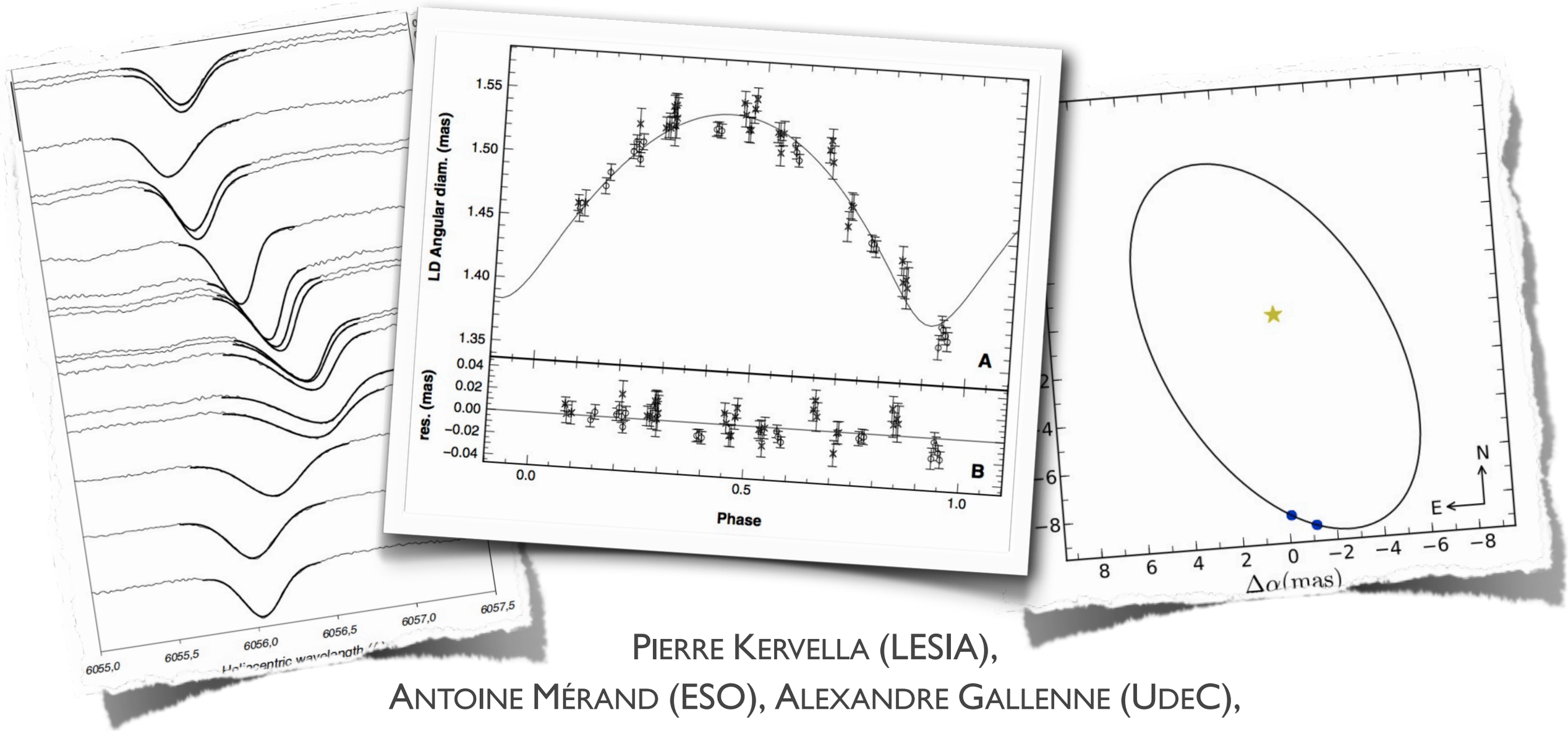
THE CHARA CEPHEID PROGRAM



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ANTOINE MÉRAND (ESO), ALEXANDRE GALLENNE (UDEC),
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JOHN MONNIER (UMICH), AND MANY OTHERS

THE CHARA CEPHEID PROGRAM

- A long-term effort started in 2004 on CHARA
- Three "sub-programs":

1. Baade-Wesselink distances: FLUOR, VEGA
2. Circumstellar envelopes: FLUOR
3. Cepheids in binary systems: MIRC

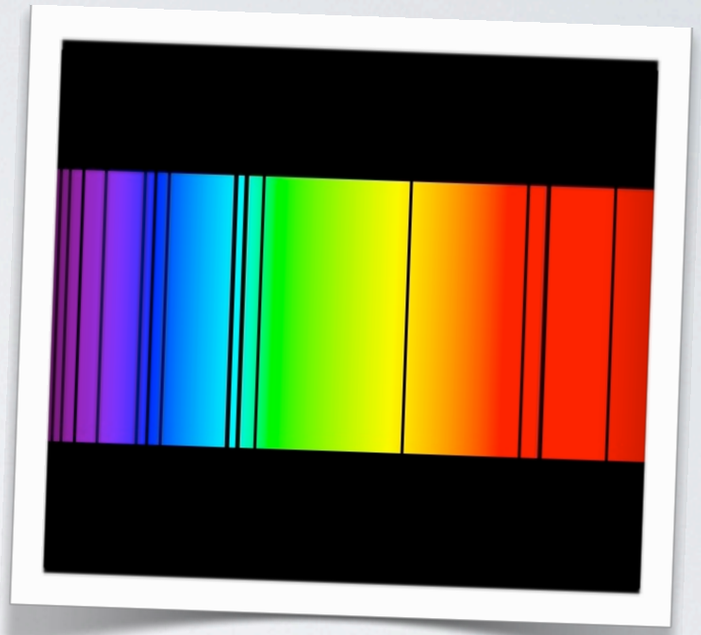
THE INTERFEROMETRIC BAADE-WESSELINK TECHNIQUE (IBW)

Gives the radius and the distance of a pulsating star

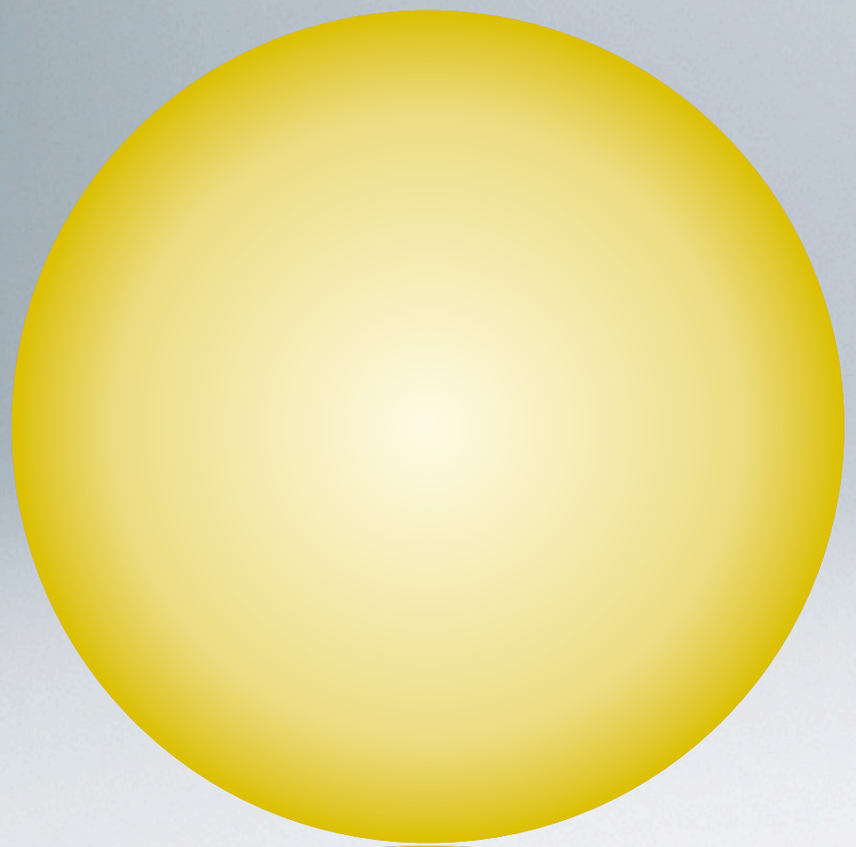
Based on two types of data:

