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New Light Curve Analysis for Large Numbers of Eclipsing Binaries III. SMC and Galactic Center

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Abstract. We improved the method of light curve analysis for large numbers of eclipsing binaries. Current methods require a week to analyze the light curves of an eclipsing binary for its physical and orbital parameters. Therefore, we developed a new method to treat large numbers of light curves of eclipsing binaries. We tested the new method by analyzing more than 14 hundred light curves and 9 hundred light curves discovered by OGLE in the Small Magellanic Cloud and Galactic center, respectively.

Keywords. stars, eclipsing binaries, data analysis, fundamental parameters

1. Introduction

Up to the 1990s, approximately 4000 and 200 eclipsing binaries have been discovered in our galaxy and nearby galaxies, respectively. After several survey observations for microlensing, more than 5000 close binaries were discovered in other galaxies. New surveys are expected in the future with the Large Synoptic Survey Telescope (LSST) and the Panoramic Survey Telescope and Rapid Response system (Pan-STARRS). Currently, Kepler is producing light curves of large numbers of variable stars. We expect those surveys to yield light curves of hundreds of thousands of new variable stars and eclipsing binaries.

The current methods of light curve analyses require technical skill and experience. It takes a week to model a single binary system. Therefore, a new method is needed to analyze large numbers of light curves of eclipsing binary stars. Prša *et al.* (2008) and Guinan (2009) introduced the concept of Eclipsing Binaries with Artificial Intelligence (EBAI) that aims to provide estimates of principal parameters for thousand of eclipsing binaries. Kang (2008, 2010) and Hong & Kang (2009) suggested a new iteration method of light curve analysis using standard eclipsing binaries.

2. Expanded standard eclipsing binaries and initial parameters

We increased the number of standard eclipsing binaries by collecting original data on the light curves and radial velocity curves of approximately 80 eclipsing binary stars. We defined the standard eclipsing binary star as an eclipsing binary star whose multicolor light curves and double-line radial velocity curves were published in good quality. We re-analyzed all light curves and radial velocity curves of these standard eclipsing binaries using the 2005 version of the Wilson and Devinney (WD) differential correction program. The 80 eclipsing binaries will be used as standard eclipsing binaries. The parameters of one of these standard eclipsing binaries will be used as initial parameters for target eclipsing binaries. A morphology of light curves can be characterized by depth and width of the primary eclipse and curvature outside the eclipses. We measure the depth, width, and curvature of the representative observed light curve (usually light curve among multi-color light curves). Then, we select the best similar light curve among the standard eclipsing binaries using the three measurements. We use parameters of the selected standard eclipsing binary star as initial parameters.

3. Improved iteration order

We modified the 2005 version of the WD program to run the differential correction by iterations. First, we adopted theoretical values for initial values of limb darkening coefficients, albedo, gravity darkening exponents. Then we adjusted only L1 to adjust the level of light curves. Then, we adjusted the set of (i,T2,L1), (i,P2,L1), (A2,t2,L1), (A1,X1,L1), (X2,A2,L1), (P1,L1,X2), (i,t2,A1,A2,P1,P2,L1,X1,X2) for each detached system. We basically adjusted 2-3 times for each parameters during whole one cycle. We checked the fitness with deviation between observation and model light curves. If the fitness is not acceptable, then we repeated the iteration of the entire cycle for better adjustment.

4. Application to eclipsing binaries discovered by OGLE

The OGLE project (Wyrzykowski *et al.* 2003) produced I light curves of approximately 1,404 and 934 eclipsing binaries observed in the Small Magellanic Cloud and Galactic center, respectively. They made B and V observations outside of eclipses in order to determine the temperatures of the binary systems. Therefore, we analyzed light curves of a total of 2338 eclipsing binaries in order to test our iteration programs. For SMC binaries, model light curves of 1014 binary systems were successfully conserved to the observations using 7-9 iterations with the mode 2 program, which is for a detached system. Another 243 and 141 light curves were also compared to the observations using 7-9 iterations with mode 4-5 and mode 3, respectively. We discovered that 72 percent of a total 1404 SMC eclipsing binary stars are detached systems. Another 17 and 10 percent are semi-detached and contact binaries, respectively. However, the binary star distribution in the Galactic center direction (Bade window) is different from those of the SMC. The detached, semi-detached and contact binaries are distributed 38 percent, 38 percent and 23 percent, respectively. It is very interesting that 269 of 1014 (27 percent) detached systems in the SMC have eccentric orbits, while only 5 of 357 (2 percent) stars have eccentric orbits.

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