# Absolute parameters of the O-type eclipsing binary V1007 Sco = HD 152248

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## Introduction

V1007 Sco (HD 152248, HIP 82691) is one of the most intriguing early-type binary stars. Its binary nature has been discovered by Struve (1944). Soon afterwards a photometric variability was observed, but only several decades later Mayer et al. (1992) were able to prove the existence of eclipses. Over the years, additional spectroscopic and photometric data on V1007 Sco had been secured by different observers, revealing an eccentric orbit with a period of $\approx 5.816$ days (Stickland et al. 1996).
Several attempts have been made to determine the parameters of this system. Most notable are the first solution of the light curves by Penny et al. (1999) and a spectroscopic solution by Sana et al. (2001), who classified the binary as O7.5III(f)+O7III(f). According to the new results of Heap et al. (2006), this classification implies an effective temperature of $\approx 34000$K. The first analysis by Penny et al. (1999), combined with information from IUE spectra, arrived at component masses of $24 M_\odot$ and $26 M_\odot$, while Sana et al. (2001) derived values of $29.9 M_\odot$ and $29.6 M_\odot$.
In spite of an extensive data set the accurate determination of the system parameters was complicated by the lack of sufficient high-quality measurements. Nevertheless the simultaneous analysis of the available comprehensive photometric and spectroscopic data base allowed to derive a consistent solution of unprecedented quality and reliability for such a complex and important eccentric O-type system like V1007 Sco.

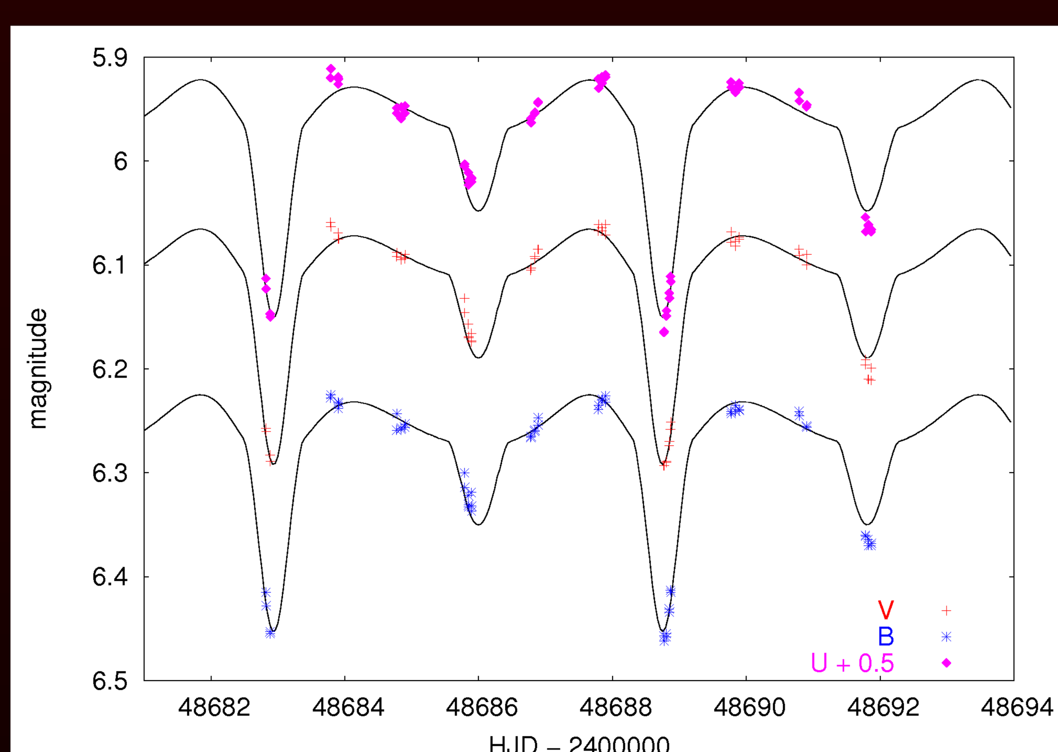


FIGURE 1: $U$, $B$ and $V$ light curves obtained between 29 Feb 1992 and 10 Mar 1992 with best fits.

For the analysis of the light curves we used the following sets of photoelectric observations:

1. $UBV$ observations obtained by Mayer et al. (1992) plus additional $UBV$ observations secured by RL in 1993 and 1994.
2. Hipparcos $H_p$ magnitudes, transformed into Johnson $V$ using the transformation formula given by Harmanec (1998).
3. $V$ observations of Strömgren photometry published by Sterken et al. (1994).
4. $UBV$ observations obtained by MW during 6 nights in 2004 with the 50 cm telescope at SAAO.

