AMBER+FINITO+UT Science Demonstration Proposal

A Sharp View on the Tip of Orion's Sword - The distance to ι Ori

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Abstract:

We propose to observe the two runaway stars ι Ori and μ Col maybe emerging from a common binary-binary encounter. With the help of only one astrometric measurement of the separation of the spectroscpic binary ι Ori we can determine the distance to the system, since the spectroscopic orbit is known and the inclination can be estimated due to grazing eclipses witnessed in this system. In the case of μ Col, an apparent single star, we want to search for yet unknown companions in the niche neither covered by adaptive optics, nor radial velocity measurements.

Scientific Case:

ι Ori is a spectrocopic binary of type SB2 with a period of 29.13 days and an eccentricity of 0.76 (Stickland et al. 1987). The spectral types of the components are O9.5 III and B0.8 III-IV. Masses of about 40 $M_\odot$ and 20 $M_\odot$ have been derived (Stickland et al. 1987), but these are not fully consistent with the spectral types according to the latest calibrations (Martins et al., 2005). ι Ori is a most important system, because it is believed to be the remnant of a past binary-binary interaction in the Orion Nebula cluster, which sent two other massive stars AE Aur (O9.5V) and μ Col (O9.5V/B0) off as runaway stars in directly opposite directions (Hoogerwerf et al., 2000). This binary-binary interaction is supposed to have led to an exchange reaction which formed the current SB2. We want to check if this scenario is tenable, by resolving ι Ori for the first time. Its semi-major axis can be determined to be almost exactly 1 AU (provided the masses given above are correct), thus the expected angular separation is about 2 mas or more (considering the eccentrcity and the emphemeris). Resolving ι Ori will give us an independent measure of its distance and we can test if the object is indeed located in the outskirts of the Orion Nebula.

A close companion has been detected around ι Ori by means of speckle interferometry (Mason et al. 1998). This turns ι Ori into a triple system (two wide companions at separations of 11" and 50" are not now confirmed to be gravitationally bound). In the collision scenario the speckle companion either survived the binary-binary encounter or has been captured during this process. The speckle companion might be also the reason for the high eccentricity of the orbit of the spectroscopic binary.

This spectrocsopic orbit has been determined very accurately by Stickland et al. (1987) by combining archival and own radial velocity measurements. They also determined the mass ratio of the two stars and found $M_\mathrm{A}/M_\mathrm{B} = 2.03$. Nonetheless, two parameters are still uncertain: the inclination of the orbit i and the position angle of the line of nodes Ω. Not knowing the inclination also means that the dynamical mass of the system $(M_\mathrm{A} + M_\mathrm{B}) \sin^3 i$ and the semimajor axis $a \sin i = 0.54\,\mathrm{AU} \sin i$ are not known. While in the case of ι Ori the inclination can be estimated with $47^\circ \pm 5^\circ$ (Stickland, 1987) due to the fact that the stars show grazing eclipses, Ω cannot be determined at all from spectroscopic measurements.

However, we know exactly the relative position of the companion in the orbit at the time of the here proposed AMBER observation. The separation is independent of Ω and only a function of i (Figure 1). If we adopt the value of the inclination from the literature we immediately get the absolute separation of the components (error less than 5%, see Figure 1). **An interferometrically derived spatial separation of the components would then lead directly to the absolute distance of the system**. Although it is essential to know the distance of the remnants of the binary-binary collision, the distance to ι Ori is only discriminated with a high uncertainty. In the 'Hipparcos Catalogue' (ESA, 1997) a distance of 406^{+185}_{-96} is reported. If for example the distance would be inconsistent with that of the Orion Nebula Cluster at the time of the collision, the scenario of a binary-binary collision could be definitely ruled out.

On the other hand, if we adopt the distance (range) of ι Ori from the literature, we can determine i in the 'i-Ω-plane' (Figure 1) independent of a priori assumptions. This is done by adjusting i in such a way, that the relative position corresponds to the measured separation. Afterwards, the position angle of the line of nodes Ω is pinned down by simply reading it off from the graph. The inclination allows us the derive the dynamical mass. Together with the mass ratio derived by radial velocity measurements the **individual masses** of the stars are fixed and may serve as a independent calibration of the masses of spectral types and luminosity classes. It has to be mentioned that no assumption like the radii of the disks of the stars (like for the determination of i by the grazing eclipses) is necessary. The knowledge of Ω is also very important, because then all orbital elements are fixed and the orbit can be **astrometrically fully described**. This is crucial to optimise future interferometric observations, e.g. to determine the apsidal motion in this highly eccentric orbit, because the appropriate baselines can be chosen.

