Accurate and Precise Effective Temperature Measurements for FGK Stars with *TESS*

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Eclipsing binary stars as benchmarks

Stars with accurate (±50 K), direct measurements of T_{eff} are essential for testing and calibrating stellar models.

The log*g*-T_{eff} parameter space populated by stars in the *Geneva-Copenhagen Survey* & *Kepler LEGACY* samples is only very sparsely covered by *reliable T_{eff} standard stars*.
More benchmark stars are needed!

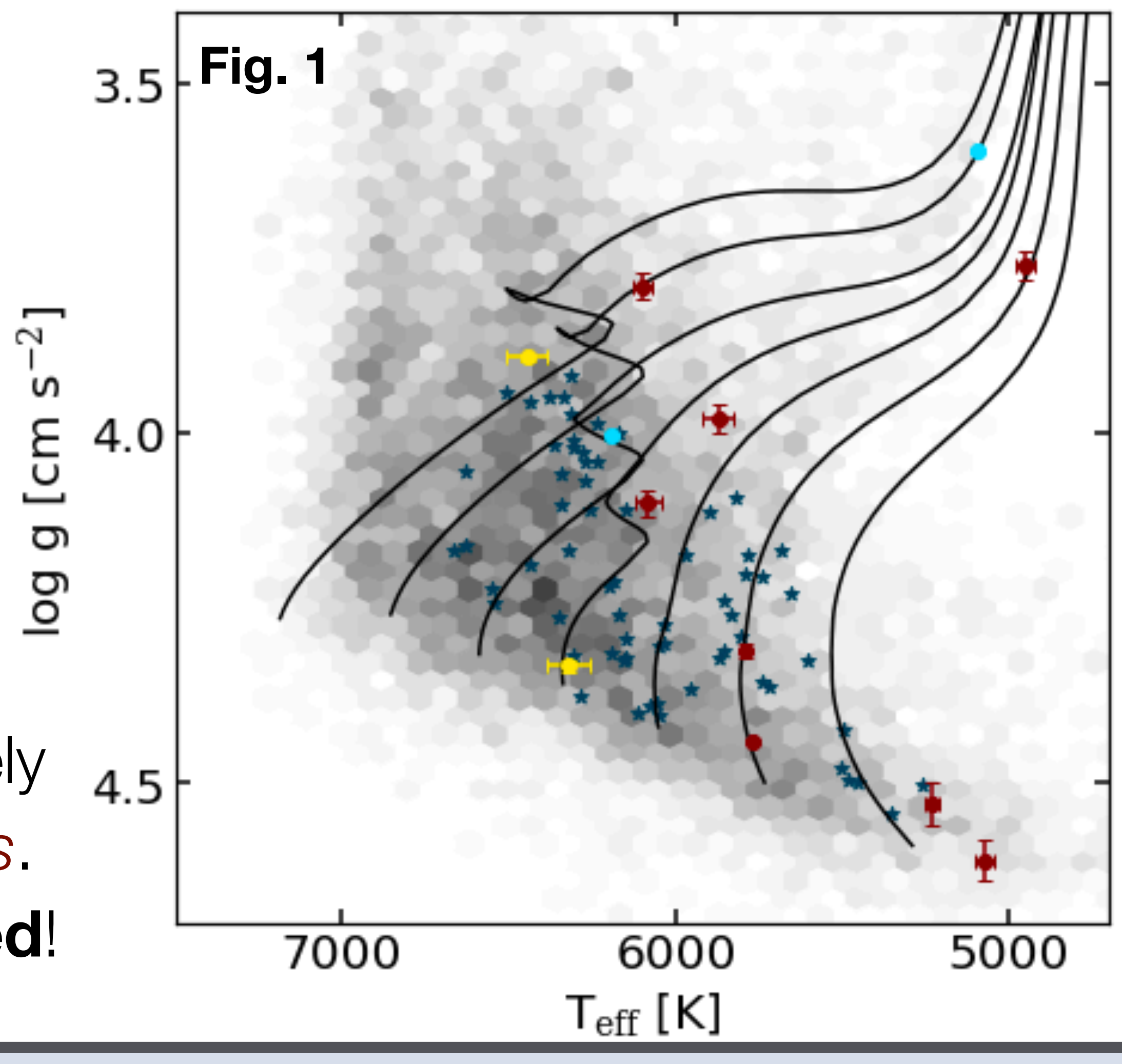
Fig. 1

Long-period eclipsing binaries (EBs) with high quality light curves from *TESS* and radial velocities can provide independent measures of mass *M* and radius *R* to **< 1% accuracy.**

