Contact Binaries Towards Merging - CoBiToM project (2012-2017)

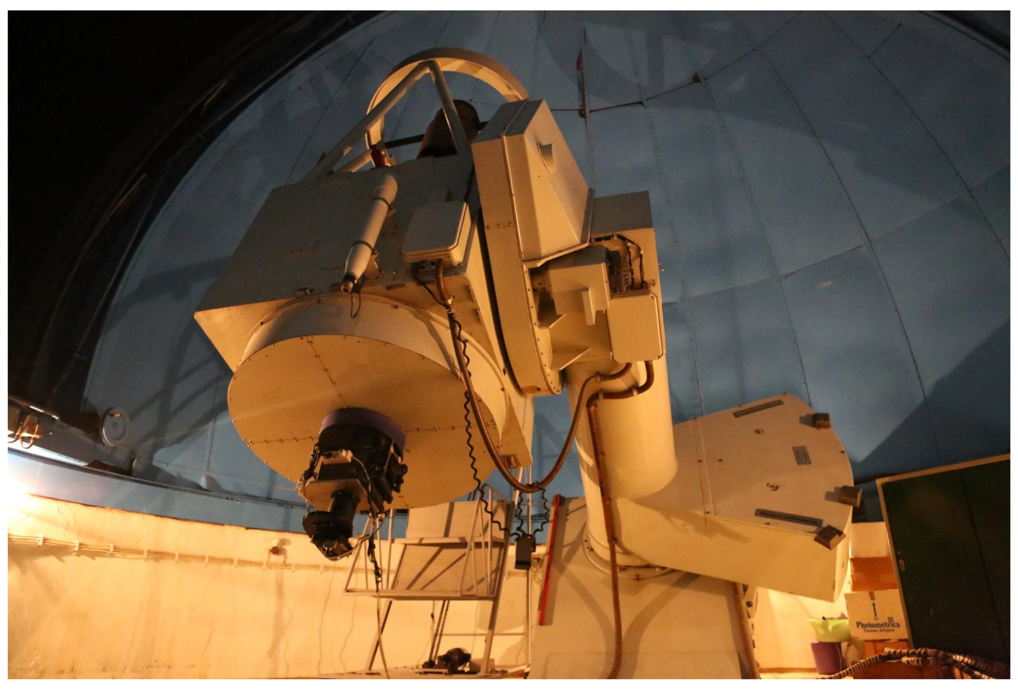
K. Gazeas

Department of Astrophysics, Astronomy and Mechanics, National and Kapodistrian University of Athens, GR 157 84 Zografos, Athens, Greece

Abstract. Contact binaries are the most frequently observed type of eclipsing star systems. They are small, cool, low-mass binaries belonging to the old Galactic stellar populations. They follow certain empirical relationships that closely connect a number of physical parameters to each other, mainly due to constraints coming from the Roche geometry. As a result, contact binaries provide an excellent test of stellar evolution, specifically for stellar merging scenarios. A large number of contact binaries exhibits extraordinary behavior, requiring follow-up observations to study their peculiarities in detail. For example, a doubly-eclipsing quadruple system (TYC 3807-759-1 & TYC 3807-759-2) consisting of a contact and a detached binary is a highly constrained system, that serves as an excellent laboratory for testing evolutionary theories. *CoBiToM Project* is a new observing campaign, which was initiated at the University of Athens in 2012, in order to investigate the possible lower limit for the orbital period of binary star systems before coalescence, as a prediction of stellar evolution prior to merging. Such an investigation will provide crucial information about the final evolutionary stages of these systems and spread light on the origin of stellar mergers and rapidly rotating stars, which are frequently observed in old globular clusters.

