Eclipsing binary stars with Kepler K2

A foretaste of PLATO complementary science

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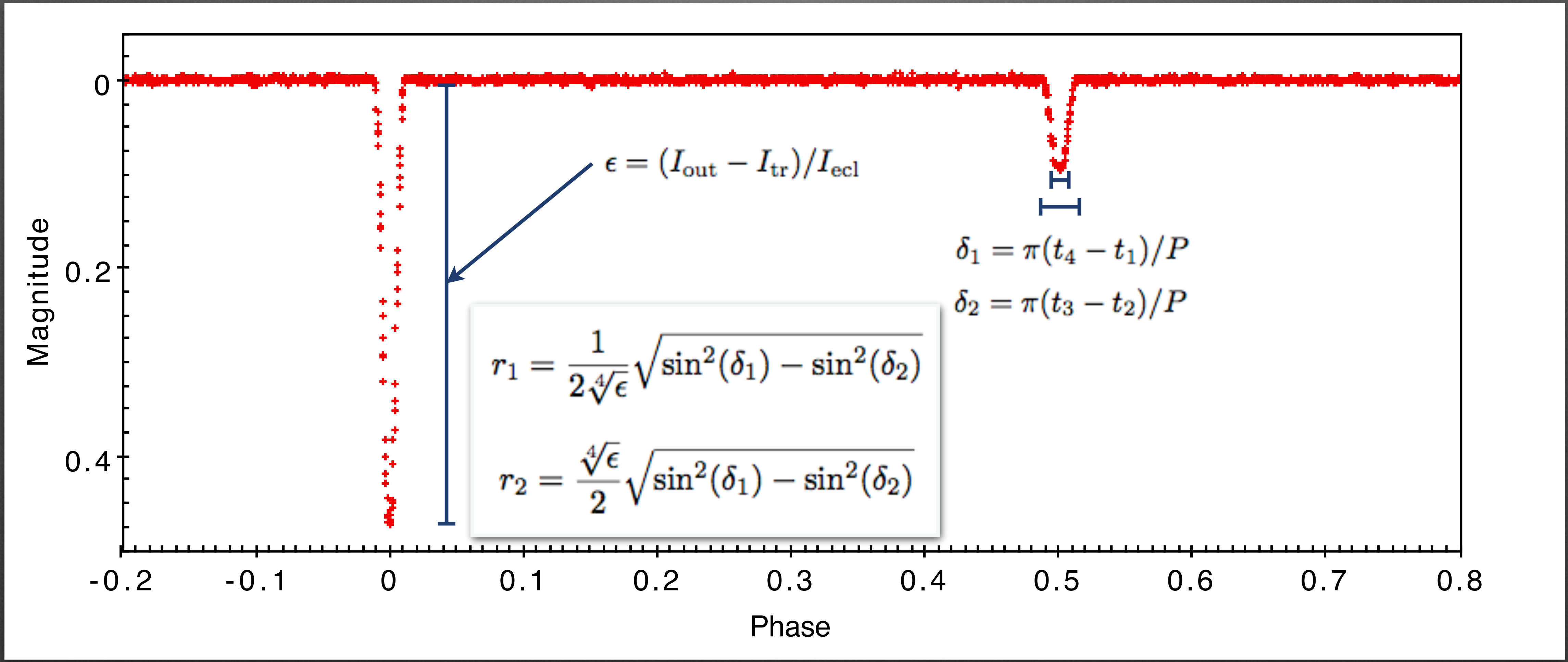
Detached eclipsing binaries

- Best source of *precise*, *model-independent* mass and radius measurements for normal stars
- Ideal for testing/calibrating stellar models
- With parallaxes, can also add *precise, model-independent* T_{eff} measurements.
- Spectroscopic analysis ⇒ T_{eff}, [Fe/H], [α/Fe], A_{Li}

Total eclipses



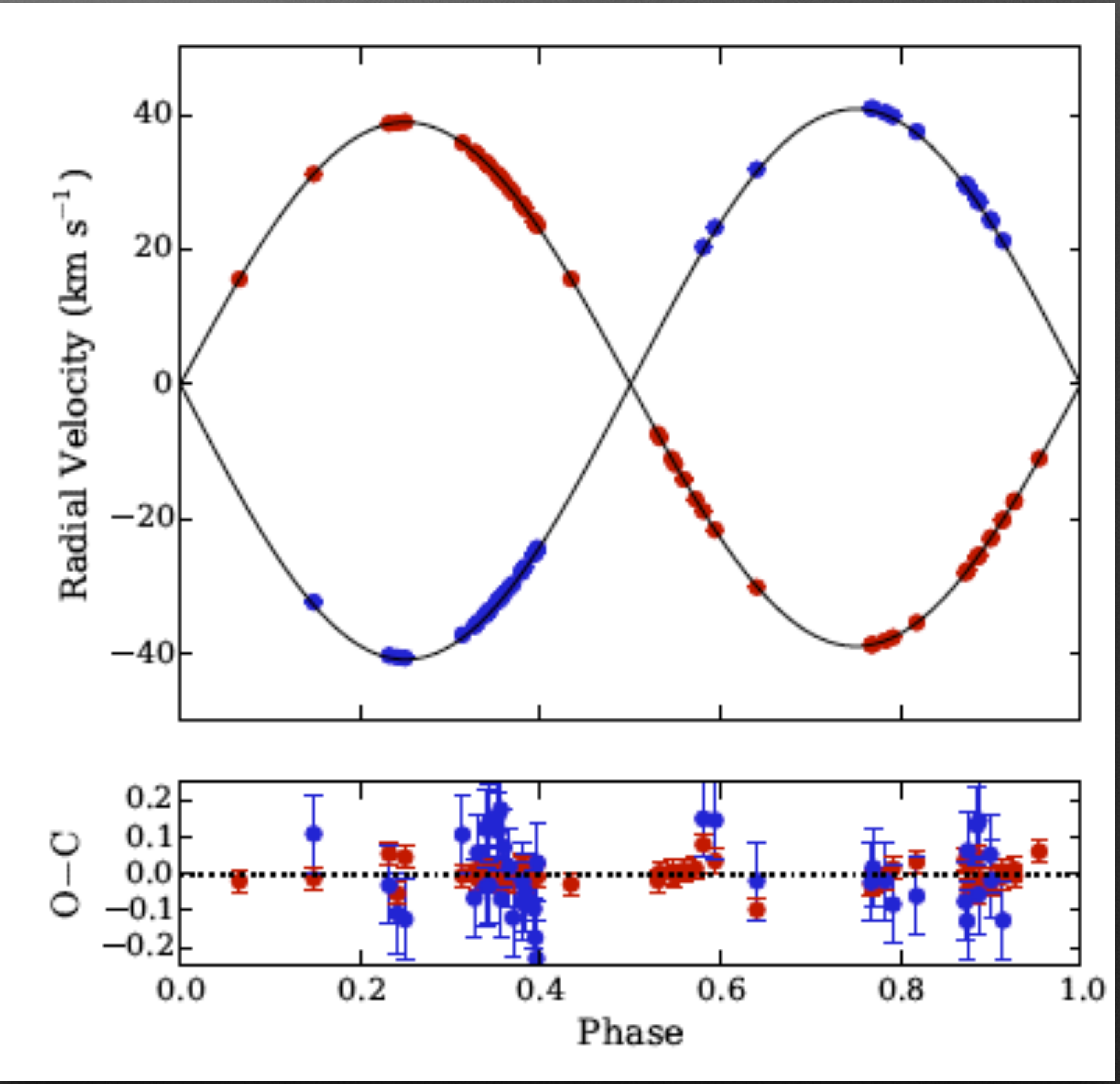
- Light curve gives $r_1 = R_1/a$, $r_2 = R_2/a$, i, $e \cos \omega$, , $e \sin \omega$, f_2/f_1
- **Narrow total eclipses** ⇒ inclination $i \cong 90°$
- Deep partial eclipses give similar accuracy in parameters
- Shallow partial eclipses more ambiguous — spectroscopy helps.