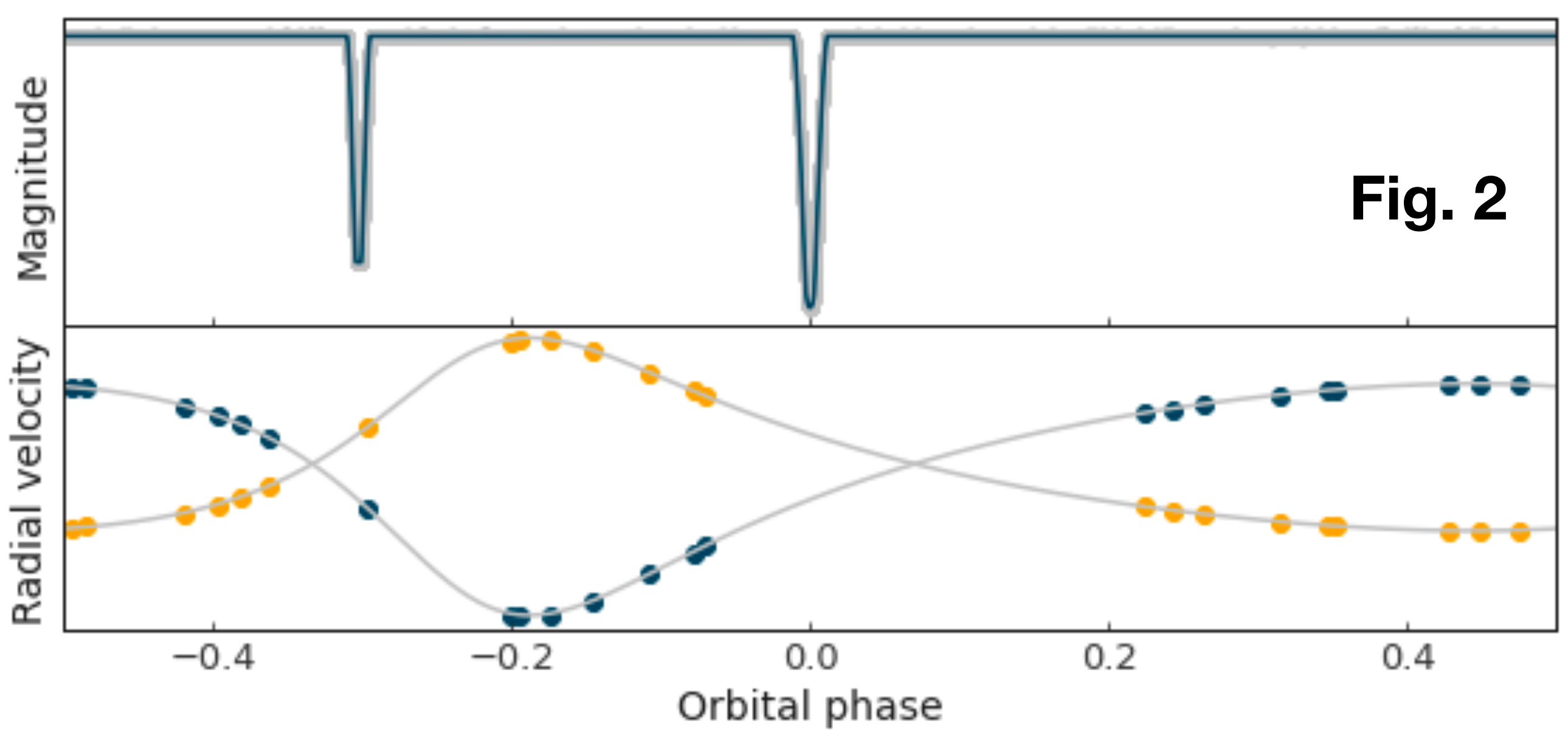
Fig. 2

A new approach to measuring fundamental effective temperatures

- Takes information about **angular diameters** (*θ*) and **bolometric flux** ($f_{0,b}$) to obtain *fundamental* effective temperature (1)
- Angular diameters derived from *R* and parallax from *Gaia*
- Bolometric flux obtained using Legendre polynomials ($P_j(x)$) to **distort model SEDs**, which determine realistic small-scale spectral features, to fit **multi-bandpass photometric data**, which determine broad shape (2)
- Best fit found by sampling posterior probability distribution with MCMC.

