Light curve solutions for bright detached eclipsing binaries in SMC: absolute dimensions and distance indicators

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ABSTRACT

This paper presents a careful and detailed light curve analysis of bright detached eclipsing binaries (DEB) in the Small Magellanic Cloud, discovered by OGLE collaboration, on the basis of recently available difference image analysis (DIA) photometry. The 19 binaries brighter than 16.4 mag in I band and with the depth of primary and secondary eclipse greater than 0.25 mag were investigated. The solutions were obtained by a modified version of the Wilson-Devinney program. The quality of DIA light curves – a good phase coverage and relatively small scatter – is enough to calculate realistic estimates for the third light \( l_3 \) and the argument of periastron \( \omega \). It was found that solutions of detached, eccentric systems with flat light curve between eclipses usually may suffer from indetermination of \( l_3 \) in contrast to those of similar systems having some proximity effects.

The physical properties of the stars were estimated on the basis of their photometric elements and indices assuming the distance modulus to SMC \( \sim 18.9 \) and consistency between an empirical mass-luminosity relation and the flux scaling. The method was tested on three LMC stars of known absolute dimensions and a good agreement was found for \( m - M \sim 18.5 \). Such an approach may give fast and accurate estimates of absolute dimensions for large and homogeneous samples of eclipsing binaries in the Magellanic Clouds and other close galaxies. Moreover, this method allows also for independent estimation of \( E(B-V) \) in the direction to a particular binary.

The subset of six bright DEB’s worth future intensive investigations as likely distance indicators to SMC, was chosen. They are SC3 139376, SC4 53898, SC5 129441, SC6 67221, SC6 215965 and SC9 175336.

Key words: binaries: eclipsing – Magellanic Clouds

1 INTRODUCTION

Accurate determination of absolute dimensions of eclipsing binaries based, among others, on detailed light curve analysis is still a very important task of modern astronomy. It gives an opportunity for testing advanced evolutionary models of stars (e.g. Pols et al. 1997) but also allows for very precise distance determination. The method, at least in principle, is quite straightforward (see Paczyński 1997 for an outline and Clausen 2000 for a review). Three distance determination for eclipsing binaries in the Large Magellanic Cloud were quite recently presented: HV 2274 (Guinan et al. 1998), HV 982 (Fitzpatrick et al. 2001) and EROS 1044 (Ribas et al. 2002) giving the distance modulus \( m - M \sim 18.4 \). Light curve solutions together with estimation of physical parameters and the distance to the Small Magellanic Cloud were obtained also for two eclipsing binaries: HV 2226 (Bell et al. 1991) and HV 1620 (Pritchard et al. 1998) giving for the distance modulus \( m - M \sim 18.6 \). Very recently ten eclipsing binaries have been analysed in the central part of the SMC giving mean distance modulus \( m - M = 18.9 \pm 0.1 \) (Harries, Hilditch & Howarth 2003). The light curve analysis in their paper was based on DoPHOT OGLE photometry (Udalski et al. 1998).

In recent years, extensive CCD photometry have been undertaken during the projects of microlensing searching toward the Magellanic Clouds and Galactic Bulge. As a byproduct, thousands of eclipsing binaries were discovered and placed in catalogs (Grison et al. 1995, Alcock et al. 1997, Udalski et al. 1998). Preliminary solutions for MACHO LMC catalog were found by Alcock et al. (1997). They fitted 611 light curves of eclipsing binaries using the EBOP code (Etzel 1993). That code uses a tri-axial ellipsoid approximation what makes this code very fast. But the code cannot properly account for the proximity effects present in most of the eclipsing binaries detected by
MACHO. For SMC eclipsing binaries OGLE collaboration (Udalski et al. 1998) extracted from their catalog a sample of 153 detached binaries with well defined, narrow eclipses of similar depth and relatively good photometry. It was argued that the sample contains the best systems for distance determination. Wyithe & Wilson (2001, 2002 – hereafter WW1, WW2) presented an excellent analysis of the whole OGLE data containing 1459 eclipsing binaries using an automated version of the Wilson-Devinney (1971, Wilson 1992) code. This program can provide very detailed treatment of proximity effects. They used public domain DoPHOT photometry available at OGLE homepage [http://sirius.astrouw.edu.pl/ogle/ogle2/var...stars/smcecl](http://sirius.astrouw.edu.pl/ogle/ogle2/var...stars/smcecl) in the analysis. They extracted in an objective way two subsets of detached binaries with very narrow eclipses and complete eclipses as the most likely good distance indicators. Subset of semi-detached eclipsing binaries was also chosen as distance indicators on the basis of similar surface brightness between components and complete eclipses. The authors intend, also, to extract such subsets for contact binaries. In general it is believed that the close-to-ideal system chosen as a distance indicator, should have two stars of similar temperature and luminosity and the separation of the components should be significantly larger than their radii. But well-detached, eccentric systems may suffer from the aliasing of photometric solutions. WW2 argued that semi-detached and contact binaries, and also detached eclipsing binaries showing larger proximity effects, have their photometric solutions better defined and may serve as potential best distance indicators as in the case of recently analyzed 15-th magnitude binary EROS 1044 (Ribas et al. 2002). In this paper I focused my attention on detached eclipsing binaries.

The release of new DIA photometry by OGLE collaboration motivated me to reanalyse the light curves of eclipsing binaries in SMC for the purpose of extracting a sample of the best distance indicators. This sample was chosen using additional important criteria which were not used in the selections made by Wyithe & Wilson. The analysis was restricted only for bright systems. It is obvious that those systems have, in general, the largest probability of obtaining high-quality light curves and radial velocity curves. Thus the searching for distance indicators should start from the analysis of the brightest candidates. Moreover using DIA photometry we can achieve more realistic determination of the light curve parameters than in the case of using the older DoPHOT photometry.

2 THE DATA

2.1 Photometry

CCD differential photometric observations of SMC eclipsing binaries were obtained by OGLE between 1997 and 2000. The data were acquired using 1.3 m Warsaw Telescope at Las Campanas Observatory. The photometric I indices were calculated using the technique of difference image analysis (DIA) as was reported in Zebruń, Sośnizynski & Woźniak (2001a). The new photometry was quite recently facilitated on OGLE homepage [http://sirius.astrouw.edu.pl/ogle/ogle2/dia](http://sirius.astrouw.edu.pl/ogle/ogle2/dia) (Zebruń et al. 2001b). The OGLE database contains all variables detected in the LMC and SMC (68 thousand) during the course of the OGLE-II project. The DIA is argued as a superior method over classical DoPHOT method because of its better accuracy, especially in crowded fields (Zebruń et al. 2001a). The light curves based on OGLE-DIA photometry are characterized by considerably smaller scatter of observations and higher smoothness of the light curves. Also, in most cases the phase coverage is better because the DIA photometry includes OGLE observations which have extended almost two years after the moment when original catalog of SMC eclipsing binaries (Udalski et al. 1998) was published.

