Orbital and physical parameters of eclipsing binaries from the ASAS catalogue - V. Investigation of subgiants and giants: the case of ASAS J010538-8003.7, ASAS J182510-2435.5, and V1980 Sgr

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ABSTRACT

We present absolute physical and orbital parameters for three double-lined detached eclipsing binary systems from the All Sky Automated Survey (ASAS) catalogue with subgiant and giant components. These parameters were derived from archival V-band ASAS photometry and new radial velocities. The radial velocities were calculated from high quality optical spectra we obtained with the 8.2 m Subaru/HDS, ESO 3.6 m/HARPS, 1.9 m Radcliffe/GIRAFFE, CTIO 1.5 m/CHIRON, and 1.2 m Euler/CORALIE using the two-dimensional cross-correlation technique (TODCOR) and synthetic template spectra chosen for every system separately as references.

The physical and orbital parameters of the systems were derived with the PHOEBE and JKTEBOP codes. We checked the evolutionary status of the systems with several sets of isochrones and determined distances for each system. The derived uncertainties for individual masses of ASAS J010538-8003.7, ASAS J182510-2435.5, and V1980 Sgr components vary from 0.7% to 3.6% while the radii are in the range 1% to 24%. For all of the investigated systems such a detailed orbital and physical analysis is presented for the first time.

Key words: binaries: eclipsing – binaries: spectroscopic – stars: fundamental parameters – stars: individual: ASAS J010538-8003.7 – stars: individual: ASAS J182510-2435.5 – stars: individual: V1980 Sgr

1 INTRODUCTION

Stellar astrophysics, in many aspects, is based on precisely determined fundamental parameters of stars such as their masses and radii. With a few exceptions, only the eclipsing binaries of SB2 type enable us to determine directly those parameters with the required precision. Hence such objects allow us to test the predictions of theoretical stellar evolution models. Recent review papers about detached eclipsing binaries (e.g., Torres et al. 2010) present the comparison between observations and theoretical models for late spectral type objects. Systems containing stars in advanced stages of evolution (e.g., red giants) are much less investigated than, for example, low-mass binaries (which consist of dwarfs), also considered to be poorly studied (e.g., Ribas et al. 2008; Helminiak & Konacki 2011)

So far, only a dozen of stars with subgiant and giant components in eclipsing binaries have been characterized in the Milky Way with the required masses and radii accuracy of 3% (upper limit by Torres et al. 2010), which is indicative of their usefulness as test beds for theoretical models (e.g. TZ For, MY Cyg, HY Vir). Worth mentioning is also very informative system AI Phe (Andersen et al. 1988; Helminiak et al. 2008) – a rare example of differential evolution. The combination of a main sequence star with one that is already at the lower giant branch is ideal for an empirical verification of the stellar evolution theoretical models. Ad-
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ditionally, there are 12 extragalactic systems with well charac-
terized giants discovered in LMC (Pietrzyński et al. 2004,
2011, 2013) and SMC (Graczyk et al. 2012). The analysis of these
systems shows that our knowledge of the more advanced
stages of stellar evolution (following the main se-
queness phase) is incomplete.

An increasing number of observations of late type bina-
rives have intensified theoretical work on stellar structure and
evolution. However, we are still lacking high quality data.
Using high resolution spectographs and available photo-
metric measurements we can increase the sparse sample of
giants with accurately determined parameters.

In this paper we present the latest results of
our on-going spectroscopic survey (Helminiak et al. 2009,
Helminiak & Konacki 2011) of eclipsing binaries from the All Sky Automated Survey
(ACVS; Pojmanski 2002, Paczyński et al. 2006). We fo-
cus on three systems where both components are subgiant or
giant stars. First we describe our targets, then its data col-
collection and analysis, and finally the results we obtained. Sec-
tion 6 contains the discussion about the evolutionary status
of the systems, and age and distance determination, while
Section 7 summarizes the main conclusions.

2 TARGETS

The observing strategy included the selection of detached
eclipsing binaries from the extensive ACVS Catalogue of
Variable Stars (ACVS; Pojmanski 2002) and a spectroscopic
campaign to infer the evolutionary status of every compo-
ment and determine their physical and orbital parameters.
The systems were selected on the basis of the following cri-
teria: P > 8 days, change in brightness < 1 mag, V-K > 1
mag, in order to search for detached, non-Algol systems
with components of solar radius or larger. The analyzed sam-
ple include the binary systems: ASAS J010538-8003.7, ASAS
J182510-2435.5, and V1980 Sgr.

