Updated modelling of the oscillating eclipsing binary system AS Eri

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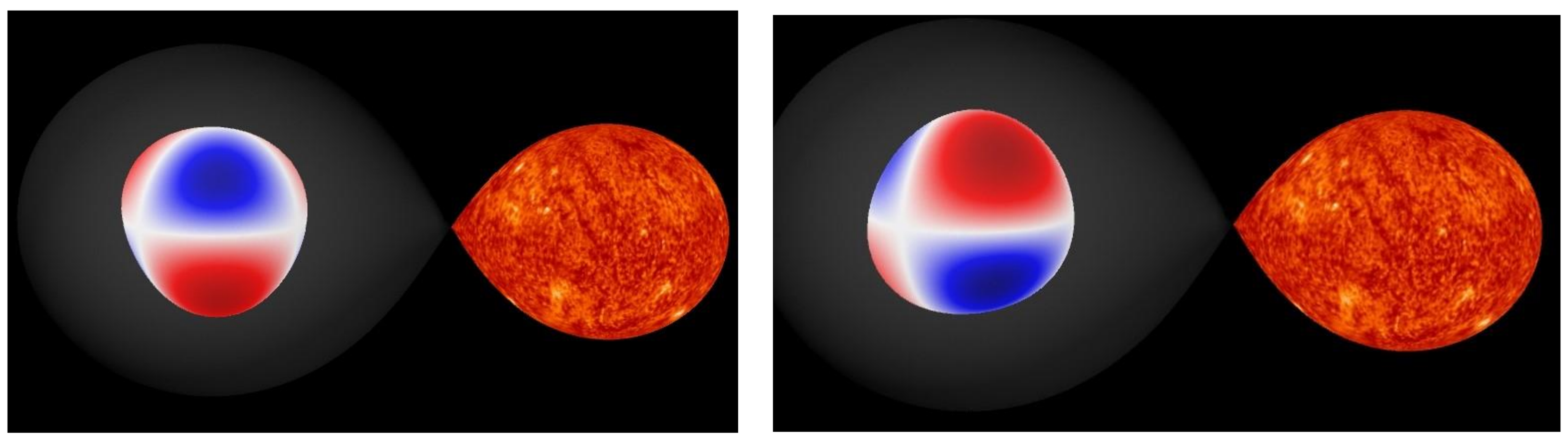
Astrophysical rationale

Eclipsing systems are essential objects for understanding the properties of stars as well as stellar systems. Double-lined eclipsing systems offer model-independent fundamental parameters of their components that can be used as direct constraints in search of relevant models of stellar structure and evolution across the HR-diagram (Torres, Andersen & Giménez 2010). Eclipsing systems not only provide the fundamental properties needed in the search for a precise model, they also may undergo phenomena that are intrinsically linked to the gravitational forces and evolution, for example tidal effects and mass transfer stages. The '**oEA stars**' (Mkrtichian et al. 2002, 2004) form a special class of evolved, semi-detached systems with pulsating, mass-accreting components whose evolution is different from that of the classical δ Scuti pulsators.



Figs. 1a and 1b. Images of the oscillating eclipsing binary RZ Cas depicted with its main pulsation modes (2,-1)(3,-2) (1,0) (Mkrtichian et al. 2018). The full sequence showing an animation of the non-radial pulsations of the **oEA star** RZ Cas was created by Mr Pattana Chintarungruangchai from Thailand.