The quality of OGLE-DIA photometry can be demonstrated by a comparison of the I light curves obtained with both methods. As an example I present a 17-th magnitude eccentric eclipsing binary SMC SC1 25589 – Fig. 1 – together with preliminary light curve solutions. Note that according to the analysis of DIA light curve the system has apparently total eclipses and much larger separation between components than in the case of the analysis of DoPHOT data.

The candidates for the analysis were chosen after the visual inspection of the light curves of eclipsing binaries in SMC released by Udalski et al. (1998). A preliminary set of about 25 binaries were selected brighter than $I = 16.4$ mag at maximum brightness and with the depth of the primary and secondary eclipses greater than 0.25 mag. The candidates fall into three separate groups. The first group,
hereafter called A, consist of well-detached, eccentric systems with, usually, deep narrow eclipses. The second group, hereafter called B, comprise the short-period systems with apparently circular orbits and the small separation between components. As a result, the systems from group B show quite large proximity effects in their light curves. The third group C comprises well separated long period systems with circular orbits. As we expect long period systems to be, in general, eccentric this is most probably a chance selection.

Afterwards, the photometric data for each selected star were extracted, using the coordinates as identifier. Some stars were not found in OGLE-DIA database because they probably passed undetected through the variability checking filters (I. Soszyński 2002, private communication). The Table 1 gives the names and identification of 19 selected systems together with a summary of photometric parameters.

### 2.2 Initial data preparation

The observations were folded with trial periods following the method given by Kaluzny et al. (1998). The searches were usually restricted to a period close to the period given by Udalski et al. (1998). The final period was found by tuning to the shape of the minima. It was found that in most cases the resulting periods agreed very well with those given by Udalski et al. (1998). However, for SC6 67221, I have found a new period resulting from observations of both eclipses. This binary turned out to be a very eccentric system with the orbital period of 10.977 days. The period is close to a whole number of 11 days and this is the reason for spurious secondary eclipse detection in the original OGLE catalog. Fig. 2 presents the light curve based on the proper period and, for comparison, the light curve from the original OGLE catalog.

Two eccentric binaries SC3 139376 and SC5 311566 show small changes in the light curve most probably due to the apsidal motion. In both cases the tuning to the shape of the primary and the secondary minimum gives significantly different periods – see as an example SC5 311566 (Fig. 3). Smooth light curves were obtained assuming that the change of the shape of minima is small and the secondary minimum was progressively shifting in respect to the primary minimum during the period of observations. The linear correction was applied to all phases corresponding to the secondary eclipse (phases: 0.35-0.55 for SC3 139376 and 0.4-0.6 for SC5 311566) in the form:

\[
\phi_i = \phi_i + \alpha \times E,
\]

where \(\phi\) and \(E\) are the phase and the epoch number of the

![Figure 2. The light curves of SMC SC6 67221: from Udalski et al. (1998) (upper panel) and from the analysis of OGLE-DIA photometry in this paper (lower panel).](image)

![Figure 3. The light curves of SC5 311566 tuned to the shape of primary minimum (upper panel) and to the secondary minimum (middle panel). Lower panel: the light curve computed assuming a progressive shift of the secondary minimum in respect to the primary minimum - see the text for explanation.](image)
Table 1. The selected eclipsing binaries

| Object    | $\alpha_{2000}$ | $\delta_{2000}$ | Perioda | Epochb (+2450000) | $I$  | $B-V$ | $V-I$ |
|-----------|-----------------|-----------------|---------|-------------------|------|-------|-------|
| SC3 139376 | 0:44:08.69      | −73:14:17.9     | 6.05213 | 629.07158         | 14.482 | −0.165 | −0.126 |
| SC5 129441 | 0:49:40.56      | −73:00:22.5     | 8.05104 | 474.20881         | 16.012 | −0.105 | −0.072 |
| SC5 311566 | 0:51:34.84      | −72:45:45.9     | 3.29132 | 468.56556         | 16.032 | −0.120 | −0.062 |
| SC6 11143  | 0:51:39.69      | −73:18:48.8     | 5.72606 | 471.95035         | 16.251 | −0.138 | −0.092 |
| SC6 67221  | 0:52:06.22      | −72:45:14.3     | 10.97765 | 466.88198         | 15.327 | −0.101 | −0.095 |
| SC6 221543 | 0:53:40.39      | −72:52:22.0     | 3.41680 | 468.59872         | 16.089 | −0.218 | −0.109 |
| SC7 274253 | 0:54:33.22      | −73:10:39.6     | 5.70970 | 469.30090         | 15.805 | −0.172 | −0.057 |
| SC9 163575 | 1:02:46.27      | −72:24:44.2     | 1.97109 | 629.49776         | 15.181 | −0.248 | −0.221 |
| SC10 37223 | 1:03:41.42      | −72:03:06.9     | 2.58124 | 630.63675         | 16.336 | −0.197 | −0.164 |
| SC4 53898  | 0:46:32.79      | −73:26:39.4     | 1.74107 | 624.86290         | 16.201 | −0.128 | −0.129 |
| SC4 103706 | 0:47:25.50      | −73:27:16.7     | 1.35585 | 623.94992         | 15.416 | −0.195 | −0.208 |
| SC6 163552 | 0:47:53.24      | −73:15:56.5     | 1.34581 | 625.35629         | 15.774 | −0.046 | −0.006 |
| SC5 38089  | 0:49:01.85      | −73:06:06.9     | 2.38941 | 469.77239         | 15.261 | −0.238 | −0.111 |
| SC6 215965 | 0:53:33.35      | −72:56:24.1     | 3.94603 | 473.26734         | 14.133 | −0.234 | −0.190 |
| SC6 319966 | 0:54:23.49      | −72:37:23.0     | 1.06466 | 466.68981         | 16.363 | −0.151 | −0.105 |
| SC8 104222 | 0:58:25.08      | −72:19:09.8     | 1.56972 | 629.39052         | 16.042 | −0.144 | −0.146 |
| SC9 175336 | 1:02:53.40      | −72:06:43.2     | 2.98654 | 628.36738         | 14.867 | −0.222 | −0.192 |
| SC4 192903 | 0:48:22.69      | −72:48:48.6     | 102.86800 | 761.00300      | 16.242 | 0.771 | 0.956 |
| SC8 201484 | 1:00:18.05      | −72:24:07.5     | 185.19000 | 641.56700      | 14.230 | 0.883 | 0.977 |

**Notes:**

*a* Calculated by the period finding program. See [11, 31].

