The fractional dimensions of close binary systems components: the reliability of their determination

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Received: November 18, 1992

Abstract. The accuracy of determining the fractional dimensions of close binary systems is analysed. The analysis is based on the catalogue of modern lightcurve synthesis photometric solutions of close binary systems. Only a small percentage of the fractional dimensions is derived with an accuracy attainable by using photoelectric photometry and modern lightcurve synthesis methods. The sources of the inaccuracy are discussed and some recommendations for improvement are given.

Key words: binaries – eclipsing – fundamental parameters

1. Introduction

The analysis of the accuracy of determining photometric elements determination of detached, semidetached and contact binary systems can provide information on the reliability of their determination using contemporary methods of the observation and solution. The analysis can detect the interaction between the components, or provide an information about other effects which influence the accuracy of the determination of the photometric elements. Catalogues of the photometric elements can be used for this analysis. The most useful source of the data is "A catalogue of modern lightcurve synthesis photometric solutions of close binary systems" (Cester et al. 1979) and its supplement (Cester et al. 1980). The catalogue contains almost 500 photometric solutions of lightcurves. It contains data for 181 close binary systems. The lightcurves were solved by using the following lightcurve synthesis methods: Berthier (1975), Binnendijk (1977), Hill and Hutchings (1970, 1971a, 1971b, 1973a, 1973b), Lucy (1973), Mochnacki and Doughty (1972a, 1972b), Nagy (1975), Rucinski (1973, 1974), Wilson and Devinney (1971, 1973), Wood (1972, 1973-1978). The most frequent methods used were the methods of Wood and then that of Wilson and Devinney. The catalogue is a homogeneous set of photometric solutions from the methodological point of view. However, the class frequency is different, the detached

Contrib. Astron. Obs. Skalnaté Pleso **23**, (1993), 50– 56.

and semidetached systems are the most numerous. The catalogue published recently by Sveschnikov and Kuznetsova (1990) is not suitable for this type of investigation as it does not give errors of the fractional dimensions.

2. The analysis of the accuracy of determining the fractional dimensions of components

For the analysis the following method was used. If for a given close binary system several photometric solutions were available, the photometric solution with the smallest errors was chosen. The accuracy of determining the fractional dimensions is very different and the spread of values reaches almost two orders of magnitude. The mean values of the errors for all binaries of a given class could be severaly influenced by a few very large errors. Therefore, comparison of the errors for the best solutions in different classes of close binaries would be more reasonable. We obtained following results:

a) Modern computational methods enable the determination of fractional dimensions with an accuracy of 0.0003 units. This limit depends on the accuracy of the observational material, also on the form of the lightcurve, on the lightcurve variations and on its peculiarities. The accuracy of determining the fractional dimensions for the close binary systems referred in this catalogue lies between 0.0003 and 0.0200 units. The complete data set consists of 134 close binary systems. The errors are not given for 47 systems. One can suppose that the errors of determining the fractional dimensions for the last mentioned group can exceed 0.0200 units.

b) The accuracy of determining hot and cool components (the terminology hot and cool is used instead primary and secondary) of the detached close binary system is approximately the same and it is equal to 0.0012 units (the mean of 5 best photometric solutions). The fractional dimensions of the hot components in the semidetached systems can be determined with an accuracy comparable with that for detached systems: 0.0010 units. However, the cool components (as a rule the secondaries) are determined with a limiting accuracy of 0.0018 units. The limiting accuracy of determining the fractional radius of hot and cool components for contact systems is 0.0025 units. Only a small part of the fractional dimensions for detached, semidetached and contact system is determined with the limiting accuracy as given above. This is clearly seen in the Tab. 1. and on Figures 1 - 3. There are only few photometric solutions for the systems sd-d and c-sd. The picture changes when the standard deviations for the whole set of photometric solutions instead of the limiting accuracy for the best solutions are compared (see section d).

c) For approximately 20% of the close binary systems referred to in this catalogue at least two independent solutions with two different methods are available. The differences between the photometric solutions are very small and they are below the limit of 3 sigma. The only exception is VW Cyg. Therefore, the different methods of photometric solutions cannot be the main source responsible for the spread of the errors of the determining the fractional dimensions.

d) The question is, how the fractional dimensions of hot and cool components are related to the photometric regions. For such an analysis the close bineries with the solutions in the UBV photometric system were taken into the consideration. The reason is that this photometric system is widely used for the observation of close binary systems. In addition, the accuracy of the solutions in U, B and V colors separately for hot and cool components for the whole sets of solutions was analysed. The values of sigma were calculated for each group (detached, semidetached and contact systems) and for each color. The results are as follows:

Detached systems. The systematic differences among the solutions in V, B and U are very small and are at the level of one sigma. The standard deviation of the solutions in all three filters is the same, however, the error of the calculation of the fractional dimensions of the cool component is by 55% higher compared with that for the hot components.

