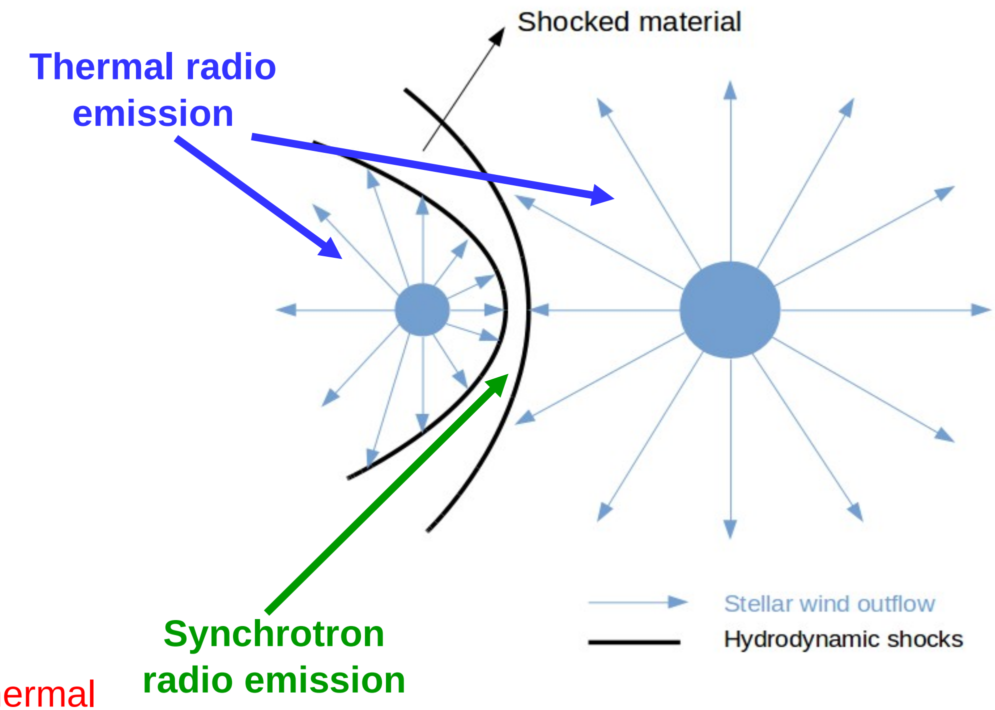


- Systems made of massive stars (O, B, WR…)
- Multiplicity is a crucial feature (binaries, triple and higher multiplicity…)
- Variability on the orbital time-scale is very important !
- Strong stellar winds collide and create strong shocks
- Shock physics is important in these systems, including particle acceleration (Diffusive Shock Acceleration, DSA)
- The existence of relativistic particles allows for non-thermal emission processes to operate

1. PACWBs and their radio emission

$$S_\nu^{\mathrm{obs}} = S_\nu^{\mathrm{th}} + S_\nu^{\mathrm{syn}} e^{-\tau_\nu^{\mathrm{ff}}}$$





The radio spectrum is a combination of thermal (optically thick) emission from the stellar winds, and synchrotron emission produced in the colliding wind region (composite spectrum!) → spectral index can be neither typical of pure NT or T emission

$$\alpha = \frac{\ln\left(\frac{S_{\nu,1}}{S_{\nu,2}}\right)}{\ln\left(\frac{\nu_1}{\nu_2}\right)}$$

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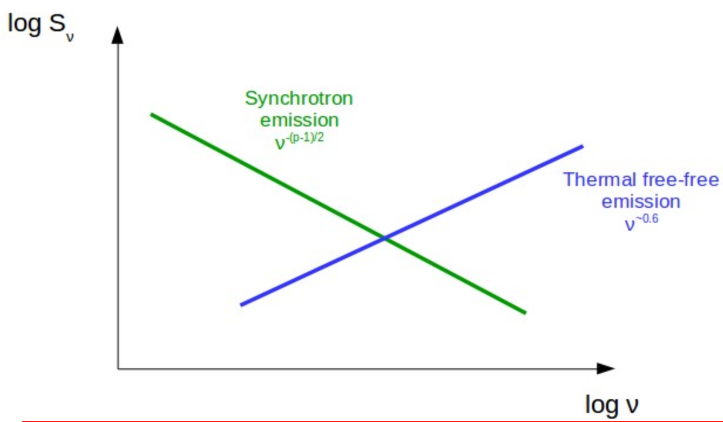

