Angular Sizes and Effective Temperatures of O Stars

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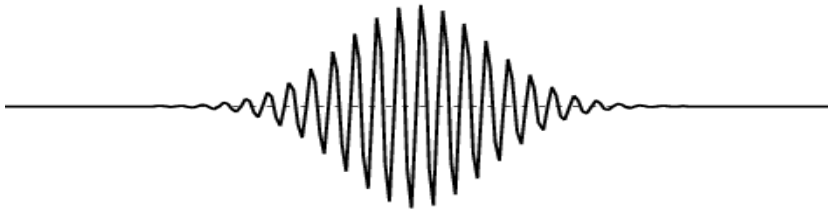
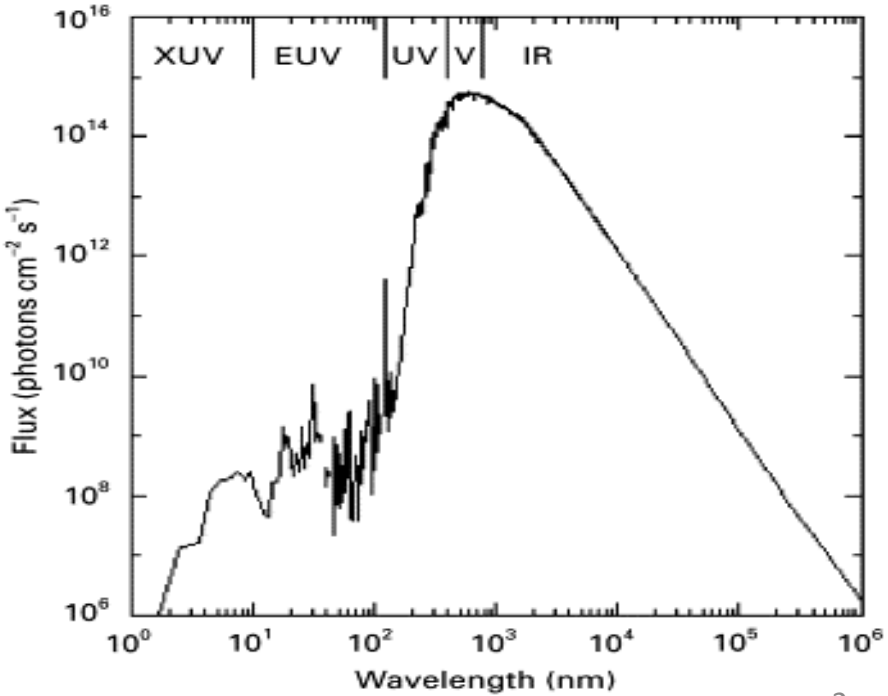
Observationally determined properties

- **Angular size + distance → Radius**
  - » **Interferometry**



- **Integrated flux + angular size → Effective Temperature**
  - » **Spectrophotometry**

