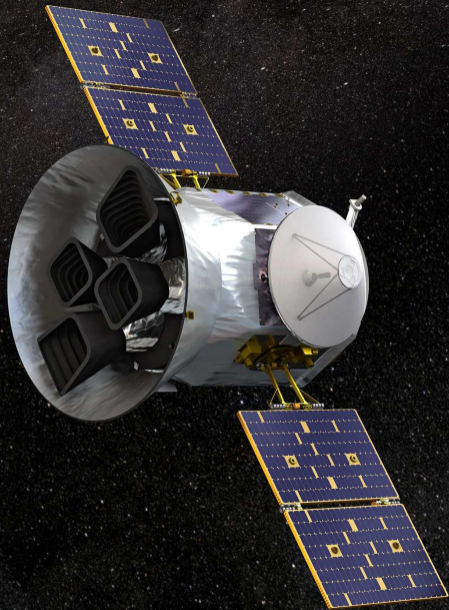


SWIPE: Stars With Pulsations and Eclipses

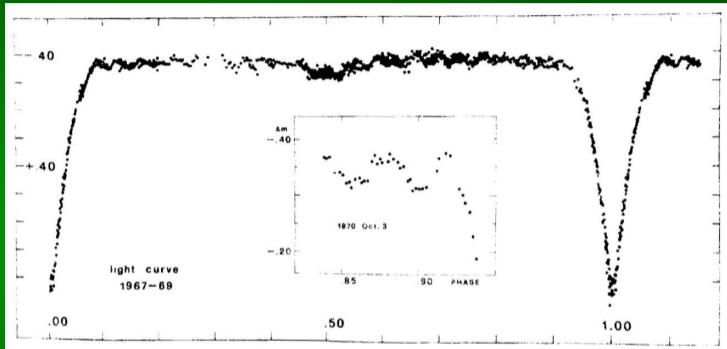
John Southworth





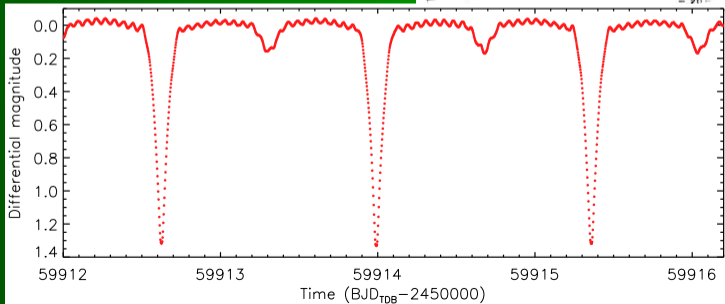
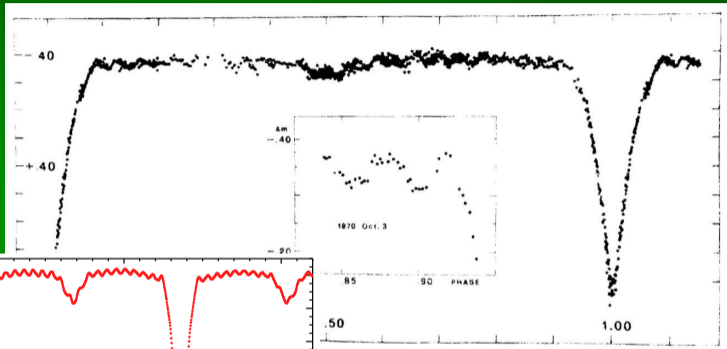
Old versus new

Light curve of AB Cas
(Tempesti, 1971)



Old versus new

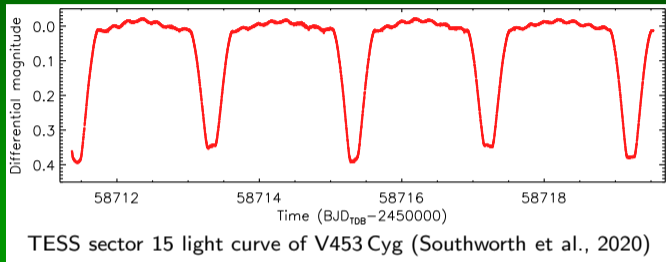
Light curve of AB Cas
(Tempesti, 1971)



TESS sector 59 light
curve of AB Cas
(see Miszuda et al., 2022)

