Particle-Accelerating Colliding-Wind Binaries: a relevant science case for radio observations

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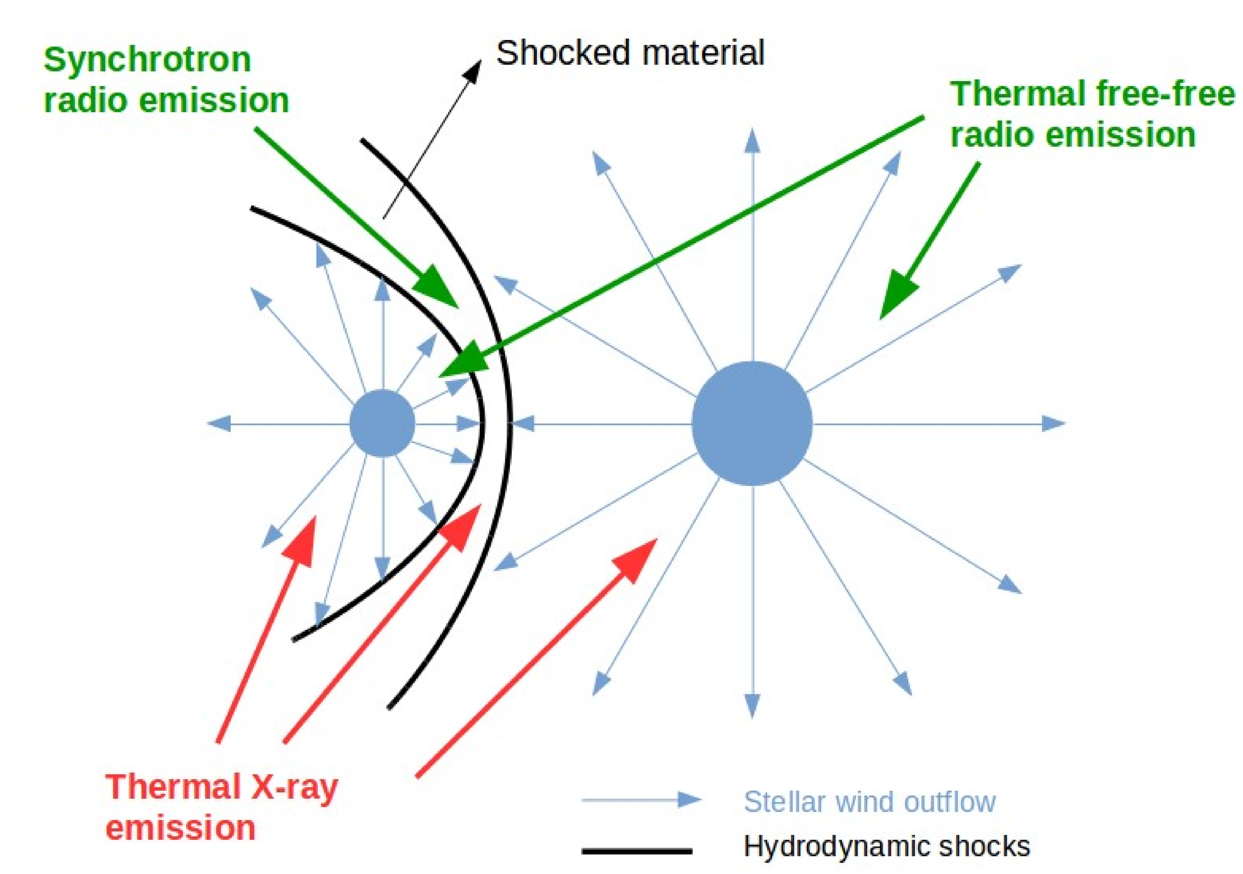
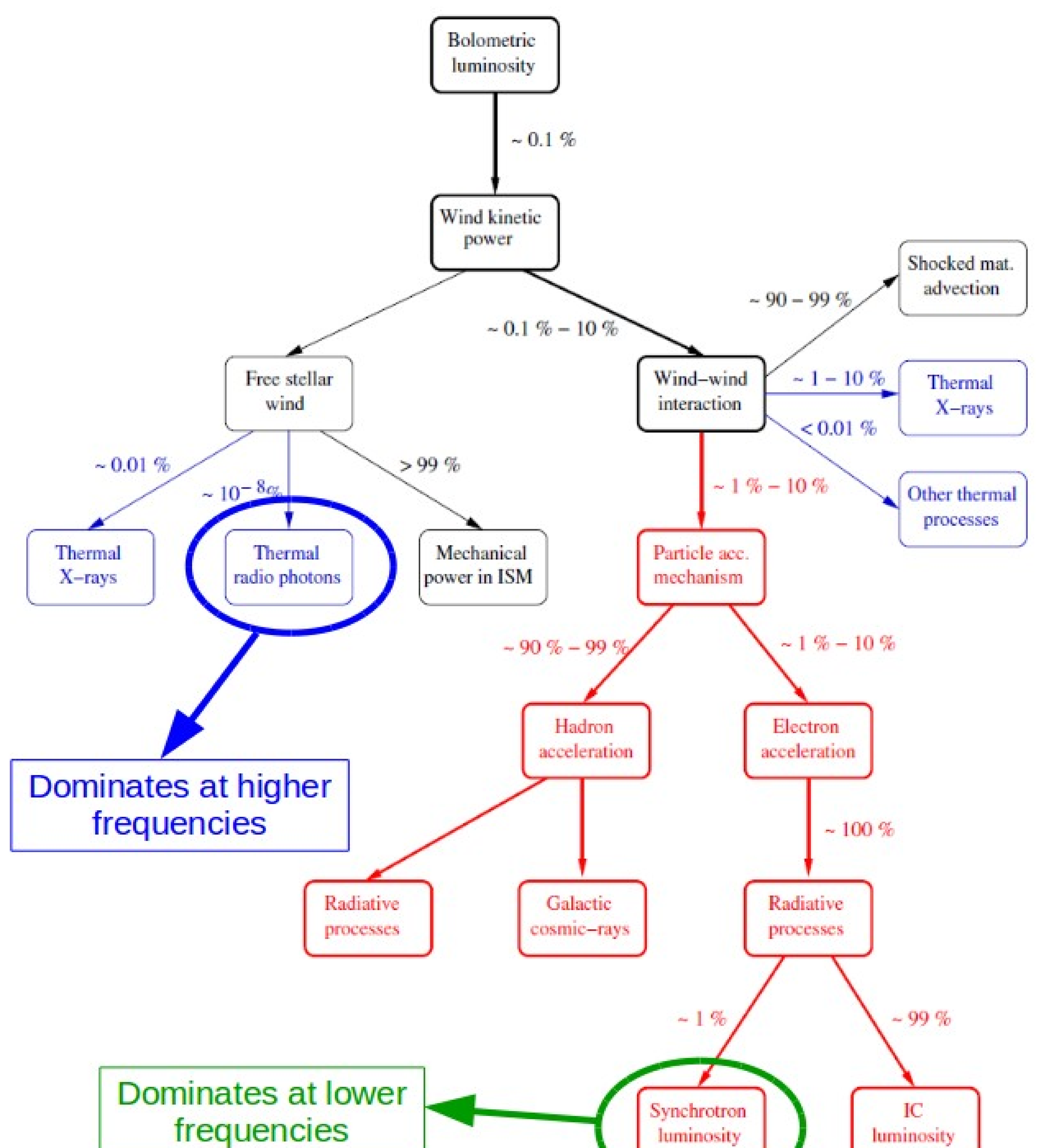
Abstract: *Synchrotron radiation identified in the radio domain for several tens of binary systems made of massive stars provides compelling evidence that a particle acceleration process is at work in these objects, hence their Particle-Accelerating Colliding-Wind Binary (PACWB) status. The processes at work for both particle acceleration and non-thermal emission are basically the same as for supernova remnants, but with different geometries and different physical parameters. Measurements of the synchrotron radio emission of PACWBs allow to investigate the non-thermal physics of these systems and to derive some of their properties. In this context, it is worth describing their emission properties at centimetric wavelengths, along with some expectations at longer wavelengths such as those measured by the Giant Metrewave Radio Telescope.*