$$f_{0,b} = f_{0,1} + f_{0,2} = \frac{\sigma_{\rm SB}}{4}\left[\theta_1^2 {\rm T}_{\rm eff,1}^4 + \theta_2^2 {\rm T}_{\rm eff,2}^4\right] \quad \textbf{(1)}$$

$$\tilde{f}_{\lambda,i} = f^m_{\lambda,i} \times \Delta_i(x) = f^m_{\lambda,i} \times \left(d_{0,i} + \sum_{j=1}^{N_\Delta} d_{j,i} P_j(x)\right) \quad \textbf{(2)}$$

Wide availability of high quality multi-wavelength photometry from e.g. *TESS* — potential to create a **benchmark catalog** of EBs with accurate, independent T_{eff} measurements

AI Phoenicis

Paper I is a proof of concept with a well-studied F7V+K0IV EB that shows promising results.

Miller et al. 2020
MNRAS, 497, 2899

F7 V primary:
T_{eff} = 6199 ± 22 K
K0 IV secondary:
T_{eff} = 5094 ± 16 K

NB. There is an additional systematic error (±11 K) from the flux scale zero point.

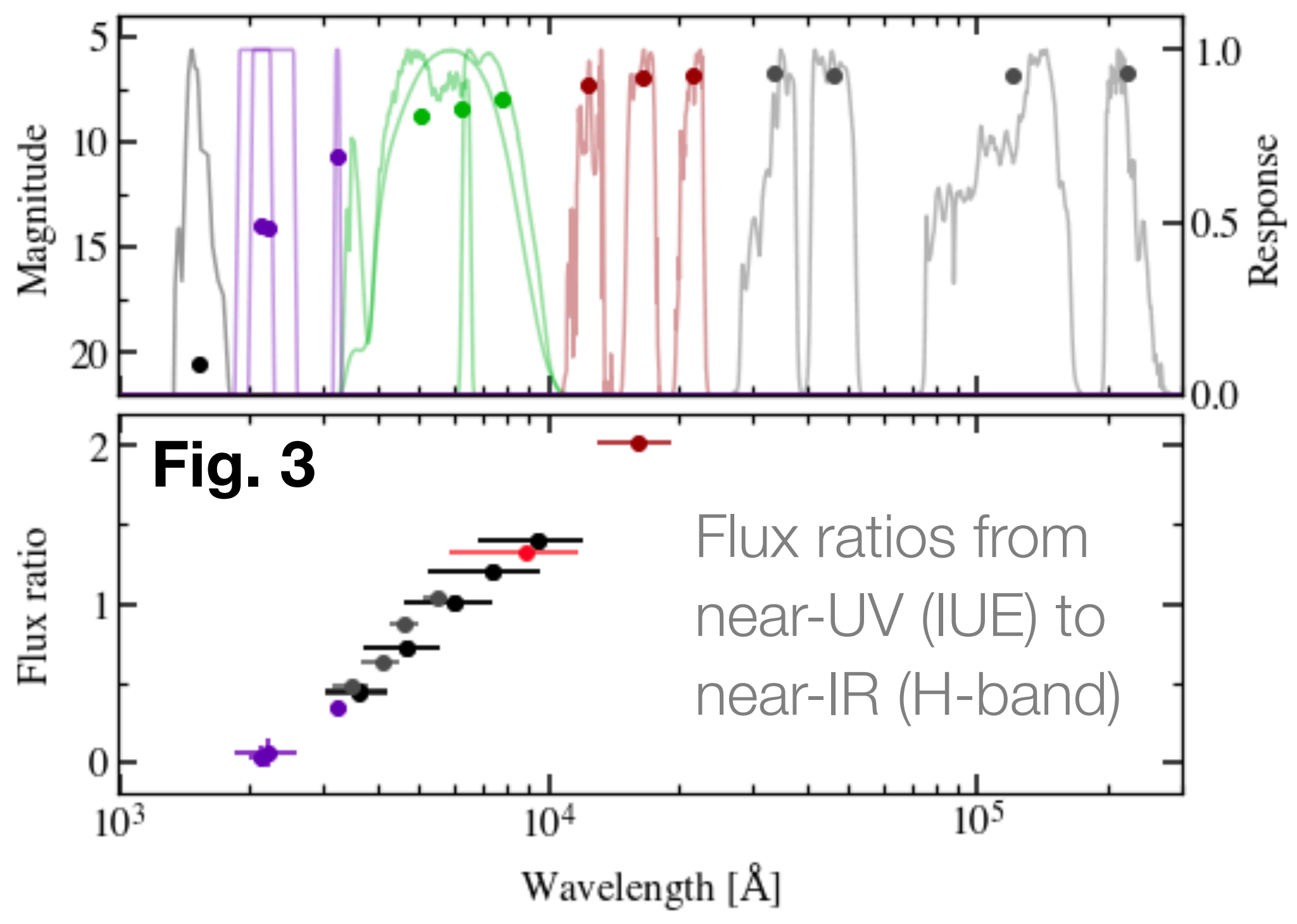
Fig. 3

Flux ratios from near-UV (IUE) to near-IR (H-band)