Precision mass measurements

TZ For, HARPS

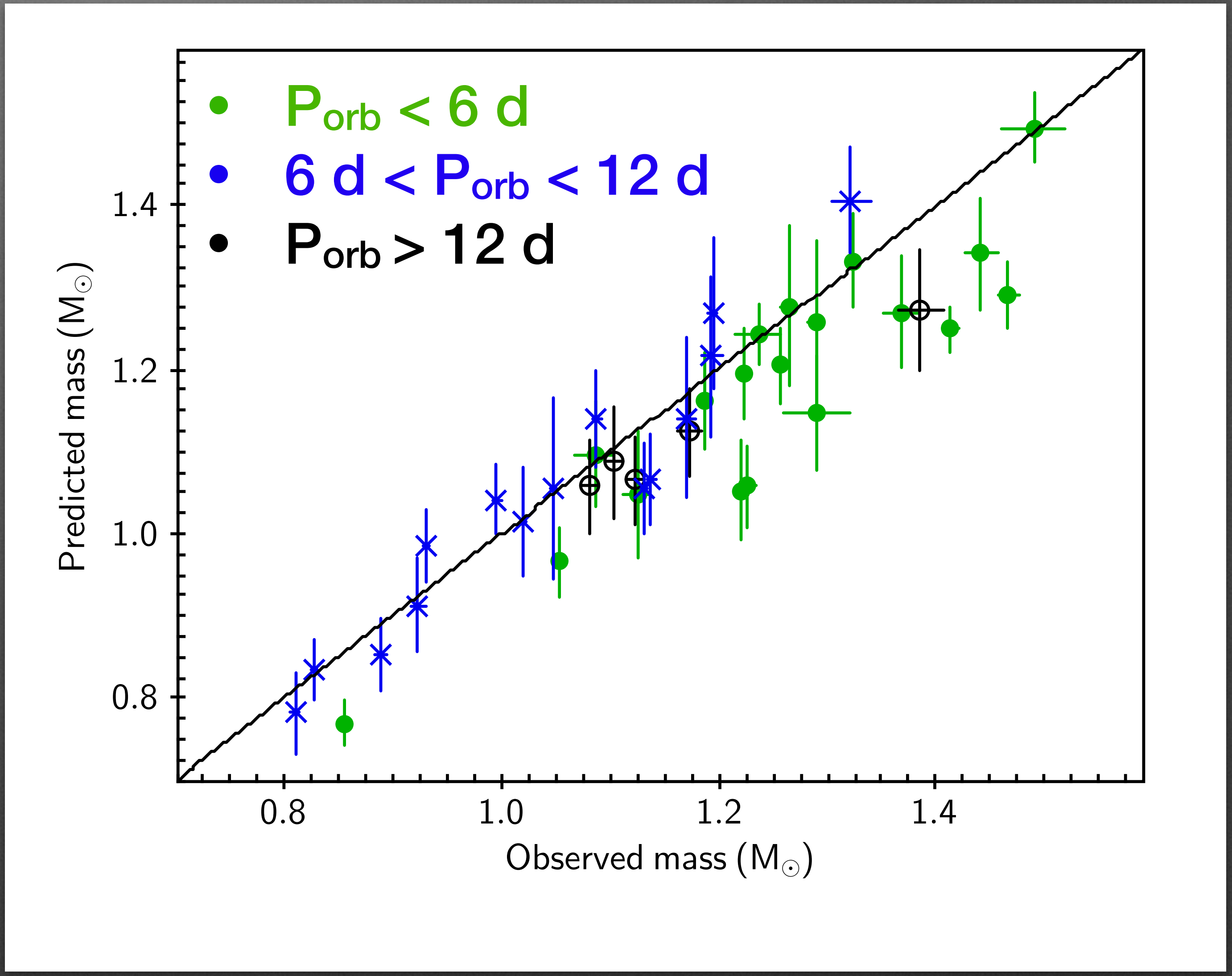
- $M_1 = 2.057 \pm 0.001\ M_{Sun}$
- $M_2 = 1.958 \pm 0.001\ M_{Sun}$

Gallene et al., 2016



Current EB sample

- Mass/radius error ± 1 - 2%
- Short orbital period
  - (tidally locked)
- Mostly “twin” stars
- Few low mass stars
- Few evolved stars
- Inhomogeneous T_{eff} scale
- [Fe/H] often missing and not homogeneous



Bayesian mass and age estimates for transiting exoplanet host stars
Maxted et al., 2015

