ACCURATE STELLAR PARAMETERS OF STARS IN TIGHT TRIPLE SYSTEMS

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INTRODUCTION

Tight Triple Systems (TTS) are **hierarchical** triple systems with the outer tertiary orbiting the inner binary system with a period of less than 1000 days. The dynamics of such systems are of short timescales and are easier to observe (e.g. vanishing eclipses of HS Hya). Probing the parameters of such systems can give us access to evolution of stars in a multiple system as well as give us constraints for star formation in scales which is usually not possible with wide binaries. Having a detached eclipsing binary (DEB) as the inner binary enables us to extract accurate stellar and orbital parameters of these systems [1]. We explore the parameters of TIC284595199 (T284), a spectroscopic triple system with an eclipsing binary, using TESS lightcurves and HIDES spectroscopy [2]. The accuracy of radius is up to 0.3% while the mass is accurate up to 2.5% for the inner stars and 9% for the tertiary.

ANALYSIS

We use the Simple Aperture Photometry (SAP) light curve (LC) for T284 eclipsing binary, available on the MAST archive. The secondary eclipse has wide dips around it, which are attributed to a spot on the primary star. To model this LC, we used the updated PHOEBE2.3 [3] code which allows for modelling spot parameters simultaneously (see Fig.1). The fitted stellar and spot parameters are presented in the next section. The errors on the parameters obtained from the light curve are derived using MCMC sampling.

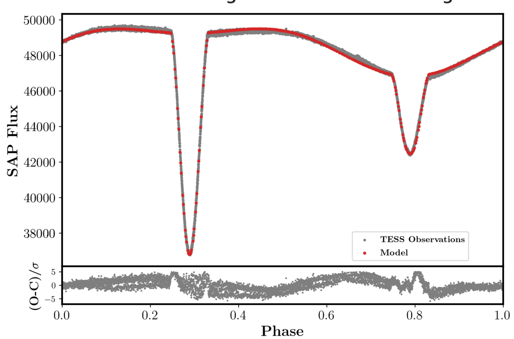


Fig.1. Phase-folded LC of T284. The red points indicate the best-fit model from PHOEBE2.3. The residuals correspond to the variations from the spot on the primary.

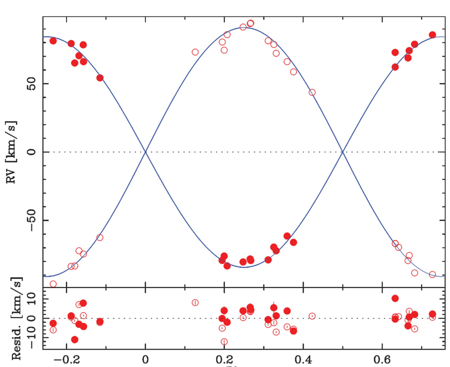


Fig.2. Phase-folded RV observations from HIDES of the primary (filled circles) and the secondary (hollow circles) in the inner binary of T284. The best-fit model from V2FIT is shown in blue.

The radial velocities (RVs) were obtained using the TODCOR algorithm [4] where the third body signature is prominent in the cross-correlation map. The RVs were fitted with the V2FIT [5] code. The final masses were obtained using inclinations obtained from the LC modelling. The total masses of the inner-binary stars was used as a constraint to get the estimate of the mass of the tertiary. The RV fits are given in Fig.2 and Fig.3.

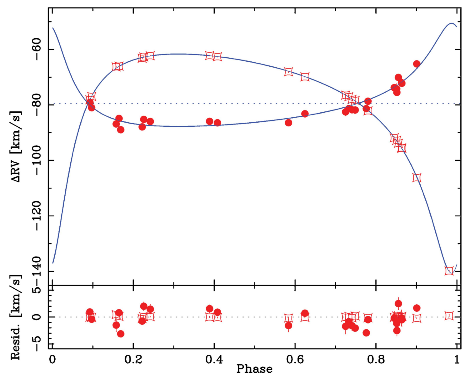


Fig.3. Phase-folded RV observations from HIDES of the center-of-mass of the inner binary (filled circles) and the tertiary (hollow squares) of T284. The best-fit model from V2FIT is shown in blue.

