THE CEPHEID LEAVITT LAW FROM GAIA DR2 PARALLAXES OF RESOLVED COMPANIONS

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Araucaria PROJECT

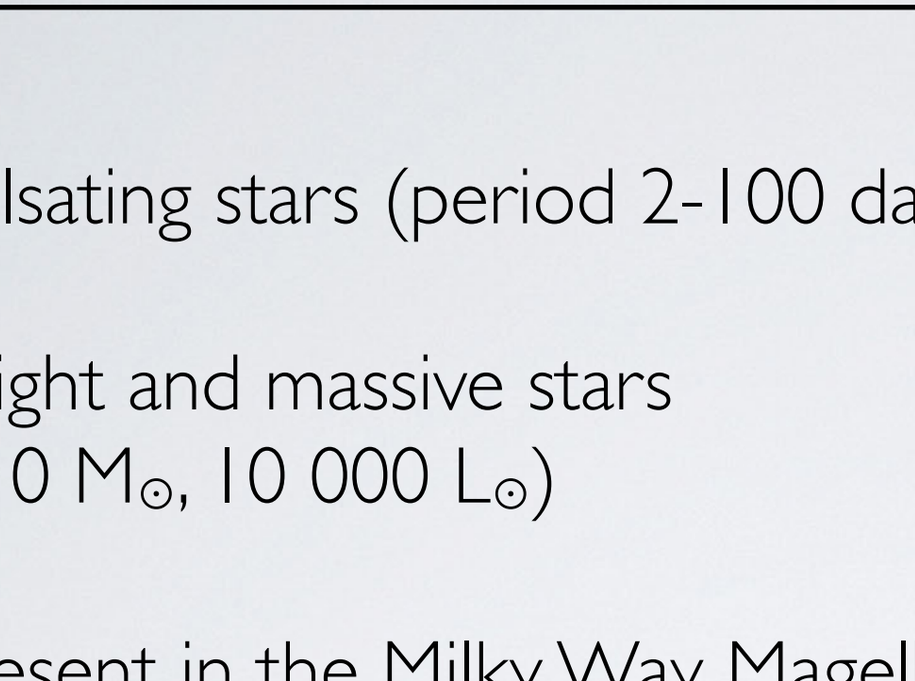
CEPHEIDS

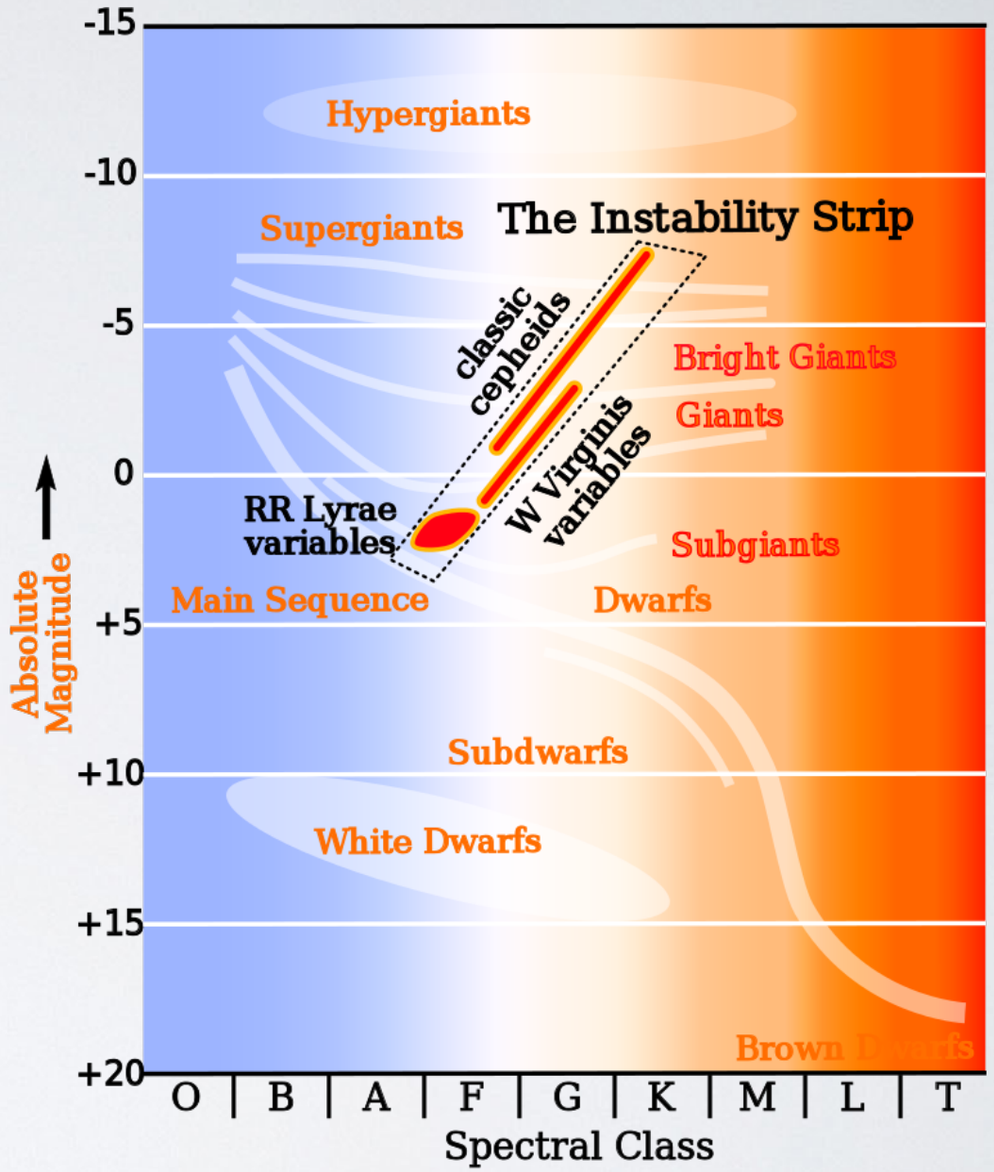
CEPHEIDS

★ Pulsating stars (period 2-100 days)

★ Bright and massive stars
(~10 $M_\odot$, 10 000 $L_\odot$)

