Optical interferometry and Gaia parallaxes for a robust calibration of the Cepheid distance scale

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Image: S. Brunier / ESO

Parallax of pulsation & SPIPS

- The accuracy of the calibration of the Leavitt law is insufficiently competitive due to systematic uncertainties

- Our project is to employ the *Gaia* parallaxes of Galactic Cepheids to:
  1. Calibrate the **parallax-of-pulsation** (PoP) technique (a.k.a. *Baade-Wesselink*).
  2. Improve the calibration of the **Leavitt law**.
  3. Apply the PoP technique to individual stars in distant galaxies using ELT, JWST,…

- We developed a robust modeling approach through the **Spectro-Photo-Interferometry of Pulsating Stars** (SPIPS) code to simultaneously fit the Cepheid photometry, radial velocities and interferometry

PARALLAX OF PULSATION

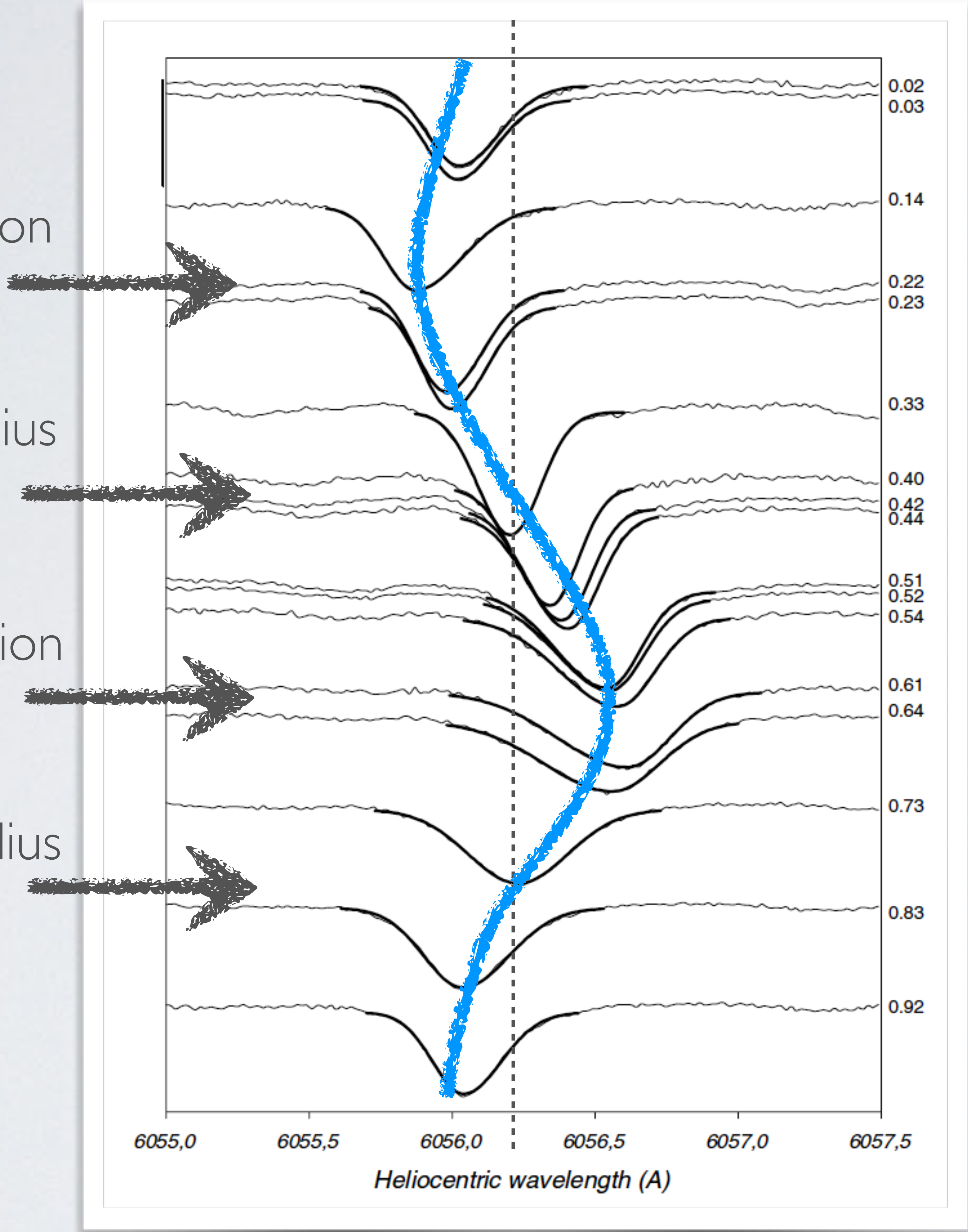
Radial velocity

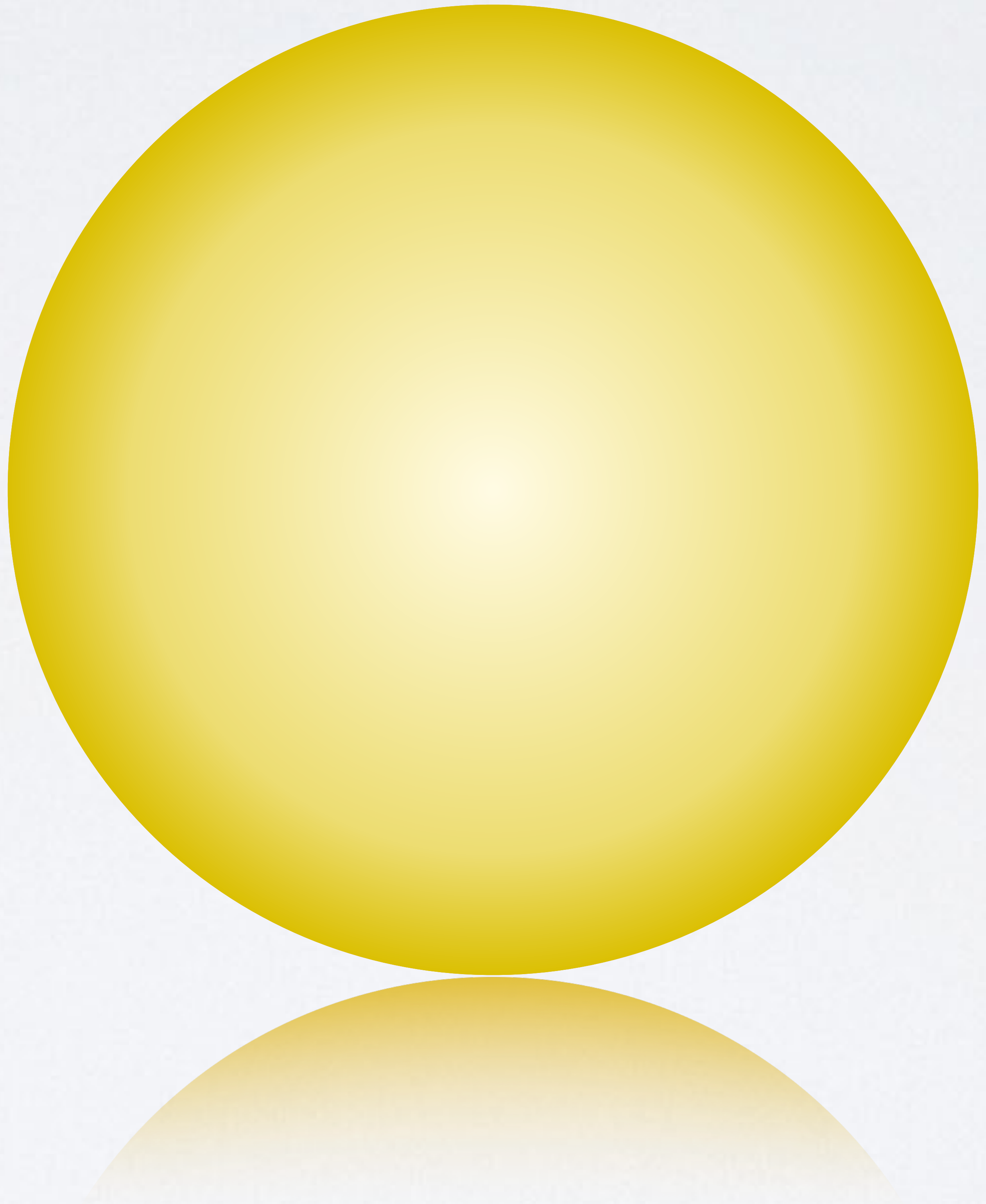
Expansion

Max radius

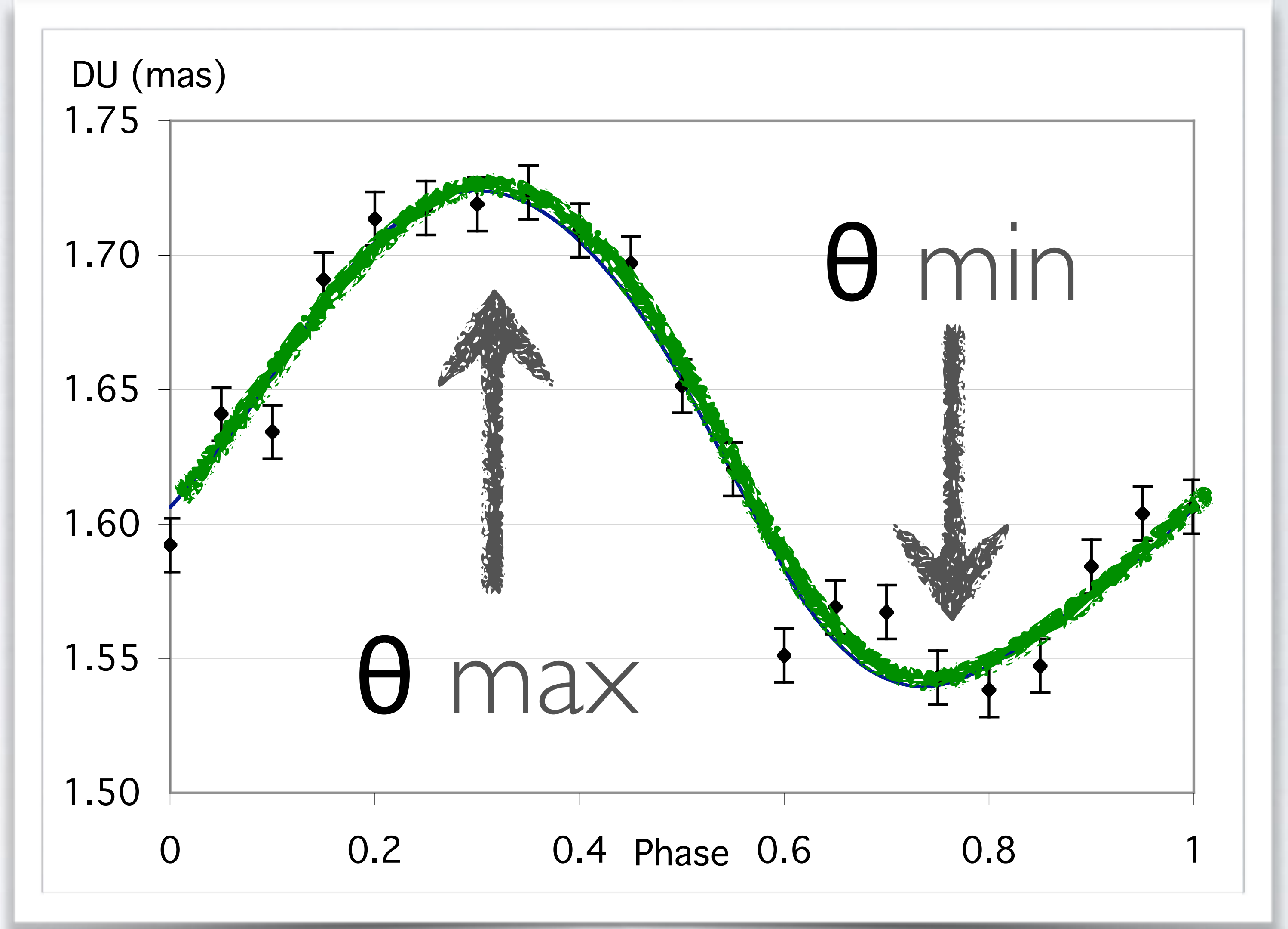
Contraction

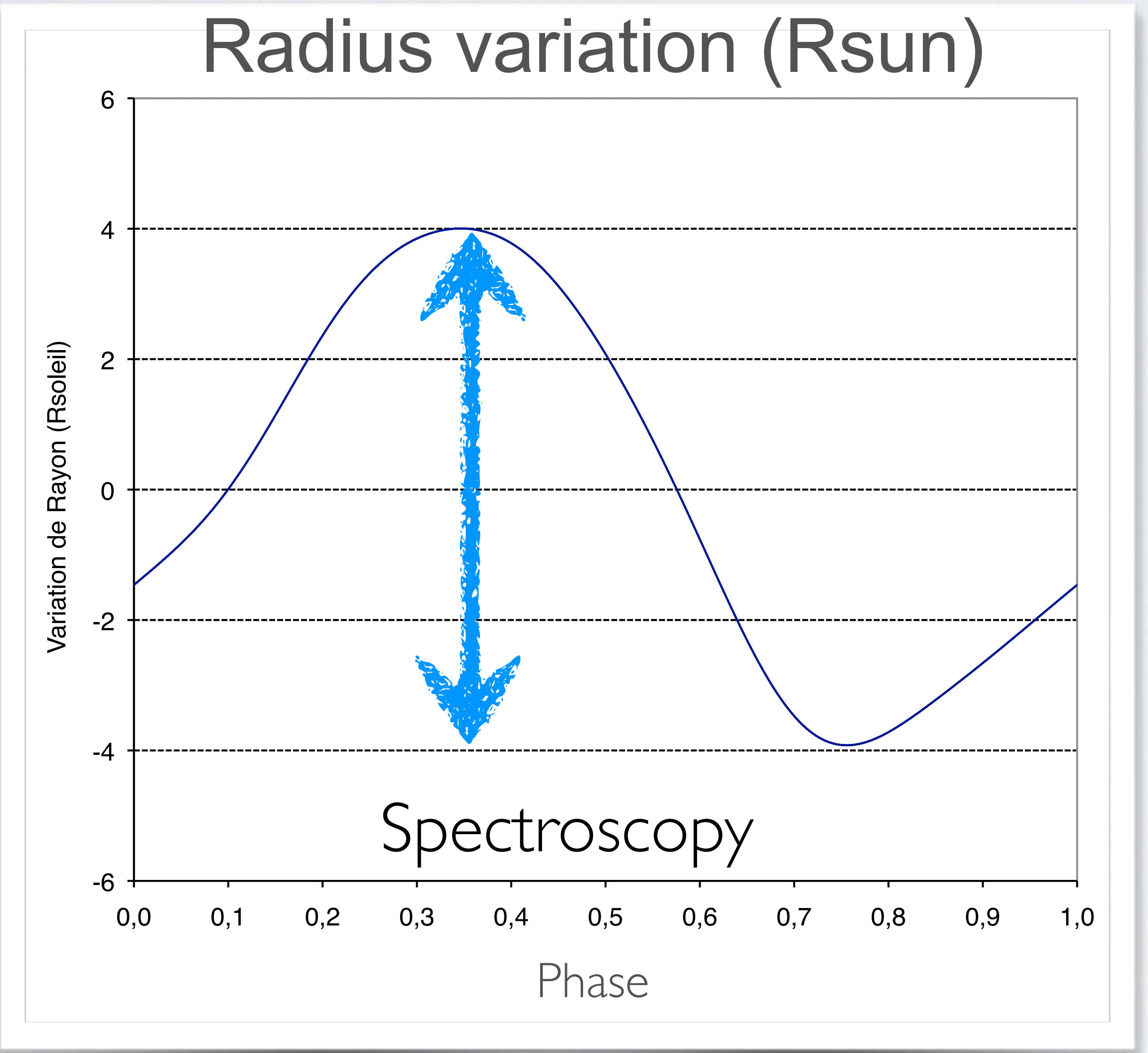
Min radius

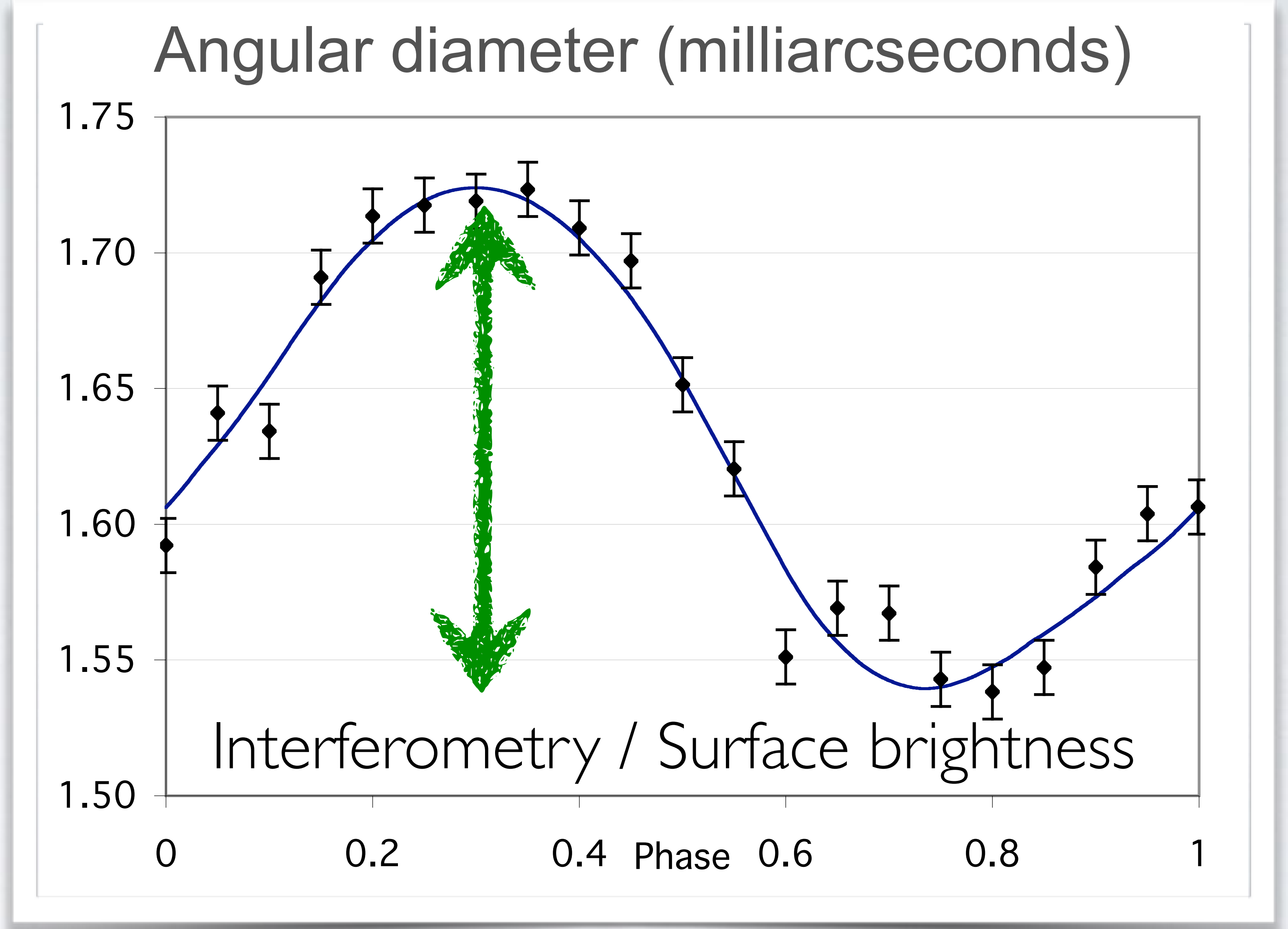




Angular diameter







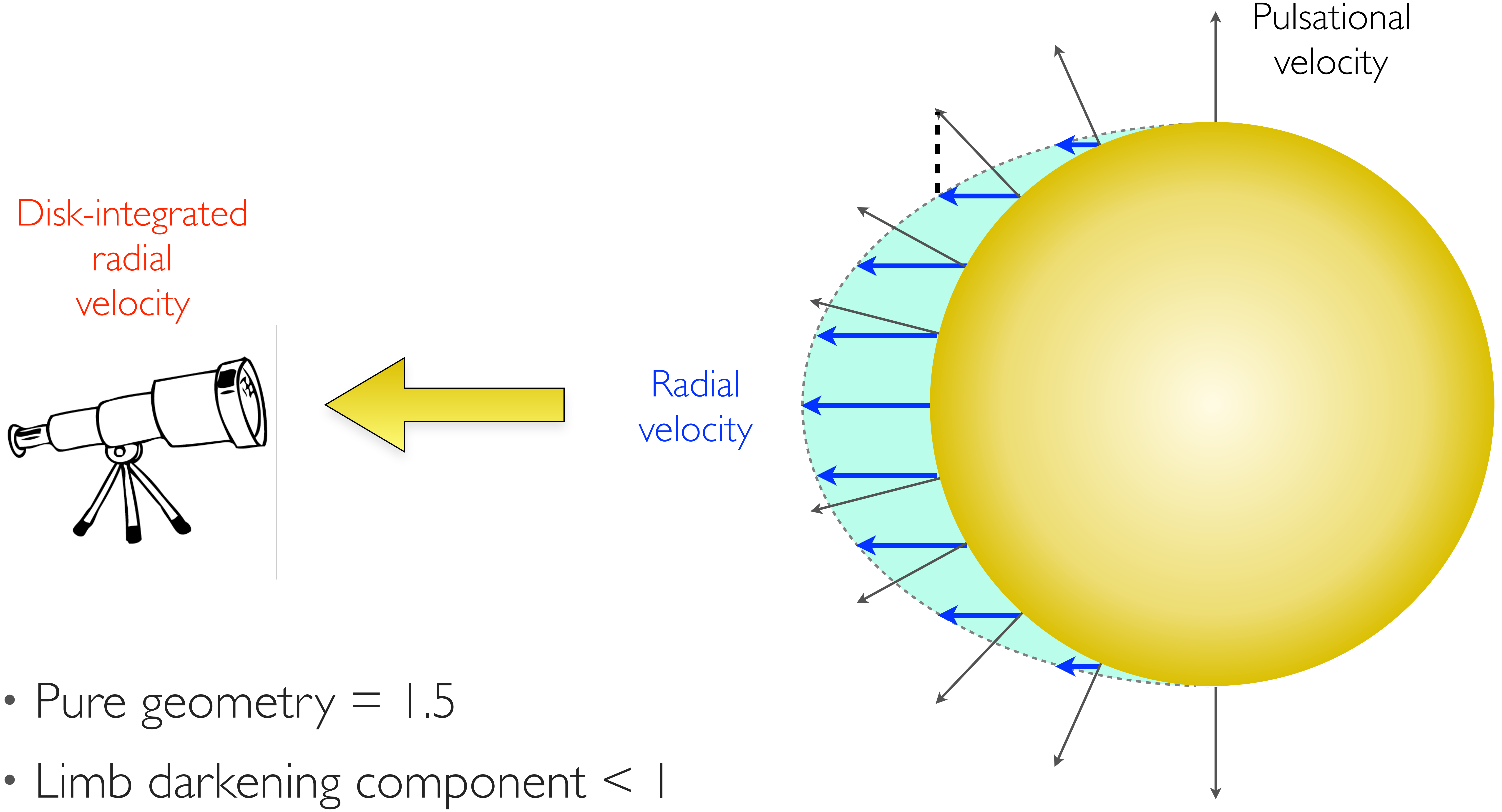
The distance *d* is given by the relation:

