THE CEPHEID LEAVITT LAW FROM GAIA DR2 PARALLAXES OF RESOLVED COMPANIONS

Louise Breuval

Observatoire de Paris, LESIA

PhD supervisor : Pierre Kervella

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CEPHEIDS

GAIA PARALLAXES

CALIBRATION OF THE P-L RELATION

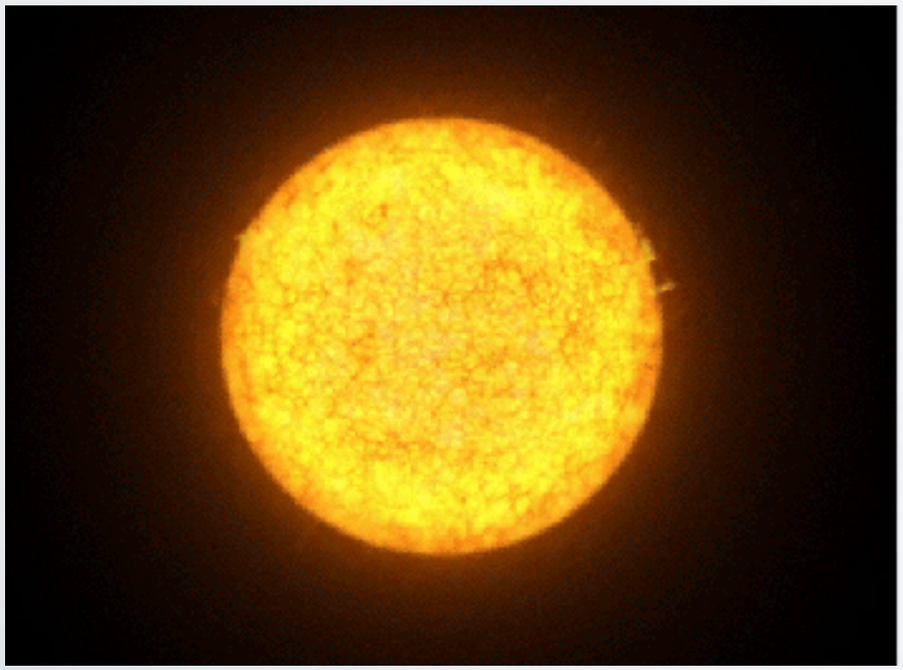
RESCALING OF H_0

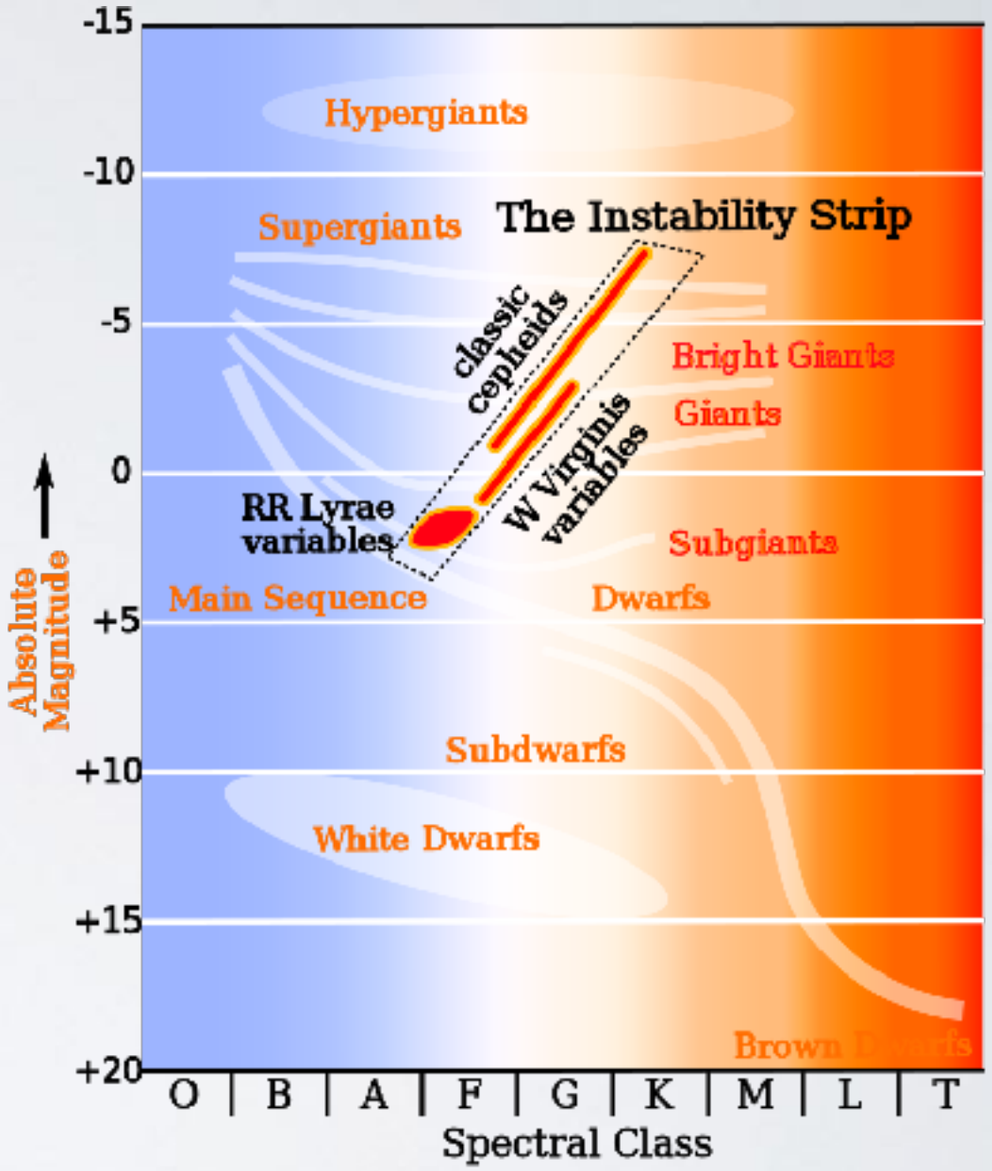
CEPHEIDS

★ 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



