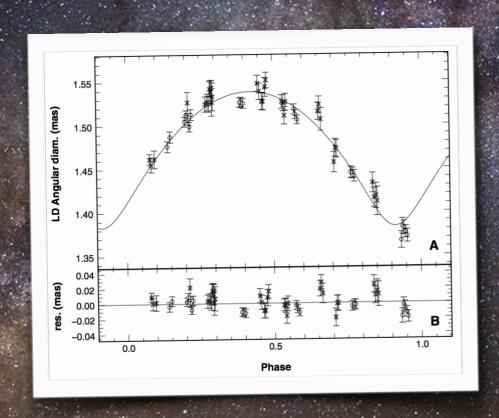
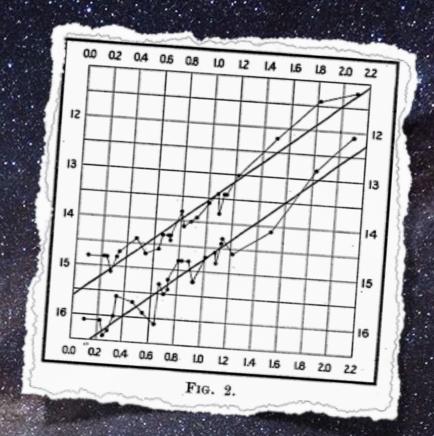
# The Cepheid distance scale and Gaia

Pierre Kervella CNRS UMI FCA 3386 & Observatoire de Paris

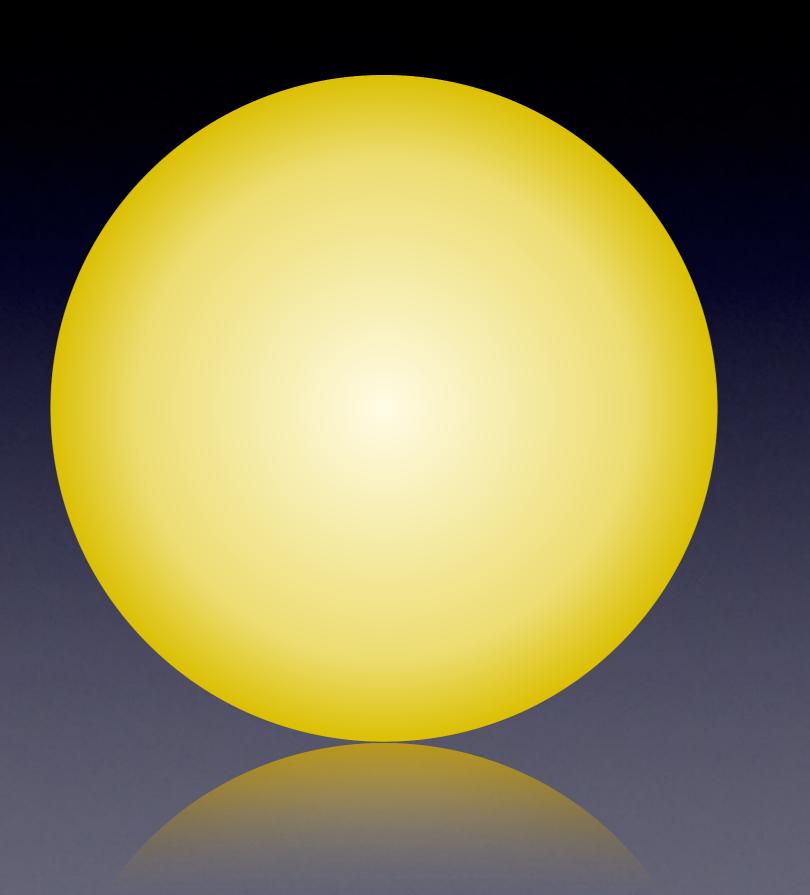
Antoine Mérand, Joanne Breitfelder, Alexandre Gallenne, Anthony Soulain,...