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

p = projection factor

k = limb darkening correction

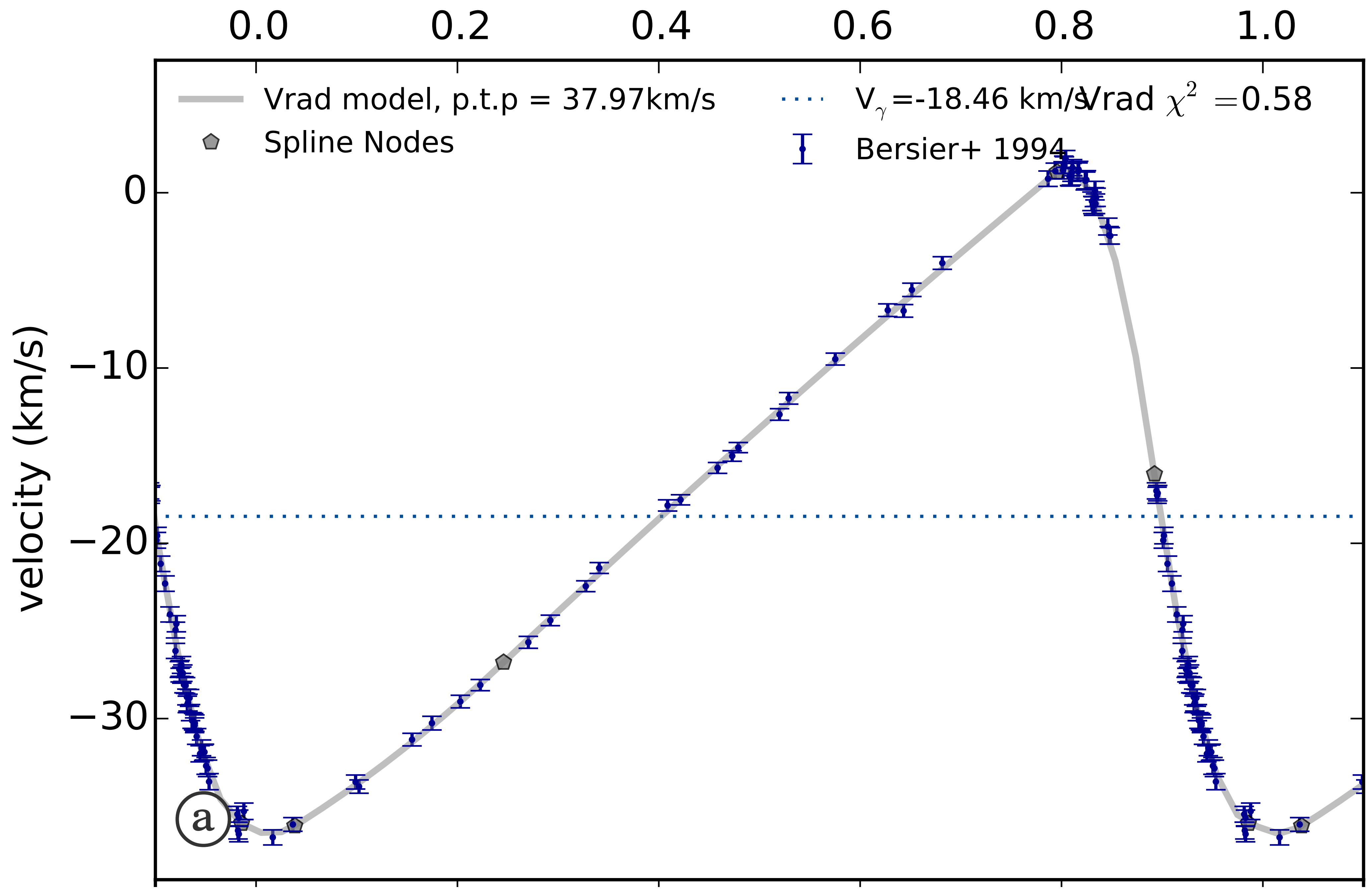
THE P-FACTOR



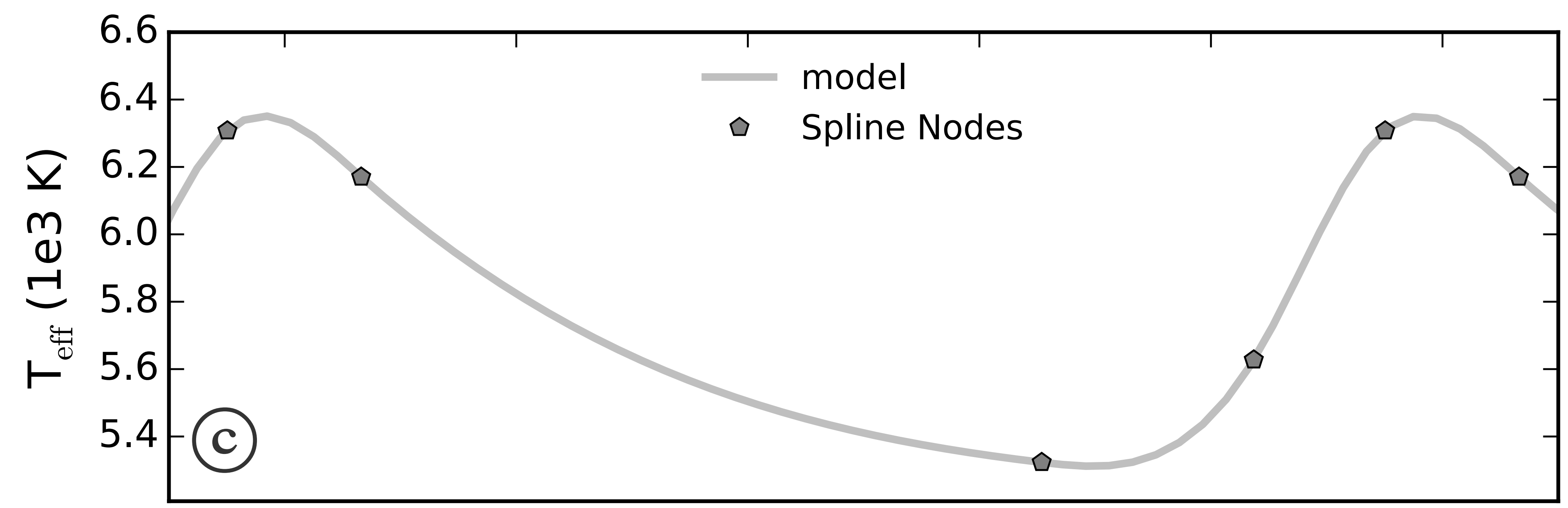
- Pure geometry = 1.5
- Limb darkening component < 1
- Atmosphere dynamics = ?

Nardetto et al. (2009, A&A, 502, 951)

Main limitation for PoP Cepheid distances



Radial velocity



Effective temperature

+ Kurucz's ATLAS9
+ Reddening law
+ Envelope

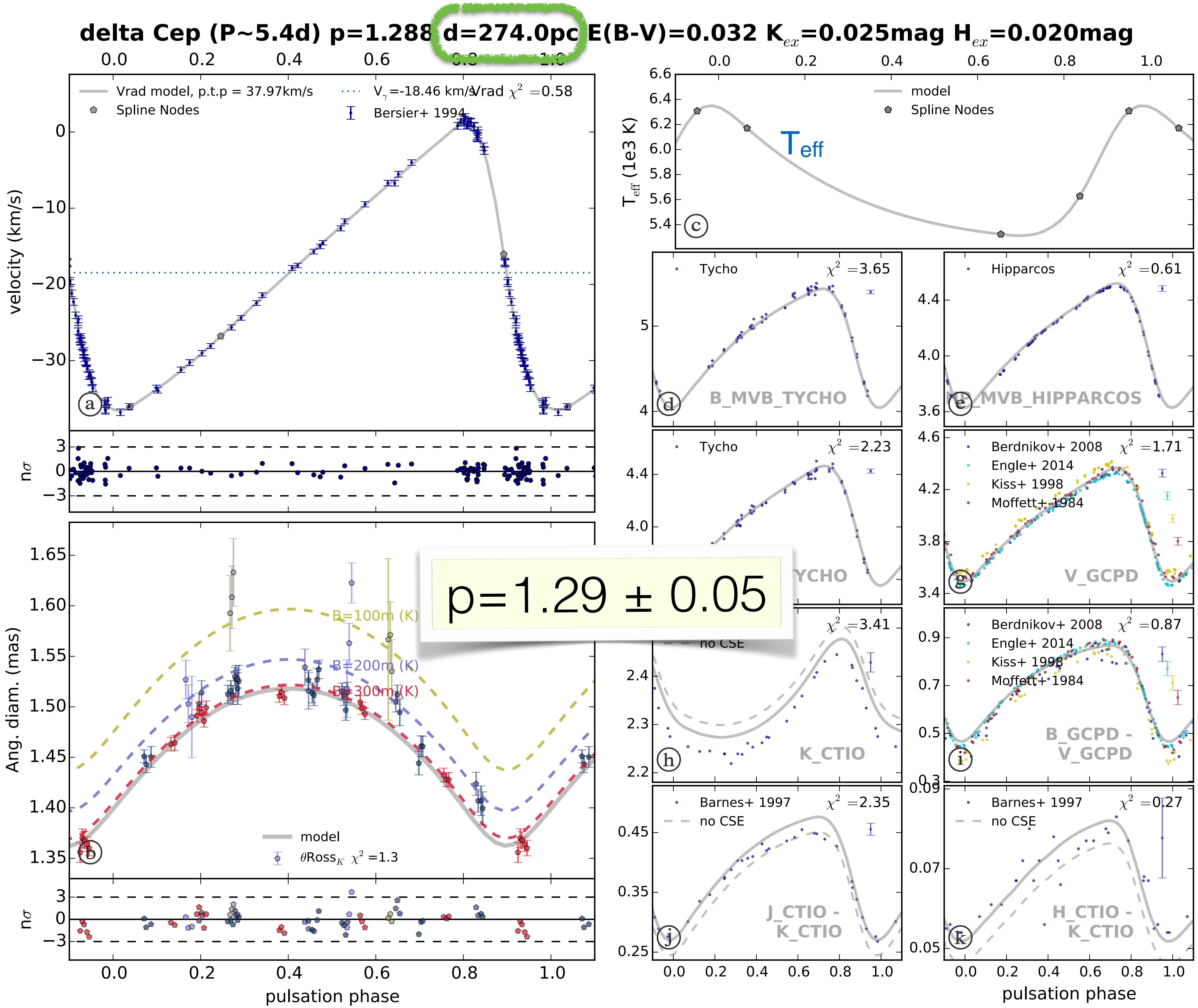
SPIPS model parameters
p-factor / distance
E(B-V)
Envelope infrared excess