★ Present in the Milky Way, Magellanic Clouds, and in distant galaxies



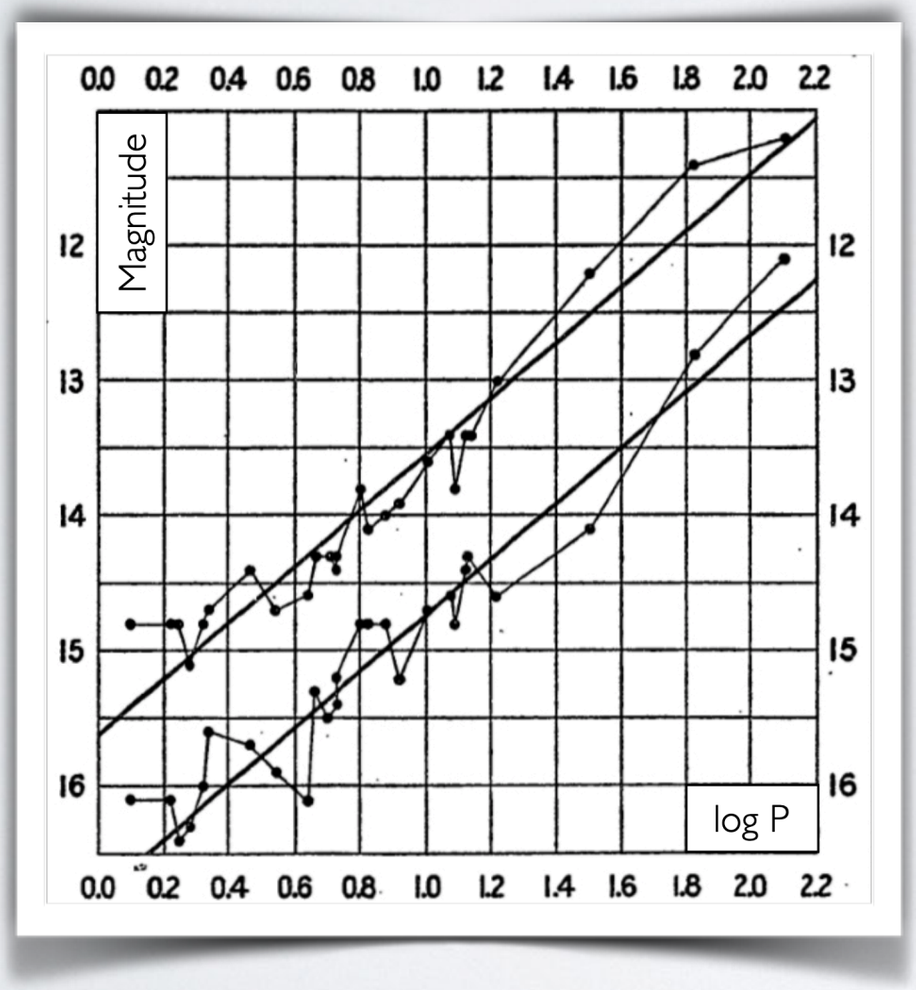


Instability strip in the HR diagram

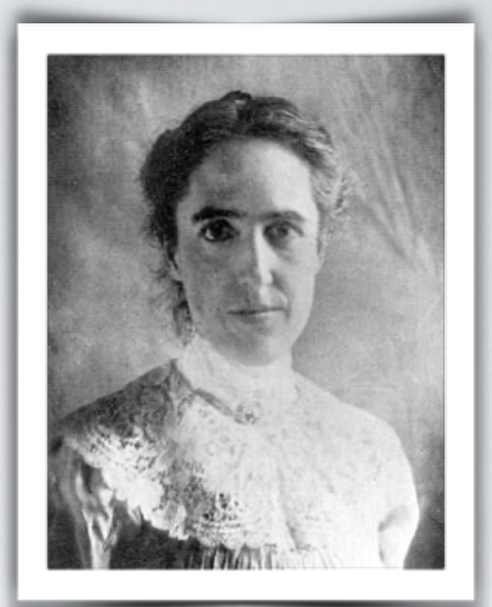
CEPHEIDS

★ 1908 : Henrietta Leavitt discovers that the pulsation **period P** of a Cepheid is linked with its **magnitude M** :