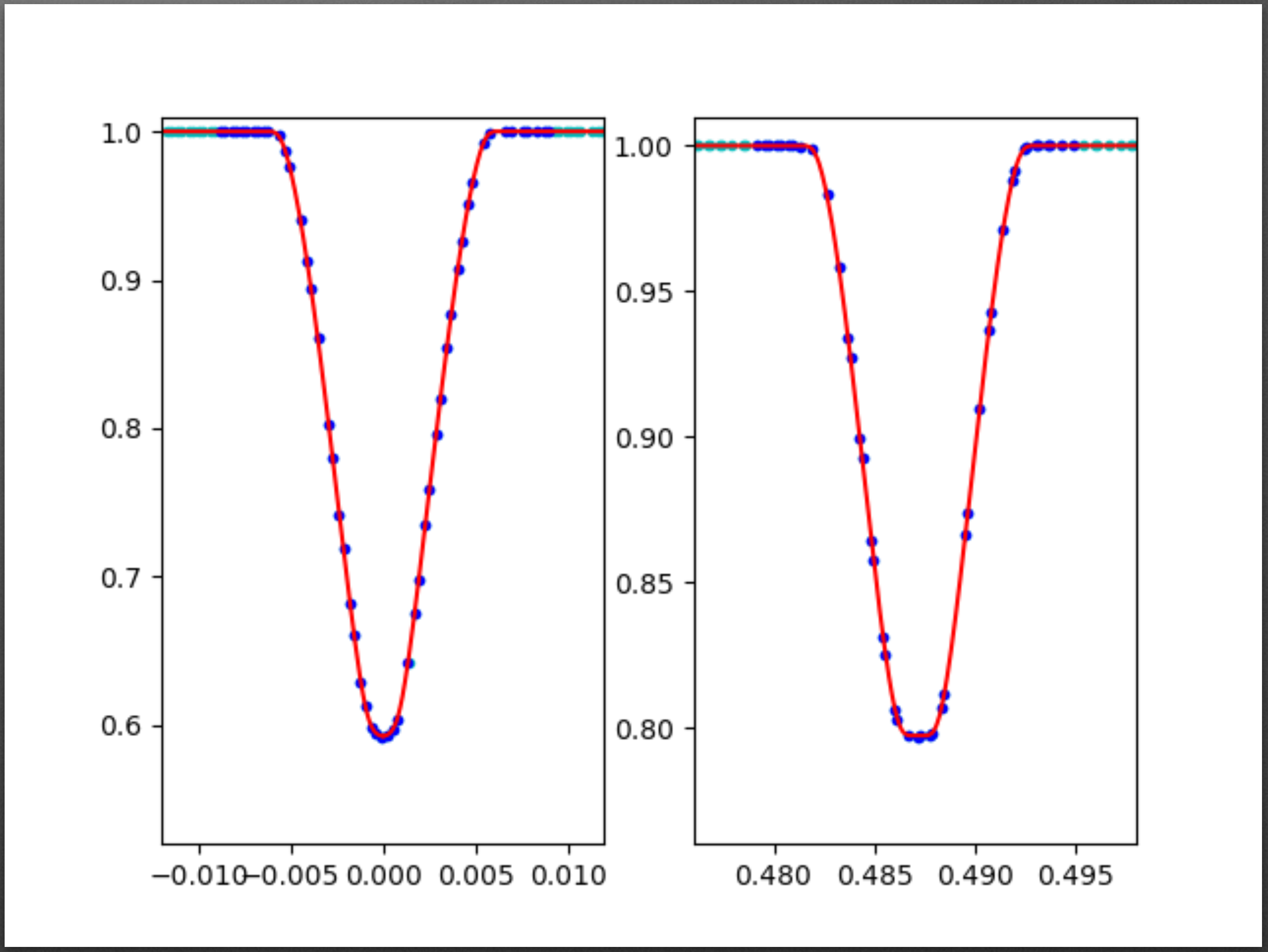
www.astro.keele.ac.uk/jkt/debcat

K2 light curves - ideal case

K2 data, K_p=10.1, P=35.02d

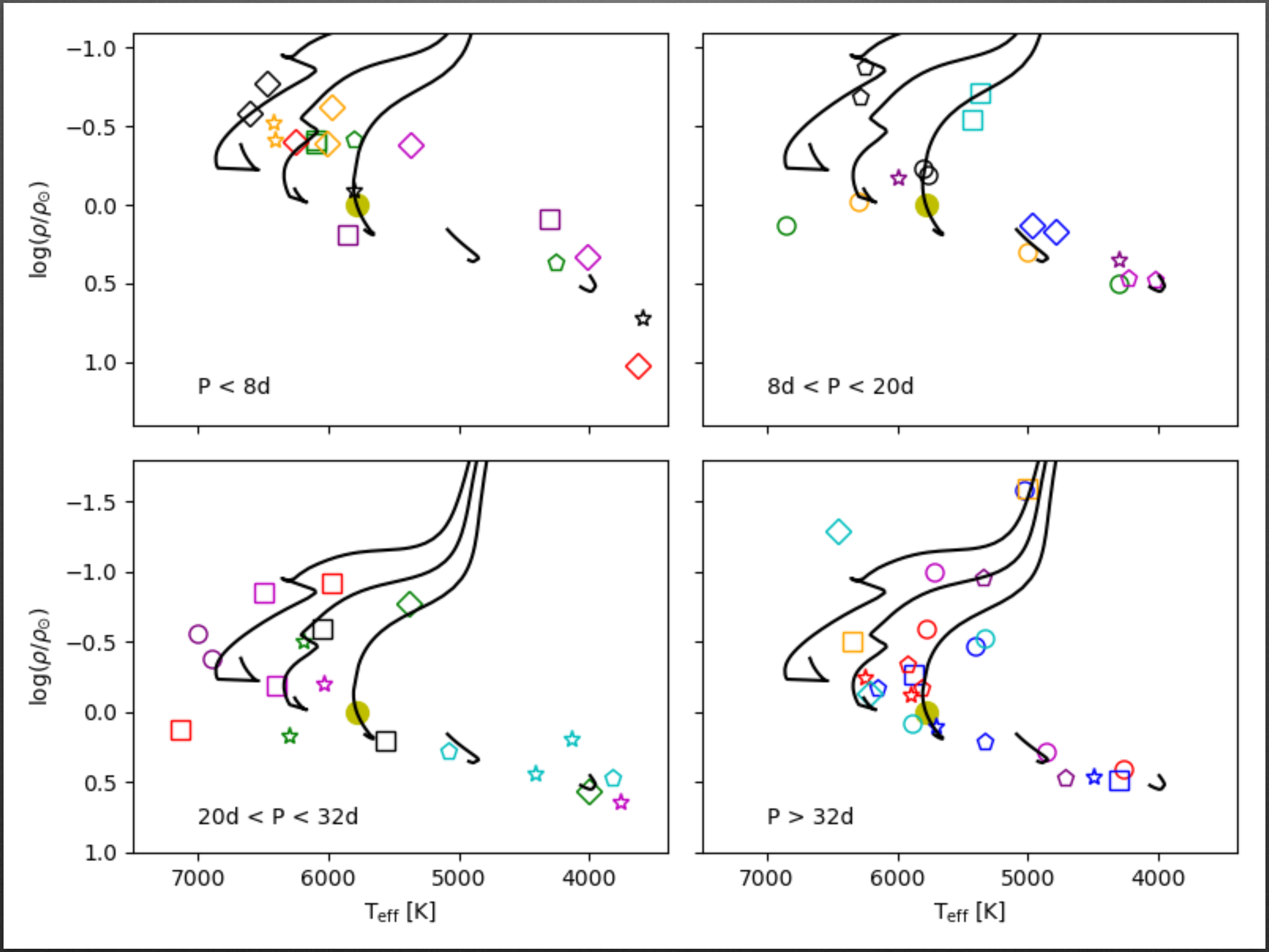
- R_1/a = 0.02082 ± 0.00002
- R_2/a = 0.01431 ± 0.00002
- i = 89.734 ± 0.004
- e = 0.0458 ± 0.0008

± systematic error (tbc)



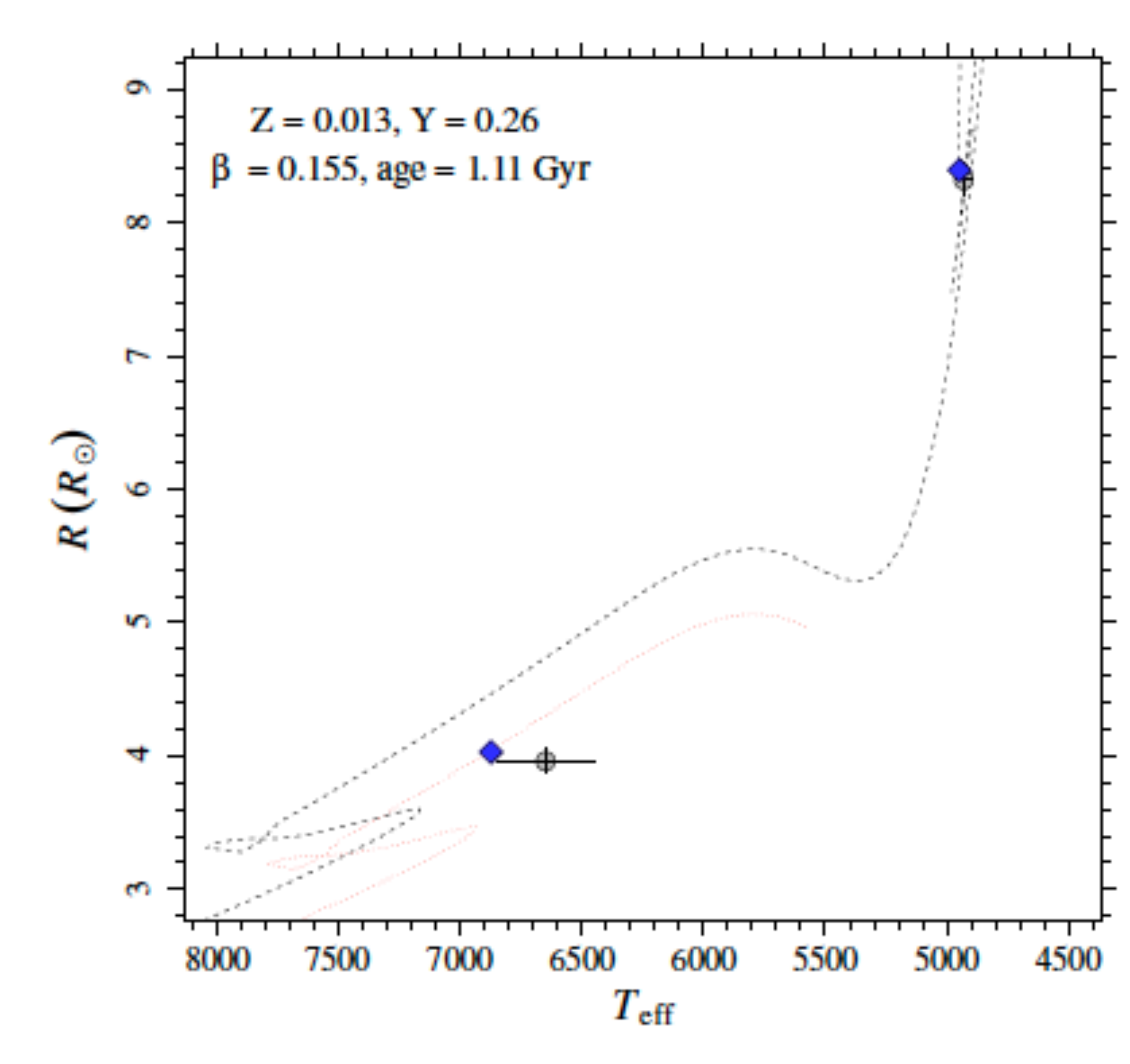
Maxted & Hutcheon, in prep.

