Eclipsing binaries in the Large Magellanic Cloud: a wealth of data for astrophysical tests

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1. Data

We have analysed publicly available MACHO lights curves of 6833 stars that were originally classified as eclipsing binaries. A careful re-determination of the periods and a new classification based on the light curve shapes showed that only 3031 stars are genuine eclipsing or ellipsoidal variables, the rest being Cepheids, RR Lyraes and other non-eclipsing variable stars.
The main aim of this project will be to find eclipsing binaries with pulsating components (work in progress).

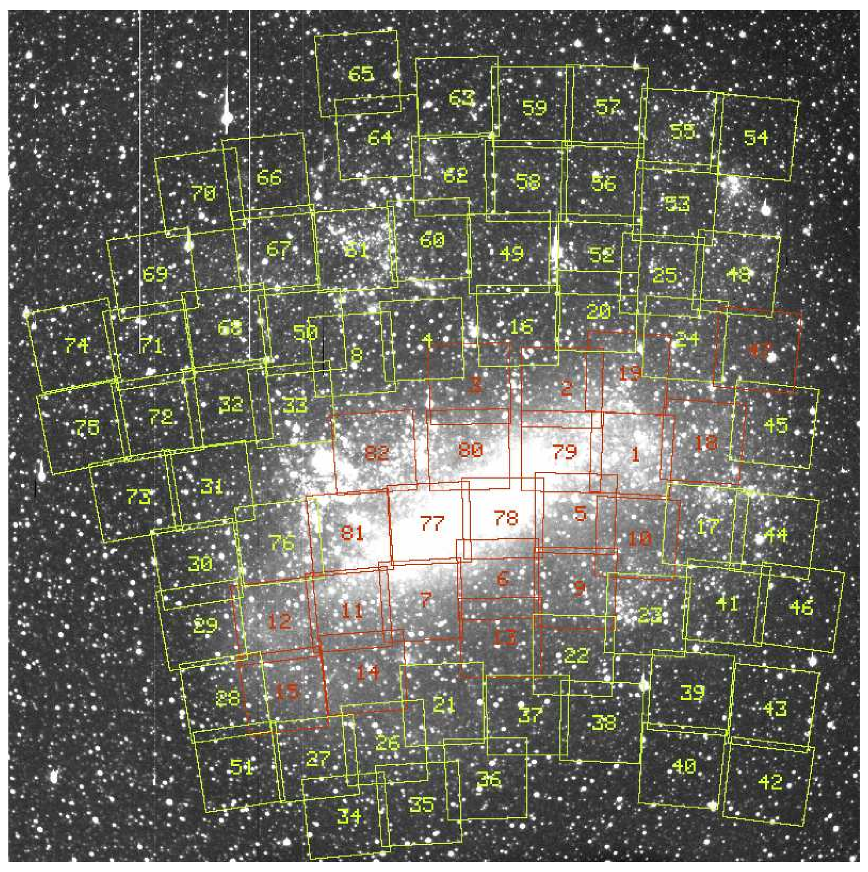

Fig. 1. The Large Magellanic Cloud in R-band showing the observed fields.

2. Period distribution

The period distribution of the sample is bimodal. The majority of systems have short periods, peaking between 1 and 2 days. Roughly 20% of stars have periods longer than 10 days, many of them with W UMa-like light curve shapes, suggesting ellipsoidal variability with giant component stars.

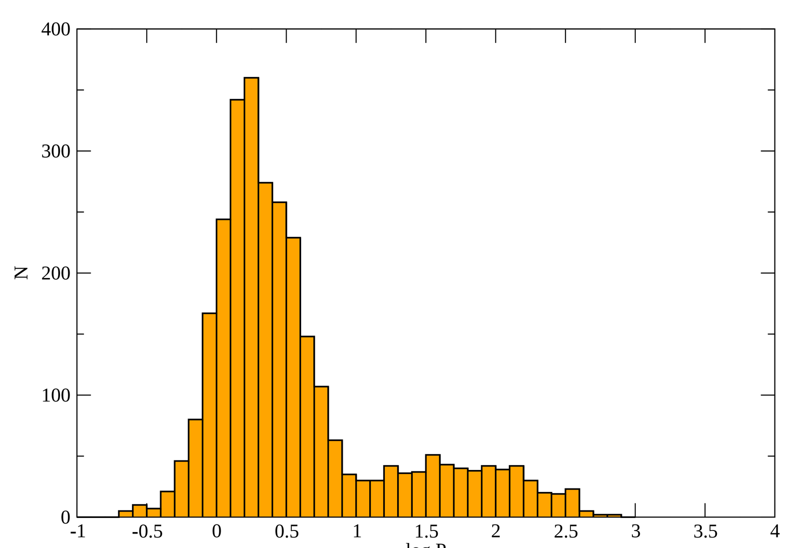

Fig. 2. Orbital period distribution of 3031 eclipsing and ellipsoidal variables in the LMC.