The space light curves

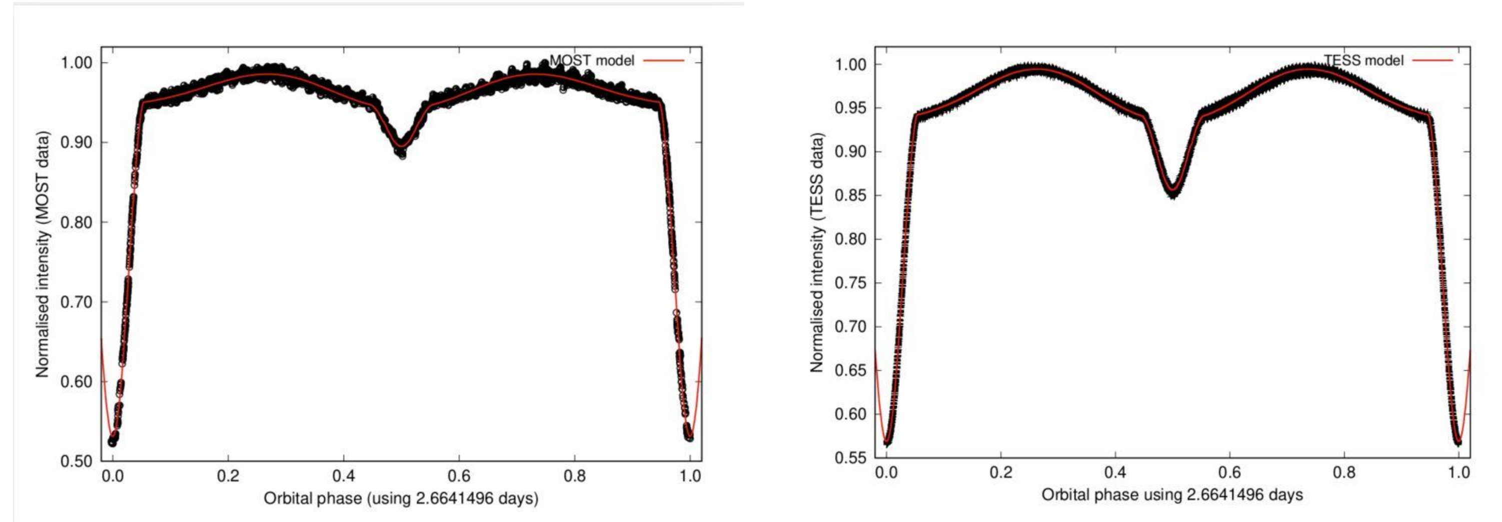
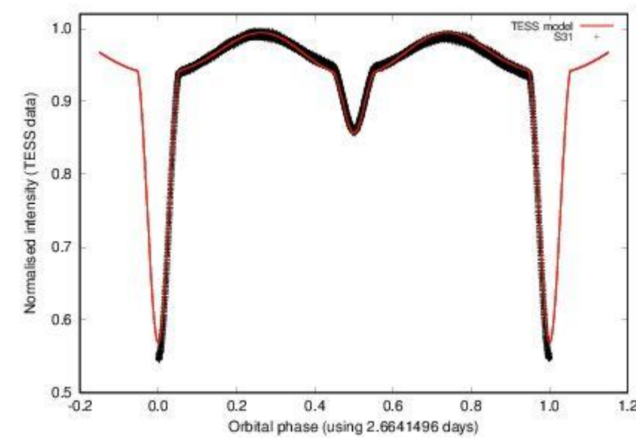


Fig. 4. The MOST (*Microvariability and Oscillations of Stars)* and TESS *(Transiting Exoplanet Survey Satellite*, *Jenkins et al. 2016)* data with the best-fit solutions (solid red lines), resp. based on MOST only (*left*) and (MOST+TESS) data sets (*right panel*). The MOST data cover the interval Oct-Nov 2013. The TESS data (Sector 4) cover Oct-Nov 2018.

Fig. 5. shows the more recent TESS data (Sector 31, Oct-Nov 2020) phased against the period of 2.6641496 days with the final (MOST+TESS) solution plotted in red. It is obvious that the shape of the light curve no longer agrees with the (MOST+TESS) model, and that the primary minima are deeper again.



Instruments for spectroscopy

Some 363 high-resolution spectra of AS Eri were acquired with échelle spectrographs located in two observatories, i.e. the HERMES spectrograph attached to the 1.2-m *Mercator* telescope on La Palma (RA11), and the TCES spectrograph attached to the *A. Jensch* telescope of the Thüringer Landessternwarte, Tautenburg, Germany (www.tls-tautenburg.de).

