RSAA Time Assignment Committee

Research School of Astronomy & Astrophysics
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1. Names and Institutions of Applicants

Name	Observer	Student
Murphy SJ Dr (SIfA, USyd)	yes	no
Streamer M Dr	yes	no
Ireland M (RSAA, ANU)	yes	no

Principal Contact: Simon J. Murphy
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Sydney Institute for Astronomy (SIfA), University of Sydney, 44-72 Rosehill St, Redfern, NSW 2016

Name of Student Supervisor(s):

2. Quarter Nov-Jan

3. Title of Project

Astrophysical modelling of the pulsating binary, TT Horologii

Summary of Scientific Objectives

Pulsations of δ Sct stars are the most promising observable for determining fundamental parameters of A and early-F stars, but they are notoriously difficult to model because of a complex non-radial modal structure. The system TT Hor is a perfect system for δ Sct mode determination and modelling : a semi-detached eclipsing binary system of 2.608d period with a δ Sct component ($\sim$40 min period and $\sim$20 mmag amplitude). We will obtain spectra of TT Hor throughout the orbital cycle to: 1) determine the spectral type of each star; 2) obtain RV measurements to measure the mass of each component; and 3) determine the pulsation modes of the δ Sct component.

4. Telescope, Instrument and Detector

Telescope:	Instrument(s):	Gratings/Filters:
2.3m	WiFeS	Predominantly B7000 and R7000, supplemented with B3000.

5. Scheduling Information

	Dark	Grey	Bright
Number of nights requested *this quarter*	0	0	4
Minimum useful allocation	0	0	1
Additional nights required to to complete project in future	0	0	0

If grey, is 1st or 3rd qrt preferred [ ]

Preferred dates:	Nov 29th – Dec 1st
Impossible dates: *(Give reasons)*	Binary has primary eclipse to be observed on night of 17th Nov or on 30th Nov. Other times are not preferable.
Special scheduling constraints *(eg lunar position)*	Preferred consecutive with K2 spectra proposal (Murphy+), if both accepted. Then time can be better distributed to get better sampled RV curve.
Remote Observing from MSO: **(WiFeS Only)**	Yes [X] No [ ]

6. Observing Requirements

Average signal-to-noise ratio required:	100+
Any seeing limitations:	Any seeing better than 2 arcsec
Required spectra resolution (if applicable):	e.g. 1 Angstrom per 2 pixel with R7000
Range in Brightness/ Surface Brightness:	Single object of $V = 11.0$, increased by 0.7 mag in eclipse

7. Assistance Required (only available during day-time)

No assistance required, but will arrive at Mt. Stromlo one night early to refresh on setup.

8. A short description of your project for the public.

TT Horologii consists of two stars orbiting each other in 2.6 d. One star is brighter than the other. We see the system edge-on, so there are eclipses. Additionally, periodic changes in the brightness of the star ('pulsations') help to determine the internal structure of the star. Unlike isolated stars, the physical characteristics, such as mass and radius, can be precisely determined for each star in a binary system. We are using spectroscopy to measure the spectral type and radial velocities of the component stars to constrain these physical characteristics so that we can develop a precise model of the system.

9. List of Principal Targets (a representative list)

Name	α	δ	V mag
TT Hor	03 27 04.402	-45 52 56.42	11.0

10. Other applications for observing time for this project in this quarter

Telescope/satellite:	Title of programme: *(include applications from all telescopes)*
AAT/UCLES (awarded service time)	"Astrophysical model of the eclipsing binary, TT Horologii" PI - Heathcote; Proposal Number -UC203

11. Report on previous applications for time for this and related projects.

Show all allocations for RSAA time in past 3 years

RSAA Reference (give # if known)	Allocation	% useful	Publications (or Comments)

12. Scientific Justification: Attach a case of no more than 2 pages, in a font no smaller than 11pt.

Science Case

Background

Isolated δ Sct stars are located on or slightly above the main sequence in the downward extension of the classical Cepheid instability strip. They generally oscillate in radial and non-radial pressure modes. The range of masses for δ Sct stars (1.5 to 2.5 $M_\odot$) spans the transition of energy transport in the outer envelope from convection to radiation. Asteroseismic investigation of these pulsators can provide insights into the nature of the convective zones in this transitional regime, and provide one of the only ways to in-principle determine the age and interior metallicity of A stars.