3. Roche-lobe classification

We classified the binary sample using Fourier-decomposition of their phase diagrams. Two coefficients, a_2 and a_4, of the cosine decomposition $\sum_{i=1}^{4} a_i \cos(2\pi i\varphi)$ allow a well-defined distinction between detached, semi-detached and contact binaries (Pojmański 2002). The results show that the sample is dominated by bright main-sequence detached (50%) and semi-detached (30%) binaries. Contact systems comprise 20% of the sample; the short period systems are all foreground objects in the Milky Way, while longer period belong to red giant binaries.

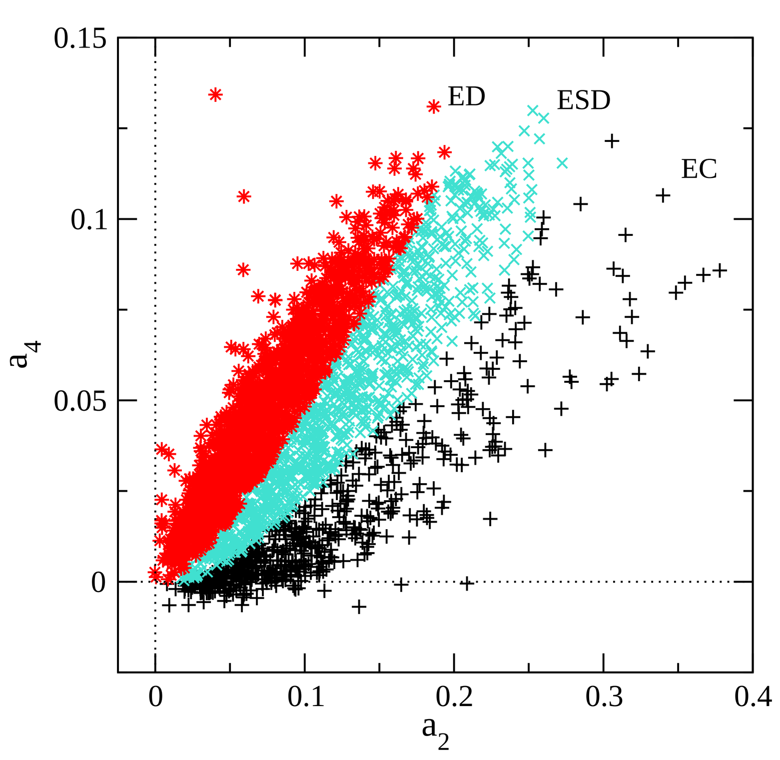

Fig. 3. Classification based on the light curve shape. The boundary lines between categories were taken from Pojmański (2002).

4. Color-Magnitude Diagram

We used the Color-Magnitude Diagram (CMD) to clean the sample of the foreground objects. For this we took evolutionary models of Castellani et al. (2003) and calculated the locations of certain minimal orbital period values (where two identical model stars are in contact). The four plots below show eclipsing stars with P < 0.5d, 0.5d < P < 1d, 1d < P < 10d, 10d < P, with which we identified systems whose positions in the CMD and periods exclude LMC membership. The cleaned sample contains about 2800 LMC binaries.