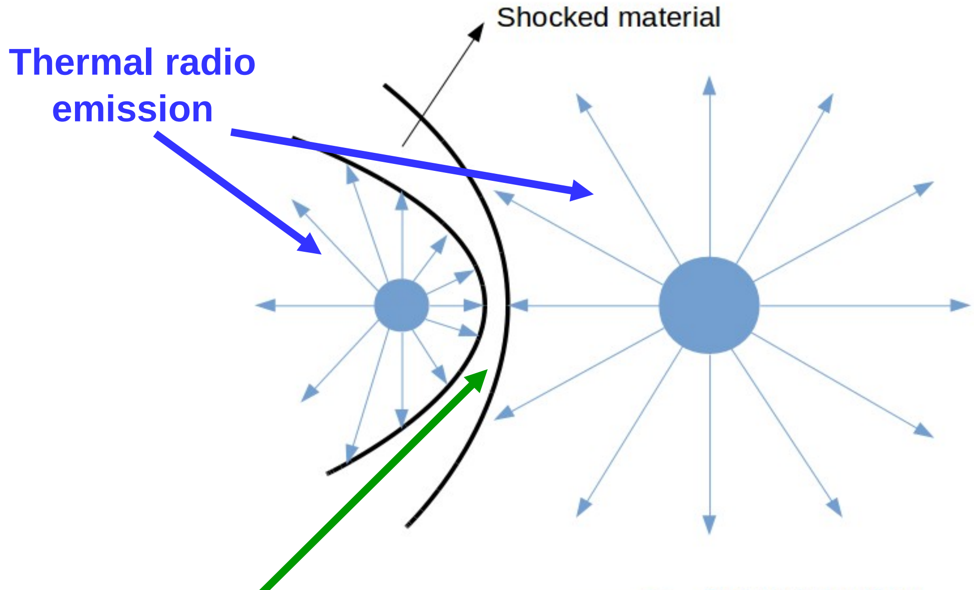

Why is it so relevant to address the question of the radio emission from PACWBs in a gamma-ray conference?

→ synchrotron radio emission is the most important tracer of particle accelation in PACWBs, among which one may find gamma-ray emitters

1. PACWBs and their radio emission

Synchrotron emission is the most efficient tracer of particle acceleration in massive binaries !
→ valuable probe for non-thermal physics in massive binaries

- Spectral index
- Brightness temp.
- Variability

$\alpha < 0.6$ (for S_ν prop. to ν^α)
→ deviation w.r.t. pure thermal emission

Component with $T_B \sim 10^6 - 10^7$ K

Emission related to the colliding-wind region
- physical conditions are phase dependent
- orientation effect due to free-free absorption

→ Catalogue of ~40 systems **(De Becker & Raucq 2013, A&A, 558, A28)**

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

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One exception ! **Eta Car** → non-thermal high energy emitter but no synchrotron radio emission detected

(→Kenji's talk, Guillem's talk)

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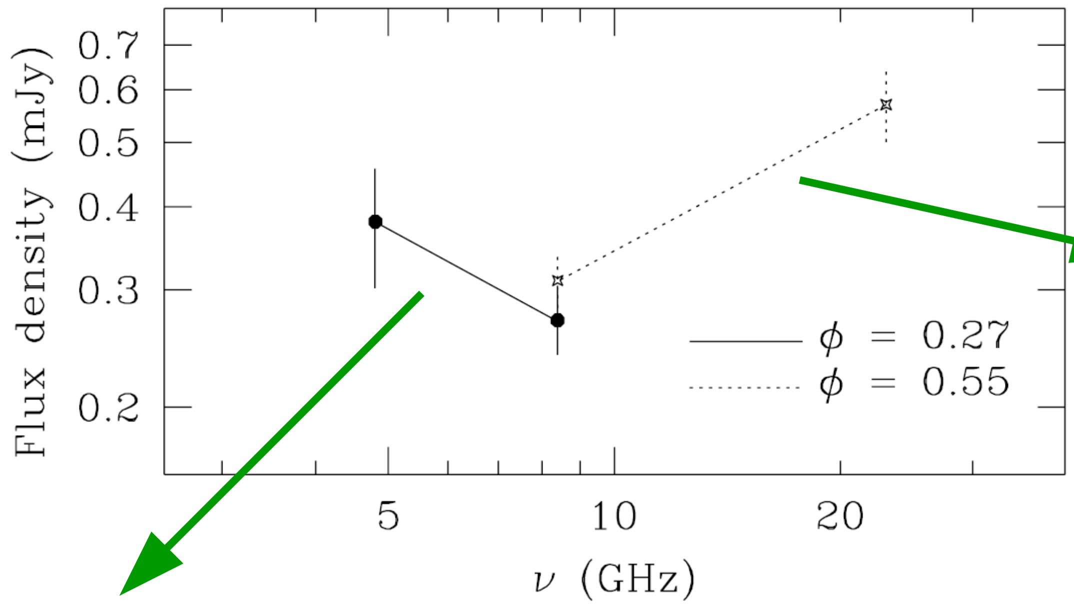
2. The multiple system WR133

WN5 + O9I
P = 112.4 d
e = 0.39
a = 105 R_{sol}

<u>Previous observations :</u>

Observations at two epochs, at 4.8 and 8.4 GHz, but no monitoring of the orbit.

(Montes et al. 2009, ApJ, 705, 899)



May2007

Thermal emission with spectral index close to +0.60

May 1993

Negative spectral index, suggesting non-thermal emission was significantly present !
→ PACWB status !

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Puzzling result ! Non-thermal radio emission detected despite the expected strong FFA, especially due to the WN wind !
→ further investigation was justified

