# Short-period eclipsing binaries: a purely photometric method to characterise components of detached systems from the *Kepler* field

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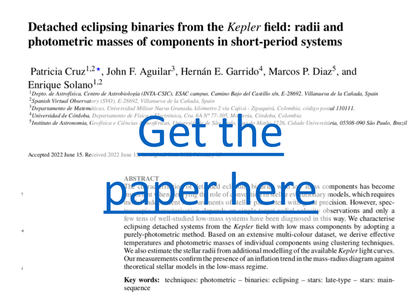
**Detached eclipsing binaries from the *Kepler* field: radii and photometric masses of components in short-period systems**

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few tens of well-studied low-mass systems have been diagnosed in this way. We characterise eclipsing detached systems from the *Kepler* field with low mass components by adopting a purely-photometric method. Based on an extensive multi-colour dataset, we derive effective temperatures and photometric masses of individual components using clustering techniques. We also estimate the stellar radii from additional modelling of the available *Kepler* light curves. Our measurements confirm the presence of an inflation trend in the mass-radius diagram against theoretical stellar models in the low-mass regime.

**Key words:** techniques: photometric – binaries: eclipsing – stars: late-type – stars: main-sequence

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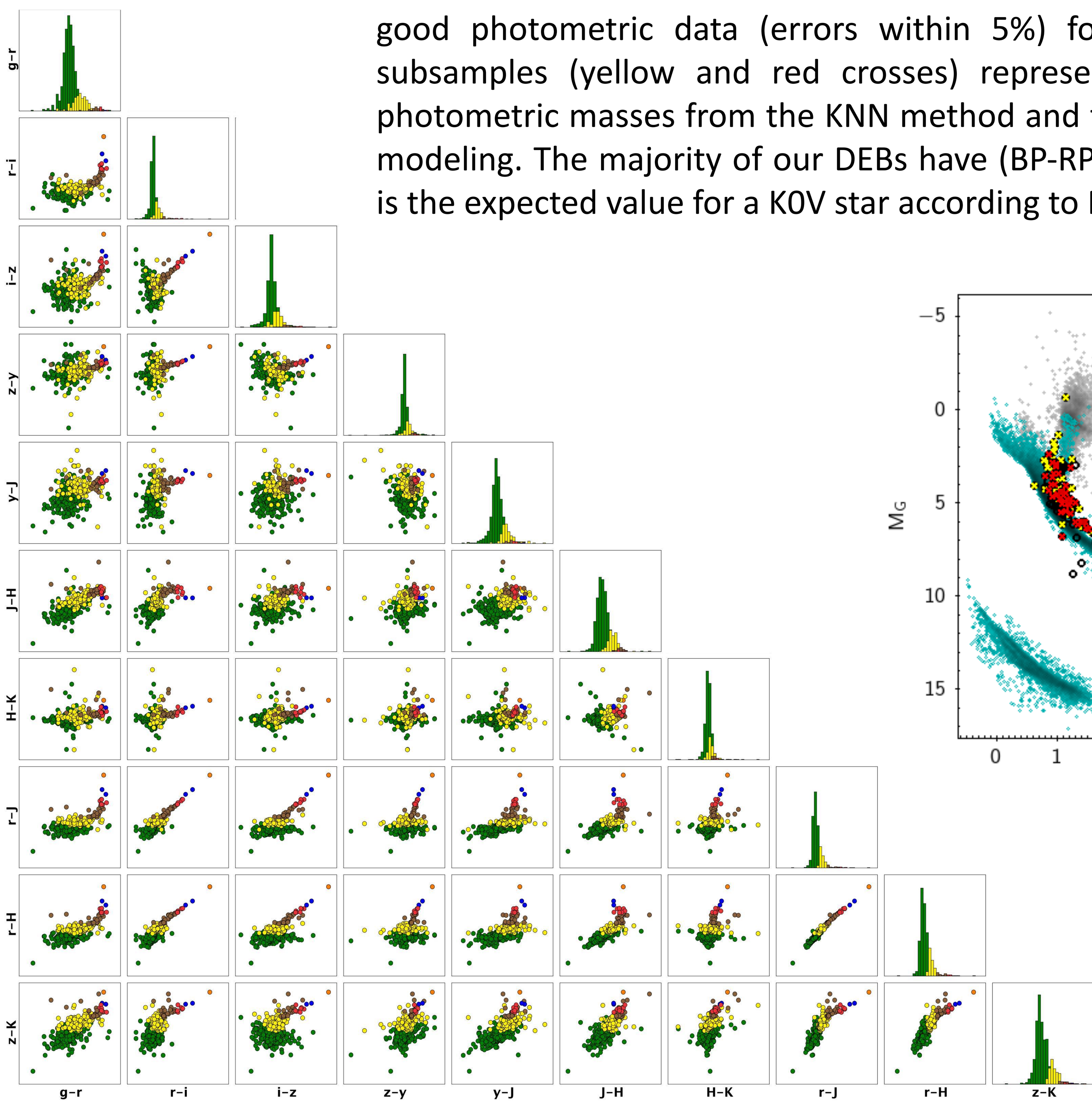
## Sample of detached EBs from *Kepler*