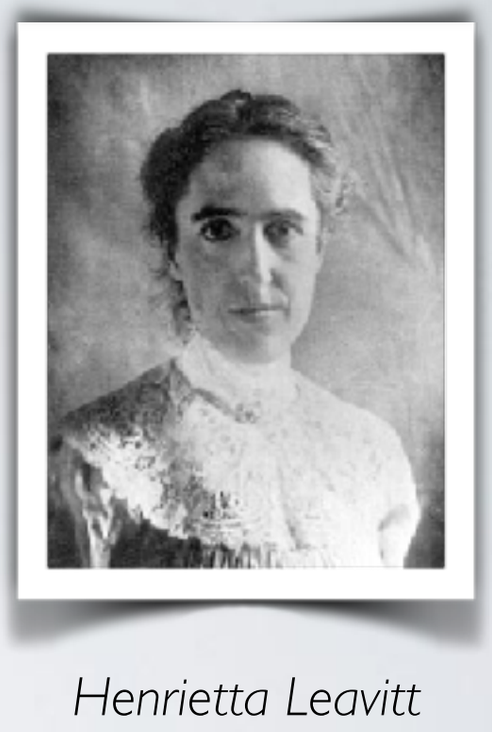


Instability strip in the HR diagram

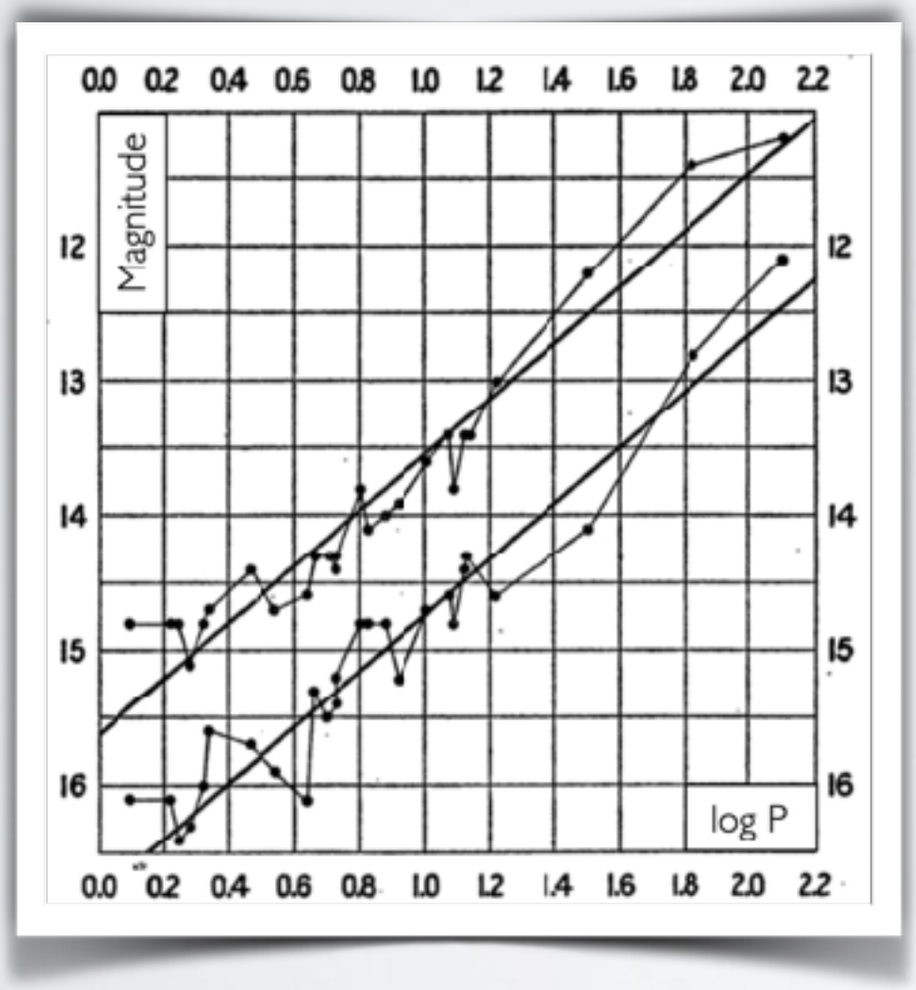
CEPHEIDS

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

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



Henrietta Leavitt



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

📚 📏 🔭 My PhD topic :

→ **precise calibration** of this relation

CEPHEIDS