2.1 ASAS J010538-8003.7

The eclipsing binary ASAS J010538-8003.7 (CD-80 28,
2MASS J01053817-8003409, TYC 9355-177-1, hereafter
ASAS-010538) is classified as an eclipsing detached binary
system (DEB) in the ACVS. Its apparent V magnitude is
10.1 (Pojmanski 2002), and the amplitude of photometric
variations in V-band is 0.44 mag. The system was briefly
analyzed by Helminiak et al. (2009) who pointed out that
the binary components are subgiants and suggested its fur-
ther investigation.

2.2 ASAS J182510-2435.5

The eclipsing binary ASAS J182510-2435.5 (TYC 6861-523-
1, hereafter ASAS-182510) is classified as a DEB in the
ACVS. Its apparent V magnitude is 10.87 (Hog et al. 2000).
However, in the ACVS it is estimated to be 10.56. The rea-
son for that significant difference is the additional visual
component that contributes to the total brightness of the

Figure 1. The observed V light curve of ASAS-010538 from
ACVS catalogue phased with the period P=8.069 d and the best-
fitting model. The residuals are shown in the lower panel.

2.3 V1980 Sgr

The eclipsing binary V1980 Sgr, known also as ASAS
J182525-2510.7 (CD-25 13101, HD 315626, TYC 6861-
2115-1, hereafter ASAS-182525) was discovered in 1962
(Hoffleit et al. 1962) and previously considered to be a semi-
detached system. However, in the ACVS it is classified
as a detached system. Its apparent V magnitude is 10.2
(Pojmanski 2002), and the amplitude of photometric varia-
tions in V-band is 0.57 mag. Additionally, significant, time-
varying, out-of-eclipse modulation is clearly visible. The sys-

3 OBSERVATIONS

3.1 Spectroscopy

All of the selected systems are double-lined spectroscopic
 binaries (SB2). In order to measure radial velocities (RVs)
of both components of all of the systems we carried out
observations with a wide range of spectographs. We used
the following telescopes and instruments: the 8.2 m Sub-
aru telescope and the High Dispersion Spectrograph (HDS;
R~60000), the 3.6 m ESO telescope equipped with the High
Accuracy Radial velocity Planet Searcher (HARPS) spectro-
graph (Mayor et al. 2003, R~115000), the 1.9 m Radcliffe
telescope and the GIRAFFE spectrograph (R~40000), the
1.5 m CTIO telescope equipped with the CHIRON4 spectro-
graph (Schwab et al. 2012), Tokovinin et al. 2013, in prepa-
ration, R~90000), and the 1.2 m Euler telescope with the
CORALIE spectrograph (Queloz et al. 2001, R~60000).

1 http://www.astrouw.edu.pl/asas/?page=acvs

2 Operated by the SMARTS Consortium
Investigation of subgiants and giants from ASAS

Figure 2. The observed RVs of both components of ASAS-010538 with their best-fitting Keperian models and O-Cs with corresponding rms (lower panel). Circles represent measurements of the primary and crosses measurements of the secondary.

Figure 3. The observed V light curve of ASAS-182510 from ACVS catalogue phased with the period P=86.648 d and the best-fitting model. The residuals are shown in the lower panel.

Figure 4. The observed RVs of both components of ASAS-182510 with their best-fitting Keperian models and O-Cs with corresponding rms (lower panel). Circles represent measurements of the primary and crosses measurements of the secondary.

Figure 5. The whole observed V light curve of ASAS-182525 from ACVS catalogue phased with the period P=40.506 d and the best-fitting model for the base season (see text). The residuals are shown in the lower panel.

3.1.1 ASAS-010538

To obtain a new spectroscopic solution for ASAS-010538 system we used 13 RV measurements for both components. Four of them were already published [Helminiak et al. 2009], but we rejected one measurement due to low SNR and high RV errors. Three additional RV measurements were derived from GIRAFFE spectra collected during an observing run in September 2010, five more were obtained using the HARPS spectrograph in June and September, 2011, two more come from spectra collected in August 2011 with CHIRON in service mode.

3.1.2 ASAS-182510

We obtained 8 RV measurements for both components of ASAS-182510 system. Four of them were derived from CHIRON spectra collected in July and September, 2011 (service mode), two were obtained using CORALIE spectrograph in September 2011 and May 2012, and two RV measurements were derived from two CCD chips (blue and red) on which the spectrum taken by the HDS spectrograph at the Subaru telescope (August 2011) was recorded.