M = a log P + b



First calibration of the Leavitt law (Leavitt & Pickering 1912)



Henrietta Leavitt

My PhD topic :

→ **precise calibration** of this relation

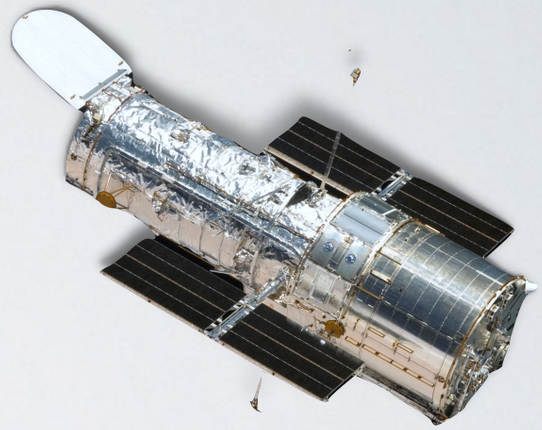
GAIA PARALLAXES

GAIA PARALLAXES OF CEPHEIDS

★ We need **very precise distances** to calibrate the PL relation

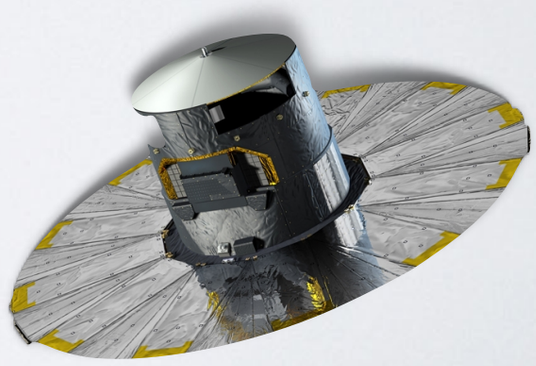
★ Over the past 20 years, only the **Hubble Space Telescope (HST)** provided Cepheid geometrical paxallaxes :

→ Freedman et al. (2001)
→ Sandage et al. (2006)
→ Benedict et al. (2002, 2007)
→ Riess et al. (2011, 2014, 2016, 2018, 2019)



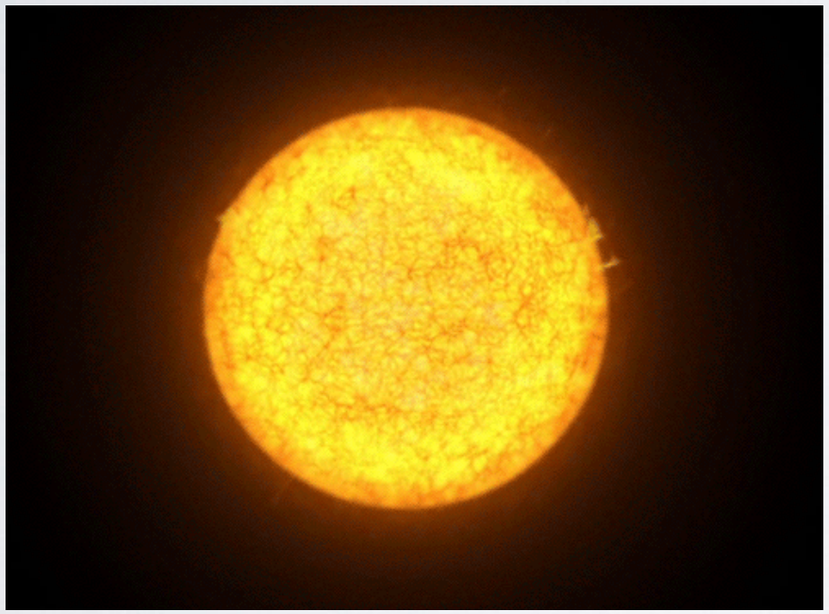
Hubble Space Telescope (NASA, ESA)

★ GAIA satellite : first alternative to HST parallaxes (1.3 billion stars)



GAIA satellite (ESA)

GAIA PARALLAXES



★ Gaia parallaxes are derived assuming that the stars have a **constant color** and a **constant brightness**.

Lindegren et al. (2018), Mowlavi et al. (2018)

→ Not made for Cepheids !

→ Astrometric bias : parallaxes of Cepheids are potentially unreliable.