$$F_{obs} = \frac{1}{4}\alpha^2 F_{em} \qquad F_{em} = \sigma T_{eff}^4$$



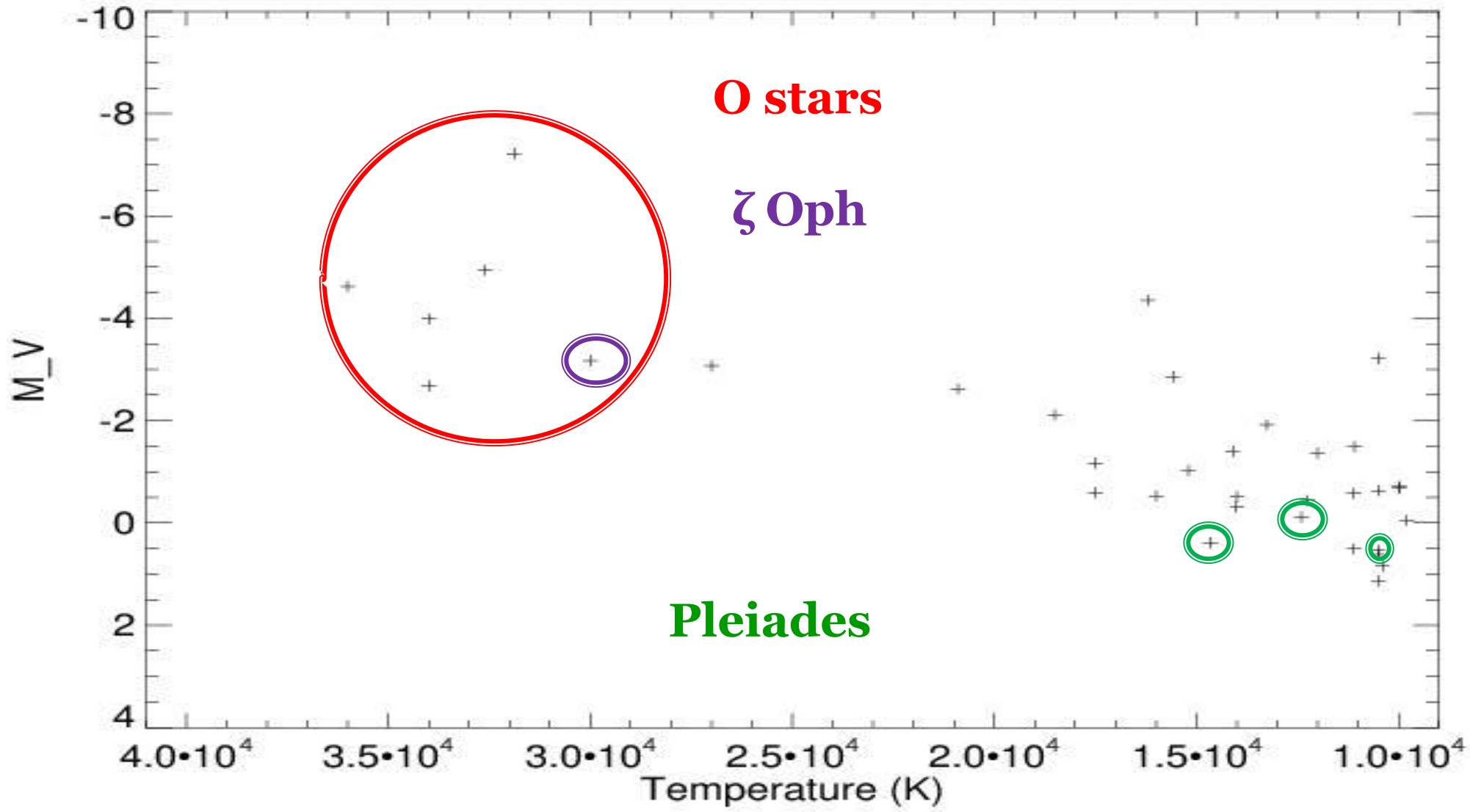

O stars
ζ Oph
Pleiades
M_V
-10
-8
-6
-4
-2
0
2
4
4.0•10^4
3.5•10^4
3.0•10^4
2.5•10^4
2.0•10^4
1.5•10^4
1.0•10^4
Temperature (K)

Table 1. Parameters of target stars

Identifier	Star Name	HD Number	Spectral Classification	V (mag)	$B-V$ (mag)	$V-K$ (mag)	$T_{\rm eff}$ (kK)	$\log g$ (c.g.s)	$V \sin i$ (km s^{-1})
a	ξ Per	24912	O7.5 III(n)(f)	4.06	0.02	0.11	34.8±1	3.43±0.13	215
b	α Cam	30614	O9.5 Ia	4.29	0.05	0.05	29.5±0.8	3.04±0.13	111
c	λ Ori A	36861	O8 III((f))	3.47	0.01	−0.56	34.3±0.7	3.66±0.10	68
d	ζ Ori A	37742	O9.7 Ib	1.88	−0.11	−0.44	29.5±1	3.25±0.25	124
e	ζ Oph	149757	O9.2 IVnn	2.56	0.02	−0.06	32.5±0.9	3.65±0.10	348
f	10 Lac	214680	O9 V	4.88	−0.21	−0.62	36.4±1	3.99±0.05	124

NOTE—Effective temperatures and gravities are average values taken from the sources listed in Table 2. $V \sin i$ values are from the Catalog of Stellar Rotational Velocities (Glebocki & Gnacinski 2005).

Companions: λ Ori A ⟶ spectrophotometry – 1

ζ Ori A ⟶ spectrophotometry – 2
interferometry – 1 (28 mas)

