On the requirement for a high resolution spectrograph to investigate the multiplicity of massive stars with the DOT

Michaël De Becker

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

Abstract: *The investigation of the multiplicity of massive stars constitutes a key aspect of their understanding. On the one hand, the evolution of short period systems is tremendously influenced by the companion (through mass exchange, common envelope evolution,...). On the other hand, the wind-wind interaction region in massive multiple systems is the seat of a high level physics, including strong thermal X-ray emission, particle acceleration and non-thermal emission processes. The description and understanding of these processes require the accurate determination of orbital parameters, notably through spectroscopic studies. In this context, I will overview and anticipate some relevant applications of a high resolution spectrograph (HRS) mounted on the DOT, emphasizing its potential complementarity with other Indian facilities such as the GMRT and Astrosat.*

A few biases which severely affect multiplicity investigations...

- *Orientation of the system :*
  The ideal orientation to reveal a binary motion differs with the technique. Radial velocity (RV) variations investigated using a HRS can be measured on spectral lines for not too low inclinations.

- *Time sampling :*
  Multiplicity investigations require a lot of observing time to sample the orbit. For long period orbit, observation campaigns can be quite long, and potentially difficult to organize. In addition, eccentric systems may display strong variations close to periastron passage only, with a flatter RV curve at other orbital phases.

- *Period range :*
  Very long period systems (typically more than ~10 years) are difficult to study because of the long duration of the required time basis, and more important because of the low amplitude of the RV variations which fall below the detection limit (typically not better than several km/s because of the large rotational broadening of massive star spectral lines).

Some good reasons to mount a high resolution spectrograph on the DOT...

- Improve the capability to investigate Northern sources with a 3.6m telescope. Not so many telescopes of that size exist in the Northern hemisphere.

- Open the access to a telescope whose scheduling is much less constrained than for most major observatories. Repeated observations with high oversubscription factor telescopes are most of the time difficult to organize, preventing thus long term multiplicity studies to be organized.

- The size of the DOT is especially well adapted for the study a massive stars up to a few kpc, with good resolution (R ~ 30000-50000) and high signal-to-noise ratio (>100) spectra in a rather short exposure time (less than 1 hour).

A (non-exhaustive) selection of scientific questions that would benefit of a HRS on the DOT

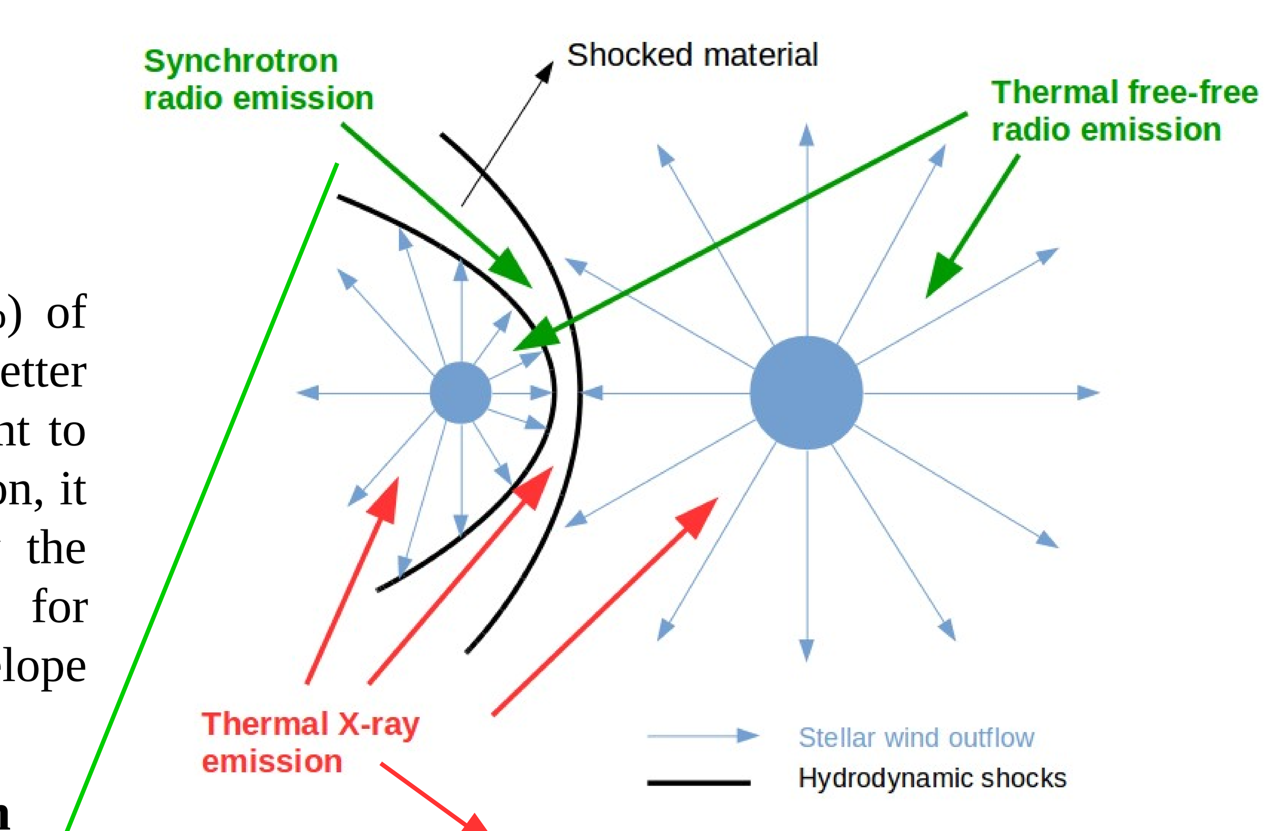
1. Determination of the binary fraction among massive stars...