*b* Calculated from light curve analysis. See § 3.1.

$i$-th observation. Denoting the period resulting from the tuning to the primary eclipse by $P_p$ and to the secondary one by $P_s$, the factor $\alpha$ was calculated by formula: $\alpha = (P_s - P_p)/P_p$ and was $7.5 \cdot 10^{-5}$ and $7.0 \cdot 10^{-5}$ for SC3 139376 and SC5 311566, respectively.

The old reference epochs $T_o$ given by Udalski et al. (1998) were used to fold up the observations. New reference epochs were determined later during the light curve analysis — see § 3.1. For each star I calculated out-of-eclipse $I$ magnitude at the maximum of the brightness. The DIA data does not include the $B$ and $V$ photometry. For the purpose of obtaining the most accurate $B-V$ and $V-I$ colours I recalculated the out-of-eclipse $B$, $V$ and $I$ magnitudes using the old DoPHOT photometry. Note, that the magnitudes which I have found refer to the mean magnitudes at the maximum brightness rather than to the maximal magnitudes given in the original OGLE catalog. Resulting out-of-eclipse $I$ magnitudes were then used to normalize the light curves.

In two cases (SC6 11143 and SC9 163575) the light curve shows considerable amount of scatter, much larger than the average error of the observations. The light curves of both systems are presented on Fig. 4 (upper panel). I have removed observational points when the eclipses occurred and rerun the period finding program to find some periodicity in the scatter. It turns out that in the case of SC6 11143 the out-of-eclipse observations assemble with the period of 2.618 days and form a light curve with two well-defined, narrow minima of different depth (middle panel of Fig. 4). It is likely that the binary SC6 11143 blends with another short period and slightly eccentric eclipsing binary. The similar analysis done for the system SC9 163575 shows that the out-of-eclipse observations assemble with the period of 1.985 days and form two minima separated by a half of the period. It seems that the system SC9 163575 blends also with a short period eclipsing binary. Their periods are very close to each other and in the original light curve the points, corresponding to the minima of the blend, form two clumps situated around the minima of SC9 163575. The light curves of both systems were cleaned by removing from the light curve all points corresponding to the moments when the eclipses occurred in the blended binary. The resulting light curves are presented in the lower panel of Fig. 4. Also the system SC5 38089 in spite of its relatively high brightness ($I_{\max} = 15.26$) has quite large scatter of observations. The analysis done for this system shows that the changes of the brightness are randomly distributed and thus, it is likely that the reason of the scatter is some kind of an intrinsic variability.

### 3 LIGHT CURVE ANALYSIS

#### 3.1 Method

All fits to the light curves were obtained using a modified version of the Wilson-Devinney (1971, Wilson 1979, 1992, hereafter WD) program with a model atmosphere procedure based on the ATLAS9 code and developed by Milone, Stagg & Kurucz (1992). An automated iterations scheme of WD program was employed. For A subset a detached configuration (mode 2) was chosen for all solutions and simple reflection treatment was used (MREF=1, NREF=1). In the
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Figure 4. Upper panel: the original DIA light curves of SC6 11143 and SC9 163575. Middle panel: the out-of-eclipse observations of both stars folded up with a period and an epoch given in each picture. Both light curves suggest that a blend is an eclipsing binary. Lower panel: the final light curves after removing the variability of the blend.

case of B subset both detached and semi-detached (mode 5) configurations were used to obtain solutions. For B and C subsets the detailed reflection treatment with a double reflection was taken into account (MREF=2, NREF=2). For all stars $\log g = 4.0$ was fixed except for stars from C subset for which $\log g = 2.0$ was assumed.

I have found the initial guess via trial-and-error fitting of the light curves. The convergence is defined to have been achieved if the parameters corrections given by WD program are smaller than 0.75 times the standard errors (1.0 in the case of eccentricity and argument of periastron) on two consecutive iterations. The adjusted parameters were the surface potentials ($\Omega_1, \Omega_2$), the effective temperature of the secondary ($T_2$), the luminosity of the primary ($L_1$), orbital inclination ($i$) and the zero epoch offset ($\Delta \phi$). For A subset I have adjusted two more parameters: eccentricity ($e$) and the argument of periastron ($\omega$).

If for an eccentric system the convergence was not achieved I suppressed the adjustment of $e$, $\omega$ and $\Delta \phi$ provided the correction were smaller than the standard error for these parameters on three consecutive iterations. It turned out that such procedure allowed for better convergence and the solution was achieved in all cases. Afterwards I have run additional iterations, allowing all parameters to vary, to find error estimates of the final solution. Similar procedure was employed for the systems from B and C subsets, just fixing the circular orbit and the suppressing included only the zero phase offset. Among the systems in B subset the third light ($l_3$) adjustment was needed to get the convergence in most cases. For all systems correction $\Delta T_o$ to the epoch given by Udalski et al. (1998) was applied in the form: $\Delta T_o = \Delta \phi \cdot P$, where $\Delta \phi$ is the zero epoch offset of the final solution and $P$ is the period of the system.

