A new study of Cepheids p-factor : application on κ Pav and RS Pup

Advisors

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1. Measuring distances : why and how?

2. Cepheids and the parallax-of-pulsation method

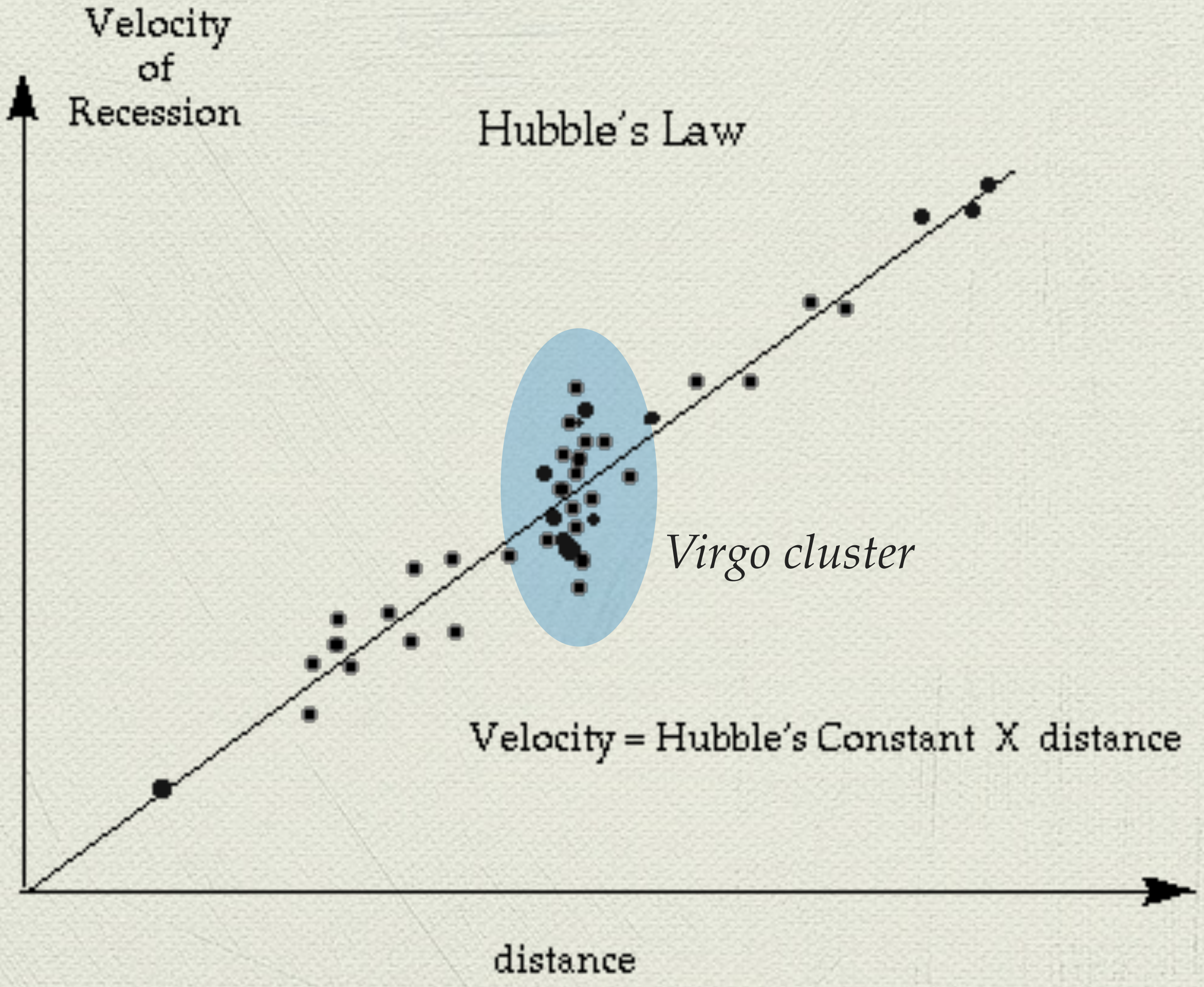
3. The projection factor

4. two examples : kappa Pav and RS Pup

5. and after?

Measuring distances : why ?

1929 : E. Hubble discovers the expansion of the Universe $v = H_0 \cdot d$



Measuring distances : why ?

H_0

- It represents the
- Gives the age of the Universe
- Constrains the values of cosmological parameters

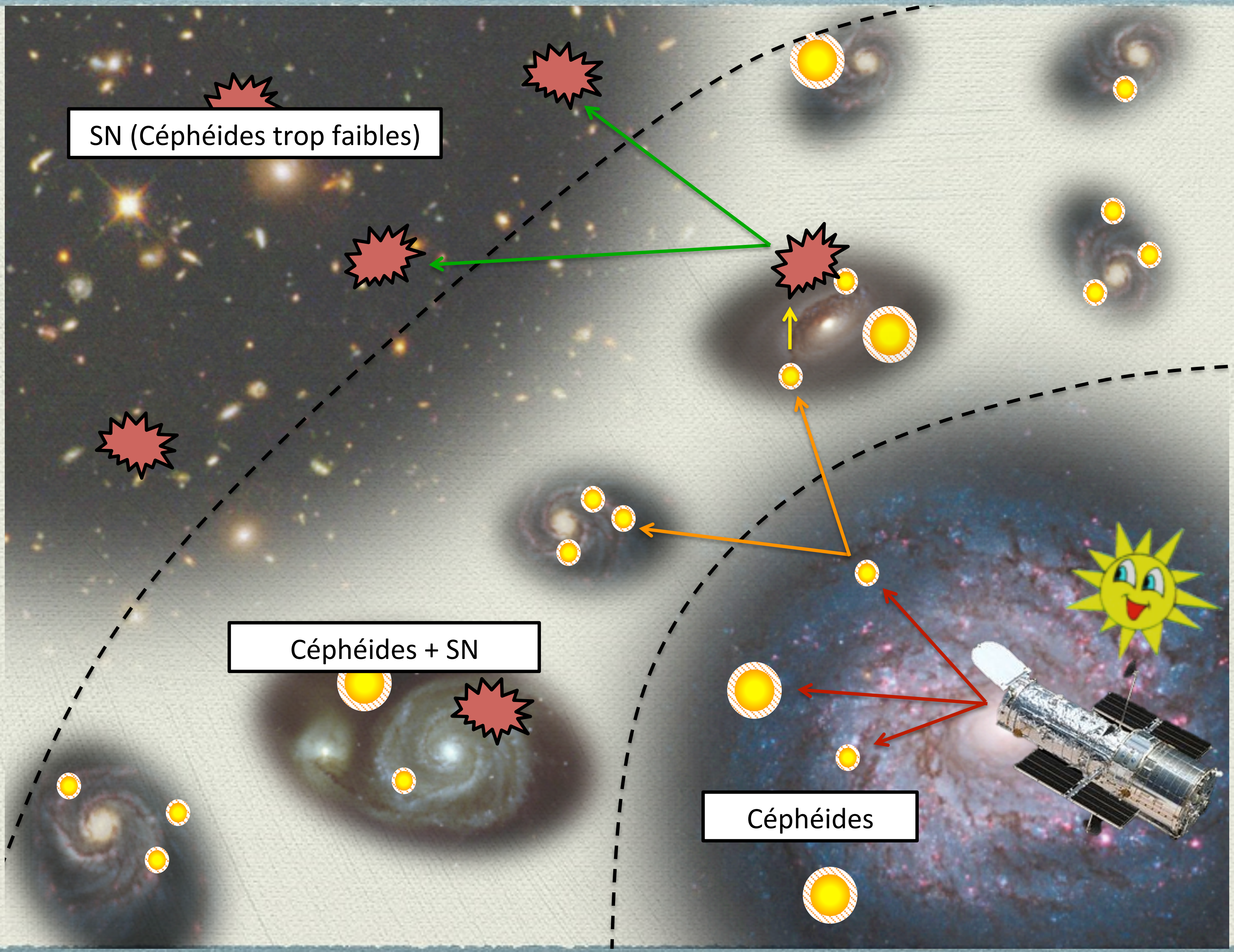
➙ But we need to reach the

State of the art : 3.1% measurement
from Riess et al. (2011)

Nobel Price 2011 to Riess, Perlumutter and Schmidt for the acceleration of the expansion

How to reach the Hubble Flow ?