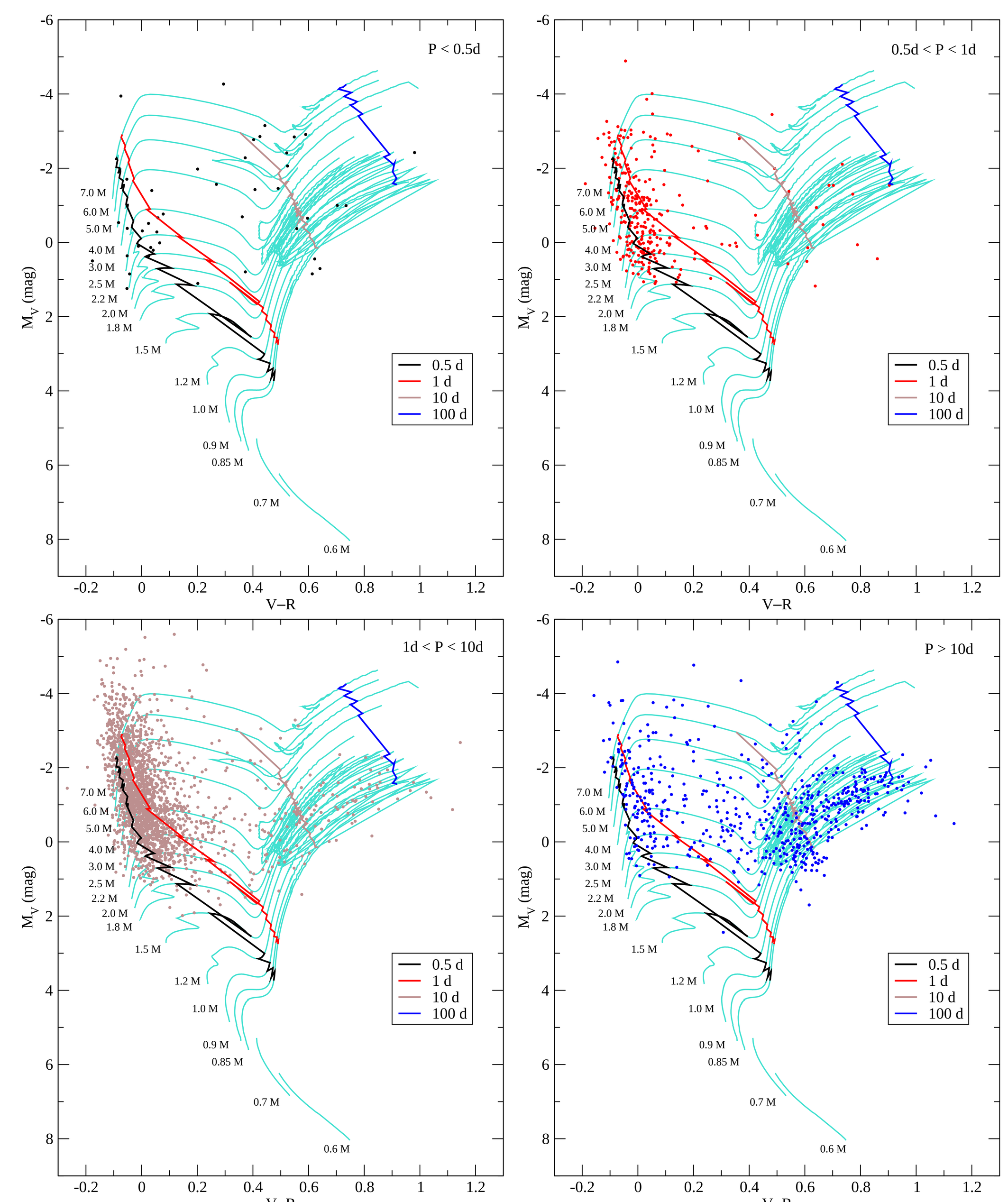

Fig. 4. The CMD and four period ranges of the sample.

5. P–L relations

Detached and semi-detached binaries are spread uniformly in the period-K magnitude plane, while there is a well-defined sequence for the contact systems. In Fig. 5 we show their P–L sequence (labelled "E") together with LMC pulsating red giants. The widely accepted sequence of EBs between Seqs. C and D, known as Seq. E, does not exist. The correct position for Seq. E is at periods a factor of two greater, as shown. A simple Roche-model describes Seq. E very well. Although Seq. E seems to merge into Seq. D of the Long Secondary Periods (Wood et al. 2004), the two groups are significantly different in their amplitude properties (Derekas et al. 2006).

