AMBER+FINITO+UT Science Demonstration Proposal

Title: Absolute mass determination of Massive Stars

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Abstract:
We propose to measure the angular separation between the components of known long-period massive spectroscopic binaries in order to (i) estimate the system inclination by taking advantage of the known orbital solution, (ii) provide constraints on the absolute mass of the objects. Additionally, these observations will prove the feasability of such measurements and will help us to determine which objects are suitable for a long term astrometric monitoring.

Scientific Case:
Massive stars of spectral type O, and their evolved descendants the Wolf-Rayet stars, are among the brightest and most luminous stellar components of the galaxies. Because of their extreme properties (high luminosities, powerful stellar winds, death as supernovae), they largely influence their environments. A detailed understanding of their life and evolution is not only relevant for stellar and galactic astronomy, but is a key elements to some of the nowadays more intriguing astrophysical questions: the origin of the gamma-ray burst and the formation of black holes.

Despite their importance in modern astrophysics, the massive stars remain incompletely understood. This reflects their actual rareness, and the subsequent large distance at which they are found. As a consequence, basic parameters such as *their mass* remain very difficult to accurately measure. Such a quantity is however critical to calibrate the evolutionary models up to the pre-supernova stage.

So far, only SB2 spectroscopic eclipsing binaries (SB2E) offer reliable constraints on the absolute masses, thanks to the combination of orbital constraints coming from radial-velocity and eclipse itself to lift the degeneracy between mass and orbit inclination. According to recent reviews (Gies 2003, GOC-v2.0 2007), less that 25 direct measurements have been achieved. This is far insufficient to cover a parameter space that spans 80 $M_\odot$ in mass, 20,000 K in temperature, 1.5 dex in luminosity and 15 $R_\odot$ in radius. In addition, SB2E systems only give access to short period binaries ($P < 10$ d, typically). For such close objects, it is often difficult to exclude a prior mass-transfer event that could modify the amount of mass in each individual stars, especially for evolved objects of class III and I. This adds an additional degree of uncertainty in the difficult task of calibrating the massive stars evolutionary tracks.

By breaking the K=7 magnitude limit, AMBER+FINITO+UTs strongly increases the number of O-stars with possible accurate mass measurement by allowing us to reach objects with a larger separation than typical SB2E systems. Indeed, the combination of known spectroscopic SB2 orbit with relative astrometrical measurements from interferometry allows to free our-self from the limitations imposed by the rareness of the eclipsing systems. As shown in Fig. 1 (Sana & Zinnecker 2008), systems with period in the range 100 to 5000 d at 1 to 2 kpc (a typical distance for *nearby* O stars) are accessible by both radial-velocity and by the VLTI. Combining those two techniques will allow us to recover the orbits in the 3D space, overthrowing the uncertainty on the inclination.

As a first step in this direction, we propose to measure the angular separation of known long-period massive spectroscopic binaries in order to estimate the system inclination by taking advantage of the known orbital solutions. We have selected a set of 4 binary systems with period in the range 100 to 3000 d and with primary massive ranging 20 to 45 $M_\odot$. This will provide new constraints on the *absolute mass* of these objects. As a matter of fact, the planned observations will also prove the feasibility of such measurements and will further help us to determine which kind of objects are suitable for a long term astrometric monitoring (to be submitted in P83).

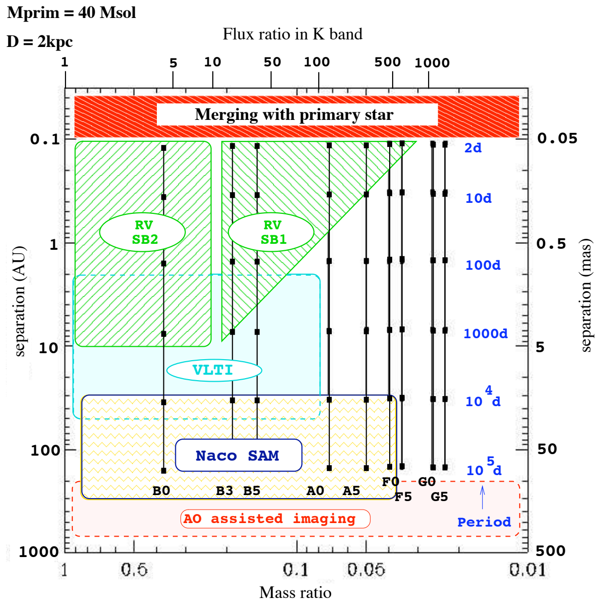

Fig. 1: Sketch of the typical binary parameter domain accessible using different observational techniques. A main sequence 40 $M_\odot$ primary star has been assumed. Mass-ratio-physical separation track are indicated for various companion types and various orbital periods (non-eccentric orbits assumed). Separation scale in mas (right-hand scale) is computed assuming a typical distance of 2 kpc as quoted on top of the graph. Primary over secondary flux ratio in the K-band is also given on top of the graph. Figure taken from Sana & Zinnecker (2008).

All our targets are spatially resolved by AMBER/VLTI, excepted HD 168137 which is only marginally resolved and so should be assigned the lowest priority. The expected contrast ratio is within the range $2 - 10$ (in flux, not magnitude), and so lead to a visibility effect in the range $50\% - 10\%$, which is well within the AMBER capabilities.

Calibration strategy:

We will ideally make use of all AMBER observables: absolute visibilities, absolute closure-phase and differential phases since our required accuracy is well within the AMBER performances. Moreover, in case of poor absolute calibration, it has been proved that differential visibilities and differential closure-phases across the H/K-bands are sufficient to fit a binary star model (see Kraus, 2008).

Targets and number of visibility measurements

The *size* parameter is the expected separation between the components (most probable). Real separations can be within a range $0.5 - 2$ of these values. Because of the binary nature of the targets, we expect high visibilities ($> 50\%$, enough to detect and follow the fringes) on at least 2 baselines in either the H- and/or the K-bands.

Target	RA	DEC	V mag	H mag	K mag	Size (mas)	Vis.	Mode	# of Vis.
HD 54662	07 09 20.3	-10 20 48	6.2	6.2	6.2	3.5		LR	1
HD 164794	18 03 52.3	-24 21 38	5.9	5.7	5.7	10.9		LR	1
HD 168075	18 18 36.1	-13 47 37	8.7	7.4	7.3	2.4		LR	1
HD 168137	18 18 56.2	-13 48 31	8.9	7.7	7.6	1.8		LR	1

Time Justification:

We only need one interferometric observation per target to provide a first estimation of the inclination and to prove the feasability of a larger project in the incoming periods.

References:

Gies D.R. 2003, IAUS 212, 91, *Masses and other parameters of massive binaries*
GOC v2.0 (Galactic O-star Catalog, v2.0 2007): see Maz-Apellniz J., et al. 2004, ApJS 151, 103
Kraus S., et al., 2008, SPIE conference, *Infrared Spectro-Interferometry of YSOs*
Sana & Zinnecker 2008, EPoS2008 The Early Phase of Star Formation, *The multiplicity of massive stars*