One knows that a significant fraction (>50%) of massive stars are at least binary systems. A better determination of that fraction is very important to constrain stellar formation scenarios. In addition, it is clear that binarity influences significantly the evolution of massive stars [1]. One may for instance mention mass and common envelope evolution [2] .

2. Investigation of the particle acceleration and non-thermal physics in massive binaries...

A fraction of massive binaries are known to accelerate particles up to relativistic energies. This process is revealed mainly by the identification of synchrotron radio emission in about 40 systems [3], along with non-thermal X-ray and gamma-ray emission at least in the case of Eta Car [4,5]. See [6] for a general discussion.

As these processes occur in the collidind-wind region, they vary as a function of the orbital phase, and it is crucial to know as much details as possible to discuss that physics in the appropriate context. The use of high quality spectroscopic data collected with the DOT would help to derive accurate orbital elements, which is required to model these environments. Such observations may complement *GMRT* campaigns dedicated to these objects.



3. Investigation of the thermal X-ray emission from massive binaries...

When the stellar winds of massive stars collide in a binary system, strong shock are produced. The post-shock is heated up to temperatures of a few 10^7 K, and such a hot plasma is produced thermal X-ray emission [7]. The detailed investigation of this X-ray emission allows one to study the hydrodynamics of the shocks.

The measured X-ray spectrum is phase-locked with the orbital motion [e.g. 8]. On the one hand, the emission process depends on the stellar separation which is varying in eccentric systems. On the other hand, the stellar wind material is responsible for a significant photoelectric absorption that depends on the line of sight. This is clearly an orientation effect, whose modelling requires an accurate description of the orbit of the system. In this context, combined observations involving the DOT and *Astrosat* could be envisaged.

5. Determination of fundamental parameters of massive stars...

Using stellar spectrosocpy to study the orbital motion of massive stars leads the determinaiton of their minimum masses. When a complementary technique can be used to determine the inclination of the system, absolute masses can me obtained. Tis is for instance the purpose of combined interferometric and spectroscopic measurements [9]. Absolute masses constitute key parameters to understand stellar evolution.

4. Investigation of the production of dust particles in evolved WC-type binaries...

Among the most evolved counterparts of massive stars, WC-type stars produce very dense stellar winds. A noticeable feature of these winds is the significant enrichment in carbon, which is the signature of the triple-α process [10].

When a WC wind si compressed because of a collision with the companion's wind in a binary system, the wind collision region gas reaches a density high enough for the nucleation of dust particles [11]. This phenomenon is at the origin of the so-called pinwheel nebulae revealed by infrared imaging [12].

The knowledge of orbital elements is a prerequisite for any attempt to model such a dust production process.

1. Sana H. et al. 2012, Science,
2. Taam R.E. & Sandquist E.L., 2000, ARA&A, 38, 113
3. De Becker M. & Raucq 2013, A&A, 558, A28
4. Farnier C. et al. 2011, A&A, 526, A57
5. Hamaguchi K. et al. 2018, Nature Astronomy, 2, 731
6. De Becker M. 2018, BSRSL, 87, 185
7. Pittard J.M. & Parkin E.R. 2010, MNRAS, 403, 1657
8. De Becker M. et al. 2006, MNRAS, 371, 1280
9. Le Bouquin J.-B. et al. 2017, A&A, 601, A34
10. Crowther P.A. 2007, ARA&A, 45, 177
11. Williams P.M. 2014, MNRAS, 445, 1253
12. Tuthill J. et al. 2008, ApJ, 675, 698

Acknowledgements: I would like to thank the organizers for allowing me to present this poster in the Second BINA workshop.