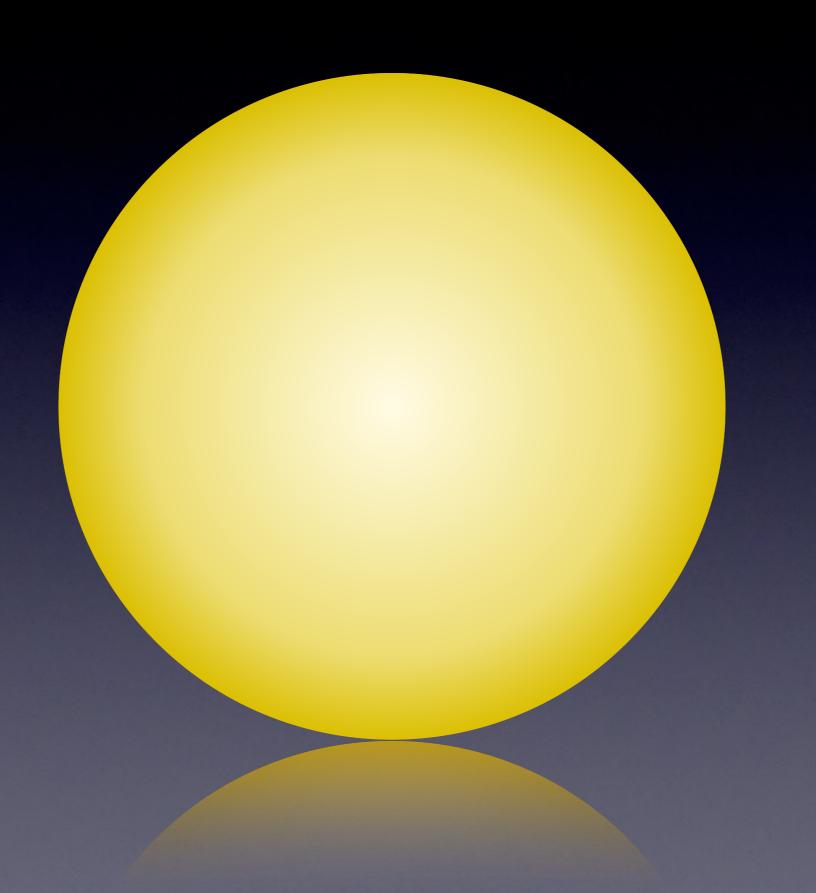




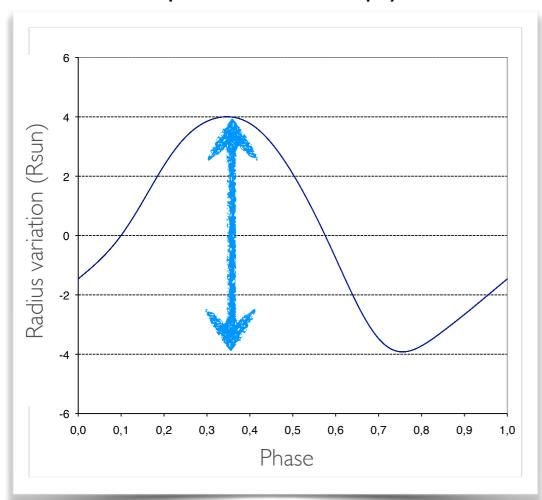
# Pulsation of a Cepheid

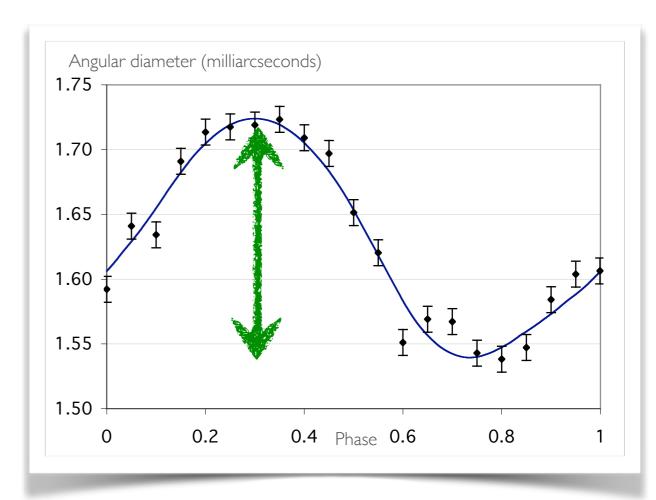


# Pulsation of a Cepheid



#### Interferometry / Surface brightness

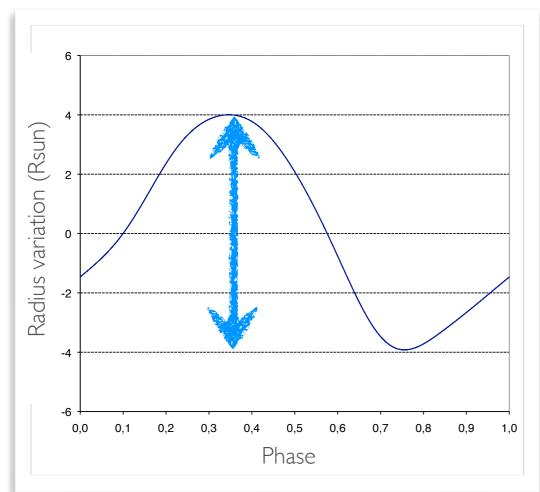


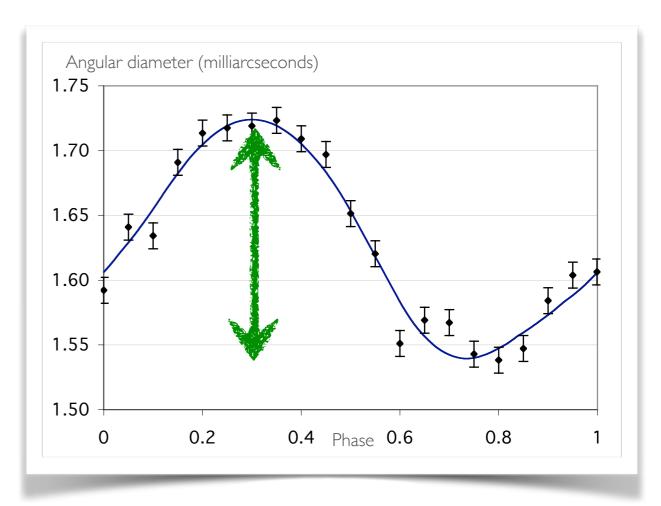