3.1.3 ASAS-182525

We obtained 7 RV measurements for both components of ASAS-182525 system. Two of them were derived from CHIRON spectra collected in July 2011 (service mode), three were obtained using the CORALIE spectrograph in September 2011 and May 2012, and two RV measurements come from the two separate CCD chips of the HDS spectrograph (August 2011).
allows spectra to be reduced in near real-time. The pipeline performs barycentric corrections. The instrument works in a simultaneous wavelength calibration mode, so Thorium-Argon exposures are taken simultaneously with the exposure of an object.

Spectra from the CORALIE spectrograph were also taken in a simultaneous Thorium-Argon mode, where one of the fibres observes a target and the other an arc lamp. For the data reduction, calibration, and barycentric corrections we used an automated pipeline developed at Pontificia Universidad Católica de Chile. It is briefly described in Penev et al. (2013), a full description will be presented in an upcoming work (Jordan et al. 2013, in prep.).

The RVs were calculated using our own implementation of the two dimensional cross-correlation technique (TODCOR; Zucker & Mazeh 1994) using as references various synthetic spectra computed with the ATLAS9 and ATLAS12 codes (Kurucz 1992). The formal RV errors were computed from the bootstrap analysis of TODCOR correlation maps created by adding selected single-order maps. To obtain a best-fit with reduced $\chi^2 \approx 1$ to our RV data, we multiplied the formal errors by an appropriate factor.

The RV measurements, their final errors (formal errors multiplied by a calculated factor), and O-Cs are collected in Tables A1–A3 in Appendix A. The tables also include the exposure times and a signal-to-noise ratio (SNR) per collapsed pixel at $\lambda=5500$ Å of each spectrum.

As we work with heterogenous datasets, we checked if there is no differences between RV zero points from spectrographs we use. To deal with that, we fit an additional parameter, which allows to compensate for different zero points in the procedure we use to obtain preliminary results from RV measurements. Initially, we set the parameter free and concluded the difference in RV zero points between spectrographs is insignificant and has no influence on the final results, thus the final fits were done with that parameter fixed to 0.

4.2 Modelling

Our RV measurements were combined with the ASAS photometry to derive absolute orbital and physical parameters of the systems. To accomplish these goals we proceeded as follows:

- To obtain a preliminary solution from RV measurements we used a procedure that fits a double-Keplerian RV orbit and minimizes the $\chi^2$ function with a Levenberg-Marquardt algorithm. Every system components’ mass ratio was derived in this manner and applied in the further analysis.

- The light curve modelling was done with JKTEBOP (Southworth et al. 2004) based on EBOP (Eclipsing Binary Orbit Program; Popper & Etzel 1983; Etzel 1981). The code fits a geometric model of a detached eclipsing binary to a light curve in order to derive components’ and systems’ parameters. JKTEBOP includes also an extensive Monte Carlo error analysis algorithm which was used to determine robust uncertainties in the parameters which the program derives. We checked the eccentricity for every system and concluded that all of the orbits are consistent
with being circular, so we kept the eccentricity fixed at 0 for the further analysis. The parameters like the period and time of minimum ($P$ and $T_0$) were much more precise than the quantities from the ASAS analysis presented in ACSV, the inclination were calculated and applied to the repeated RV - Keplerian orbit fitting procedure. We used jktebop to derive the fractional stellar radii of the components.

- To estimate the semimajor axis, systemic velocity, luminosities, gravitational potentials, and effective temperatures of system components and deal with spots (in the case of ASAS-182525) we used the phoebe code (Physics Of Eclipsing Binaries; Prsa & Zwitter 2005) - an implementation of the Wilson-Devinney code (Wilson & Devinney 1971), which uses the computed gravitational potential of each star to determine the surface gravity and effective temperatures.

- To derive absolute values and their uncertainties we used the procedure jktebopdim (Southworth et al. 2004a,b). It calculates the absolute dimensions, related quantities, and the distance of the detached eclipsing binary from the results of a radial velocity and light curve analysis.