GAIA PARALLAXES

★ Other independent bias :

→ uncertain parallax **zero-point** offset

ZP_{Gaia} (mas)	Reference	Type of sources
−0.029	Lindegren et al. (2018)	Quasars
$-0.031_{\pm 0.011}$	Graczyk et al. (2019)	Eclipsing binaries
$-0.0319_{\pm 0.0008}$	Arenou et al. (2018)	MW Cepheids
$-0.035_{\pm 0.016}$	Sahlholdt & Silva Aguirre (2018)	Dwarf stars
$-0.041_{\pm 0.010}$	Hall et al. (2019)	Red giants
$-0.046_{\pm 0.013}$	Riess et al. (2018b)	MW Cepheids
$-0.049_{\pm 0.018}$	Groenewegen (2018)	MW Cepheids
$-0.053_{\pm 0.003}$	Zinn et al. (2019)	Red giants
$-0.054_{\pm 0.006}$	Schönrich et al. (2019)	GDR2 RV
$-0.057_{\pm 0.003}$	Muraveva et al. (2018)	RR Lyrae
$-0.070_{\pm 0.010}$	Ripepi et al. (2019)	LMC Cepheids
$-0.082_{\pm 0.033}$	Stassun & Torres (2018)	Eclipsing binaries

Estimations of Gaia DR2 parallax zero-point offset (Breuval et al. 2019, A&A, submitted)

CALIBRATION OF THE P-L RELATION

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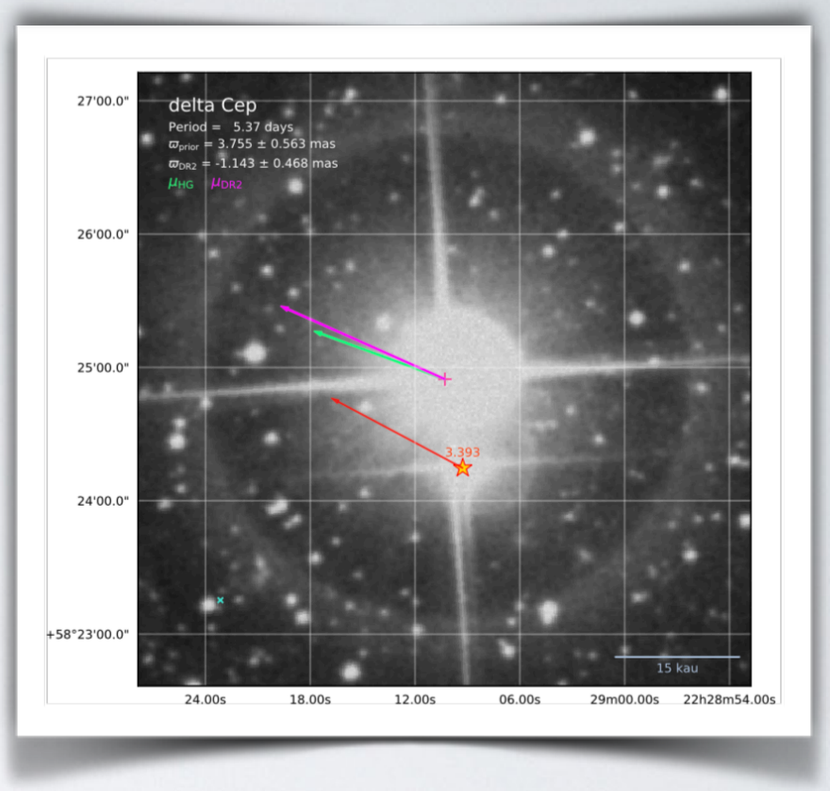
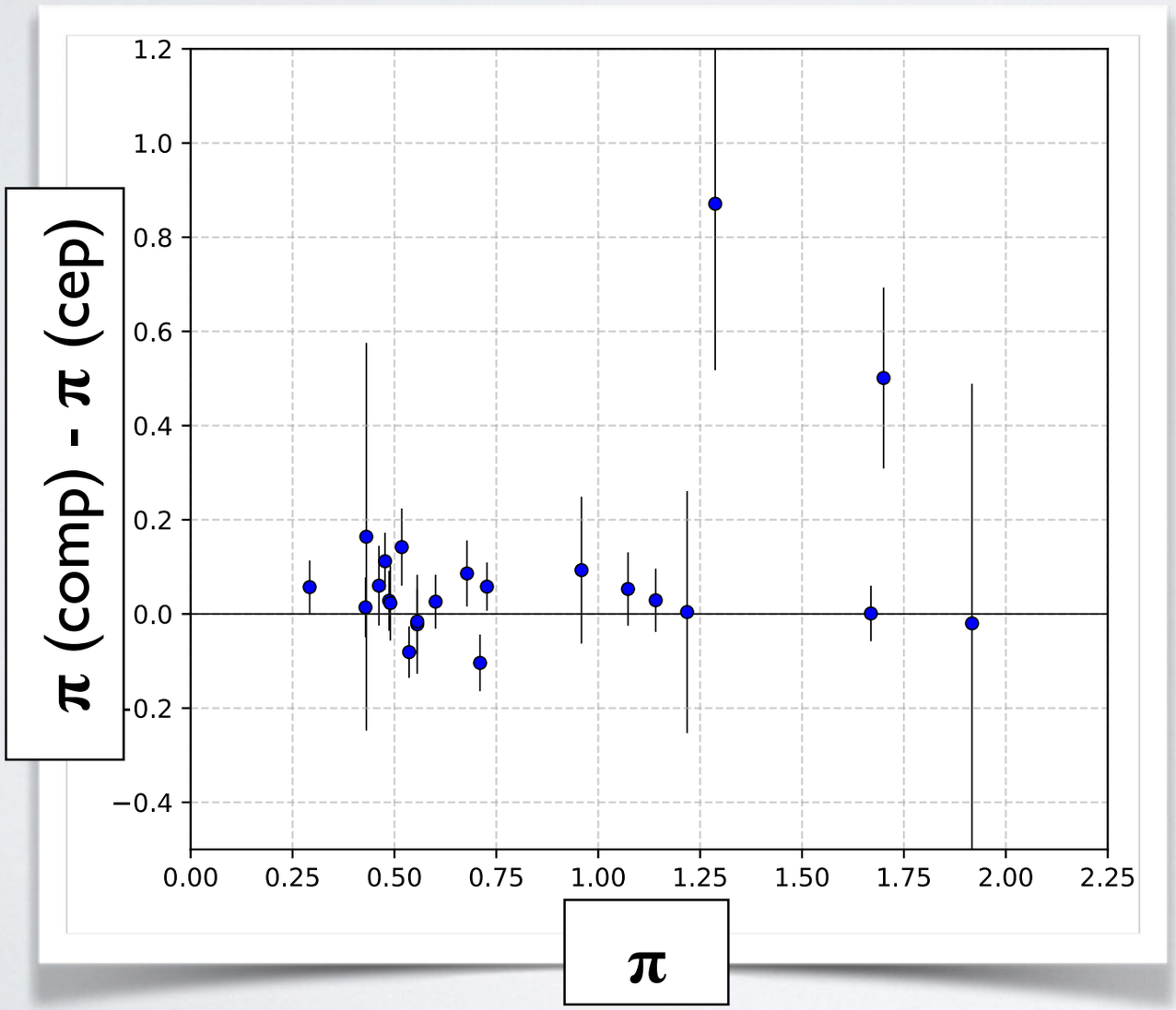
★ 23 Milky Way Cepheids with close-in **resolved** companions.
(Kervella et al. 2019b)