WW1 introduced a quantity $F_\chi$ which is greater than unity for systems with complete eclipses:

$$F_\chi = \frac{M_2}{M_1 + M_2}$$
\[ F_e = \frac{r_g + r_s - \cos \iota}{2r_s}, \]  
where \( r_g \) is the fractional the radius of larger star and \( r_s \) is the fractional radius of the smaller star, both expressed in units of semi-major axis \( A \). \( F_e \) is valid, in the form presented above, for circular orbits or perpendicular orbits (\( \iota = 90^\circ \)) and also for eccentric orbits provided the fractional radii of components are expressed in units of the distance between stars at the moment of the mid-eclipse. In general case of eccentric orbits, if one eclipse occurs in the neighbourhood of periastron and is complete, the other may be partial and in the extreme cases, there may be an eclipse near periastron and none near apastron. The instantaneous distance between components \( d \), in units of semi-major axis \( A \), is given by the equation:

\[ d = \frac{1 - e^2}{1 + e \cos \nu}, \]  
where \( \nu \) is the true anomaly. The primary and secondary minima occur when the true anomalies \( \nu_1 \) and \( \nu_2 \) are (neglecting higher powers of \( e \), see Kopal 1959, Chapter 6, equation (9-22)):

\[ \nu_1 = 90^\circ - \omega - e \cos \omega \cot^2 \iota \left( 1 - \sin \omega \csc^2 \iota \right), \]  
\[ \nu_2 = 270^\circ - \omega + e \cos \omega \cot^2 \iota \left( 1 - \sin \omega \csc^2 \iota \right), \]  
respectively. Substituting \( \nu_1 \) and \( \nu_2 \) into Eq. 3 the distances were calculated at the moments of both mid-eclipses. Then appropriate quantities \( F_1^2 \) and \( F_2^2 \) referring to the primary and the secondary eclipse, respectively, were computed.

Semidetached configuration (mode 5) were investigated for all stars from the B subset in order to check which systems are definitively separated. When the semidetached configuration was investigated the mass ratio \( (q) \) of the components was adjusted and secondary surface potential \( (\Omega_2) \) was set by \( q \). However, it turned out that no solution could be found in this mode for any star from B subset in spite of many tests for different sets of adjustable parameters. Accordingly, in subsequent part of the paper I will refer only to detached solutions found in mode 2.

### 3.2 Parameter choice

In the analysis presented here I have included the temperature of binary’s components resulting from an intrinsic colour \((B-V)_0\) of the system. All \((B-V)\) colours from Table 1 were dereddened using the average reddening toward SMC \( E(B-V) = 0.087 \) (Massey et al. 1995, Udalski 2000). I set the temperature of the primary \((T_1)\) respectively to the \((B-V)_0\) colour of the system using Flower’s (1996) empirical calibration. Almost all the selected binaries have minima of similar depth what indicates that the difference between the temperatures of the components is small. Thus such a procedure is justifiable. For those stars for which \((B-V)_0\) colour suggested a very high temperature (~ 410 K for SC5 38089, SC6 215965, SC9 163575, SC9 175336) I set up \( T_1 = 35,000 \) K.

I used a logarithmic law for the limb darkening (e.g. van Hamme 1993). The I limb darkenings \( x_{1,2}, y_{1,2} \) and bolometric limb darkenings \( x_{1,2}^{bol}, y_{1,2}^{bol} \) were calculated from van Hamme’s (1993) tables of limb darkenings for appropriate log \( g \) and \( T \). During the iterations the secondary’s limb darkening coefficients were calculated according to its temperature \( T_2 \). The bolometric albedo and gravity brightening exponent were set to the canonical value of 1.0 for stars with radiative envelopes (von Zeipel 1924). However, for two red long-period systems SC4 192903 and SC8 201484 values typical for convective envelopes were assumed – bolometric albedo was set to 0.5 and gravity brightening exponent to 0.32. The synchronous rotation of both components was assumed \((F_1 = F_2 = 1)\). No level depending weighting of observations was applied – parameter NOISE was set to 0.

The mass ratio was assumed to be \( q = m_2/m_1 = 1 \) in all calculations. WW2 pointed out that in the case of detached eclipsing binary the light curve is almost insensitive to the mass ratio parameter. Only if one of the components is highly evolved (when its radius \( R \) increase to about a half of the total separation \( A \)) or if the system has a very low mass ratio, the light curve becomes sensitive for this parameter. The preliminary tests show that no component from the set of binaries has fractional radius \( R_1 = R_1/A \) larger than 0.4. However, for two systems from B subset it was necessary to adjust the mass ratio in order to get a good solution (see §3.4).

### 3.3 Solutions for A subset

For each system from A group the automated fitting scheme described in §3.1 was employed. Only in three cases: SC6 67221, SC6 221543 and SC6 272453 was the convergence achieved by adjusting simultaneously all free parameters. The Figure 5 shows the best-fitting model light curves, together with \( O-C \) residuals, whose photometric parameters are given in Table 2. All arguments of the periastron refer to the epoch 1999.0.

For all systems from the A subset reasonable solutions were found assuming \( l_3 = 0 \). However, in the case of SC6 11143 and SC9 163575 we expect that some amount of the third light is present in the system because of the blending with another eclipsing variable. In order to estimate third light component an additional grid of solutions for different values of \( l_3 \) was calculated in the range of 0.05-0.40 with a step of 0.05. For SC6 11143 the best solution was found at \( l_3 = 0.30 \), while for SC9 163575 \( l_3 = 0.10 \). It is worth noting that the solutions found with \( l_3 = 0 \) for these systems have almost no systematic trends in O-C’s residuals, thus the intrinsic variability of the blend is the only sign of the third light component.

The solutions for SC6 67221 converged very rapidly and had the smallest residuals. Only slight systematic residuals are visible near phase 0.04 (just after the egress from primary minimum), most probably due to the strong mutual reflection effect. Similar but even stronger systematic effect is visible near first quadrature \((\phi \approx 0.11)\) in SC5 129441. Because of the presence of the proximity effects both systems were additionally investigated in order to estimate possibly the third light contribution by adjusting \( l_3 \) as a free parameter. In each case synthetic light curves produce a tiny improvement only for unphysical values \( l_3 < 0 \), but such solutions were invariably unstable. The conclusion is that these binaries show virtually insignificant third light contribution what is consistent with \( l_3 = 0 \). For a brief discussion of both systems see § 5.1.2.

Small residuals and relatively quick convergence charac-
Characterize also SC3 139376 and SC9 163575, whereas, the largest apsidal motion for two binaries from the sample. The change of displacement per one orbital revolution $ω$ (Eq. 1) so the rate of advance of periastron $\omega$ is estimated by $\omega = \frac{\epsilon \sin \omega}{\sqrt{1 - \epsilon^2}}$.

However for our purpose we can still use this formula also for inclination close to 90° provided the timescale of a displacement change is small with respect to an apsidal period $U$. The change of displacement per one orbital revolution $(P)$ is simply $\alpha$ (Eq. 1) so the rate of advance of periastron is approximated by:

$$\omega \approx \frac{365 \alpha \sqrt{1 - e^2}}{P \epsilon \sin \omega} \ [^\circ/yr].$$

Substituting numerical values we get 5°8/yr and 1°8/yr for SC3 139376 and SC5 311566, respectively.