1. Radial velocity from spectroscopy

2. Angular size from interferometry



1. SPECTROSCOPY

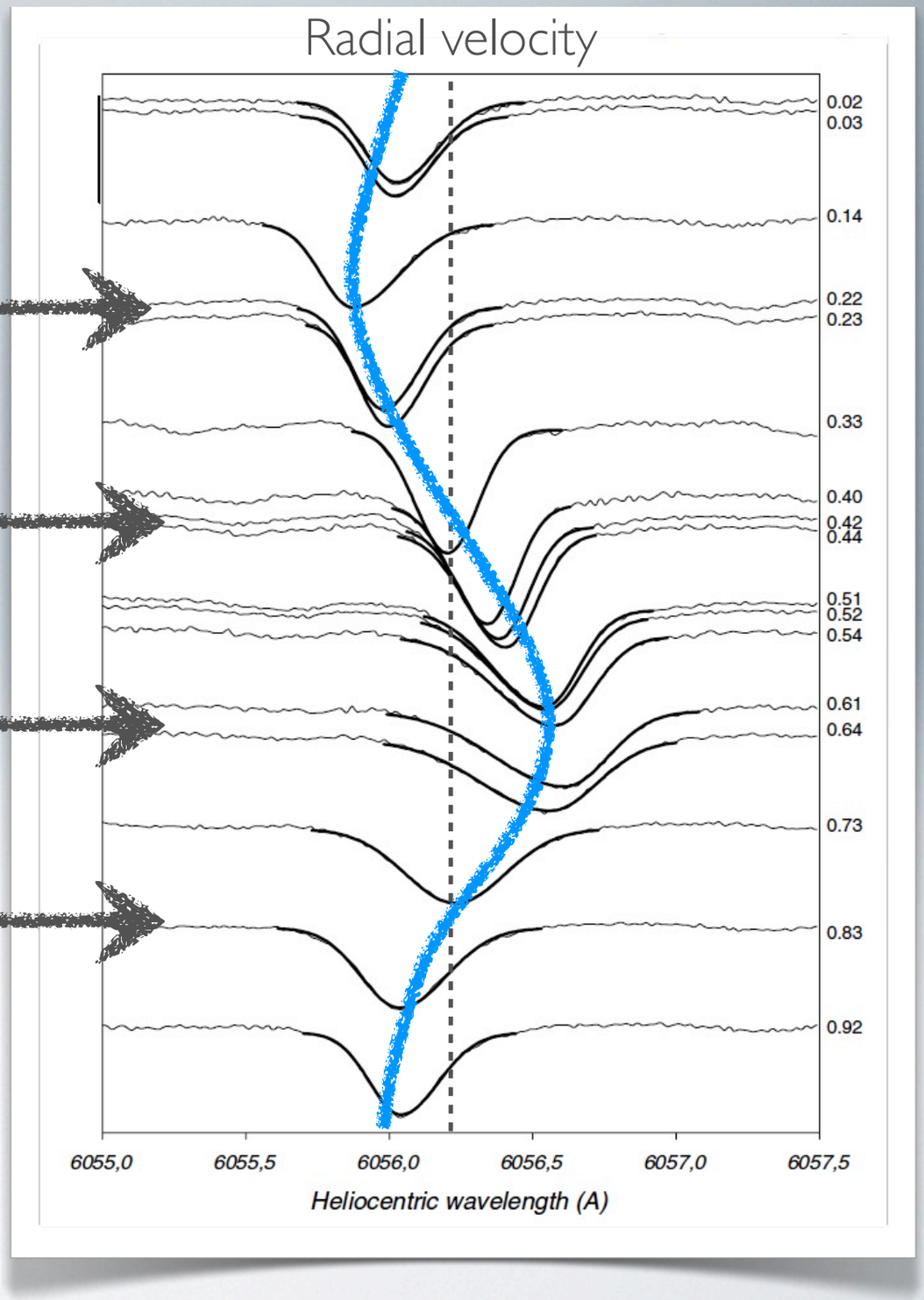


Expansion

Max radius

Contraction

Min radius

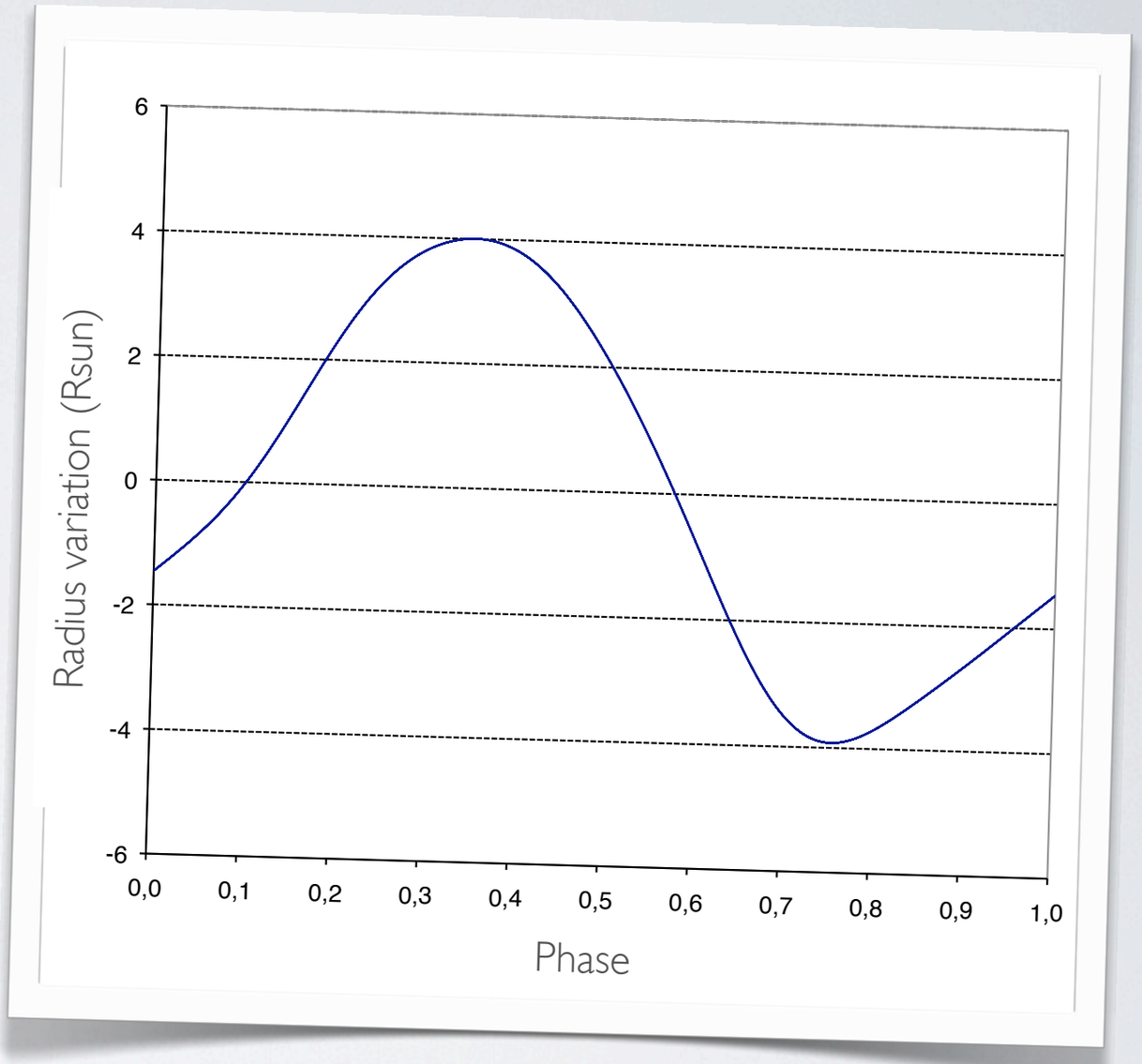


Spectroscopy gives the *variation* in linear radius of the star from:

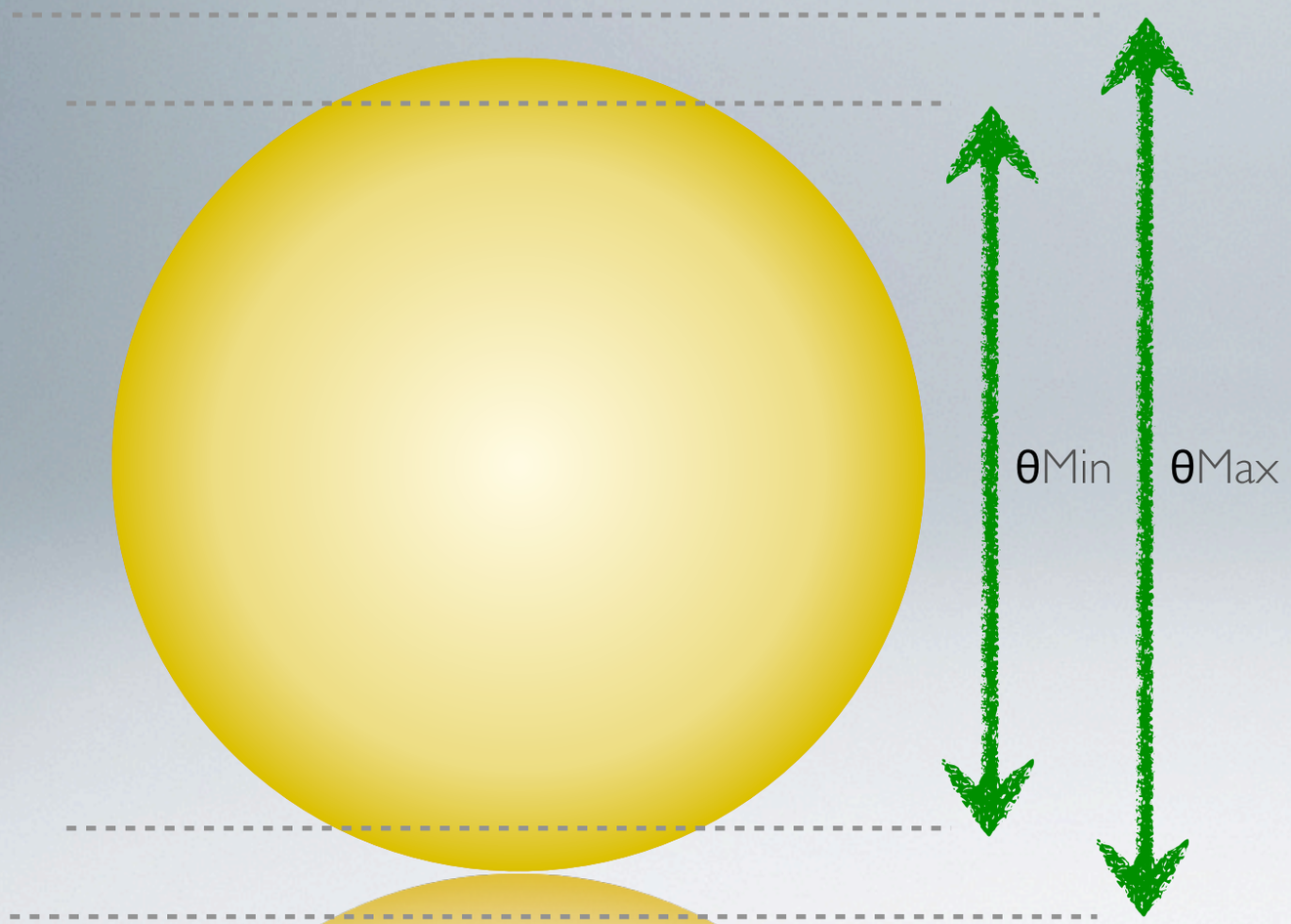
$$\delta R(T) = -p \int_0^T v_{\mathrm{rad}}(t)\, dt$$

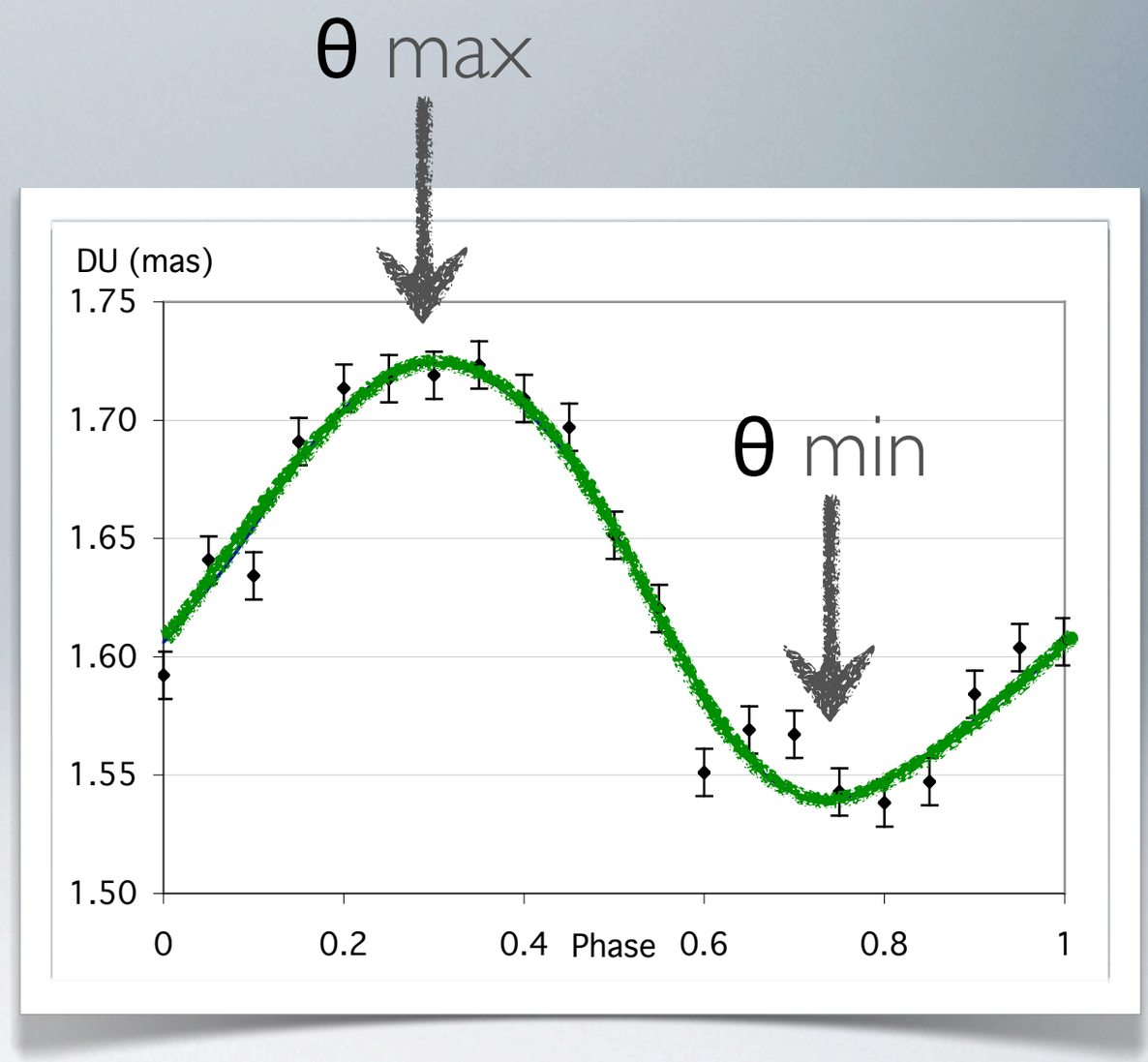
p = projection factor
$= V_{puls} / V_{rad}$
~ 1.3