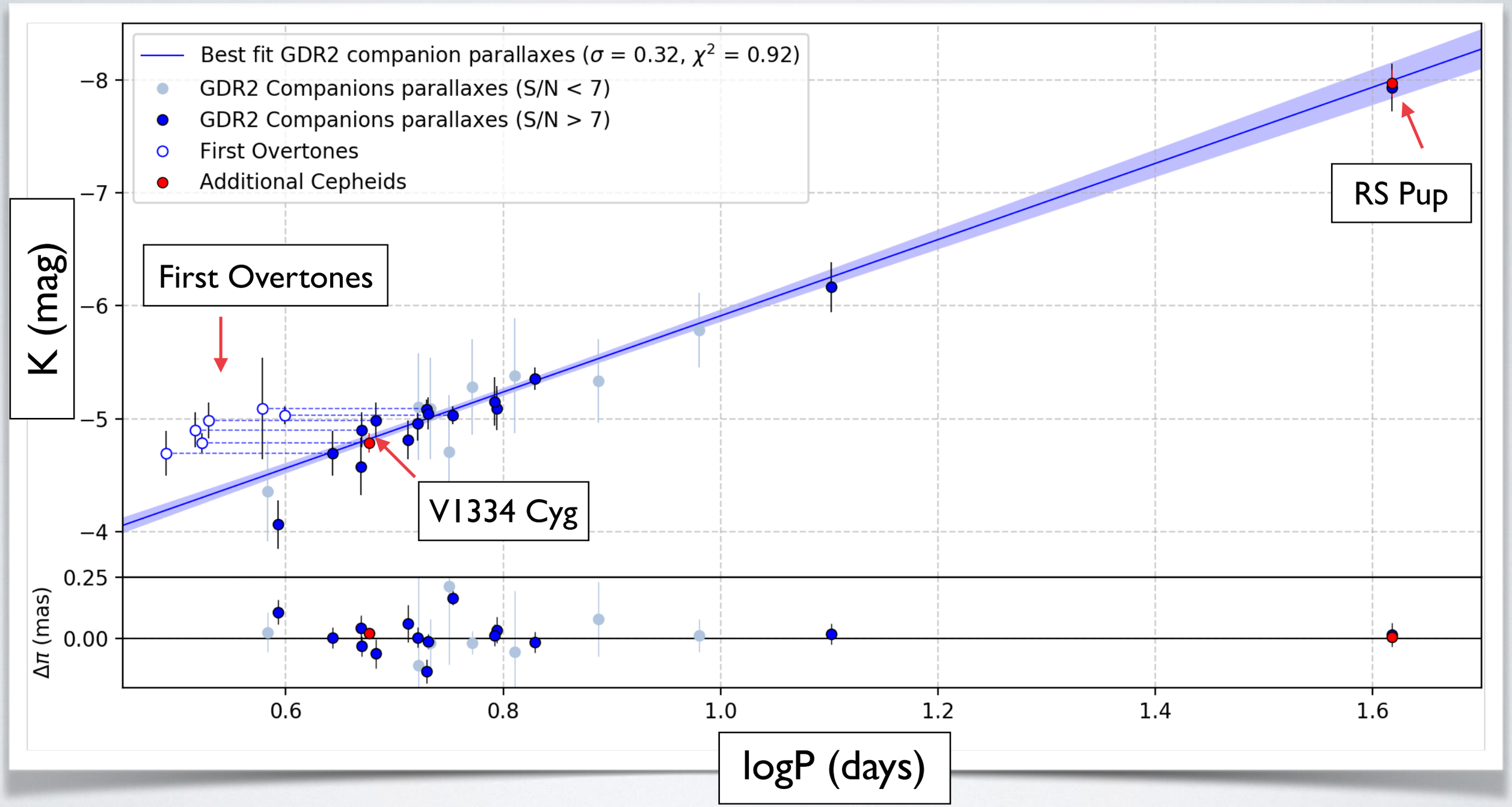
Proper motion of Delta Cep and its companion (Kervella et al. 2019b)