...By building a “cosmic scale”



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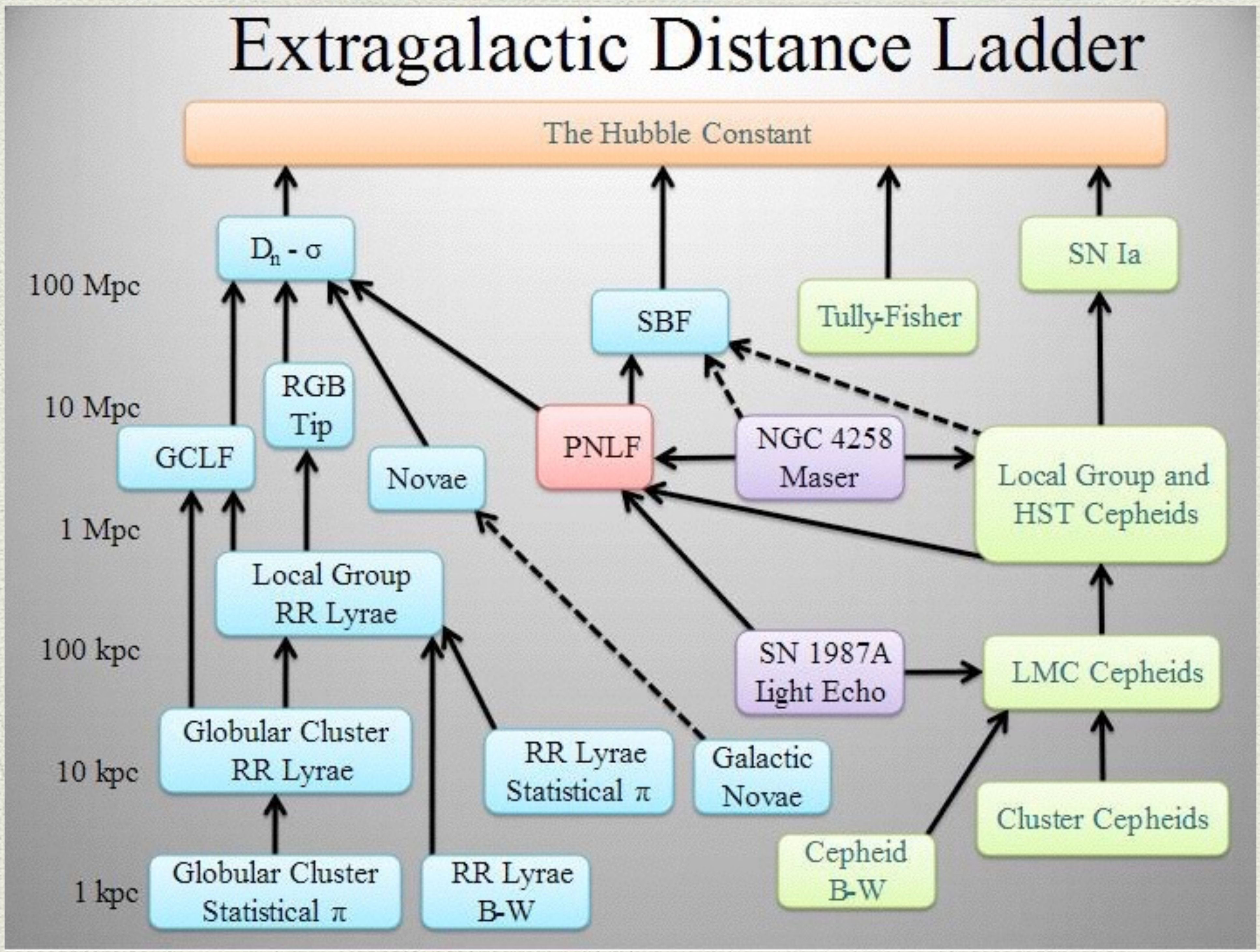

How to reach the Hubble Flow ?

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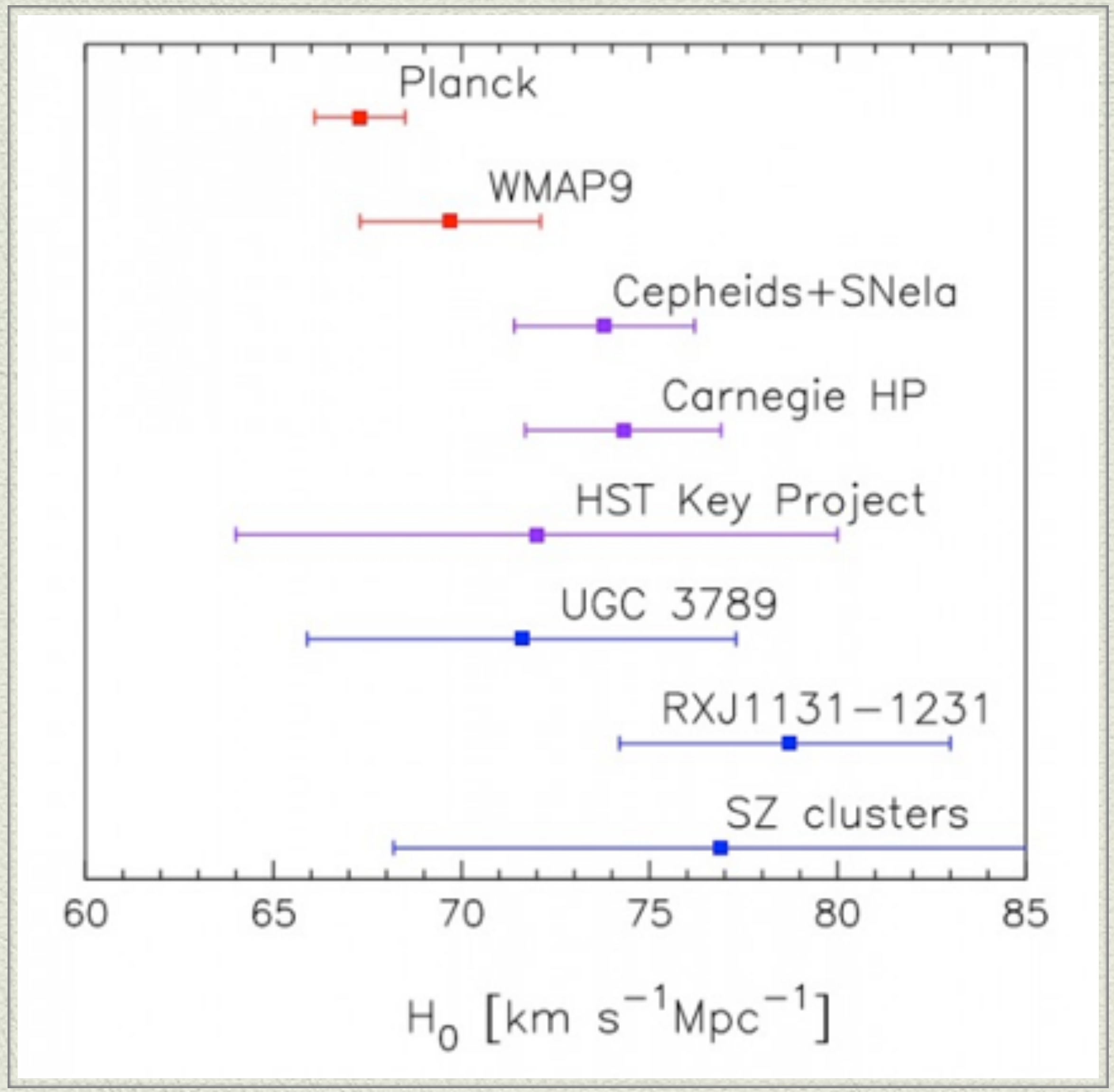