5 RESULTS

The results of our modelling of the selected systems are shown in Table I. The physical and orbital parameters are given with their $\sigma$ uncertainties. The primary component is defined as a star eclipsed during the deeper (primary) eclipse in a light curve and $T_0$ is adopted as the moment of a deeper eclipse. Temperatures of the stars whose contribution to the total light of the system is greater (for ASAS-010538 it is the secondary, for ASAS-182510 - primary, for ASAS-182525 - primary) were obtained from the colour-temperature calibration by Worthey & Lee (2011). We used colour values from the TYCHO-2 catalogue (Hog et al. 2000). These temperatures were fixed when calculating the temperatures of the other components of the systems using the phoebe code. The uncertainties of temperatures of the stars with a greater contribution to the total light of the system are based on the colour-temperature error propagation (Worthey & Lee 2011), the error budget in the case of the other components is based on both the uncertainties obtained in phoebe and the errors of colour-based temperatures.

The photometric scale factors were adjusted in phoebe. Gravitational darkening coefficients were set at the value of $\beta = 0.32$ (Lucy 1967), and a limb darkening effect was assumed to be based on the logarithmic law (Klinglesmith & Sobieski 1970) with the values of coefficients from the tables of van Hamme (1993). We checked the presence of the third light fitting it in phoebe and as for ASAS-010538 and ASAS-182525 the result was statistically insignificant (the third light values were less than its errors), we assumed there is no third light and applied it in the further analysis (the case of ASAS-182510 is discussed in Section 5.2). The surface albedo values were assumed to be the default values from phoebe.

The photometric and spectroscopic solutions are presented in Figures 1–6 for the systems ASAS-010538, ASAS-182510 and ASAS-182525, respectively. Colour plots are available in the electronic version of the paper.

5.1 ASAS-010358

The resulting $rms$ in the radial velocities are 1.289 km/s and 3.488 km/s for the primary and secondary of ASAS-010538, respectively. The higher value of secondary’s $rms$ corresponds to the higher rotational velocity of the star which causes spectral line broadening. The average photometric error is 0.034 mag, and the LC $rms$ is 0.033 mag.

The system’s components are ~1.4 more massive than the Sun, with radii of 2 $R_\odot$ and 5.3 $R_\odot$. A significant difference between our result and radii determined by Helminiak et al. 2009, 3.14 $M_\odot$ and 4.06 $M_\odot$ is caused by more data points we used in our analysis and thus the ratio of the radii is better constrained. We would like to stress that for ASAS-010538 we derived the relative errors in the masses ($\Delta M/M$) and radii ($\Delta R/R$) at the 2%, 3%, 14% levels. The improved values of the period $P$, an ephemeris timebase $T_0$, alongside with the RV amplitudes $K_1$ and $K_2$, systemic velocity $\gamma$, inclination $i$, semimajor axis $a$, rotational velocities, and temperatures are presented in Table I. Despite comparable masses we noticed a significant difference in the components’ temperatures, which is a manifestation of the slightly different evolutionary stages of each star.

5.2 ASAS-182510

The resulting RV $rms$: 0.263 km/s and 0.363 km/s for the primary and secondary, respectively, is significantly lower than for the ASAS-010358 system because of the smaller uncertainties of radial velocities due to lower values of rotational velocities of the components. The average photometric error is 0.028 mag, and the LC $rms$ is 0.027 mag.

During the photometric analysis we realized that a close visual companion affected the ASAS light curve, so the third light contribution was taken into consideration. The ASAS apparent $V$-band magnitude of 10.56 mag was assumed as the magnitude of the binary and the companion. We adopted the magnitude of the binary system $V = 10.87$ mag from the Tycho-2 catalogue (Hog et al. 2000) and calculated intensities of both the binary and the companion. The fraction of total light of the system due to the third body was determined to be 0.25 and fixed in the analysis.

We note that the components of ASAS-182510 are the most massive in the analyzed sample. The masses are almost equal and come to $\sim 3.3 M_\odot$ while the radii are 23.4 $R_\odot$ and 15.3 $R_\odot$, respectively. The derived relative errors in the masses ($\Delta M/M$) and radii ($\Delta R/R$) are 1%, 1%, 13%, and 24%, respectively. The results of our detailed analysis of the system are presented in Table I.

