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Photometric study of the eclipsing systems DU Boo, CW Lyn, HS Aqr and MR Del

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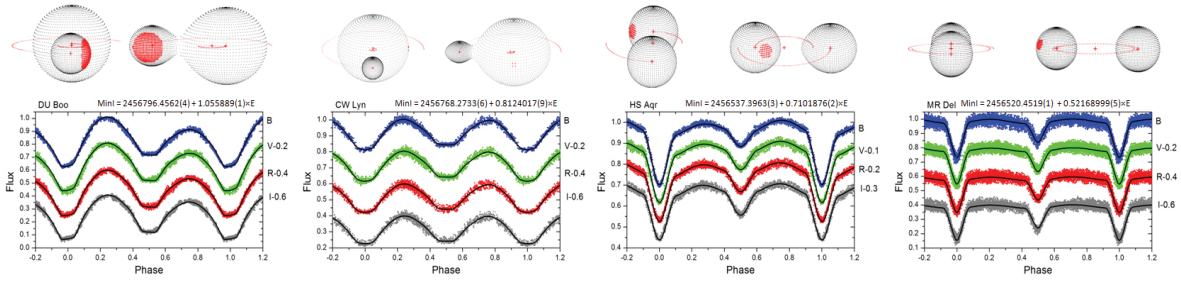
Abstract: In this work we present the photometric study of the close interacting binary systems DU Boo, CW Lyn, HS Aqr and MR Del, in search of their absolute physical parameters and light variations. A combined photometric and spectroscopic solution was achieved for all systems, using photometric measurements obtained at the University of Athens Observatory and publicly available spectroscopic data. The solution provides a detailed model for each system, through the use of modern modeling methods and techniques. It is deduced that DU Boo has one of the longest orbital periods ever observed on contact binaries, while its components present a large temperature difference of about 1000 K. In addition, light curve asymmetries are apparent and therefore a spot model is proposed, to explain the OConnell effect. The contact binary CW Lyn has one of the smallest mass ratios among contact binaries and a spotted solution is proposed, being the first given in literature for this system. This study also confirms the presence of a third body orbiting the binary system MR Del, which was previously detected through spectroscopic observations. It is also the first to suggest a detached configuration for the system HS Aqr. Finally, both MR Del and HS Aqr show magnetic activity and spotted solutions were introduced to explain their photometric behavior.

1 Observations and data reduction

The eclipsing binary systems under study, namely DU Boo, CW Lyn, HS Aqr and MR Del, were observed with the aim of determining their physical parameters and providing conclusive results on many of their debatable aspects. The observations were obtained at the University of Athens Observatory. DU Boo was observed on April and May 2014 and CW Lyn was observed on March, April and May 2014. HS Aqr was observed between August and September 2013, while MR Del was observed between July and August 2013. We used the 0.40 m f/8 Cassegrain reflector, with an SBIG ST10 XME CCD camera, equipped with a set of BVRI (Bessell) filters and an f/6.3 focal reducer. All models were produced by using PHOEBE software [5], which utilizes the Wilson-Devinney code [9] . Temperature and limb darkening coefficients were computed, taking into account the spectral type of each system ([2] and [8]). DU Boo shows light curve asymmetries and therefore a spot model is introduced in order to explain the OConnell effect. The temperature difference between the two components is about 1000 K, which is very large for a contact binary system. The spectroscopic mass ratio of DU Boo was determined by [3] and taken as fixed. CW Lyn has no spectroscopically determined mass ratio and therefore we conducted a "q-search" method. Our findings suggest that CW Lyn has an extremely small mass ratio for a W UMa type system, with a value of q=0.067±0.005, being even smaller than the mass ratio of AW UMa (q=0.099±0.003) [7]. Photometric light curves of both systems show total eclipses, which is supported by the large inclination found for both systems. Spectroscopically determined mass ratio for the system HS Aqr is given by [6] and for MR Del by [4] and they are used as fixed parameters in our model. The semi-detached assumption for HS Aqr that had been proposed by [1] was not sufficient for producing a highly accurate model with our observed data (Fig.1). We found that the secondary component does not fill the respective Roche lobe and therefore we suggest a detached configuration.



	DU Boo		CW Lyn		HS Aqr		MR Del	
M ($M_\odot$)	2.04(6)	0.48(3)	1.68(1)	0.11(1)	1.36(4)	0.85(2)	0.66(2)	0.60(2)
R ($R_\odot$)	3.12(7)	1.66(7)	2.81(2)	0.96(1)	1.42(1)	1.42(1)	0.72(1)	0.77(1)
L ($L_\odot$)	32(1)	5.2(4)	12.9(7)	1.29(5)	2.64(4)	1.17(2)	0.27(1)	0.21(1)

Figure 1: Observed and theoretical light curves, calculated 3D model and absolute physical parameters for the four systems presented in this study.

2 Conclusion

DU Boo is a W UMa-type contact binary with an unusually long orbital period. This may imply that the system has just entered the contact configuration, and it evolves towards mass ratio inversion. This is also in accordance to the large temperature difference between the two components and the relatively small mass ratio. CW Lyn appears to be the contact binary which has the smallest mass ratio observed in W UMa-type systems. The more massive component 'swallows' the secondary, a fact that is evident by the large fill-out factor. This system most likely evolves rapidly towards merging. MR Del is a short period detached eclipsing binary with small components, which is a member of a triple system. HS Aqr was initially thought to be a semi-detached binary, while we suggest a detached configuration, fitting our observed light curves much better. Our study shows that all four systems are magnetically active and therefore we included cool spots in our models. The resulted absolute physical parameters of all systems in this study are shown in Fig1. Secondary components of the detached systems in this study are relatively more evolved than their correspondent primaries. The fact that the secondary component in HS Aqr almost fills its Roche lobe, implies that the present secondary was formerly the primary, and a great portion of its mass was transferred through the Lagrangian point L1. Contact binaries DU Boo and CW Lyn are older in general, which is in accordance to the fact that all components are located above TAMS line and are significantly oversized for their mass, as a consequence of gravitational interaction with their companions.

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