Synchrotron radio emission as a proxy to identify long period massive binaries

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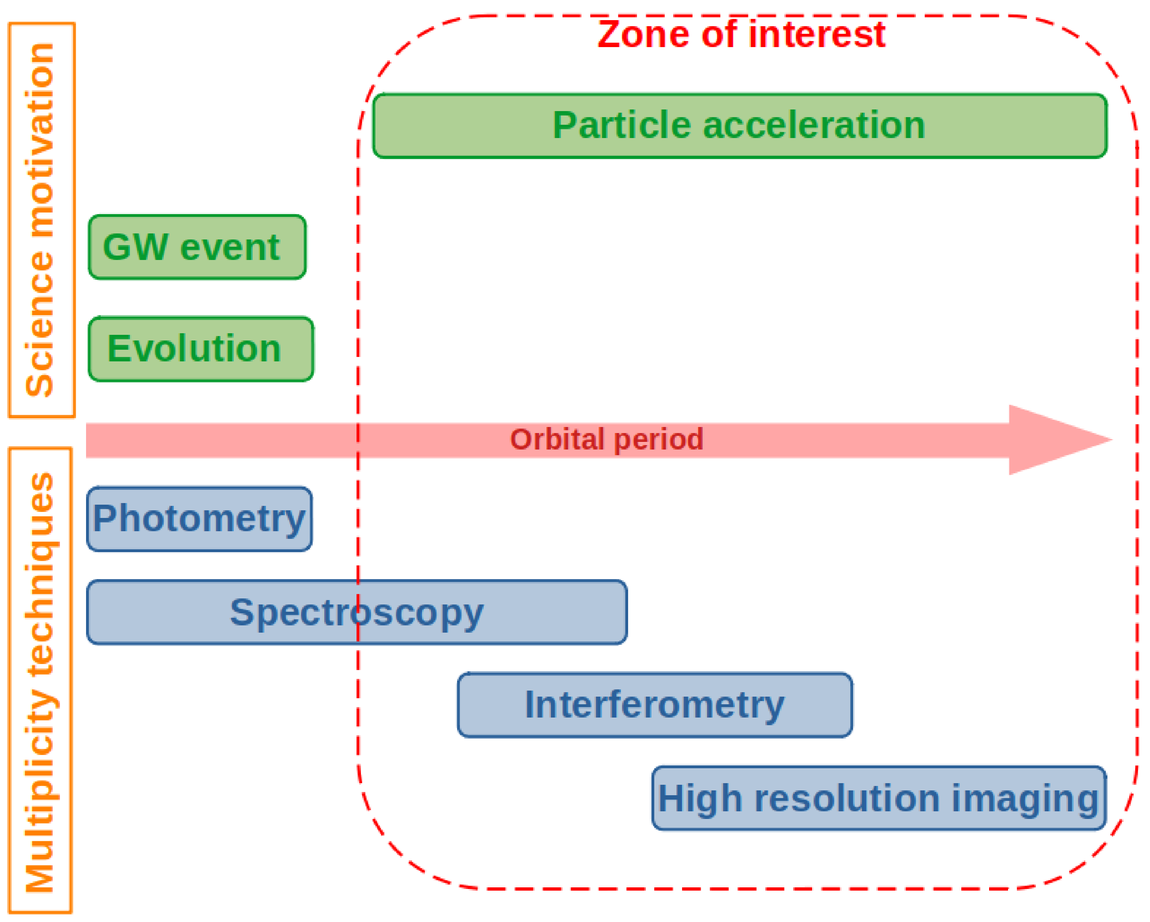
Abstract: ***The multiplicity of massive stars is known to be significantly high. Even though the majority of massive stars are located in binary systems, the census of binaries is biased toward shorter periods as longer period systems are more difficult to identify. Alternatively, the search for binary systems with periods of at least a few years may proceed differently. As massive binary systems are typically colliding-wind systems, hints for processes occurring in the colliding-wind region could be used as a valuable proxy to identify likely binary systems, and then organize dedicated spectroscopic or interferometric campaigns on a short list of pre-selected targets. In this context, any hint for synchrotron radio emission is seen as a promising indicator of long period binaries. Usual techniques to identify synchrotron radio emitters constitute thus valid tools to explore that poorly investigated part of the massive binary parameter space.***

The multiplicity of massive stars

A large fraction of massive stars are part of binary, or higher multiplicity systems. However, the census of binary systems is dependent on the specificities of the direct techniques used to investigate their multiplicity,

- shorter time-scales are easier to monitor (shorter time series needed)
- photometry and spectroscopy are well-known techniques easy to implement, and especially efficient at unveiling and characterizing short period systems (typically a few days, even though spectroscopy can be efficient up to a few year)
- Long baseline interferometry is a complementary technique very useful to investigate periods of the order of 1 year, up to a few tens of years. However, only a couple of facilities exist, and this is not enough to organize significant surveys **[1,2]**
- Non-interferometric high resolution (HR) imaging is relevant for much longer periods, but such long time-scales are not easy to monitor **[3]**

→ Long period systems are still poorly investigated, leading to a significant bias in the exploration of the massive binary parameter space.



Science drivers as a function of the orbital period

Shorter period systems are privileged targets for modern stellar astrophysics for two main reasons,

1. They constitute potential progenitors for gravitational wave (GW) events (black hole mergers, neutron star mergers…) **[4]**
2. Mass exchange between components of short period binary systems is a key aspect of massive star evolution **[5]**

Long period systems are relevant laboratories to investigate shock physics, and the stellar winds of both stars collide at high speeds, leading to high Mach number adiabatic shocks,

→ in particular, particle acceleration through the Diffusive Shock Acceleration process is occurring **[6]**

→ non-thermal emission processes signatures will reveal the occurrence of this acceleration process, at work only in massive binaries: Synchrotron radio emission is a key process in this context **[7]**

Synchrotron radiation as an efficient tracer of long period massive binaries

- Most particle accelerators among massive binaries (Particle-Accelerating Colliding-Wind Binaries, PACWBs **[8]**) are identified through the detection of synchrotron radio emission from the colliding-wind region **[e.g. 9,10,11,12,13]**.
- Free-free absorption (FFA) is expected to be high, especially in orbital configurations where the stellar wind plasma is dense enough → longer period system offer better chances of detection.

General strategy

- The radio measurement of many massive stars not known to be long period binaries is expected to reveal synchrotron radiation for some of them, according to well-established interpretation guidelines **[14]**: variability studies, high-angular resolution measurements, spectral index measurements based on at last two spectral bands, search for high brightness temperature.
- If synchrotron radiation is identified, it points to a binary with a period long enough not to be dominated by FFA

  → identification of a long period binary

  → targets tagged for more specific studies aimed at detecting the companion, and provide further confirmation for a binary status
- This approach deserves also to be considered for known short period binaries, as it is likely to reveal triple systems. Triple systems have been unveiled after hints for the third object were suggested by the a synchrotron emitter status (either using spectroscopic or interferometric techniques)**[15,16]**

Concluding remarks

- *Synchrotron radio emission from massive stars is an excellent tracer of particle acceleration (PA)*
- *These non-thermal processes occur in the colliding-wind region in binary systems, but the low efficiency of PA and the high efficiency of FFA in short period systems restrict PACWBs to periods greater than several weeks, typically years or even decades.*
- *Given the difficulty to reveal long period binaries with usual techniques, synchrotron emission is a good proxy to unveil them.*
- *A better census of massive star multiplicity is important for population synthesis and stellar dynamics purposes in stellar clusters.*

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