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ABSOLUTE PARAMETER DETERMINATION IN LOW-MASS ECLIPSING BINARIES. RADIATIVE PARAMETERS FOR BH VIR, ZZ UMA AND CR CAS.

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ABSTRACT

A new uvby and Hβ monitoring program of low mass eclipsing binaries is currently being carried out in the framework of a 5 year observational program which also involves radial velocity determinations. The scope of this work is to provide very accurate absolute astrophysical parameters: mass, radius and effective temperatures, for main sequence late-type stars. One of the main goals is to improve the mass-luminosity relation in the low and intermediate mass range. A second objective is to perform accurate tests of the most recent grids of evolutionary models. This program is complementary to that currently being in progresss by the Copenhagen group.

In this contribution we present the photometric preliminary results obtained for three of the systems included in our long term survey: BH Vir, ZZ UMa and CR Cas for which, primary eclipses have been observed. Particular attention is paid to the determination of reddening, distances and radiative properties. A more detailed study will be carried out when the light curves and radial velocity measurements are completed

INTRODUCTION

New and more accurate observational determinations of masses, radii, temperatures and abundances are needed in order to test the new available grids of evolutionary models. Those physical quantities are poorly defined at the end of the Main Sequence. Only a few stars have astrophysical parameters determinations with the required accuracy ($< 3\%$).

Mass, radius, temperature and abundances can be derived only for double lined eclipsing binaries with accurate light and radial velocity curves. With this aim, we have started a 5 year monitoring program in order to obtain good photoelectric uvby & Hβ photometry and radial velocity measurements for six selected systems. This program is complementary to that currently carried out by Andersen et al. 1992 for early and intermediate type stars.

In this contribution we present preliminary results for three binaries: BH Vir, ZZ UMa and CR Cas.

The measurements have been carried out from March 1990 up to now at The Calar Alto Observatory (Almeria, Spain), located at 2168 m above the sea level, on seven observing runs. The telescope used was the 1.5 m reflector equipped with either a multipurpose UBVRI one-channel photoelectric photometer or, alternatively, a uvby-Hβ four-channel photometer, both using Stromgren uvby filters as well as Crawford's narrow and wide Hβ filters. More details about the instrumental configuration and reduction procedures can be found in Fabregat and Reglero 1990.

We have selected two comparisons for each binary system and obtained differential light curves within the observational accuracy of our differential photometry quoted in a few millimagnitudes (0.007 mag. in the V filter). We have measured standard stars from the lists of Perry et al. (1987) and Olsen (1991), during nights of the best photometric quality, to transform instrumental magnitudes into the standard system, standard values for the comparisons and targets are reported in Table 1.

DISCUSSION

BH Vir Photometric studies of this interesting eclipsing binary have been carried out by several authors: Kitamura et al. (1957), Koch (1967), Sadik (1978), Botsula (1978), Hoffmann (1982) and Scaltriti et al. (1985). More recently in a detailed analysis of the available light curves using the Wilson-Devinney code, Zhai et al. (1990) derived the most relevant astrophysical parameters of both components. The analysis of the photometric light curves for BH Vir is a difficult task mainly due to the large and very fast amplitude variations outside eclipses. Koch (1967) reported changes in the depth of the primary eclipse of a tenth of a magnitude, in only few days. Despite this problem, BH Vir has been included in our program due to the lack of late-type eclipsing binaries without photometric variations outside eclipse. The associated waves generated by the presence of spots in the stellar surfaces is a well know signature of late-type fast rotators.

For the present work, in order to avoid this important source of uncertainty, we have used the data obtained within a single night (JD=2448640) with measurements from phase 0.8 to 0.1 and including a well defined primary minimum. The upper limit of the ratio of luminosities Lc/Lh(V)=0.88 has been derived using the primary minimum values and an average of points outside eclipse and far away from the contact points, around phase 0.10. In this way, the observed magnitudes and colors for the combined light are nearly simultaneous (same night) with the values for the primary minimum and essentially free of variability effects (close in phase). The visual magnitudes for the primary minimum Vp=10.42 mag. and for the combined light outside eclipse Vt=9.59 mag. are in good agreement with those reported by Scaltriti et al. (1985).

Before discussing the radiative parameters of the binary, a study of the local interstellar extinction was done. An accurate determination of the reddening is needed to eliminate uncertainties in the determination of physical parameters.

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TABLE I Radiative Parameters.

name	V_o	$(b-y)_o$	m_o	c_o	$H\beta$	dm_o	dc_o	E(b-y)	B-V
SAO2770	9.780	0.276	0.165	0.507	2.673	0.006	0.059	0.01	0.43
SAO139643	9.518	0.367	0.185	0.344	2.609	0.018	0.026	0.01	0.58
BH Vir H	10.276	0.356	0.152	0.333	2.600	0.062	0.043	0.00	0.54
BH Vir C	10.422	0.408	0.208	0.309	2.580	0.018	0.036	0.00	0.65
SAO15242	10.120	0.368	0.163	0.333	2.595	0.059	0.053	0.00	0.57
SAO15251	9.995	0.397	0.212	0.344	2.599	0.000	0.050	0.00	0.64
ZZ UMa H	10.704	0.370	0.200	0.301	2.600	0.014	0.011	0.00	0.59
ZZ UMa C	10.501	0.424	0.180	0.362	2.583	0.067	0.104	0.00	0.67

TABLE II Radiative Parameters.