measured on **δ** Cep + models



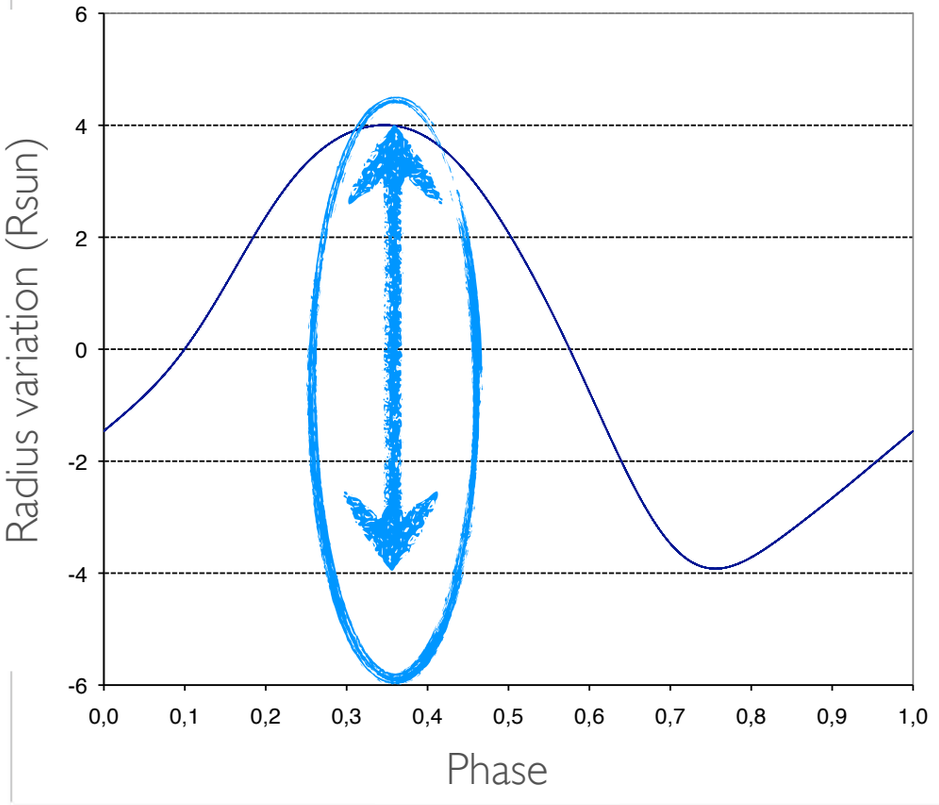
2. INTERFEROMETRY



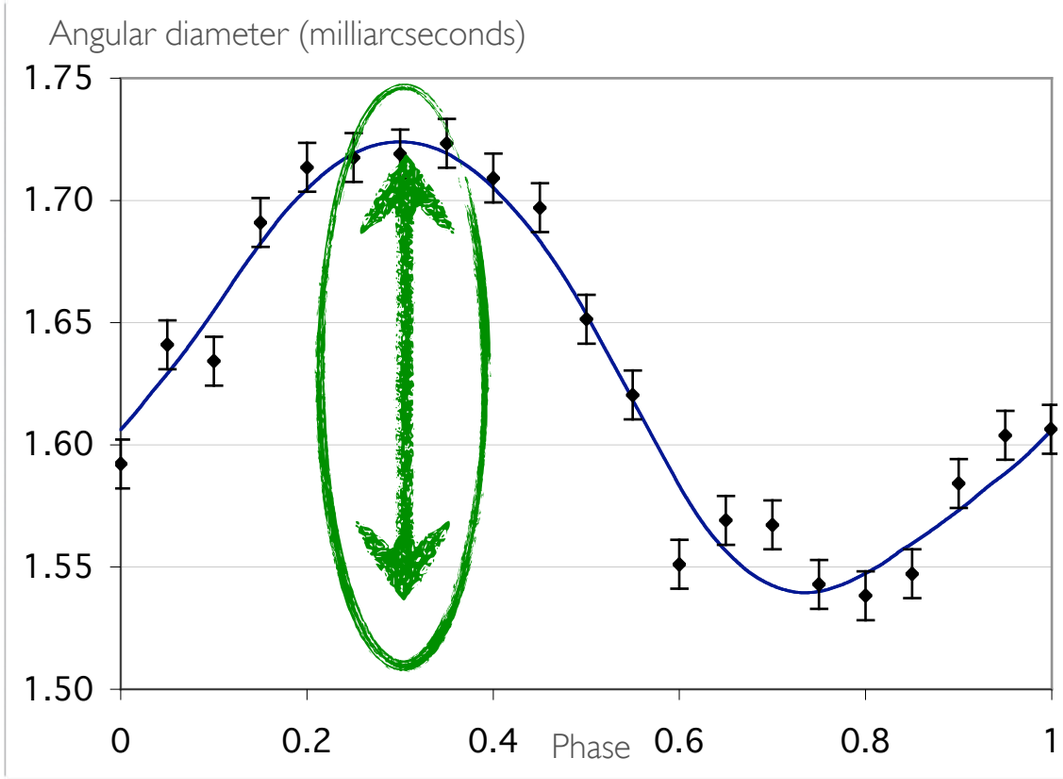


Gives the *angular size variation* of the star

Spectroscopy



Interferometry



The distance *d* is given by the relation:

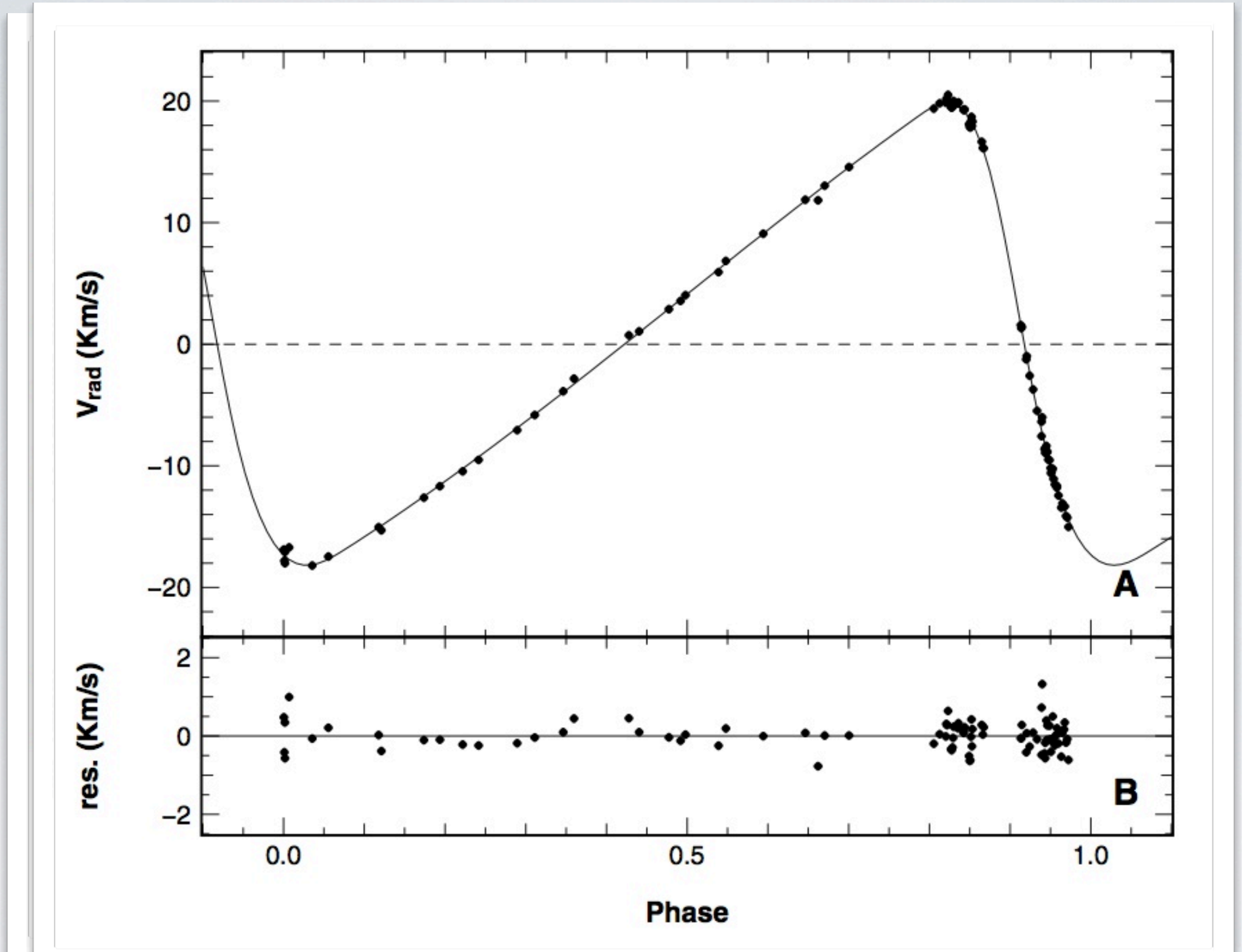
$$d = \frac{2\delta R(T)}{\delta\theta(T)} = \frac{-2\,k\,p\,\int_0^T v_{\mathrm{rad}}(t)\,dt}{\theta_{\mathrm{UD}}(T) - \theta_{\mathrm{UD}}(0)}$$

k = limb darkening correction (from models)