5.3 ASAS-182525

We noticed out-of-eclipse and time-varying brightness modulations in the ASAS-182525 light curve. The detailed spectral studies yielded the detection of strong Ca II H (3969 Å) and K (3934 Å) emission lines which can indicate the presence of an active chromosphere for late-type stars.
Table 1. Orbital and physical parameters of ASAS-010538, ASAS-182510, and ASAS-182525

| Parameter | ASAS-010538 | ASAS-182510 | ASAS-182525 |
|-----------|-------------|-------------|-------------|
| $P$ [d]   | 8.069388 ±0.000021 | 86.6486 ±0.0047 | 40.50556 ±0.00055 |
| $T_0$ [JD-2450000] | 1873.4519 ±0.0051 | 2063.304 ±0.073 | 2005.297 ±0.021 |
| $v_{rot1}$ [km s$^{-1}$] | 75.74 ±0.26 | 45.45 ±0.12 | 42.53 ±0.59 |
| $v_{rot2}$ [km s$^{-1}$] | 73.0 ±1.3 | 45.12 ±0.13 | 41.14 ±0.57 |
| $\gamma$ [km s$^{-1}$] | -7.597 ±0.053 | 14.237 ±0.014 | 53.541 ±0.048 |
| $q$ | 1.04 ±0.02 | 1.007 ±0.004 | 1.03 ±0.02 |
| $e$ | 0.0 (fixed) | 0.0 (fixed) | 0.0 (fixed) |
| $i$ | 79.97 ±0.65 | 85.61 ±0.86 | 84.2 ±1.4 |
| $a$ [R$_\odot$] | 24.201 ±0.028 | 152.663 ±0.066 | 67.29 ±0.11 |
| $M_1$ [M$_\odot$] | 1.415 ±0.051 | 3.353 ±0.025 | 1.227 ±0.039 |
| $M_2$ [M$_\odot$] | 1.467 ±0.029 | 3.377 ±0.024 | 1.269 ±0.040 |
| $R_1$ [R$_\odot$] | 2.02 ±0.29 | 23.44 ±2.97 | 12.97 ±0.97 |
| $R_2$ [R$_\odot$] | 5.27 ±0.16 | 15.26 ±3.89 | 12.74 ±1.06 |
| $v_{rot1}$ [km s$^{-1}$] | 12.6 ±1.9 | 13.7 ±1.7 | 16.2 ±1.2 |
| $v_{rot2}$ [km s$^{-1}$] | 33.1 ±1.0 | 8.9 ±2.3 | 15.9 ±1.3 |
| $T_1$ [K] | 6156 ±176 | 4800 ±97 | 4783 ±82 |
| $T_2$ [K] | 4880 ±98 | 4800 ±107 | 4600 ±163 |

Figure 7. Spectral ranges of continuum-normalized spectra of ASAS-182525 in the core of Ca II K (left panel) and H (right panel) lines. Emission in these lines is clear and corresponds to the chromospheric activity of the components.

The derived orbital and physical parameters of ASAS-182525 are presented in Table 1. The resulting rms in radial velocities are 0.998 km/s and 0.771 km/s for the primary and secondary of ASAS-182525, respectively. The average photometric error is 0.098 mag.

The analysed system’s components have almost equal masses of ~1.2 M$_\odot$ and radii of 13 R$_\odot$ and 12.7 R$_\odot$. The
derived relative errors in the masses ($\Delta M/M$) and radii ($\Delta R/R$) are 3%, 3%, and 8%, 8%, respectively. The physical characteristics of the components and orbital parameters of the ASAS-182525 system are presented in Table 1.

We emphasise that the modulation in brightness of the whole system in seasons 5 and 6, where the influence of spots is significant, reaches ~0.31 mag in comparison to season 1, which corresponds to a 25% decrease in the total flux of the system. That means the spot would cause a ~44% decrease in the flux of the primary component of ASAS-182525. This is the first known case where the spots (here approximated by one spot) block almost half of the stellar flux.

6 DISCUSSION

6.1 Evolutionary status and age determination

To check the evolutionary status of the selected systems we compared our results with the Yongsei-Yale stellar evolution models (hereafter YY; Yi et al. 2001). Evolutionary tracks interpolated for the determined masses and α-enhancement of zero are presented in Fig. 1. As the tracks for solar metallicity have matched only observations for ASAS-010538 system, we adopted the metallicity of $Z=0.015$ for ASAS-182510, and $Z=0.007$ for ASAS-182525.

We can clearly estimate the status of all of the analysed systems - stars belonging to ASAS-182510 and ASAS-182525 are located at the red giant branch. ASAS-010538 is a system with components at slightly different phases of evolution - the secondary is a red giant while the primary has evolved away from the main sequence and appears to be at a subgiant phase.