Fig. 2. The *Mercator* telescope is located at the observatory Roque de los Muchachos, La Palma (Spain). Equipped with HERMES, it offers high-efficiency and high-resolution spectroscopy to all the partners of the HERMES Consortium.

Summary

Our modelling of the Algol-type eclipsing binary AS Eri is based on the combination of the MOST and TESS light curves as well as a collection of very precise radial velocities obtained with the spectrographs HERMES and TCES. The primary component is an **oEA star** of type A3 V. We fitted the light and RV data with the package PHOEBE (Prša et al. 2011) and determined the best-fitting model. We used the orbital period of 2.6641496 ± 0.0000001 days, consistent with the epochs of the MOST and TESS light curves. We obtained the absolute component parameters listed in Table 1 with T_{eff2}/T_{eff1} = 0.662 ± 0.002 (adopting 8500 K for the primary). Although the orbital period appears to be stable on the long term, we show that the models derived for each light curve separately reveal some differences - e.g. in the temperature of the companion and the inclination of the system- and that the shape of the light curve is affected by a years-long modulation. We attribute this to the magnetic activity of the cool component. We intend to study the properties of the pulsations using the new residual light curves in combination with existing and recent high-resolution time-series spectra collected with the SALT spectrograph.

Component properties

Parameter	Primary	Secondary
Mass ($M_\odot$)	2.014 ± 0.004	0.211 ± 0.001
Radius ($R_\odot$)	1.733 ± 0.006	2.19 ± 0.01
Lumin. ($L_\odot$)	14.125 ± 0.008	4.345 ± 0.008
Log g (cgs)	4.264 ± 0.005	3.078 ± 0.003
T_{eff} (K)	8500*	5482 ± 26 (MOST) 5646 ± 7 (both)

Table 1. Accurate stellar parameters based on the final (MOST+TESS) solution.