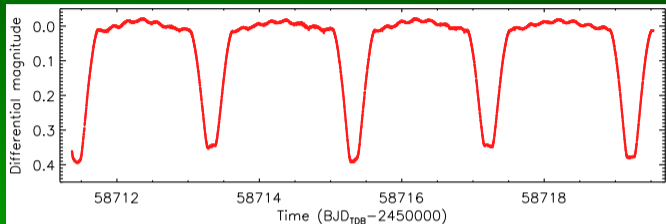
First results: V453 Cyg and VV Ori

- V453 Cyg:
 - first accurate mass measurement of a β Cephei star
 - low radial order pressure and gravity modes
 - common in $8\text{--}25 M_{\odot}$ stars
 - tidal effects modify pulsation frequencies

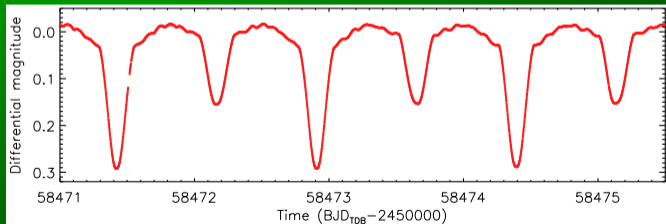


First results: V453 Cyg and VV Ori

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TESS sector 15 light curve of V453 Cyg (Southworth et al., 2020)



TESS sector 6 light curve of VV Ori (Southworth et al., 2021)

Second results: β Cep and γ Dor pulsators in EBs

- “High-mass pulsators in eclipsing binaries observed using TESS”
 - Southworth & Bowman (2022)
 - catalogue of 26 high-mass EBs with pulsations
 - SLF, β Cephei, SPB

Monthly Notices

ROYAL ASTRONOMICAL SOCIETY

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High-mass pulsators in eclipsing binaries observed using TESS

John Southworth ¹* and Dominic M. Bowman ²

¹ Astrophysics Group, Keele University, Staffordshire ST5 5BG, UK

² Institute of Astronomy, KU Leuven, Celestijnenlaan 200D, B-3001 Leuven, Belgium

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ABSTRACT

Pulsations and binarity are both common features of massive stars. The study of pulsating massive stars in eclipsing binary systems holds great potential for constraining stellar structure and evolution theory. However, prior to the all-sky *Transiting Exoplanet Survey Satellite* (TESS) mission, few such systems had been discovered or studied in detail. We have inspected the TESS light curves of a large number of eclipsing binaries known to contain high-mass stars, and compiled a list of 18 objects which show intrinsic variability. The light curves were modelled both to determine the physical properties of the systems, and to remove the effects of binarity in order to leave residual light curves suitable for asteroseismic analysis. Precise mass and radius measurements were obtained for δ Cir, CC Cas, SZ Cam V436 Per and V539 Ara. We searched the residual light curves for pulsation signatures and, within our sample of 18 objects, we find six definite and eight possible cases of β Cephei pulsation, seven cases of stochastic low-frequency (SLF) variability, and eight instances of possible slowly pulsating B (SPB) star pulsation. The large number of pulsating eclipsing systems we have identified makes asteroseismology of high-mass stars in eclipsing binaries a feasible avenue to constrain the interior physics of a large sample of massive stars for the first time.

Key words: stars: binaries: eclipsing – stars: fundamental parameters – stars: oscillations.

1 INTRODUCTION

High-mass stars are preferentially found in binary and multiple systems (Sana et al. 2012, 2014; Kobulnicky et al. 2014) and a significant fraction have short orbital periods. They are also bright so are overrepresented in magnitude-limited samples. As a result, a relatively large number of high-mass stars have been found to be members of eclipsing binaries (EBs). Of particular interest are high-mass stars in EBs with orbital periods long enough for them to have evolved as single stars. For these objects it is possible to measure their masses and radii directly and use these properties to compare with or to calibrate theoretical models of the evolution of single stars (e.g. Andersen, Clausen & Nordström 1990; Ribas, Jordi & Giménez 2000; Torres, Andersen & Giménez 2010). A prominent recent trend is the finding that the properties of high-mass EBs need stronger internal mixing processes than predicted by standard