δ Sct stars are also found in eclipsing binary systems which provide the physical constraints to allow direct measurement of stellar parameters. Combined time-series photometry and spectroscopy give the absolute masses, orbits and radii of the two stars. In turn, shape, surface gravity, starspot activity and mean density of the stars are derived, as well as the presence of any third body.

Streamer was a principal member of the team that discovered δ Sct pulsations in 3 bright southern eclipsing binary systems [1]. One of these targets, TT Horologii, is of particular interest in that the pulsations are more evident during the primary eclipse compared to other phases of the eclipse cycle (Fig. 1). Two causes are possible, with the first being the most likely:

1. Preliminary modelling of the system indicates that the orbit is inclined ($\sim 76°$) to our line of sight. During primary eclipse the dimmer star acts as a spatial filter, masking part of the brighter star (see Figure 1), in this case the pulsating component. Normally, the surface pattern of nodes and antinodes partially cancel each other but during primary eclipse, the cancellation effects are reduced. This allows a more accurate determination of the phases and amplitudes of the non-radial modes of pulsation.
2. The oscillations are tidally excited with their observed amplitudes dependent on the orbital phase.

TT Hor is an oEA system. Mkrtichian et al. [2] defined this as "a pulsating, mass-accreting star of spectral type B-F in a semi-detached, Algol-type system." More precise spectral types have been attempted. Moriarty et al. [1] measured the blended spectral type as F0-F2, while Svechnikov et al. [3] statistically gave (A2) + [G6IV], but the true types remain uncertain. The system has a V magnitude of 11.0, with 0.65-mag primary eclipses and weak 0.03-mag secondary eclipses. Its period is 2.608 d, while the primary pulsation periods are on the order of 40 min with 10–20 mmag amplitudes.

For pulsating stars in binary systems, where the mass is given absolutely from RVs, measuring pulsation frequencies identifies the pulsation mode, which in turn can aid asteroseismic studies. Mode identification is also feasible using line profile variations (LPVs) – the variation in the shape of spectral lines due to the pulsationally-induced changes in temperature and velocity of the photosphere. While LPV detection is not possible with the 2.3-m telescope because the required integration time is too long compared to the pulsation periods, Streamer and colleagues have Service time allocated in a complementary proposal on the AAT/UCLES which is to be used to study the LPVs.

Simultaneous photometric and spectroscopic measurements allow independent identification of modes, as radial velocities are most sensitive to the near point of the observed hemisphere, while

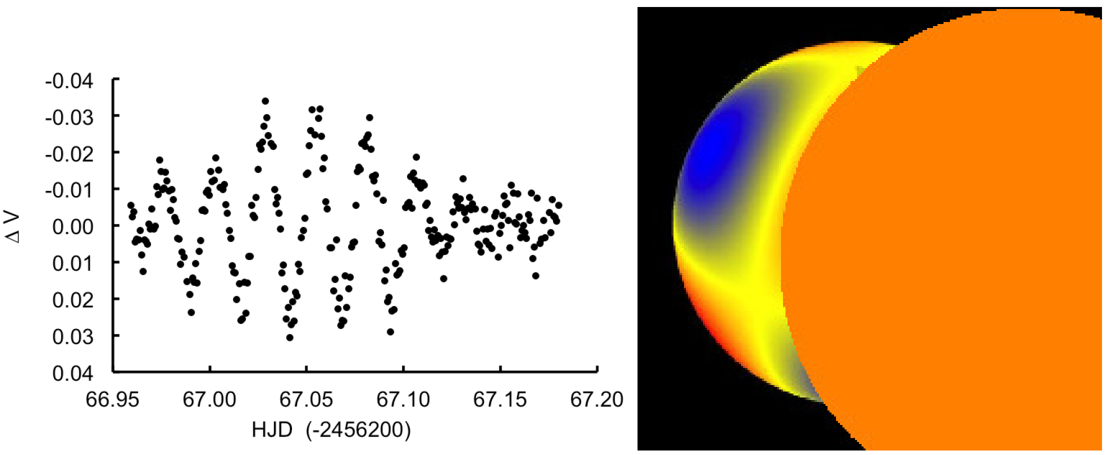

Figure 1: Left: Oscillations during primary eclipse (with mean eclipse lightcurve subtracted), with increased amplitude compared to the non-eclipsed pulsations. Right: Illustration of our preferred system geometry, where the secondary eclipses part of the primary, spatially-filtering the non-radial oscillations.