Particle-Accelerating Colliding-Wind Binaries (PACWBs)

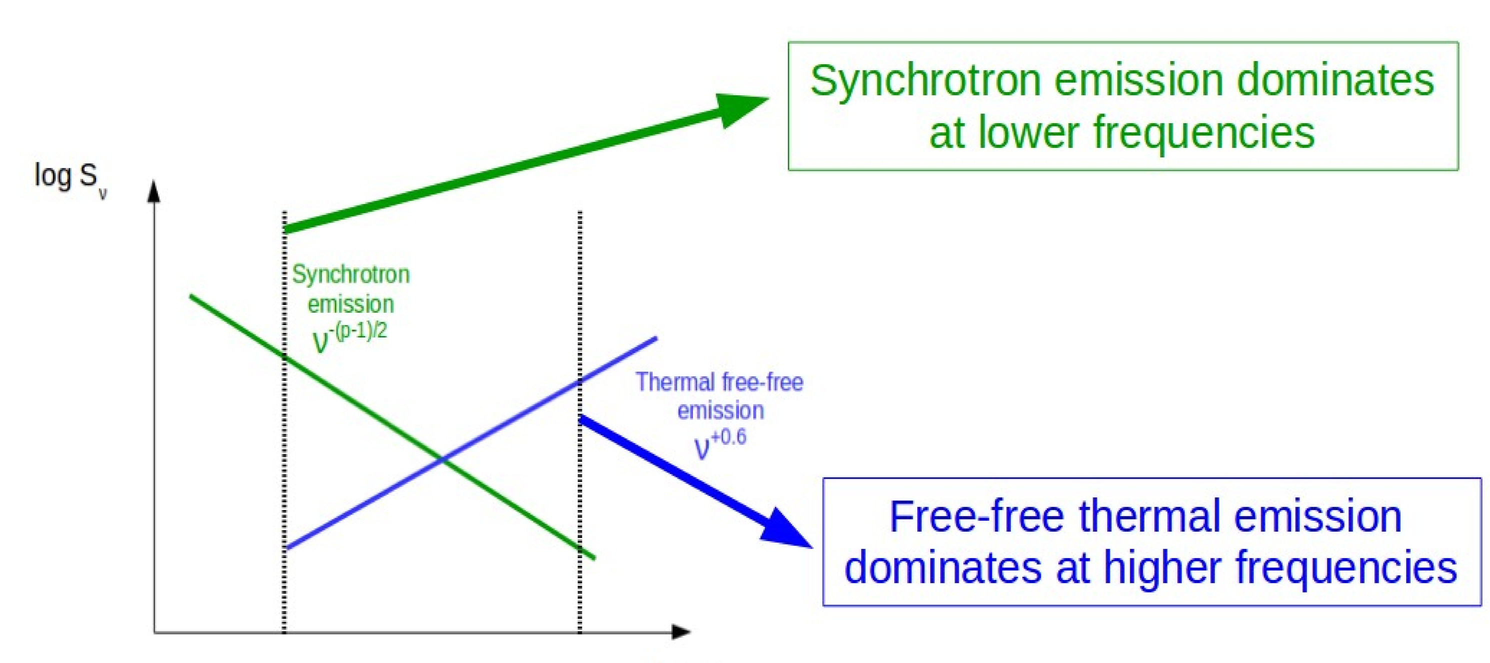
- Binary or high multiplicity systems made of hot, massive stars (O-type, early B-type, and their evolved counterparts, Luminous Blue Variable, Wolf-Rayet stars...): stars with strong stellar winds with terminal velocities of 2000-3000 km, and high mass loss rates (10^{-7} – 10^{-5} solar mass/year)
  → high wind kinetic power to feed many physical processes! (see thee energy budget below)
- In multiple systems, their winds collide and produce strong shocks: shock physics is important!
- Diffusive Shock Acceleration is also likely responsible for the acceleration of particles up to relativistic velocities, as evidenced in about 40 systems, hence the Particle-Accelerating Colliding-Wind Binary status (De Becker & Raucq 2013, catalogue of PACWBs [1]).
- Most particle accelerators among massive binaries are identifed through the detection of synchrotron radio emission [e.g. 2,3,4,5,6,7].





Radio emission from PACWBs

- Optically thick thermal emission from the stellar winds, with a spectral index $\alpha \sim 0.6$, for a dependence of the flux density on frequency as S_{ν} µ ν^{α} [8,9]
- Synchrotron radio emission from the colliding-wind region, identified mainly through (i) a negative or flat index α, (ii) a high brightness temperature, (iii) a significant phase-locked variability on the time scale of the orbit, and (iv) in a few cases the imaging of the emission region coincident with the colliding-wind region [1,10].



- Un-resolved systems lead frequently to the measurement of a composite spectrum, including both thermal and non-thermal emission, with a proportion varying with the frequency (see the Figure above)
  → Lower frequencies favor the measurement of the synchrotron component, hence the high interest of Giant Meterwave Radio Telescope measurements.
- However, lower frequencies are likely to be severely affected by turn-over processes, in particular free-free absorption (FFA) by the stellar wind material, as a function of wind properties and orbital phase [e.g. 11]
  → Confrontation of actual measurements in the turn-over spectral region to expectations for an unaffected optically thin synchrotron spectrum allows to quantify the turn-over, which is important for the modelling of these objects
- The modelling of these objects can thus deeply benefit of radio investigations
  → A better understanding of these objects constitutes a strong requirement to improve our understanding of their non-thermal physics, and notably evaluate the overall contribution of PACWBs to the production of Galactic cosmic-rays [e.g. 12].

Concluding remarks

- PACWBs are valuable targets for radio observatories, in particular the GMRT appears especially promosing to characterize their radio emission at frequencies below 1 GHz.
- PACWBs constitute a highly valuable opportunity to study shock physics in stellar environments, in particular shocks in relation with colliding-winds.
- PACWBs are complemetary with other non-thermal galactic sources such as supernova remnants: they share globally the same physics, but in a different part of the parameter space and with a different geometry. In addition, these systems demonstrate the role of pre-supernova massive stars in the production of Galactric cosmic rays, which is most of the time overlooked.

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