Radial velocity
Photometry
Angular diameters

Multiparameter fit
to observations

Radial velocity (spectroscopy)

Angular size (interferometry)



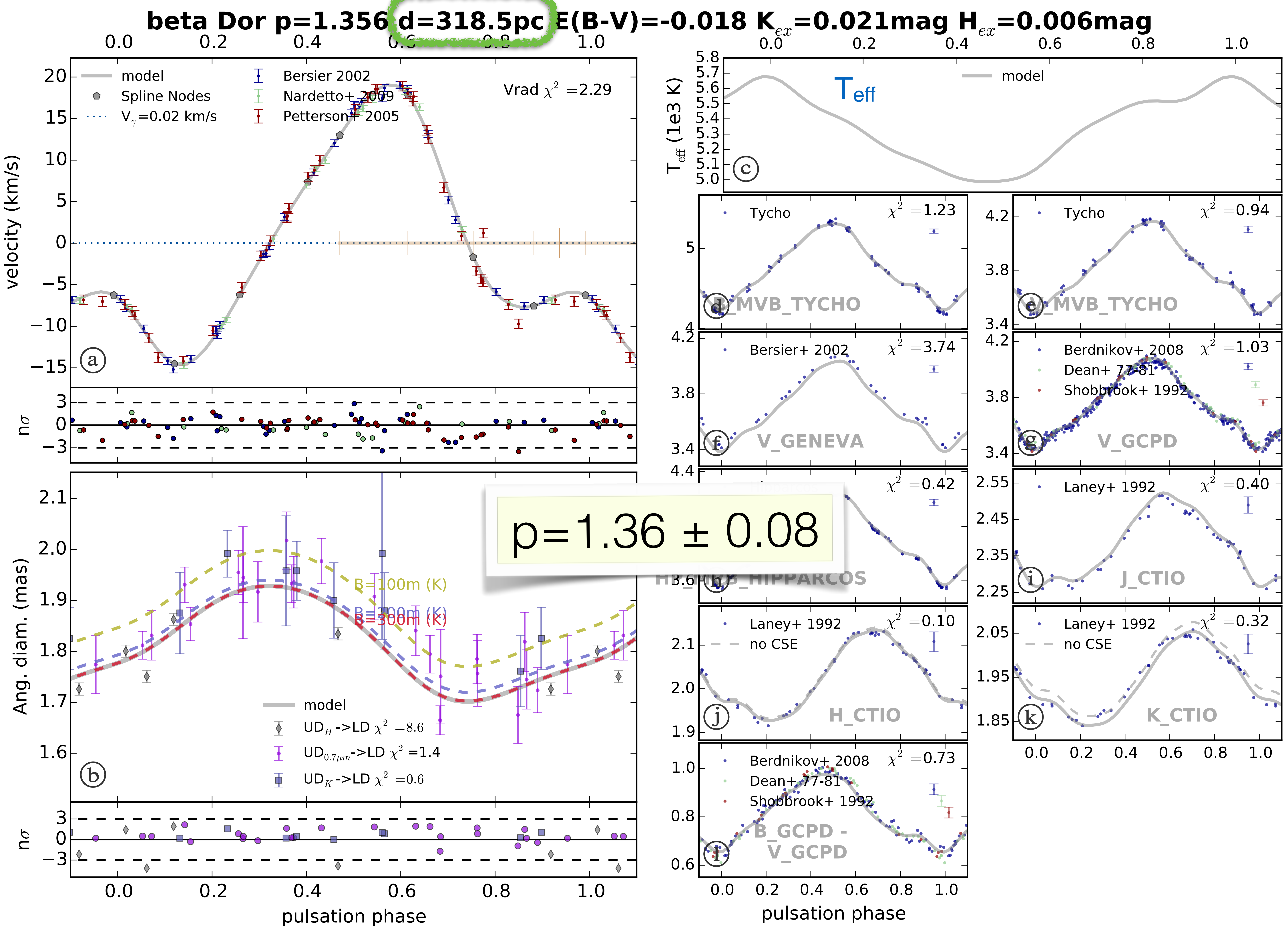
Photometry

Mérand et al. 2015, *A&A*, 584, A80

Breitfelder et al. 2016, A&A, 587, A117

Radial velocity

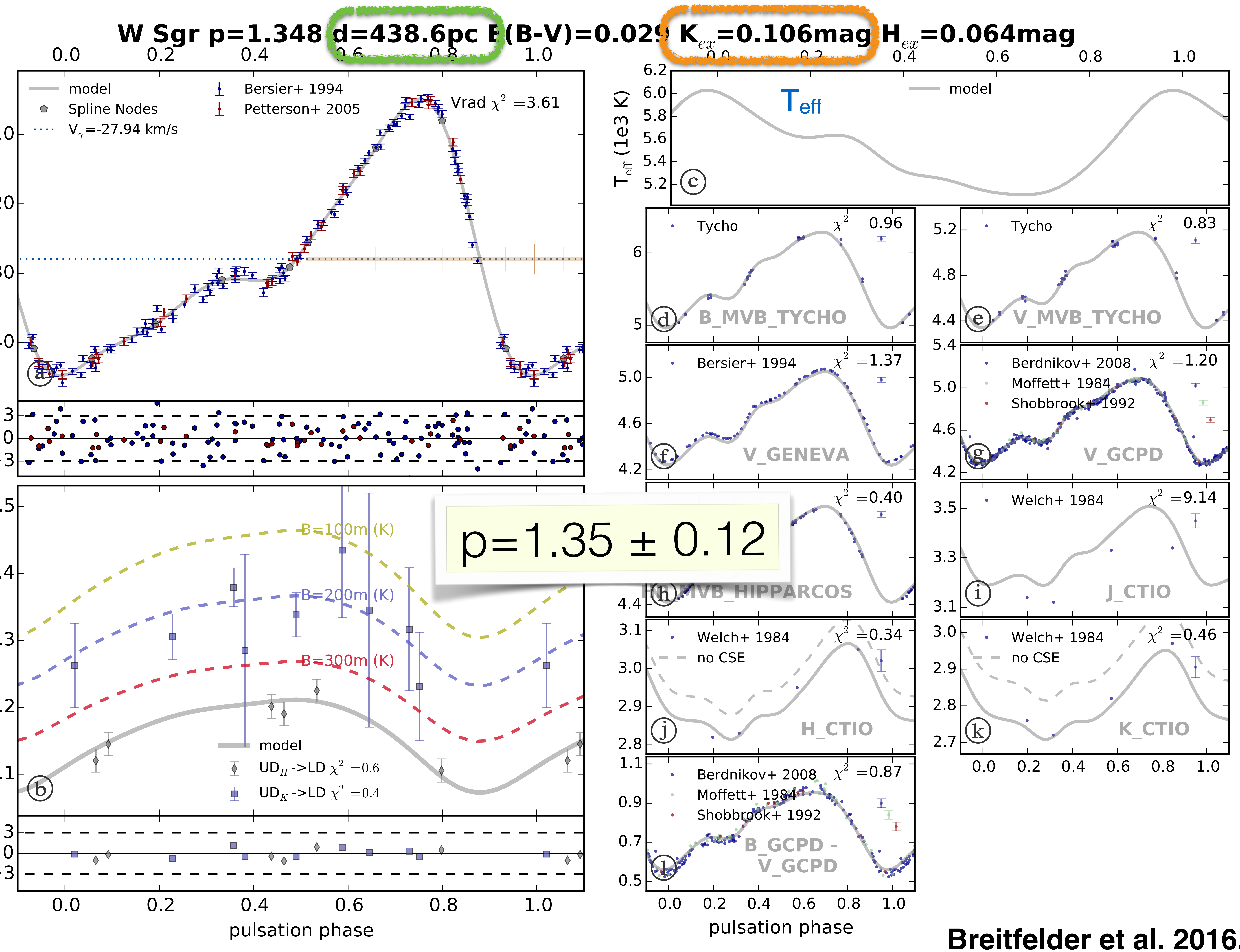
Angular size



Photometry

Radial velocity