Introduction

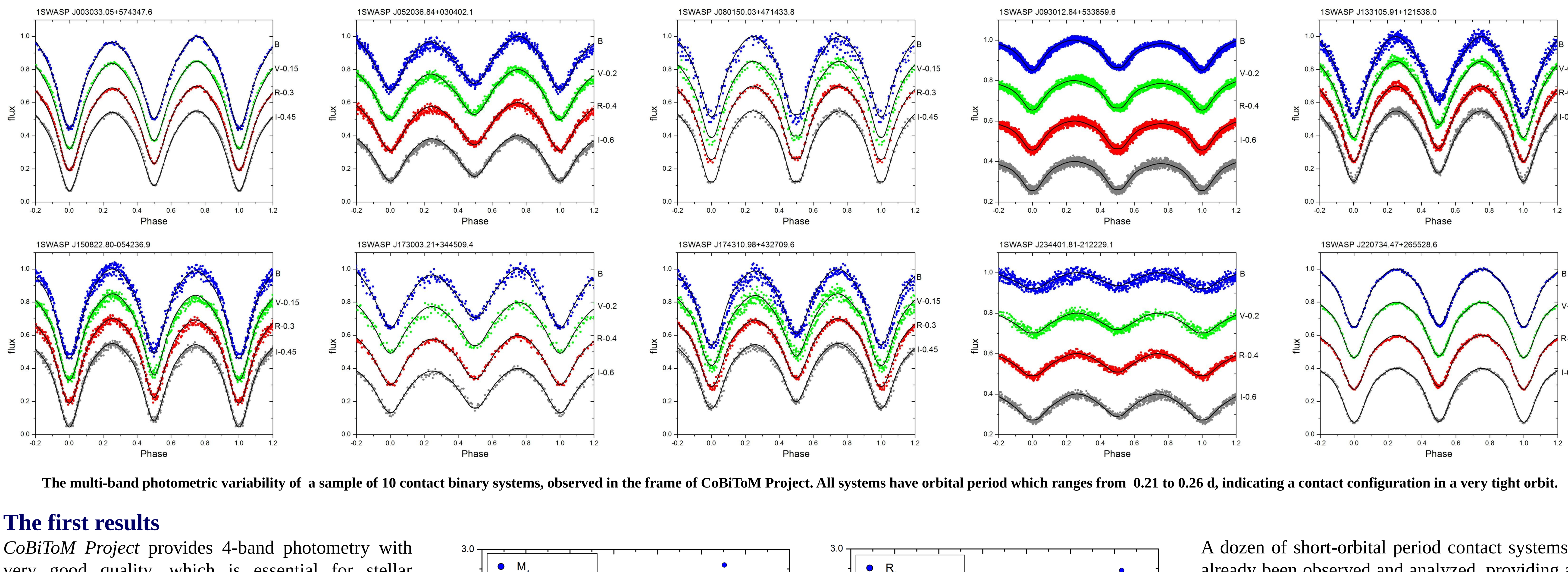
We have more than a century of knowledge, gathered around contact binaries. Several attempts to understand their nature have been done since '50s and '60s. However, very recently (last 2-3 decades) serious observational studies have been conducted, trying to understand the nature of these objects. Contact binaries are the most frequently observed type of systems with a common envelope. They are small, cool, lightweight, and occupy the old population group of Galaxy. They are excellent astrophysical tools for the determination of the fundamental parameters (mass, radius, luminosity) of low-temperature stellar components, with the aim to determine their evolutionary channels. Such systems are often used as distance indicators (Rucinski & Duerbeck 1997, Rubenstein & Bailyn 1996; Edmonds et al. 1996; Yan & Mateo 1994). Astrophysical study on this field has been mainly performed by the means of photometry and spectroscopy. As a result, contact binaries provide a great opportunity to investigate certain evolution tracks, such as stellar merging. Stępień (2006) showed that the short period cut-off for contact binaries (0.22 d) is due to the finite age of the Galaxy. Low mass stars, which could evolve to shorter orbital period, have not yet had enough time to do so, since such process takes more than 10-15 Gyr. Stępień & Gazeas (2012), Gazeas & Stępień (2008) and Gazeas & Niarchos (2006) demonstrated that there are clear correlations between their fundamental parameters and the orbital period. However, the short-period end of these correlations is defined by only a few systems, and there is considerable scatter between their parameters. Increasing the number of objects in this period range which can be modeled will therefore allow these correlations to be tested further and improved upon.