Planck Collaboration (Ade et al. 2013)

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Cepheids as standart candles

Cepheids

1912

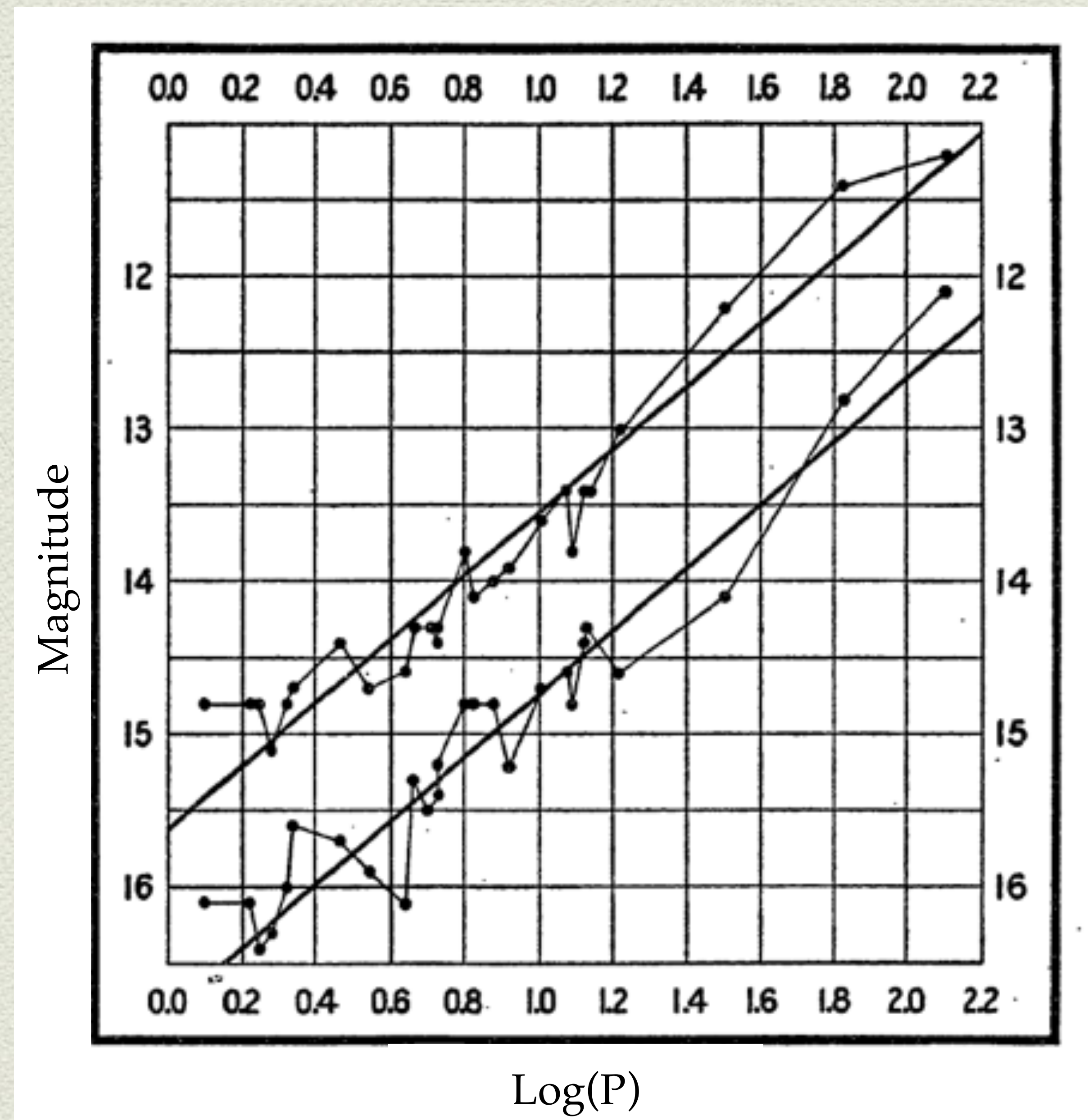
$$M = a \log P + b$$

Zero-point b ?

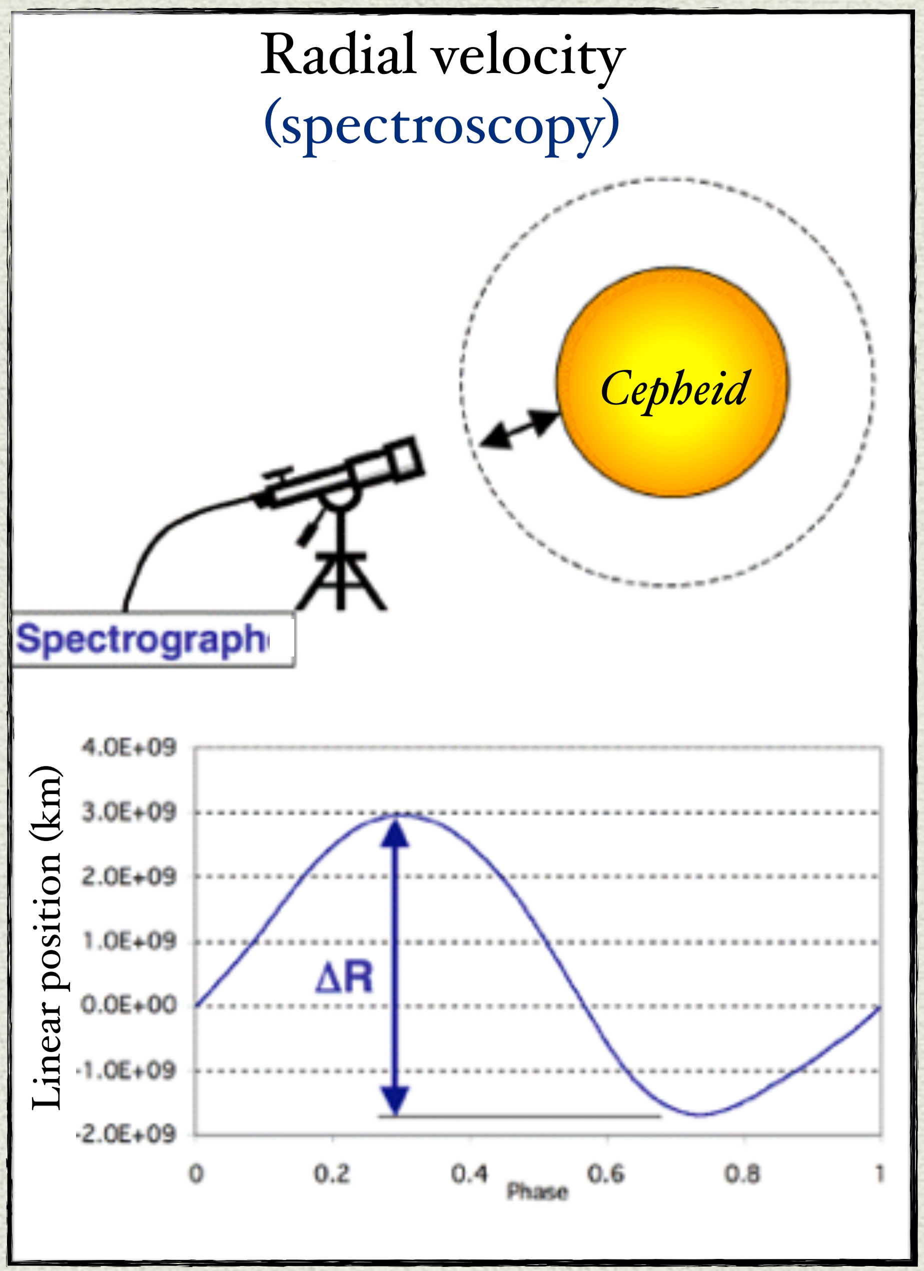
Slope a : Cepheids in the Magellanic clouds

