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ORIGINAL ARTICLE

Binaries with Total Eclipses in the LMC: Potential Targets for Spectroscopy

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Abstract 35 Eclipsing binaries presenting unambiguous total eclipses were selected from a subsample of the list of Wyrzykowski et al. (2003). The photometric elements are given for the I curve in DiA photometry, as well as approximate $T_{\rm eff}$ and masses of the components. The interest of these systems is stressed in view of future spectroscopic observations.

Keywords LMC · Stars: fundamental parameters

1. Introduction

As recalled by Wyithe and Wilson (2001), "systems where the stars are completely eclipsed are particularly important because they can provide robust measurements of the ratio of radii", k. Accurate determination of k is indeed a well known problem in partially eclipsed systems. An impressive demonstration of this is provided by Fig. 3 of Gonzáles et al. (2005). Here, I draw attention to a few tens of totally eclipsing systems in the LMC, which would deserve spectroscopic observations for an orbit determination, and possibly additional photometric ones for a more accurate determination of radii and surface brightness ratio. Such systems will be useful, not only for distance determination, but also for comparison with stellar structure models.

2. Sample, lightcurve solution and stellar parameters

From the sample of Wyrzykowski et al. (2003) based on OGLE photometry, we have selected a subsample of 510 binaries with $I_{max} \leq 18.0$, a depth of the secondary minimum ≥ 0.20 mag and an EA type. This is the same sample as that used by North and Zahn (2004). All lightcurves were solved interactively with the EBOP code, assuming a linear limb-darkening coefficient $u_p = u_s = 0.18$ except in the few cases of clearly cool components. Out of this sample, we selected visually 35 systems with clearly total eclipses. The fundamental stellar parameters were determined through interpolation in the evolutionary tracks of Schaerer et al. (1993) computed for a metal-content $Z = 0.008$ typical of the LMC. This was done as in North and Zahn (2004), but without the hypothesis of identical components and assuming $(m - M)_0 = 18.5$. The relative radii, orbital period and surface brightness ratio J_s were used to constrain the solution. J_s was calibrated in terms of $T_{\rm eff}$ ratio through the models of Kurucz (1979). In addition, $E(B - V)$ and $A_V = 3.1\ E(B - V)$ were determined simultaneously, using the measured $B - V$ index, following North (2004). The condition that both components lie on the same isochrone was not implemented, because of the presence of some post-mass exchange systems; for the latter, the masses given are just those of single stars with same $T_{\rm eff}$ and luminosity, and therefore may be wrong. For main sequence systems lacking a $B - V$ index, stellar parameters were determined in a cruder way, assuming both components lie on a $\log t = 7.0$ isochrone. The $T_{\rm eff}$ of cool giants in a few systems were derived from the $B - V$ or the $V - I$ index assuming $E(B - V) = 0.143$, while the masses were assumed identical to those of stars with same M_V on the isochrone. Some parameters of the I DIA lightcurve as well as $T_{\rm eff}$ and mass of both components are given in Table 1, a more complete version of which is available at the site `http://obswww.unige.ch/~north/DEB/tot_param`.

The errors are the formal ones given by the EBOP code and give an idea of the quality of the fit, though one has to

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Table 1 Totally eclipsing systems in the LMC. The errors on r_p, k and $e\cos\omega$ are given as the last digit(s) of the corresponding values. The null uncertainties stand for parameters which were fixed during the fit, though they were generally adjusted in a previous iteration. Eleven stars in the list are common to Michalska and Pigulski (2005): W03 No 114, 362, 1148, 1291, 1520, 1551, 1748, 1880, 1996, 2279 and 2462. The $T_{\rm eff}$ of cool stars were estimated from $B-V$ with the calibration of Hauck and Künzli (1996) or from $V-I$ with the calibration of Kenyon and Hartmann (1995) (their Table A5)