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GAIA PARALLAXES OF CEPHEIDS

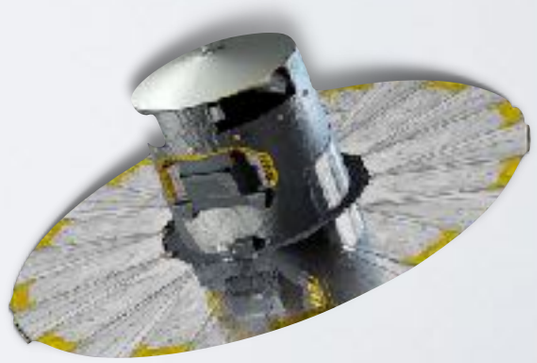
★ We need **very precise distances** to calibrate the PL relation

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

→ 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.



GAIA satellite (ESA)

GAIA PARALLAXES

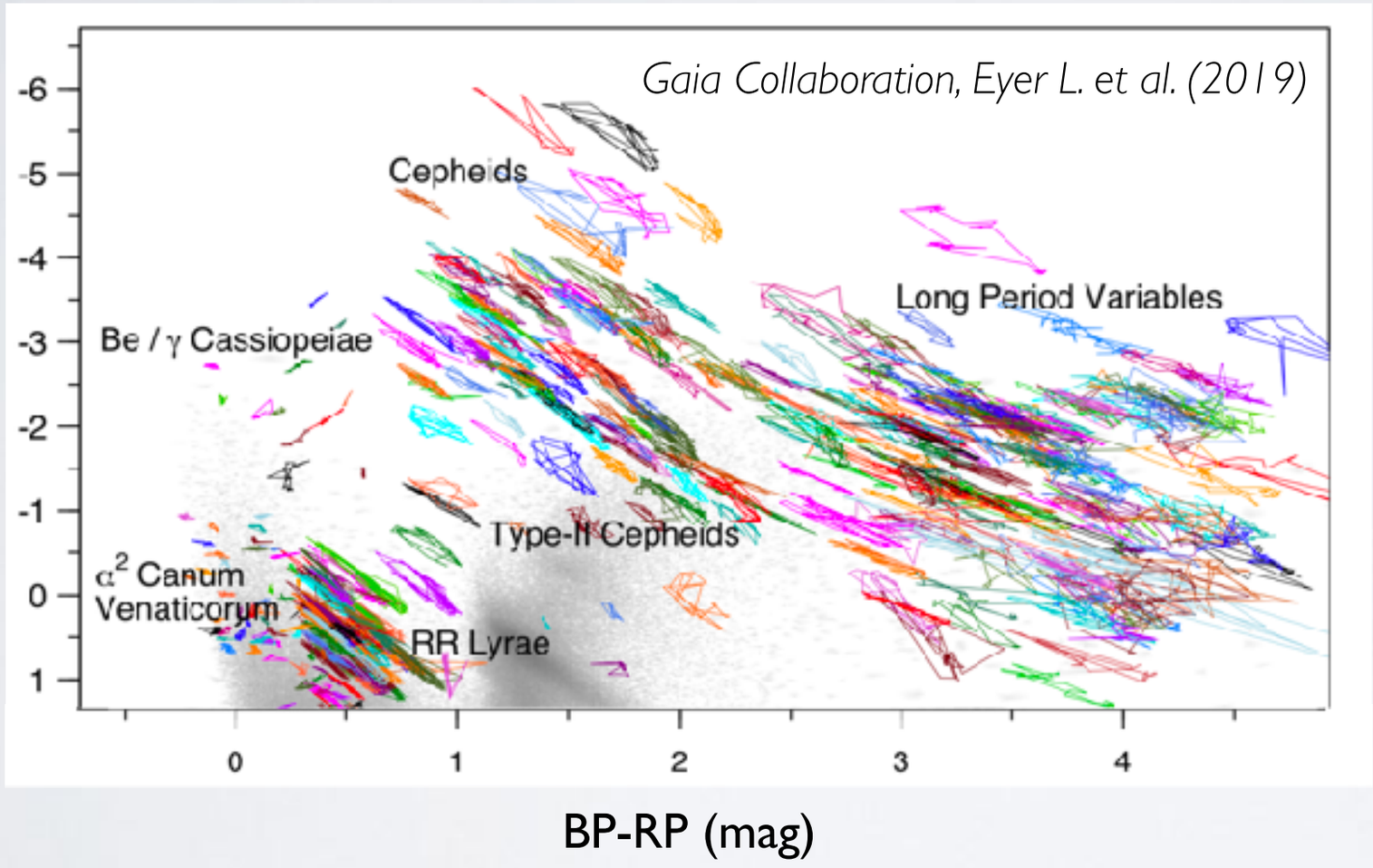
★ The Gaia DR2 parallax **zero-point** is still not precisely known:

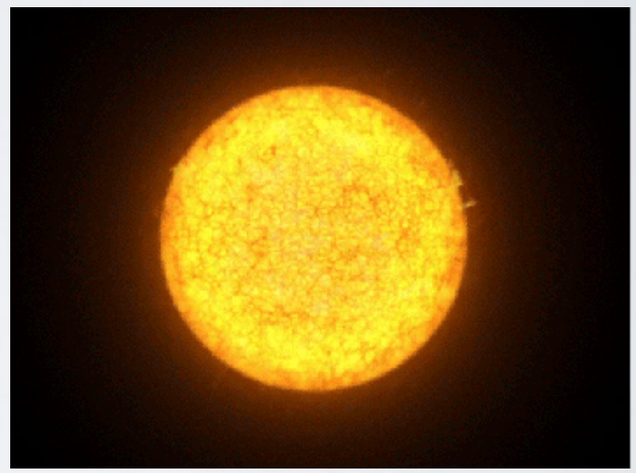
ZP_{Gaia} (mas)	Reference	Type of sources
−0.029	Lindegren et al. (2018)	Quasars
$-0.031_{\pm 0.011}$	Graczyk et al. (2019)	Eclipsing binaries
$-0.0319_{\pm 0.0008}$	Arenou et al. (2018)	MW Cepheids
$-0.035_{\pm 0.016}$	Sahlholdt & Silva Aguirre (2018)	Dwarf stars
$-0.041_{\pm 0.010}$	Hall et al. (2019)	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

Recent estimations of Gaia DR2 parallax zero-point offset

GAIA PARALLAXES

★ Gaia DR2 parallaxes are derived assuming that the stars have a **constant color** and a **constant brightness**. (Lindegren et al. 2018, Mowlavi et al. 2018)





★ No chromaticity correction → data reduction not adapted to Cepheids !

→ **Astrometric bias** : some parallaxes of Cepheids may be potentially **unreliable**.