to B3 on the main sequence but can reach B5 during the giant phase. They pulsate in low-radial order pressure (p) and g modes with periods of order a few hours (Stankov & Handler 2005). The pulsation modes of SPB and β Cephei stars are driven by a heat-engine mechanism operating in the partial ionization zones of iron and nickel at 200 000 K (Dziembowski & Pamyatnykh 1993; Dziembowski, Moskalik & Pamyatnykh 1993). This opacity-based driving mechanism produces periodic standing waves (i.e. coherent pulsation modes), from which forward asteroseismic modelling can reveal a star’s interior physics (Aerts, Christensen-Dalsgaard & Kurtz 2010; Aerts 2021). See Bowman (2020) for a recent review of forward asteroseismic results of SPB and β Cephei stars. In particular, the combination of dynamical masses and radii from binary modelling with asteroseismic modelling of pulsations in eclipsing systems has shown great promise in being able to precisely constrain stellar structure and evolution theory (see e.g. Schridl & Aerts 2016;

Second results: β Cep and γ Dor pulsators in EBs

- “High-mass pulsators in eclipsing binaries observed using TESS”
 - Southworth & Bowman (2022)
 - catalogue of 26 high-mass EBs with pulsations
 - SLF, β Cephei, SPB
- “Four bright eclipsing binaries with γ Doradus pulsating components: CM Lac, MZ Lac, RX Dra and V2077 Cyg”
 - Southworth & Van Reeth (2022)
 - all new discoveries



High-mass pulsators in eclipsing binaries observed using TESS

John Southworth¹* and Dominic M. Bowman²

¹Astrophysics Group, Keele University, Staffordshire ST5 5BG, UK

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ABSTRACT

Pulsations and binarity are both systems holds great potential for *Exoplanet Survey Satellite* (TESS) light curves of a large num which show intrinsic variability. to remove the effects of binarity radius measurements were obtain for pulsation signatures and, with seven cases of stochastic low-freq The large number of pulsating e binaries a feasible avenue to com

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Four bright eclipsing binaries with γ Doradus pulsating components: CM Lac, MZ Lac, RX Dra, and V2077 Cyg

John Southworth¹* and Timothy Van Reeth²

¹Astrophysics Group, Keele University, Staffordshire ST5 5BG, UK

²Institute of Astronomy, KU Leuven, Celestijnenlaan 200D, B-3001 Leuven, Belgium

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ABSTRACT

The study of pulsating stars in eclipsing binaries holds the promise of combining two different ways of mea properties of a star to obtain improved constraints on stellar theory. Gravity (g) mode pulsations such as those i stars can be used to probe rotational profiles, mixing, and magnetic fields. Until recently few γ Doradus stars i were known. We have discovered g-mode pulsations in four detached eclipsing binary systems from light cur *Transiting Exoplanet Survey Satellite* (TESS) and present an analysis of their eclipses and pulsational chara unresolved g-mode pulsations at frequencies 1–1.5 d⁻¹ in CM Lac, and measure the masses and radii of th from the TESS data and published radial velocities. MZ Lac shows a much richer frequency spectrum, includi and tidally excited g-modes. RX Dra is in the northern continuous viewing zone of TESS so has a light-cur year, but shows relatively few pulsation frequencies. For V2077 Cyg we formally measure four pulsation f available data are inadequate to properly resolve the g-mode pulsations. V2077 Cyg also shows total eclips obtain the first measurement of the surface gravity of the faint secondary star. All four systems are bright ar for detailed study. Further TESS observations are scheduled for all four systems, with much improved tempo cases of RX Dra and V2077 Cyg.

Key words: binaries; eclipsing – stars; fundamental parameters – stars; oscillations.

1 INTRODUCTION

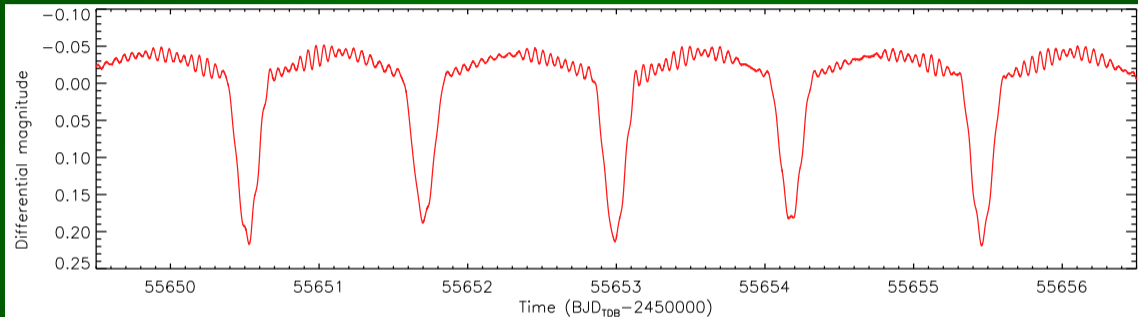
mode pulsations with periods ranging from 0.3

The SWIPE project

We need
a logo!