= θ_{UD} / θ_{LD}

~ 0.94 in visible, 0.98 in IR

δ CEP : A MEASUREMENT OF *p*



p-factor = 1.27 ± 0.06, with d=274 ± 11 pc from HST-FGS

Mérand et al. 2005, A&A 438, L9

FF Aql

Radial velocity

P=4.47 d

T Vul

P=4.44 d

FF Aql

R = 33.6 ± 2.2 R⊙

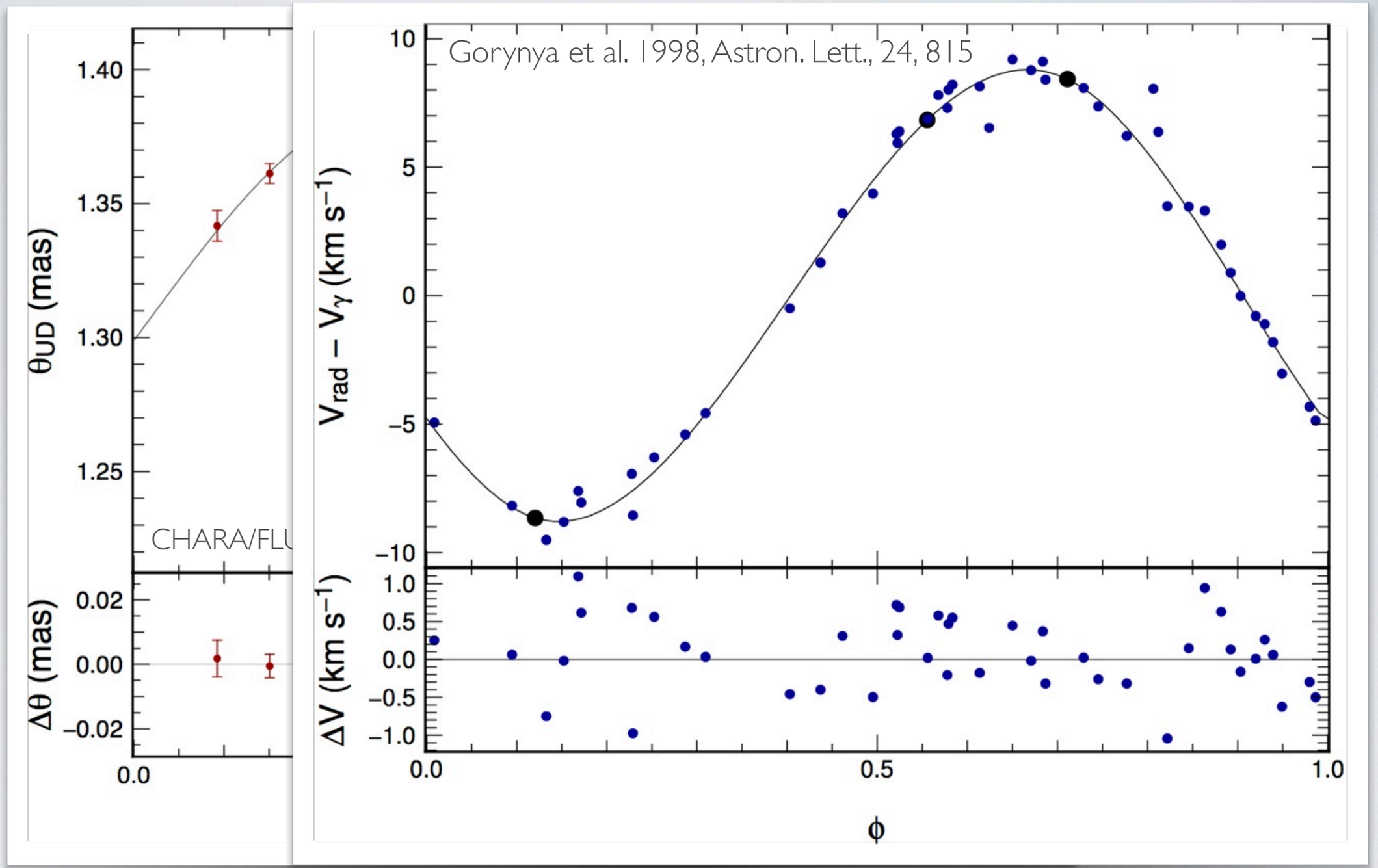
CHARA/FLUOR

T Vul

R = 35.6 ± 4.4 R⊙

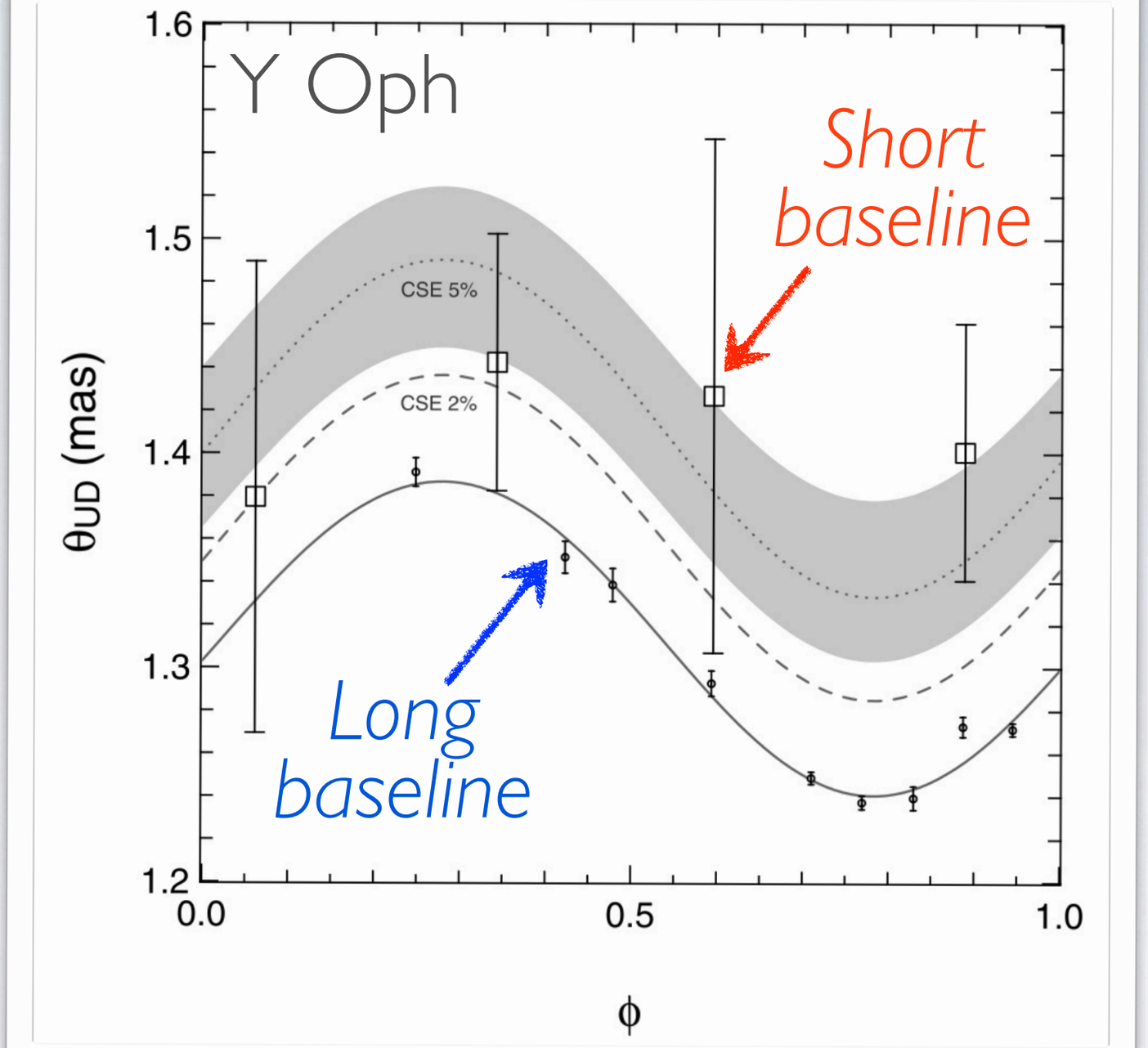
Gallenne et al. 2012, A&A, 541, A87

Y OPH



Distance: 472 ± 18 pc (4%) for $p = 1.27$ and $k = 0.983$

Mérand et al. 2007, ApJ 664, 1087
Gallenne et al. 2013, in prep.