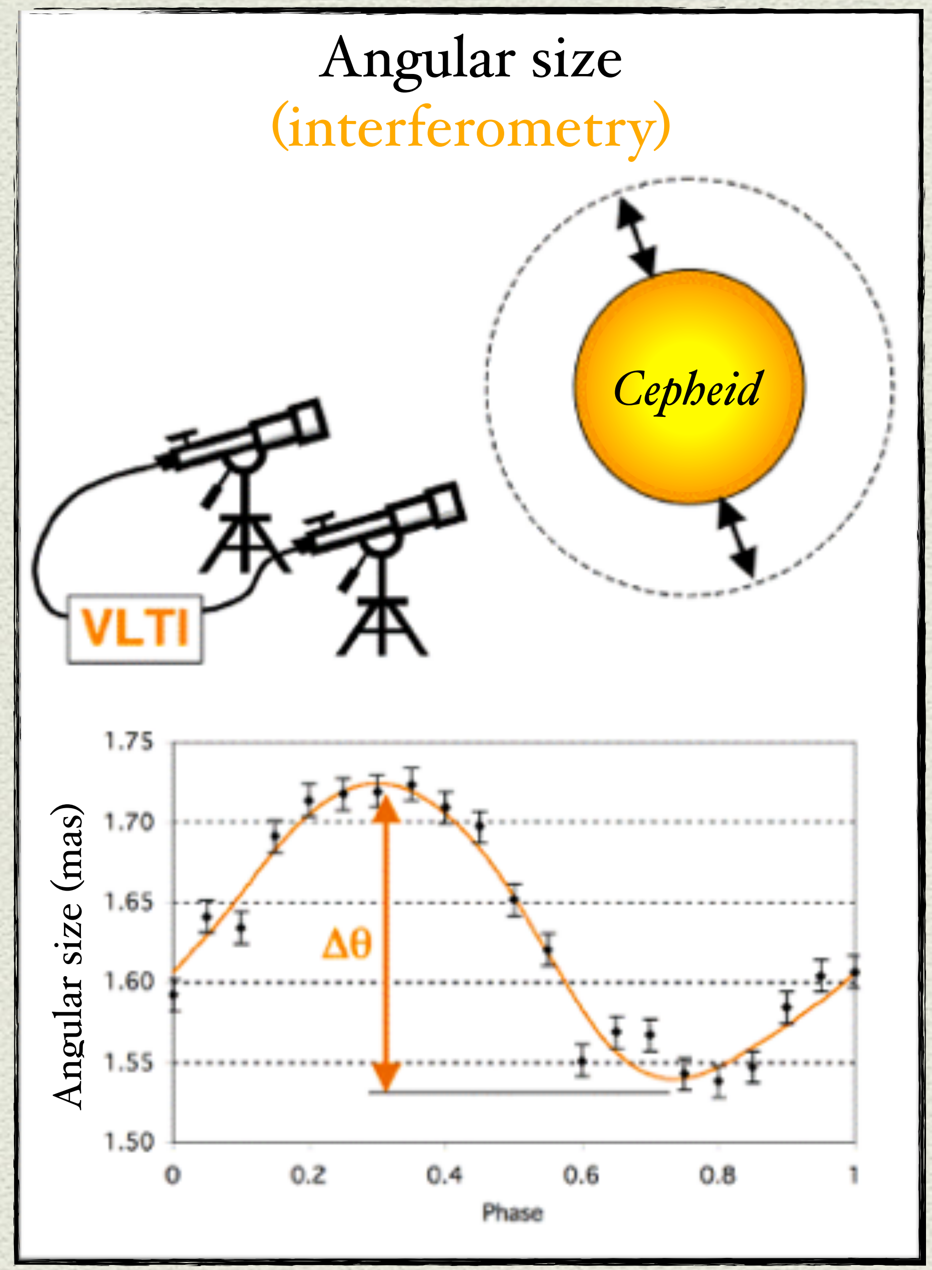
Need of

→ Parallax, light echoes, binary systems...



The Interferometric Parallax-of-Pulsation



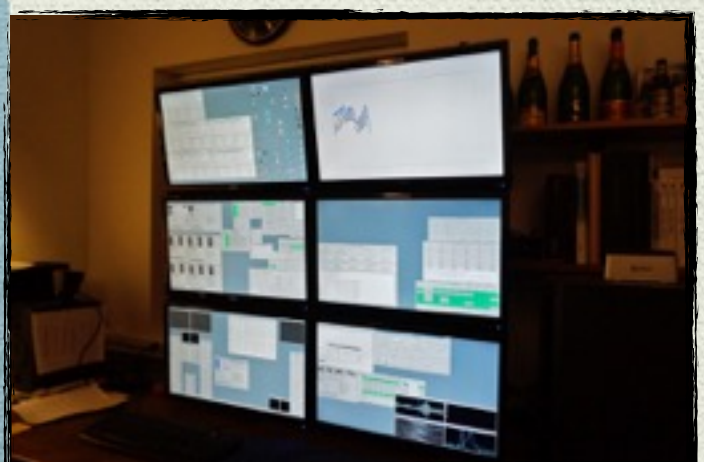


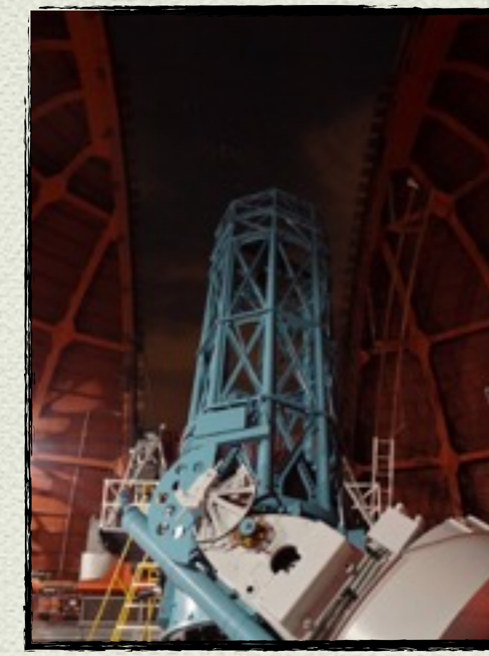
ΔR and $\Delta\theta$ are the **linear** and **angular** variations of diameter : $d \propto \dfrac{\Delta R}{\Delta \theta}$

Interferometric data

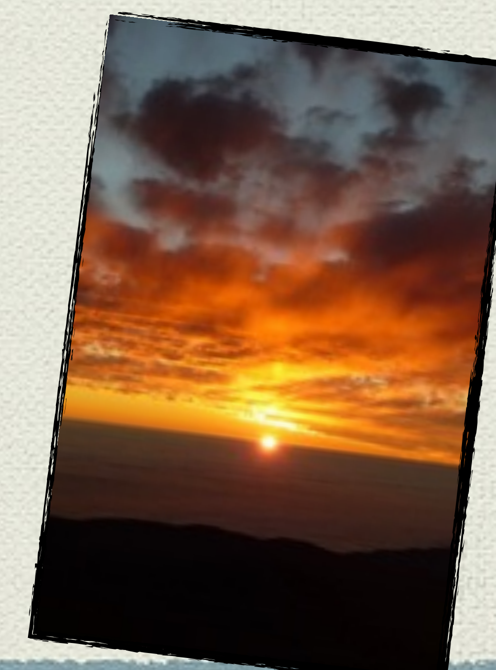
Large observing program in both hemispheres

- CHARA (Mont Wilson observatory - California)





