Angular Diameters, Temperatures, And Luminosities Of Massive Stars: Prospects For SIM-Lite

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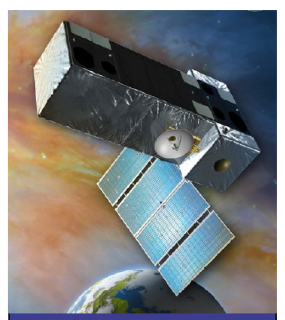


SIM Lite ASTROMETRIC OBSERVATORY

ABSTRACT: O and B stars are among the brightest stars observable in galaxies, and are often considered signs of recent star formation or used for distance estimates. However, the fundamental properties of these stars (temperature and luminosity) are poorly understood because we do not have accurate distances and diameters of nearby O and B stars. SIM Lite will be able to provide parallaxes for these bright stars accurate to 1% at a distance of 2.6 kpc. Optical Long Baseline Interferometry (OLBI), from instruments such as CHARA/PAVO, can yield accurate temperatures and once the distance is known from SIM, we will have accurate radii and luminosities. Here we present an initial observing list for the CHARA Array and the PAVO (R band) beam combiner, as well as spectral energy distributions (fit with TLUSTY models) for the sample. These SEDs will provide a direct comparison for angular diameter measurements of hot stars that will be measured with the CHARA Array in the next year.

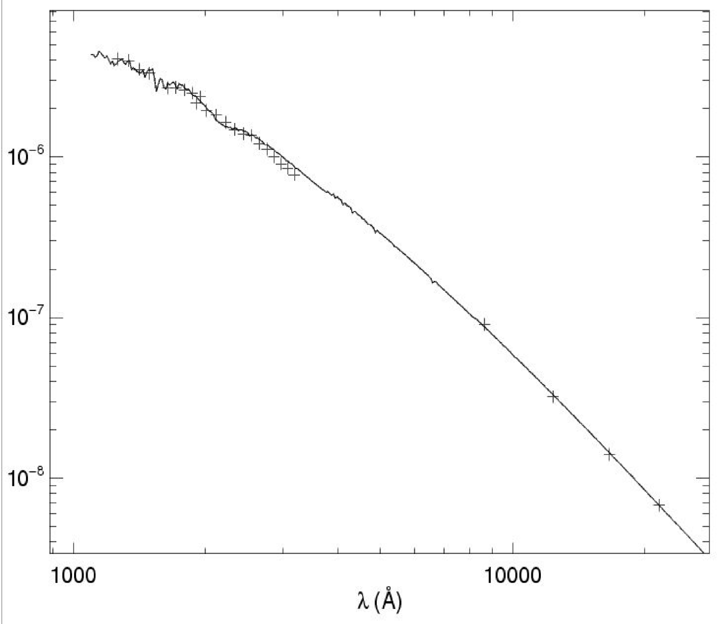


Figure 1: Example SED fit to 15 Mon, yielding an angular diameter θ, reddening *E(B-V)* and ratio of total to selective extinction *R*. Values for all of our highest priority SIM and CHARA targets are given in Table 1. The fit is based on TLUSTY models, and values of effective temperature and log g are from the literature.