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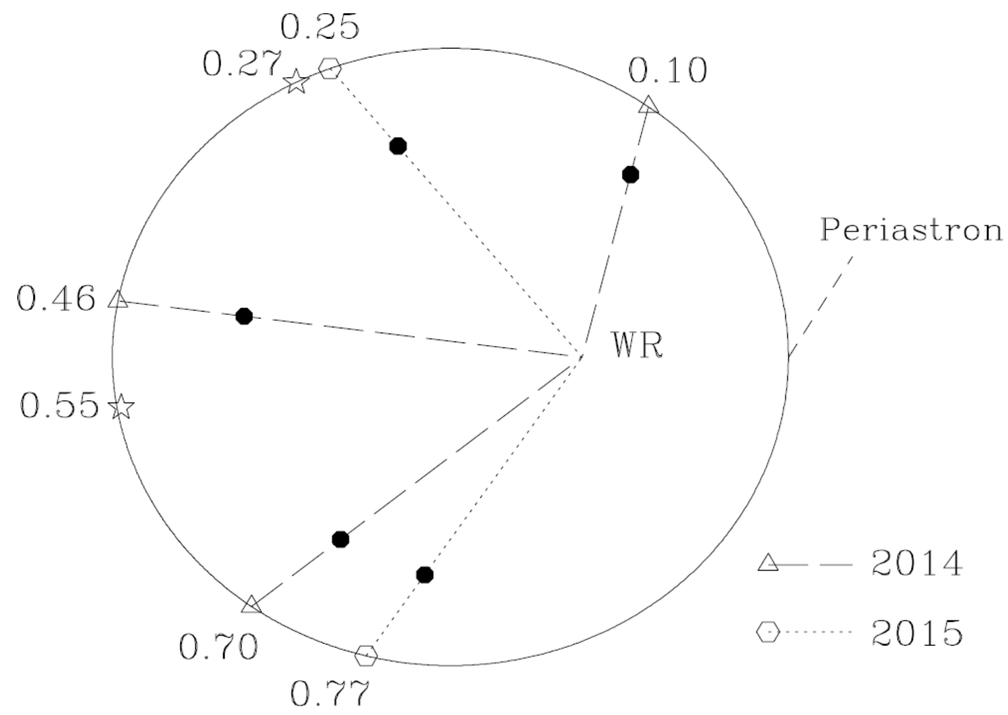
Additional JVLA observations :
Several pointings at 5.5 and 9 GHz to sample the orbit (in 2014 and 2015)
(De Becker, Isequilla & Benaglia 2019, A&A, 623, A163)

→ Constant radio emission along the orbit, with a thermal spectral index



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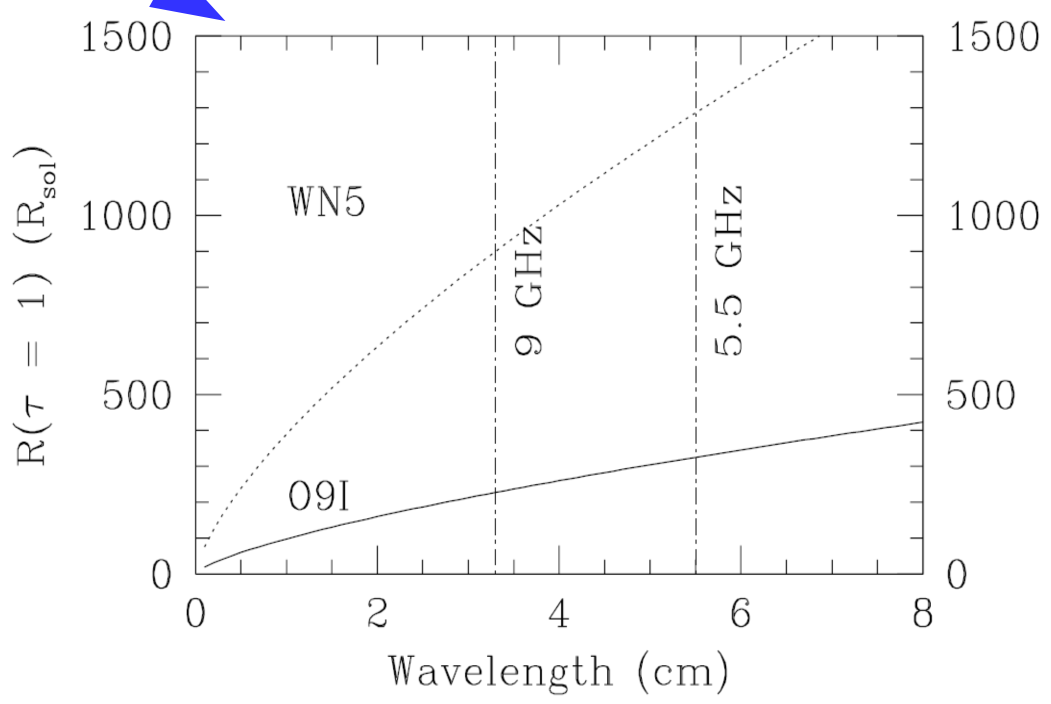
→ Constant radio emission along the orbit, with a thermal spectral index

→ What about the non-thermal emission reported by Montes et al. (observation in 1993)?



2. The multiple system WR133

Case 1 : Our measurements are not correct
→ unlikely (cross-checked, measurements consistent)

Case 2 : Problem in the determination of the flux densities by Montes et al.
→ no, we reprocessed the data and obtained the same results

Case 3 : All measurements are correct
→ a consistent explanation is needed

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WR133 may be a triple system, with a still unidentified companion on a wide orbit !

