Updated modelling of the oscillating eclipsing binary system AS Eri

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Abstract We present the results of a recent study of the Algol-type eclipsing binary system AS Eri 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 operating at the Mercator telescope, La Palma, and TCES operating at the A. Jensch telescope, Tautenburg. The primary component is a known A3 V-type pulsating, mass-accreting star. We fitted the light and radial velocity data with the package PHOEBE (Prša et al., 2011), and determined the best-fitting model adopting the configuration of a semi-detached system. We used the orbital period of 2.6641496 $\pm$ 0.0000001 days obtained from an updated (O-C) analysis and the phase gap between the MOST and TESS light curves. The absence of any cyclic variation in the (O-C) residuals confirms the long-term stability of this period. We obtained the absolute component parameters: $L_1 = 14.125 \pm 0.008\ L_\odot$, $M_1 = 2.014 \pm 0.004\ M_\odot$, $R_1 = 1.733 \pm 0.006\ R_\odot$, $\log g_1 = 4.264 \pm 0.005$ and $L_2 = 4.345 \pm 0.003\ L_\odot$, $M_2 = 0.211 \pm 0.001\ M_\odot$, $R_2 = 2.19 \pm 0.01\ R_\odot$, $\log g_2 = 3.078 \pm 0.003$ with $T_{\mathrm{eff},2}/T_{\mathrm{eff},1} = 0.662 \pm 0.002$. Although the orbital period appears to be stable on the long term and the final solution shows residuals within expected limits, we show that the models derived for each light curve separately entail small differences, e.g. in the temperature of the companion, allowing us to conclude that the light curve is affected by a years-long modulation. We believe that this is caused by the magnetic activity of the cool companion.

Keywords: Stars: binary: eclipsing, Stars: binary: evolution, mass accretion, Stars: variable, Stars: oscillations (incl. pulsations)

1 Introduction

Eclipsing systems are essential objects for understanding the properties of stars as well as stellar systems. Double-lined eclipsing systems offer the advantage of model-independent fundamental parameters of their components that can be used as direct constraints in the search for relevant models of stellar structure and evolution across the HR-diagram (Torres et al., 2010). Not only do eclipsing systems with pulsating components provide the fundamental properties needed in the search for a precise asteroseismic model, they also undergo phenomena that are intrinsically linked to the gravitational forces acting on the components, for example tidal effects and mass transfer stages. These phenomena can and will influence the stellar interiors and surfaces, including stellar pulsations. Various kinds of interactions are observed in different configurations (e.g. circular versus eccentric systems). Tides can generate stellar pulsations, for example, by a resonance mechanism such as in the eccentric "heartbeat" systems (Fuller and Lai, 2012; Cheng et al., 2020). In turn, tidally excited non-radial oscillations can affect the evolution of close binaries (Aerts, 2021). In particular, the "oEA stars" are pulsating, mass-accreting components of semi-detached systems whose evolution is different from that of the classical δ Scuti pulsators (Mkrtichian et al., 2004).

2 The photometric and spectroscopic data

We used the light curves collected by the MOST (Microvariability and Oscillations of Stars) and TESS (Transiting Exoplanet Survey Satellite, Ricker et al. (2016)) space missions. The MOST data cover the interval Oct-Nov 2013, whereas the TESS data (Sector 4) cover the interval Oct-Nov 2018. Fig. 1 shows the light curves with their respective best-fit solutions (solid red lines).

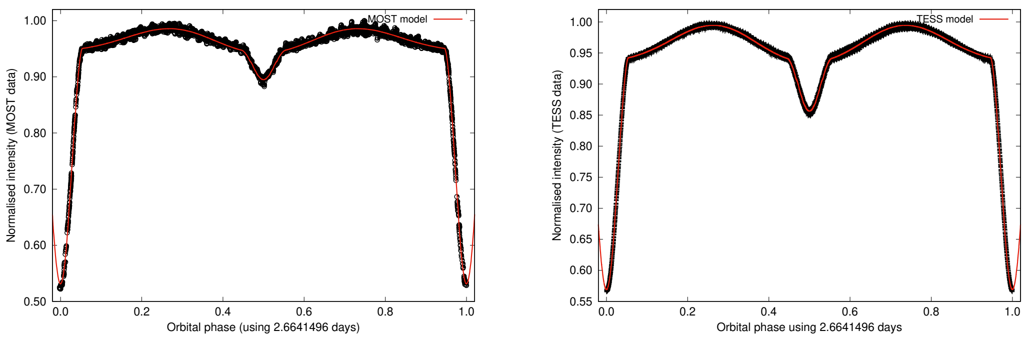

Figure 1: The light-curve solutions (solid red lines), resp. based on the MOST only (left) and combined (MOST+TESS) (right) data sets.