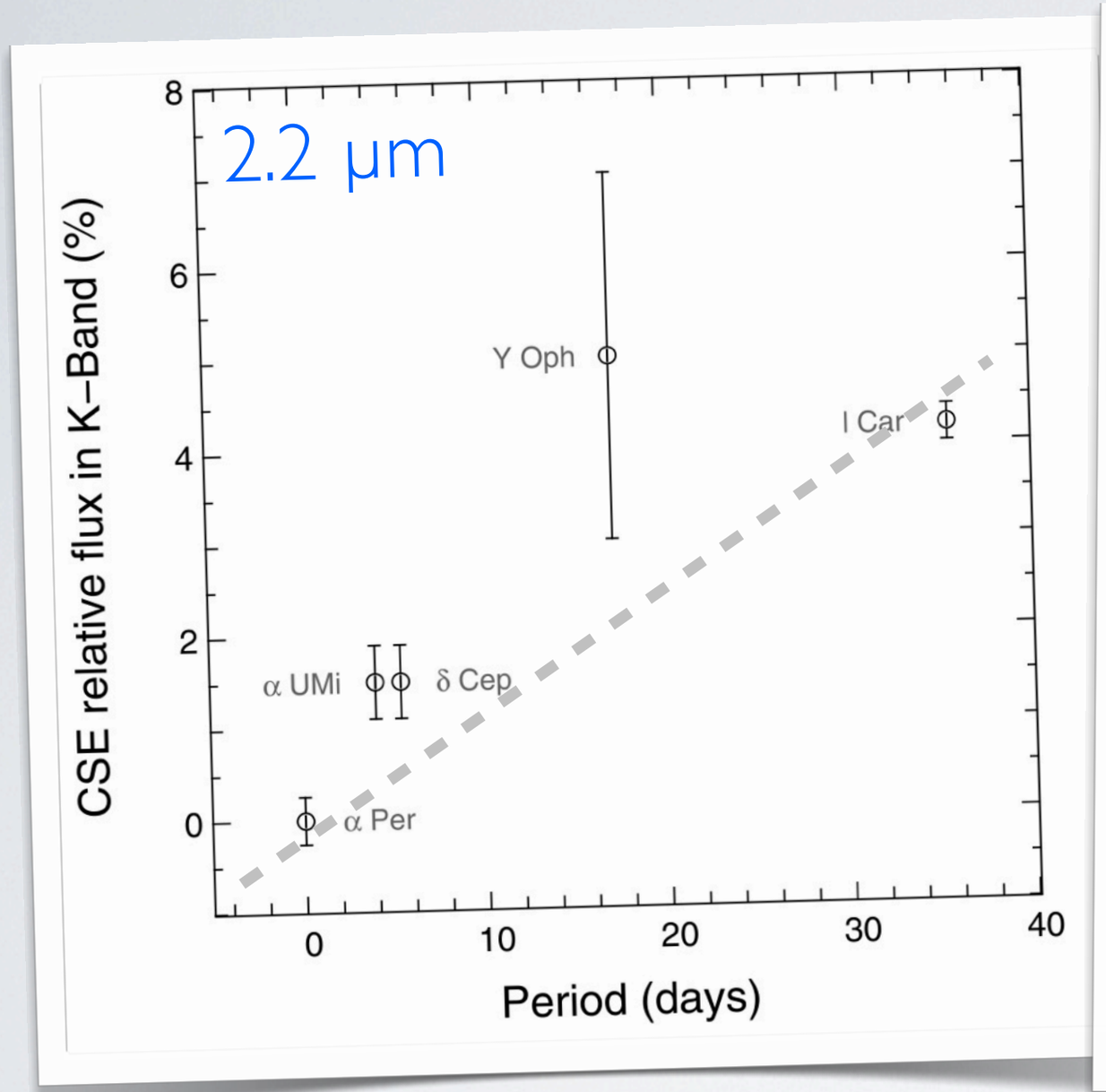


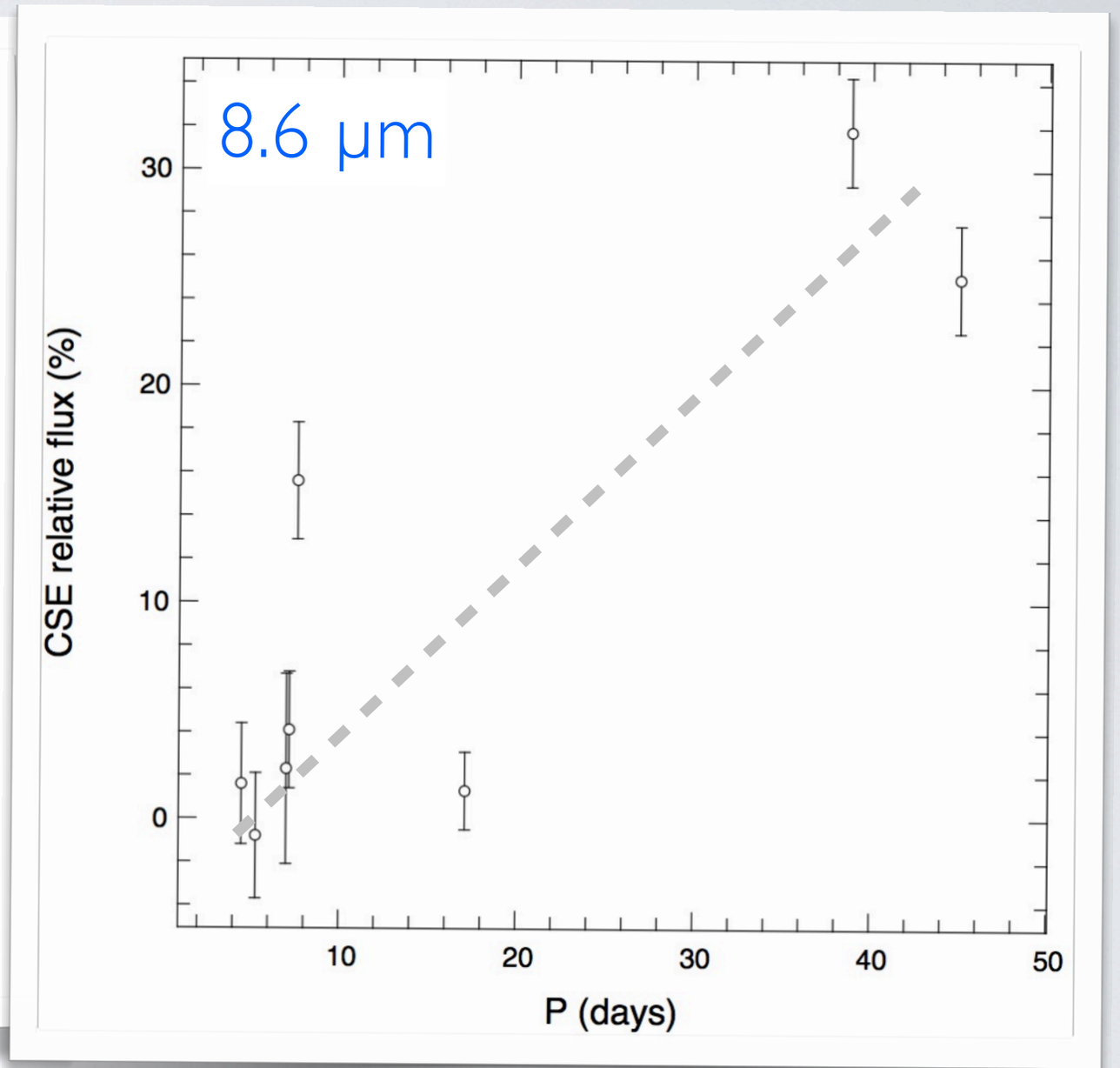
Extended circumstellar emission ~5% of the total flux in K