The distance d is given by the relation:

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

#### Interferometry / Surface brightness

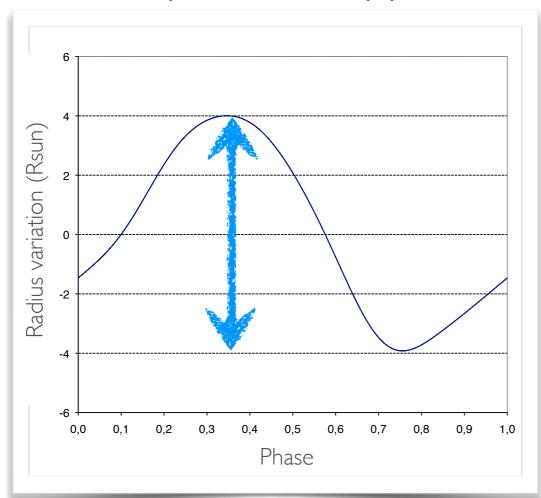


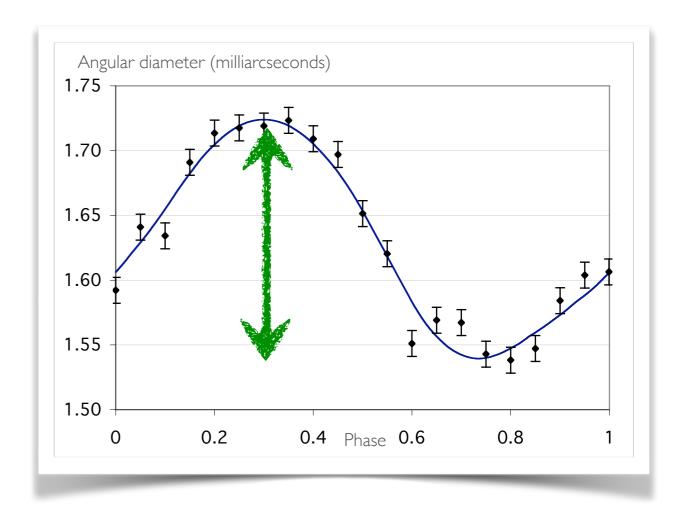


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#### Interferometry / Surface brightness