### 3.4 Solutions for B and C subsets

The photometric parameters for the stars from B and C subsets are presented in Table 2. Appropriate light curve solutions are shown in Figs. 6 and 7. In contrast to the A subset, almost all solutions from B subset (beside SC6 215956) were found only by adjusting the third light $l_3$ in the system. There is a simple explanation of this effect - see a discussion in section 6.1. SC6 215956 was also investigated for possible third light contribution but values of $l_3$ suggested by WD program were invariably negative. SC6 215965 has very small residuals and the solution for this system converged rapidly. Also it seemed to be most stable of all in B subset.

The solution for SC5 38089 was obtained using the spectroscopic mass ratio $q = 1.12$ and more appropriate temperatures ($T_{1,2} \approx 29000$ K) determined for this binary by Harries et al. (2003). Third light contribution in this system is spurious although some improvements to the fits can be obtained for $l_3 > 0.2$.

In spite of the small residuals in SC9 17536 its solution was extremely unstable and exhibited large systematic $O-C$ deviations, especially near external contacts. The tests showed that the reason was the sensitivity of the light curve to the mass ratio $q$ as the larger and cooler component seemed to be noticeably more evolved than the hotter one. The same problems arose for SC4 53989 which seems to be similar in many respects to the former, although its light curve is less sensitive for $q$. Both systems show complete eclipses which allow for more accurate determination of photometric parameters including the photometric mass ratio. Thus I allowed for adjusting of $q$ for both systems in detached configuration. The convergence was achieved and a stable solution obtained: in the case of SC9 17536 for $q = 1.15 \pm 0.05$ and in the case of SC4 53989 for $q = 1.36 \pm 0.12$.

The solutions for two systems from C subset converged very rapidly. No third light $l_3$ was adjusted in both cases because of the lack of any systematic residuals in the solutions (Fig. 7). Moreover the solution for SC8 201484 has the smallest residuals from all of the subsets.

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Table 2. Photometric parameters

| Object   | Radius $R_1/A$ | Radius $R_2/A$ | Temperature ratio $T_2/T_1$ | Inclination $i$ | Eccentricity $e$ | Argument of periastron $ω$ | Third light $l_3$ | Luminos. ratio $l_2/l_1$ | $F_1^2$ | $F_2^2$ |
|----------|----------------|----------------|-----------------------------|----------------|----------------|-----------------------------|-----------------|--------------------------|--------|--------|
| SC3 139376* | 0.177±0.004   | 0.194±0.004   | 1.007±0.006                | 83.3±0.2       | 0.064±0.003   | 133.7±5.7                  | 0.0             | 1.191                    | 0.734 | 0.704 |
| SC5 129441†† | 0.158±0.001   | 0.162±0.002   | 0.999±0.001                | 85.2±1.0       | 0.375±0.001   | 172.0±0.4                  | 0.0†            | 1.079                    | 0.797 | 0.773 |
| SC5 311566† | 0.157±0.004   | 0.147±0.002   | 0.962±0.005                | 85.7±0.6       | 0.251±0.004   | 070.0±0.1                  | 0.0             | 0.843                    | 0.841 | 0.721 |
| SC6 11143† | 0.133±0.004   | 0.112±0.002   | 0.972±0.020                | 88.8±0.1       | 0.263±0.001   | 234.3±0.6                  | 0.30±0.05       | 0.704                    | 0.983 | 1.022 |
| SC6 6721†* | 0.131±0.002   | 0.119±0.002   | 1.154±0.011                | 83.9±0.3       | 0.401±0.002   | 043.5±0.9                  | 0.0†            | 1.058                    | 0.757 | 0.533 |
| SC6 221543† | 0.202±0.006   | 0.182±0.005   | 0.960±0.007                | 84.2±0.7       | 0.099±0.002   | 146.1±2.7                  | 0.0             | 0.745                    | 0.794 | 0.764 |
| SC6 272453† | 0.149±0.004   | 0.180±0.004   | 0.961±0.006                | 85.2±0.6       | 0.035±0.002   | 236.0±4.5                  | 0.0             | 1.392                    | 0.815 | 0.831 |
| SC9 163575† | 0.234±0.004   | 0.225±0.004   | 0.891±0.007                | 80.6±0.4       | 0.043±0.002   | 010.7±7.4                  | 0.10±0.05       | 0.762                    | 0.661 | 0.655 |
| SC10 37223 | 0.202±0.004   | 0.195±0.004   | 0.951±0.006                | 83.8±0.3       | 0.087±0.003   | 142.3±2.4                  | 0.0             | 0.874                    | 0.757 | 0.728 |

The A subset

The B subset

The C subset

The stars chosen in this paper as likely distance indicators are marked by an asterisk. The stars indicated by Wyithe & Wilson (2001, 2002) are marked by a dagger. A double dagger means that the binary has most probably no third light contribution.
Figure 5. The light curves solutions and their residuals for the systems from the A subset.
Figure 6. The light curves solutions and their residuals for the systems from the B subset.
4 PHYSICAL PARAMETERS

We cannot directly calculate absolute dimensions and masses without knowing spectroscopic orbit. However it is possible to estimate stellar parameters using the inversion of the method of parallaxes of eclipsing binaries. The method of parallaxes was elaborated by Dworak (1974) who based it on Gaposchkin (1938) algorithm. We assume that we know distance to SMC and we use it to calculate absolute dimensions by scaling the system to obtain the observed flux at Earth. The calculations are quite straightforward. For early B or O type stars the Rayleigh-Jeans approximation may be used in visible and near-infrared region of the spectrum so total V or I luminosity of each star is a linear function of temperature $L_{1,2} \sim T_{1,2}$. Using this approximation we can disentangle the temperatures $T_1$ and $T_2$ of both components:

$$T_1 = T_0 \frac{1 + L_2}{1 + L_2 (T_2/T_1)},$$

where $L_{21} = L_2/L_1 = l_2/l_1$ is the luminosity ratio of the components known from the light curve solution (Table 2) and $T_0$ is the "mean" temperature corresponding to the total $(B-V)_0$ colour of the system. The temperature $T_2$ is then directly calculated from the temperature ratio. Initially $(B-V)_0$ was found for each binary assuming total, foreground and internal, mean reddening to SMC $E(B-V) = 0.087$ (Massey et al. 1995). The foreground reddening of $E(B-V) = 0.037$ was assumed (Schlegel, Finkbeiner & Davis 1998) with the ratio of the selective to the total extinction $R = 3.1$, while for the internal reddening I assumed $R = 2.7$ (Bouchet et al. 1985). The resulting temperatures $T_{1,2}$ were used to calculate approximate intrinsic colours $(B-V)_0$ and bolometric corrections $B_{C1,2}$ of both components via Flower’s (1996) calibration for main sequence stars. The "standard" mean value $m-M = 18.9$ of the distance modulus $(DM)$ for SMC was assumed. The semi-major axis $A$ can be then computed by the following formula:

$$\log A = 0.2 DM + \log r_1 - 2 \log T_1 + 7.524 + 0.2 (M_V^0 - BC1 - V_1 + RE(B-V)).$$

where $M_V^0$ is the $V$ absolute magnitude of the Sun (assumed +4.75), $V_1$ is the out-of-eclipse $V$ magnitude of the primary (calculated assuming $L_2^V/L_1^V \approx l_2/l_1$ and that $l_3$ contribution in $V$ band is comparable to that in $I$ band). The total mass of the system results simply from application of Kepler’s third law. The absolute scale of the system gives immediately the bolometric luminosity $L$ of each component.

Now we proceed to the second step of the method. We can represent the luminosity of the star as a function of its mass, which is well-known as Eddington’s relation. This relation works only for main sequence stars, but it should be kept in mind that for an early spectral type star (massive and luminous at the same time) its luminosity is not a strong function of the age. The dependence is rather weak and such star tends to evolve from ZAMS along almost horizontal line on HR diagram. Moreover, no binary from the sample (beside two red systems from C subset) seems to contain considerably evolved components.

Fig. 6 presents the mass-luminosity relation. The data for massive $(M > 2.2M_\odot)$ Galactic stars were taken from compilation of detached, double lined eclipsing binaries done by Pols et al. (1997 and references therein) and for three LMC eclipsing systems from Ribas et al. (2000), Fitzpatric et al. (2001) and Ribas et al. (2002). The inclusion of LMC stars gives an opportunity to check how this relation depends on the metallicity. Indeed the Galactic stars seems to have a little smaller luminosity then LMC stars (having [Fe/H]$\approx -0.35$) at a given mass. For a Galactic star the mass-luminosity $M-L$ relation may be approximated by a simple linear function in wide range of masses $(2.2M_\odot < M < 20M_\odot)$:

$$\log L = 3.664(47) \log M + 0.227(38),$$

i.e. $L \sim M^{3.66}$. The sample of LMC stars do not cover such wide range of masses and I assumed that the slope of the $M-L$ relation is the same like for the Galactic stars. Then the data can be fitted by:

$$\log L = 3.664(47) \log M + 0.380(27).$$

Above equation (labeled 2 in Fig. 6) gives the approximate $M-L$ relation for LMC stars. This relation can be compared with a mass determination for two detached eclipsing systems in SMC done by Harries et al. (2003) – see Fig. 6 Components of SC6 215965 lie very close to the predicted M-L relation, but there are some problems with components of
SC 38089: especially a more massive component of 38089 seems to be a less luminous one. As the physical parameters of 215965 are more precisely determined than in the case of 38089 I decided to adopt the mass-luminosity relation given by Eq. 1 for SMC stars. Relying on this assumption we can check the consistency between parameters found from the flux scaling (Eq. 9) and from $M - L$ relation (Eq. 11).

Such treatment allows for independent determination of the unknown reddening in the direction to the particular binary and thus a reasonable $(B - V)$ intrinsic colour can be obtained. Although the mean foreground reddening toward SMC is quite low some large random internal reddenings (up to 0.2) were reported for individual B type stars (Larsen, Clausen & Storm 2000). It is obvious (e.g. Flower’s 1996 calibration) that for early type stars the temperature is a very strong function of the $(B - V)_0$ colour and a small change of this colour causes a large change of the temperature. As the temperature enters Eq. 9 at a relative high power even a small error in determination of reddening $E(B - V)$ produces large errors in luminosities and masses. Let us return to the problem of the determination of physical parameters. We can compute the expected mass ratio $q$ as follows:

$$\log q = (\log L_2 - \log L_1)/3.664,$$

where $L_1, 2$ are the absolute luminosities computed using Eq. 9. Then the masses of individual components $M_{1, 2}$ are calculated from Eq. 11. If there is a consistency between the flux scaling and $M - L$ relation a quantity $\beta$:

$$\beta = 0.5 (\log L_1 + \log L_2 - 3.664 (\log M_1 + \log M_2))$$

should be equal or close to the free term in Eq. 11 i.e. 0.38. I have allowed $\beta$ parameter to vary in the range of 0.36-0.40.

The above method was tested on three LMC eclipsing binaries which have their physical parameters known with high accuracy. As a free parameter I assumed distance modulus to the LMC. The best ”fit” to the original data were obtained for $m - M = 18.5$ what is a value still accepted as close to the true one (e.g. Gibson 1999) and marginally consistent with $DM$ obtained using eclipsing binaries (Ribas et al. 2002). The comparison between original data and parameters given in Table 3 (low panel) show that the ”fit” is excellent – the method allows for consistent and accurate estimation of masses, sizes, temperatures, luminosities and reddenings of all three systems. It may serve as a proof that such an approach of estimation of physical parameters works well and may give fast and proper information about the absolute dimensions for large samples of eclipsing binaries – see § 3.4 for a discussion. It is worth to note that the initial value of reddening is irrelevant to the method and the same results we obtain adopting another initial $E(B - V)$.

Table 3 gives the final estimation of the physical parameters of each component of binaries in the sample. The spectral type and luminosity class of each star was estimated from $T$ and $\log g$. SC4 53898 and SC9 175336 were treated in a slightly different way. The mass ratio for both systems was not calculated from Eq. 12 but was assumed to be equal to the photometric mass ratio determined from the light curve solution (see § 3.4). The further calculations were done in a similar way like for the rest of the sample. For two binaries from C subset which host evolved and cool components the reddening was assumed to be equal to the initial value and just the simple flux scaling was applied.

The temperatures $T_1$ from Table 3 in a few cases (SC4 163552, SC5 311566, SC9 175336) significantly differ from initial $T_1$ for which light curve solutions were found. Additional tests show, however, that photometric parameters recalculated for the temperatures resulted from the flux scaling were consistent with those from Table 2 within quoted errors.