K2 campaigns 1, 2 and 3



Maxted & Hutcheon, in prep.

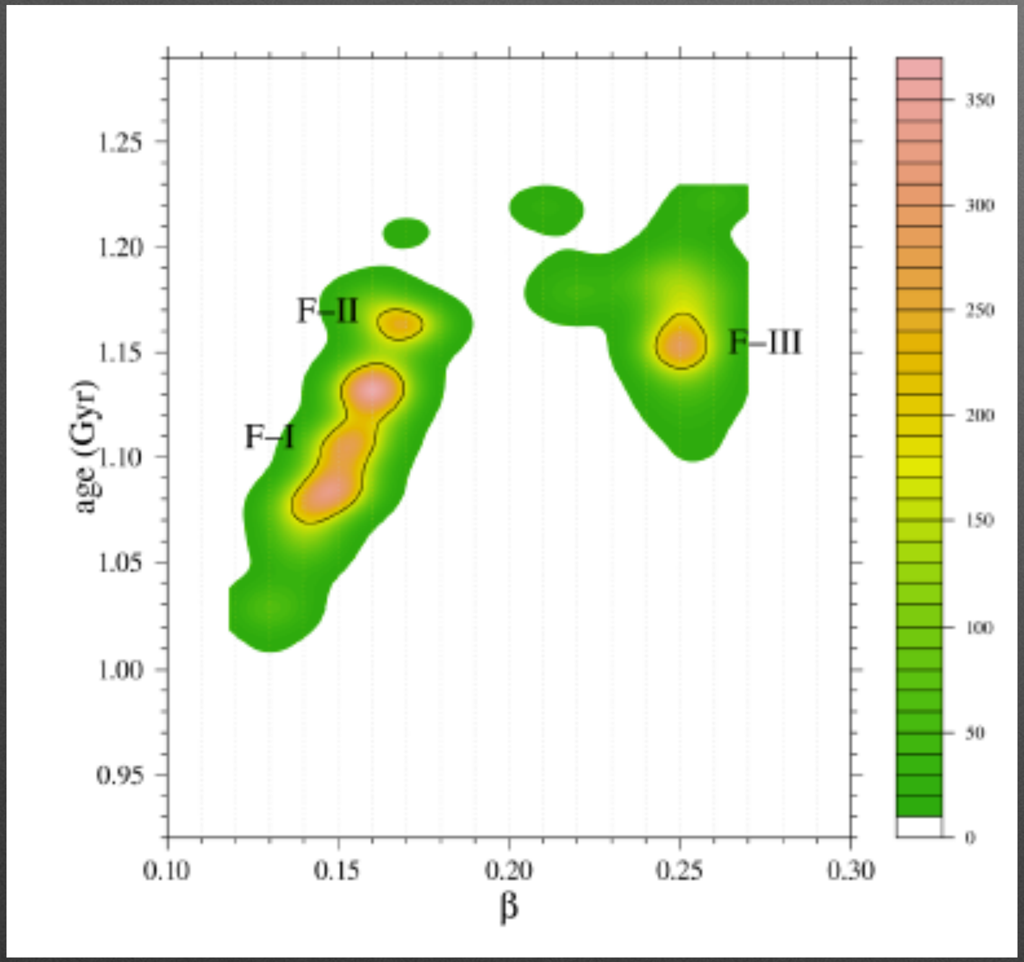
TZ For



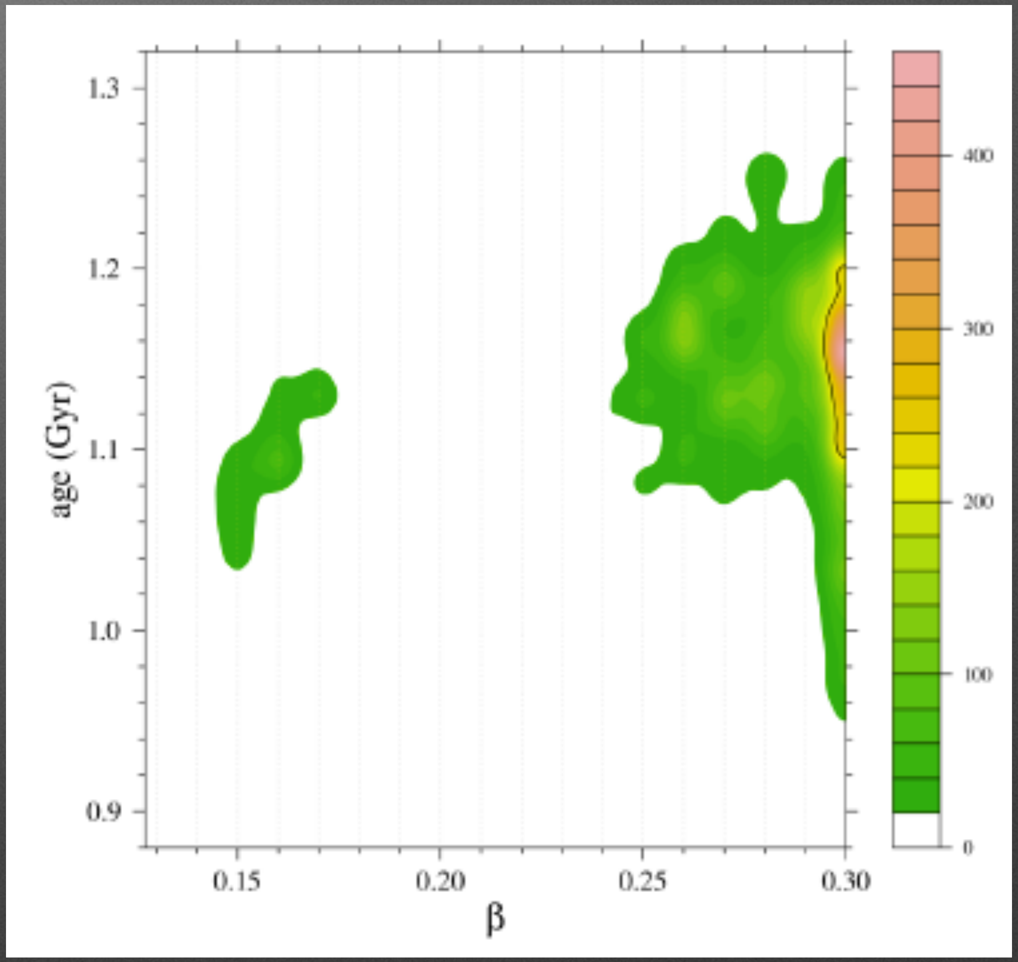
Gallene et al., 2016

TZ For - mass error effect

0.1% mass error