The distance d is given by the relation:

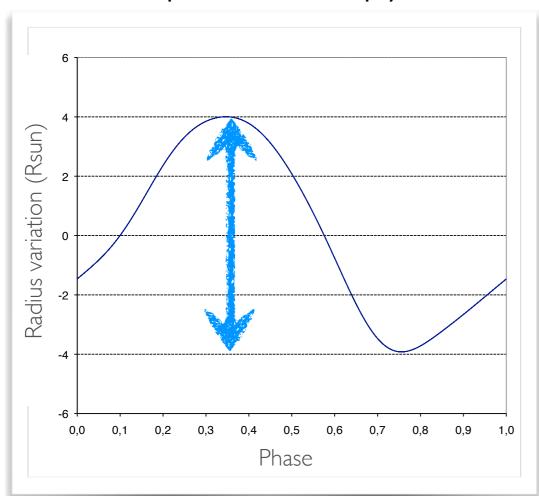
$$d = \frac{2\delta R(T)}{\delta \theta(T)} = \frac{-2kp \int_0^T v_{\text{rad}}(t) dt}{\theta_{\text{UD}}(T) - \theta_{\text{UD}}(0)}$$

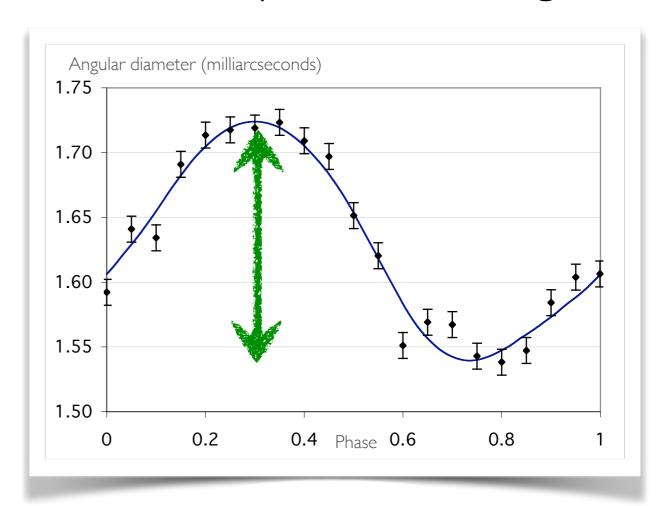
k = limb darkening correction (from models)