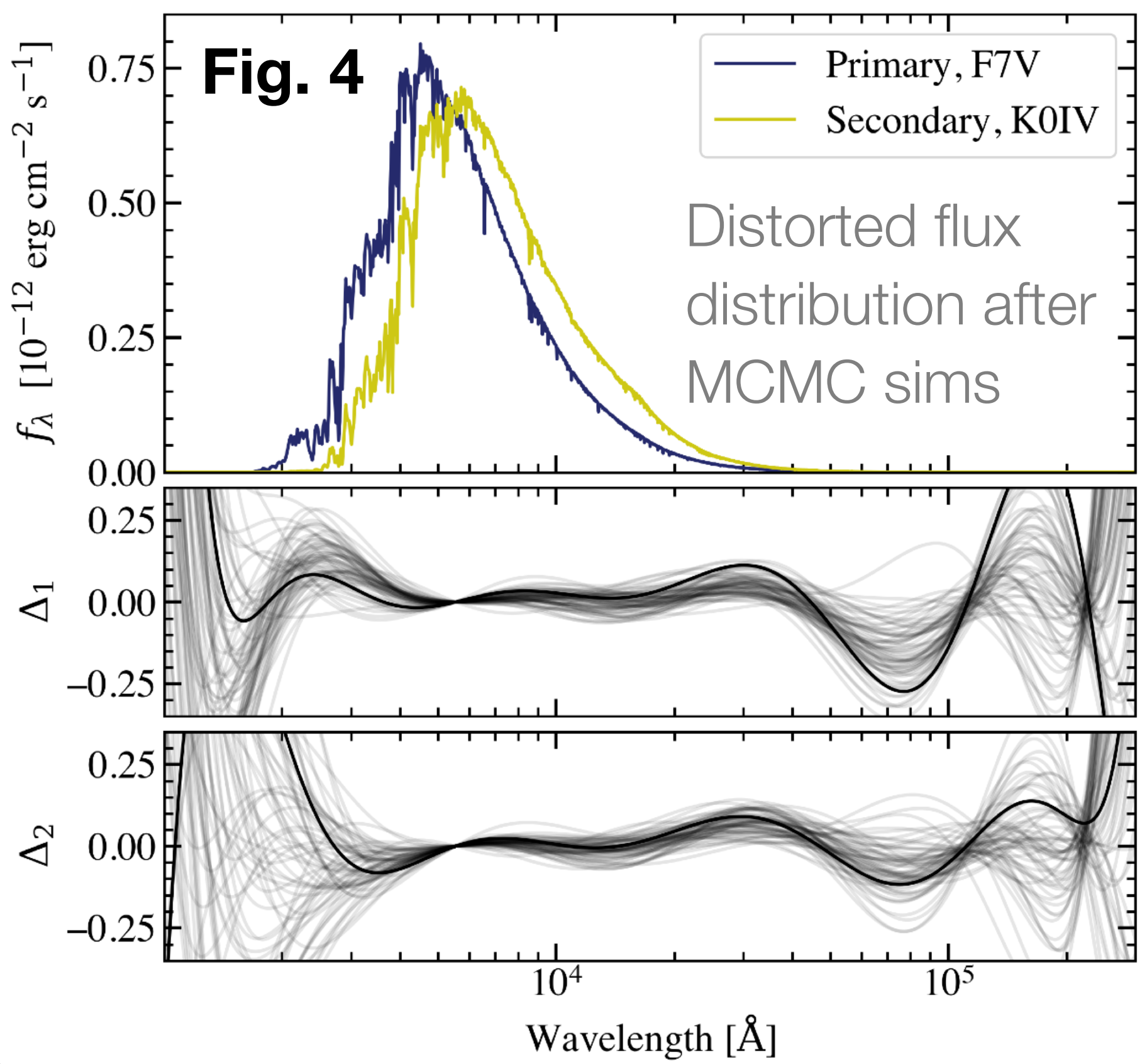
Fig. 4

Distorted flux distribution after MCMC sims

- Robust prior on **interstellar reddening** (±0.01 mag) **essential**
- Flux ratios in near-UV useful to constrain shape of model SEDs
- Choice of input model (T_{eff}, [Fe/H]) has no significant effect

CPD-54 810

Paper II tests the limits of the method with a recently published EB with fewer observations.

Miller et al. 2021
(in prep)

F5 V primary:
T_{eff} = 6502 ± 52 K
F6 V secondary:
T_{eff} = 6377 ± 56 K

The high quality of the *TESS* light curves is essential to get errors on *R* << 1% and hence error on T_{eff} < ~50 K.