Angular size

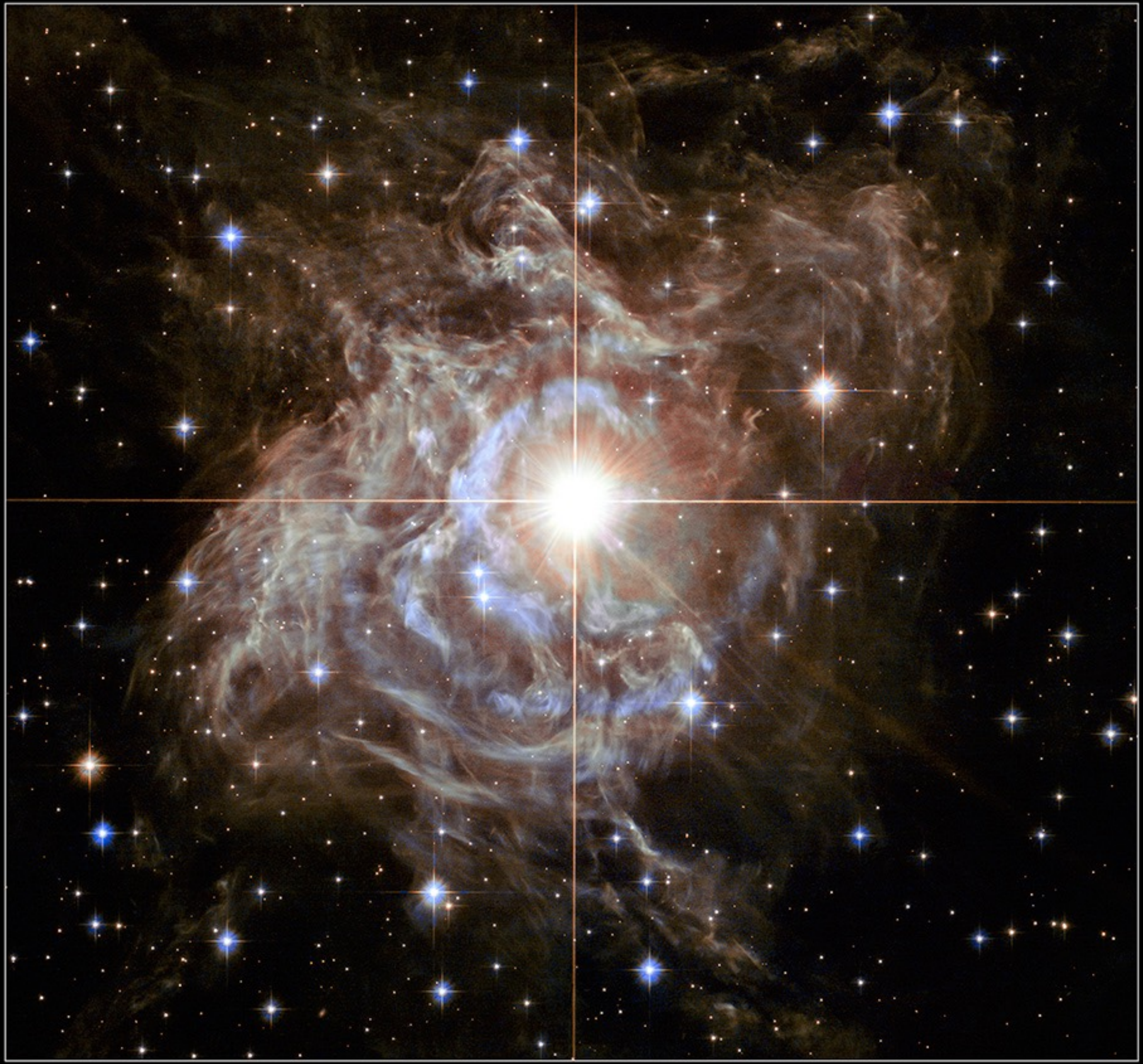


Photometry

Breitfelder et al. 2016, A&A, 587, A117

RS Puppis

- Long-period Cepheid
  P = 41.5 days
- $\pi = 0.524 \pm 0.022$ mas
  (4.2%) from its light echoes



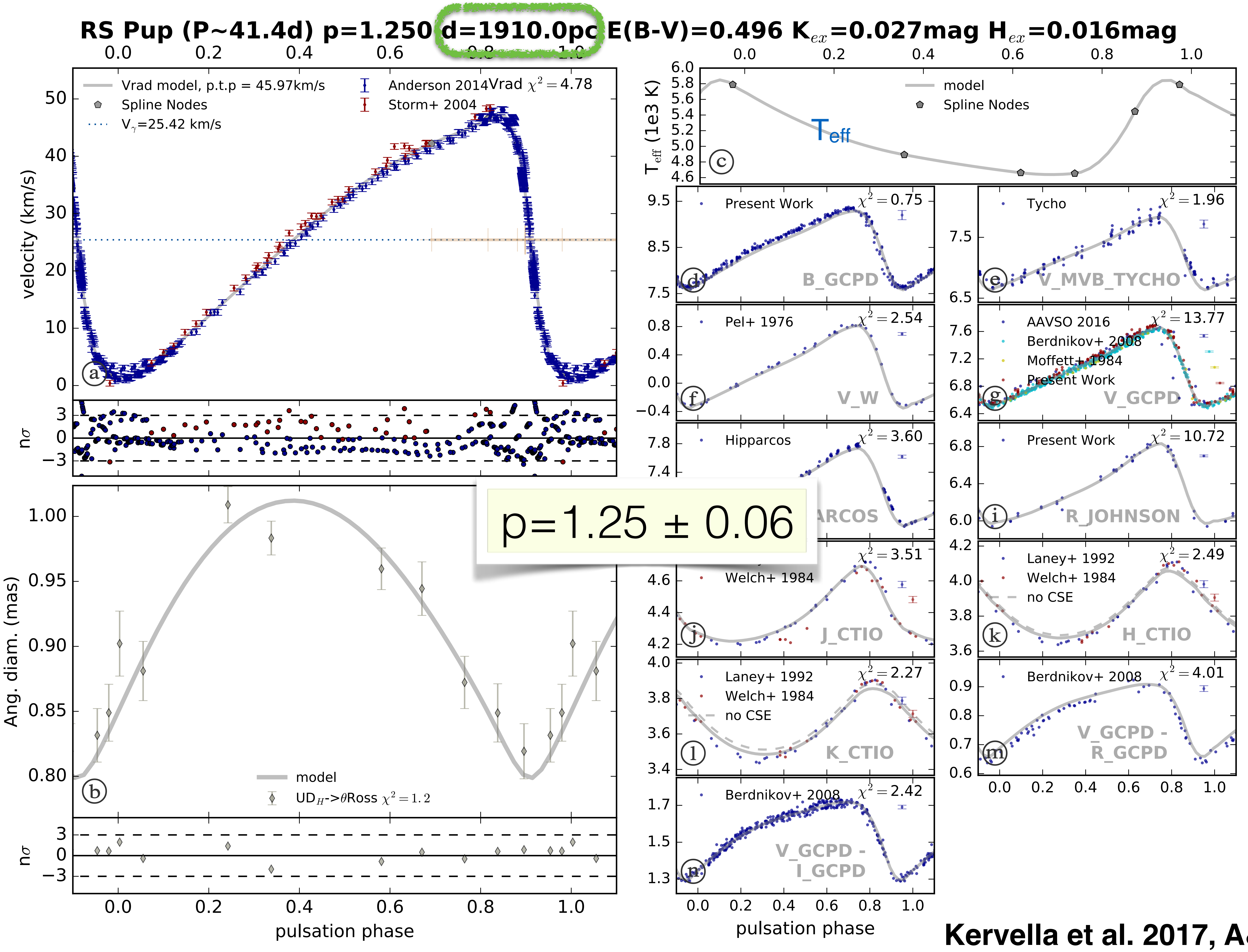
Kervella et al. (2014, A&A, 572, A7)


https://vimeo.com/108581936

Radial velocity

Angular size (interferometry)