5 DISTANCE INDICATORS

Below the discussion of individual eclipsing binaries as distance indicators to SMC is presented. Six candidates were chosen according to the following criteria: the presence of complete eclipses, small residuals, small and well determined third light contribution and the spectral type. Two binaries from this subset were also advocated to be possible distance indicators by WW1. Another four systems which were selected by WW1 and WW2 were also briefly discussed in a separate subsection, where reasons against their selection were given and additionally SC5 38089 used recently for distance determination to SMC is also discussed.

5.1 Most likely candidates

5.1.1 SC4 53898 and SC9 175336

These two binaries may serve as the best candidates because of the presence of complete eclipses, high brightness (especially SC9 175336), modest proximity effects allowing
Table 3. Physical parameters

| Object | Spectrum | Mass ratio q | Mean radius | Temperature | Luminosity |
|--------|----------|--------------|-------------|-------------|------------|
| SC3 139376* | B0V+B0V | 15.4±0.2 | 16.3±0.2 | 1.06±0.11 | 7.8±0.9 | 8.6±1.0 | 3.84 | 3.79 | 31500±1100 | 31700±1100 | 4.731 | 4.823 | 0.128 |
| SC129441† | B3III+B3III | 7.1±0.6 | 7.2±0.6 | 1.01±0.07 | 6.5±0.4 | 6.7±0.4 | 3.67 | 3.65 | 16900±400 | 16900±400 | 3.486 | 3.506 | 0.094 |
| SC5 311556 | O9V+O9V | 11.9±1.6 | 11.0±1.5 | 0.92±0.10 | 4.2±0.5 | 3.9±0.5 | 4.28 | 4.30 | 34200±1300 | 32900±1200 | 4.324 | 4.199 | 0.180 |
| SC6 11143‡ | B2V+B2V | 7.5±0.8 | 6.6±0.7 | 0.88±0.08 | 4.3±0.5 | 3.6±0.4 | 4.04 | 4.14 | 21600±600 | 21900±600 | 3.565 | 3.367 | 0.103 |
| SC6 67221* | B2V+B1V | 10.0±1.1 | 11.1±1.2 | 1.11±0.09 | 7.5±0.6 | 6.8±0.6 | 3.69 | 3.82 | 21700±600 | 25100±700 | 4.052 | 4.218 | 0.153 |
| SC6 221543 | B2V+B2V | 8.2±1.0 | 7.4±1.0 | 0.90±0.09 | 4.8±0.5 | 4.3±0.5 | 3.99 | 4.03 | 22400±600 | 21500±600 | 3.715 | 3.554 | 0.027 |
| SC6 272453 | B2V+B2IV | 7.9±0.9 | 8.4±1.0 | 1.06±0.09 | 5.1±0.6 | 6.1±0.6 | 3.93 | 3.79 | 21400±600 | 20500±500 | 3.680 | 3.775 | 0.065 |
| SC9 163575 | O5+O7 | 16.9±2.4 | 14.6±2.0 | 0.86±0.10 | 4.9±0.6 | 4.7±0.6 | 4.29 | 4.26 | 43300±1800 | 38600±1500 | 4.875 | 4.640 | 0.073 |
| SC10 37223 | B1V+B1V | 8.4±1.0 | 7.8±0.9 | 0.93±0.08 | 4.0±0.4 | 3.9±0.4 | 4.15 | 4.15 | 25100±700 | 23900±650 | 3.766 | 3.648 | 0.064 |

Note: all parameters were estimated assuming $m-M = 18.9$ for SMC stars and $m-M = 18.5$ for LMC stars. The spectrum was estimated from $T$ and $\log g$ and, in the case of LMC stars, adopted from the literature. The stars chosen in the present paper as likely distance indicators are marked by an asterisk. The stars indicated by Wyithe & Wilson (2001, 2002) are marked by a dagger. A double dagger indicates a photometric mass ratio derived from the light curve analysis.

for reasonable determination of the third light contribution to the system and at last, small residuals. In both cases the primary is slightly cooler and considerably larger than the secondary component. As a result there is a quite high luminosity ratio between components $l_2/l_1 \sim 3$ (see Table 3), which may by regarded as the only disadvantage of using these systems. The expected velocity semiampilitudes should be $K_1 \sim 250 \text{ km/s}$ and $K_2 \sim 190 \text{ km/s}$ for SC5 53809, while $K_1 \sim 220 \text{ km/s}$ and $K_2 \sim 190 \text{ km/s}$ for SC9 175336. The latter lies near the large HII emission region and OB association – NGC 371. Both stars were not included by WW1 or WW2 as likely distance indicators.

5.1.2 SC5 129441 and SC6 67221

Very high eccentricity and clear proximity effects visible near the periastron passage are features of both systems. SC5 129441 consists of two somewhat evolved B3 stars of equal temperatures. In the second system – SC6 67221 – during the primary eclipse (phase 1.0) the cooler and probably larger component is eclipsed and the strong mutual reflection causes the brightening of the system visible as a hump around phase 1.0. Both systems may serve as ideal testers of mutual reflection treatment used in modern light curve synthesis programs. Indeed, the presence of small residuals visible near phase 1.1 in SC5 129441 and near the primary eclipse in SC6 67221 may (Fig. 5) suggest that simple reflection used in the analysis (see §3.1) might be too crude a simplification. Unfortunately the use of the detailed reflection (which should be more appropriate for these binaries) together with the eccentric orbits makes WD program practically unsuitable for analysis due to an enormously large computational time (Wilson 1992).

Both systems show no substantial third light contribution. The expected velocity semiampilitudes should be $K_1 \sim K_2 \sim 140 \text{ km/s}$ for SC5 129441 and $K_1 \sim 150 \text{ km/s}$ and $K_2 \sim 140 \text{ km/s}$ for SC6 67221. SC5 129441 was suggested by WW1 to have complete eclipses, but the present light curve analysis did not support this thesis. SC6 67221 was not included by WW1.

5.1.3 SC3 139376

This binary seems to be the most massive and the most luminous in the sample (beside SC9 163575), consisting of two B0 V-IV stars of similar temperature: $T \sim 32000 \text{ K}$. It is the only "classical" well-detached system included in the subset of likely distance indicators – the fractional radii of both components are below 0.2. The residuals of solution are very small and only some larger scatter can be seen during eclipses due to very fast apsidal motion. The rate of the motion is $\omega \approx 5^\circ/\text{year}$, so the apsidal period $U$ is only ~ 60 years. Thus the analysis of this system can give parallel information about the components and an indepen-

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dent check of stellar evolution models. The expected velocity semi-amplitudes should be $K_1 \sim 190$ km/s and $K_2 \sim 180$ km/s.