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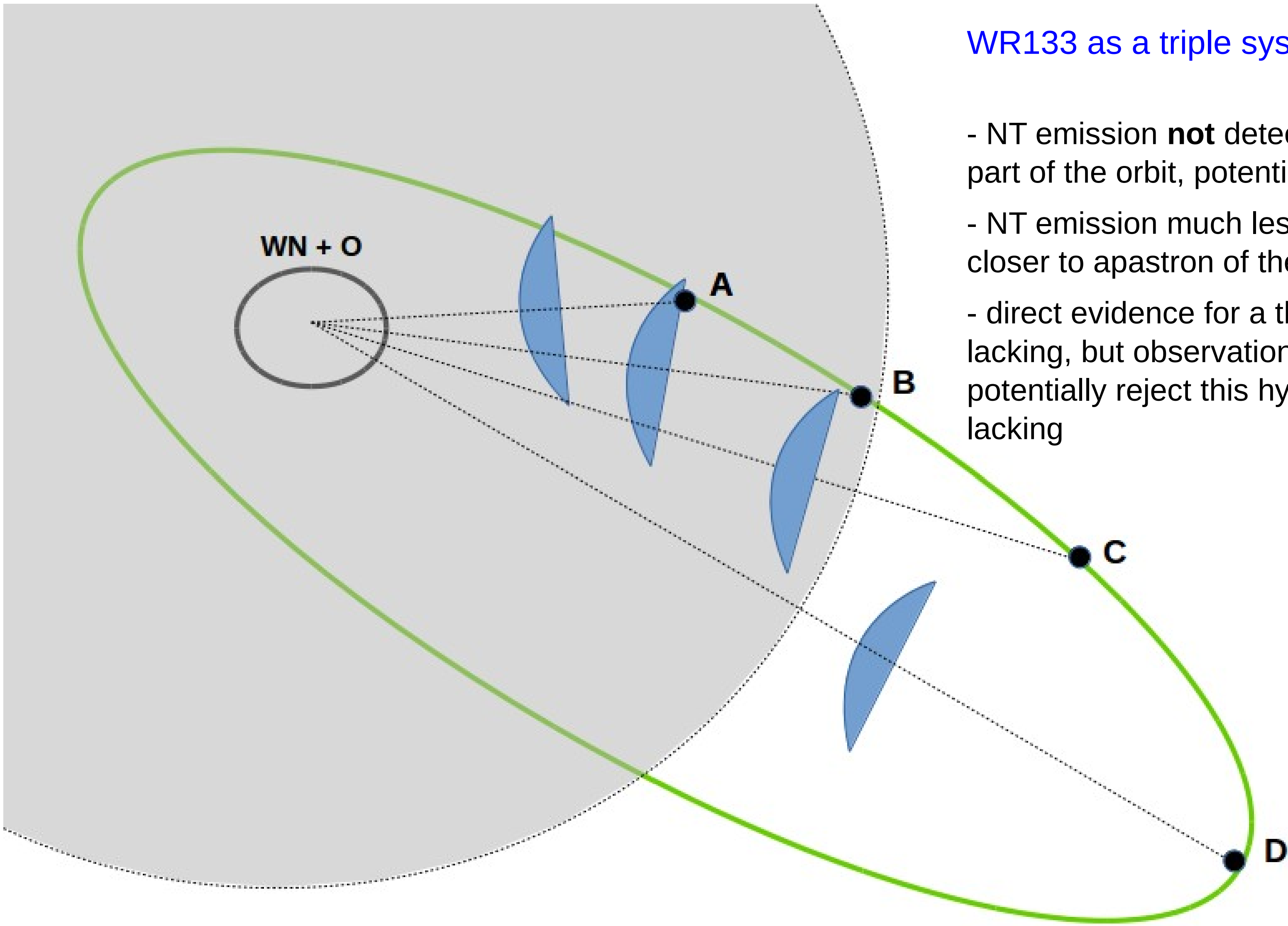

WR133 as a triple system :

- NT emission **not** detected in a large part of the orbit, potentially years (FFA)
- NT emission much less FF-absorbed closer to apastron of the long orbit
- direct evidence for a third object is still lacking, but observations required to potentially reject this hypothesis are still lacking