CEPHEIDS

GAIA PARALLAXES

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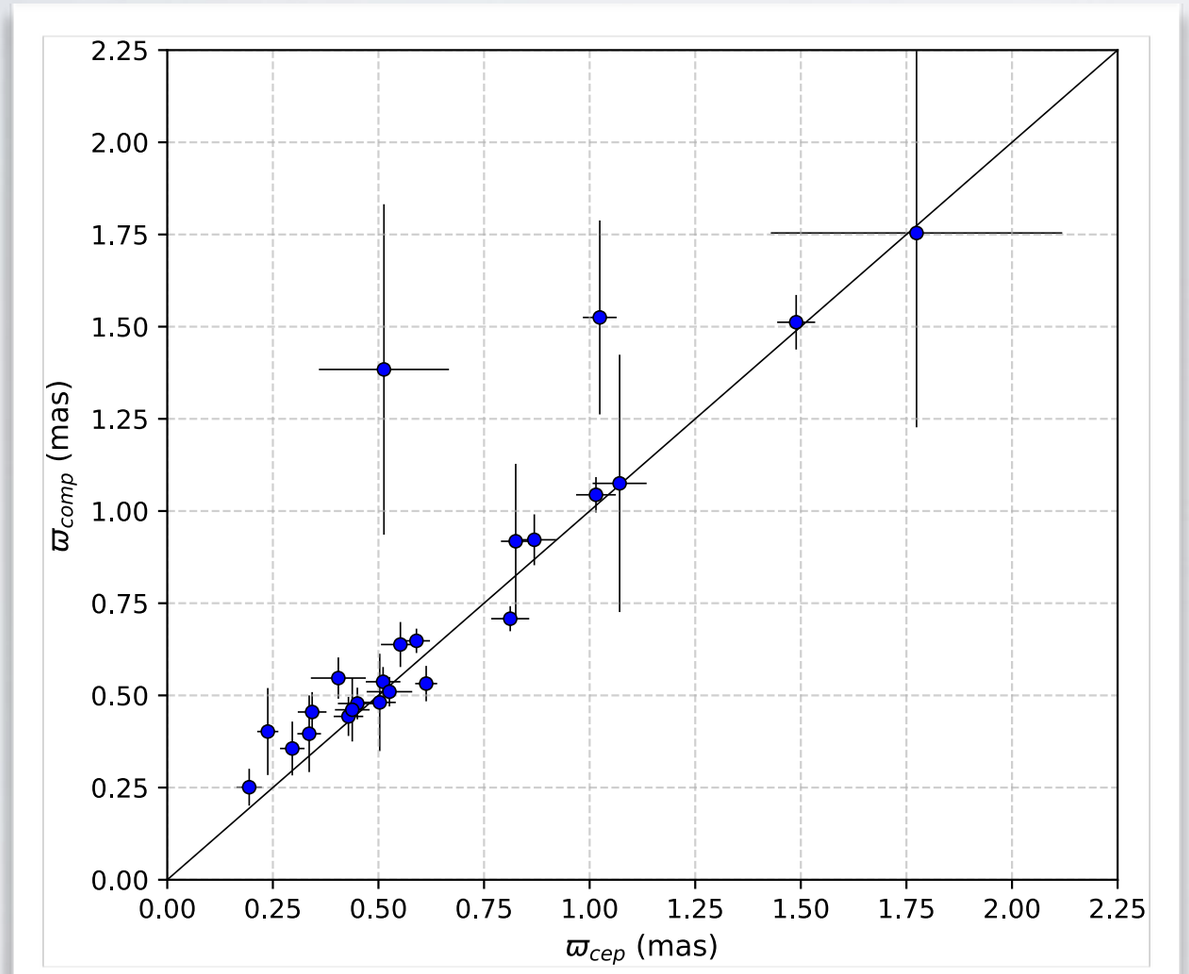
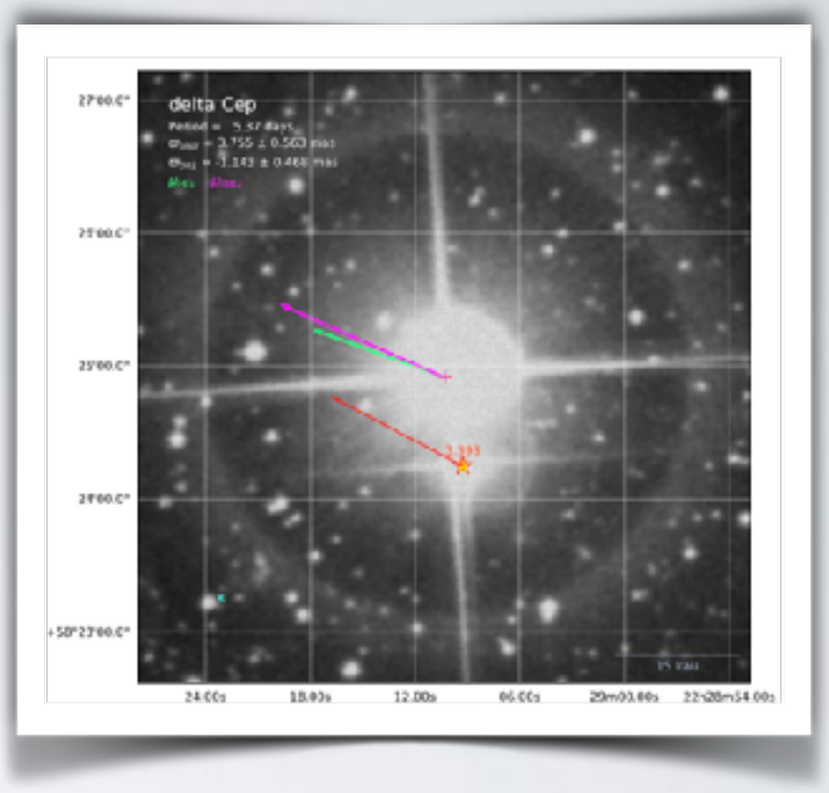
CALIBRATION OF THE P-L RELATION

