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Photometric study of two W UMa-type systems in the intermediate age open cluster Be 33

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Abstract. Study of eclipsing binaries in open clusters offers information regarding the age of the cluster in addition to the properties of the component stars. In this paper we present the analysis of two W UMa systems discovered in the open cluster Be 33 using the Wilson – Devinney method.

1. Introduction

The W Ursae Majoris stars are a group of binary systems with the two components enclosed in a common envelope. The spectral type of these systems range from around mid A to early K with the majority concentrated in mid F through early G. Binnendijk (1970) has identified two classes, W - types and A - types. The W- types, for which the deeper eclipses are of the smaller stars, generally have spectral types later than F8 and have strongly convective outer envelopes. The A- types, for which the deeper eclipses are those of the larger components, have spectral types earlier than F8 and their colour variations imply abnormally low gravity and limb darkening. This is interpreted as an indication that the convection extends well into the A- types, effective temperature range.

Over the last few years surveys have been conducted to search for such short period W UMa type systems in intermediate and old open clusters like M 67, with a view to studying the frequency and properties of these systems as a function of cluster age. A number of them have been discovered and the photometric light curves of some have been obtained. In the following we report the analysis done on two W UMa type systems in the open cluster Be 33.

2. Observational data

The photometric observations of the faint open cluster Be 33 ($\alpha_{2000} = 6^h\ 57^m\ 51^s$, $\delta_{2000} = -13^\circ\ 13'$, $l = 225^\circ.6$, $b = -4^\circ.6$) in V and I passbands done by Mazur, Kaluzny and Krzeminski (1993) using CCD are available for further analysis. The observations reveal two W UMa type

variables and one Algol type variable. Their work shows Be 33 to be a highly reddened, intermediate age (0.7 G yr) open cluster. The following are the basic parameters of the two W UMa variables.

Star	α_{2000}	δ_{2000}	P(days)	I_{max}	(V – I)	(B – V)	Amp (band)
Var 1	$6^h57^m36^s.3$	$-13^\circ 14' 36''$	0.2292	13.78	1.44	1.30	0.50
Var 2	$6^h57^m42^s.1$	$-13^\circ 13' 14''$	0.3263	16.74	1.26	1.10	0.45

3. Analysis and conclusions

A visual inspection of the light curves in V and I bands indicates that the variables are of W UMa type. From the observed minima, the epoch is noted and from the periods given by Mazur, Kaluzny and Krzeminski (1993), the phases are calculated for the given observations.

Analysis of the light curves are performed using the Wilson – Devinney method (1971, 1993-program version), as it gives reliable elements for the components. Due to the contact configuration of the systems, mode 3 is used for analysis and the following parameters are fixed.

The effective temperatures for the primaries are obtained for their respective unreddened (B – V) values from the tables provided by Allen (1976), Popper (1980) and Schmidt Kaler (1982) as

for Var 1 T_{eff} = 3996 K (Sp. type – K7)

for Var 2 T_{eff} = 4388 K (Sp. type – K4)

The later spectral types indicate that both the systems are W–type contact binaries with convective outer envelopes. Hence for both the systems, the gravity-darkening coefficients G_h, G_c are taken as 0.32; orbital eccentricity e as o; the bolometric albedos (A_h, A_c) as 0.5 (for convective envelopes) and the limb-darkening coefficients (x_h, x_c) as 0.6 (A1 - Naimiy, 1978).

Since no spectroscopic data are available for fixing the values of mass-ratio 'q', the computation of elements for both the variables are performed for various values of mass-ratio. The values chosen are from q = 0.2 to 1.2 in steps of 0.1, and from 0.9 to 1.1 in steps of 0.02, the corresponding values of potentials are calculated using the equations given by Kopal (1959).

Computations are carried out using the DC program of the W – D method by varying the parameters viz., i, L_h and T_c successively till the sum of the residuals, $\Sigma W(O-C)^2$ showed a minimum and the corrections to the parameters became smaller than their probable errors. In order to check the internal consistency of the results, separate solutions for each of the V and I light curves are made for the two variables.

Table 1. Be 33 Var 1: Elements obtained from the solution of individual and combined VI light curves using W – D method, keeping $T_{e,h}$ = 3996 K and q = 0.96 as fixed parameters.

Element		V	I	Combined VI solution
1		2	3	4
*$T_{e,h}$ K		3996	3996	3996
$T_{e,c}$ K		3840	3717	3857 ± 37
*q		0.96	0.96	0.96
i°		70.87	70.61	69.82 ± 0.04
r_h	pole	0.3595	0.3595	0.3595 ± 0.0013
	point	0.5000	0.5000	0.5000 ± 0.0014
	side	0.3778	0.3778	0.3778 ± 0.0014
	back	0.4085	0.4085	0.4085 ± 0.0015
r_c	pole	0.3527	0.3527	0.3527 ± 0.0020
	point	0.4916	0.4916	0.4916 ± 0.0020
	side	0.3702	0.3702	0.3702 ± 0.0019
	back	0.4013	0.4013	0.4013 ± 0.0020
L_h		0.5726	0.5819	V 0.5655 ± 0.0007 I 0.5445 ± 0.0008
L_c		0.4275	0.4181	V 0.4345 I 0.4555
+L_3		0.0	0.0	V 0.0 I 0.0
x_h		0.60	0.78	V 0.62 I 0.76
x_c		0.80	0.80	V 0.78 I 0.82
*A_h		1.00	1.00	1.00
*A_c		1.00	1.00	1.00
*G_h		1.00	1.00	1.00
*G_c		1.00	1.00	1.00

* Fixed parameters
\+ In units of total system at phase 0.25

The results of analysis for individual V and I light curves given in columns 2 and 3 of Tables 1 and 2 for variables 1, 2 'respectively' indicate that individual solutions are consistent and that combined solutions for V and I is adequate to derive the system parameters. The plot of $\Sigma W(O\text{-}C)^2$ versus 'q' for Var 1 indicates that a minimum occurs at q = 0.96 for both the passbands and that for Var 2, it indicates that a minimum occurs at q = 1.0 for both the passbands.

