TESTING CONVECTION IN STELLAR MODELS USING DETACHED ECLIPSING BINARIES

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The approximate treatment of convection in theoretical stellar models strongly compromises the predictive power of the models. The convective parameters can be calibrated using the observed properties of detached eclipsing binary stars, but additional information is needed for each system to get an accurate calibration. This can be done by studying eclipsing binaries in open clusters or with pulsating components.

THE PROBLEM

Theoretical models of stellar evolution are of fundamental importance to astrophysics, because they allow us to derive the age, internal structure and chemical composition of stars from basic observational data. Unfortunately, their predictive power is compromised by uncertainty in the extent of convective core overshooting in high-mass stars and the mixing length in low-mass stars. This causes significant uncertainties in the ages of open and globular star clusters (Bragaglia & Tosi 2006; Chaboyer 1995).

The study of detached eclipsing binary stars (dEBs) allows us to derive accurate masses, radii and luminosities of two stars of the same age and chemical composition (Andersen 1991; Southworth et al. 2005b). The properties of dEBs have been used to constrain overshooting and mixing length (Andersen et al. 1990; Ribas et al. 2000; Ludwig & Salaris 1999). However, definitive results have not been possible because insufficient information is available for the average dEB. Further constraints are needed for each system.

SOLUTION 1: ECLIPSING BINARIES IN OPEN CLUSTERS

The study of eclipsing binaries in open clusters allows strong constraints to be placed on theoretical models. The models must be able to simultaneously match both the accurately-known properties of the dEB and the radiative properties of every other star in the cluster. We are constructing a sample of dEBs in open clusters with a range of ages and compositions. Results so far (Southworth et al. 2004abc, 2005a) have been promising but we have not yet been able to match a well-studied dEB to a well-studied cluster. Therefore in 2006 July we obtained CCD photometry of the young open cluster NGC 7128. This cluster contains at least five eclipsing binaries, and for two of these we now have good light curves and spectroscopy.

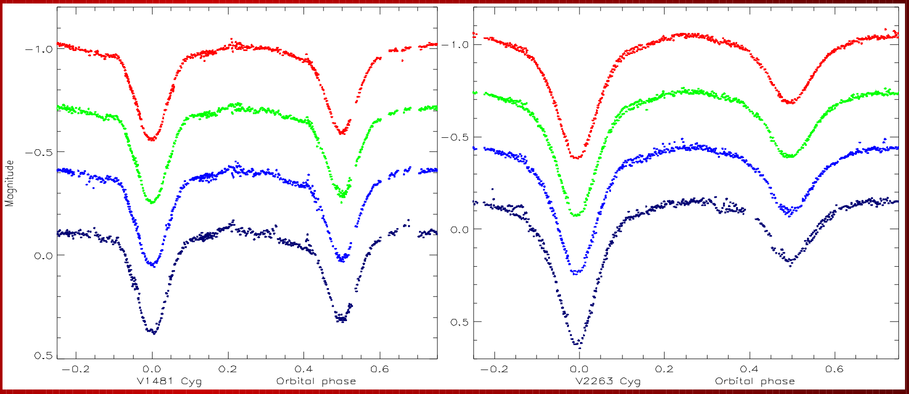

Fig. 1: Strömgren *uvby* light curves of the eclipsing binaries V1481 Cyg (left) and V2263 Cyg (right) in the young open cluster NGC 7128. The properties of V1481 Cyg and NGC 7128 can be used to constrain theoretical models. V2263 Cyg is semi-detached so cannot be used to constrain single-star evolution theory, but will provide an accurate distance to the cluster. The data are not yet debiassed or flat-fielded.

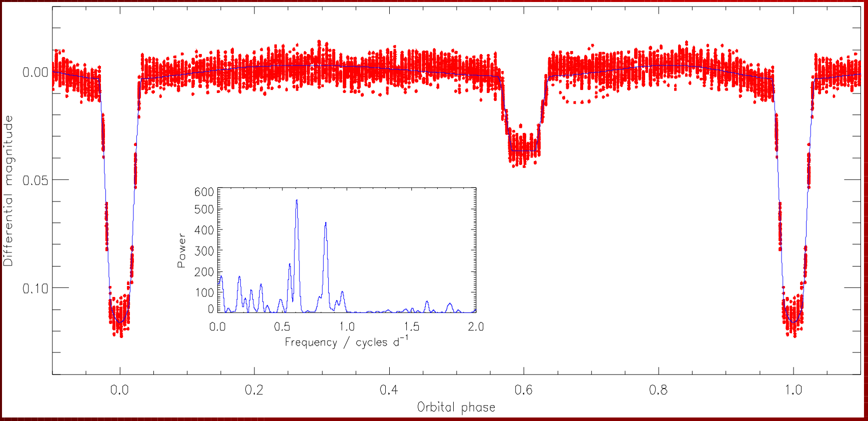

Fig. 2: Preliminary fit to the light curve of AR Cassiopeiae (main panel) with a periodogram of the residuals (inset) showing periodicity at several frequencies including the primary star rotational period. Accurate absolute dimensions of a pulsating star can be used to strongly constrain theoretical models.

SOLUTION 2: ECLIPSING BINARIES WITH PULSATING COMPONENTS

The study of pulsating stars can strongly constrain the treatment of convection in stellar models. Models of pulsating stars can indicate their helium abundance, internal structure, core overshooting and amount of differential rotation. These results can be improved by studying stars with accurately known masses and radii. We are conducting a program to obtain high-quality light curves of bright dEBs with pulsating components. Our photometry comes from the WIRE satellite, which typically observes each target for several weeks (for 30% of each 90 min Earth-orbit) with 1--3 mmag scatter.

Our first target was ψ Cen (Bruntt et al. 2006) which we discovered to be a long-period dEB where the primary has *g*-mode pulsations at two frequencies. We have measured the fractional radii of the stars to unique accuracies of 0.1% and 0.2% and are currently obtaining radial velocities to measure the masses. Our second target is the dEB AR Cas (Fig. 2), which has shallow total eclipses on a 6.0 day period and at least six photometric frequencies. One is the rotational period of the primary component, suggesting that surface inhomogeneities may exist.

References

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