name	Mv	Fv	[Fe/H]	T_{eff}	d	Sp
SAO 2770	3.0	3.811	0.1	6604	230	F4 V
	0.3	0.034	0.2	60	30	
SAO 139643	4.3	3.748	0.0	6017	113	G0 V
	0.3	0.026	0.2	60	15	
BH Vir C	4.4	3.760	-0.5	5973	150	F9-G0 V
	0.3	0.026	0.2	60	22	
BH Vir C	4.5	3.741	-0.1	5714	150	G5 V
	0.3	0.034	0.1	100	22	
SAO 14242	4.2	3.762	-0.4	5904	151	G0 V
	0.3	0.034	0.2	60	20	
SAO 15251	4.2	3.747	0.1	5823	143	G2 V
	0.3	0.034	0.1	100	19	
ZZ UMa H	4.7	3.761	0.0	6008	158	G0 V
	0.3	0.034	0.2	60	20	
ZZ UMa C	4.5	3.733	-0.3	5630	158	G5 V-IV
	0.3	0.034	0.1	100	20	

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The interstellar reddening of the system has been derived following a procedure similar to that described by Reglero et al. (1990). The two comparison stars SAO 2770, and SAO 139643 indicate a mean reddening of E(b-y)=0.01+0.004 mag. The small apparent angular distance between the comparisons and BH Vir and their location at 230 and 113 pc in front and behind BH Vir, suggests no significant interstellar extinction for BH Vir itself.

The derived physical quantities for the comparisons are listed in Table 2. The quoted errors arise from the uncertainties on the photometric calibrations and error formulae. We have used the well know standard calibration procedure for F type stars given by Crawford (1975) and extended by Olsen (1988) for early G type stars, using Hβ index as a reddening free independent parameter. Effective temperatures Teff, and visual surface brightness parameters, Fv, were derived from the semiempirical calibrations of Saxner and Hammarback (1985) and Moon (1985) respectively. Both comparisons appear to be main sequence stars with solar metal abundances and located at 230 and 113 pc respectively. Their spectral types can be estimated, from the present photometric calibrations, as F4V and G0V stars respectively, with the former slightly more evolved according to its δc_o difference.

Following the decoupling procedure described by Gimenez et al (1991) and using the upper limit for the luminosity ratio Lc/Lh=0.88 discussed above, we have estimated the magnitudes, colours and indices for the hot component of BH Vir listed in Table 1.

The E(b-y)=-.003 mag. and E(b-y)=0.008 mag. computed for the hot and cool components are very close to those derived from the comparisons. Using these four independent reddening determinations of 0.007, 0.012, -0.003 and 0.008 mag. giving a mean value of E(b-y)=0.006+0.006 mag. The radiative parameters for the hot and cool components have been derived following the same procedure as described above for the comparison stars. For the cool component we have used the standard photometric calibrations given by Olsen (1984) for late type stars. Results are given in Table 2.

Reglero et al. (1990) showed that the distance (Mv) to most RS CVn systems can be estimated using the non-active star, usually the hot component. BH Vir is a more complex case. The analysis of activity carried out by several authors in the last years, suggests that the hot component is the active star but probably also the cool star is active. The indetermination induced in the absolute magnitude determinations for the presence of surface activity can be minimized with a supplementary equation DMv = Dmv. Where D is de difference in magnitudes between the hot and cool components. In other words, the distance is the same for both stars in the binary.

Effective temperatures, visual flux brightness Fv and absolute magnitudes from Table 2 led us to classify the hot component as a F9-G0 type star with a marginal metal deficiency, measured through the m_1 index (δm_o=0.062), and slightly evolved (δc_o=0.043). The cool component can be classified as a G5 main sequence star with solar composition. This photometric classification from the derived radiative parameters indicate a later spectral type for the cool star that those currently assigned in the literature. The effects of the spots on the stellar surface can not be discarded as a cause of this discrepancy.

The metal deficiency of the hot-active star is in good agreement with the

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relation between activity an apparent metal underabundances measured through the m_1 index, derived by Gimenez et al. (1991) for RS CVn systems. In contrast, the less active or non-active cool component shows a solar metal content. The location of both stars in the c_o-$(b-y)_o$ plane indicate their evolved nature close to the TAMS.

ZZ UMa

We have used as comparison stars for this binary system SAO 15242 and SAO 15251. Averaged standard values for both stars are reported in Table 1. The interstellar reddening computed from its calibration shows the absence of interstellar extinction in this region up to 150 pc. Both systems appear as main sequence G0V and G2V stars with solar chemical composition. The derived parameters are listed in Table 2.

Following a procedure similar to that for BH Vir, we have decoupled the hot and cold components for ZZ UMa. The estimation of the reddening for the hot component is in very good agreement with the interstellar extinction indicated by the comparisons. No indication of interstellar extinction in this region of the sky and up to 150 pc have been found in accordance with the expected values. The radiative parameters for the hot and cool components are reported in Table 2.

The hot component appears as a G0V main sequence star with solar chemical abundance. The cool star shows a later spectral type, G5, and is more evolved (δc_o=0.10) and can be located close to the TAMS.

Marginal variability outside eclipses of 0.01 mag. in the V filter has been observed in ZZ UMa as a common signature of the late-type fast rotators.

CR Cas

CR Cas has been included in the present program because of its classification as a G5 star (Leung et al.(1977)). Their uvby and Hb indices, however, are not compatible with the late type classification. A highly-reddened, E(b-y)=0.6 mag., early-B type system seems to be the most realistic approach. Our partial coverage of the light curve does not allow us to derive a photometric calibration of the radiative parameters for the components. Although, CR Cas should consequently be dropped out of the scope of the present program on low mass binaries, we will continue the photoelectric coverage of this rewarding binary.

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