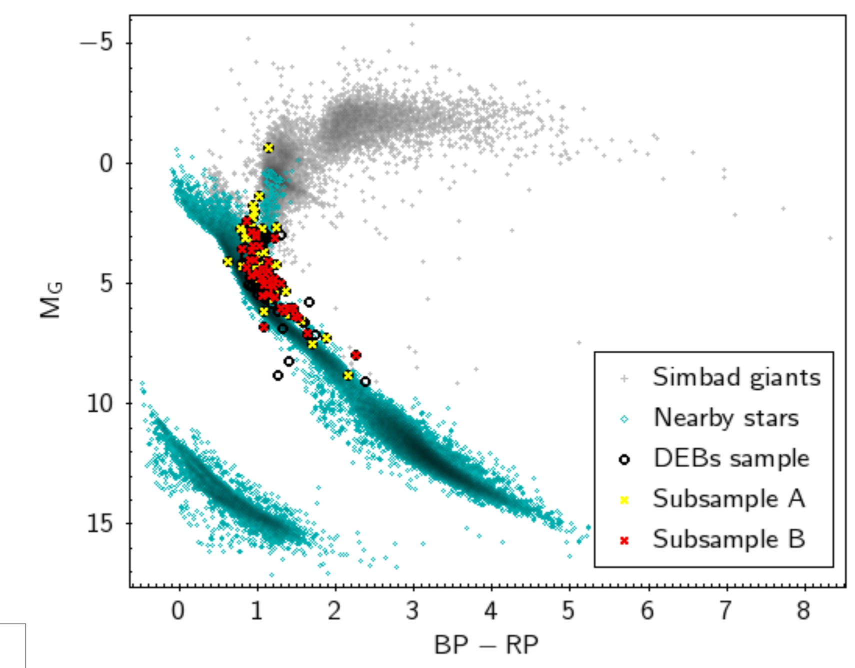
The characterisation of detached eclipsing binaries with low mass components has become important when verifying the role of convection in stellar evolutionary models, which requires model-independent measurements of stellar parameters with great precision. However, spectroscopic characterisation depends on single-target radial velocity observations and only a few tens of well-studied low-mass systems have been diagnosed in this way. We characterise eclipsing detached systems from the Kepler field with low mass components by adopting a purely-photometric method.

We selected eclipsing binary systems from the Kepler Eclipsing Binary Catalog (Kirk et al. 2016), with orbital period of 4 days or less, and with effective temperature up to 6 000 K. The selection was cross-matched to broad-band photometric catalogs, keeping only those EB systems with available data from Pan-STARRS and 2MASS.

The DEB candidates went under a supervised statistical analysis which used the K-Nearest Neighbors classifiers method (Hartigan 1975), a clustering technique, to assign Teff for each component of the system by searching for similarities between observed data and models based on a multi-color dataset. We then constructed a PanSTARRS–2MASS ten-color calibration grid of synthetic composite colors using over 180 000 synthetic binaries, based on the stellar models for dwarf and giant stars from Bressan et al. (2012). Photometric masses were then obtained for each component from the semi-empirical values of stellar colors and effective temperature sequence by Pecaut & Mamajek (2013).




We cross-matched the identified detached EB sample Gaia EDR3, where we found good photometric data (errors within 5%) for 161 systems. The overplotted subsamples (yellow and red crosses) represent those systems with Teff and photometric masses from the KNN method and those with radii estimates from LC modeling. The majority of our DEBs have (BP-RP) colour redder than 0.983, which is the expected value for a K0V star according to Pecaut & Mamajek (2013).




We identified 164 detached systems with only main-sequence stars as components (V+V systems).