- VLTI (Cerro Paranal - Chile) - PIONIER



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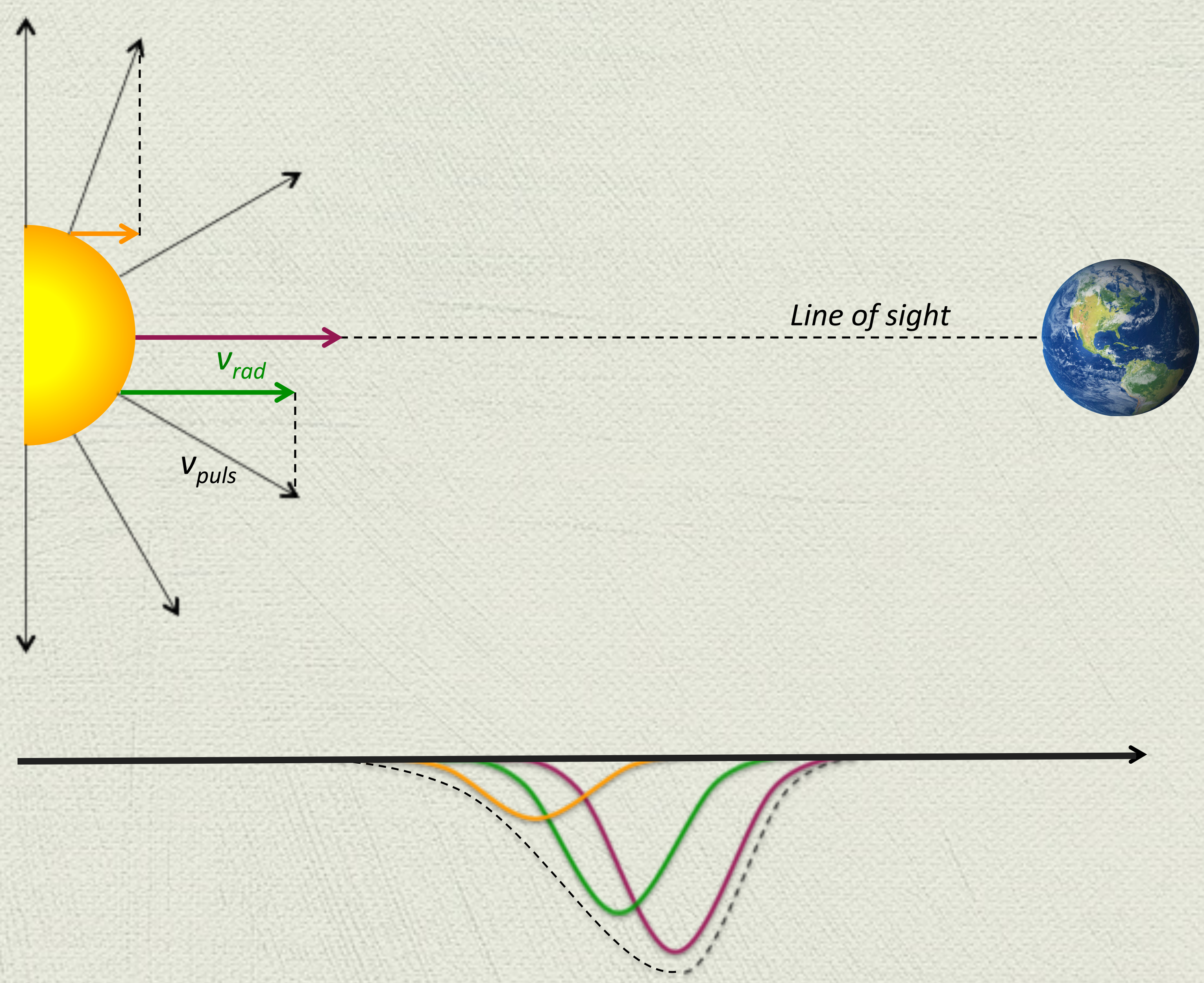
The projection factor

Main limitation of the parallax-of-pulsation method



$$V_{puls} = p.V_{rad}$$

p includes :

- Geometry
- Limb-darkening
- Atmospherical effects
- Way of deriving the Vrad
- ...

Tricky parameter !

The projection factor

Main limitation of the parallax-of-pulsation method

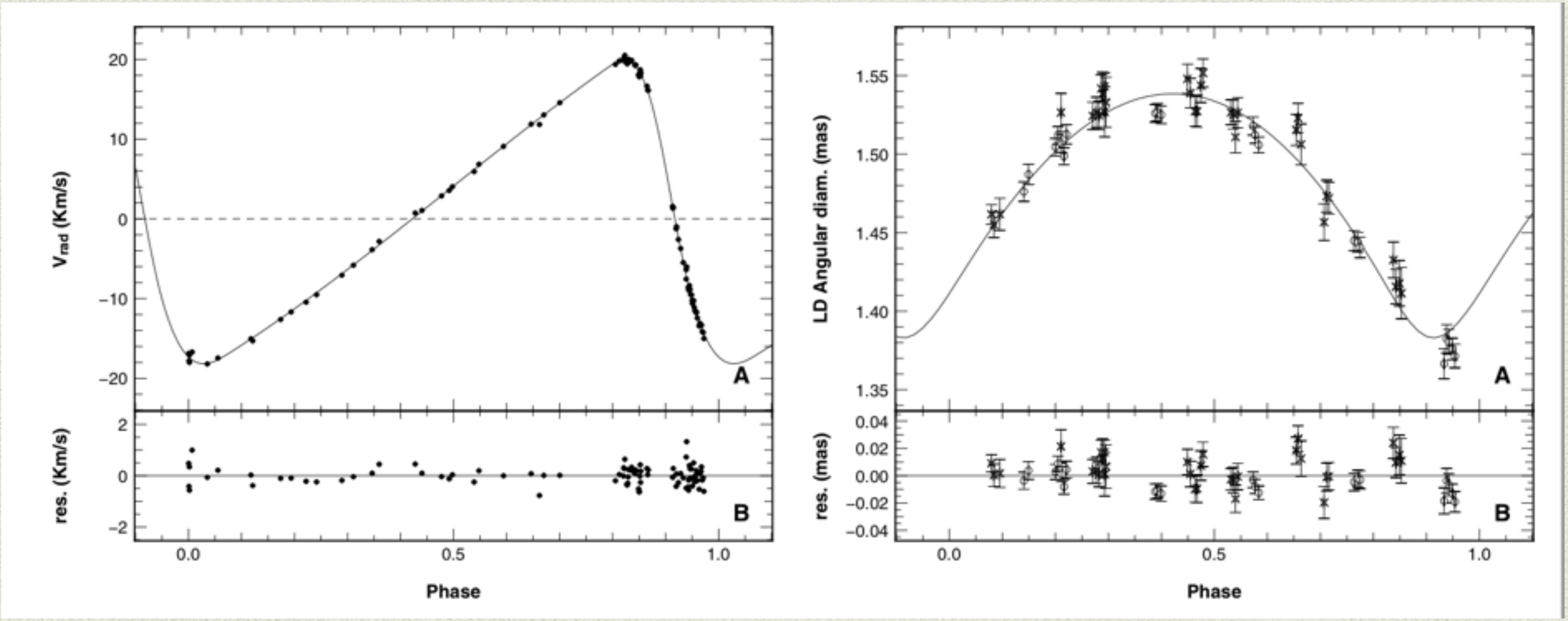
Main equation of the parallax-of-pulsation (PoP) method :

$$\theta(T) - \theta(0) = -2\frac{p}{d}\int_0^T \left(V_{\mathrm{rad.}}(t) - V_\gamma\right) \mathrm{d}t$$

- Degeneration between *p* and the distance
- Dispersion of the values in the literature : 10% !
- If we know the distance, we can measure the *p*-factor *via* an invert use of the PoP method

Observationnal values of the p-factor :

First result on Delta Cep (Merand et al. 2005)



The 4% *HST* parallax measurement of Benedict et al. 2002 leads to a p-factor of **p = 1.27 +/- 0.06**