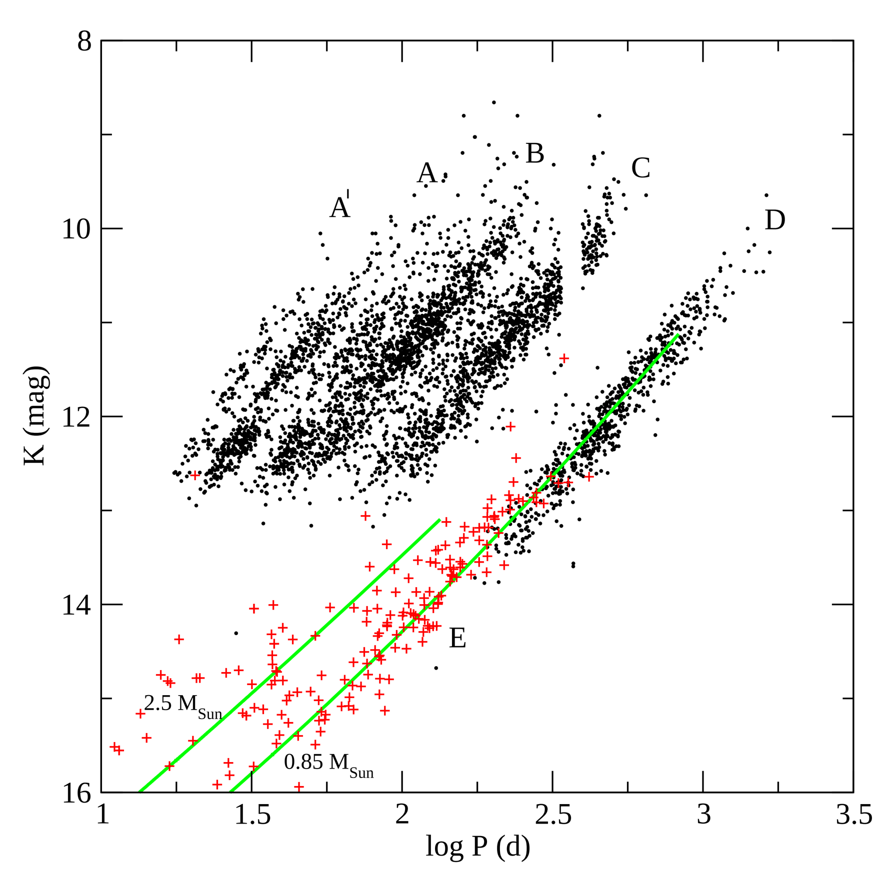

Fig. 5. P–L relations of ellipsoidal variables (red pluses) red giant pulsators (black dots). The two lines show a simple model using evolutionary tracks and Roche-geometry.

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6. Period changes I.: Light–Time Effect

From the 8 years of MACHO observations we measured period changes using the O–C method applied to seasonal subsets of the data. We found about 80 parabolic and 45 cyclic period changes, the rest showing linear O–C diagrams. A significant fraction of the former two groups are candidates for light-time effect in hierarchic triple systems. Three examples are shown below.

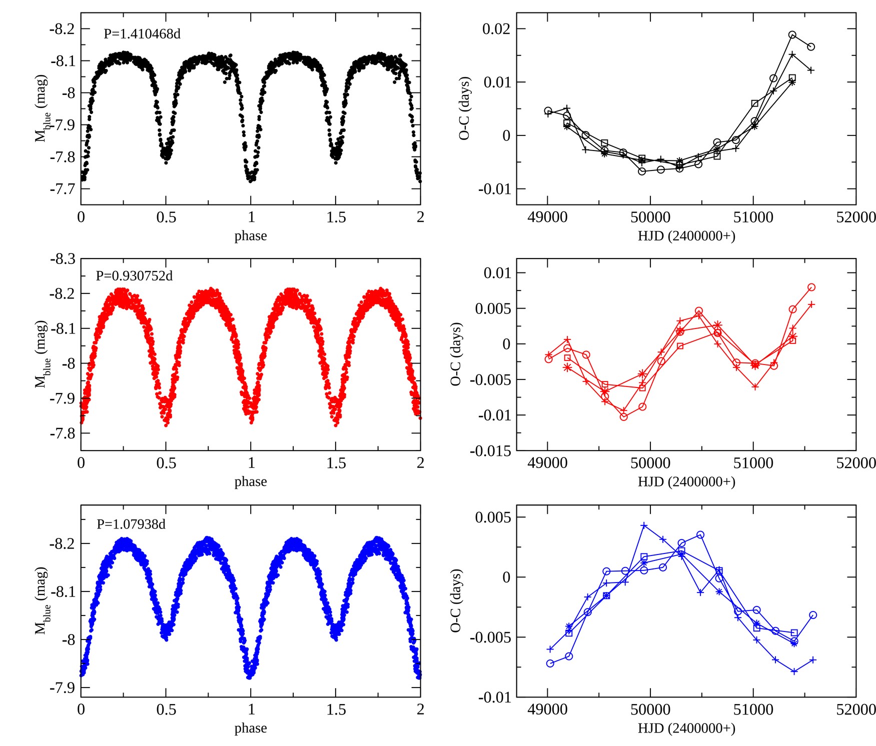

Fig. 6. Examples for parabolic and cyclic O–C diagrams.