Table 5. Observations and measured angular diameters

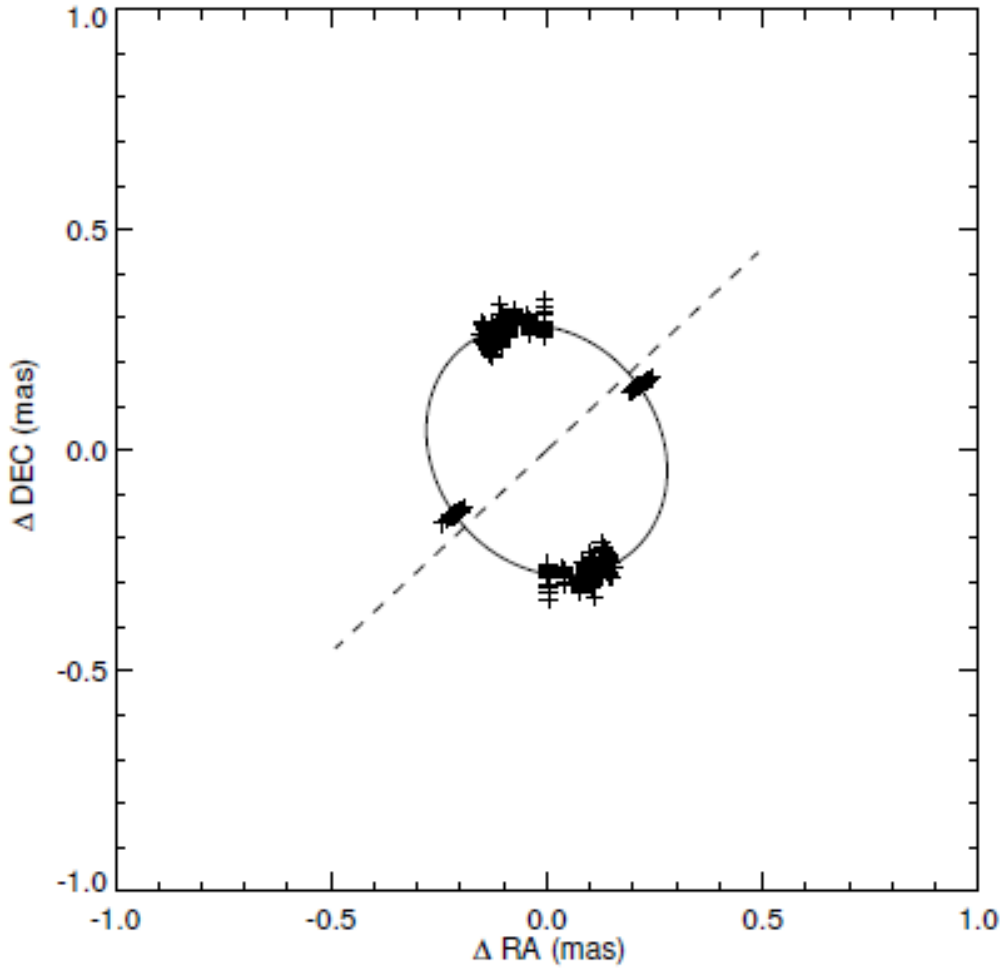
Star	HD	Baselines	N_{V^2}	θ_{UD} (mas)	μ	θ_{LD} (mas)
ξ Per	24912	W1E1	23	0.21±0.02	0.174	0.21±0.02
α Cam	30614	S1E1	23	0.226±0.019	0.250	0.229±0.019
λ Ori A	36861	S1E1;W1E1	161	0.219±0.015	0.253	0.226±0.015
ζ Ori A	37742	W1E1	23	0.424±0.006	0.203	0.430±0.006
ζ Oph	149757	S2W1	69	0.490±0.010	0.204	0.498±0.010
		S2E2	161	0.580±0.010		0.588±0.010
10 Lac	214680	S1E1	119	0.12±0.03	0.183	0.12±0.03

ζ Ori A – about 0.01 mas smaller when incoherent flux of companion accounted for

ζ Oph – observed rotational distortion (vsin(i) = 348 km/s)
15% variation in size