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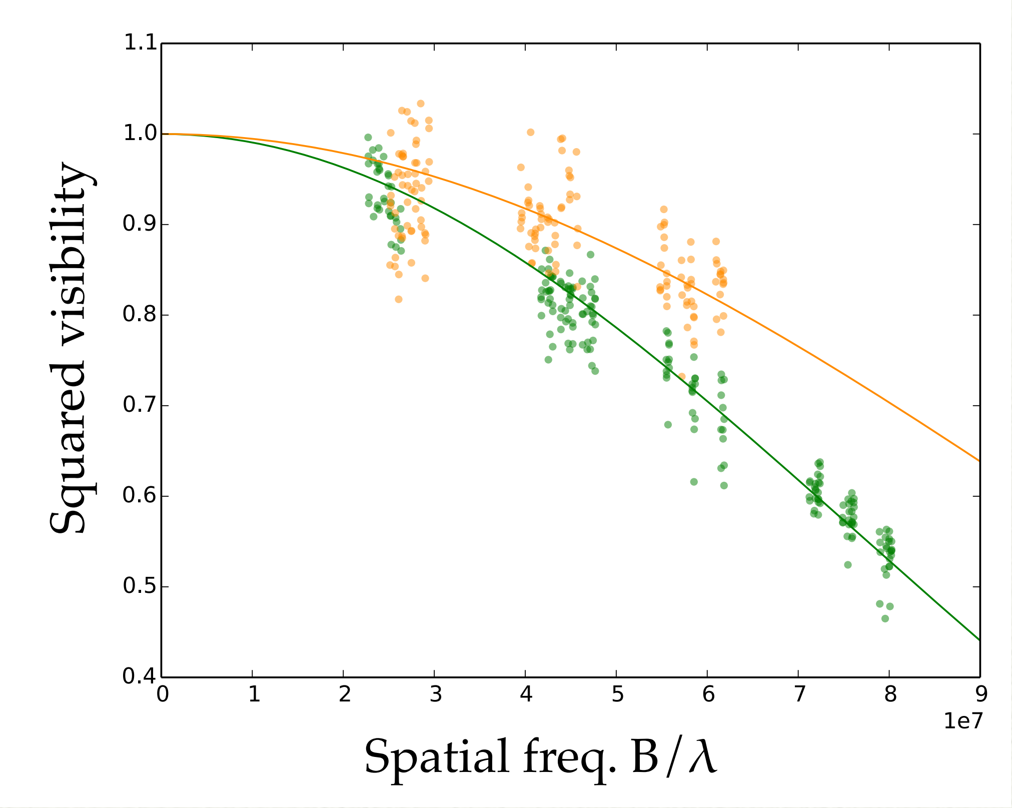
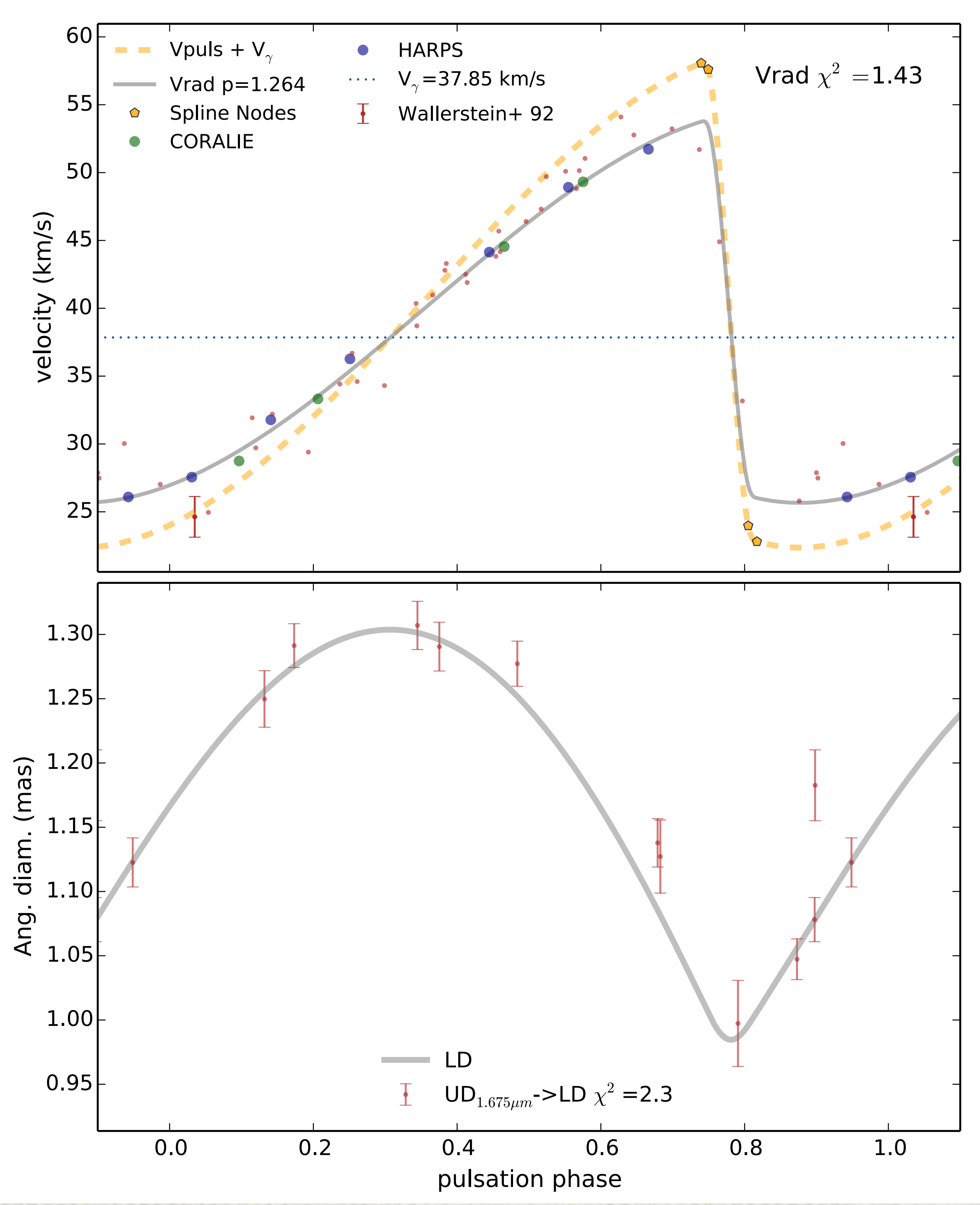
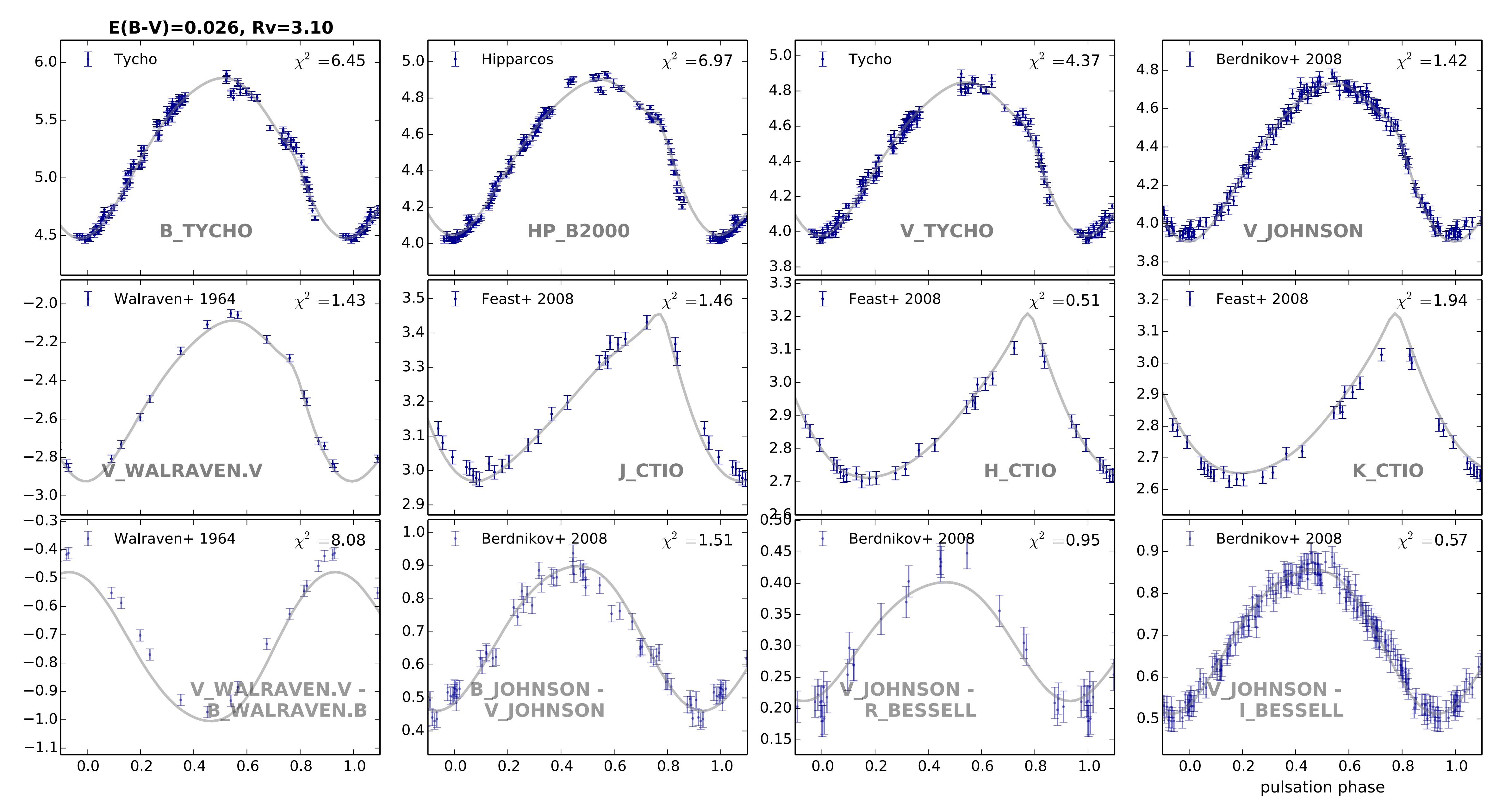
Application on the type II Cepheid kappa Pavonis