## Light-curve modelling with JKTEBOP and AGA

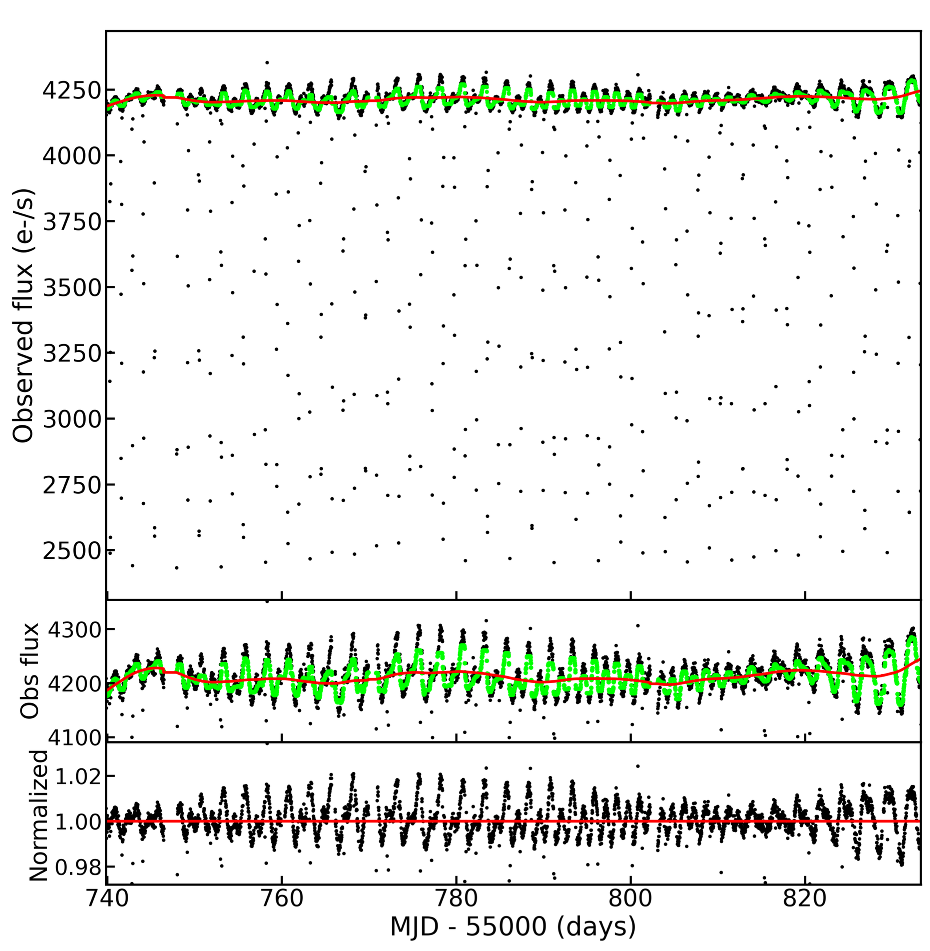
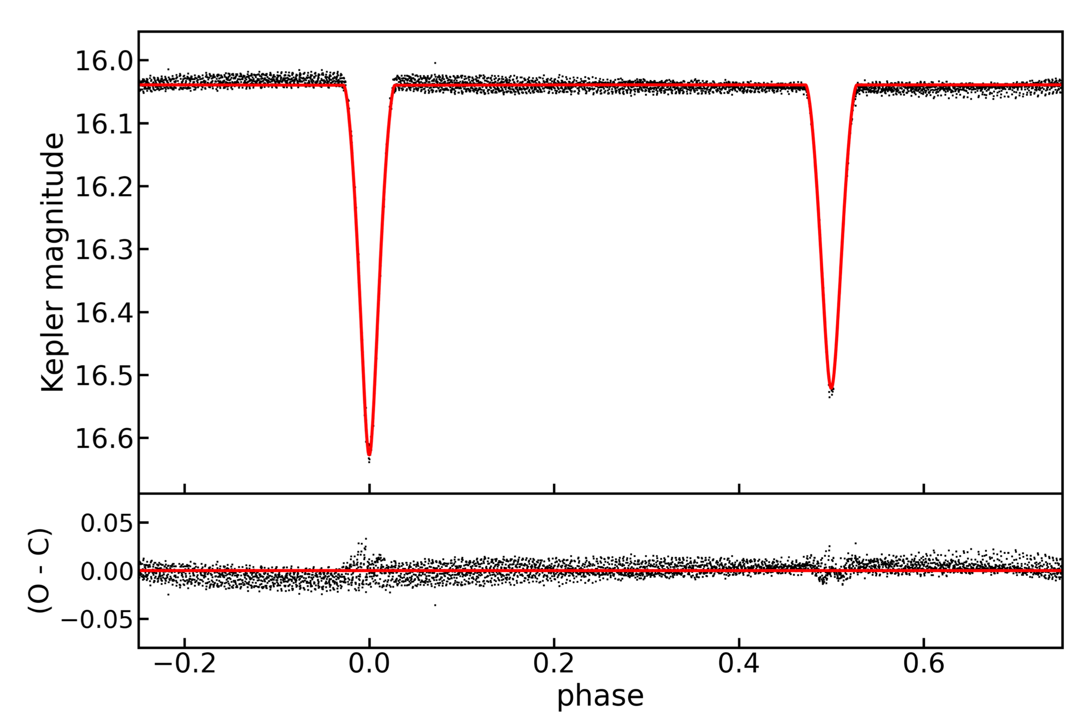



Figure on the left shows the normalized LC for KIC09656543 as an example. Top and middle panels show the calculated median light curve in green (sliding median method), and the red curve represents the normalization function obtained by a spline fit. The normalized light curve (for one quarter of observations) is presented in the bottom panel.

