1 Scientific Justification

Stellar evolutionary models are used in many different areas of astrophysics, for example, understanding exoplanets and galaxy evolution modelling. Yet, it is known that stellar evolutionary models can under-predict the radii of low mass stars, and over-predict their effective temperatures. As an example, Mann et al. (2015) looked at 183 K and M type stars, and found that on average, the temperature was over-predicted by 2.2% and the radii under-predicted by 4.6% (Figure 1). One proposed solution is magnetic fields generated by the rapid rotation of the stars, however Mann et al. (2015) and Boyajian et al. (2012) found no clear correlation between the model offsets and magnetic activity. There are examples where the inclusion of magnetic fields into stellar evolutionary models has helped produce models that are consistent with observations (Torres et al., 2015), however Feiden & Chaboyer (2014) found that unreasonably strong interior magnetic fields of 10 MG were needed to reproduce the radii of low mass, fully convective stars. There is still a large amount of uncertainty within this area of research, and there are numerous free parameters (e.g. mixing-length, convective overshooting and helium abundance) that need calibrating.

Surveys such as Wide Angle Search for Planets (WASP) that search for transiting exoplanets, are also useful in studying eclipsing binary systems, as they can monitor the brightness of large numbers stars for long periods of time. Four detached eclipsing binary systems have been identified within the WASP data, which when combined with radial velocities from UVES spectra, we aim to measure masses and radii to a precision of 1%. Combining these with measurements of effective temperature and metallicity, will allow the ages of the stars to tightly constrained, due to the combination of a subgiant and a main-sequence star, make them ideal for calibrating stellar models (Lastennet & Valls-Gabaud, 2002). Recent work using WASP photometry for the 24.6-day detached eclipsing binary system, AI Phe yielded high-precision masses and radii were used to place tight constraints on helium abundance (Kirkby-Kent et al., 2016). This was due to precise stellar parameter of the subgiant providing tight constraints on the age of the system. There is potential for something similar to be achieved with these 4 new systems, provided we obtain masses and radii to the required precision. The periods of these four binary systems are sufficiently long ($P > 7$ days), that effects from tidal forces do not influence the evolution of the stars and can be treated as though they have evolved as single stars.

Currently, the photometric analysis of one of these binaries, J1046-28, has failed to produce the accuracy in the radii needed for the overall objective (current: 4%, objective: 1%). It is thought, this is related to the nearby by star which is included in the apertures used for the WASP photometry, and so the lightcurve itself contains a large amount of scatter (Figure 2). Observations proposed here would be used to complement previous observations made with the 1.0m, which due to poor weather, only partial coverage of each eclipse was obtained.

During times when our main targets are not in eclipse we will use the telescope time to observe low mass eclipsing binary systems (EBLMs). These systems are F/G/K hosts with a faint K/M dwarf companion which are found in abundance by transit surveys as they resemble exoplanet systems. Over 100 EBLMs, discovered by WASP, have been studied spectroscopically with the CORALIE échelle spectrograph resulting in orbital measurements alongside T_{eff} and [Fe/H] for the host star. We require high-quality light curves with discernible contact points to measure the mass and radius to the desired accuracy of a few percent (Torres, Andersen & Giménez, 2010). We intend to empirically calibrate the mass-radius-[Fe/H]-luminosity relationship for very low mass stars (VLMS) using these EBLMs, because the mass, radius and composition relationships for VLMS are poorly understood (Gómez Maqueo Chew et al., 2014), which can lead to biases in mass and radius measurements obtained using evolutionary models. The analysis of a large sample of EBLMs will provide empirical calibrations for VLMS (Enoch et al., 2010; Southworth, 2011).

2 Technical Justification

Good coverage of the eclipses' contact points is key to obtaining accurate radii. As the eclipses last ≈8 hours, observing an entire eclipse is not possible in one night, therefore, the binary needs to be observed over multiple orbital periods. Consecutive observable eclipses only occur between a specific range of dates, as given in the preferred date section, with no eclipses visible outside these times. The STE4 camera provides a wide field of view, which will be needed to locate suitable check and comparison stars for differential photometry. Differential photometry is needed as targets will be observed throughout the night. The targets are bright and are unaffected by the moon phase. To achieve the necessary precision in the photometrically determined parameters, high-precision photometric observations are necessary. To achieve this a high signal to noise ratio of 200 will be needed. The star that contaminates the WASP aperture sits 16" away from the target binary. The resolution of STE4 on the 1.0m telescope will be more than adequate to separate the two. Previous observations made with the 1.0m (Figure 2) show that this setup is suitable for what we would like to achieve.