We supplemented the light curves with 360 high-resolution spectra of AS Eri acquired with échelle spectrographs located in two sites, i.e. the HERMES spectrograph attached to the 1.2-m Mercator telescope (Raskin et al., 2011) of the Institute of Astronomy (IvS), Leuven, Belgium, and the TCES spectrograph of the Thüringer Landessternwarte, Tautenburg, Germany (TLS). Thus, we obtained the phase-resolved radial velocity curves of both components (Fig. 2).

3 Results and Conclusions

- We derived an accurate model and updated absolute stellar parameters for the semi-detached eclipsing binary AS Eri based on a simultaneous spectroscopic-photometric analysis (Lampens et al., 2022).
- A plot of the (O-C)'s of observed times of minima based on a revised ephemeris illustrates the long-term stability of the orbital period. Nothwithstanding this, we show that the light curve of AS Eri is affected by a years-long modulation which is most probably due to the magnetic activity of the cool companion (i.e. the mechanism described by Applegate (1992)). This can explain the two values

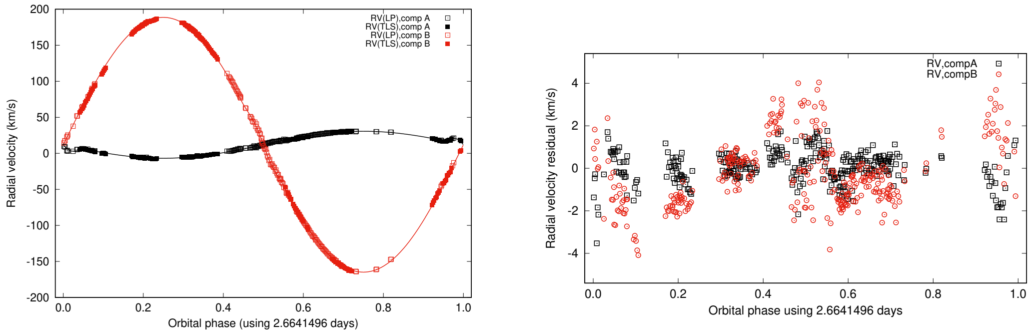

Figure 2: Component radial velocities (RVs) superposed unto the final PHOEBE solution (solid lines, left) and their corresponding residuals after the best-fit model subtraction (right).

we obtained for $T_{eff,2}$ and the older value (4725 $\pm$ 14 K) obtained by Van Hamme and Wilson (1984).
- The residual RVs of the cooler companion (Fig. 2) 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 an inhomogeneous distribution of the gas in the system.
- The more recent TESS data (Sector 31, unused), phased against the orbital period of 2.6641496 days, were compared with the adopted (MOST+TESS) solution (Fig. 3, solid red lines). The comparison reveals that the observed primary minima are deeper (again), from which we conclude that the shape of the light curve changed over a couple of years.
- Finally, we intend to study the pulsation properties using the light residuals (incl. the pulsational signal) obtained after subtraction of our model in combination with time-series spectra collected with the high-resolution SALT spectrograph. Spectrophotometry of AS Eri would be desirable as well.

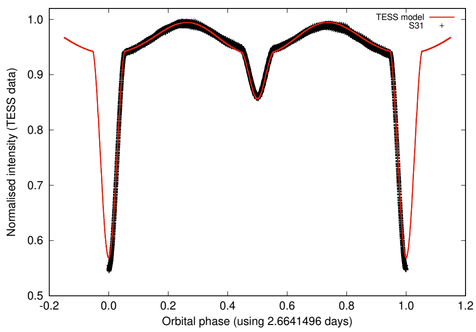

Figure 3: Comparison of the (MOST+TESS) model with the light curve of Sector 31.

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