- Low metallicity
- Representant of the galactic halo
- Irregular variations in the pulsation period
- 5% parallax measurement from the *HST*



12 diameter measurements
obtained with PIONIER





The 5% *HST* parallax (Benedict et al. 2011) leads to ***p* = 1.267 +/- 0.072** (Breitfelder et al. 2014).

<u>We checked as well :</u>
- A small K excess
  (CSE detected by Gallenne et al. 2012)
- No obvious signal of a companion
  (although predicted in precedent studies)

Parameter	Value	$\sigma_{stat.}$	$\sigma_{sys.}$
p-factor	1.26	0.04	0.06
θ (UD) at $\phi = 0$ (mas)	1.1654	0.0025	0.014
Avg. θ (UD) (mas)	1.1823	0.0021	0.014
v_γ (km/s)	37.87	0.18	0.50
$E(B-V)$ (mag)	0.02	0.01	0.04
Avg. T_{eff} (K)	5739	9	107
Avg. radius ($R_\odot$)	22.83	0.04	1.14
Final reduced χ^2	2.62		

The projection factor

RS Pup and the light echoes...

- Cepheid in a reflecting nebula
- Propagation of light echoes
- Long period (~41.5 days)

HST/ACS color composite image of RS Pup

The projection factor

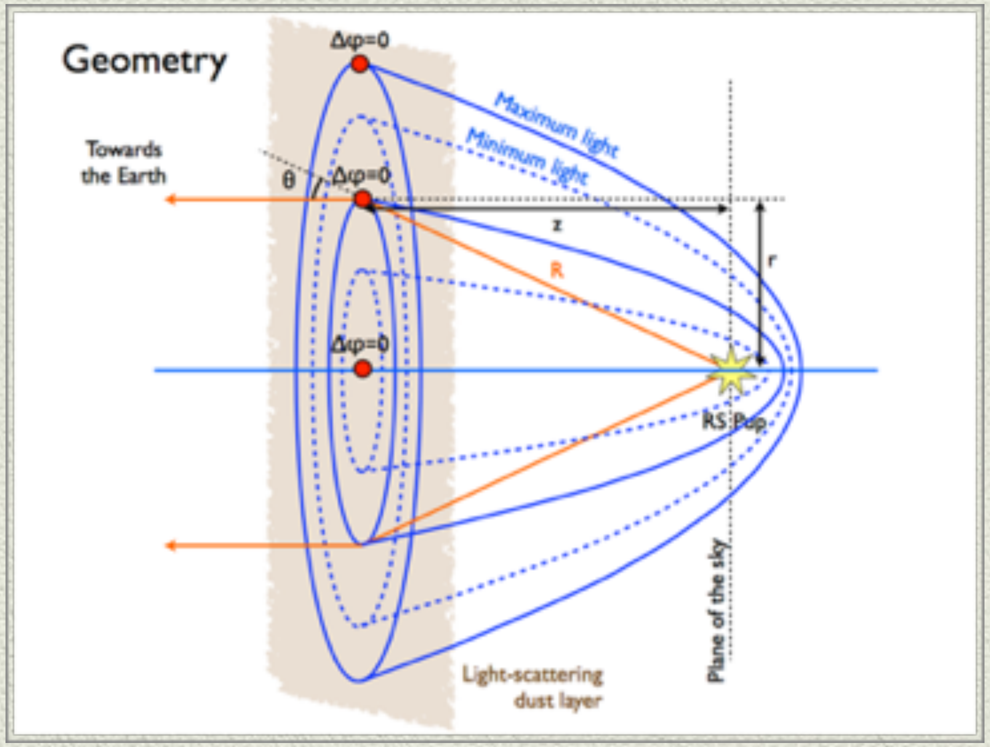
RS Pup and the light echoes...

The projection factor

RS Pup and the light echoes...

The distance can be derived from the light echoes,
but **only if we know the geometry of the scattering material**

- Polarimetric imaging from the HST ➙ Degree of linear polarization
- Degree of linear polarization ➙ Scattering angle
- Scattering angle ➙ Geometry of the nebula



d = 1910 +/- 80 pc (Kervella et al., 2014)

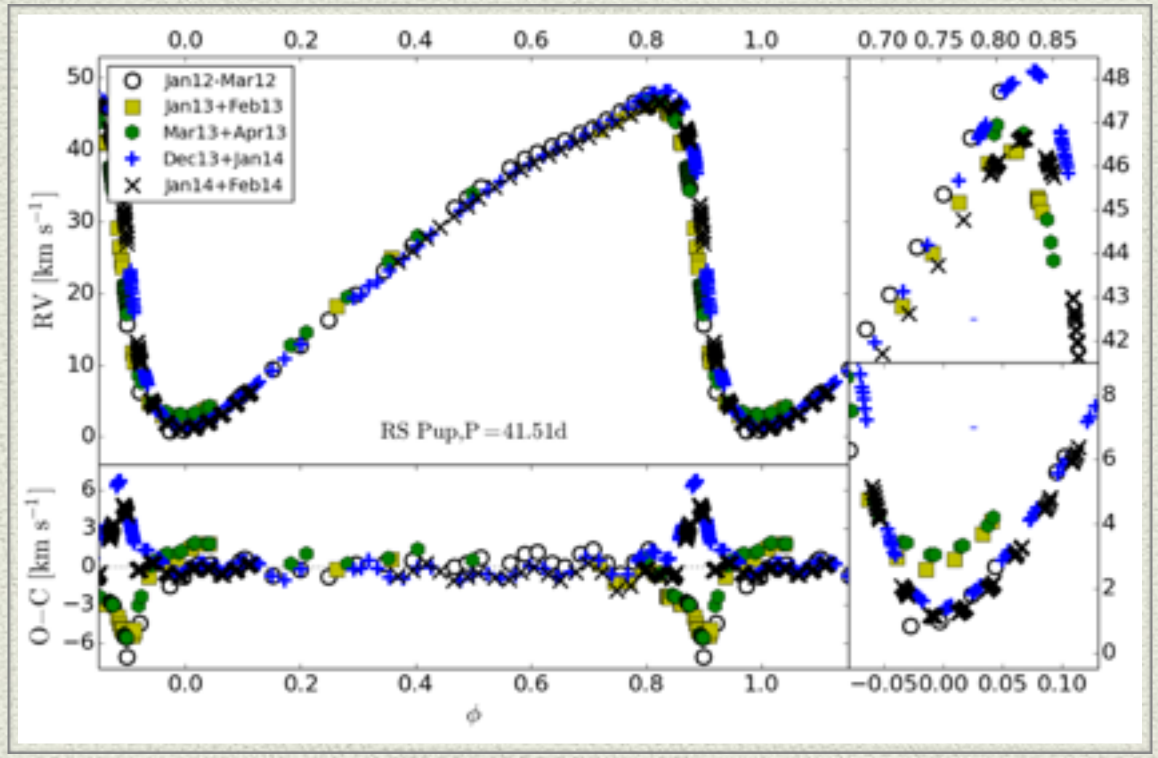
The projection factor

RS Pup and the light echoes...