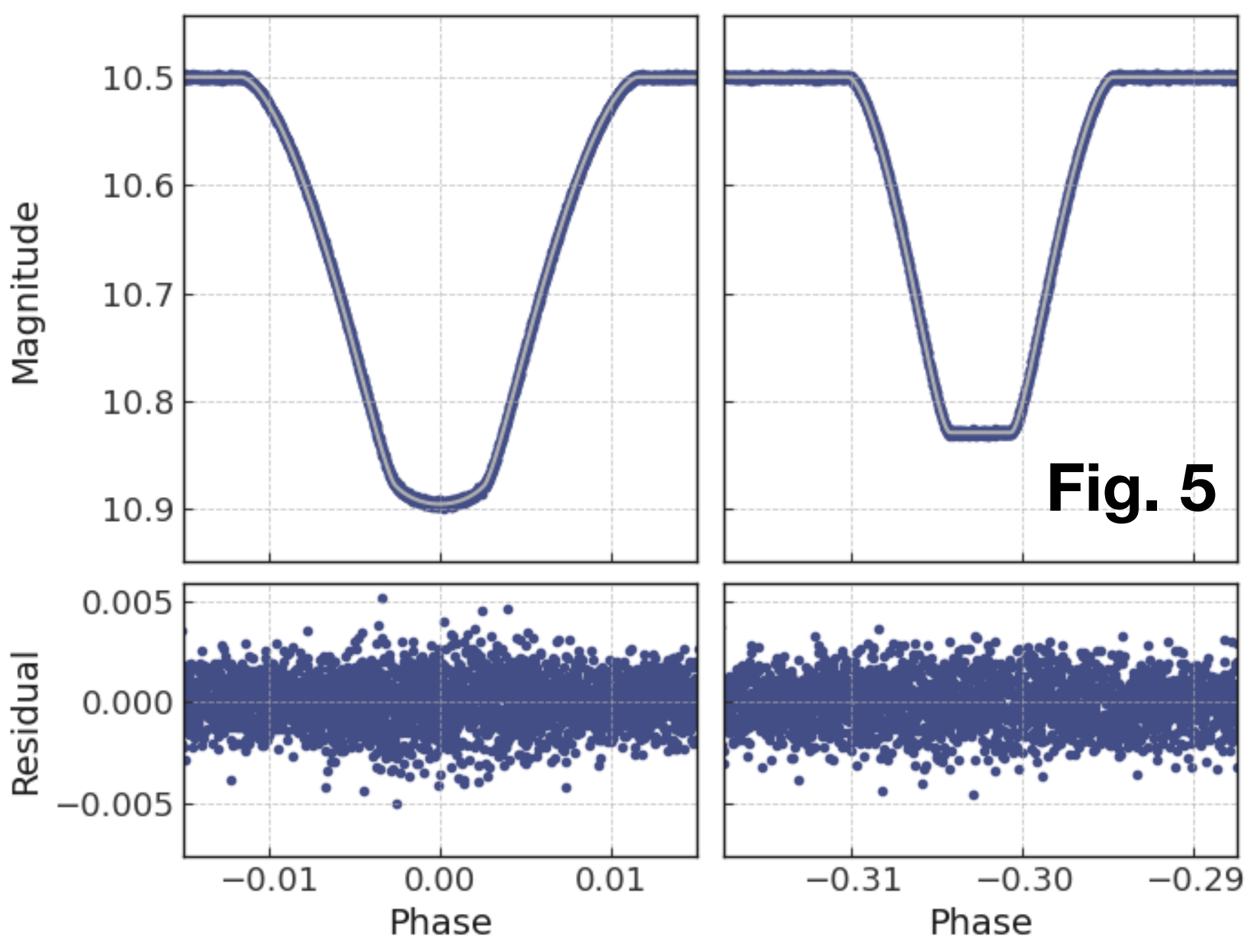
Fig. 5

Phase-folded *TESS* light curve (5 sectors) in blue, with JKTEBOP fit in grey.

Spectroscopic T_{eff} vs. Photometric T_{eff}

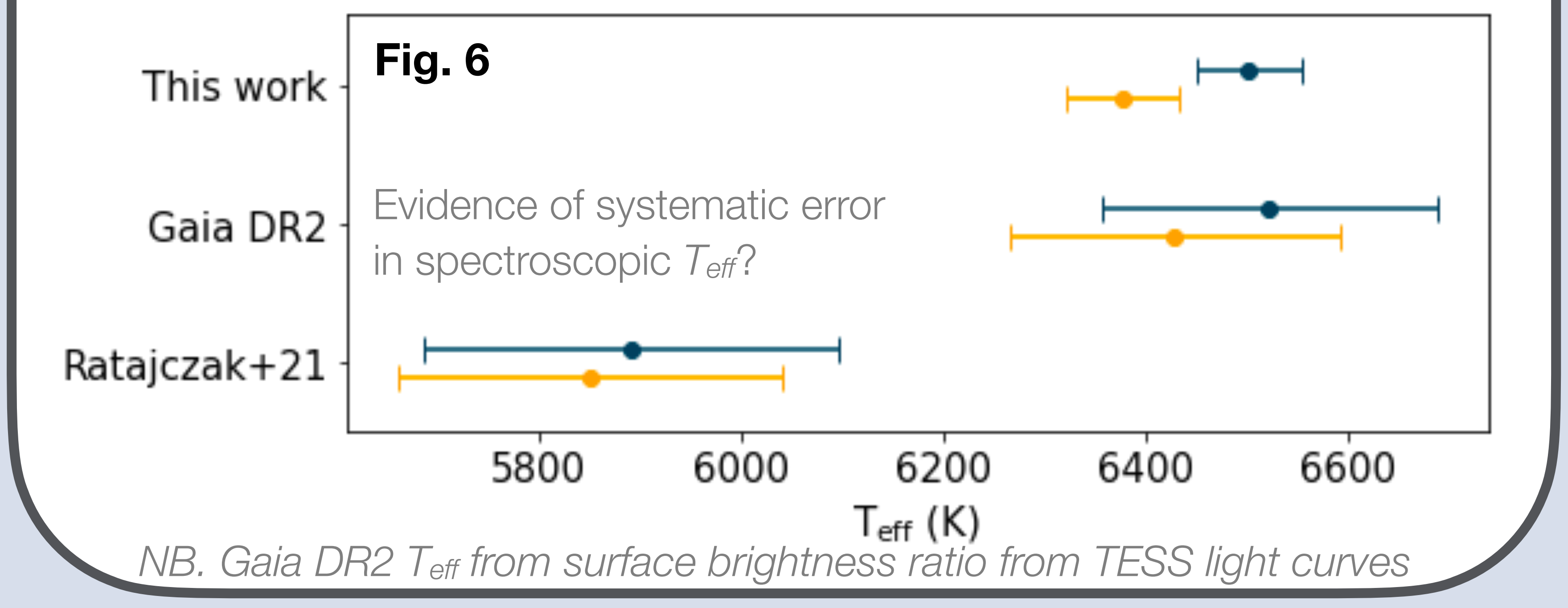
Fig. 6

Evidence of systematic error in spectroscopic T_{eff}?

NB. Gaia DR2 T_{eff} from surface brightness ratio from TESS light curves

References: Fig. 1: Silva Aguirre et al. 2017, *APJ*, **835**, 173; Heiter et al. 2015, *A&A*, **582**, A49; Holmberg et al. 2009, *A&A*, **501**, 941. Fig. 2: Ratajczak et al. 2021, *MNRAS*, **500**, 4972.