photometry is sensitive to the entire visible hemisphere. Within our ground-based photometry network, we are able to acquire the photometry concurrently with any spectral studies.

Our objectives for TT Hor are:
1. Determine the spectral type for each component, including metallicity and abundances.
2. Determine RVs for both components throughout the orbital cycle, for accurate modelling of the system including determination of the stellar masses, and for confirmation of the oEA status.
3. Conclusively determine which component is pulsating using the RV measurements, and combining photometry and RV (in and out of eclipse) for mode identification.

Technical Justification

Our target is high in the sky during the bright time at the end of November, having an altitude above 50 deg for all but the final hour of the night. It is continuously >65 deg from the Moon. At magnitude V=11.0, a single 100-s exposure with the R7000 grating achieves a spectrum with S/N = 140. The R7000 grating is required for the most precise radial velocity measurements (cf. objectives 2 and 3). For these calculations, made with the WiFeS exposure calculator, we used bright moon phase, 1.5″ seeing and 1.20 airmass. From our previous experience with using WiFeS, we estimate the overheads to be about 2 minutes per exposure, dominated by read-out time. Thus each radial velocity measurement can be made in only ~ 4 min.

Spectral classification is usually conducted in the blue-violet spectral region because of the greater number of lines and both temperature- and luminosity-sensitive features there [4]. We require a spectrum in the blue that also covers the Ca II K line at 3933Å to provide spectral types of each star (cf. objective 1). The wavelength coverage of the B3000 grating is therefore ideal, whereas the B7000 grating that does not extend blue-ward enough to cover Ca II K. A single 100-s exposure with the B3000 grating provides a S/N of 220 under the aforementioned conditions. Only one B3000 exposure is required for a spectral type, but we will take exposures at different orbital phases (e.g. during eclipses) to enhance the differences between the two components.

Switching between the B/R3000 and B/R7000 gratings involves only the use of a drop-down menu on the remote observing terminal, and thus adds essentially zero time to the overheads. Furthermore, the B3000 and R7000 can be used simultaneously with the RT615 dichroic, providing good spectrophotometric temperatures with the longer wavelength range (M. Bessell priv. comm.; [5]). This lends optimum efficiency to our proposed observing plan.

Finally, it is noteworthy that Murphy+ have submitted a WiFeS proposal for the same season with the same time/date preferences. While each proposal should be judged on its own merits, if both were awarded time and that time were allocated consecutively, then each proposal would benefit substantially. For the purpose of this proposal, radial velocity measurements could be spread over a greater time base and be intensified at the maxima and minima of the radial velocity curve for increased precision on derived orbital parameters.

References

1. Moriarty, J. W., Bohlsen, T., Heathcote, B., Richards, T. and **Streamer, M.** 2013, JAAVSO 41, 1
2. Mkrtichian, D. E., Kusakin, A. V., Gamarova, A. Yu., and Nazarenko, V. 2002, in Radial and Nonradial Pulsations as Probes of Stellar Physics, eds. C. Aerts, T. R. Bedding, and J. Christensen-Dalsgaard, ASP Conf. Ser. 259, 96.
3. Svechnikov et al. (1990) Vizier catalog V/124 "Approximate elements of eclipsing binaries"
4. Gray R.O. & Corbally C.J. (2009) 'Stellar Spectral Classification'. Princeton University Press
5. Dopita, M., Hart, J, McGregor, P., Oates, P, Jones, D. 2007, "The Wide Field Spectrograph (WiFeS)", Ap&SS, 310, 255.