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W UMa-type systems in globular clusters

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Abstract. W UMa systems can be found everywhere in the Galaxy. They can be used as a distance tracer. Therefore, W UMa systems are very important to investigate the structure of the Galaxy. The distance to W UMa systems in globular clusters (GCs) is determined using a period–color–luminosity relation. It is found that the mean distance (r_a) of W UMa systems is consistent with their host cluster distances ($r_{\rm GC}$) deduced from their intrinsic distance moduli if $r_{\rm GC} \leqslant 10$ kpc. There is a significant difference between r_a and $r_{\rm GC}$ for $r_{\rm GC} \geqslant 10$ kpc. We discuss the reasons causing this deviation.

Keywords. binaries: eclipsing, globular clusters: general

1. Introduction

W UMa contact binaries (also known as EW systems; Rucinski 2000) are unique objects in which the luminosity is redistributed through their common envelope. W UMa systems are very easy to detect and identify owing to (i) the rather large amplitudes of their light changes and (ii) their short periods, so that limited-duration monitoring is sufficient (Rucinski 2000). W UMa systems can be found everywhere in our Galaxy. In fact, many EW systems have been detected in Galactic cluster searches (see Rucinski 1998). Meanwhile, the absolute magnitude of EW systems is related to their orbital periods and colors, implying that EW systems can be used as distance indicators and would play an important role in studying the structure of our Galaxy (Rucinski 2004).

2. EW systems as a distance indicator to globular clusters

Many EW systems have been found in GCs. We have collected data for the EW systems in 17 GCs: see Table 1. The absolute magnitude of EW systems is determined through a period–color–luminosity (PCL) relation (Rucinski 2000),

$$M_{V,\rm Ruc} = -4.44 \log P + 3.02(B-V)_0 + 0.12, \tag{2.1}$$

or

$$M_{V,\rm Ruc} = -4.43 \log P + 3.63(V-I)_0 - 0.31. \tag{2.2}$$

If the effect of metallicity must be taken into account, Rucinski (2000) provided metallicity corrections, $\delta M_V^{BV} = -0.3$[Fe/H] and $\delta M_V^{VI} = -0.12$[Fe/H], respectively. The distances to EW systems can then be calculated using

$$5 \log r = (m-M)_{V,\rm Ruc} + 5 - A_V. \tag{2.3}$$

This leads to a mean distance (r_a) of EW systems in a given GC. However, the color excess and interstellar extinction of each EW system are usually taken to be a mean value relavent to their host GC, except for EW systems in NGC 3201 and M12, in which these quantities have been obtained for individual systems (von Braun & Mateo 2002;

Table 1. Some parameters for 17 GCs.

Clusters	l (deg)	b (deg)	$r_{\rm GC}$ (kpc)	$E(B-V)$ (mag)	$(m-M)_V$ (mag)	[Fe/H] (dex)	$N_{\rm EW}$	$r_{\rm a}$ (kpc)	$r_{a,\rm met}$ (kpc)	Refs
NGC 104	305.90	−44.89	4.4	0.04	13.37	−0.76	7	4.1	3.68	1
NGC 288	152.28	−89.38	8.4	0.03	14.69	−1.24	2	12.81	10.8	1
NGC 4372	300.99	−9.88	7.1	0.39	15.01	−2.09	8	6.4	4.8	1
Rup 106	300.89	+11.67	18.5	0.20	17.25	−1.67	2	5.7	4.6	1
NGC 5139	309.10	+14.97	6.4	0.12	13.97	−1.62	18	5.44	4.97	1
NGC 5272	42.21	+78.71	12.2	0.01	15.12	−1.57	1	6.41	5.16	1
NGC 5466	42.15	+73.59	17.2	0.00	16.15	−2.22	2	16.21	11.91	1
NGC 6121	350.97	+15.97	5.9	0.36	12.83	−1.20	16	3.65	3.09	1
NGC 6362	325.55	−17.57	5.3	0.08	14.79	−0.95	4	3.91	3.43	1
NGC 6397	338.17	−11.96	2.96	0.18	12.36	−1.95	8	3.72	3.34	1,2,3
NGC 6441	353.53	−5.01	3.5	0.44	16.62	−0.53	13	5.46	5.09	1,4
NGC 6752	336.50	−25.63	5.2	0.04	13.13	−1.56	7	4.91	3.96	1
NGC 6838	56.74	−4.56	6.7	0.25	13.75	−0.73	8	5.09	4.60	1,5
NGC 6934	52.10	−18.90	16.5	0.09	16.09	−1.53	2	6.84	5.53	6
NGC 3201	277.23	+8.46	4.65	0.24	14.08	−1.54	9	4.81	4.42	7,8,9
M12	15.7	+26.3	4.9	0.26	13.46	−1.54	1	5.40	5.00	10
NGC 6388	345.6	−6.7	6.16	0.40	15.19	−1.20	5	5.26	4.84	11

Columns: l, Galactic latitude; b, Galactic longitude; $E(B-V)$, colour excess; $r_{\rm GC}$, distance to the Sun; $(m-M)_V$, distance modulus; [Fe/H], metalicity; $N_{\rm EW}$, total number of EW systems in the cluster; r_a, average distance of EW systems; $r_{a,\rm met}$, average distance including the effect of metallicity.