The only exception is the system CW Eri. Its fractional dimensions are strongly dependent on the photometric region. The hot component in the U photometric region is approximately by 10% smaller (at the level of 26 sigma) compared with the V region. The cool component is in the U filter approximately by 17% greater (at the level of 31 sigma) compared with the fractional dimension in the V filter. The difference is lower between the solutions in the B and V filters. Popper (1983) removed the discrepancy between the values in B and V, but the discrepancy in U still exists.

Semidetached systems. The hot components in the B photometric band are by 1% larger compared with the fractional dimensions in the V band. The difference is at the 4 sigma level. The difference among other values are very small and they are approximately at the 1 sigma level. The errors of the fractional dimensions in the U photometric region are by 36% greater compared with the solutions in the B and V band where the accuracy is approximately the same.

The great discrepancies are in the case of the binary systems SZ Cam and RW Tau. The fractional dimensions of the hot component of SZ Cam are by 12% and 17% smaller in the B and U filters, respectively, compared with the value in the V filter. The cool component is greater by 6% and 8% in the B and U filters, repectively, compared with the fractional dimensions in V. Later on, Chochol (1980) derived new photometric elements using his own observations. Large differences remained between both sets of the photometric elements and among the values in U, B and V photometric bands, too. New observations are needed. They can be obtained in the nights with very good seeing as a bright star is in the distance of few arcsec from the variable. The discrepancies in RW

Tau are not so high as in the case of SZ Cam . The system RW Tau has a resemblance to W Ser type stars and thus the differences are not surprising.

Contact systems. There is a weak indication that the cool components are smaller in U photometic region compared to fractional dimensions in the B and V region. However, the difference is below 3 sigma. Surprisingly the U and the B solutions for the cool components were obtained with a little bit higher accuracy: 27% and 11%, respectively. The accuracy of the solutions for the hot components in all three filters is approximately the same.

3. Conclusions and recommendations

a) If we accept the value of 0.0020 units as a reasonable upper limit for the mean error of the determination of the fractional dimensions we see that only a small portion of the photometric solutions fulfills this condition (Figs 1, 2 and 3, Tab. 1.). If we take a more severe limit, the situation would be even worse. The frequency of errors within given limits for different types of close binary systems is presented in Figures 1, 2 and 3. Table 1. contains the numbers of close binary systems distributed by type, and each type is divided into three groups: the group with the accuracy better than 0.0020 units and the group of close binary stars with errors of determining the fractional dimensions below this limit. In the last group are the systems with incomplete data.

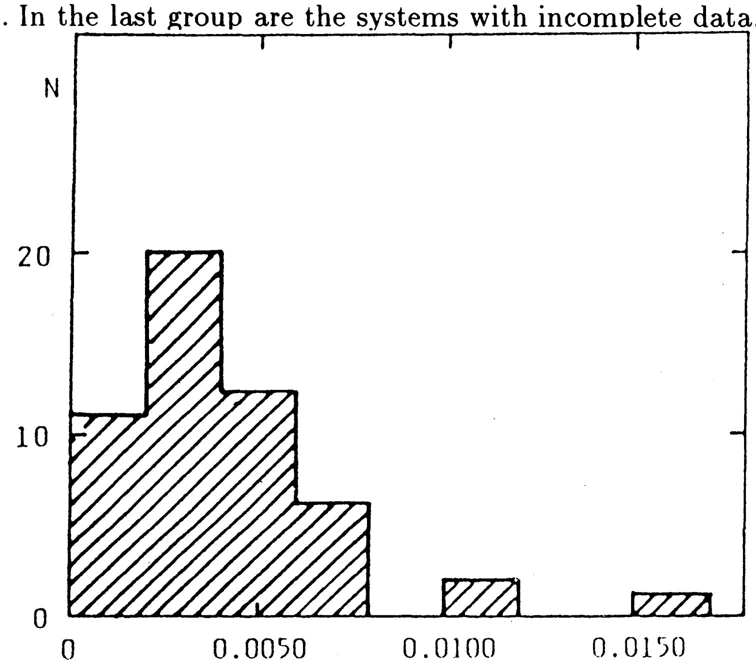

Figure 1. The frequency class of the errors. The detached systems.

b) We suppposse that the main sources of lower accuracy of determining the fractional dimensions are as follows:

1) The spread of the individual photometric observations

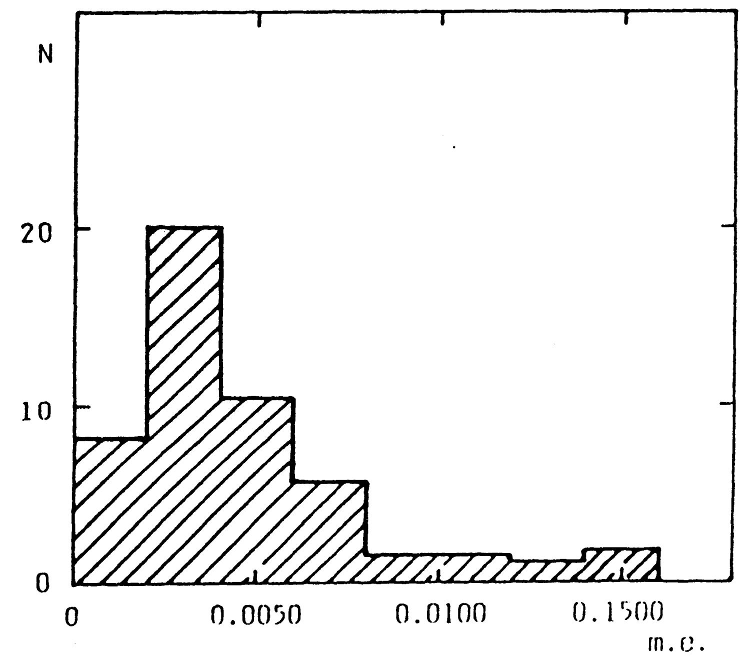

Figure 2. The frequency class of the errors. The semidetached systems.

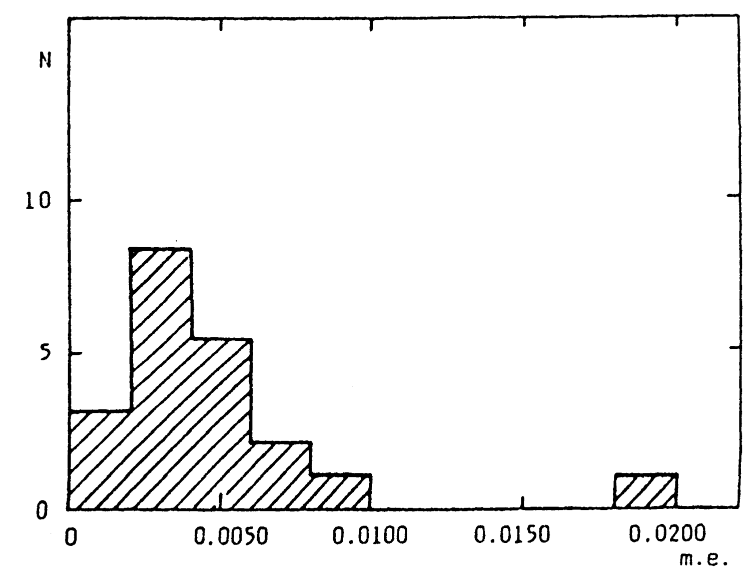

Figure 3. The frequency class of the errors. The contact systems.

Table 1

Error Type	≤0.0020	>0.0020	Incomplete data	Total
d	12	41	19	82
sd	9	41	6	56
c	3	19	19	41
sd-d	2	6	0	8
c-sd	0	1	1	2
Unknown	0	0	2	2
N	25	108	47	181

2) Inappropriate use of the methods (e.g. in the case of spotted stars)
3) Real changes of light curves

In order to minimize the influence of the above-mentioned effects we propose to observe the following rules:

A) The use of perfect instruments for observations (e.g. dual-channel photometers), the correct choice of the comparison star and check star, the choice of the optimum scheme of the observation, etc. The observations should be made on consecutive nights and the phases of the lightcurve should be covered at least twice and, if possible, several times. Items 1 and 3 can thus be checked.

B) The observational material should be carefully treated before solving the lightcurve. Mean lightcurves and seasonal lightcurves are not recommended. If lightcurve changes are detected, they should be analysed, and their phasedependence, light amplitudes and timescales should be investigated. The method of the reference curve or the method of the difference curve can be used for small lightcurve changes (Bakos et al. 1991). The analysis of long series of photometric observations can reveal the nature of the lightcurve changes. It should be noted that real changes of the lightcurve are detected on a timescale of a few days (Hrivnak 1982, Bakos et al. 1991, Demircan et al. 1992).

C) The refinement methods of lightcurve solutions, the implementation of the procedures for modelling hot spots, cool spots and other effects.

The observation of these rules will not only increase the accuracy of the determining the fractional dimensions, but can also detect lightcurve variations and help to explain their nature. For example, the treatment of the numerous photometric observations of AW UMa obtained on consecutive nights, which covered the phases of the lightcurve several times, led to the detection of the rapid changes (Hrivnak 1982, Bakos et al. 1991, Demircan et al. 1992) which cause difficulties in the theory of the solar-type spots on the surface of this variable star.

Acknowledgements. The author thanks the Slovak Academy of Sciences for the allocation of the grant 2/61/1992 which made this research possible.

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