Accurate and Precise Effective Temperatures for Cool Stars

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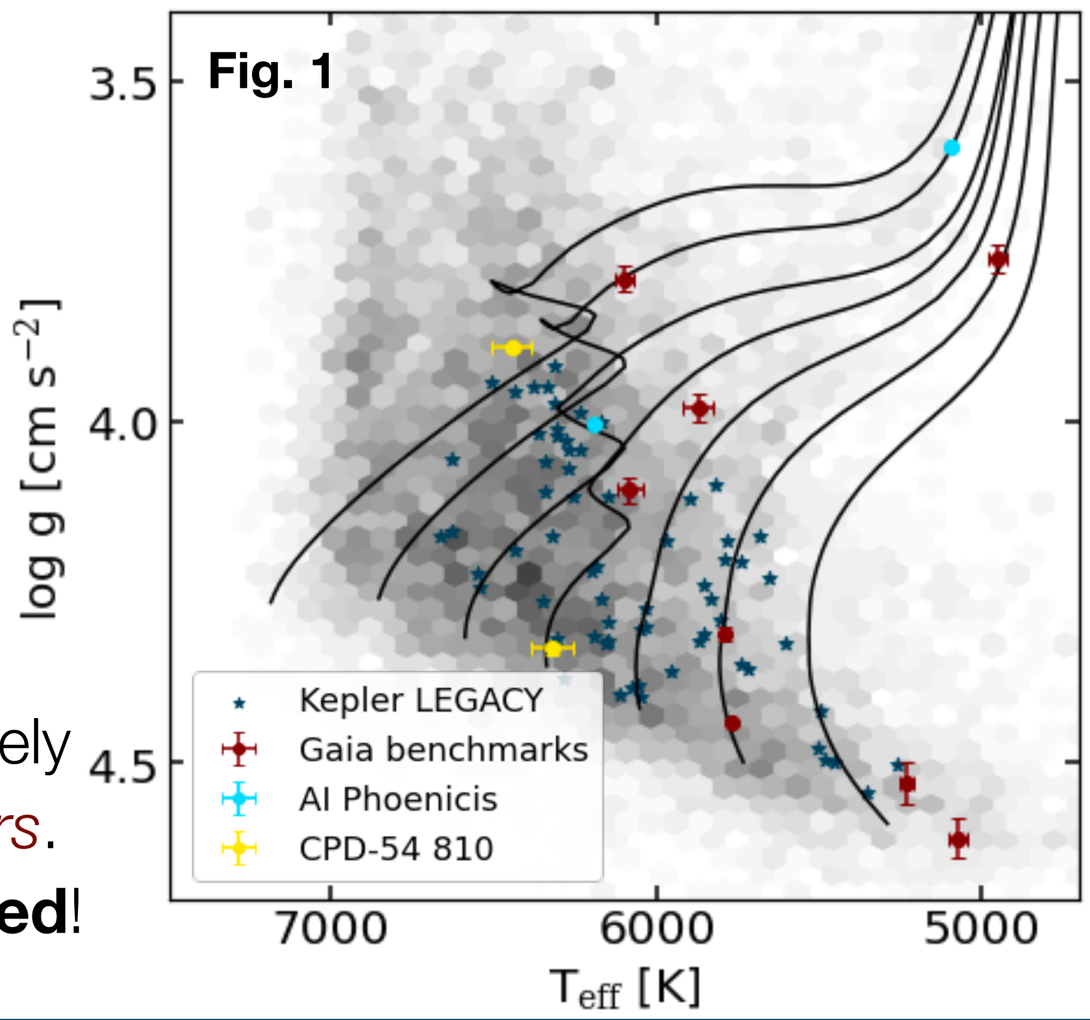
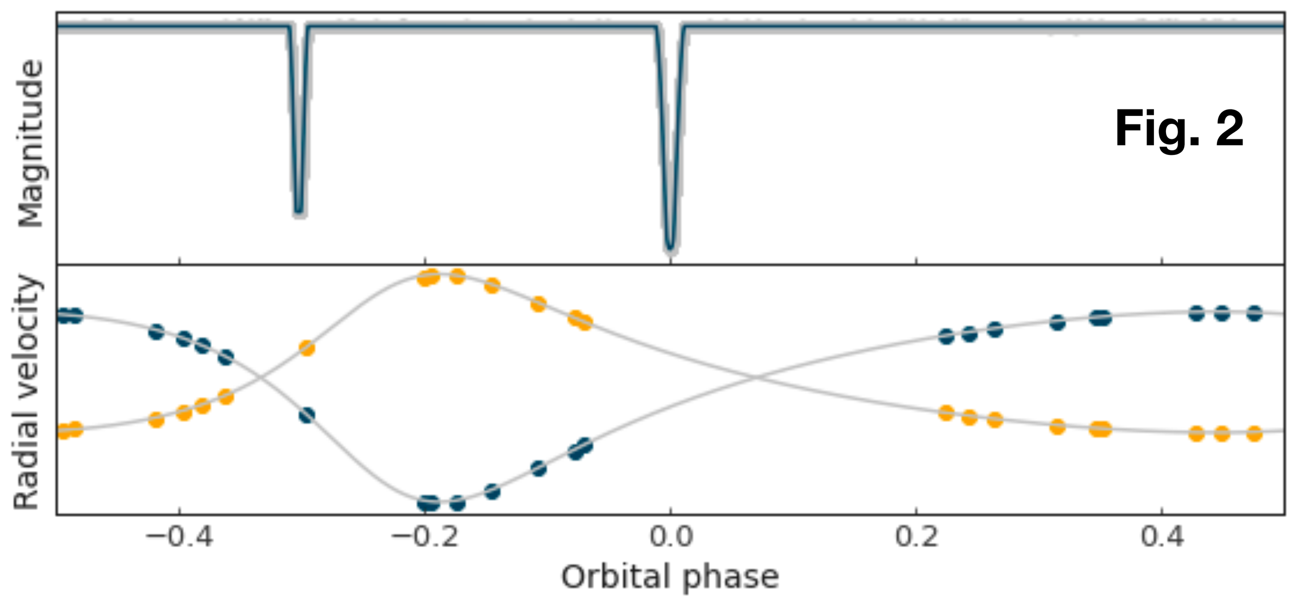
Eclipsing binary stars as benchmarks