5.1.4 SC6 215965

The brightest binary in the sample ($V = 13.94$) with the spectrum B0 V-IV + B1 IV. Table 4c suggests that the cooler component is more massive one and it is slightly evolved. The light curve solution showed that the contribution of the third light to this system might be neglected and photometric parameters such as the temperature ratio (surface brightness ratio) could be very accurately determined. Also very small residuals suggested that the system had no essential intrinsic variability. This system was yet used by Harries et al. (2003) for a distance determination to SMC giving $m - M = 18.83 \pm 0.15$. The physical parameters of both components are reasonably close to that presented in Table 3. It can be considered as an independent check of the method given in Section 4 and an additional argument for use this star for an accurate individual distance determination. WW1 included this binary in their catalog on the basis of having complete eclipses but the present analysis (and results of Harries et al.) excludes this suggestion.

5.2 SC5 38089 and the candidates suggested recently by Wyithe & Wilson

5.2.1 SC5 38089

Harries et al. (2003) determined absolute dimensions and a distance to this B0V+B0V system: $m - M = 18.92 \pm 0.19$. Their light curve solution is essentially the same as the solution reported in this paper. However, there is an apparent discrepancy between the observational data on SC5 38089 and the mass-luminosity relationship shown on Fig 4. Thus I would not recommended this star for individual distance determination, although it is very interested target for spectroscopic investigations in the future. Table 3 gives the estimate of physical parameters assuming that both components are normal main sequence stars. The expected $B$ luminosity ratio is very close to unity what indeed was reported by Harries et al.

5.2.2 SC4 103706

Formally this binary also seems to have complete eclipses (it was included by WW1 in their subset of binaries showing totality) but the very large third light contribution ($l_3 \sim 0.4$) may cause serious problems during modelling of the spectral energy distribution and thus I decided not to include this star into the most suitable candidates.

5.2.3 SC4 163552

WW2 included this binary according to the presence of complete eclipses, but as in the case of SC6 215965, the light curve analysis contradicted this thesis. The third light contribution to this system is substantial, at about 26%.

and temperature ratio are very close to unity. The expected velocity amplitude is $K \sim 250$ km/s for both components.

5.2.4 SC6 11143

WW1 classified this system as a well-detached. Indeed, my analysis showed that the components had the smallest fractional radii of all the sample (beside SC6 67221) and are normal B2 V stars. However, this binary happens to blend with another eclipsing binary (see §2.2) which contributes about 30% to the total light of system. Thus any detailed analysis of SC6 11143 should at the same time take into account a careful analysis of the blending binary. Probably this includes simultaneous solution of multimour light curves of both binaries what is, in principle, possible, but may give ambiguous results.

5.2.5 SC6 319966

This binary was included by WW1 according to the presence of complete eclipses which seems to be incorrect in the view of my analysis. This binary had the highest $l_3$ contribution from the total light – nearly 50% – which is most probably too large for a detailed modelling of spectrophotometry.

6 CONCLUDING REMARKS

6.1 Third light contribution problem

The observed difference of the $l_3$ contribution to the total light between binaries from A and B subsets may be understood as follows. The components of binaries from B subset are relatively much closer to each other than those from A subset and the proximity effects, depending on the gravitational distortion and overall geometry of the system, are much more distinct. Thus proximity effects give us additional constraints to the solution. When we consider the third light $l_3$ we see that its influence on the light curve of well-detached systems is of little importance: equally good solutions can be obtained for wide range of $l_3$ values.

The situation is different for closer systems – small changes of $l_3$ produce noticeably systematic O-C residuals, especially near quadratures. This is an important reason for preferring such systems over classical well-detached systems in determination of the distance using individual eclipsing binaries, especially in the case of the extragalactic binaries observed usually on a rich stellar background of a host galaxy. The probability of blending with another star(s) in such environment is high (crowding effect). Also the blend may be a member of the system itself as at least 30% of binaries (Batten 1973) are found to form hierarchical multiple systems of stars. Indeed, neglecting of the third light contribution in the case of HV 2274 and HV 982 may be one of the prime sources of small differences on the level 1.5σ between distances derived for three LMC systems as was announced by Ribas et al. (2002).

6.2 Fast information about absolute dimensions

The idea of deriving the absolute properties of binary stars from knowledge of their photometric properties alone has
long tradition (e.g. Gaposchkin 1938, Kopal 1959 - Chapter 7). The methods based on this idea use somewhat statistical approach: one or both components of a binary conform an empirical mass-luminosity relation and the temperature is imposed by observed spectral type. There are two important advantages of such statistical method 1) it may be used for large samples of binaries and 2) it gives fast, though approximate physical parameters of binaries. Afterward we can choose from the sample most interesting systems and investigate them more accurately using spectroscopy, spectrophotometry or multicolor photometry. However, past methods neglected the interstellar reddening (which influences both the brightness and the colours) and, what is more important, the distance to the binary. As a matter of fact the distance is irrelevant to these methods and thus it can be derived simply by comparison with the apparent magnitude $m$, even without any radial velocity measurements (e.g. Gaposchkin 1968, Dworak 1974). Moreover, they based their reasoning on quite crude spectral type - temperature calibrations and, of course, as the temperature come in high powers into equations involved in the method, the obtained parameters were usually very inaccurate.

In present paper this "old-fashioned" method was innovated to account for the interstellar reddening $E(B - V)$ and recent $B - V$ colour - temperature calibration (Flower 1996). It turns out that such approach causes a big improvement in the temperature determination and overall physical parameters as was demonstrated by an accurate "reproducing" of absolute dimensions of three LMC eclipsing binaries. However, it was done for a little bit larger distance to LMC than the distance derived, on average, from these LMC stars. A shift of the distance modulus $\Delta(m - M) = +0.1$ is quite small and comes probably from some inaccuracies of Flower’s temperature or/and bolometric corrections calibration for hot stars.

Anyway we should expect that this kind of method may give fast approximate determination of absolute dimensions for many binaries in the Magellanic Clouds, especially as we have large archives of binaries discovered by OGLE, MA-CHO and EROS projects at our disposal, and may be used also for eclipsing binaries in other close galaxies in the near future.

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