Some of the major astronomical facilities in Greece are used in CoBiToM Project. Among them, the University of Athens Observatory with the 0.4 m telescope (left) was used for 120 nights between 2012-2015, Kryoneri Astronomical Station with the 1.2 m telescope (center) was used for 25 nights between 2013-2014 and Helmos Observatory with the 2.3 m telescope (right) was used for 4 nights between 2014-2015.

The observing program

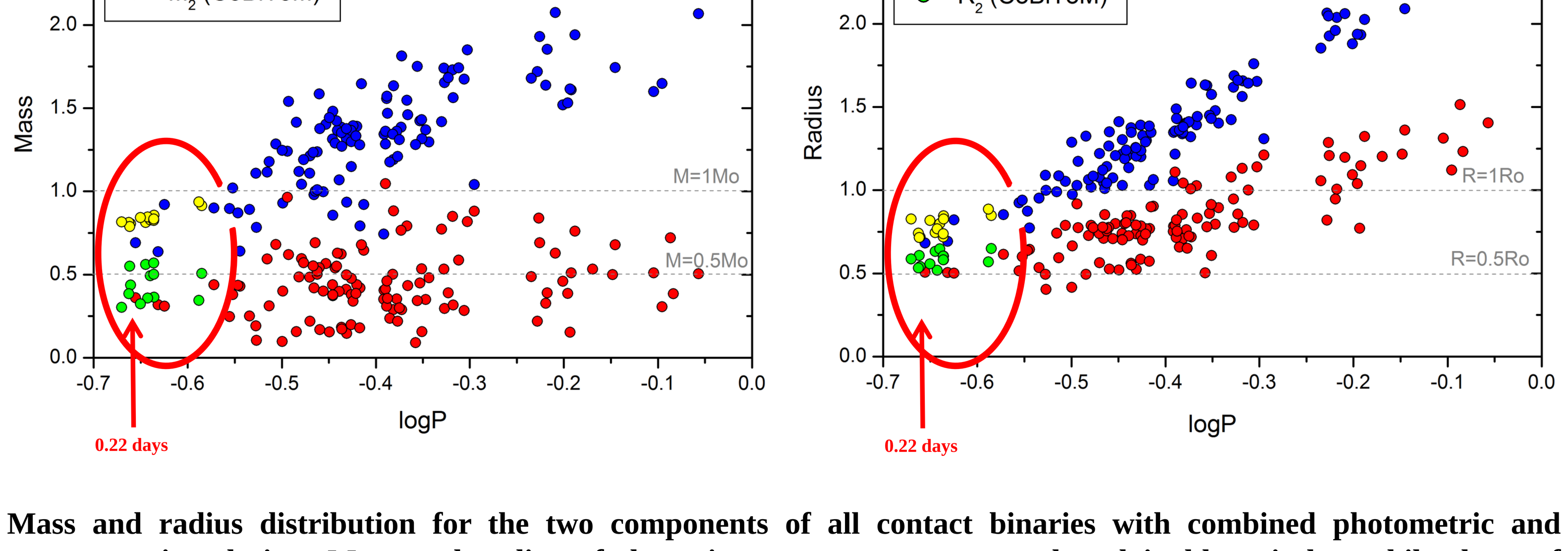
Several observing programs bring into the scene thousands of contact binaries, as a by-product of photometric surveys, but only a handful of contact systems close to the short period cut-off are known. In parallel, SuperWASP photometric survey (Pollacco et al. 2006) gave recently a list of 53 short-period candidates, using the wide-field cameras of their project (Norton et al. 2011). This survey has a detection limit of m_V=15 mag and gave a significant amount of photometric data on these systems. Their light curves are ruled by large rms scatter, making the determination of physical properties a difficult task. High accuracy photometric and spectroscopic observations are required in order to determine the absolute physical parameters with an accuracy of less that 10-15% and make scientific use of their values. An observing project was initiated at the University of Athens since 2012 with the 0.4 m telescope, in order to investigate the lower limit of orbital period, as a consequence of stellar evolution. Seeking for the contact binary with the shortest orbital period we are looking at the ultimate state of an eclipsing binary. Coalescence is the end of binary nature, after a long journey of stellar formation, evolution, angular momentum loss, mass exchange and a series of astrophysical processes. *CoBiToM Project* is an observing campaign, which focuses on very short period (P < 0.3 d) contact binaries from the sample list provided by Norton et al. (2011). Supplementary work is provided by the Kryoneri Astronomical Station (1.2 m telescope) and Helmos Observatory (2.3 m telescope), where fainter targets are needed to be observed. The aim of the current work is to perform detailed photometric (and consecutively spectroscopic) observations on the low-mass, short-period contact binaries, in order to increase the sample of such objects substantially and investigate their properties in detail. Having a larger and better sample of these systems we can test the ideas put forward by Stępień (2006) concerning the evolution of low mass binary stars and the mass-radius-period relationships outlined by Gazeas & Stępień (2008). A photometric sample of multi-band light curves, obtained in the frame of *CoBiToM Project* is shown in the plots below.