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



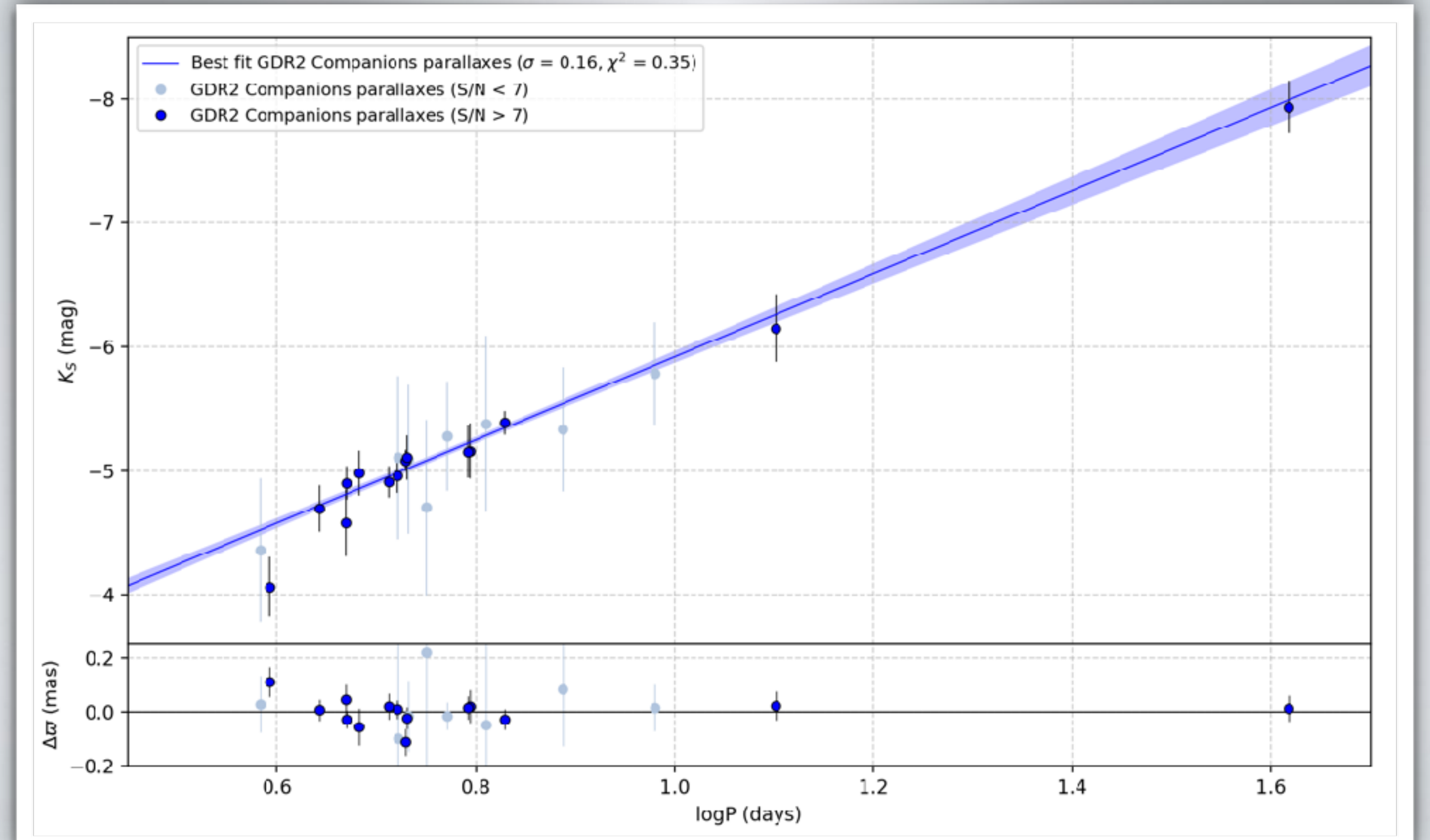
Comparison of Gaia DR2 parallaxes of Cepheids with those of the companions