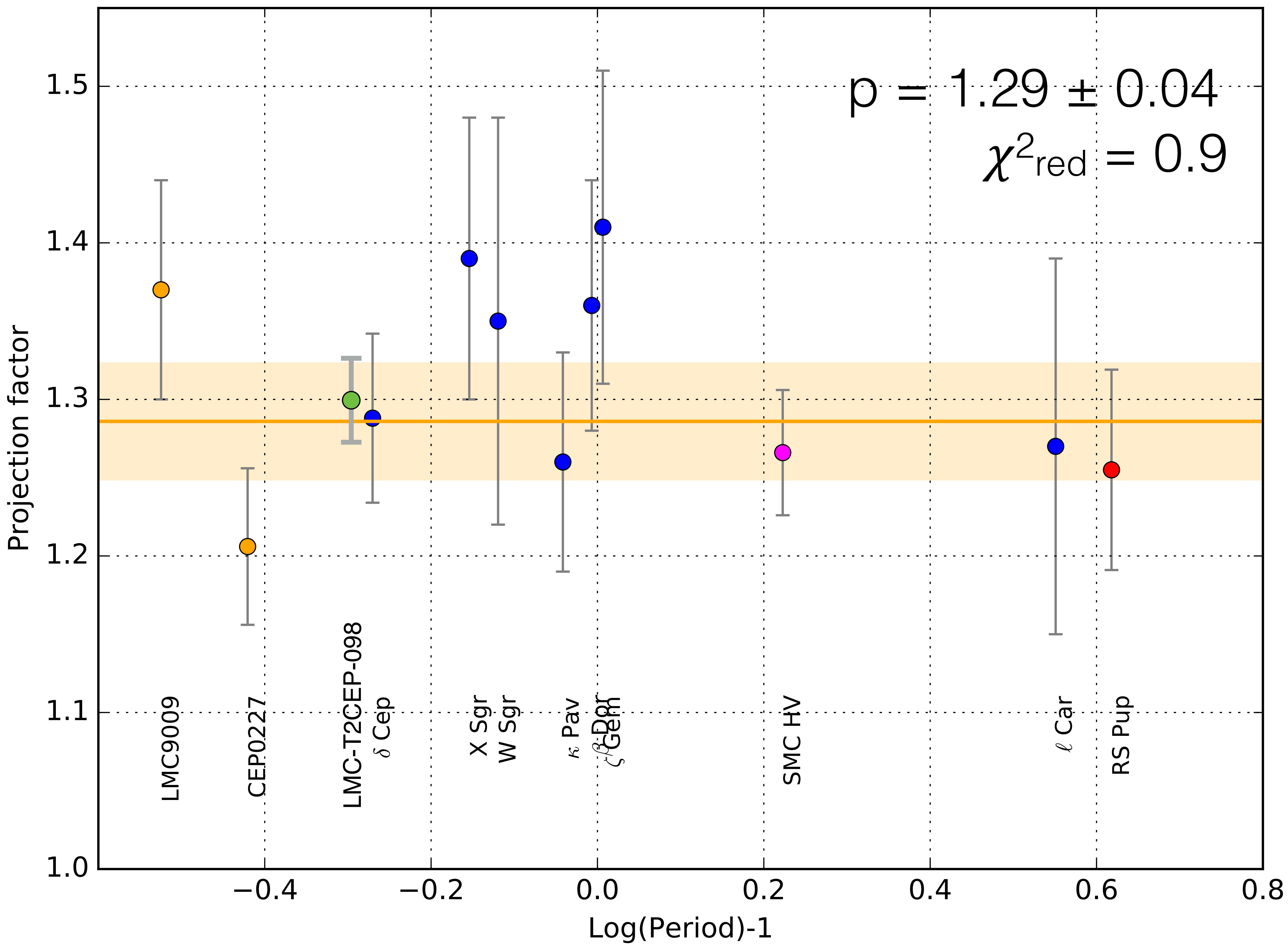
Photometry



p=1.25 ± 0.06

Kervella et al. 2017, A&A, 600, A127

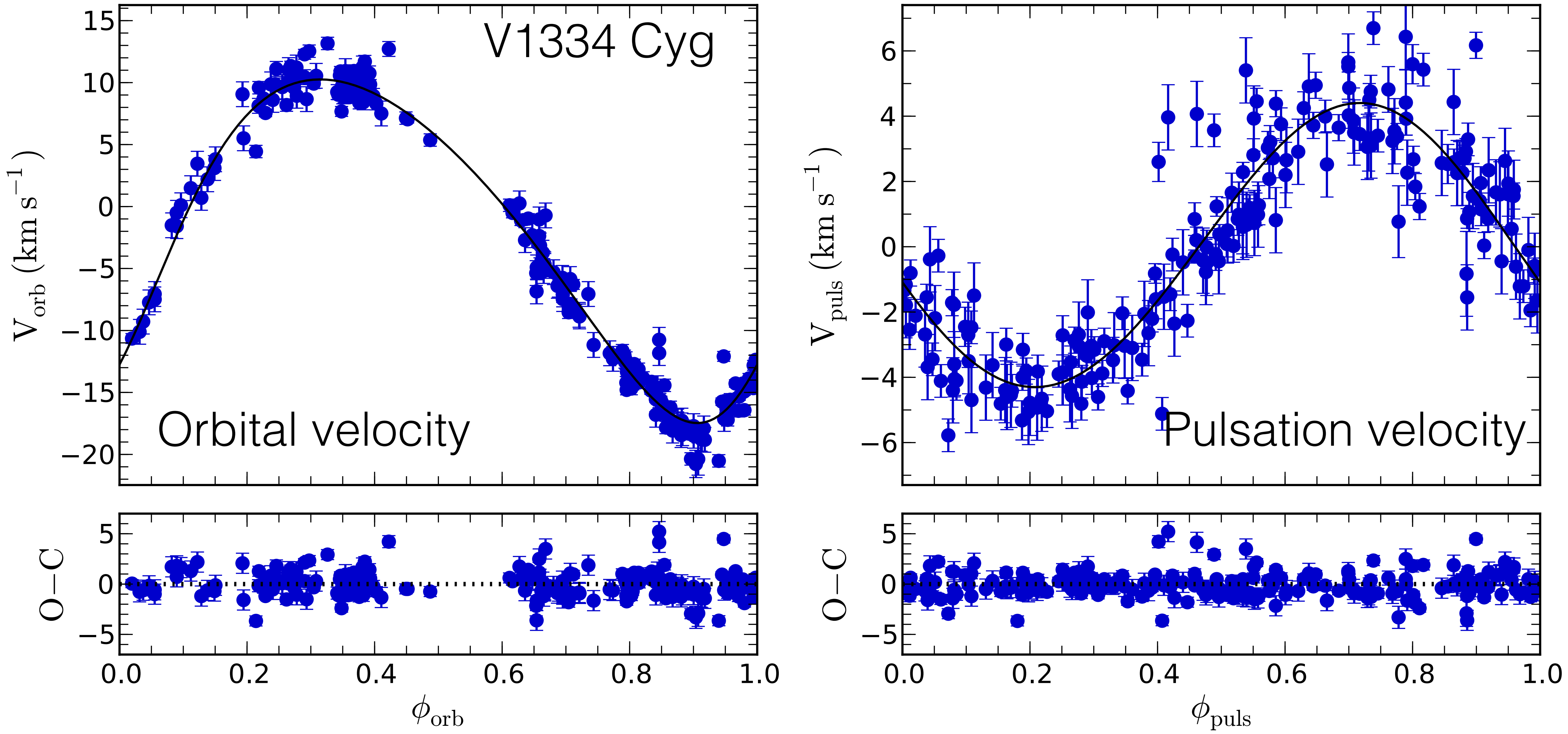
Projection factor vs. Period

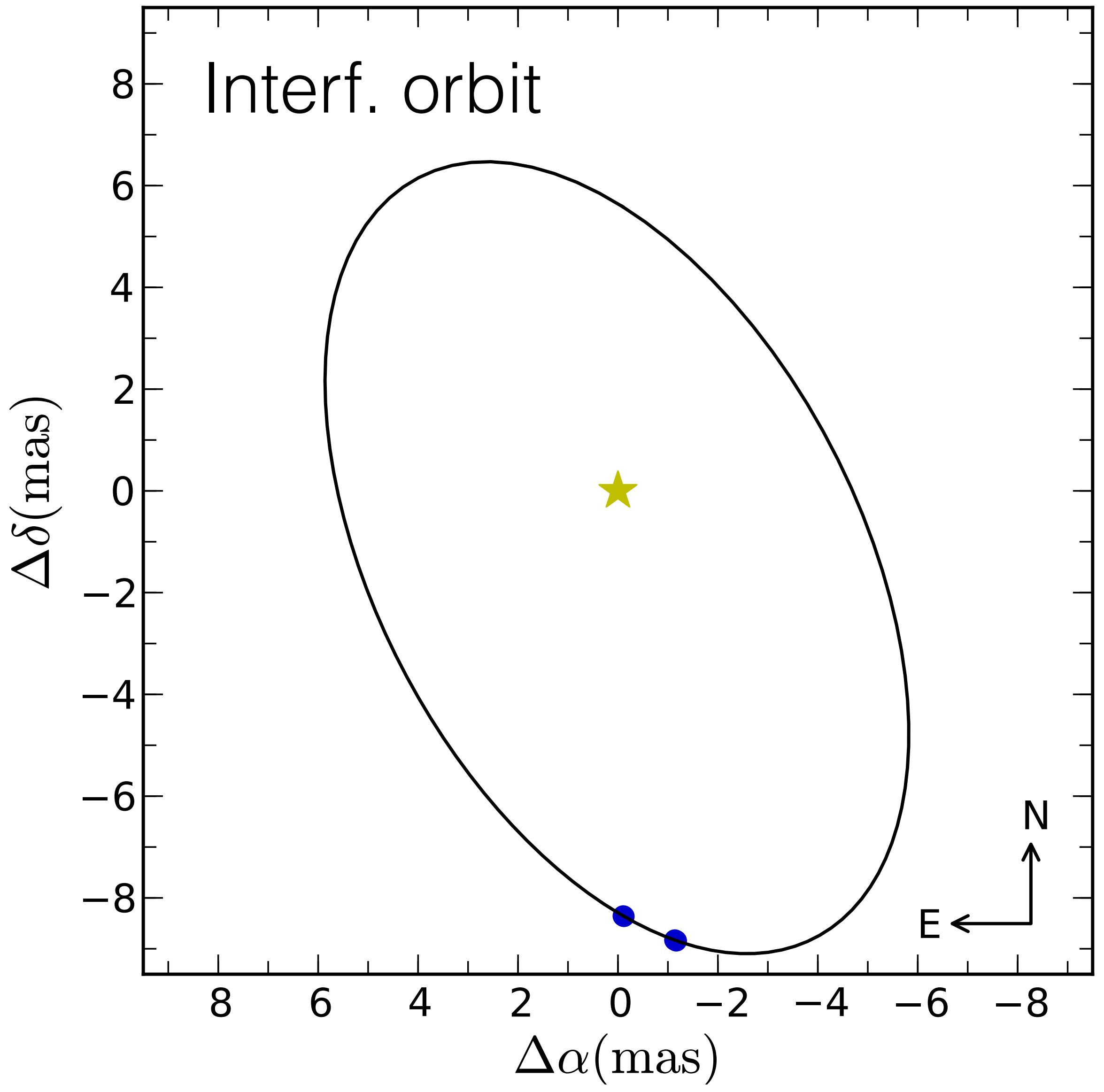


Kervella et al. 2017, A&A, 600, A127