10 Lac – really small!

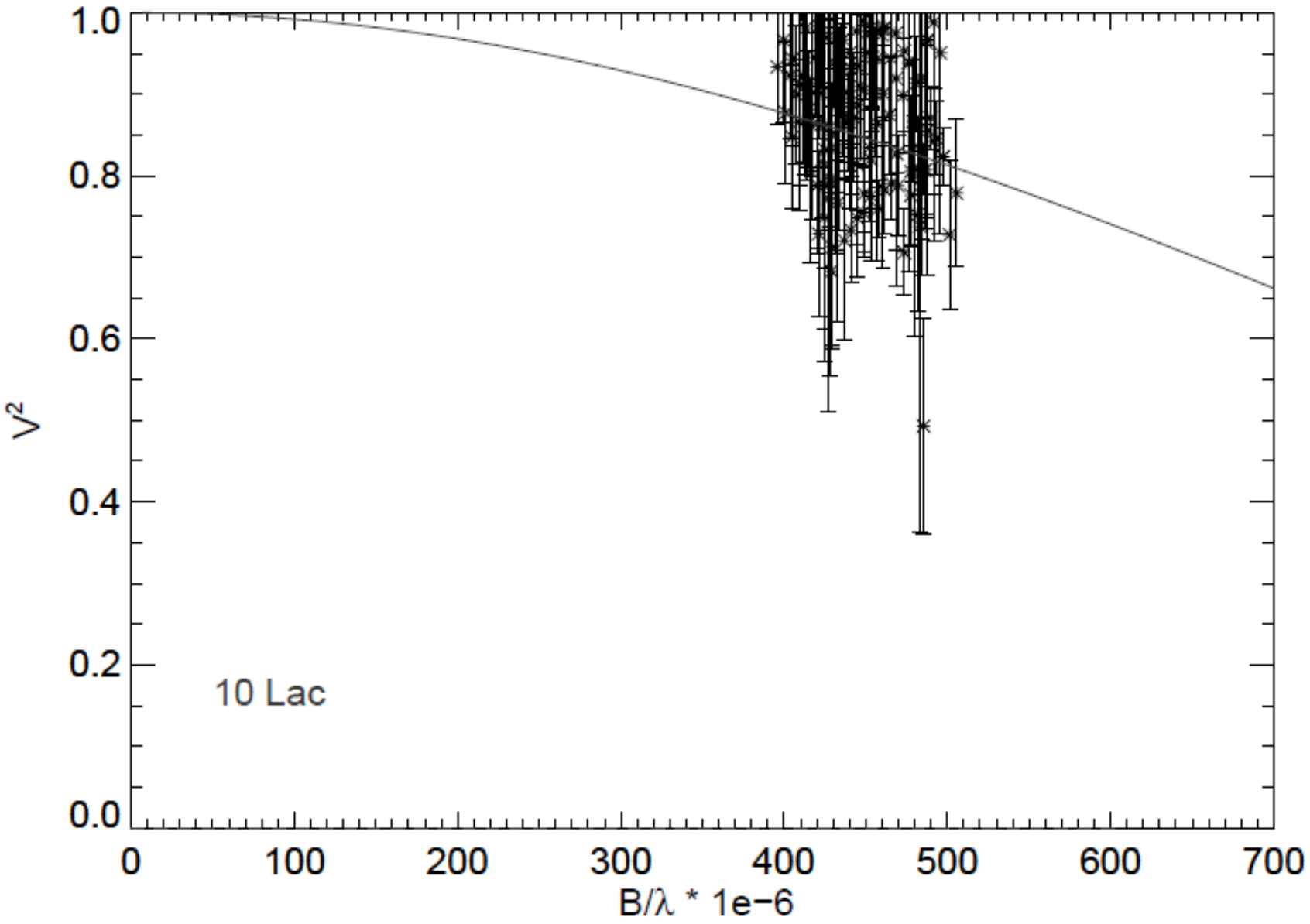
ζ Oph



Assumed PA of 132.5° (Poeckert et al. 1979)

major axis = 0.6 mas
minor axis = 0.5 mas

Observed values: 0.588 mas
0.498 mas



0.12 mas

Spectrophotometry

UV – IUE (corrected with routine from Massa & Fitzpatrick 2000)

Optical – Burnashev 1985, Kharitonov et al. 1988, or Krisciunas et al. 2017

IR – 2MASS, WISE, and AKARI

⟶ WISE and AKARI points not used for giants and supergiants

Special Cases:

λ Ori A – UV from OAO

α Cam – NUV from HUT

10 Lac – high quality spectrum from HST/STIS (UV to optical)

Modeling

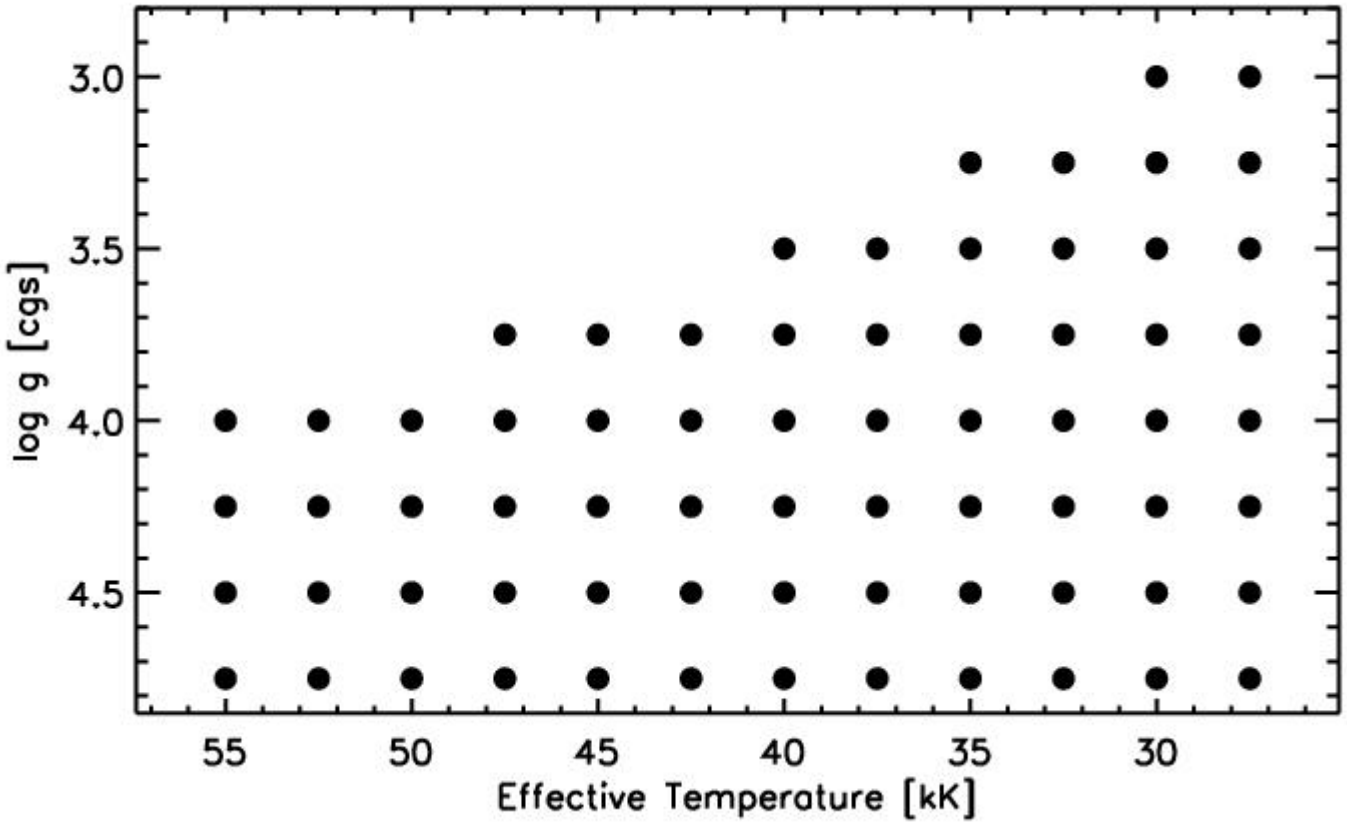
TLUSTY O star models:

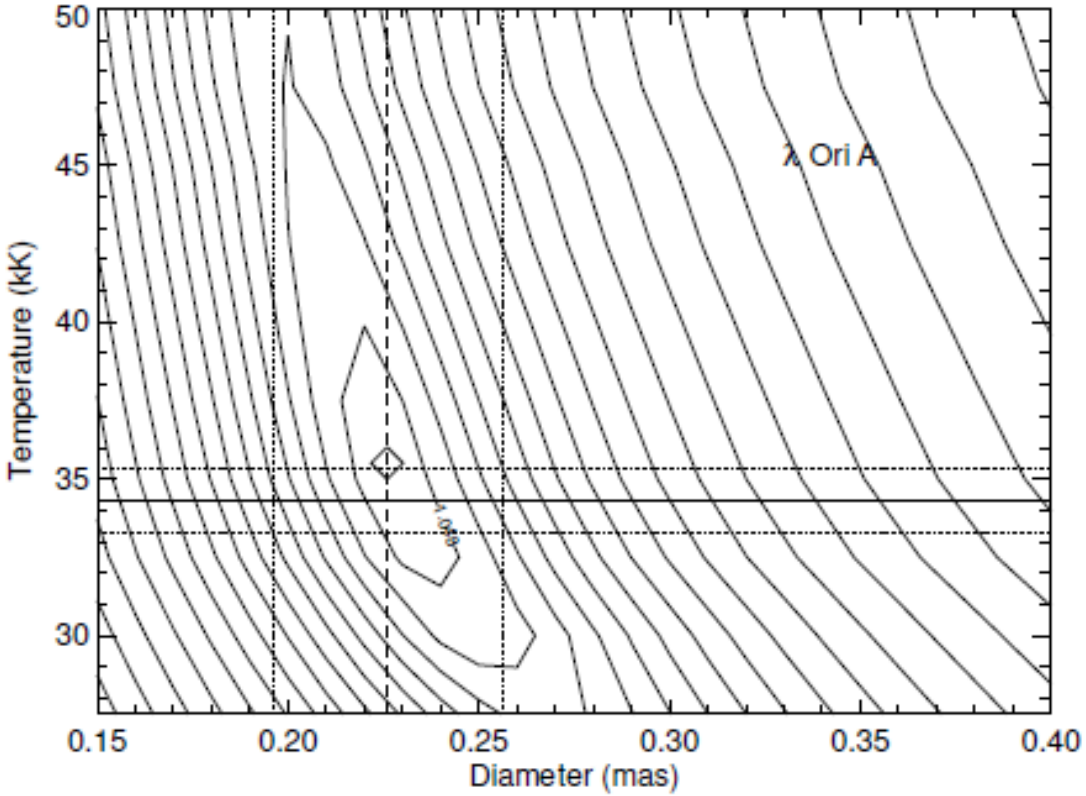
- 27500 – 55000 K with 2500 K steps
- Log*g* range from 3.0 to 4.75
- Galactic abundance
- V_t = 10 km/s

Fitting program:

- Used a grid search χ^2 method to fit for three parameters at once – angular size, effective temperature, and E(B-V)

- Plots of T vs. θ with contours showing χ^2 space




λ Ori A
Temperature (kK)
Diameter (mas)
50
45
40
35
30
0.15
0.20
0.25
0.30
0.35
0.40