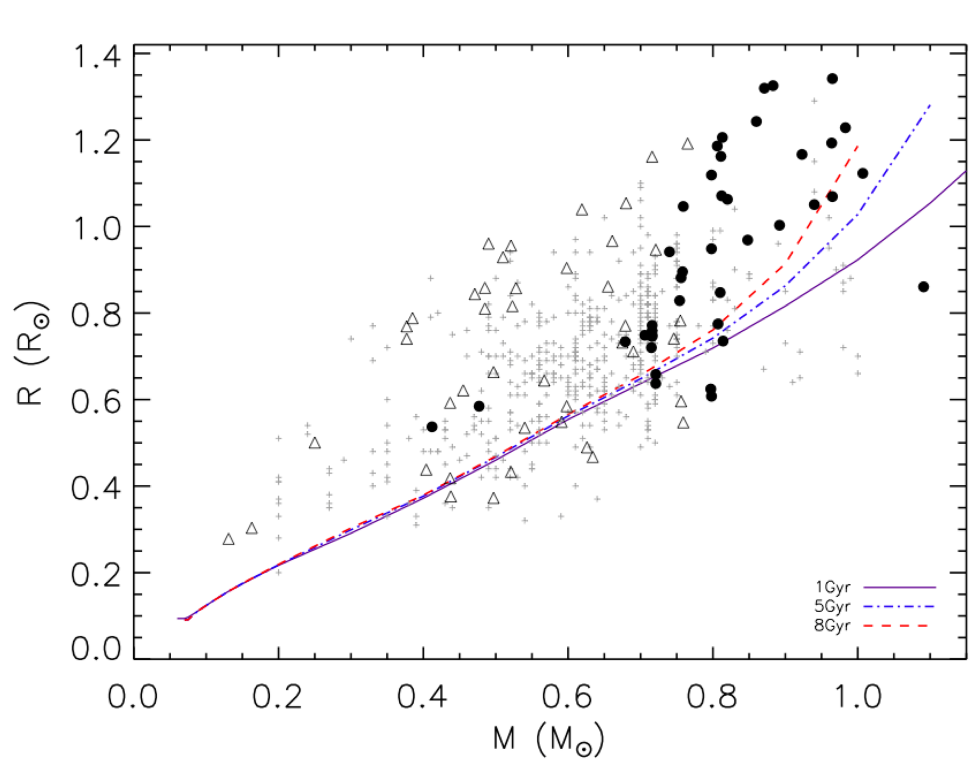
We performed the fitting of Kepler LCs using the JKTEBOP code (Southworth et al. 2004; Southworth 2013) – which is suitable for detached systems – modified with an asexual genetic algorithm (AGA; Coughlin et al. 2011), to obtain the orbital solution for each EB system and derive the stellar radii




Convergence was achieved for 94 DEB systems after four complete iterations. The figure shows the phase-folded light curve of KIC09656543 for only one quarter of observations, where we adopted phase zero for the primary eclipse minimum. The best-fitting model is repented by a red solid line.

We obtained the orbital parameters for 94 V+V detached binary systems from Kepler light-curve modelling.

## The mass-radius diagram




The figure shows the mass-radius diagram for some studied DEB systems. Primary and secondary components are represented by filled circles and open triangles, respectively. Baraffe et al. (2015) standard stellar for 1, 5, and 8 Gyr are represented by solid, dot-dashed, and dashed lines, respectively. DEB candidates from the CSS (Garrido et al. 2019) are illustrated as small gray crosses.

Our objective was to study homogeneously the whole sample, rejecting unreliable or biased mass or radius estimates, not dealing with each system separately. The average difference between the measured stellar radius and expected value (5-Gyr model) – as an estimate of the radius inflation – appears to be larger for the secondary than for primary components, by over 20% more inflated. More detailed studies of the sample presented here are still important to the understanding of the radius inflation.

Further search for correlations between the measured inflation and metallicity, age, stellar activity, and/or rotation may hold clues to the mechanism behind the mass-radius anomaly.

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