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ELEVEN MORE ECLIPSING SYSTEMS WITH APSIDAL MOTION IN THE LARGE MAGELLANIC CLOUD

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With the bulk of time-series photometric data coming from the long-term, mainly microlensing surveys (OGLE, MACHO, EROS, ASAS, NSVS and others), different properties of eclipsing binaries can be studied statistically and confronted with the theory of binary star formation and evolution. As these surveys cover both our Galaxy and Magellanic Clouds, the properties of eclipsing binaries in the environment of different metallicity can be examined. There are already many examples of the use of the large photometric databases for binary star studies (e.g., Paczyński et al., 2006; Derekas et al., 2007b) but the information included in these databases is still far from being exploited.

Apsidal motion, a phenomenon observed in eccentric systems, can be used to test internal structure of components (Claret & Gímenez, 1993; Claret, 1999) or even to derive their parameters (e.g., Benvenuto et al., 2002). Typically, apsidal periods are at least decades long and thus require very long observing runs. Photometric surveys we listed above, many of them still ongoing, are therefore ideal for detection and monitoring of this phenomenon.

In our study of detached eclipsing binaries in the Large Magellanic Cloud (LMC) that are suitable for distance determination (Michalska & Pigulski, 2005, hereafter Paper I), 98 systems were presented, of which fourteen showed apsidal motion clearly. However, a more detailed analysis led us to the detection of eleven more systems in the sample we studied. In these new systems, the apsidal motion is not so well pronounced as in those found earlier albeit still detectable. Thus, in the present paper, we update the list of eclipsing binaries with apsidal motion in the LMC. A discovery of about 40 systems with apsidal motion in the LMC was also recently announced by Derekas et al. (2007a). They used MACHO microlensing survey as the source of data.

Like in Paper I, the main source of the data we used was the OGLE-II I-band photometry of Żebruń et al. (2001) supplemented by the two-colour photometry from the MACHO (Allsman & Axelrod, 2001) and EROS (Grison et al., 1995) sources for stars in common. The light curves in all bands were analyzed simultaneously by means of the improved version of the Wilson–Devinney (WD) program (Wilson & Devinney, 1971; Wilson, 2001).

The detection of the apsidal motion was made in the same way as in Paper I. First, the data were divided into several subsets. For each subset the inclination, the phase shift, the eccentricity, e, the longitude of periastron, ω, the temperature of the secondary,

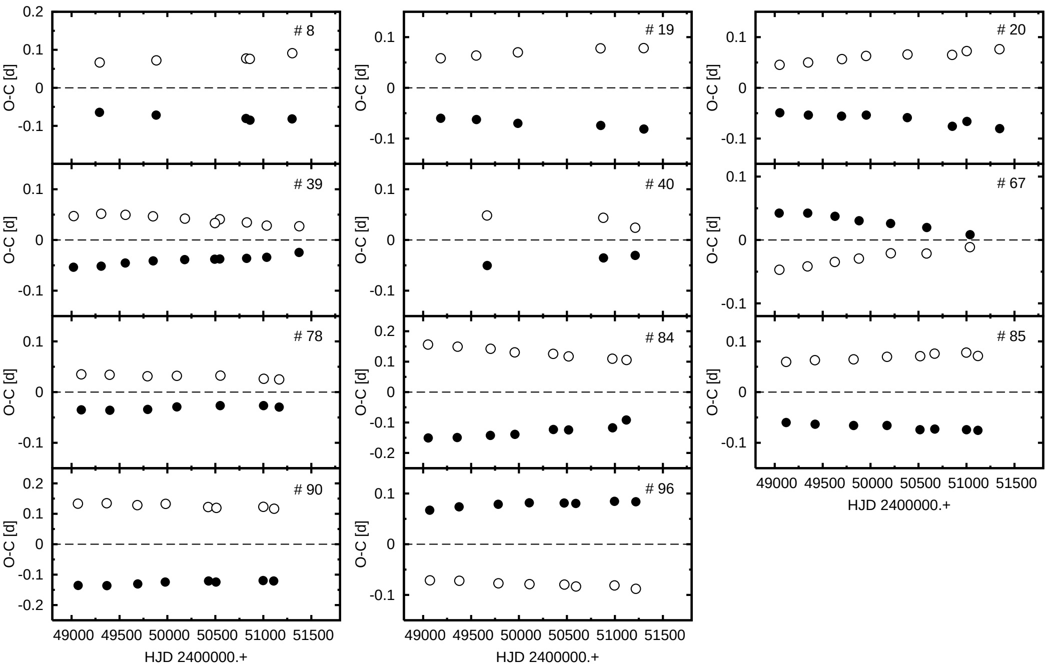

Figure 1. The $O-C$ diagrams for 11 systems with apsidal motion. The filled and open circles denote the primary and secondary times of minimum, respectively

