# Physical parameters of eclipsing binary components, discovered by STEREO


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**Abstract.** Using photometric observations made with the Heliospheric Imager 1 onboard NASA's STEREO mission a list of eclipsing binary systems was prepared which can be observed with the Coude spectrograph of the National Astronomical Observatory of Bulgaria, Smolyan, Bulgaria. The epoch and orbital period of each system were determined. The full complement of data consist of light curves extracted from STEREO HI-1 cameras photometry, wide coverage Echelle spectra obtained with the ARCES spectrograph at Apache Point Observatory, New Mexico, USA, for stellar characterization and Coude spectra with $R \approx 15000$ and $R \approx 30000$ obtained at NAO Rozhen for radial velocity curves. Here we present preliminary results from applying the Wilson-Devinney models for the determination of some physical parameters of three SB2 eclipsing binary systems - HD 103694, HD 185990, and HD 214688.



**Key words:** stars: binaries: eclipsing – stars: binaries: spectroscopic – stars: individual: HD 103694 – stars: individual: HD 185990 – stars: individual: HD 214688


## Introduction

The detached eclipsing binary stars are our best source of accurate data on stellar masses and radii (Torres, Andersen & Gimenez 2000). If we assume that the components of detached binaries are non-interacting, they will evolve independently and their structure will be representative of single stars. In the case of double-lined spectroscopic binaries (SB2) it is possible in principle to determine the absolute dimensions and masses of the components.

The Solar-TErrestrial RElations Observatory (STEREO, Socker et al. 2000) is a wide-field survey mission. As it observes the heliosphere, it also images the star field in the background. In this study, photometric data from HI-1 imagers has been used. We are then complementing the photometric observations from STEREO with wide coverage echelle spectra obtained with the ARCES spectrograph at APO, New Mexico, for stellar characterization and spectra obtained with the Coude spectrograph at NAO Rozhen for radial velocity curves.

Here we present preliminary results from modeling of three SB2 eclipsing binary systems - HD 103694, HD 185990, and HD 214688. In section 1, we describe the Wilson-Devinney model used for the determination of some of the orbital elements and physical parameters. In section 2, we show the results from modeling the observational curves. Finally, we make a short summary and list some of our future goals.

## 1 Methodology

The Wilson-Devinney code (WD; Wilson & Devinney 1971) produces synthetic light curves in a specified set of bandpasses and radial velocity curves based on a user-defined set of input system parameters.

First, the period $P$ and initial epoch $JD_0$ are determined from the available STEREO light curves (LC). The new ephemeris for the systems studied in this paper are given in Table 1 together with available $V$ magnitude and spectral type. High precision LC parameters are expected from the light curve solutions since each LC contains thousands of measurements. The typical photometric precision of STEREO data is of the order of 0.03 mag for a $V = 10$ mag star and for a $V = 5$ mag star the errors are $\approx 0.003$ mag.

The high resolution spectra obtained with the Coude spectrograph at NAO and the ARCES echelle spectrograph at APO were reduced using standard IRAF procedures - bias was subtracted, flat field, wavelength calibration, and heliocentric correction were applied. After the initial reduction the IRAF fxcor task was used to obtain the radial velocities (RV) of the SB2 systems.

Next, we use the period $P$ and initial epoch $JD_0$ from the photometric observations to obtain synthetic LC and RV curves, which we then compare with the observed curves. During this initial process we are able to roughly estimate additional parameters such as the mass ratio, semi-major axis, orbital inclination, third light.

Finally, the observed LC and RV velocity curves are provided as input to a fitting routine which is included in the WD code that computes a converging best-fit solution based on differential corrections to the initial estimated solution. The input to the fitting routine comprises the observed curves together with our initial estimates for the parameters.

A complete simultaneous solution was obtained for each binary system which provided the fundamental stellar parameters such as masses and radii of both components, as well as the orbital elements of the systems.

## 2 Results

After following the procedure described above, masses and radii are obtained for the components of the three SB2 systems together with orbital inclination and semi-major axis. The results are presented in Table 1. The upper half of the table includes the available $V$ magnitude and the spectral type of the stars, as well as the period and initial epoch derived from the STEREO observations. The lower half part of the table presents the masses for the primary and secondary, the radii of the components, the orbital inclination $i$ and the semi-major axis $a$.

The STEREO photometric precision was estimated from the aperture photometry of 2100 Tycho 2 stars with $V_T < 10.5$ mag extracted from 20 days of data from the HI-1 images. The high precision of the LC measurements also allows the precise determination of the period $P$ and initial epoch $JD_0$ from the STEREO light curves. However, additional tests are required in order to estimate the uncertainties in the derived parameters. This is the reason these values are not given in Table 1.

The best-fit simultaneous solution for the binary systems is presented in Fig. 1, Fig. 2, and Fig. 3. The left panel in all the figures shows the observed light curve from STEREO with gray points and the best-fit solution with a black solid line. The right panels contain the combined observed radial velocity curves from NAO and APO with their uncertainties. The fit for the primary component is shown with a solid line, and the fit for the secondary component - with a dotted line.

The light curve of HD 103694 shows an interesting variation between the primary and secondary minimum. We suspect that this might be due to spots on the surface of the late spectral type component. Additional tests are required to confirm or reject this hypothesis. However, it is quite feasible taking into account the late spectral type of the star.