3 Preferred dates

The preferred dates cover a 3 week period between 12th April and 2nd May 2017. This would allow coverage of all contact points for both eclipses. 2 weeks (19th April - 2nd May) would be the minimum useful time, to get observations of each ingress, and the bottom of each eclipse. The additional week 12th - 19th April, would allow us to check our coverage of the egress contact points. There is also a two week period (22nd February - 8th March) where eclipses are visible over two orbital period, however the timing of these eclipses would not provide suitable coverage of the contact points, due to the telescope's pointing limits.

References

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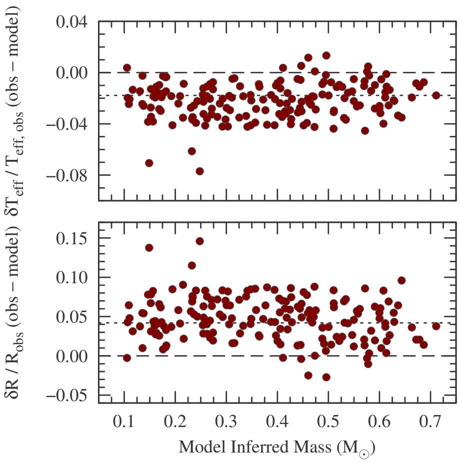

Figure 1: Relative model offsets for $T_{\rm eff}$ (top) and radius (bottom) predictions as a function of the inferred stellar mass. Masses were derived from the mass luminosity relation of Delfosse et al. (2000), observed $T_{\rm eff}$ obtained from spectra and the radii were calculated from angular diameter and measured parallax. Model parameters were obtained using a Markov Chain Monte Carlo method, outputting $T_{\rm eff}$ and luminosity. Typical 1σ observational uncertainties are given by dotted lines (Mann et al., 2015).

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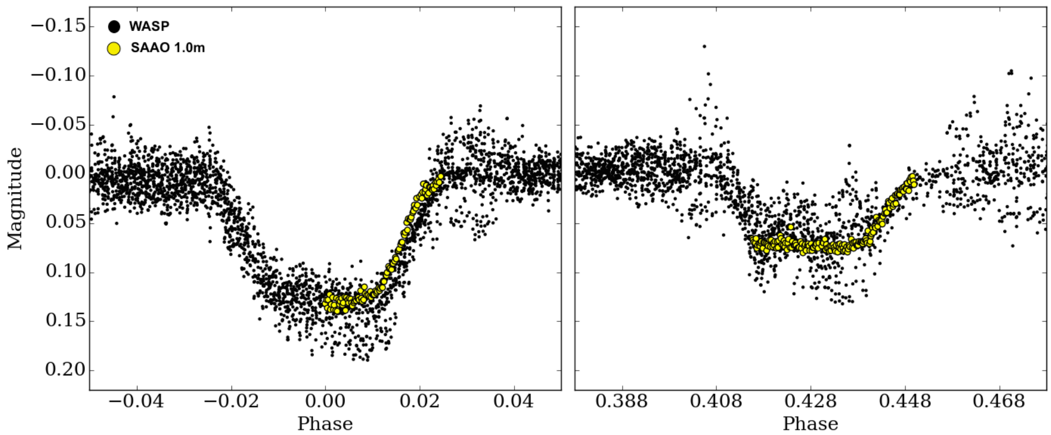

Figure 2: Phase folded WASP photometry (black) of the primary and secondary eclipses for J1046. SAAO 1.0m telescope R-band filter observations (yellow) normalised to the WASP data. The WASP data is not producing the 1% precision required for the radii, due large amounts of scatter. The 1.0m data has far less scatter and a clearly defined contact points in the secondary. Additional data covering the remaining contact points should allow the accuracy needed for 1% precision in the radii.