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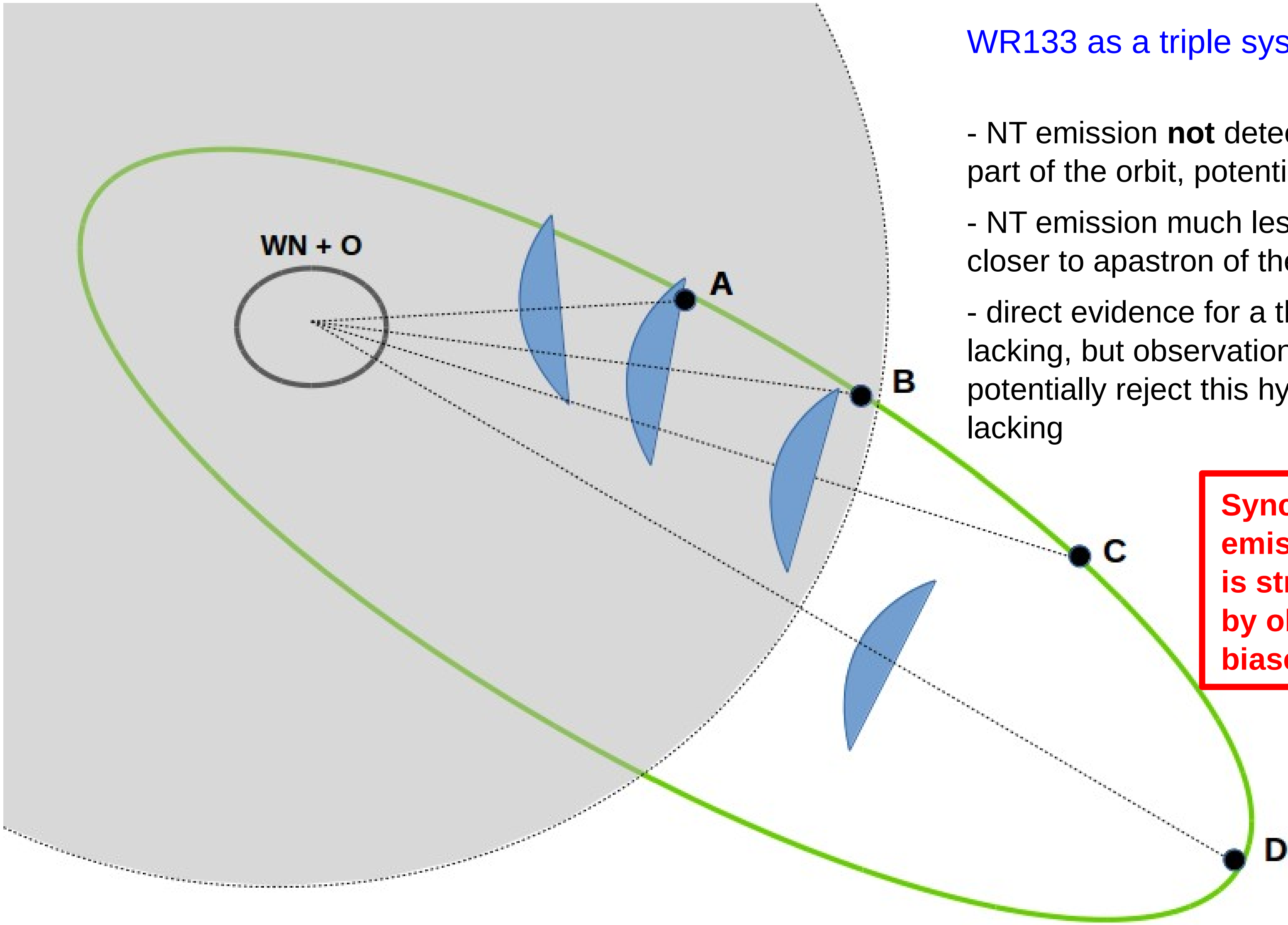

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Synchrotron radio emission detection is strongly affected by observational biases !

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WC8 + O7.5III
P = 78.5 d
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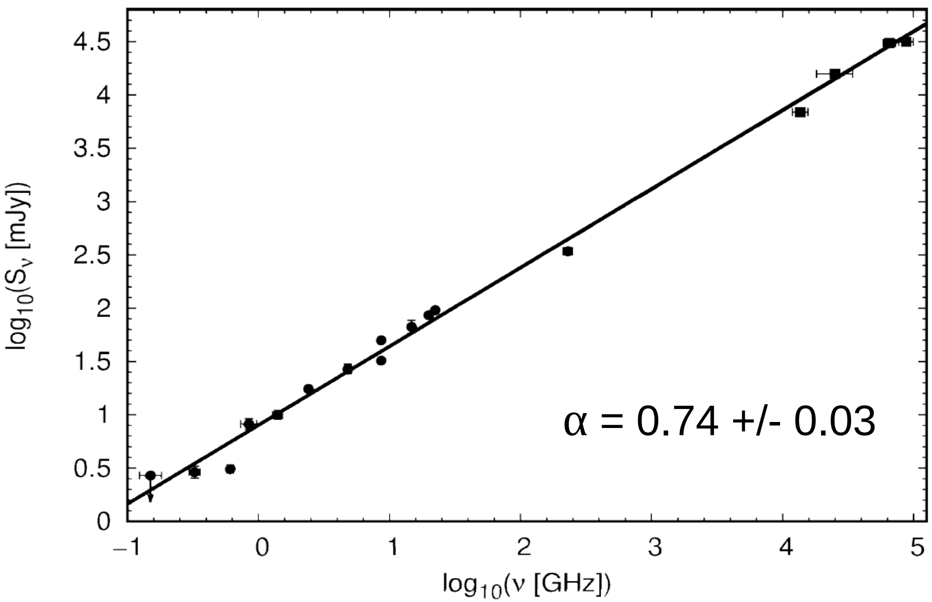
Candidate counterpart of the Fermi source 4FGL J0809.5-4714 (Pshirkov 2016)

(→ Olaf's talk)

Data covering several orders of magnitude in frequency
→ thermal emission spectrum, with no hint for synchrotron emission

(Benaglia, del Palacio, Ishwara-Chandra, De Becker, Isequilla & Saponara 2019, A&A, 625, A99)