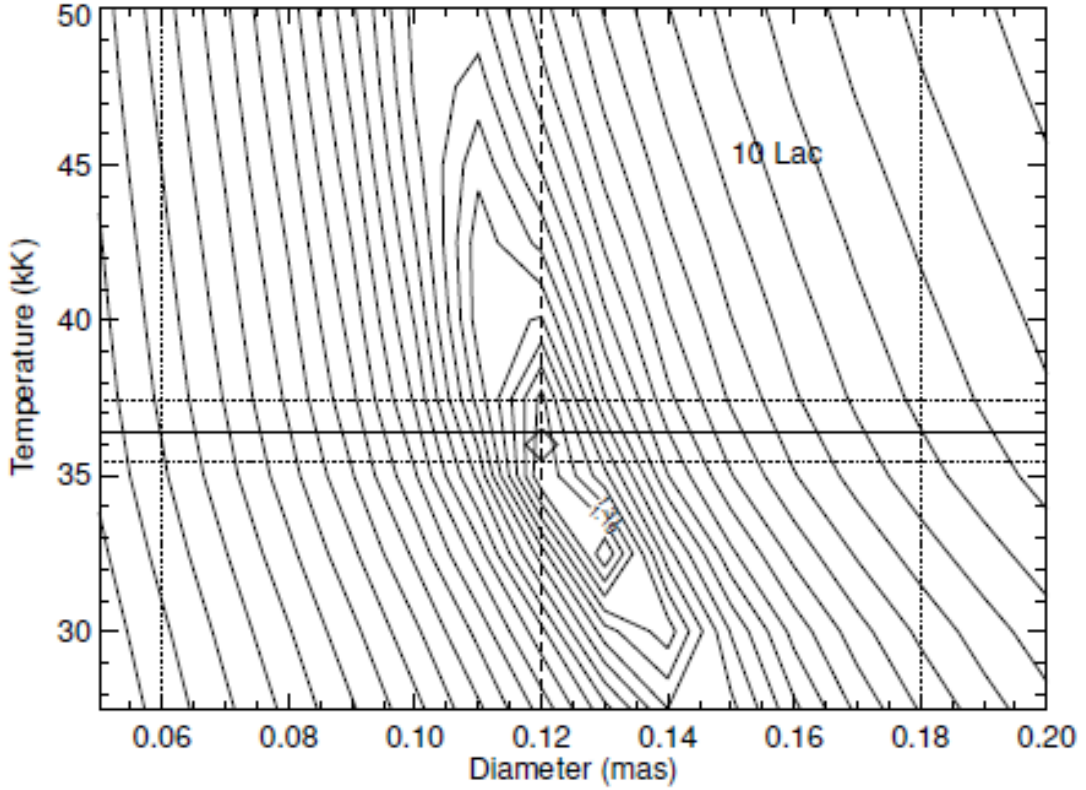
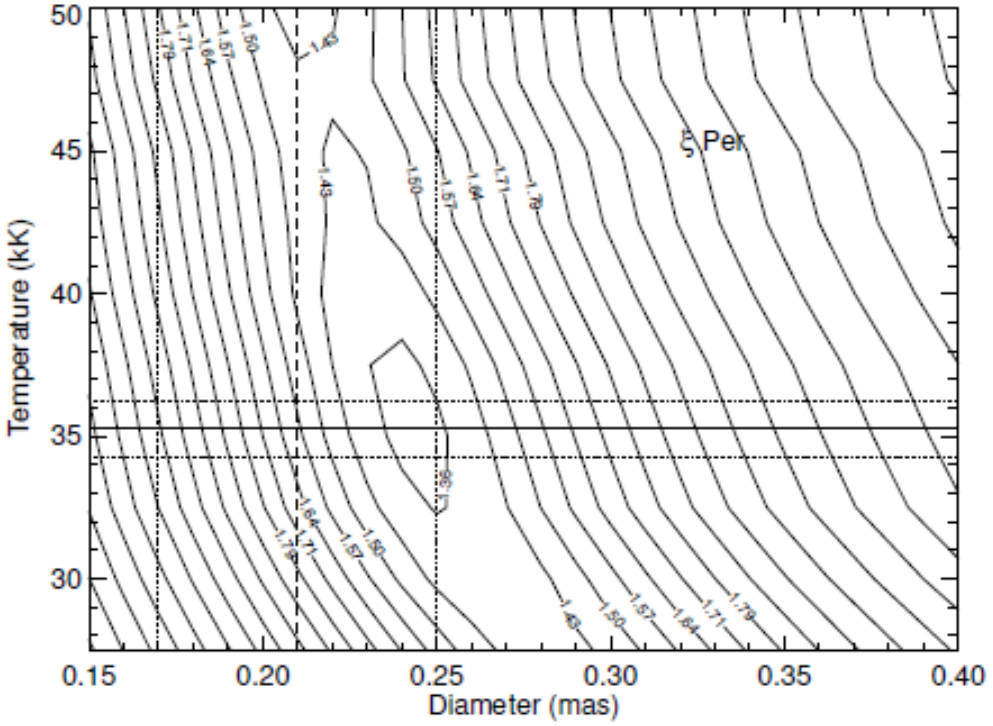
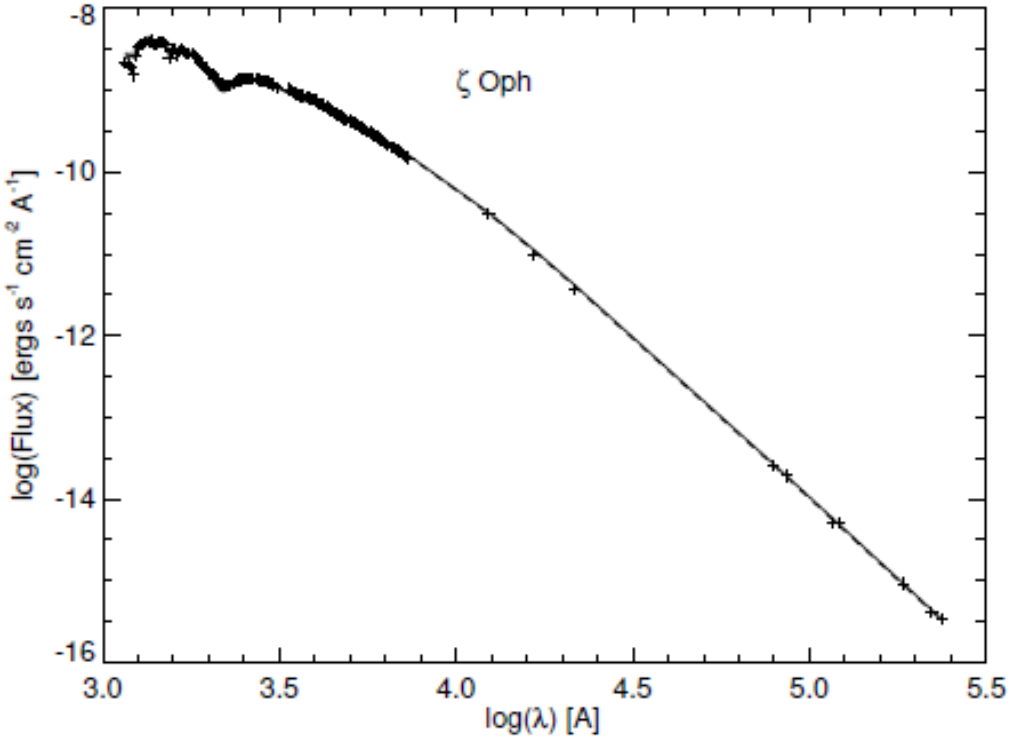