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

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

CALIBRATION OF THE P-L RELATION



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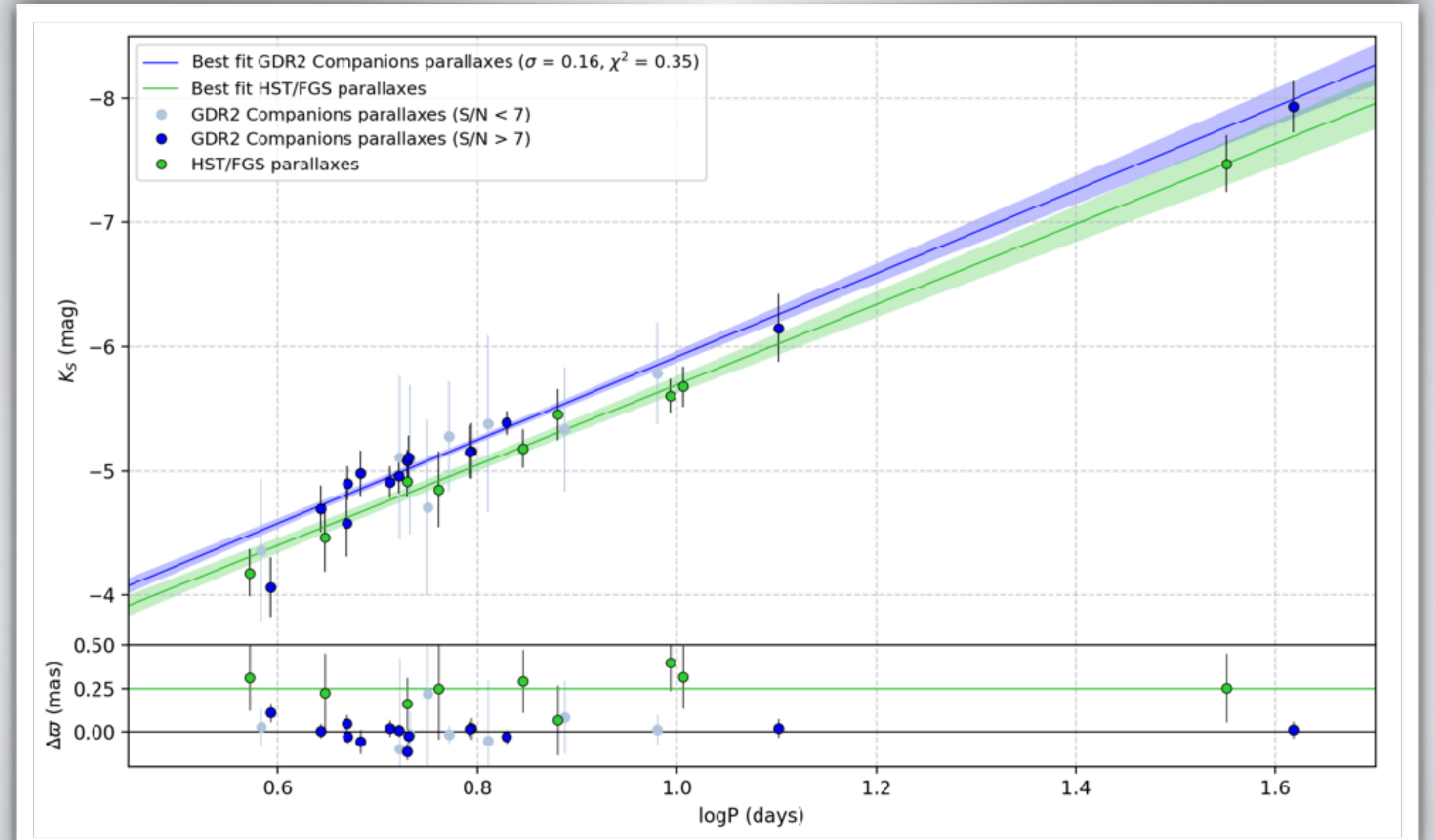

CEPHEIDS

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CALIBRATION OF THE P-L RELATION