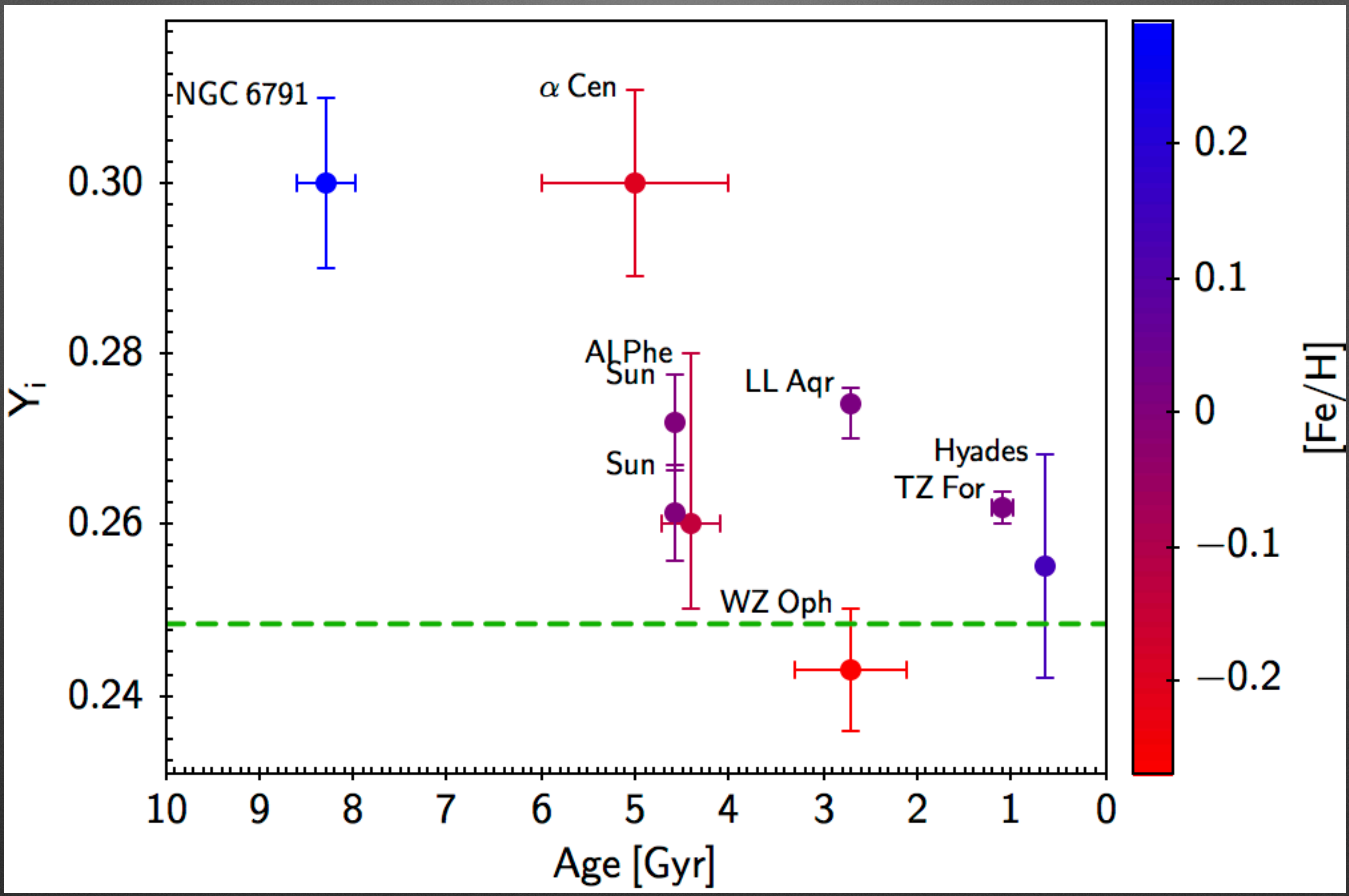


1% mass error



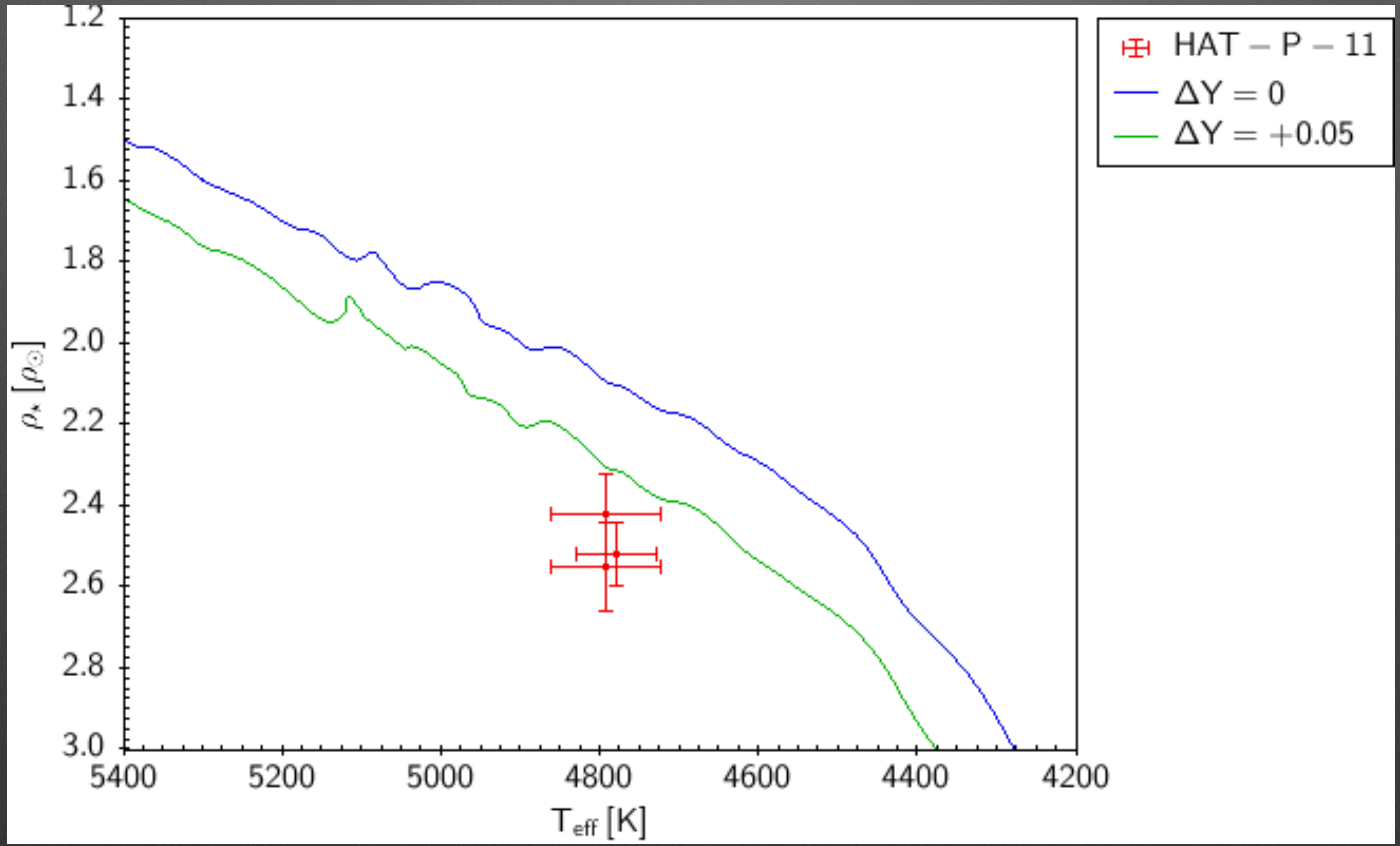
Valle et al. 2017

Helium abundance



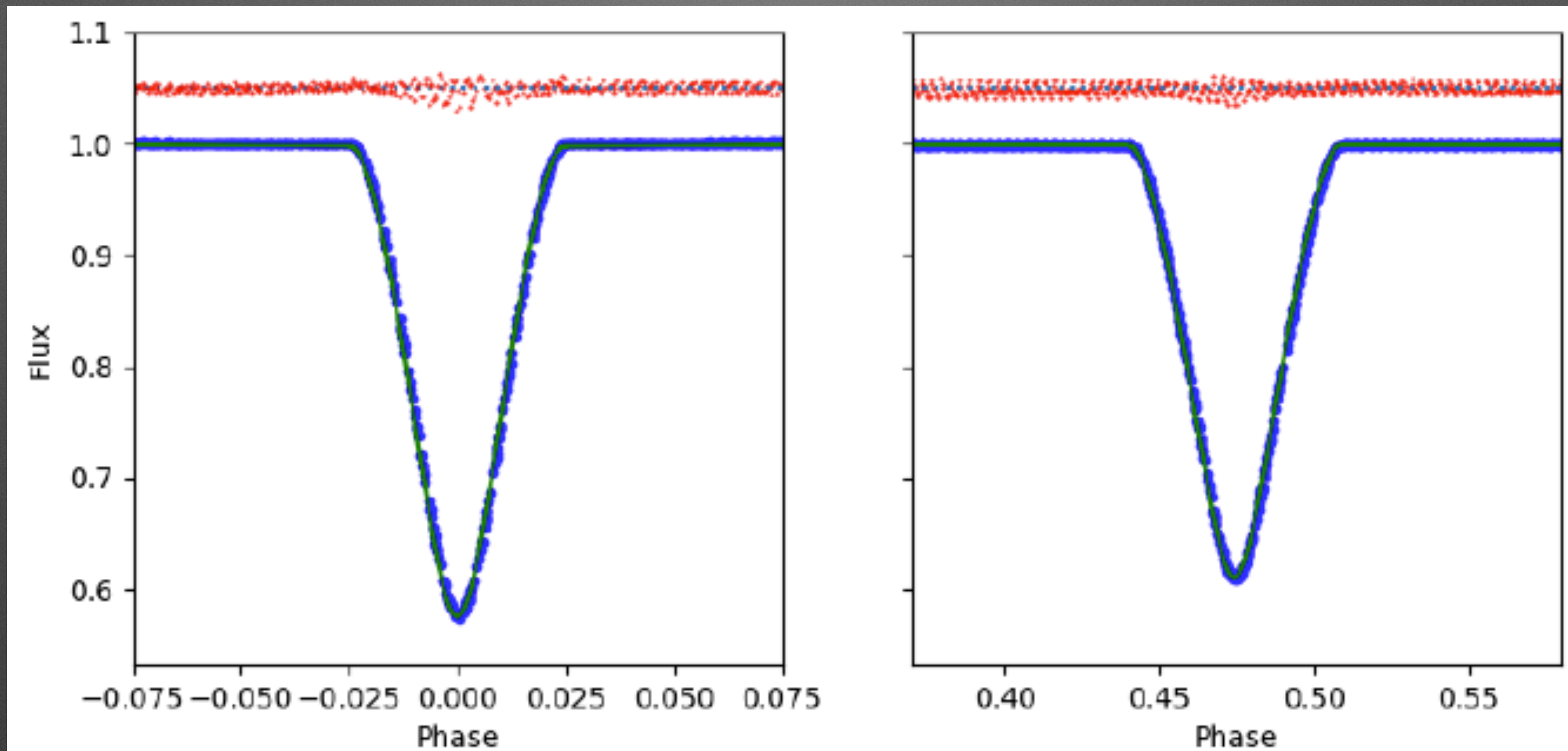
HAT-P-11