To estimate the age of the systems we compared the results with three sets of widely used isochrones: YY (Yi et al. 2001; Demarque et al. 2004), Padova (Girardi et al. 2000; Marigo et al. 2008), and Dartmouth (Dotter et al. 2007) assuming the metallicity we obtained from evolutionary status analysis (Z=0.02 for ASAS-010538, Z=0.015 for ASAS-182510, and Z=0.007 for ASAS-182525) and α-enhancement of zero. We determined the location of the systems’ components in three planes: $M_{bol}$ - Mass, $log T_{eff}$ - Mass, and $log g$ - Mass and checked if a single isochrone fits both stars of the system simultaneously. One can find the plots for every system in Fig. 10–12.

We found the age of ASAS-010538 to be around 3.05 Gyr (see Fig. 10). Isochrones of that age generated by all YY, Padova and Dartmouth codes are consistent with the observational data.

ASAS-182510 results were compared with just two sets of isochrones (YY and Padova). Dartmouth codes start with the age of 1 Gyr). YY gives a consistent for both components result of 0.305 Gyr but we encounter problems reproducing such a value using the Padova sets of isochrones which indicate the age of the system to be around 0.28 Gyr (see Fig. 11). The discrepancy between age estimation originates in the different definition of the zero-age (the ages computed in YY models include also a pre-MS stage) and differences in physics adopted for certain models.

We estimated the age of ASAS-182525 to be around 4.3 Gyr (YY), 4.2 Gyr (Padova), 5 Gyr (Dartmouth; see Fig. 12). The reason of the disagreement between values obtained using various codes is the same as for ASAS-182510.

Table 2. Parameters of a spot on the primary component’s surface of ASAS-182525 in various seasons.

| Season | Colat. [deg] | Long. [deg] | Radius [deg] | Temp. [T/T⊙] |
|--------|--------------|-------------|--------------|-------------|
| 1      | –            | –           | –            | 0.85        |
| 2      | 75           | 281         | 23           | 0.85        |
| 3      | 22           | 204         | 66           | 0.85        |
| 4      | 40           | 179         | 58           | 0.89        |
| 5      | 47           | 140         | 56           | 0.79        |
| 6      | 37           | 114         | 56           | 0.75        |
| 7      | 19           | 130         | 56           | 0.79        |
| 8      | 10           | 314         | 56           | 0.70        |
| 9      | 29           | 81          | 75           | 0.97        |
| 10     | 18           | 73          | 45           | 0.97        |

It is worth mentioning that the temperature of systems’ components which have the greater contribution to the total light of the system were obtained from the colour-temperature calibration and are based on the colours of the whole system, what is an additional source of uncertainty in temperatures determination. In order to avoid this issue multi-colour photometry is essential.

6.2 Distance determination

One can derive the distances to the analyzed systems using various methods. The traditional method uses bolometric corrections to find the absolute visual magnitude. The luminosity of each star was calculated from its radii and effective temperature, and the obtained values of absolute bolometric magnitudes were converted to absolute visual magnitudes using the bolometric corrections of Bessell et al. (1998). The combined absolute visual magnitude of the two stars was then compared to the apparent visual magnitude in order to find the distance to the system. The estimation of the reddening was performed using maps of dust infrared emission by Schlegel et al. (1998). We obtained colour excesses $E(B-V) = 0.061$ mag, 0.44 mag, and 0.45 mag for ASAS-010538, ASAS-182510, and ASAS-182525, respectively. The distance determination procedure was performed in jktab-sdim and the results are as follows: $d_{ASAS-182510} = 459 \pm 15$ pc, $d_{ASAS-182525} = 1758 \pm 232$ pc, $d_{ASAS-182525} = 765 \pm 45$ pc.

The second method (Southworth et al. 2001) allows us to determine the distance to ED system from the use of empirical relations between surface brightness and effective temperatures, derived from interferometry by Kervella et al. (2004). However, the established laws between angular sizes and effective temperatures are valid only for main sequence stars and subgiants. We tried to use that method for ASAS-010538 which consists of a subgiant and a giant but the derived distance was not consistent with the value obtained from the use of bolometric corrections.