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

The logg-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**!



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



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 generated by using Legendre polynomials ($P_j(x)$) to **distort model SEDs**, which determine realistic small-scale features, to fit **multi-bandpass photometric data**, which determine broad shape (2)
- Best fit found by sampling posterior probability distribution with MCMC.

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

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

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

AI Phoenicis

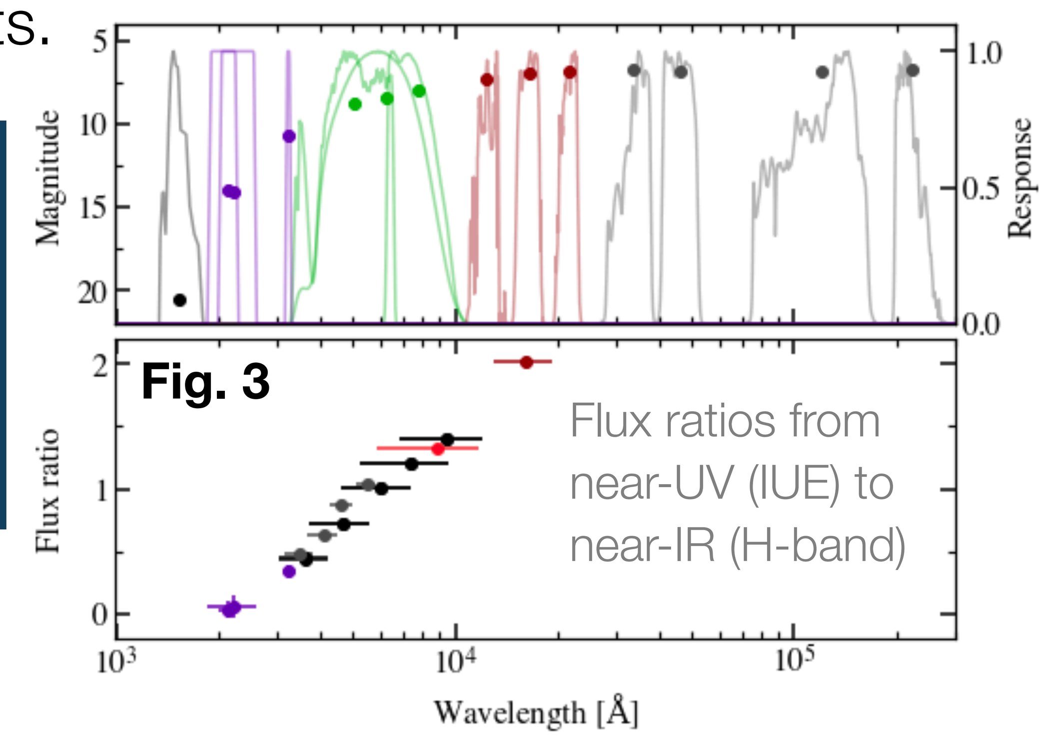
Paper I is a proof of concept with well-studied EB that shows promising results.

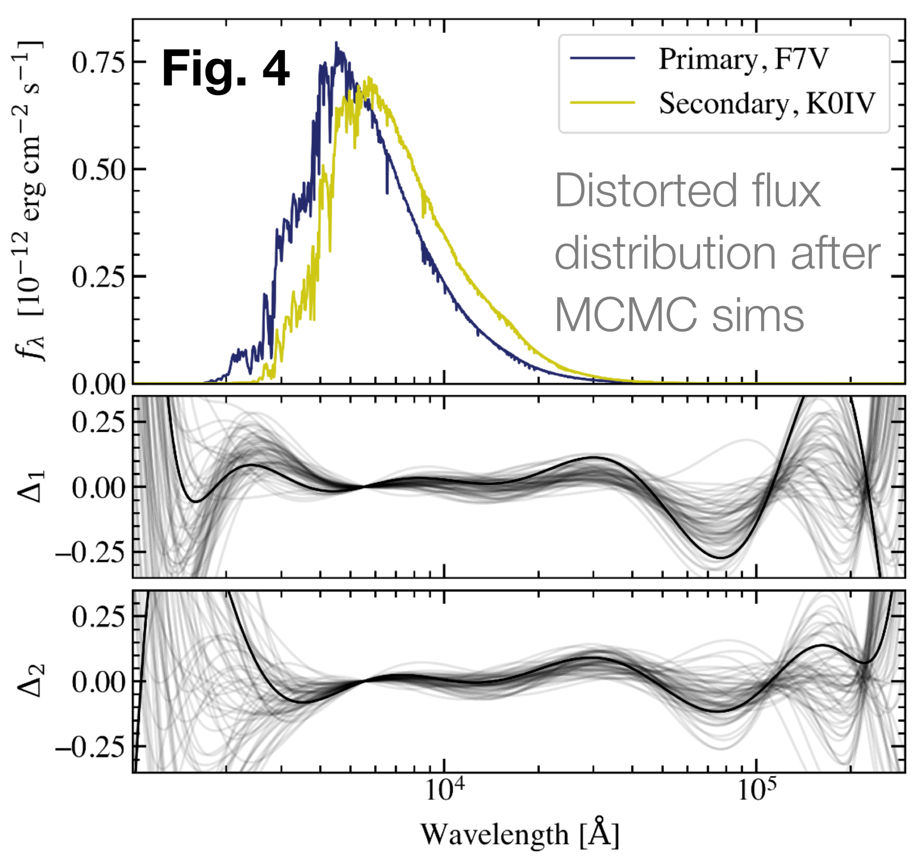
Miller et al. 2020
MNRAS, 497, 2899

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.