For each of the variables, taking the average parameters of the solutions given in columns 2 and 3 of Tables 1 and 2 as preliminary elements, a final combined solution is obtained keeping i, L_h and T_c as adjustable parameters and the other parameters as fixed. The results of the combined solutions for both the variables are given in column 4 of the respective tables.

Table 2. Be 33 Var 2: Elements obtained from the solution of individual and combined VI light curves using W – D method, keeping $T_{e,h}$ = 4388 K and q = 1.0 as fixed parameters.

Element		V	I	Combined VI solution
1		2	3	4
*$T_{e,h}$ K		4388	4388	4388
$T_{e,c}$ K		4397	4032	4404 ± 37
*q		1.0	1.0	1.0
i°		69.52	73.46	70.25 ± 0.04
r_h	pole	0.3561	0.3561	0.3561 ± 0.0013
	point	0.5000	0.5000	0.5000 ± 0.0014
	side	0.3740	0.3740	0.3740 ± 0.0014
	back	0.4050	0.4050	0.4050 ± 0.0015
r_c	pole	0.3561	0.3561	0.3561 ± 0.0020
	point	0.5000	0.5000	0.5000 ± 0.0020
	side	0.3740	0.3740	0.3740 ± 0.0019
	back	0.4050	0.4050	0.4050 ± 0.0020
L_h		0.4970	0.5785	V 0.4947 ± 0.0007 I 0.4947 ± 0.0008
L_c		0.5030	0.4215	V 0.5053 I 0.5033
+L_3		0.0	0.0	V 0.0 I 0.0
x_h		0.60	0.78	V 0.62 I 0.76
x_c		0.80	0.80	V 0.78 I 0.82
*A_h		1.00	1.00	1.00
*A_c		1.00	1.00	1.00
*G_h		1.00	1.00	1.00
*G_c		1.00	1.00	1.00

* Fixed parameters
\+ In units of total system at phase 0.25

The theoretical curves for the V passband obtained from the elements given in column 4 of Tables 1 and 2 are shown in Figs 1 and 2 for Var 1 and Var 2, as open circles. In the figures the solid circles represent individual observations.

The fit of the theoretical curves to the observations for Var 2 is found to be satisfactory. However for Var 1 there is a discrepancy in the fit at phases 0.25 and 0.75. This could be due to presence of spots on one of the components of the system as found in many W UMa binaries.

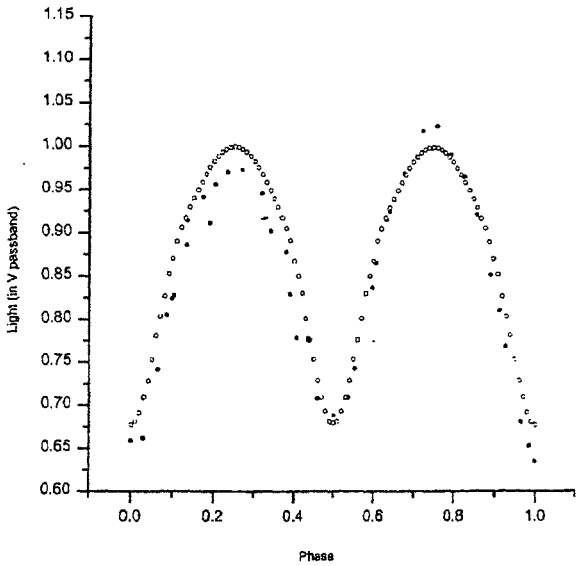

Figure 1. Be33 Var1 : Light curve in the V passband. Solid circles (•) represent observations and open circle (o) represent theoretical values obtained from Wilson - Devinney solution.

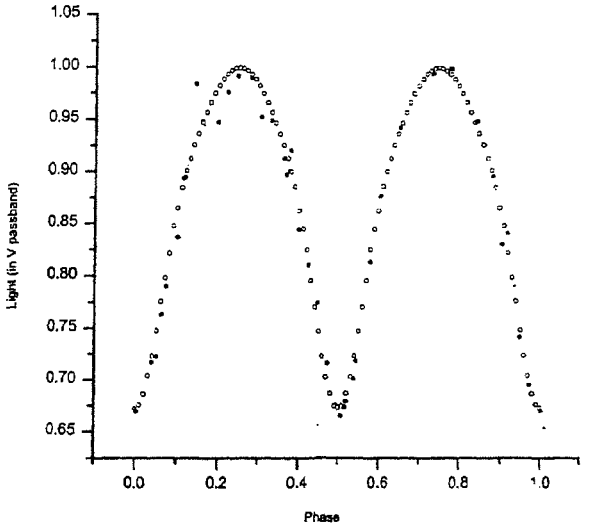

Figure 2. Be33 Var2 : Light curve in the V passband. Solid circles (•) represent observations and open circle (o) represent theoretical values obtained from Wilson - Devinney solution.

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