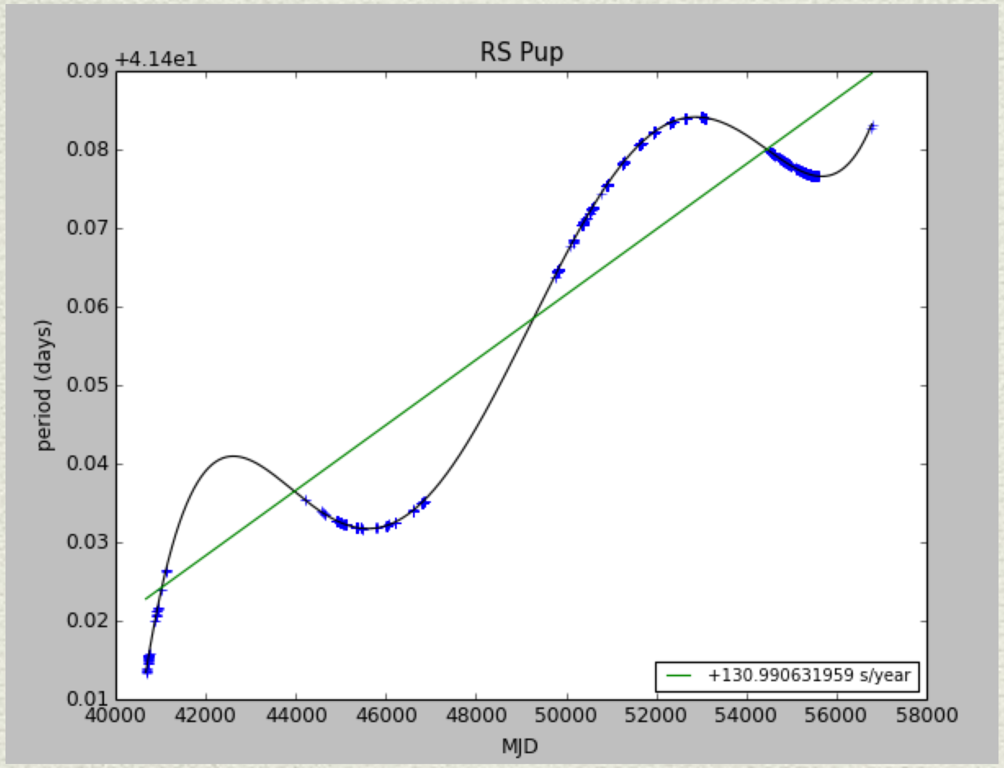
Now that we know the distance, we can derive the p-factor !

More complicated that what we thought :

- Amplitude variations in the radial velocity curve
- Tricky period variations (over 40 years of data!)



Cycle-to-cycle amplitude variations
(Anderson 2014)



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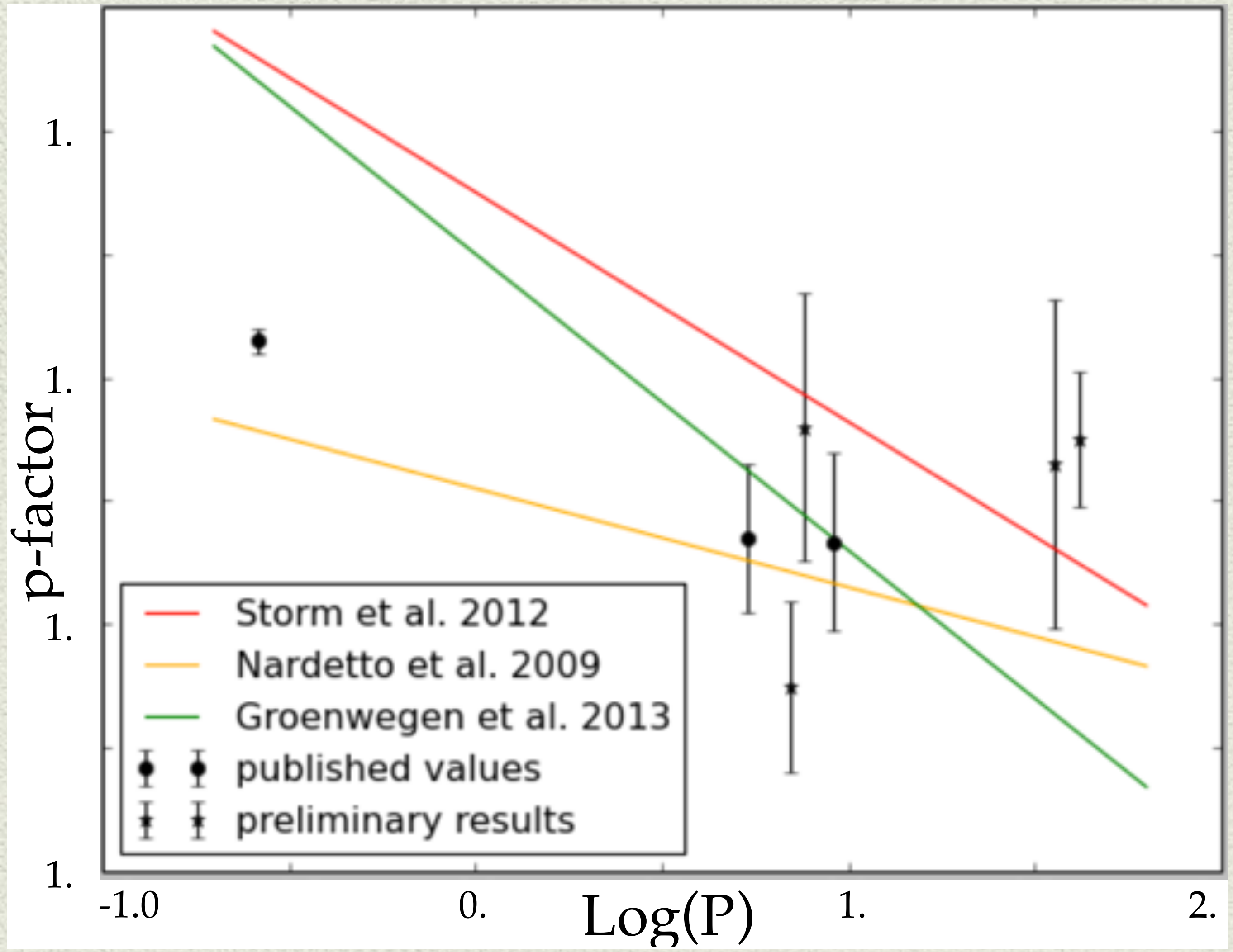
Next step :
Measuring the p-factor of a larger sample of Cepheids



- Observational values important to help constraining models
- A lots of values will allow us to study the dependancies of the *p*-factor
- Cepheids with an *HST* parallax (~10), and in a near future *GAIA*

Thanks for your attention!

Questions ?