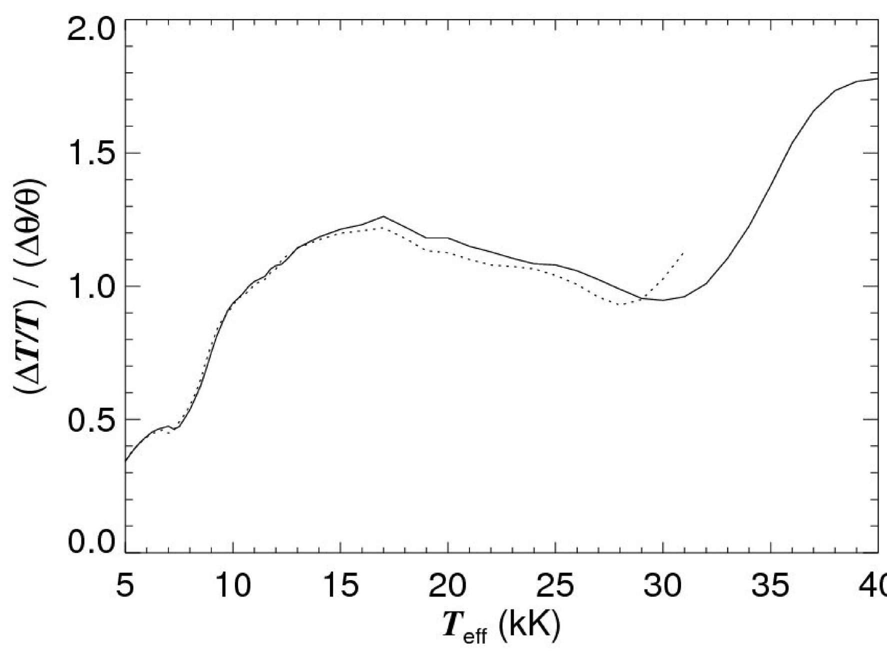


Figure 2: The ratio of fractional error in derived effective temperature to the fractional error in measured angular diameter as a function of model effective temperature. The solid line shows the prediction for main sequence stars (with log g = 4.0) while the dotted line shows the relation for more evolved stars (log g = 3.5), based on models from Robert Kurucz.

Angular diameters from ground-based interferometry offer the means to determine T_{eff} in two fundamental ways. The model independent approach was first demonstrated in a seminal paper by Code et al. (1976, 203, 417) who determined the integrated flux across the spectra and combined these bolometric fluxes with angular diameter to find T_{eff} for 32 bright stars in the spectral range O5 to F8. However, for most OB stars, a large fraction of their flux is emitted at wavelengths shorter than 912 Å, where the interstellar medium is opaque (Cassinelli et al. 1995, ApJ, 438, 932). Consequently, we must rely instead upon model estimates of the monochromatic surface flux as a function of T_{eff} to estimate T_{eff} from the observed flux and angular diameter in the second method. This approach should yield T_{eff} measurements to better than the 5% accuracy currently derived from spectral line studies. Figure 2 shows that the fractional errors in observed θ and derived T_{eff} are comparable for the OB stars, and since OLBI can yield angular diameter measurements better than 1% (Aufdenberg et al. 2006, ApJ, 645, 664), we expect that interferometry will become the best method of finding T_{eff} for relatively nearby hot stars.

Table 1: O star targets for CHARA/PAVO + SIM

Star Name	HD No.	T_{eff} (K)	log g (cgs)	Ref	*E(B-V)* (mag)	error (mag)	*E(B-V)*(5) (mag)	*R*	error	θ (mas)	error (mas)	π (mas)	error (mas)
ξ Per	24912	37000	3.7	1	0.325	0.009	0.33	3.16	0.09	0.250	0.008	2.62	0.51
δ Ori*	36486	33000	3.1	1	0.081	0.016	0.09	4.66	0.95	0.447	0.029	4.71	0.58
λ Ori*	36861	36000	3.6	1	0.160	0.034	0.12	3.73	0.96	0.283	0.039	2.97	0.55
θ^1 Ori C*	37022	37000	4.0	2	0.273	0.012	0.32	6.30	0.28	0.205	0.006	-13.0	5.05
ι Ori*	37043	34000	3.4	1	0.007	0.009	0.07	3.1	…	0.296	0.008	1.40	0.22
ε Ori	37128	28000	2.85	1	0.057	0.010	0.05	3.1	…	0.612	0.017	1.65	0.45
ζ Ori*	37742	31000	2.95	1	0.025	0.010	0.05	3.1	…	0.511	0.014	4.43	0.64
15 Mon*	47839	40000	3.9	1	0.082	0.008	0.07	3.38	0.36	0.124	0.003	3.55	0.50
ζ Oph	149757	34000	3.7	3	0.338	0.011	0.32	2.93	0.07	0.505	0.018	8.91	0.20

In this table, we list the O star targets for CHARA/PAVO and SIM. The angular diameters (θ) are small, but long baseline interferometers such as the CHARA Array can now resolve such objects. The derived effective temperatures will be extremely precise after the observations and analysis of the PAVO data are completed, but only with SIM Lite can we also obtain parallaxes, and hence radii and luminosities, which will create a fundamentally determined HR diagram for luminous, hot stars.