$$= \theta_{UD} / \theta_{LD}$$

~ 0.94 in visible, 0.98 in IR

#### Interferometry / Surface brightness





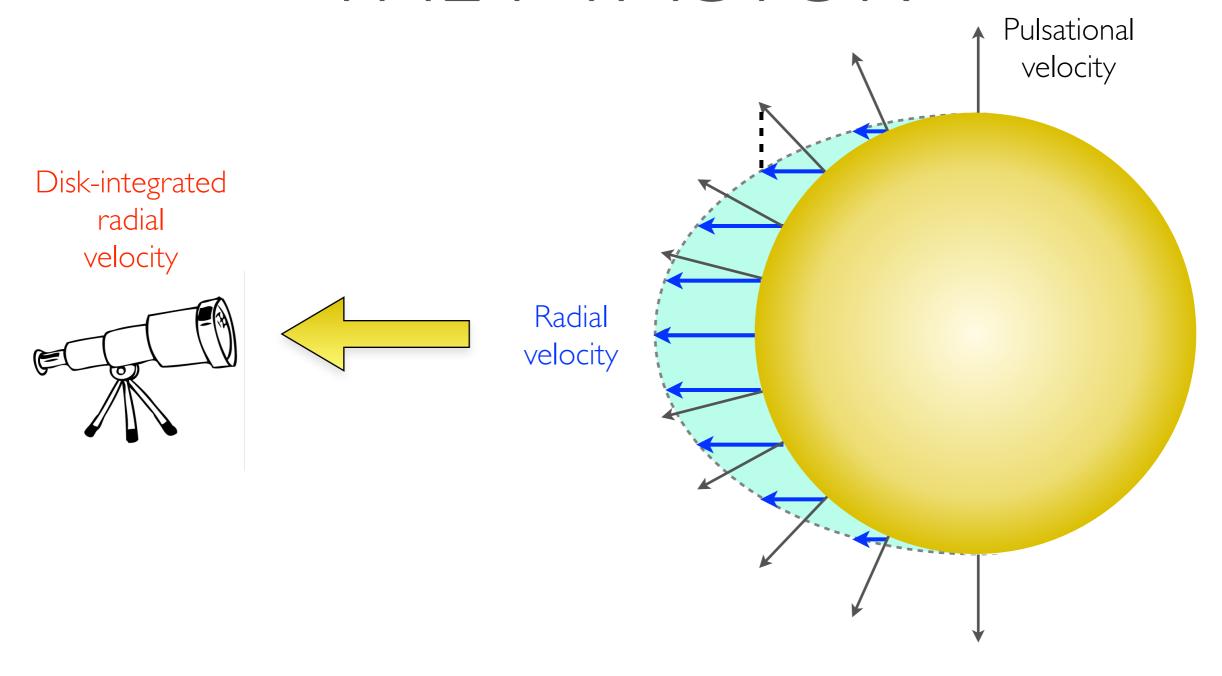
The distance d is given by the relation:

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

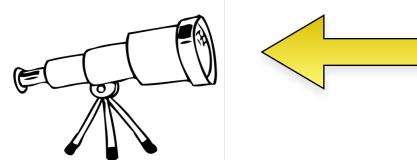
k = limb darkening correction (from models)

$$= \theta_{UD} / \theta_{LD}$$

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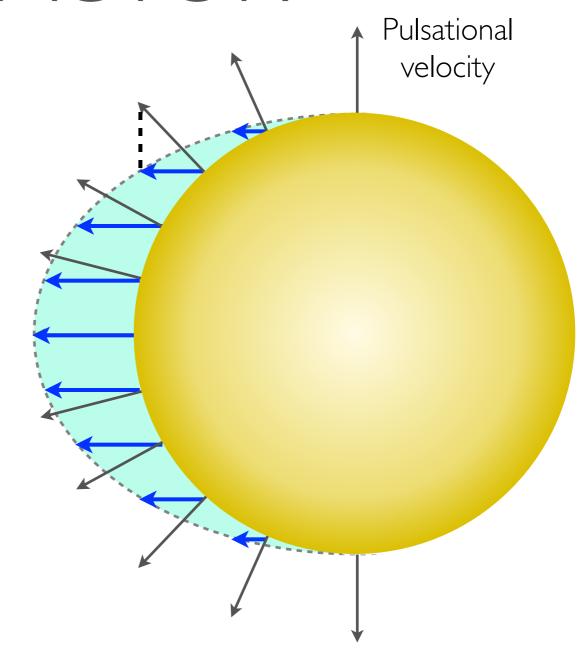
Disk-integrated radial velocity



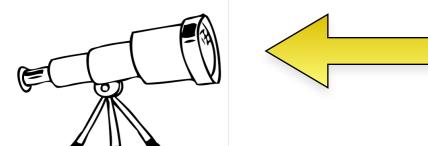
Radial velocity



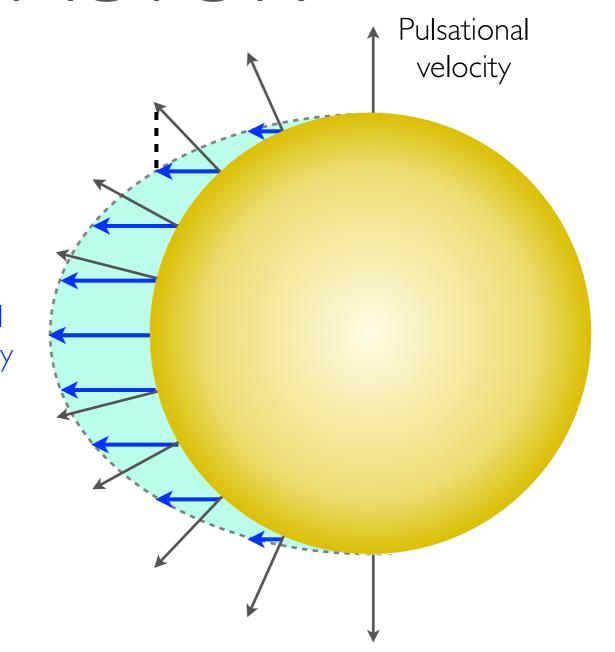
- Limb darkening component < I
- Atmosphere dynamics = ?