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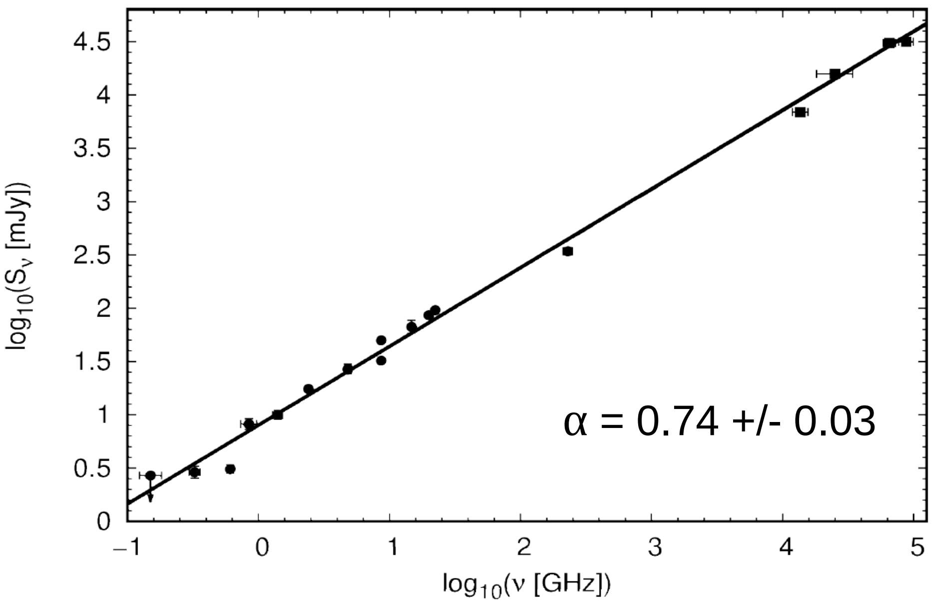

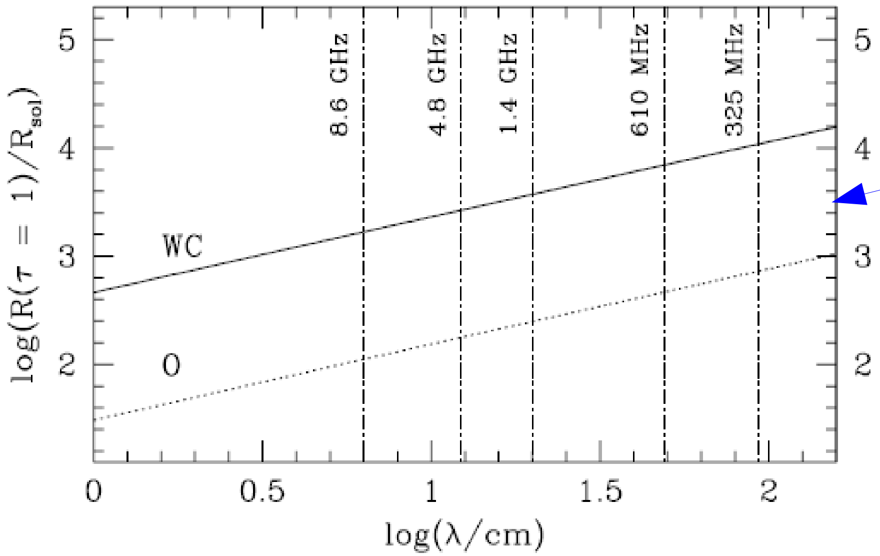

Not surprising !

The size of the orbit is much shorter than the expected 'radio photosphere' radius leading to a complete suppression of synchrotron emission, if any !

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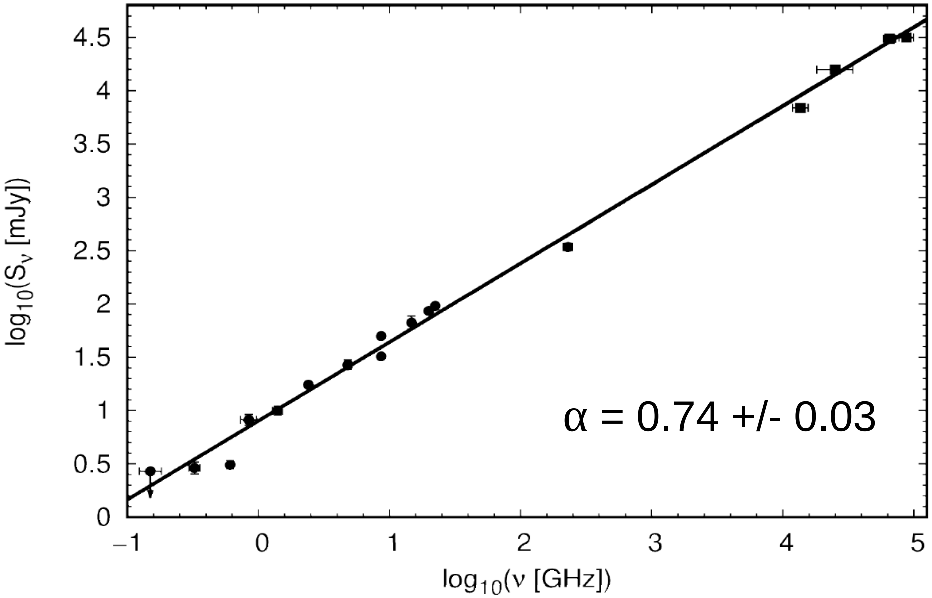

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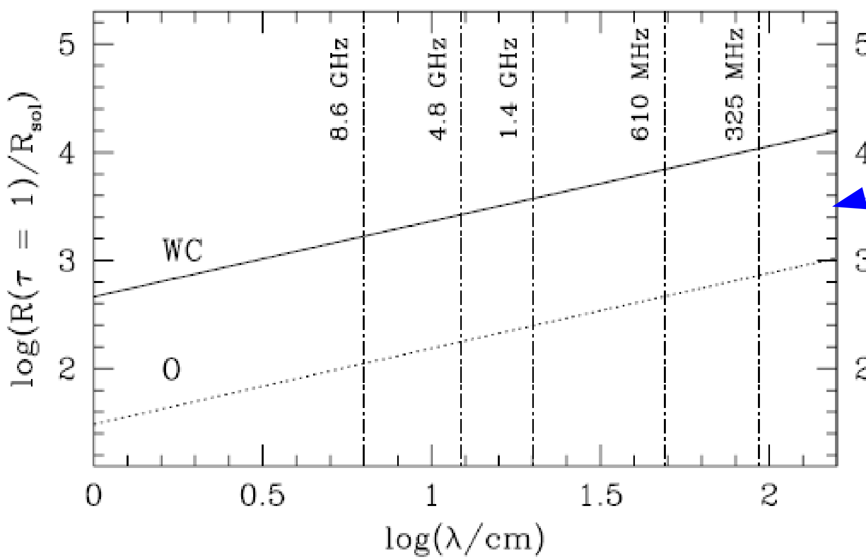