$$Y = Y_{\mathrm{BBN}} + 0.984\,Z + \Delta Y$$

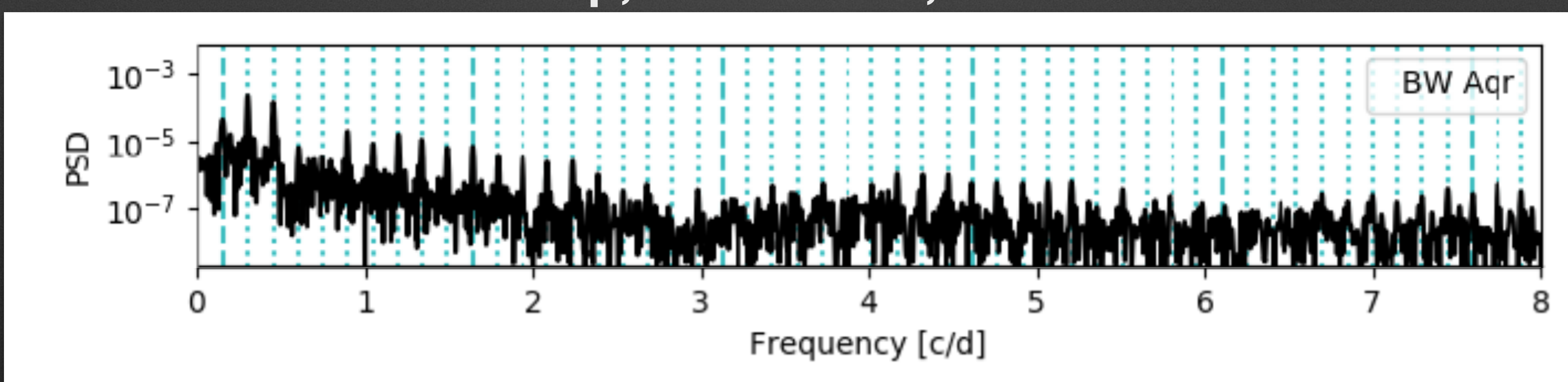


$$\rho_\star = \frac{3\mathrm{M}_\star}{4\pi {\mathrm{R}_\star}^3} = \frac{3\pi}{GP^2(1+q)}\left(\frac{a}{\mathrm{R}_\star}\right)^3$$