PARAMETERS

Spot Parameters:

Colatitude: 22 deg
Longitude: 180.50 deg
Radius: 42.236 deg
Relative Temperature: 0.86323 (w.r.t primary star)

Stellar Parameters:

Mass of Primary: $1.0227^{+0.0253}_{-0.0253} M_\odot$
Mass of Secondary: $0.9471^{+0.0360}_{-0.0360} M_\odot$
Radius of Primary: $2.2143^{+0.0050}_{-0.0059} R_\odot$
Radius of Secondary: $1.1689^{+0.0025}_{-0.0019} R_\odot$
Ratio of effective temperatures ($T_{secondary}/T_{primary}$): $0.76134^{+0.00078}_{-0.00088}$
Mass of the Tertiary: $0.9279^{+0.0853}_{-0.0853} M_\odot$
Third Light Fraction: $0.000254^{+0.000053}_{-0.000047}$
Estimated Radius of Tertiary: 0.87 to 1.78 $R_\odot$

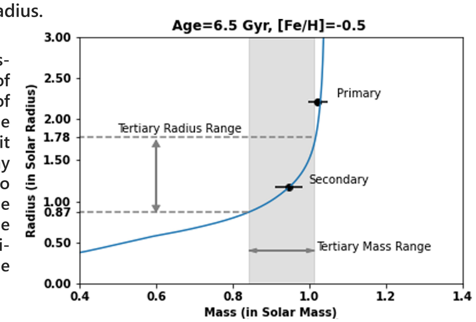
Orbital Parameters:

Period of inner binary: 3.4727 d (fixed during fitting)
Period of the tertiary orbit: $254.849^{+0.062}_{-0.062}$ d
T_0 of superconjugation of inner binary: $2458740.82647^{+0.00032}_{-0.00024}$ d (BJTD)
Inclination of the inner binary: $84.151^{+0.013}_{-0.016}$
Inclination of the outer orbit: 76.5 deg
Eccentricity of inner orbit: 0.0 (fixed during fitting)
Eccentricity of outer orbit: $0.5977^{+0.0024}_{-0.0024}$
Semi-major axis of inner orbit: $12.101^{+0.025}_{-0.025} R_\odot$
Semi-major axis of the tertiary orbit: $241.231^{+4.342}_{-4.342} R_\odot$

AGE, METALLICITY AND DYNAMICS

Using the masses and radii of the stars of the inner binary, the age and metallicity were estimated with isochrone fitting using MIST [6] stellar library which incorporates MESA models . The fit assumed that rest of the input parameters are solar-like. The age is estimated to be **6.5 Gyr** and the metallicity is estimated to be **-0.5 dex.** Assuming that the three stars are co-evolving without any interactions, the tertiary would lie on the isochrone. Using the mass of the tertiary, we estimate the radius of the tertiary to be between 0.87 and 1.78 solar radius.

Fig.4. Mass-Radius distribution of the stars of the inner binary of T284. The blue line represents the best fit isochrone. The gray region corresponds to the mass range of the tertiary star. The dashed lines show estimated range of the tertiary radius.



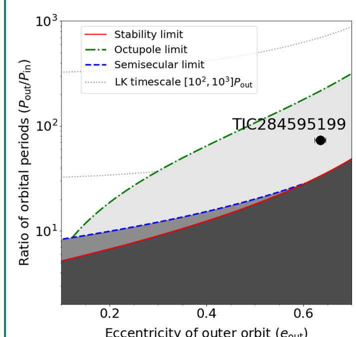


Fig.5. The period ratio vs outer orbit eccentricity of T284. [Ref: Interactive plot at https://bndr.it/wr64f.]

Following the treatment in [7], we use the parameters obtained and a range of 0-90 degrees for the mutual inclination, we estimate the dynamics of the system to lie in a region dictated by octuple terms (see Fig.5). This points to the possibilities of inclination flips of the inner binary. The regimes in Fig. 5 are explained in detailed in [7].

Future Prospects: Spectral disentangling to get individual spectra can help estimate the tertiary parameters independently and therefore can constrain the system better. This paves the way for better tests of stellar evolution in triples.

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