7. Period changes II.: Apsidal Motion

In about 40 eccentric binaries we measured different O–C variations for the primary and the secondary minima, which indicates apsidal motion. With this we double the number of known binaries with apsidal motion in the LMC (Michalska & Pigulski 2005).

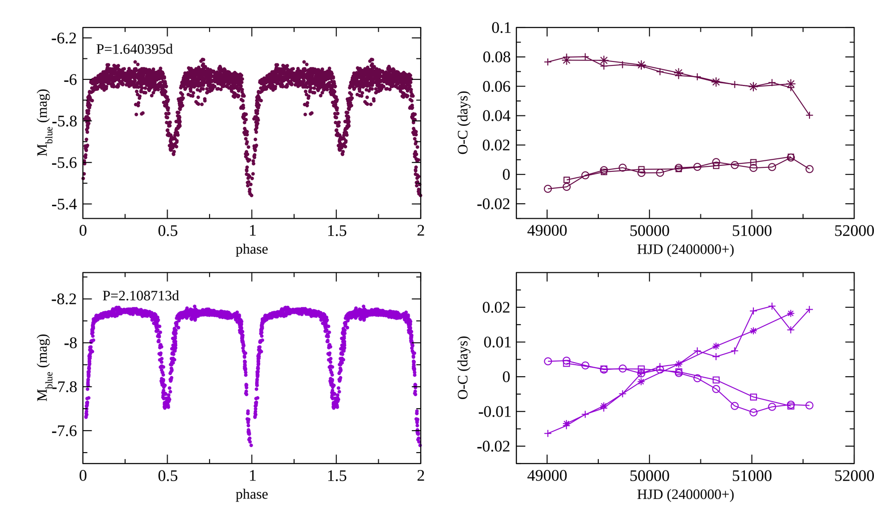

Fig. 7. Two examples for apsidal motion.

8. Secular amplitude variations

In a few objects we discovered gradual amplitude variation, which can be explained by rapid variations in the orbital geometry, most notably in inclination. A third body in the system can perturb the eclipsing pair in such a way that the eclipse depth, as a sensitive indicator of the inclination variations, follows these perturbations. In Fig. 7 we present an example (P_{ecl} = 0.77d), for which the large scatter in the O–C diagram may suggest an orbital period of ≤ 100*d* for the hypothetical third companion.

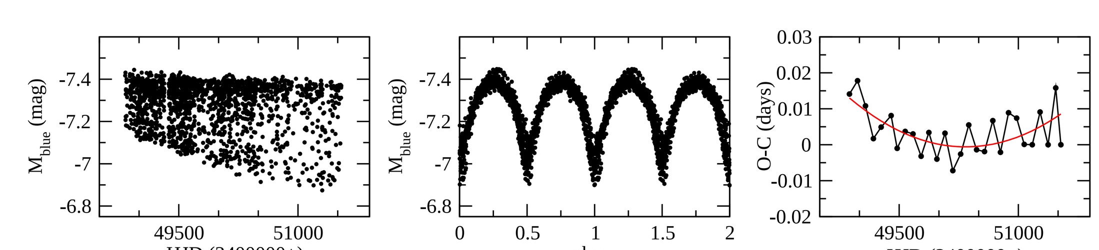

Fig. 7. An example for changing minimum depth.

Acknowledgements

This work has been supported by the Australian Research Council. LLK is supported by a University of Sydney Postdoctoral Research Fellowship. AD is supported by an Australian Postgraduate Research Award. This paper utilizes public domain data obtained by the MACHO Project, jointly funded by the US Department of Energy through the University of California, Lawrence Livermore National Laboratory under contract No. W-7405-Eng-48, by the National Science Foundation through the Center for Particle Astrophysics of the University of California under cooperative agreement AST-8809616, and by the Mount Stromlo and Siding Spring Observatory, part of the Australian National University.

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