Disk-integrated radial velocity



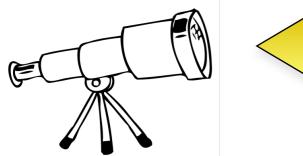
Radial velocity



- Geometrical component = 1.5
- Limb darkening component < I
- Atmosphere dynamics = ?

 $p \sim 1.39 - 0.03 \log P$  from stellar atmosphere models (Hindsley & Bell 1986, PASP, 98, 881)

Disk-integrated radial velocity

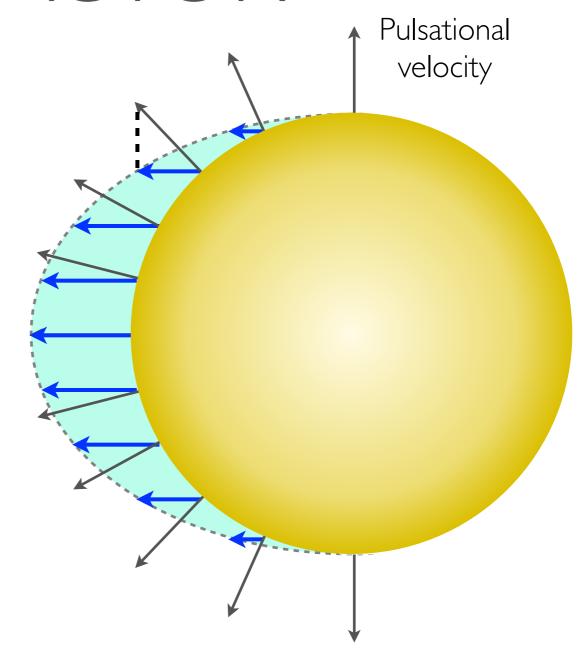




Radial velocity

- Geometrical component = 1.5
- Limb darkening component < I</li>
- Atmosphere dynamics = ?

 $p \sim 1.39 - 0.03 \log P$  from stellar atr (Hindsley & Bell 1986, PASP, 98, 881)



Main limitation for BW Cepheid distances

 $\ell$  Car p=1.403 d=497.5pc E(B-V)=0.134 0.0 0.2 0.4 0.6 8.0 1.0 0.2 0.4 0.6 8.0 1.0 model Bersier+ 2002 model  $\chi^2 = 6.28$ Spline Nodes 20l Peterson+ 2004 5.2  $\bigcirc$  $V_{\gamma} = 3.90 \text{ km/s}$ Taylor+ 1997 Effective temperature  $\mathsf{T}_{\mathrm{eff}}$  (1e3 | 5.0 Anderson+ 15 4.8 10 velocity (km/s) 4.6 (c) -2.6 =3.70 Pel+ 1976  $\chi^2 = 4.72$ Berdnikov+ 2002 Madore+ 1975 4.0 -3.0 3.6 -10Radial velocity V\_GCPD V W -153.2  $\chi^2 = 3.74$ Laney+ 1992 Laney+ 1992  $\chi^2 = 1.33$ 1.3 1.8 J\_CTIO 1.1 **H\_CTIO** 3.2 1.6  $\chi^2 = 3.30$ Pel+ 1976  $\chi^2 = 6.28$ Laney+ 1992 1.3 Ang. diam. (mas) 1.6 3.0 1.4 1.1 Angular size 1.2 **BW** -K\_CTIO (interferometry) 0.9 h 0.0 0.2 0.4 0.6 8.0 1.6 Berdnikov+ 2002  $\chi^2 = 4.62$  $UD_{2.16um}$ ->LD  $\chi^2$  =4.4 2.6 **Photometry** Madore+ 1975  $UD_{1.65\mu m}$ ->LD  $\chi^2$  =0.9 Ŧ 1.4  $\mathrm{UD}_{0.7\mu m}\text{->LD}\ \chi^2=\text{1.1}$ Mérand et al. 2015, A&A, 1.2 submitted GCPD - $\mathsf{n}_\sigma$ V GCPD Breitfelder et al. 2015, A&A, 1.0 in prep. 0.0 0.2 0.4 0.6 0.8 1.0 0.0 0.2 0.4 0.6 0.8 pulsation phase pulsation phase