10 Lac
Temperature (kK)
Diameter (mas)
50
45
40
35
30
0.06
0.08
0.10
0.12
0.14
0.16
0.18
0.20

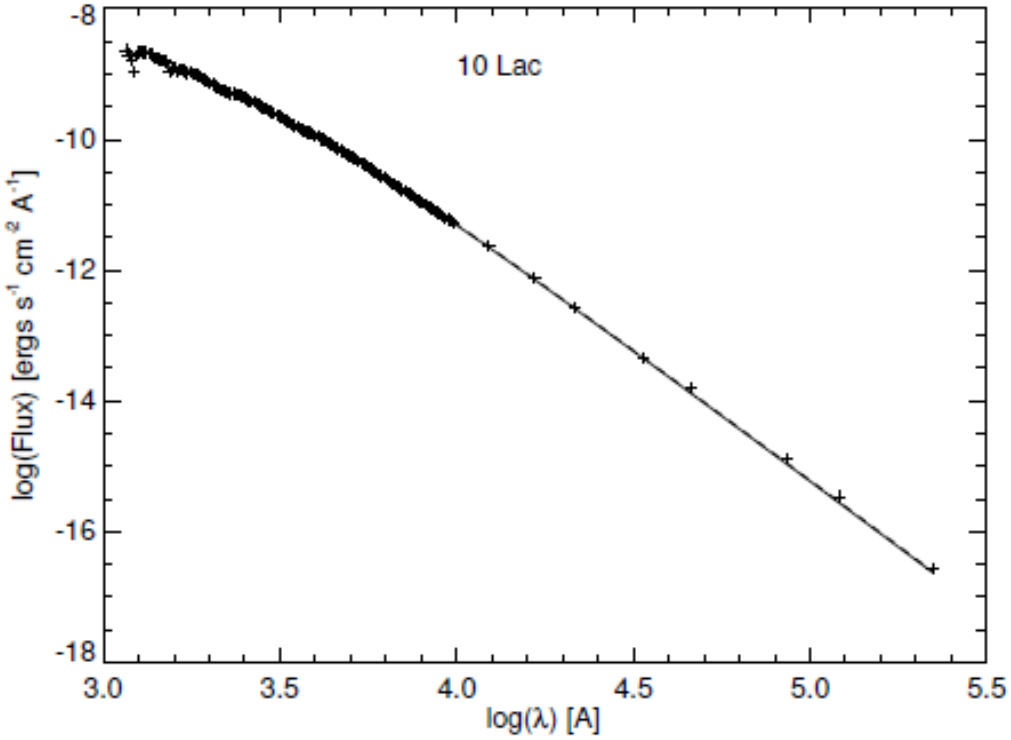
Table 10. Comparison of best fit and literature values