The multi-band photometric variability of a sample of 10 contact binary systems, observed in the frame of CoBiToM Project. All systems have orbital period which ranges from 0.21 to 0.26 d, indicating a contact configuration in a very tight orbit.

The first results

CoBiToM Project provides 4-band photometry with very good quality, which is essential for stellar models. A future task in the same frame is to gather spectroscopic data for these targets using larger telescopes. Gathering all information and perform combined spectroscopic and photometric analysis for a large number of targets requires significant amount of time. Existing empirical relations may be used as a first approximation (with ~5% uncertainty), such as the 2-dimensional and 3-dimensional empirical relations presented by Gazeas (2009). GAIA mission will provide about 10^6 more contact binary systems and the only way to approach the solutions will be statistically. The efforts to calibrate the empirical relations across the entire range of parameters will give us a strong tool for calculating the physical parameters of contact binary stars and the development of a better evolutionary model.



Mass and radius distribution for the two components of all contact binaries with combined photometric and spectroscopic solution. Mass and radius of the primary components are plotted in blue circles, while those of secondaries in red circles. Short orbital period systems from CoBiToM Project are plotted in yellow/green circles, respectively. Note that the mass of the secondaries are independent of orbital period and lies between the limits of 0-1 $M_\odot$, while all other values of mass and radius of both components gradually increases, almost proportional to logP.

A dozen of short-orbital period contact systems have already been observed and analyzed, providing a new picture for the mass/radius vs orbital period correlation diagrams. Increasing the number of objects in the short period cut-off range will allow these correlations to be tested further and improved upon and results in the development of a better evolutionary model.

REFERENCES

Edmonds P. D., Gilliland R. L. et al., 1996, ApJ, 468, 241
Gazeas K. D., & Niarchos P. G., 2006, MNRAS, 370, L29
Gazeas K., & Stępień K., 2008, MNRAS, 390, 1577
Gazeas K., 2009 CoAst, 159, 129
Norton et al., 2011, A&A, 528, A90
Pollacco D. L., Skillen I. et al., 2006, PASP, 118, 1407
Rubenstein E. P., & Bailyn C. D., 1996, AJ, 111, 260
Rucinski S. M., & Duerbeck H. W., 1997, PASP, 109, 1340
Stępień K., 2006, AcA, 56, 347
Stępień K., & Gazeas K., 2012, AcA, 62, 153
Yan L., & Mateo M., 1994, AJ, 108, 1810