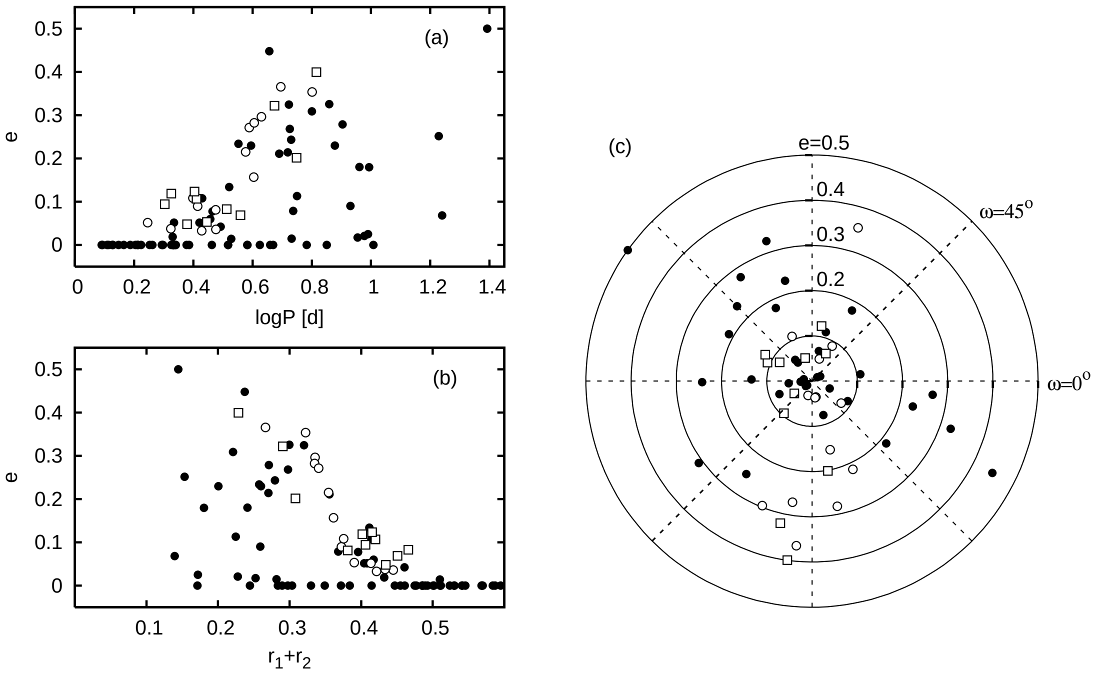

Figure 2. The eccentricities of EA-type binaries in the LMC plotted against: the logarithm of orbital period (a), the sum of fractional radii (b), and longitude of periastron, ω (c). Systems with apsidal motion we found are plotted as open circles (14 systems from Paper I) and open squares (this paper). The remaining points are for systems in which apsidal motion was not detected

Table 1: Parameters for eleven new systems with apsidal motion

Star	OGLE designation	e	ω [°]	$\dot{\omega}$ [°/year]	P_{mean} [d]	$T_{0,\mathrm{mean}}$ [HJD 244...]
#8	05350218-6944178	0.081	323	4.16 ± 0.26	2.989470	9292.7814
#19	05371417-7020015	0.083	150	4.40 ± 0.29	3.256681	9184.2182
#20	05164453-6932333	0.202	280	0.62 ± 0.04	5.603488	9053.8272
#39	05250946-7004226	0.069	63	3.0 ± 0.3	3.625506	9021.9995
#40	05404159-6959014	0.094	229	8.6 ± 0.7	2.009973	9668.2172
#67	05312473-6925281	0.124	440	4.34 ± 0.25	2.536666	9048.9340
#78	05121869-6858325	0.048	215	4.9 ± 0.7	2.390521	9102.2382
#84	05221500-6938483	0.322	257	1.17 ± 0.05	4.722937	9054.2332
#85	05203518-6934378	0.119	151	3.5 ± 0.4	2.117476	9120.6445
#90	05264527-6944045	0.399	262	0.20 ± 0.03	6.536149	9069.1179
#96	05181271-6935245	0.107	157	3.8 ± 0.4	2.575571	9071.1041

surface potentials and the luminosity of the primary component were adjusted with the WD program. Then, the mean values of the e and ω were calculated. Next, the WD program was run separately for each subset with e and ω fixed and the phases of primary and secondary minimum were derived from the best fit. These phases were transformed into times of minimum closest to the mean epoch of all observations in a given subset. The individual times of minimum were used in the same way as explained in Paper I to derive mean orbital period, P_{mean}, and initial epoch, $T_{0,\mathrm{mean}}$, which are listed in Table 1 for all eleven systems. In Fig. 1, the $O-C$ values calculated using P_{mean} and $T_{0,\mathrm{mean}}$, are plotted. The numbers in the first column of Table 1 follow designation of stars used in Paper I. The longitudes of periastron passage, ω, are given for epoch HJD 2450500.0.

In Fig. 2 we also show how the parameters of systems with apsidal motion compare with those of all sample of 98 stars studied in Paper I. As expected, for a given eccentricity, they usually have the shortest orbital period (Fig. 2a) or the largest sum of relative radii (Fig. 2b). We have already explained in Paper I that the selection effects cause systems with detected apsidal motion tend to group around $\omega \sim 90°$ and $270°$.

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