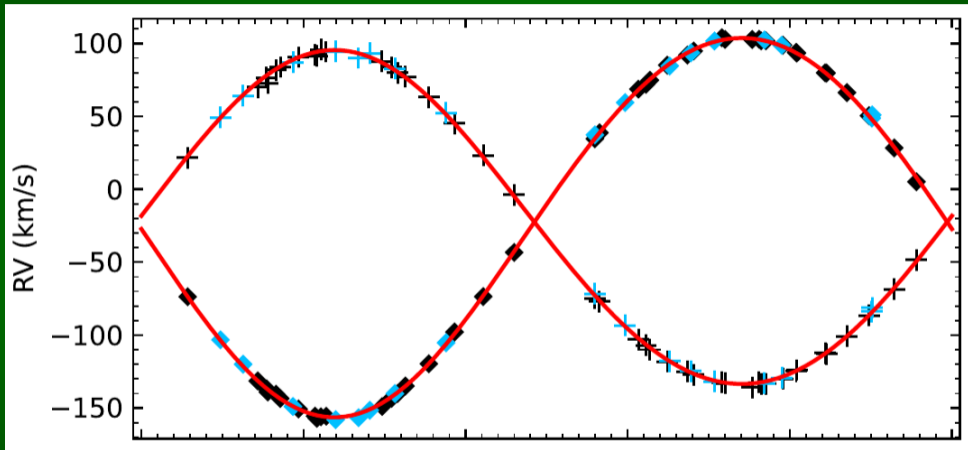
- SWIPE: Stars With Pulsations and Eclipses
 - masses and radii to 1% + pulsation frequencies
 - light curves: TESS, *Kepler*, CoRoT, PLATO
 - spectroscopy: data for 20 objects in hand
- Website: <https://www.astro.keele.ac.uk/jkt/swipe/>
- People: Southworth, Moharana, Maxted, Overall, Jennings et al.
- Future work: EBs in clusters, apsidal motion, solar-like oscillations

Example: KIC 4851217



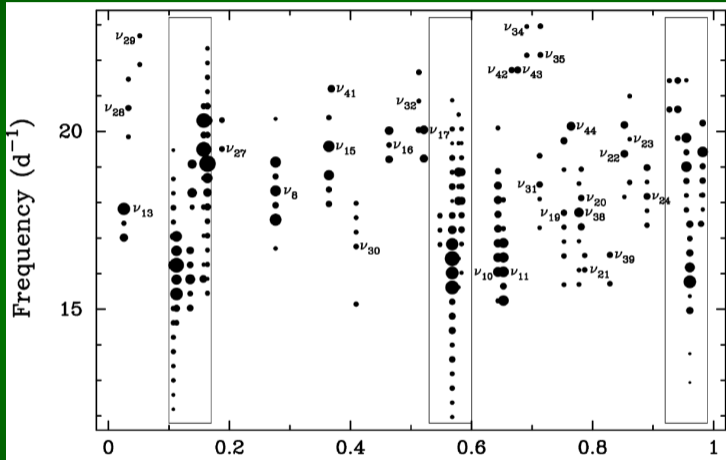
- dEB with 2.47-d period observed by *Kepler*
- Third body in 2680-day orbit
- Radii: $2.195 \pm 0.030 R_{\odot}$ and $3.077 \pm 0.039 R_{\odot}$
- Jennings et al., arXiv:2408.00126

KIC 4851217: spectroscopic orbit



- Spectra from Mercator/HERMES and WHT/ISIS
- Masses $1.899 \pm 0.008 M_{\odot}$ and $2.156 \pm 0.007 M_{\odot}$

KIC 4851217: pulsation analysis



- 200+ pulsation frequencies including 39 multiplets
- Detailed pulsation analysis ongoing

DEBnews

Mailing list about detached eclipsing binaries

<https://maillists.keele.ac.uk/mailman/listinfo/debnews>

Moderated by Pierre Maxted and John Southworth



Binary Stars in the Space Era

Conference: 1–4 July 2025

Keele University, UK