References in Table 1: (1) Rucinski (2000), (2) Kaluzny *et al.* (2003), (3) Kaluzny *et al.* (2006), (4) Pritzl *et al.* (2001), (5) Park & Nemec (2000), (6) Kaluzny *et al.* (2001), (7) Layden *et al.* (2003), (8) von Braun & Mateo (2002), (9) Mazur *et al.* (2003), (10) von Braun *et al.* (2002), (11) Pritzl *et al.* (2002).

von Braun *et al.* 2002). In addition, the distance, $r_{\rm GC}$, to the GCs can also be derived from their distance modulus, $(m-M)_V$, through Equation (2.3). These are also included in Table 1.

The relation between r_a and $r_{\rm GC}$ is shown in Figure 1. It can be seen that the values of r_a are consistent with $r_{\rm GC}$ for GCs with $r_{\rm GC} \leqslant$10 kpc, and there is a significant difference between the two distances for some GCs at greater distances: r_a is usually less than $r_{\rm GC}$ for these relatively distant GCs.

3. Discussion and conclusions

Although the average distance to the EW systems is very different from their parent cluster distance for some distant GCs, EW systems might be reliable distance indicators. We will now explore which effects might cause such differences. (i) Some EW systems found in the field of these GCs might not be cluster members. It is necessary to find a more accurate way to determine whether or not a star is indeed a cluster member. (ii) The stars in GCs are very crowded while the dust distribution in GCs is not necessarily uniform. There could be a significant difference in the reddening and extinction values for EW systems in GCs (von Braun & Mateo 2002; von Braun *et al.* 2002). (iii) Some GCs at large distances may suffer from significant effects related to their presence close to the center of the Galaxy, such as the high extinction associated with the Galactic center or reflection of its luminosity.

EW systems can be used as standard candles tracing small-scale structure, especially in our Galaxy (Rucinski 2004). Therefore, they would play an important role in studies of the structure of our Galaxy. However, color excesses and extinctions should be accurately

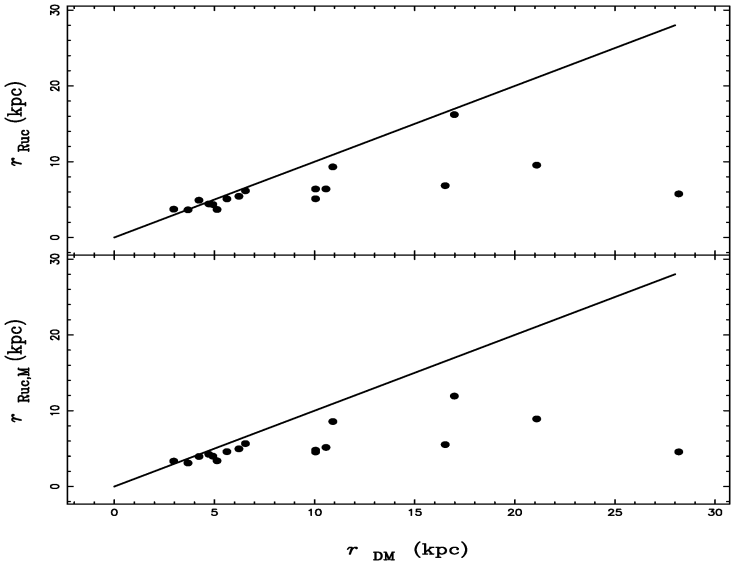

Figure 1. Relation between r_a and $r_{\rm DM} = r_{\rm GC}$. The top panel does not take into account the effects of metallicity, which are included in the bottom panel. The solid line represents $r_a = r_{\rm GC}$.

determined for each EW system separately, as done for NGC 3201 (von Braun & Mateo 2002), because the stars in GCs are very crowded and the dust distribution is usually not uniform. In fact, differential $E(V-I)$ variations of up to ~ 0.2 mag on a scale of arcminutes across NGC 3201 have been presented in the form of an extinction map (von Braun & Mateo 2001). To find accurate distances to EW systems in GCs through the PCL relation of Rucinski 2000, it is also necessary to find a way in which we can distinguish GC members from field stars.

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