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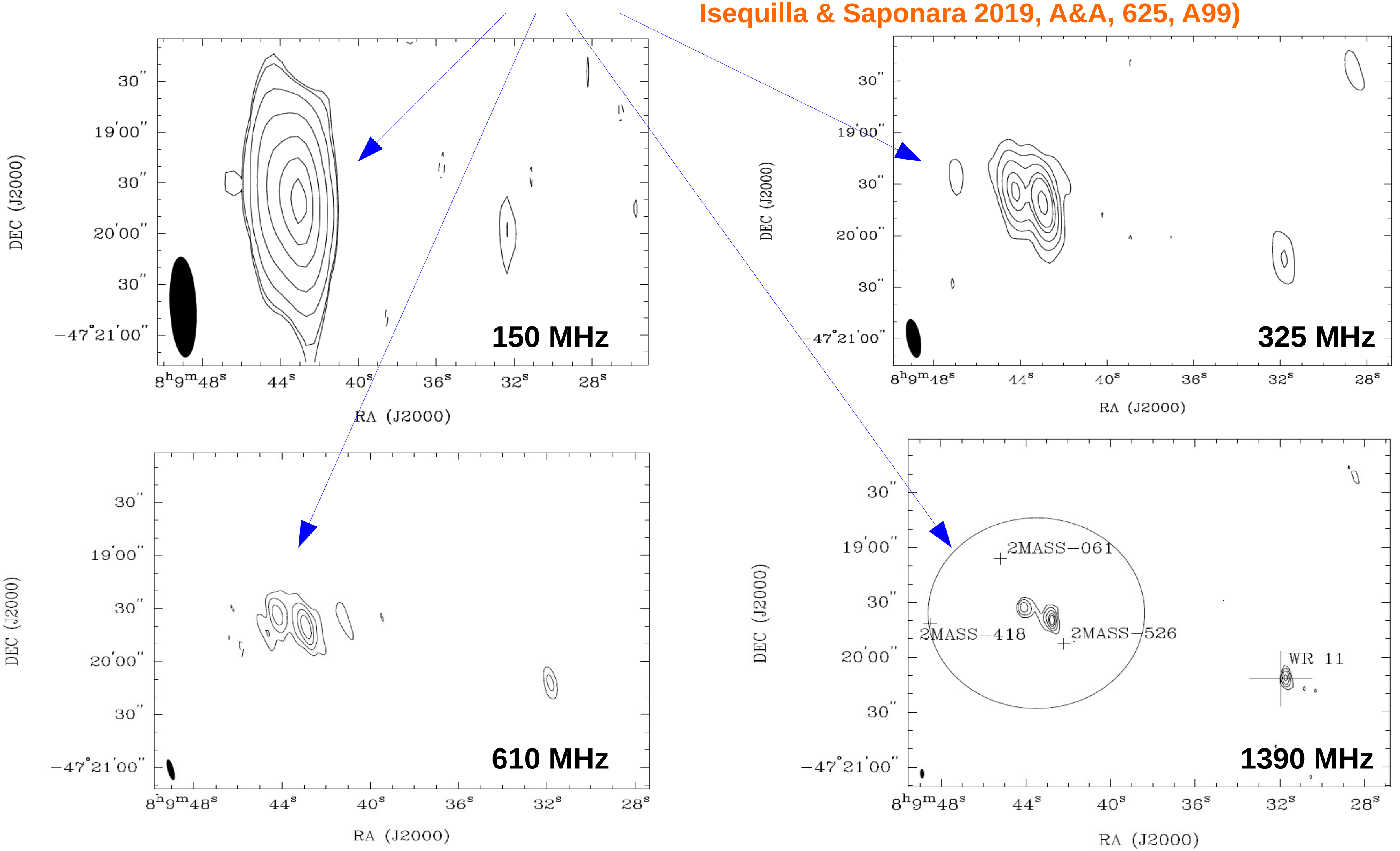
Mass loss rate determination 'compliant' with the requirement by Reitberger et al. 2017 for γ-ray emission → 2.4 10^{-5} Msol/yr

3. WR11 and its surroundings

The nearby source MOST 0808-471

(Benaglia, del Palacio, Ishwara-Chandra, De Becker, Isequilla & Saponara 2019, A&A, 625, A99)



3. WR11 and its surroundings

The nearby source MOST 0808-471

Images suggest a double-component source (→ bi-polar jets ?)