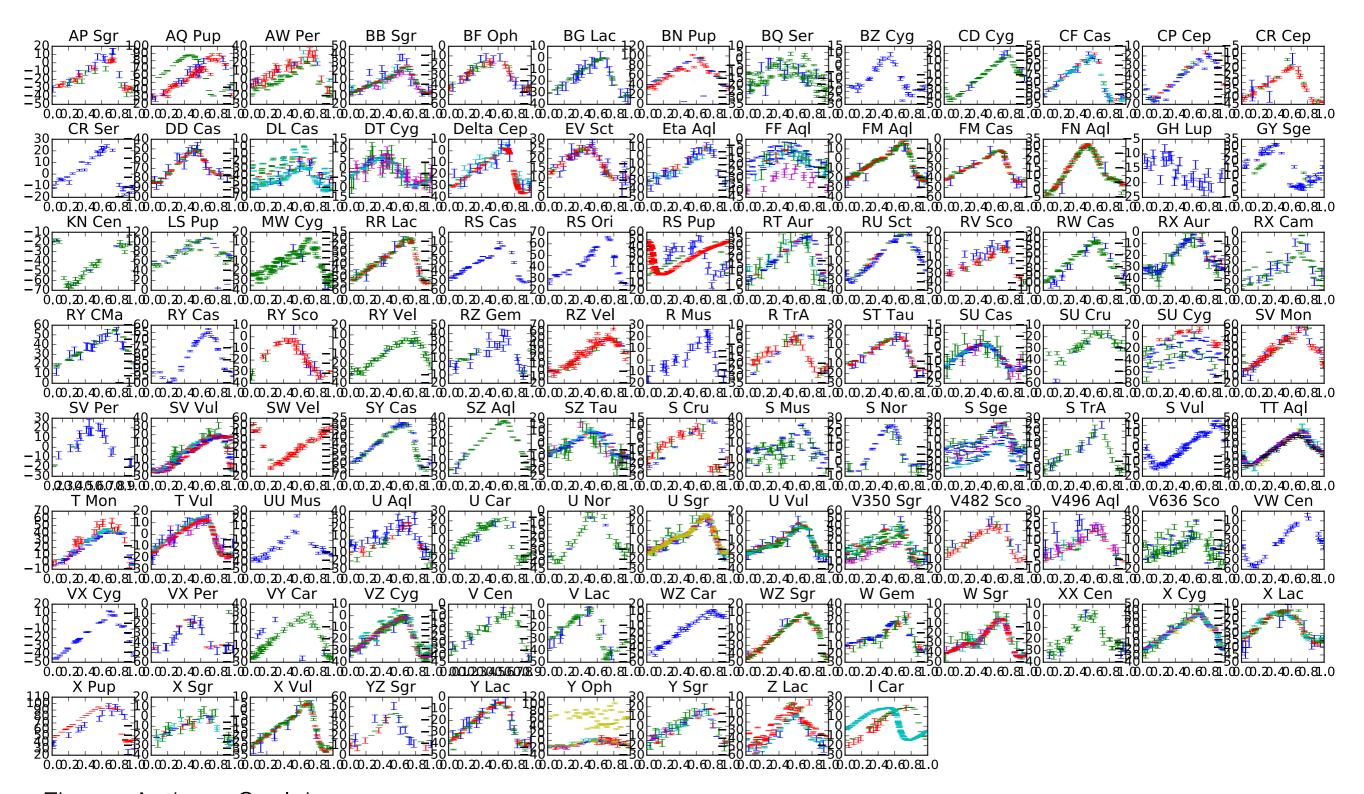
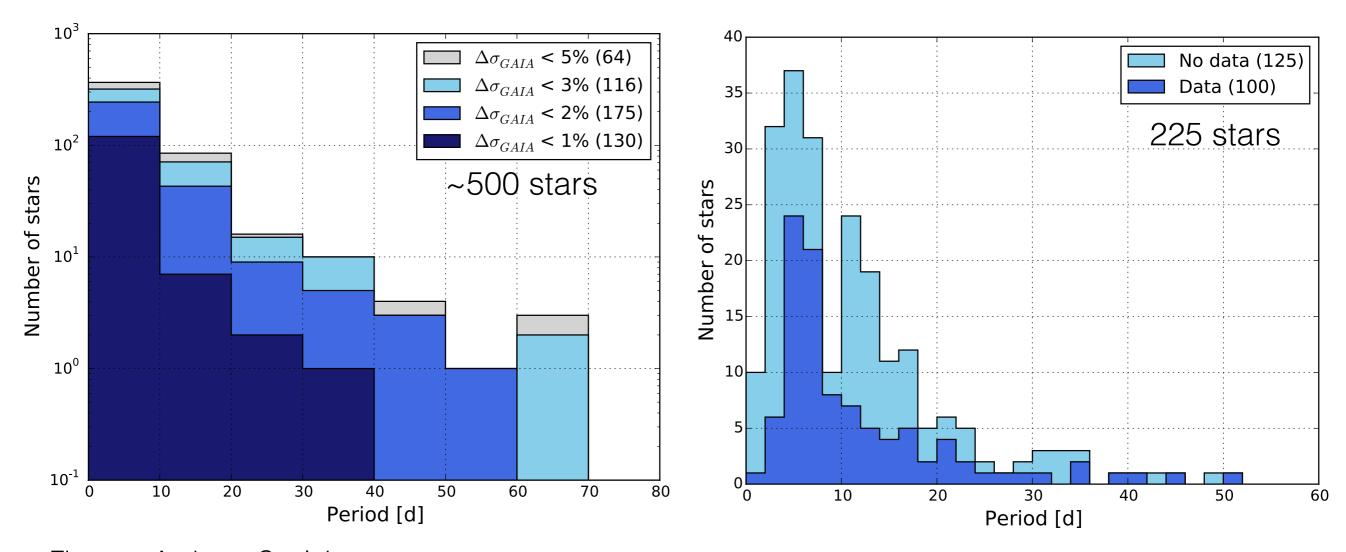