An alternative method which can be used in the case of giant stars uses the relations between surface brightness and colour indices. That solution was successfully used by Pietrzyński et al. (2004) and Graczyk et al. (2012) to determine distances to DEBs composed of evolved giants in Magellanic Clouds. They used the calibration of di Benedetto (2005) between V-band surface and V-K colour relation obtained from a sample of giant and dwarf stars for which the angular diameters were measured using interferometry.
Figure 8. Light curves of 10 seasons for ASAS-182525 with the best-fitting model. The influence of an evolving spot on the light curves is significant.
However because we have no multi-colour photometry for any of the analyzed systems, we could not employ such a method for distance determination.

Parallaxes and hence distances to any of the analyzed systems have not been derived before so we were not able to compare our results with the literature.

7 CONCLUSIONS

We present for the first time RV curves derived from high-resolution spectra, for both components of the systems ASAS-182510 and ASAS-182525. These, accompanied by a detailed analysis of the ASAS V-band photometry, have allowed us to obtain accurate orbit solutions and fundamental physical parameters of the components. We have also studied a previously analyzed system ASAS-010538 for which...
we obtained an improved orbital solution and more accurate parameters.

The masses of each of the systems’ components were determined with an accuracy of \( \sim 3\% \) or better, but we have not reached the required 3 % precision in radii. However, the results are still highly valuable for performing a reliable estimation of the evolutionary status of the components. We compared the observations with stellar evolutionary models. We find that five stars are within the error bars located on the red giants branch and one is a subgiant. The estimated ages are about 3 Gyr, 0.3 Gyr, and 4.5 Gyr for ASAS-010538, ASAS-182510, and ASAS-182525, respectively. We have not found significant differences between the empirical data and theoretical models. We have fitted single isochrones that match both components of the analyzed systems.

In order to improve the results and reach the required 3% precision in radii, precise photometric measurements for all of the systems are required. With the addition of multicolour photometry one would be able to determine radii and temperatures with a much higher precision. Moreover, the assumed metallicity of the systems is based on an analysis involving theoretical evolutionary tracks. With more available spectra we could perform a spectral disentangling and analyze individual spectra of all of the components separately to determine stellar chemical abundances. The analyzed systems are definitely interesting objects for further studies mostly because of their evolutionary status, but also because of activity (chromospheric activity indicators were found for ASAS-182525 system). Additional photometric and spectroscopic data would allow the analyzed stars to become demanding test beds of stellar evolution theories.

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APPENDIX A: RV MEASUREMENTS FOR ASAS-010538, ASAS-182510, ASAS-182525 SYSTEMS

The section includes Tables A1-A3 with RV measurements, formal RV errors, O-Cs, exposure times for each spectrum, SNR and telescope specifications for both components of the selected systems. The used telescopes/spectrographs are as follows: R/G = Radcliffe/GIRAFFE, ESO/H = ESO 3.6 m/HARPS, CTIO/CH = CTIO 1.5 m/CHIRON, EUL/C = Euler/CORALIE, SUB/HDS = Subaru/HDS (red or blue CCD chip). SNR stands for a signal-to-noise ratio per collapsed spectral pixel at \( \lambda = 5500 \) Å.

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| Table A1. RV measurements for ASAS-010538. |
|-------------------------------------------|
| **BJD-2450000** | **RV<sub>1</sub>** | **σ<sub>RV<sub>1</sub></sub>** | **O - C<sub>1</sub>** | **RV<sub>2</sub>** | **σ<sub>RV<sub>2</sub></sub>** | **O - C<sub>2</sub>** | **T<sub>exp</sub>** | **SNR** | **Tel./Sp.** |
|------------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|-------------|--------|------------|
| 4007.418443      | -25.896         | 1.170           | 1.590           | 13.767          | 2.499           | 2.095           | 3600        | 18     | R/G        |
| 4008.569095      | 34.786          | 2.262           | -2.264          | -48.402         | 2.337           | 2.147           | 3600        | 28     | R/G        |
| 4166.269636      | -63.431         | 6.604           | 3.312           | 54.048          | 6.154           | 4.502           | 3600        | 10     | R/G        |
| 5435.568405      | -63.431         | 6.604           | 3.312           | 54.048          | 6.154           | 4.502           | 3600        | 10     | R/G        |
| 5440.547112      | -32.701         | 0.803           | 0.136           | 17.075          | 8.869           | 0.242           | 3600        | 40     | R/G        |
| 5469.588733      | 53.808          | 3.437           | -0.776          | -59.849         | 3.609           | 7.595           | 3600        | 10     | R/G        |
| 5721.857804      | 30.650          | 0.317           | -0.424          | -49.181         | 2.808           | -4.392          | 1200        | 50     | ESO/H      |
| 5722.917250      | -28.711         | 0.299           | 0.484           | 15.516          | 1.583           | 2.195           | 1200        | 65     | ESO/H      |
| 5811.700692      | -30.106         | 0.335           | 0.111           | 14.861          | 1.583           | 0.555           | 1200        | 35     | ESO/H      |
| 5812.690316      | -74.520         | 0.294           | -0.381          | 54.189          | 6.552           | -2.494          | 1500        | 45     | ESO/H      |
| 5813.758491      | -79.118         | 0.281           | 0.146           | 40.717          | 0.287           | -0.207          | 720         | 15     | ESO/H      |
| 5815.875346      | 22.590          | 1.492           | 0.208           | -35.837         | 6.924           | 1.013           | 600         | 10     | CTIO/CH    |
| 5823.812070      | 15.950          | 0.650           | 0.208           | -35.031         | 5.613           | -5.020          | 600         | 15     | CTIO/CH    |