The radial velocities

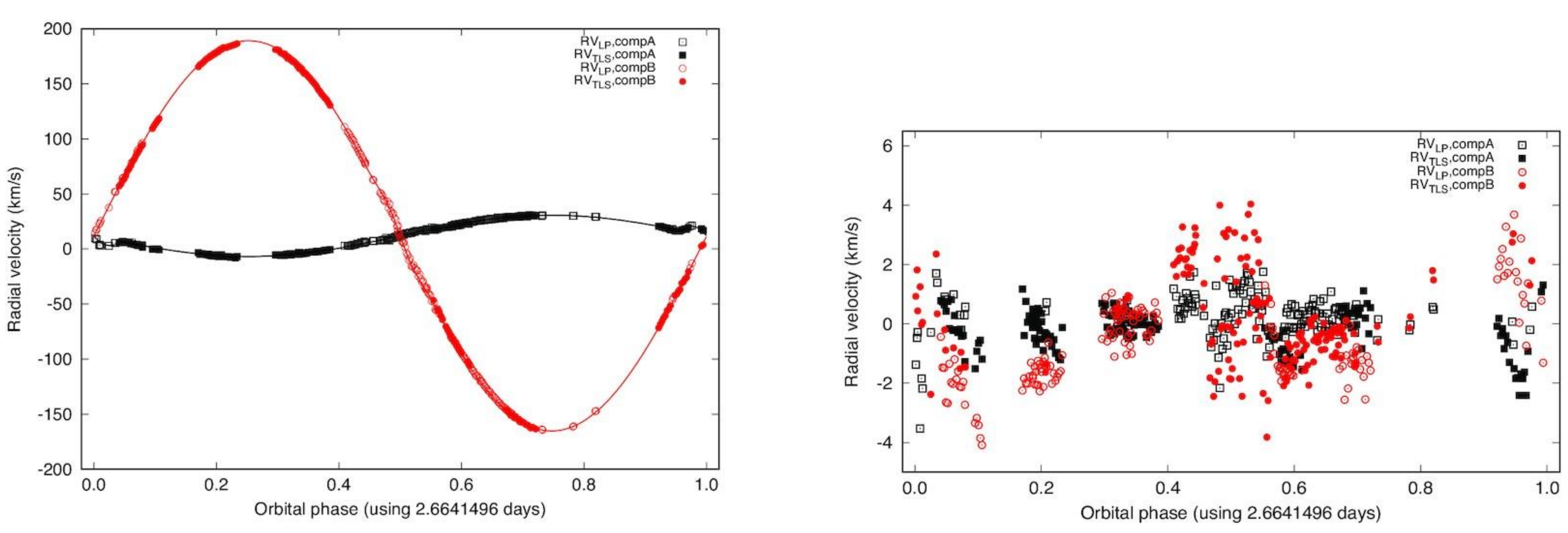
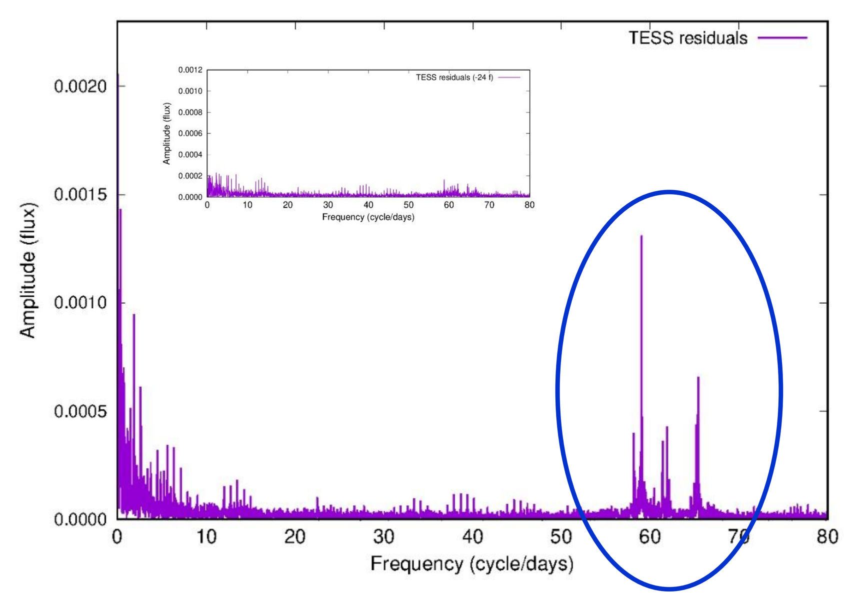


Fig. 3. Component radial velocities (RVs) superposed unto the final PHOEBE solution (solid lines, left) and their corresponding residuals after the best-fit model subtraction (right panel). The residual RVs of component B show a small systematic effect that could be modelled by assuming non-zero eccentricity, but most probably results from typical Algol-related effects such as gas flows and/or an inhomogeneous distribution of the material in the system.

The TESS LC residuals (Sector 4)

Fig. 6. illustrates the periodogram of the TESS LC residuals (after subtraction of the binary model) computed with Period04 (Lenz & Breger 2004). We detected seven significant pulsation frequencies ranging between 58 and 65.5 c/d, i.e. 59.0303, 65.3795, 65.1462, 61.9109, 58.1569, 61.4038 and 58.2803 c/d. The inset image shows the periodogram of the residuals after prewhitening of 25 frequencies.



Conclusions

- 1. Our study of the oscillating Algol-type eclipsing binary AS Eri based on high-resolution spectroscopic and recent space photometric data allowed us to derive an accurate model for the system as well as improved absolute stellar parameters (Lampens et al. 2022).

- 2. Although the orbital period appears to be stable on the long term, we show that the shape of the light curve is affected by a years-long modulation, which is most probably due to the magnetic activity of the cool companion (i.e. the Applegate mechanism). This can explain the different values of T_{eff2} (also the value T_{eff2} = 4725 ± 14 K obtained by VH&W).

- 3. The light residuals obtained after subtraction of this model will enable us to study the pulsation properties of AS Eri with a higher accuracy and more details than hitherto possible.

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