For the RV analysis we used spectroscopic data obtained from various sources, including Struve (1944), Hill et al. (1974), Conti et al. (1977), Levato & Morrell (1983), Penny et al. (1999), Sana et al. (2001) and García & Mermilliod (2001).

## Preliminary analysis

Our objective was to carry out a consistent solution of all available data including RV measurements and photometric data. Most importantly, we intended to analyze all data simultaneously, ensuring maximal constraint of the parameters. V1007 Sco is a complicated system with eccentric orbit and associated apsidal motion, as well as significant ellipsoidal deformation of the components. The resulting large number of free parameters poses a big challenge. For this difficult task we chose the computer program PHOEBE (PHysics Of Eclipsing BinariEs) developed by Prša & Zwitter(2005), which is a user-friendly implementation of the well-known Wilson-Devinney (WD) code with additional features.

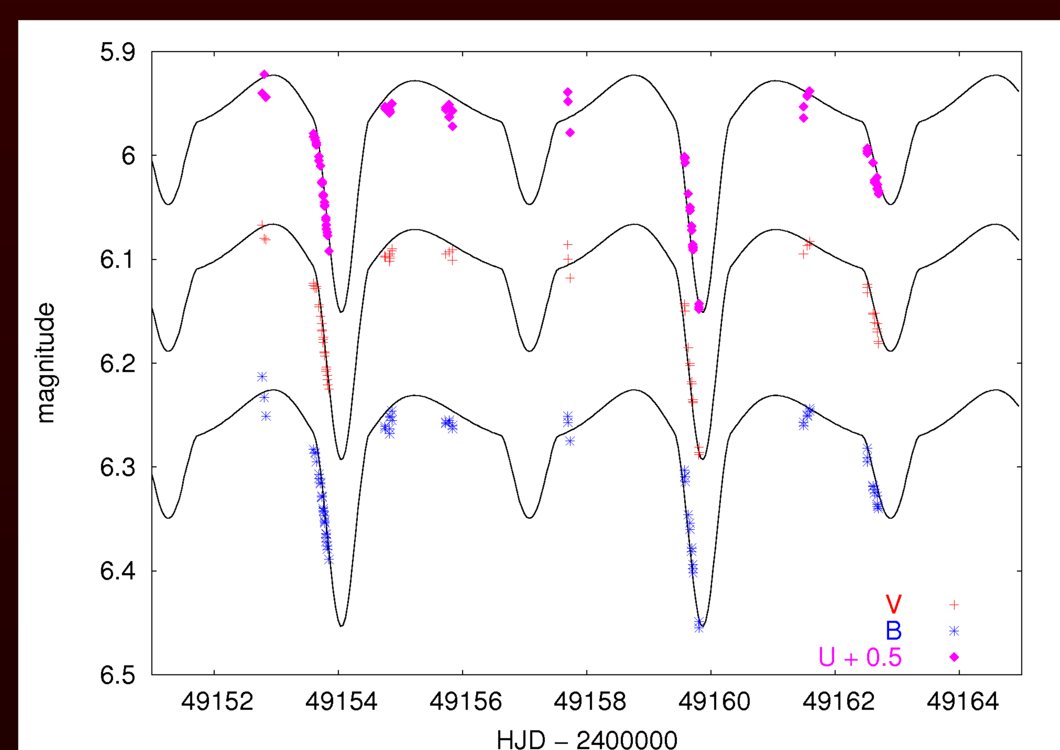


FIGURE 2: $U$, $B$ and $V$ light curves obtained between 13 Jun 1993 and 25 Jun 1993 with best fits.

A first determination of fundamental orbital parameters like inclination, eccentricity and time of periastron was made by using the light curves only, covering some 4500 days. Subsequently the much longer time base of the spectroscopic observations (spanning more than 50 years) allowed us to derive the orbital period with excellent accuracy.