| Table A2. RV measurements for ASAS-182510. |
|-------------------------------------------|
| **BJD-2450000** | **RV<sub>1</sub>** | **σ<sub>RV<sub>1</sub></sub>** | **O - C<sub>1</sub>** | **RV<sub>2</sub>** | **σ<sub>RV<sub>2</sub></sub>** | **O - C<sub>2</sub>** | **T<sub>exp</sub>** | **SNR** | **Tel./Sp.** |
|------------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|-------------|--------|------------|
| 5776.737886      | 48.344          | 0.480           | -0.699          | -21.434         | 0.243           | -0.304          | 720         | 10     | CTIO/CH    |
| 5819.556752      | -21.876         | 0.230           | 0.024           | 50.210          | 0.205           | -0.113          | 720         | 15     | CTIO/CH    |
| 5823.571475      | -12.426         | 0.169           | 0.146           | 40.717          | 0.287           | -0.207          | 720         | 15     | CTIO/CH    |
| 5854.878533      | 58.619          | 0.674           | -0.565          | -31.873         | 0.331           | -0.535          | 720         | 20     | CTIO/CH    |
| 5846.517685      | 52.704          | 0.214           | -0.112          | -24.896         | 0.191           | 0.032           | 600         | 20     | EUL/C      |
| 6081.622312      | -17.273         | 0.213           | 0.030           | 45.540          | 0.226           | -0.151          | 600         | 20     | EUL/C      |
| 5778.772055      | 44.664          | 0.149           | 0.134           | -16.570         | 0.144           | 0.016           | 600         | 70     | SUB/HDS red|
| 5778.772055      | 44.783          | 0.177           | 0.253           | -16.421         | 0.239           | 0.165           | 600         | 60     | SUB/HDS blue|

| Table A3. RV measurements for ASAS-182525. |
|-------------------------------------------|
| **BJD-2450000** | **RV<sub>1</sub>** | **σ<sub>RV<sub>1</sub></sub>** | **O - C<sub>1</sub>** | **RV<sub>2</sub>** | **σ<sub>RV<sub>2</sub></sub>** | **O - C<sub>2</sub>** | **T<sub>exp</sub>** | **SNR** | **Tel./Sp.** |
|------------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|-------------|--------|------------|
| 5776.726278      | 80.479          | 1.049           | 0.102           | 27.469          | 1.044           | 0.144           | 660         | 15     | CTIO/CH    |
| 5815.550671      | 69.652          | 0.998           | -1.386          | 36.774          | 1.031           | 0.418           | 660         | 15     | CTIO/CH    |
| 5823.592317      | 95.415          | 1.074           | -0.297          | 13.083          | 1.049           | 0.584           | 670         | 17     | CTIO/CH    |
| 5846.531984      | 16.244          | 1.090           | -0.299          | 87.947          | 1.012           | -1.125          | 480         | 20     | EUL/C      |
| 6080.665495      | 26.755          | 1.034           | 1.410           | 81.073          | 1.019           | 0.518           | 480         | 15     | EUL/C      |
| 5778.783498      | 89.888          | 1.007           | 0.681           | 18.039          | 0.990           | -0.749          | 600         | 70     | SUB/HDS red|
| 5778.783498      | 90.399          | 1.079           | 1.191           | 17.818          | 1.039           | -0.970          | 600         | 60     | SUB/HDS blue|