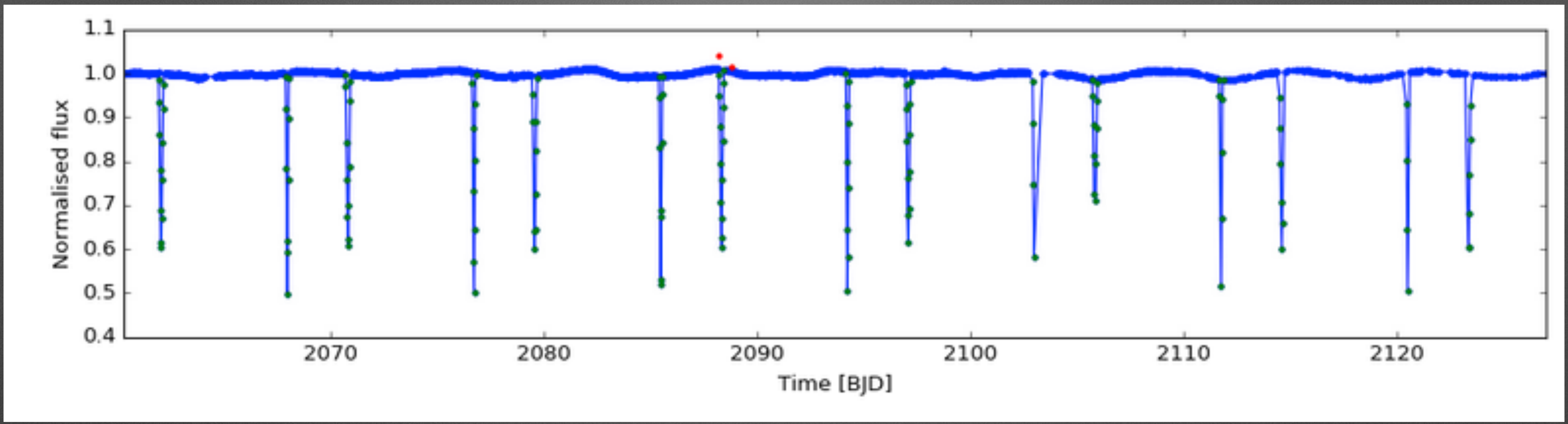
Tidally induced pulsations

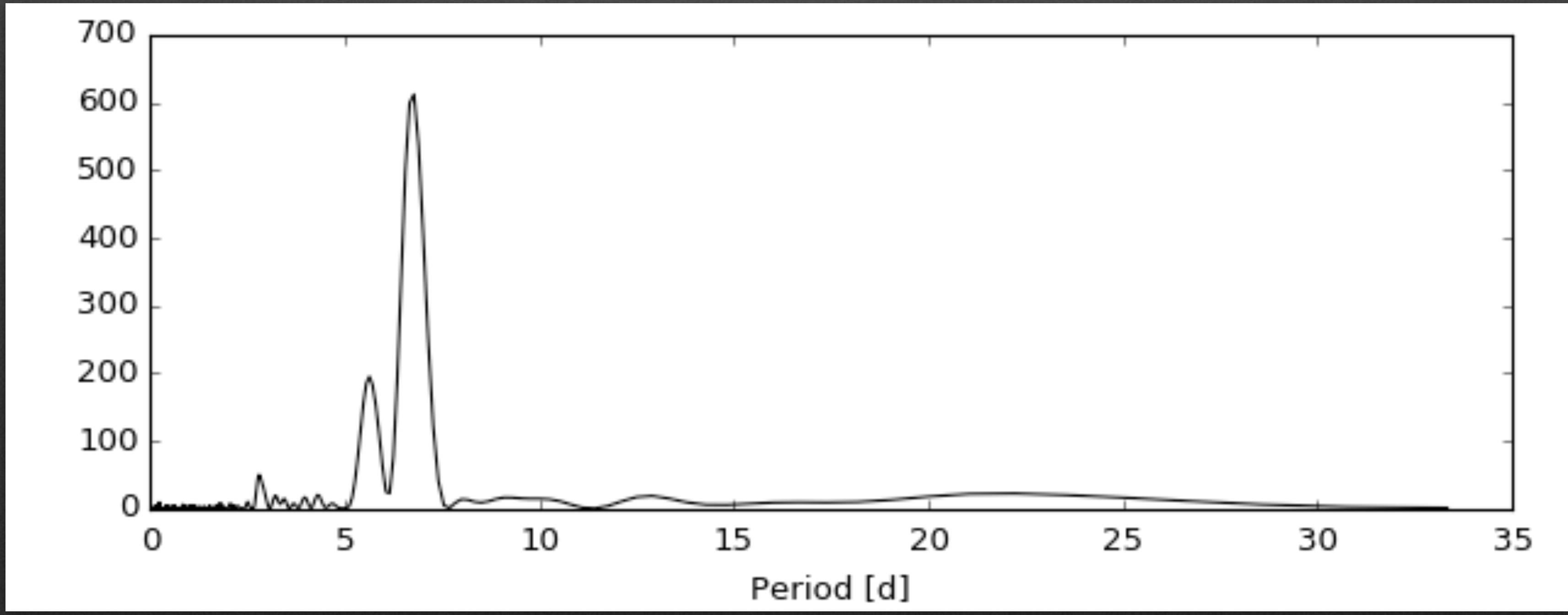


BW Aqr, P = 6.72d, e = 0.18

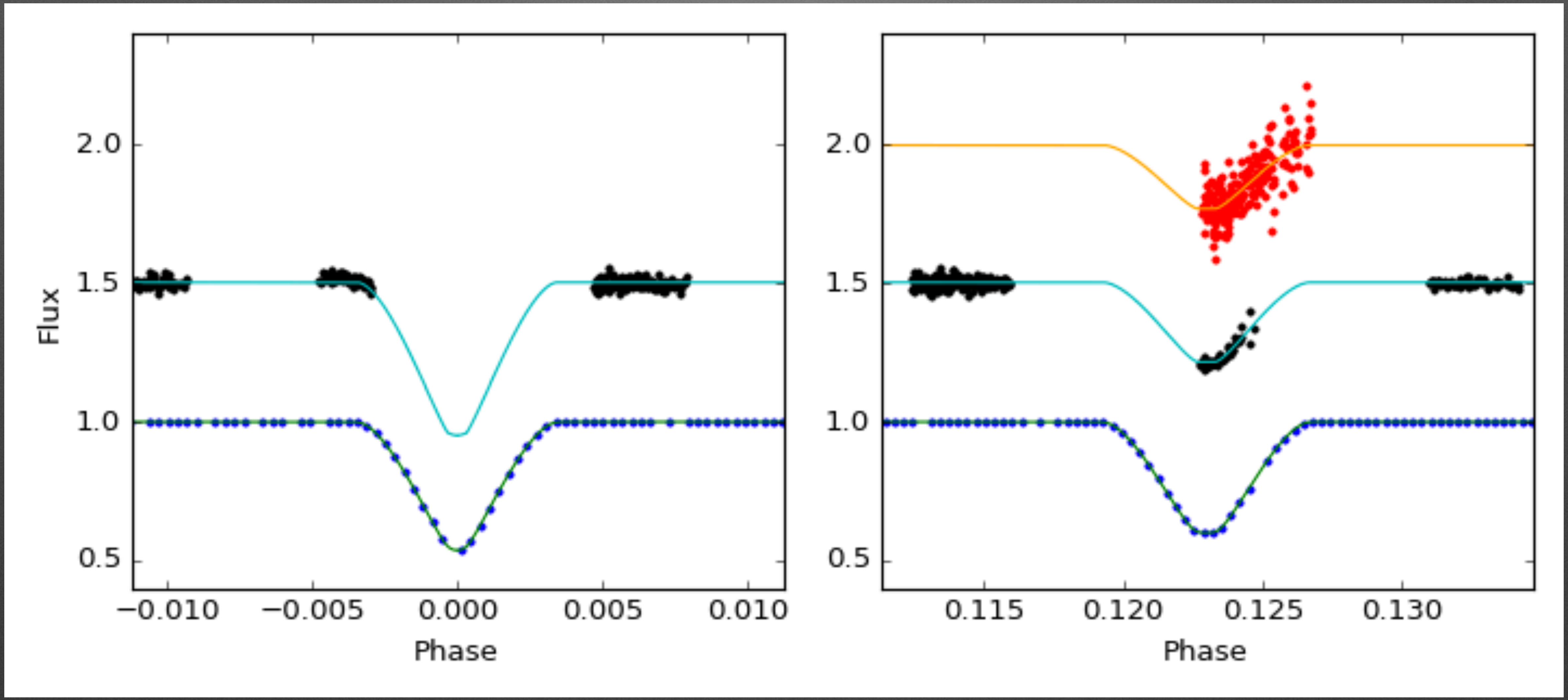


Star spot modulation





K2 + WASP

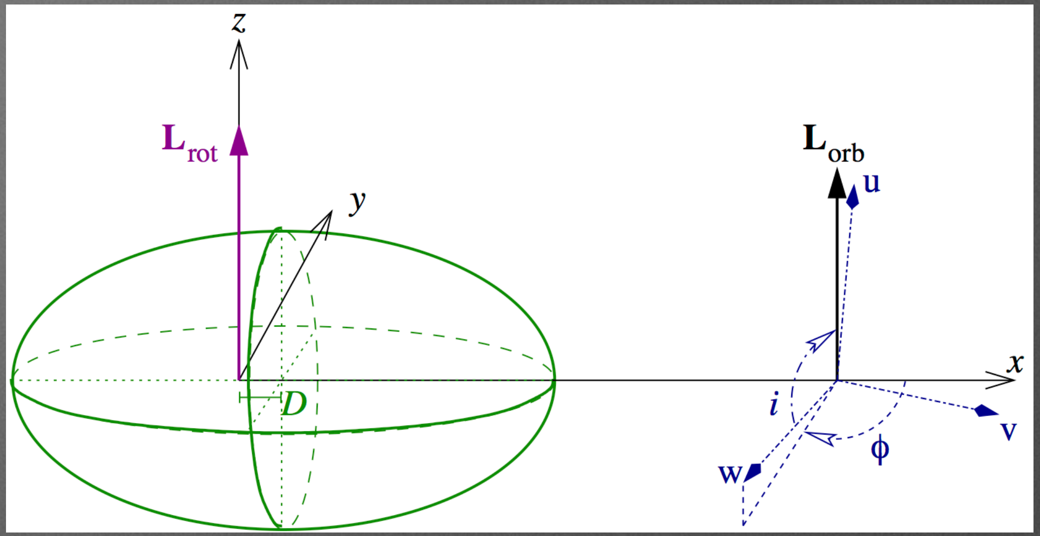


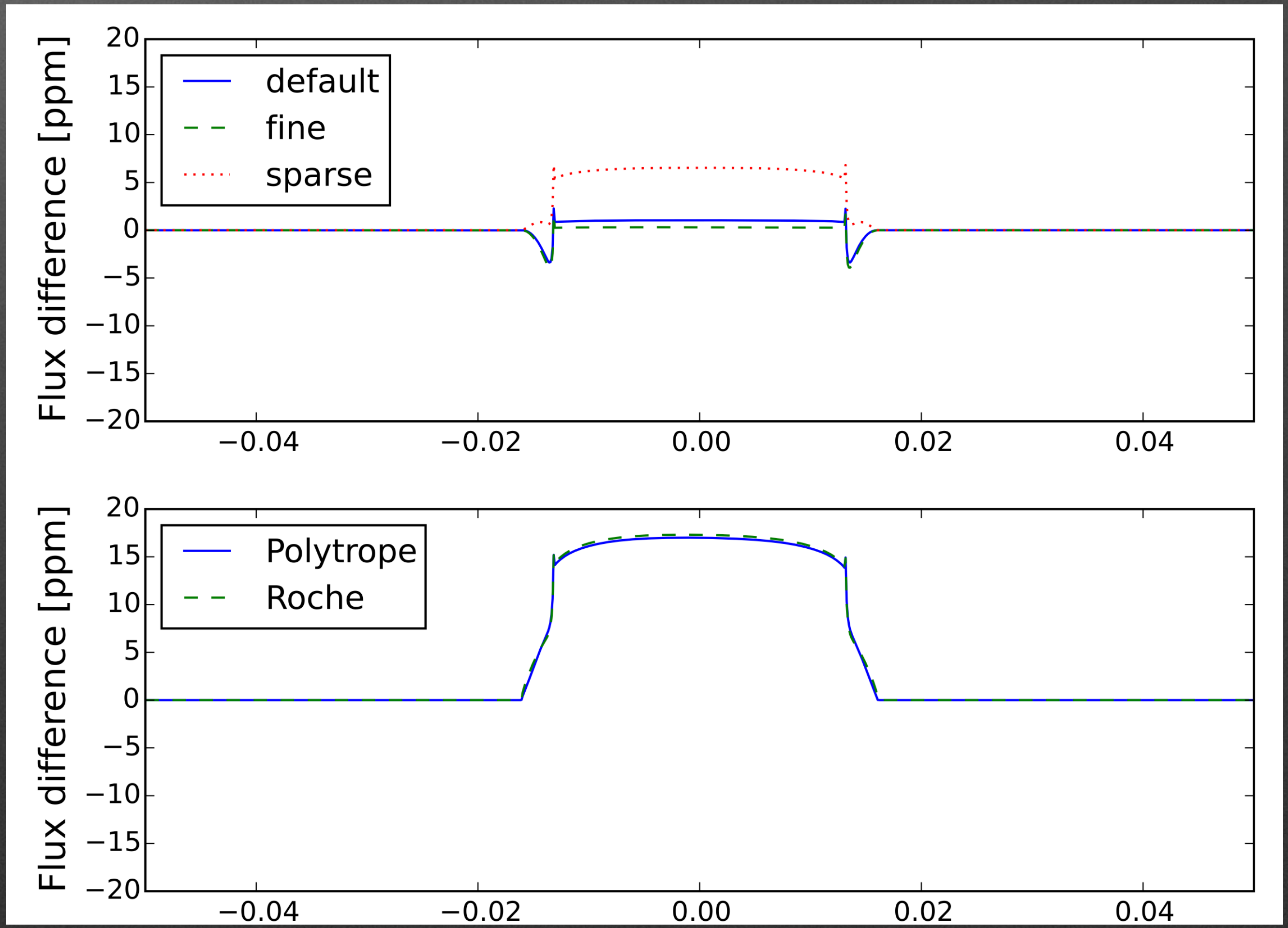
P=62.59d, e = 0.64, K_p =12.4

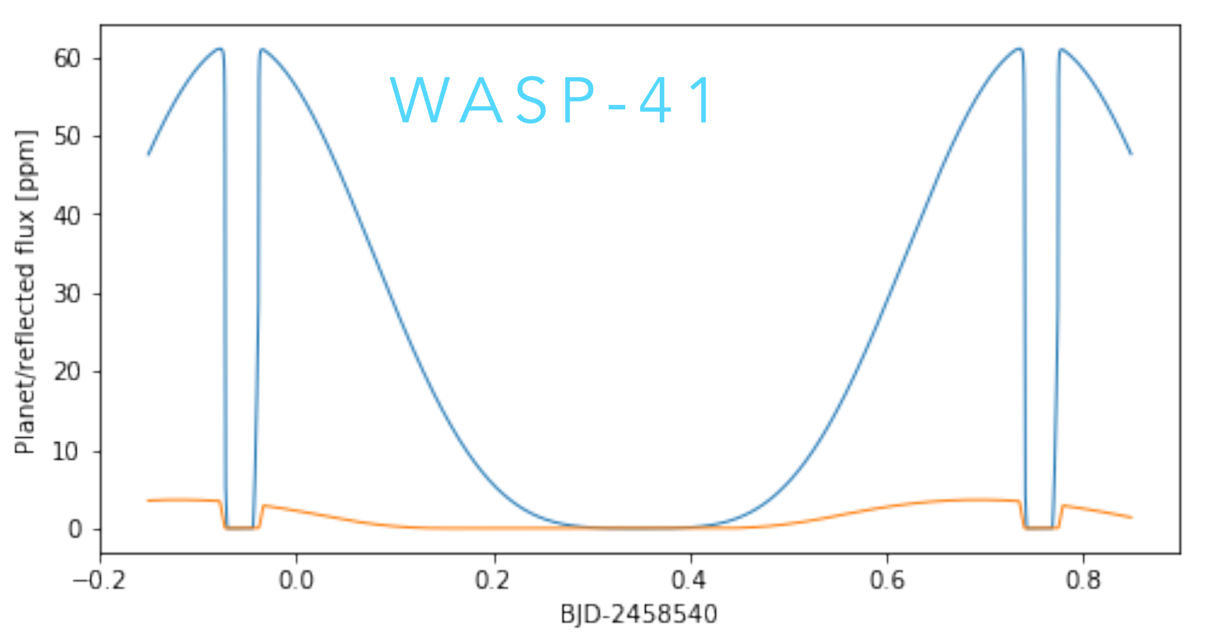
ellc

- Doppler boosting
- Light travel time effect
- Gravity darkening
- Reflection
- Spots
- Fast!

$ pip install ellc







Conclusions

- Becoming possible to select a sample of DEBS to suite a given scientific question (DEBS on demand)
  - Certainly true once TESS data are available
- Precision in mass and radius measurements has improved by an order of magnitude in recent years
  - Challenge will be to make sure accuracy is maintained
  - This precision is needed to *calibrate* models
- PLATO will provide asteroseismology for stars in DEBS
  - Can validate mass/radius estimates from asteroseismology
  - Exquisite tests of stellar physics