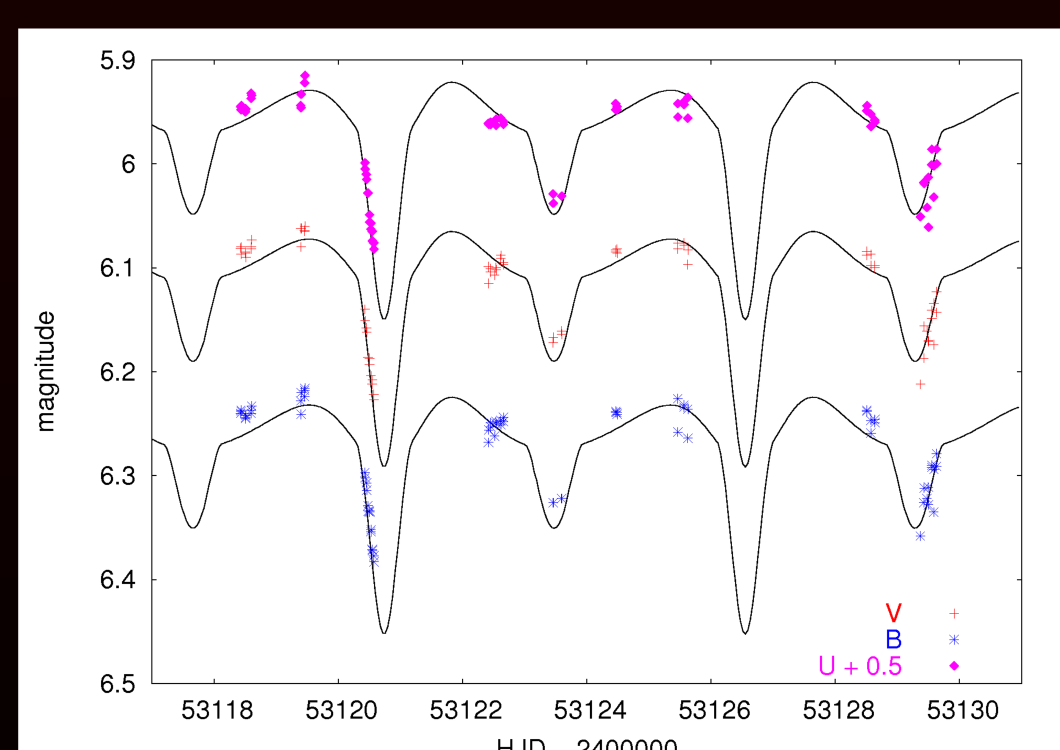


FIGURE 3: $U$, $B$ and $V$ light curves obtained between 22 Apr 2004 and 04 May 2004 with best fits.

We then proceeded with a preliminary adjustment of different parameter subsets – a necessary requirement due to the large number of free parameters.

## Parameter determination

After all parameters had been constrained sufficiently, a final solution incorporating all data at once was attempted. In order to avoid subjective influence, we devised an automatic iteration scheme using the PHOEBE scripter module. Our preliminary solution served as input for the DC minimization process. At the end of each run the derived parameters were subjected to a random dislocation (see Prša & Zwitter(2005) for a description of the method), creating new input parameters for the next run.

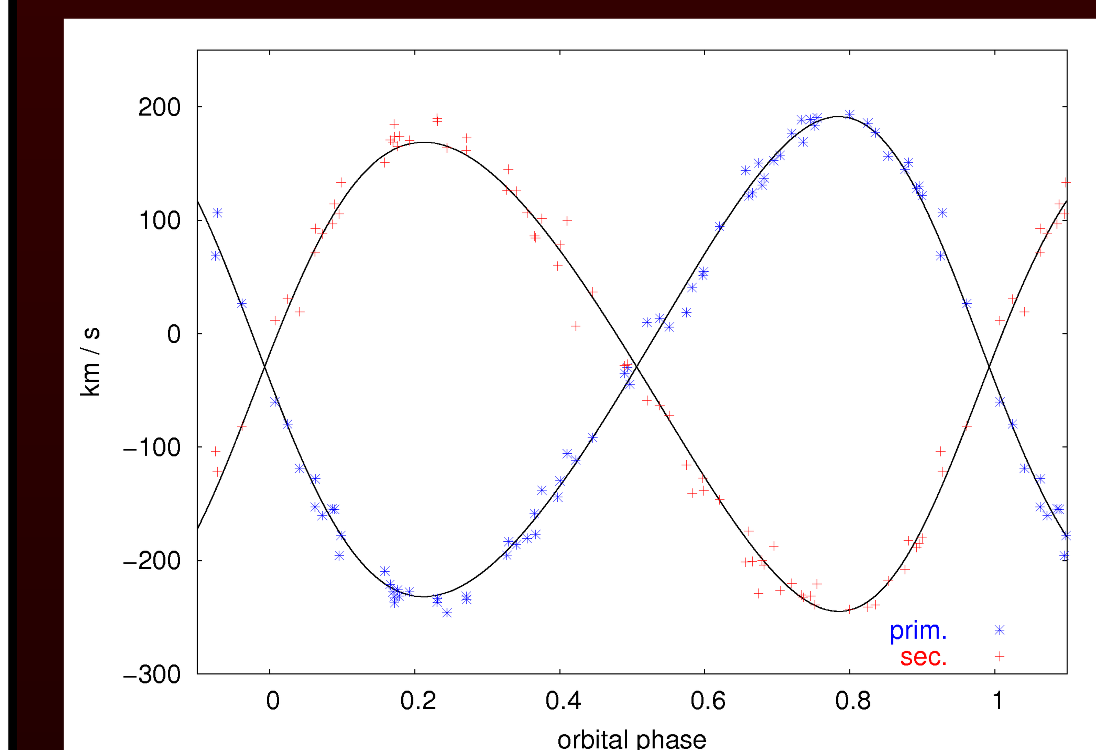


FIGURE 4: Radial velocity curves constructed for data with HJD larger than 2449448.