Difference between Cepheids and companions parallaxes from Gaia DR2

We use the Gaia DR2 parallaxes of the **companions**

CALIBRATION OF THE P-L RELATION



Breuval et al. (2019), A&A, submitted

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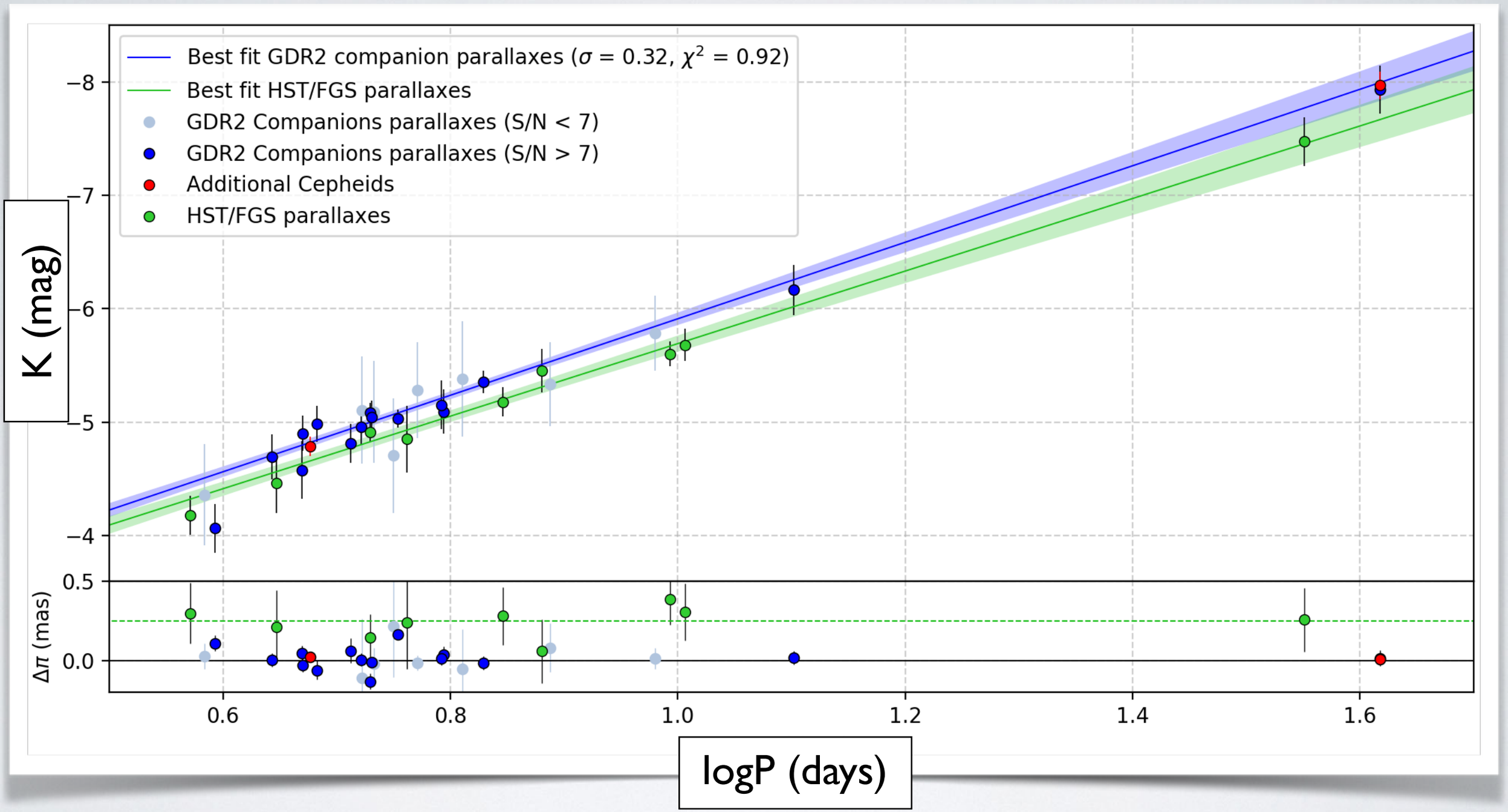

