Eclipsing binary stars in the era of massive surveys

First results and future prospects

Athanasios Papageorgiou[1,2,⋆], *Márcio* Catelan[1,2], *Rodrigo* Contreras Ramos[1,2], and *Andrew J.* Drake[3]

[1] *Pontificia Universidad Católica de Chile, Facultad de Física, Instituto de Astrofísica, Av. Vicuña Mackenna 4860, 782-0436 Macul, Santiago, Chile*
[2] *Millennium Institute of Astrophysics, Santiago, Chile*
[3] *California Institute of Technology, 1200 East California Boulevard, CA 91225, USA*

Abstract. Our thinking about eclipsing binary stars has undergone a tremendous change in the last decade. Eclipsing binary stars are one of nature's best laboratories for determining the fundamental physical properties of stars and thus for testing the predictions of theoretical models. Some of the largest ongoing variable star surveys include the Catalina Real-time Transient Survey (CRTS) and the VISTA Variables in the Vía Láctea survey (VVV). They both contain a large amount of photometric data and plenty of information about eclipsing binaries that wait to be extracted and exploited. Here we briefly describe our efforts in this direction.

1 Detached eclipsing binaries in CRTS

Focusing on the eclipsing binaries from CRTS[1] classified as detached eclipsing binaries from [2], a detailed catalog was constructed with the phenomenological properties of the observed light curves (LCs). A total of 4683 LCs were filtered in order to discard erroneous data points, and then a period search was performed to each light curve applying a variety of methods. The phase-folded LCs were visual inspected and the best period values adopted. The final catalog contains revised periods for $\sim 10\%$ of the stars. The time of minimum light (MJD_0) was calculated from the phased LCs and a linear ephemeris was constructed for each system. In order to estimate the morphological features of the LCs (e.g., the magnitude at primary and secondary eclipses, and at the quarters out of the eclipses; the difference between eclipse depths; the mean magnitudes and amplitudes; etc.), the total sample was fitted by a chain of second-order polynomials ([4, 6]). In addition, using the Artificial Neural Network (ANN) EBAI ([6]), five fundamental physical parameters can be derived: temperature ratio $\alpha = \frac{T_2}{T_1}$, sum of relative radii $\beta = \rho_2 + \rho_1$, $\gamma = e\cos\omega$, $\delta = e\sin\omega$, and $\epsilon = \sin i$,where e is the eccentricity, ω the argument of periastron, and i the inclination of the orbit. Set of $\sim$ 49,000 LCs and a 20,000 LCs of detached eclipsing binaries (DEB) in the V band were constructed using PHOEBE ([7]) for the training and validation procedure, respectively. In order to optimize the ANN, different topologies (201 input nodes $-n$ hidden nodes -5 output nodes) were tested varying the numbers of hidden nodes n. The best network topologies were found in the range of 100-130 hidden nodes.

⋆ apapageo@astro.puc.cl
[1] http://nesssi.cacr.caltech.edu/DataRelease/

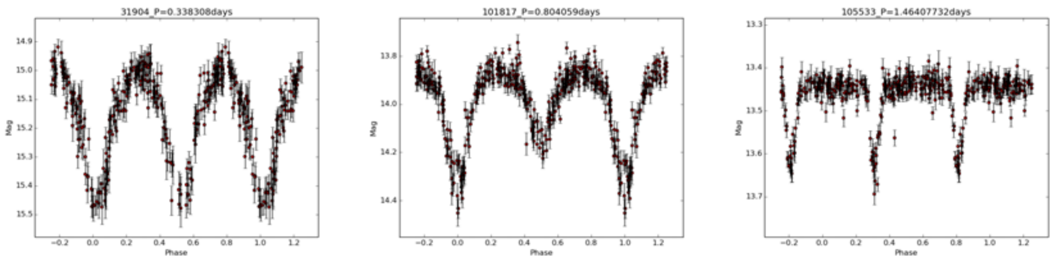

Figure 1. Representative examples of overcontact (left), semi-detached (center), and detached (right) eclipsing binaries in the K_s band from the present work. Each stars' internal id and derived period are given as headers.

2 Eclipsing binaries in VVV

We present a variability search in a $12' \times 12'$ field around the globular cluster NGC 6544 using VVV data ([1]). The observations were carried out during 2010-2015 using the Visible and Infrared Survey Telescope for Astronomy (VISTA) 4.1m telescope located at ESO's Cerro Paranal Observatory in Chile. A total of $\sim$ 160,000 sources were examined for variability, rejecting light curves with less than 10 data points and LCs with standard deviation smaller than 1.5 times the mean photometric error, resulting in 63,133 LCs. Furthermore, σ-clipping was applied to the dataset and a variability search in the K_s band carried out, applying a variety of variability indices to the time series with the python library FATS ([3], and references therein). A total of 790 suspected variables were found, and their periods determined. Among them, 18 EBs were classified as DEBs, 3 as semi-detached, 9 as overcontact, 2 as ellipsoidal, and 8 with multiple classification (Fig. 1). Using the principal component analysis method as implemented in python ([5]), we found in a projection of the variability indices that the suspected variables appeared separately from the non-variable sources of the total sample.

Acknowledgments: Support for this project is provided by the Ministry for the Economy, Development, and Tourism's Millennium Science Initiative through grant IC 120009, awarded to the Millennium Institute of Astrophysics (MAS); by the Basal Center for Astrophysics and Associated Technologies (CATA) through grant PFB-06/2007; by CONICYT's PCI program through grant DPI20140066; and by FONDECYT grants #1171273 and #3160782.

References

[1] Catelan, M., Dékány, I., Hempel, M., & Minniti, D., Boletin de la Asociación Argentina de Astronomía, **56**, 153 (2013)
[2] Drake, A. J., Graham, M. J., Djorgovski, S. G., et al., ApJS, **213**, 9 (2014)
[3] Nun, I., Protopapas, P., Sim, B., et al., preprint (arXiv:1506.00010) (2015)
[4] Papageorgiou, A., Kleftogiannis, G., & Christopoulou, P.-E., Contributions of the Astronomical Observatory Skalnate Pleso, **43**, 470 (2014)
[5] Pedregosa, F., Varoquaux, G., Gramfort, A., et al., Journal of Machine Learning Research, **12**, 2825 (2011)
[6] Prša, A., Guinan, E. F., Devinney, E. J., et al., ApJ, **687**, 542 (2008)
[7] Prša, A., & Zwitter, T., ApJ, **628**, 426 (2005)