Notes:

*. Binary, so θ represents an upper limit.

1. Lamers & Leitherer (1993, ApJ, 412, 771)
2. Vitrichenko (2000, AstL, 26, 244)
3. Villamariz & Herrero (2005, A&A, 442, 263)
4. Most of these targets are nearby for O stars, where E(B-V) is low, and R may not be accurate, so for the cases of ι, ε, & ζ Ori, we set R=3.1 in our fitting routine.
5. E(B-V) from Diplas & Savage (1994, ApJS, 93, 211)
6. π (parallax) is given for the re-reduction of the HIPPARCOS data (van Leeuwen, 2007, A&A, 474, 653). Only ζ Oph has a good trigonometric parallax. However, some O stars such as θ^1 Ori C have good orbital parallaxes (distance to θ^1 Ori C is 434 pc; Kraus et al. (2007, A&A, 466, 649).

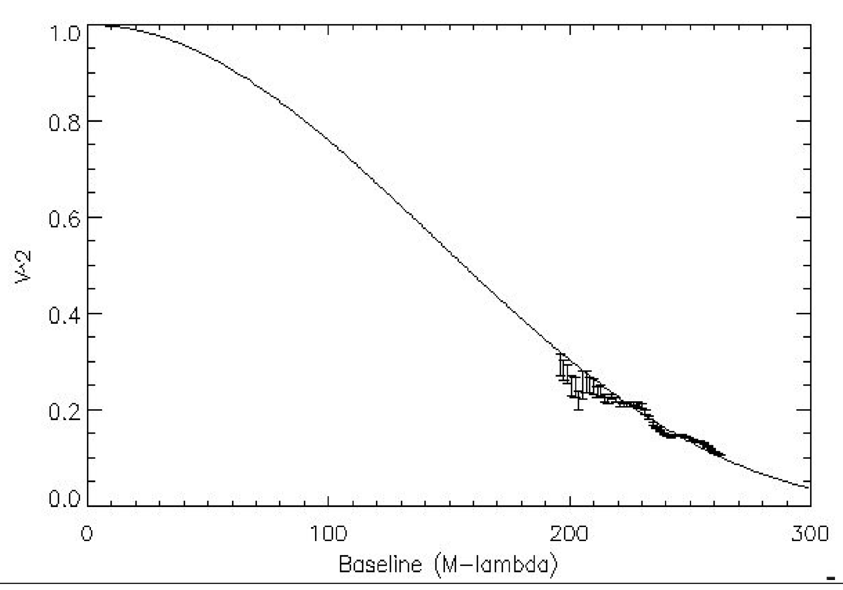
ε Ori

We began observing O and B star targets with CHARA and PAVO last November, obtaining data on 7 B stars, 3 hot supergiants, and 15 Mon. An initial look at the data with the developing reduction code gives an **angular diameter** for **ε Ori** of

0.68 ± 0.005 mas,

in good agreement with Hanbury Brown et al. (1974, MNRAS, 167, 121). The data show systematic "waves" in the visibility curve for all single stars, and we are working on calibrating this out with the reduction code. However, our larger than predicted diameter does imply a smaller temperature for ε Ori.

Figure 3: Initial visibility curve fit for ε Ori, yielding the diameter quoted above.



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Only SIM Lite and Optical Long Baseline Interferometry can yield a fundamental upper HR Diagram!