AMBER+FINITO+UT Science Demonstration Proposal

First Measurement of a Long Period Cepheid's Dynamical Mass

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Abstract:

We propose to directly detect the faint companion of the long period Cepheid T Mon and measure the angular separation of the system. T Mon is a spectroscopic binary system with ambiguous orbital inclination (Evans et al. ApJ 563-319, 1999). **The primary objective of this proposal is to provide the first dynamical mass estimate of a long period Cepheid.** The expected contrast ratio is challenging (about 1/300) but we propose an original multi-differential approach which could lead to the detection of the faintest companion by optical interferometry. We propose to use **Medium Resolution in K Band**, which combined with FINITO offers precise wavelength-differential measurements. Since the binary separation (10 to 30 mas), is well resolved by the proposed UT configuration, this will lead to rapid variations with time of the measured quantities, hence the possibility to measure time-differential quantities over one hour integration and reach the detection. The use of the UT's will guaranty that we reach the sufficient SNR (hence precision) fast enough to sample the time variations.

Scientific Case:

Cepheids pulsating stars are still, after more than a century, one of the most reliable tools to estimate distances in astronomy. Because of this, they are at the center of may astronomical problems, such as the determination of the Hubble constant (Sandage et al. ARAA 44-93, 2006). The simple relation between the pulsation period (P) and the absolute luminosity (L) makes them valuable to determine accuratly distances, especially the brightest (and thus longest period) one. However, the accuracy of the distance estimation relies greatly on the calibration of the P-L relation.

Empiric calibration of the P-L relation has been very successful, reaching high precision (of the order of a few percent) using the parallax pulsation —so called Baade-Wesselink— method. This method benefited recently from the advent of long baseline optical interferometry to reach unprecedented precision (1.6%, Mérand et al. A&A 438-L9, 2005). On the other hand, these calibrations are always performed using closeby Cepheids, which distances can be measured geometrically. There are evidences that the P-L relation is composition dependent: the most patented examples are studies of the LMC (e.g. Storm et al. A&A 415-531, 2004). This means that P-L calibrations using closeby Cepheids should be corrected when applied to galaxies with different chemical compositions. This is especially crucial for distant galaxies on which the Hubble constant measurement is based (Sandage et al. *ibid*).

One of the way to better understand this phenomenon is by modeling synthetic P-L relations. This implies combining predictions from stellar evolution models and pulsation models. Both are based on the internal structure modeling and both have the mass as one one of the key parameters. The mass is currently being treated as a free parameter, by lack of accurate mass determination for Cepheids. Theoreticians have unveiled the "Cepheids mass problem", which is a discrepancy between the masses used for the stellar evolution and the pulsation models (Bono et al, ApJ 563-319, 2001). Put simply, when an evolution model is fitted —using measured Teff, composition and luminosity— to a given Cepheid, the mass obtained is too large for the observed pulsation period.

The mass discrepancy could be explained, for example, if the star loses mass before reaching the Cepheid stage. Mass loss is usually not considered in Cepheid evolution, though it has been recently unveiled using high angular resolution (Kervella, Mérand et al. 2006; Mérand et al. 2006; Mérand et al. 2007; Kervella, Mérand et al. 2008).

That is the reason why it is of prime importance to obtain accurate dynamical mass estimates of Cepheids, in order to fix the mass in models and not have it as a free parameter. Dynamical masses, from binary orbits, are the only non-model dependent way to obtain stellar masses. Only one Cepheid had its mass dynamically determined: the short period and low amplitude α UMi (Evans et al. 2008).

The combination AMBER/FINITO/UTs offers the high angular resolution required and the light gathering capabilities leading to high signal to noise ratio. We will reach the detection by monitoring the time variations of the signal over an hour, during which the slight variations in baselines vectors will produce detectable signal in AMBER's differential observables (visibilities, phases and closure phase).

Calibration strategy:

We propose the following strategy: CAL - SCI - CAL, where "CAL" stands for the same calibrator, observed twice. We want to monitor linear drifts in the transfer function, at the time scale of the duration of the on-target observation (SCI). During the on-target observations, the various quantities (differential visibility, differential phase, etc.) should varie non linearly with time due to the slow change in baselines length and orientation. The calibrator pair will help remove any instrumental drifts.

Targets and number of visibility measurements

Target	**RA**	**DEC**	**V** mag	**H** mag	**K** mag	**Size** (mas)	**Vis.**	**Mode**	**# of** Vis.
T Mon	06 25 13	+07 05 09	6.3	3.6	3.4	1.2	0.95/0.9/0.8	MR 2.1	1h continuous

Time Justification:

We ask for one visibility measurement, but the single measurement should span at least an hour, accumulating as many observation files as needed. This is because we are interested in time variations of observables due to the change of baselines orientation. The duration of the science OB (1h) is set by the expected separation (between 10 to 30 mas) and the typical size of the baselines, in order to sample the peak to peak variations of the observables.

We need one calibrator, observed once before and once after T Mon. The calibrator does not need as much time, i.e. about half a dozen files each are enough.

The whole program adds up to approximatly 2 to 2.5 hours, including the overheads. The acceptable LST range is 3:30-5:30.