Pilecki et al. 2017, ApJ, in press

Binarity

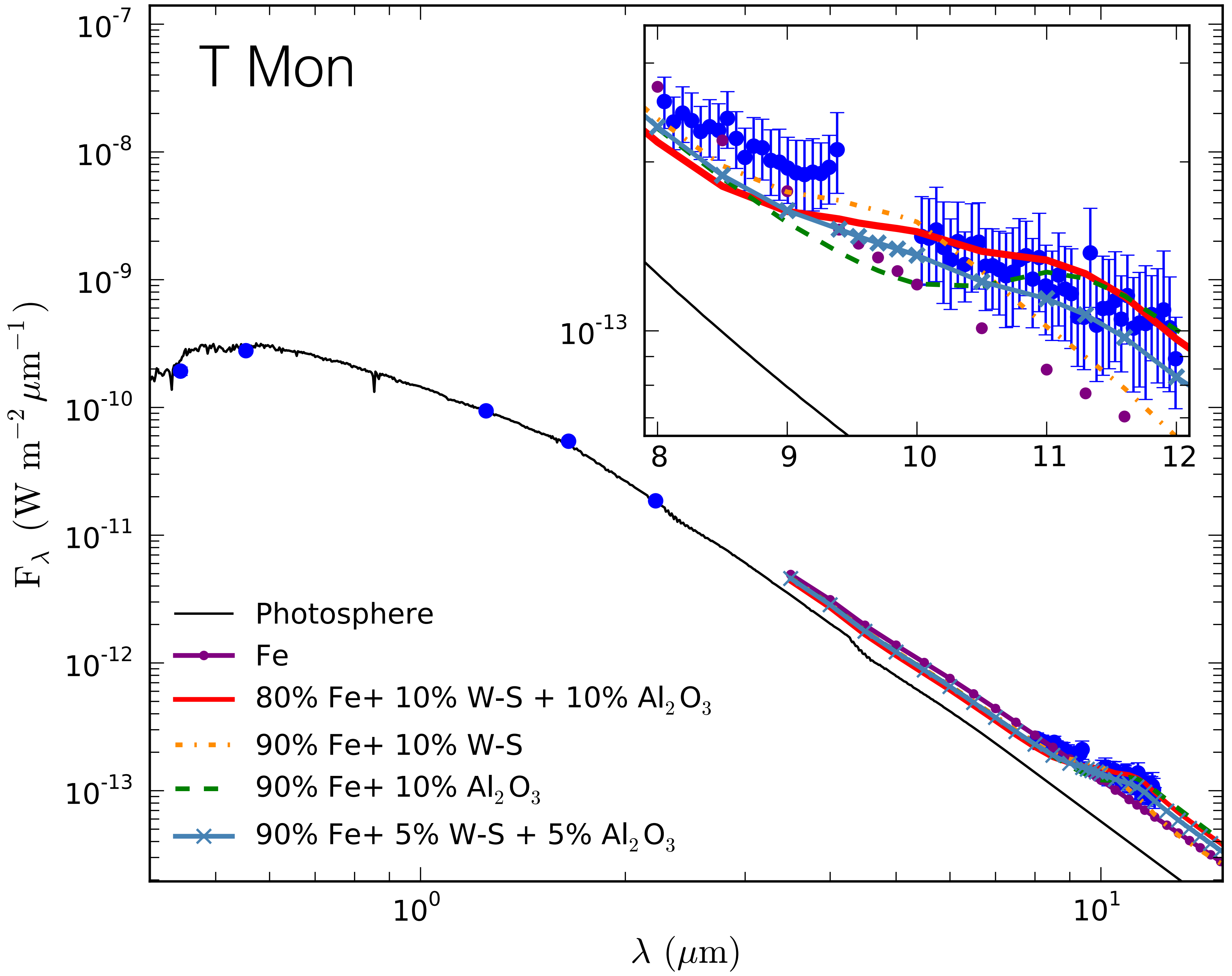
Gallenne et al. (2013, A&A, 552, A21 + 2014, 2015)
+ see poster by Alexandre Gallenne





Circumstellar envelopes

Gallenne et al. (2013, A&A, 558, A140)



Included in SPIPS modeling