The second target is the ruanway star μ Col. It has been classified as single, because neither adaptive optics techniques, nor radial velocity measurements revealed a companion. On the other hand, four companions around ι Ori are known and at least two of them are gravitationally bound. Although interferometry has a limited dynamical range (similar to that of speckle observations), it provides the unique opportunity to detect companions in the range of a few mas up to that regime that can be covered by the adaptive optics systems. Similar to the finding that ι Ori is a multiple system, the binary nature of μ Col would challenge the collision scenario.

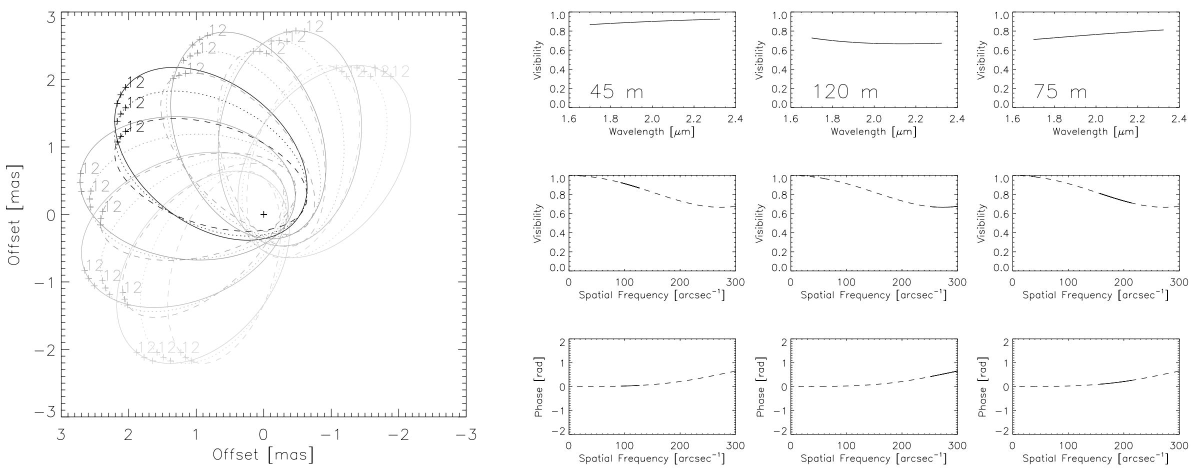

Figure 1: *Left:* The orbit derived by radial velocity measurements is here plotted for various position angles of the line of nodes $\Omega = 0°, 30°, 60°, 90°, 120°, 180°$ and inclinations $i = 30°, 50°, 70°$. Marked as crosses are the positions of the companion at October 12 (labelled), 13, and 14. A distance of 400 pc has been assumed. *Right*: The simulated K-band visibilities for the dotted black orbit ($\Omega = 90°$, $i = 50°$) on October 12 for the offered baselines for the highest possible elevation of the target (top). Also shown are the visibilities and the phases for spatial frequencies between 0 and 300 arcsec^{-1}. The solid parts of the dashed curves are covered with AMBER in the K-band. A flux ratio of 0.2 has been assumed..

Calibration strategy:

The observation require absolute calibration with the highest available accuracy. We thus ask for FINITO even in the low-resolution mode and for our relatively bright targets. The targets themselves can be used as Coudé guide star.

Targets and number of visibility measurements

Target	**RA**	**DEC**	**V** mag	**H** mag	**K** mag	**Size** (mas)	**Vis.**	**Mode**	**# of** Vis.
ι Ori	05 35 25.98	-05 54 35.6	2.8	3.6	3.8	1.8	0.9/0.7/0.7	LR	1
μ Col	05 45 59.90	-32 18 23.2	5.1	5.9	6.0	point	1.0/1.0/1.0	LR	1

Time Justification:

A single pointing for each of the two targets is sufficient. The total amount of time required for the observations adds up to 2×70 min or about 2.5 hours.