As it quickly turned out, the solution kept wandering around in a very small portion of the parameter space at random after typically 10 to 15 DC iterations. This behavior could not be alleviated using the method of multiple subsets as devised by Wilson & Biermann (1976). Therefore the best-fitting parameter sets derived during each PHOEBE run were averaged and are shown together with their respective standard deviations in TABLE I. This statistical approach ensures realistic error margins for all derived parameters.

| | |
|---|---|
| $P_{\rm sidereal}$ | 5.816066 $\pm$ 0.000001 d |
| $T_{\rm periastron}$ | 2448502.380 $\pm$ 0.001 |
| $e$ | 0.122 $\pm$ 0.001 |
| $\omega$ at $T_{\rm periastron}$ | 69.67 $\pm$ 0.45 deg |
| $d\omega/dt$ | 3.227 $\pm$ 0.045 deg/year |
| $K_1$ | 211.7 $\pm$ 2.3 km/s |
| $K_2$ | 206.9 $\pm$ 2.2 km/s |
| $q = M_2/M_1 = K_1/K_2$ | 1.023 $\pm$ 0.005 |
| $A$ | 51.70 $\pm 0.04 R_\odot$ |
| $M_1$ | 27.24 $\pm 0.15 M_\odot$ |
| $M_2$ | 27.88 $\pm 0.16 M_\odot$ |
| $R_1$ | 14.47 $\pm 0.71 R_\odot$ |
| $R_2$ | 15.99 $\pm 0.47 R_\odot$ |
| $i$ | 67.43 $\pm$ 0.22 deg |
| $\gamma$ | -29.27 $\pm$ 0.04 km/s |

TABLE I: Final parameter set of V1007 Sco.

From the derived radii and temperatures we were able to calculate the luminosity and the absolute magnitude of the stars. This leads us to a distance determination of 1580 pc, well in agreement with the previously derived distance of the open cluster NGC 6231 by Sana et al. (2005), which V1007 Sco is a member of.

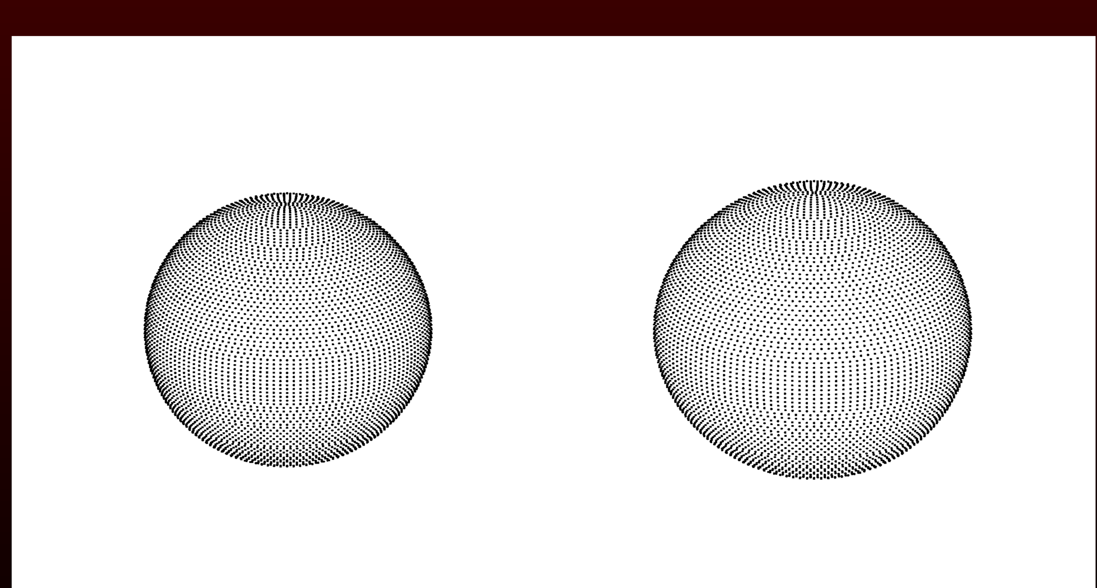

FIGURE 5: Periastron configuration of V1007 Sco for orbital phase 0.25. The ellipsoidal deformation of both components is clearly visible.

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