The synthetic light curves from the WD model of both HD 185990 and HD 214688 agree well with the observations. However, this is not true for the radial velocity curves, especially in the case of HD 185990. The obtained theoretical fits to the radial velocity curves of HD 214688 are better, but still there is some disagreement between the theoretical model and the observations for the spectroscopic orbit of both components. In the case of HD 185990 the distribution of the observational points does not allow for a good fit of the synthetic RV curves. Additional observations will be necessary to obtain better phase coverage and better constrains for the synthetic models for the system.

## Conclusion

Preliminary physical and orbital parameters of the three eclipsing binary systems, HD 103694, HD 185990, and HD 214688 were obtained. We demonstrated one way to obtain these parameters using the WD code which produces synthetic light curves in a specified set of bandpasses and radial velocity curves based on a user-defined set of input system parameters. A complete simultaneous solution was obtained that includes orbital elements of the binary systems (inclination and semi-major axis) along with fundamental parameters (masses and radii) of both components.

This is still a work in progress and the next step needs to be the estimation of the errors on the parameters, obtained using the WD code. In the

**Table 1.** Masses and radii of the binary systems obtained using the WD model

| EB system | HD103694 | HD185990 | HD214688 |
|---|---|---|---|
| $V, mag$ | 8.94 | 8.58 | 8.22 |
| Sp. type | K2 | A0V | F3V |
| $P$, days | 2.23919 | 3.70674 | 3.76552 |
| $JD_0$, 2454+ | 322.15936 | 434.67773 | 473.76040 |
| $M_1, M_\odot$ | 0.6 | 1.4 | 1.3 |
| $M_2, M_\odot$ | 0.8 | 2.2 | 1.1 |
| $R_1, R_\odot$ | 0.8 | 1.5 | 1.9 |
| $R_2, R_\odot$ | 1.5 | 2.1 | 1.7 |
| $i$, deg | 90 | 80 | 79 |
| $a, R_\odot$ | 8 | 15 | 14 |

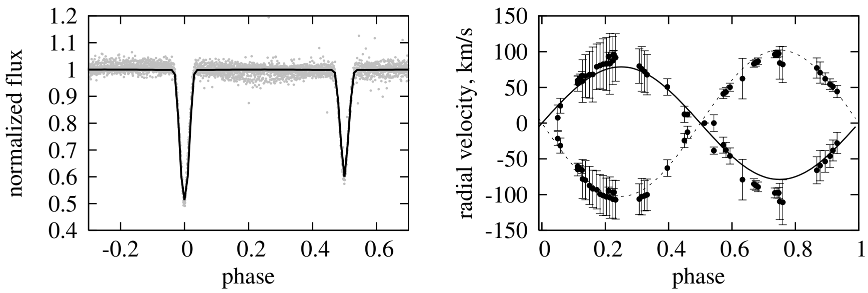


**Fig. 1.** Light and radial velocity curves for HD 103694. The left panel shows the observed light curve with gray points and the best-fit solution with a black solid line. The right panel contains the observed RV curve with its uncertainties and the fit. The fit for the primary component is shown with a solid line and the one for the secondary - with a dotted line.

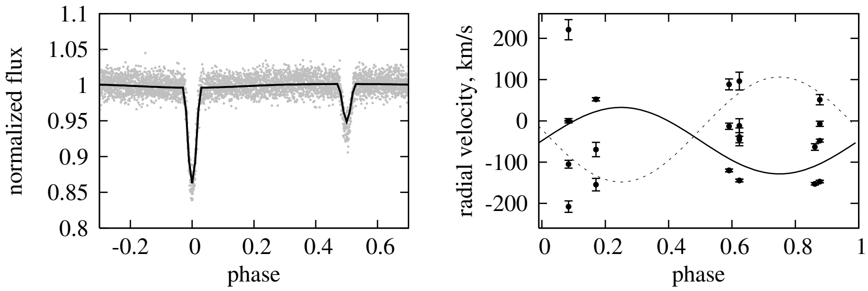


**Fig. 2.** Light and radial velocity curve for HD 185990. Panel description is as in Fig. 1.

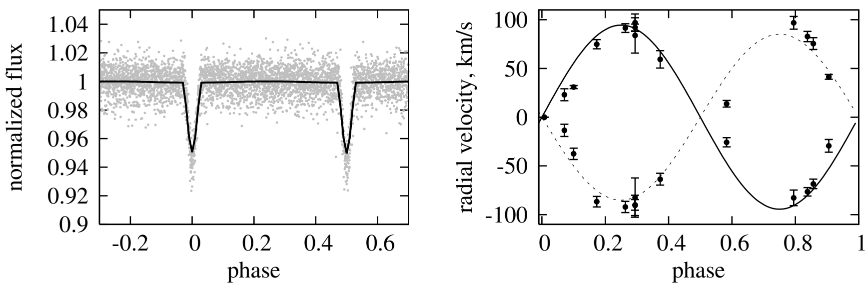


**Fig. 3.** Light and radial velocity curve for HD 214688. Panel description is as in Fig. 1.

mean time we will continue with the full characterization of the rest of the eclipsing binary systems in our sample.

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