RESCALING OF H_0

RESCALING OF H_0

★ Riess et al. (2019) based on Cepheids : $H_0 = 74.0 \pm 1.4$ km/s/Mpc

★ Planck Collaboration (2018) : $H_0 = 67.4 \pm 0.5$ km/s/Mpc

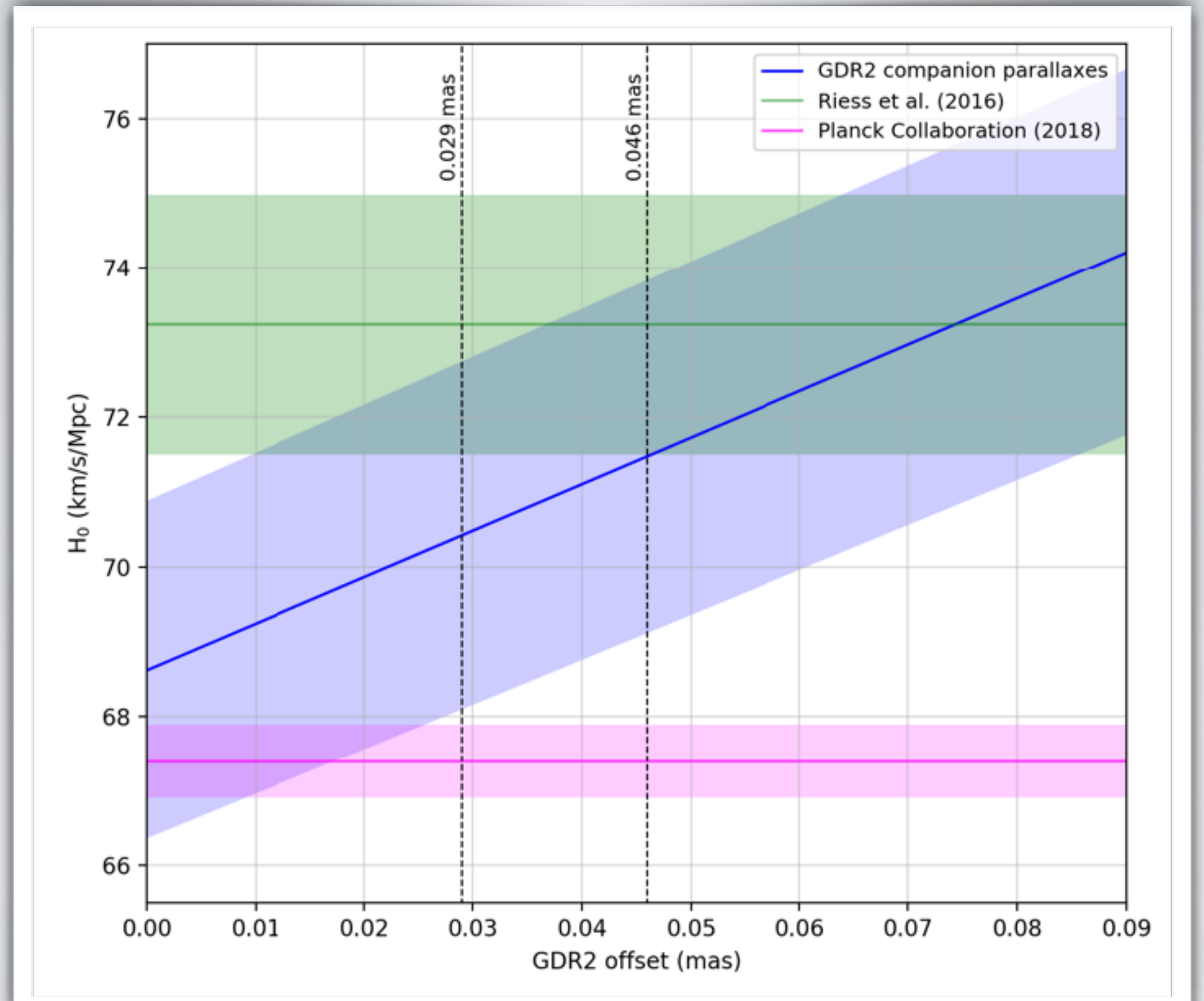
→ 4 σ tension

→ could be explained by new physics
beyond the standard model

★ Rescaled value based on Gaia parallaxes of Cepheids companions (Breuval et al. 2020) :

$H_0 = 71.0 \pm 2.5$ km/s/Mpc

RESCALING OF H_0



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 expect the Gaia DR3 to :

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

Thank you !

louise.breuval@obspm.fr