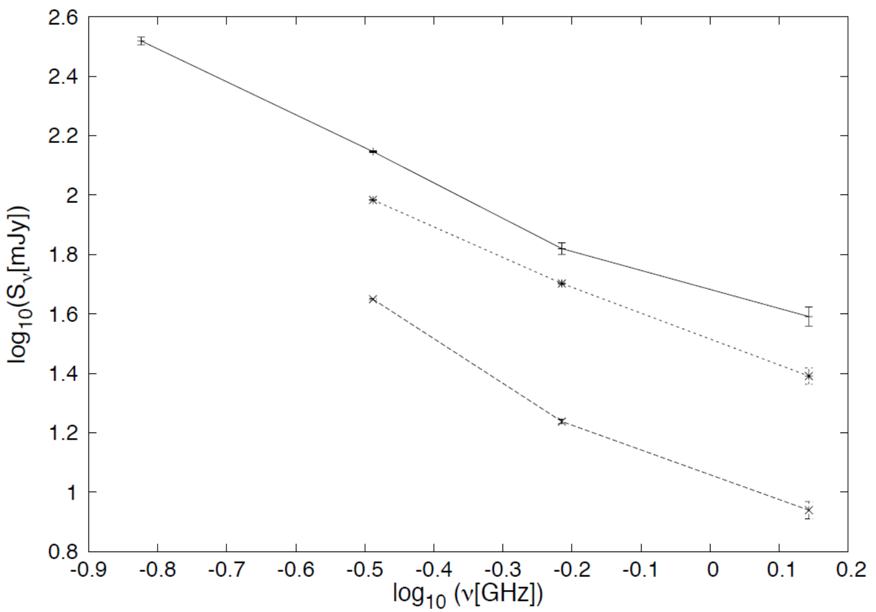
Well-pronounced non-thermal emission in both components :

Left → $\alpha = -1.2 +/- 0.1$

Right → $\alpha = -0.9 +/- 0.1$

The nature of that source is undetermined (no counterpart in X-rays, but several PMS objects in the vicinity → De Becker, del Palacio, Benaglia et al. in prep)

Might be interesting to consider for the origin of the Fermi source in this region !



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4. Low frequency observations of the Cygnus region

Just to mention it...

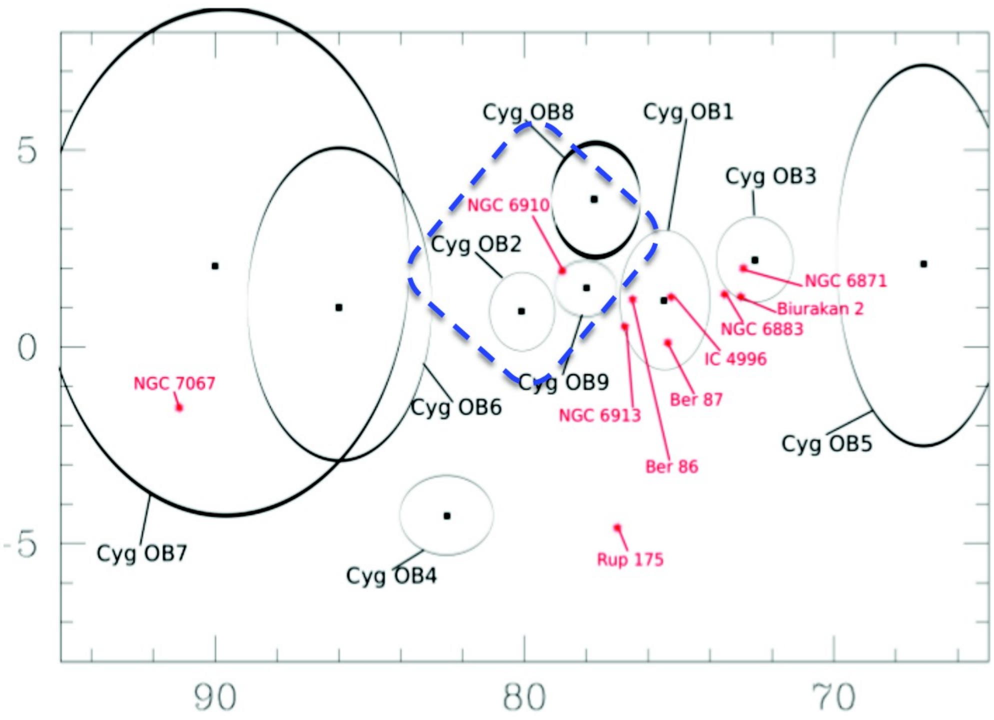
GMRT campaign on the Cygnus region, to investigate low-frequency emission from massive star systems (among other things…) :

- field of about 10 square degrees, at 325 and 610 MHz

- detection of some WR systems : WR140, WR146, WR147...

- detection of some O-type systems : Cyg OB2 #5, ...

Analysis in progress, more to come later → **Benaglia, De Becker, Ishwara-Chandra et al., in prep**



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WR133 :

- Pure **thermal emission** along the orbit, at odd with **previous NT detection**
- Potential interpretation : **triple system** involving a third star, in a wide orbit
- Consequence : **observational biases** constitute the main limitation to identify PACWBs

WR11 and its surroundigs :

- Broad band radio spectrum reveals **thermal emission only**, in agreement with expectations considering the strong FFA (provided some NT is actually produced, which is not certain)
- MOST0808-471 : potential **double-component NT source**, that deserves to be considered in discussions related to the origin of the **Fermi source**

Low-frequency studies of the Cygnus region :

- The **low frequency (< 1GHz) range** starts to be explored, with (first) detection of some massive stars in that range
- Specific **GMRT campaign** in the Cygnus region is yielding first results (more to come in the future...)

Thank you !