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RESCALING OF H_0

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New value based on GDR2 Cepheids companions

$H_0 = 73.24 \pm 1.74$ km/s/Mpc (Riess et al. 2016)

$$H_{0,\,Gaia} = (\pi_{Gaia} / \pi_{R16}) \times H_{0,\,R16}$$

Gaia DR2 companion parallax

Expected parallax from Riess et al. (2016)

Method from Riess et al. (2018a)

RESCALING OF H_0

★ Expected parallax from Riess et al. (2016) :

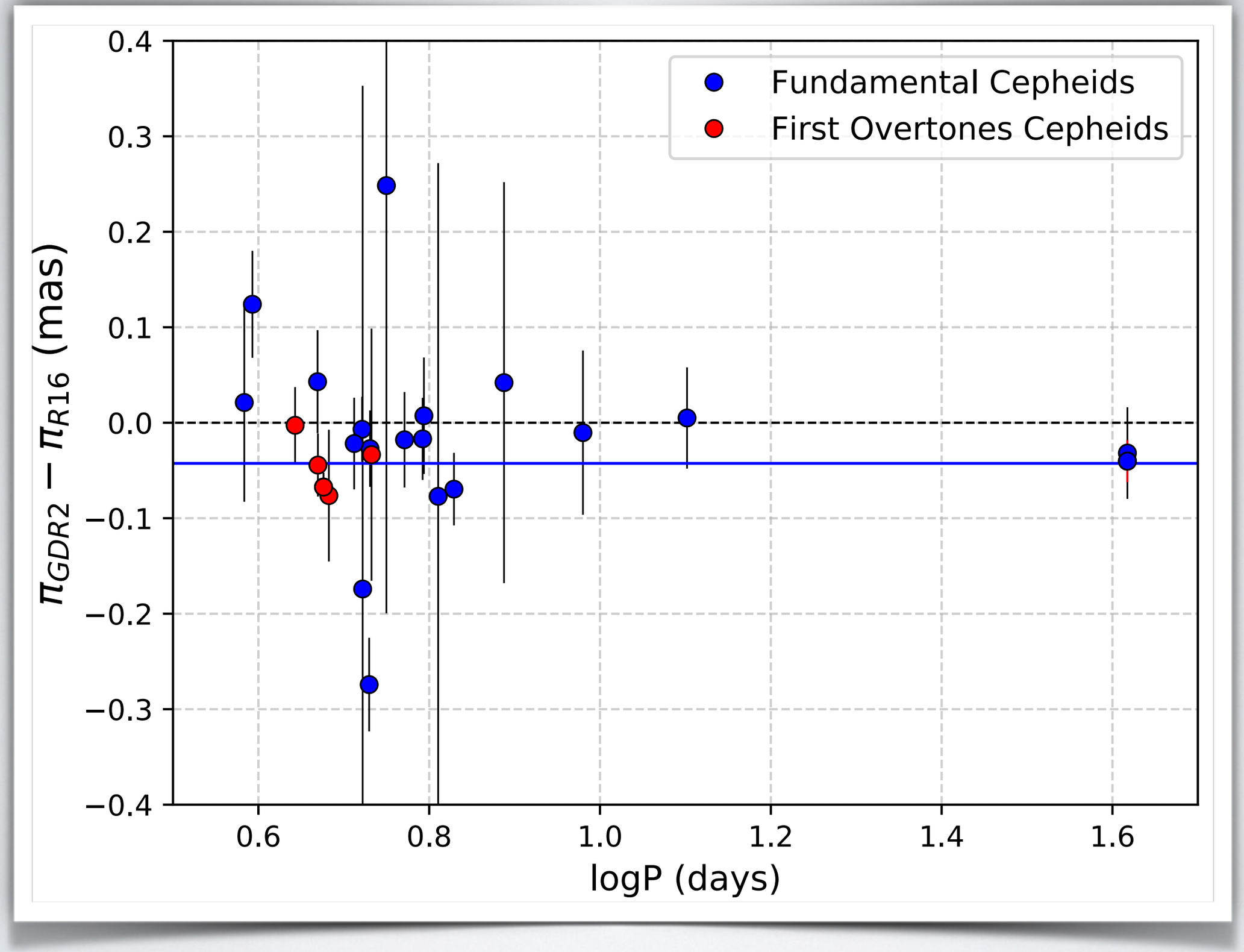
$$\pi_{R16} = 10^{-0.2\,(m - M - 10)}$$

★ Apparent magnitudes : $m = F160W - 0.386\,(F555W - F814W)$

→ reconstructed from ground magnitudes (J, H, V)