Figure: Anthony Soulain

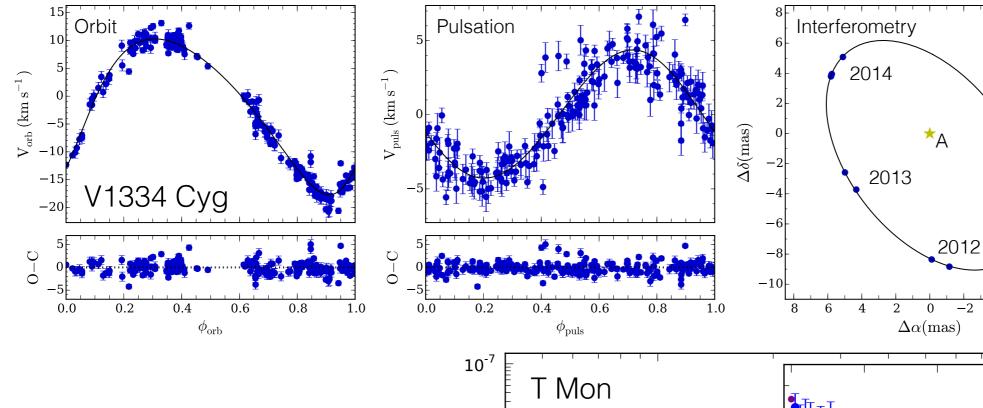
#### Gaia parallaxes of Galactic Cepheids



Figures: Anthony Soulain

### Binary Cepheids

Gallenne et al. 2013, A&A + A&A in prep.



# Circumstellar envelopes

Gallenne et al. 2013, A&A.