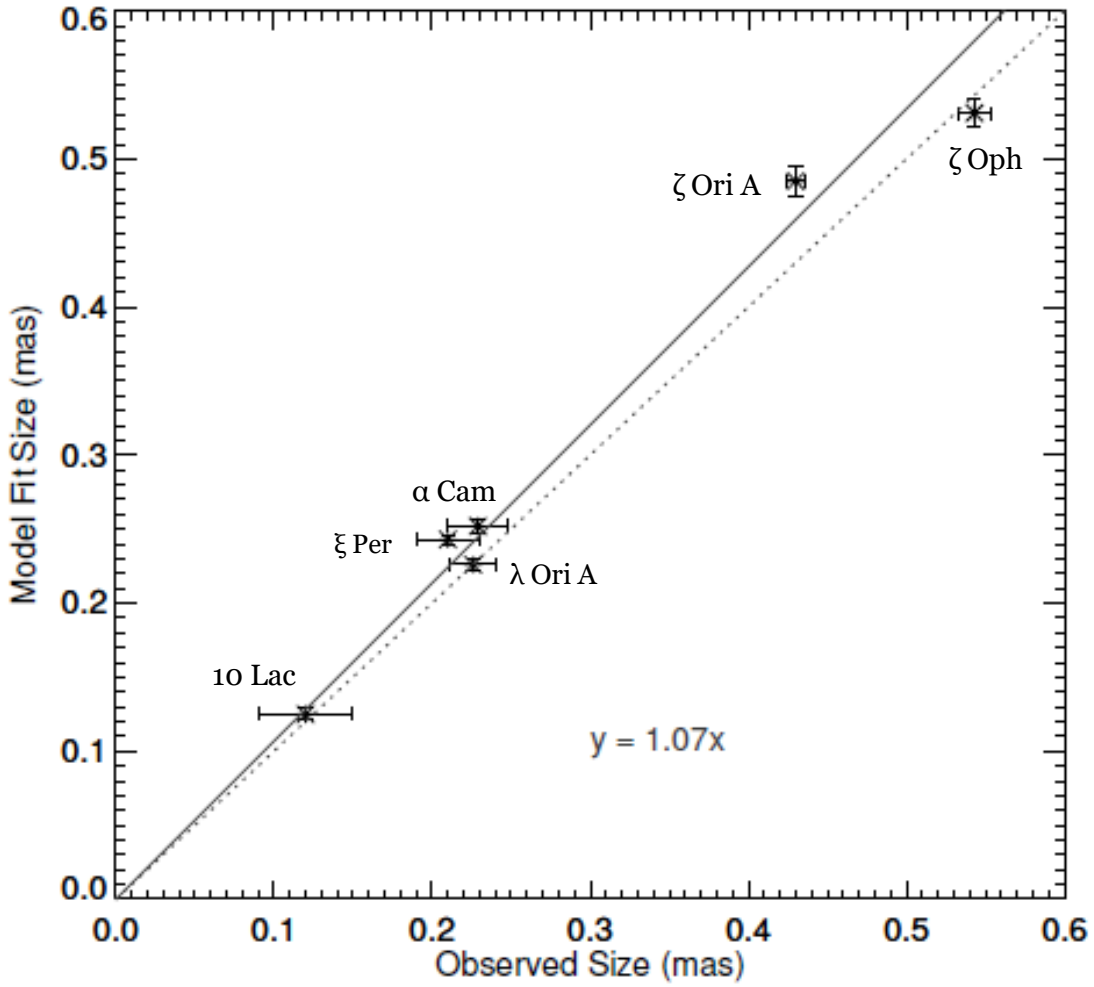
Star	Best Fit Temperature (K)	Literature Temperature (K)	E(B-V) Best Fit	E(B-V) Savage et al. (1977)	E(B-V) Maíz Apellániz & Barbá (2017)
ξ Per	···	34785	···	0.25	0.278±0.007
α Cam	30000±1500	29485	0.284	0.26	0.262±0.006
λ Ori A	36000±9000	34340	0.107	0.12	0.177±0.011
ζ Ori A	32500±500	29500	0.043	0.08	0.044±0.007
ζ Oph	32600±1300	32450	0.352	0.29	0.297±0.006
10 Lac	36000±12500	36428	0.096	0.08	0.077±0.006



Unable to find a best fit temperature for ξ Per


ζ Oph
log(Flux) [ergs s-1 cm-2 A-1]
log(λ) [A]
-8
-10
-12
-14
-16
3.0
3.5
4.0
4.5
5.0
5.5


10 Lac
log(Flux) [ergs s-1 cm-2 A-1]
log(λ) [A]
-8
-10
-12
-14
-16
-18
3.0
3.5
4.0
4.5
5.0
5.5



Stars with single brackets ⟶ more discrepant

Cooler stars ⟶ more discrepant

Possible flux differences between CMFGEN models and TLUSTY at cooler temperatures – maybe a factor?

Summary

- Accurate sizes and temperature estimates for O stars
- Reddening estimates
- Tested observations against model
  - Sizes overestimated by an average of ~7%
- Use same method for B star sample – TLUSTY B star models
  - 27 B stars, 3 Pleiades


Questions?