- 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

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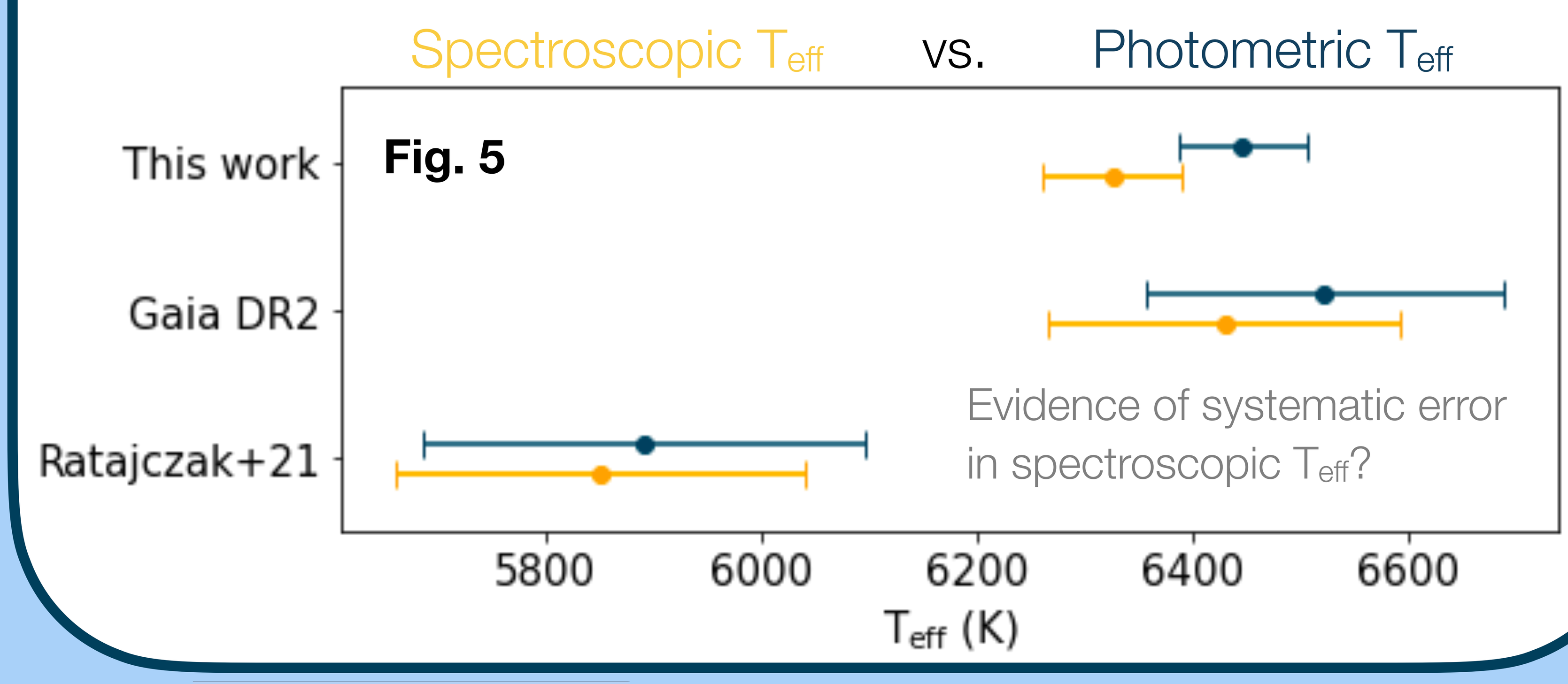
Paper II tests the limits of the method with a recently discovered EB with similar T_{eff} components and fewer photometric observations.

Miller et al. 2021
(in prep)

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



Summary

We can measure T_{eff} for stars in EBs accurate to < 1%

- Method requires UV flux (ideally light curves), *Gaia* parallaxes and multi-band light curves
- Plenty of newly-discovered EBs suitable for method
- Now applying for telescope time to obtain spectroscopy and multi-band light curves for more systems!

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.