★ Absolute magnitudes : $M = -5.93 - 3.26\,(\log P - 1)$ (Riess et al. 2016)

RESCALING OF H_0



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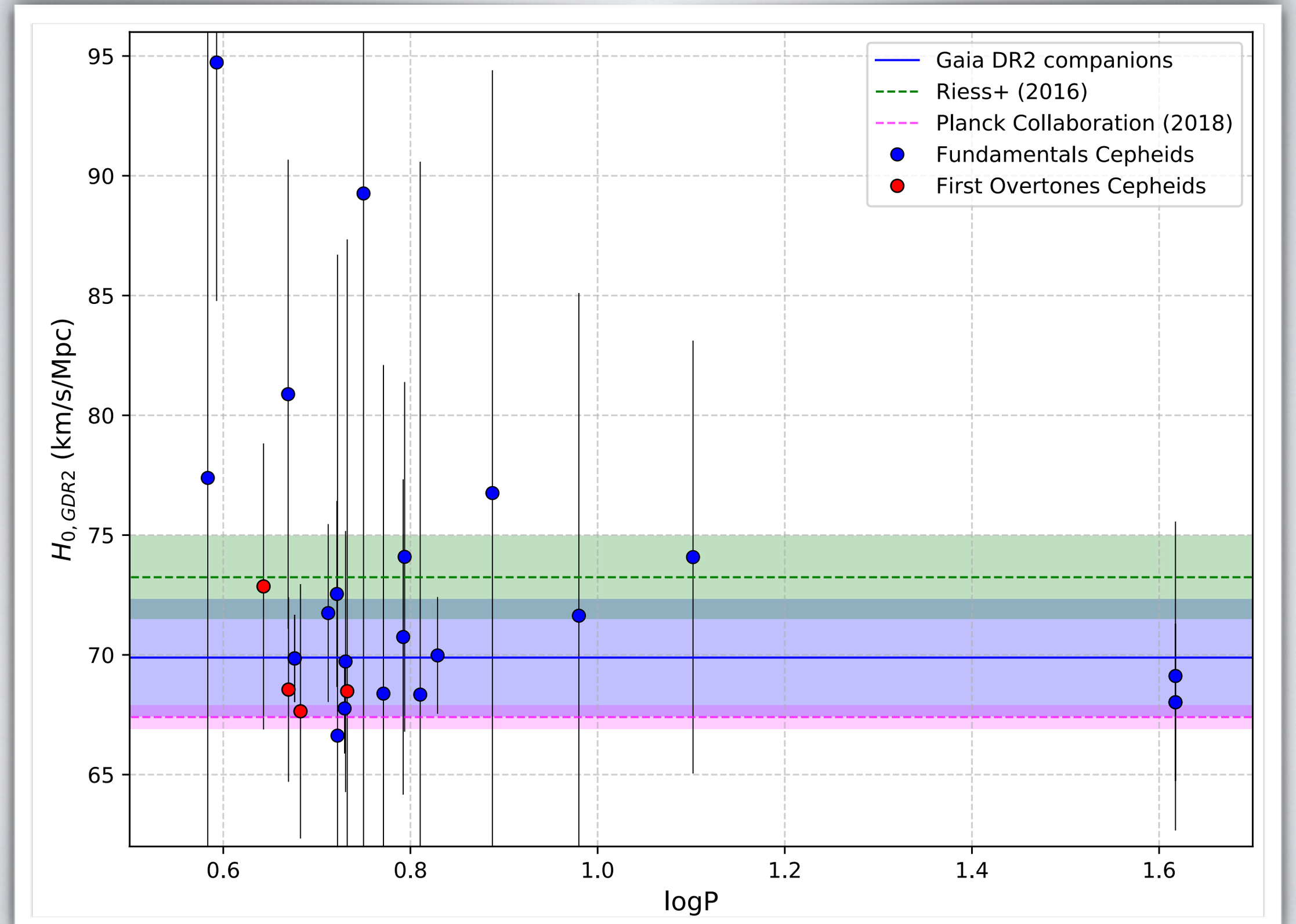

CONCLUSION

★ Using companions parallaxes allows us to :

→ bypass the bias on GDR2 Cepheids parallaxes
→ calibrate the Leavitt law with non-HST parallaxes

★ We detected a possible offset on HST/FGS parallaxes

★ We need to investigate the metallicity effect on PL relations

★ We expect the Gaia DR3 to :

→ provide a precise value of the parallaxes offset
→ provide better Cepheids parallaxes

Thank you !

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