Unbiased distance: 491 ± 18 pc (4%) instead of 472 pc

Mérand et al. 2007, ApJ 664, 1087

CEPHEID ENVELOPE CONTRIBUTIONS

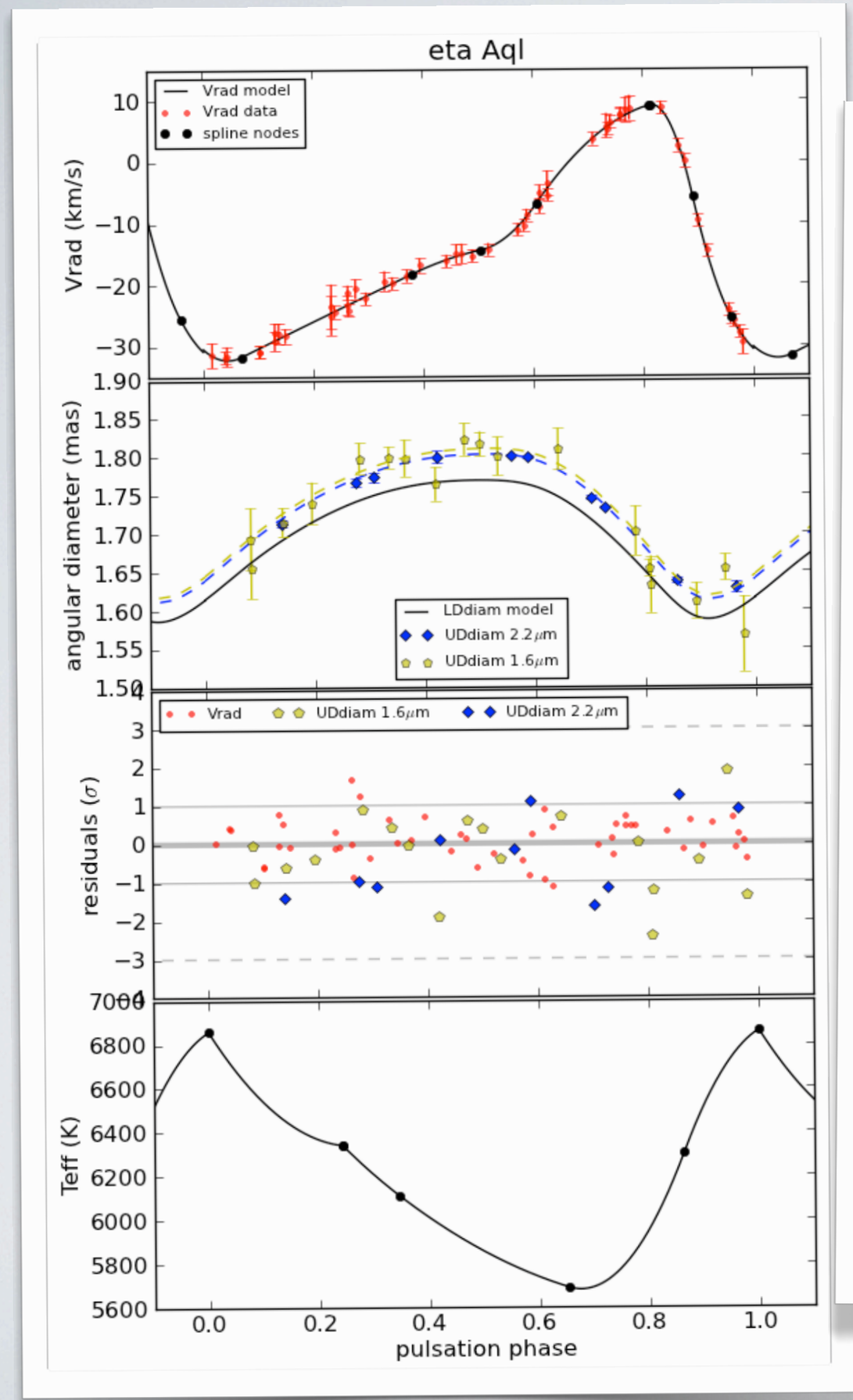


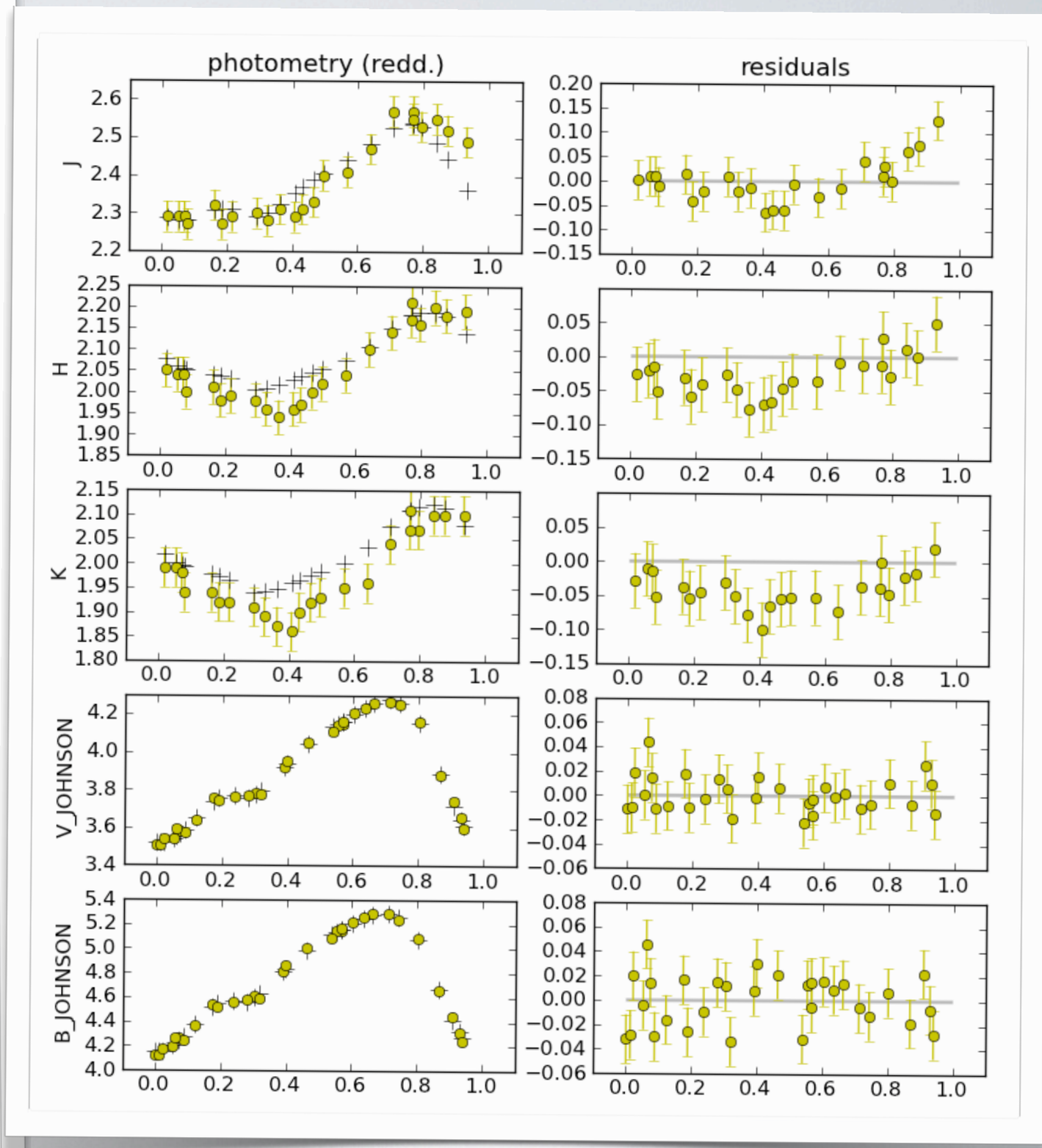


Mérand et al. 2007, ApJ 664, 1087

Gallenne et al. 2012, A&A, 538, A24

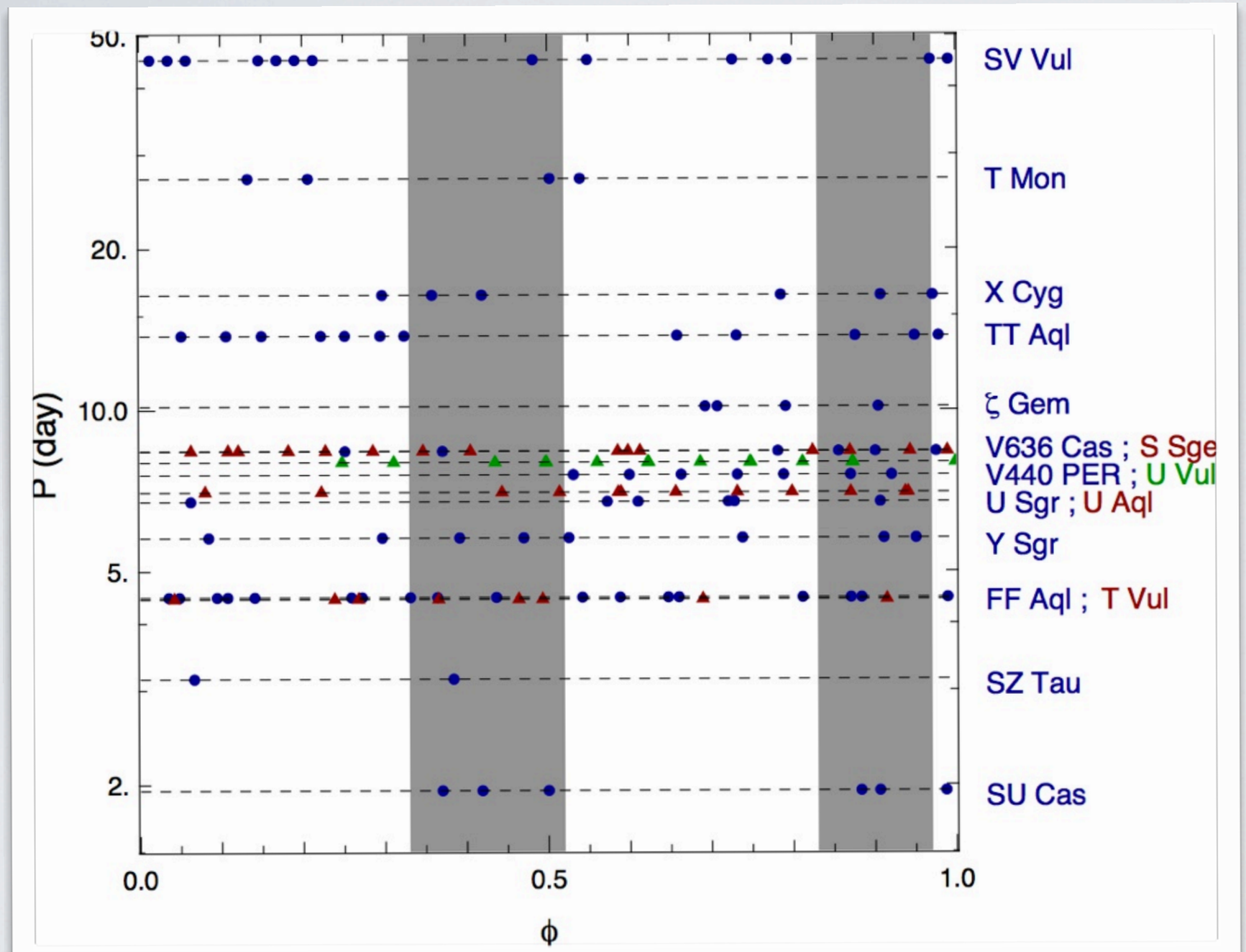
η AQL





Mérand et al. 2013, in prep.

CEPHEIDS OBSERVED BY INTERFEROMETRY



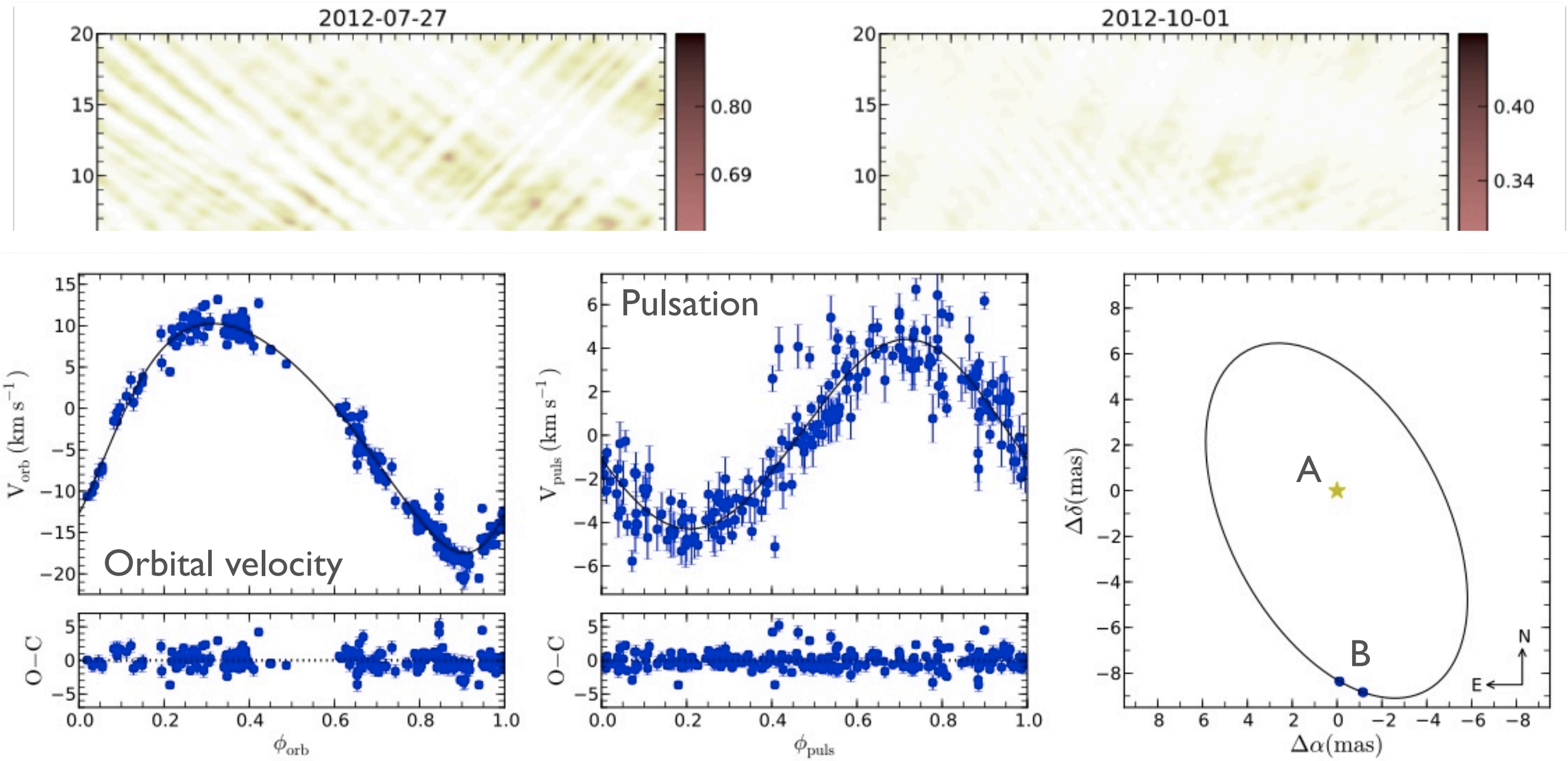
[Polaris] (3.97 d)
δ Cep (5.36 d)
X Sgr (7.01 d)
η Aql (7.17 d)
W Sgr (7.59 d)
β Dor (9.84 d)
L Car (35.6 d)
[RS Pup] (41.4 d)

24 stars, with 22 stars suitable for IBW distance

CEPHEIDS IN BINARIES

- Binary systems are very useful to derive masses and distances
- Cepheids are extremely bright (10^3 - 10^5 Lsun), companions are difficult to detect
- Only a handful discovered using UV spectroscopy (essentially by Nancy Evans et al.)
- Most systems are unresolved SB1, except Polaris and distant companions on multi-century orbits
- Survey with CHARA/MIRC and VLTI/PIONIER: the companion of V1334 Cyg has been spatially resolved with MIRC

V1334 CYG



Separation = **8 mas**, Contrast (H) = **3.1%**, Period = **5.3 yr**

Gallenne et al. 2013, A&A, 552, A21