No	$I_{\rm quad}$	$P_{\rm orb}$	r_p	k	$e\cos\omega$	L_p(I)	$T_{{\rm eff}\ p}$	M_p	$T_{{\rm eff}\ s}$	M_s
114	15.125	2.98958	0.258 2	0.537 04	0.0704 00	0.842	34768	23.2	26930	11.1
362	15.266	3.37025	0.306 1	0.733 03	−0.0093 03	0.682	21999	9.6	20959	7.8
398	16.862	3.33782	0.176 4	1.666 47	0.0031 00	0.563	23133	7.6	8256	2.7
406	18.037	13.16448	0.315 5	0.427 09	0.0000 00	0.965	6387	6.1?	4056	1.6?
416	16.736	5.16691	0.175 3	0.473 05	−0.2392 09	0.829	19066	6.6	17758	4.6
460	16.618	2.68062	0.278 4	0.423 04	0.0005 00	0.866	19924	7.2	18539	4.8
670	16.604	4.14459	0.178 4	1.632 35	0.0058 00	0.561	21405	7.0	8226	2.9
810	16.743	3.31516	0.342 4	0.357 04	0.0061 00	0.896	14032	4.9	13591	3.1
841	17.861	5.40797	0.158 3	0.542 09	−0.0012 09	0.798	12686	3.5	11453	2.5
1148	17.224	2.16054	0.262 2	0.653 05	−0.0341 09	0.741	18293	5.7	16106	4.1
1208	17.602	2.58542	0.258 3	0.476 06	0.0192 18	0.867	16308	5.0	12647	2.8
1212	18.034	2.05110	0.245 7	0.497 09	0.0535 23	0.858	7348	5.9?	6440	2.7?
1263	17.076	6.12966	0.175 2	0.556 05	0.1714 06	0.762	14506	4.6	14514	3.6
1278	17.567	7.42814	0.168 3	0.413 07	0.0011 00	0.852	11135	3.3	11313	2.4
1291	16.898	5.23194	0.184 3	0.504 05	0.1656 08	0.816	17385	5.9	15840	4.0
1344	17.710	4.14494	0.233 5	0.505 08	0.0009 17	0.812	11088	3.2	10558	2.3
1381	16.860	79.17160	0.126 2	0.526 07	−0.0016 10	0.819	5552	8.6?	5214	4.7?
1450	15.439	2.72713	0.330 1	0.605 02	0.0001 05	0.765	31983?	14.6?	23557?	8.2?
1469	17.334	1.56400	0.316 3	0.482 04	0.0006 00	0.889	19480	6.1	13044	2.8
1520	16.082	1.33832	0.354 1	0.694 04	0.0000 00	0.720	27348?	10.8?	21970?	7.2?
1551	16.393	1.53805	0.349 2	0.778 05	0.0000 00	0.716	22260	7.9	17536	5.2
1566	17.566	3.23738	0.223 6	0.450 09	−0.0256 13	0.864	15696	4.7	13351	2.9
1675	17.574	3.39105	0.295 8	0.364 09	0.0088 00	0.886	11436	3.5	11451	2.4
1748	15.544	5.45728	0.248 2	0.535 03	0.0254 06	0.800	19860	8.4	18469	5.8
1880	17.202	1.34524	0.333 3	0.668 07	−0.0001 00	0.753	18153	5.4	15305	3.8
1996	17.045	1.82795	0.258 3	0.535 05	−0.0037 12	0.850	23050	8.1	16899	4.2
2009	17.570	3.22935	0.204 4	0.447 09	−0.1751 23	0.869	18001	5.5	13873	3.0
2073	17.007	2.89578	0.303 5	0.386 06	0.0159 16	0.883	14864	4.8	14108	3.1
2279	16.289	3.31752	0.257 2	0.691 07	−0.1347 09	0.680	18293	6.5	18112	5.5
2289	17.789	3.80450	0.196 4	0.568 10	0.0001 15	0.769	13681	3.9	13130	3.0
2380	17.374	2.83324	0.275 4	0.447 07	0.0939 20	0.852	14296	4.4	13320	3.0
2462	16.767	4.26120	0.189 2	0.617 06	0.0993 10	0.766	23378?	8.1?	17646?	4.9?
2482	16.272	8.07316	0.177 4	1.547 39	0.0000 00	0.616	8800?	9.6?	7050?	8.0?
2533	17.748	3.27882	0.269 6	0.640 11	−0.0394 19	0.736	10035	2.8	9311	2.2
2583	17.717	2.07166	0.266 4	0.567 09	−0.0346 20	0.788	14909	4.2	13389	3.0

keep in mind that some parameters were kept fixed in the fit, so that the errors displayed are rather lower limits to the real uncertainties.

The HR diagrams in Figure 1 show that all but four binaries host main sequence components.

3. Discussion

Many systems with total eclipses have also relatively shallow minima. Although this might be due to 3rd light in some cases, this cannot explain all of them. Many such systems are certainly pairs of main sequence stars with a relatively small ratio of masses and radii. Among them, those for which $J_s \sim 1$ are especially interesting: they are composed of two stars close to the turn-off, with an evolved primary and an unevolved secondary. The ratio of radii is often near 0.5. Such systems allow to probe efficiently the global metallicity and helium content of each component – as far as the stellar structure models can be trusted – according to the method of Ribas et al. (2000). Since the metallicity of the LMC is less than half that of the Sun, this can potentially improve the $\Delta Y/\Delta Z$ relation obtained by Ribas et al. on the basis of Galactic systems. Adding totally eclipsing systems of the SMC will further improve the determination of this relation, even providing an independent estimate of the primordial He abundance through extrapolation to zero metallicity.

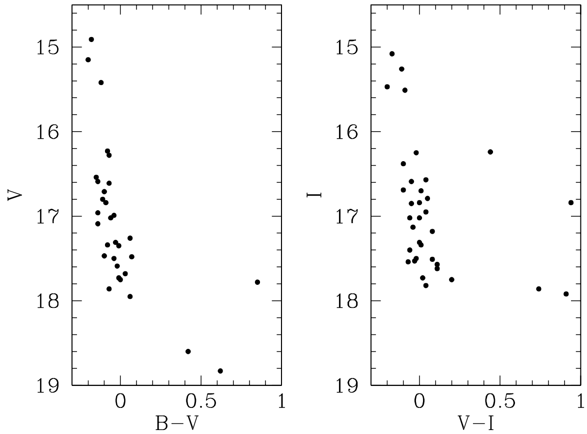

Fig. 1 HR diagram of the totally eclipsing systems in the LMC. Notice the three systems with giant components (a fourth one, in the I vs V-I diagram, is an Algol-type system)

However, the great interest of these systems has a price as regard to spectroscopic observations: the small k implies a small luminosity ratio – especially in the blue (λ domain of choice because of the number of spectral lines) if the secondary is cooler than the primary – so that high S/N spectra will be needed. The UVES instrument on the VLT, used with a wide slit, may be appropriate. Another possibility would be the use of FLAMES-GIRAFFE in the IFU "low" resolution mode ($R \sim 10000$), which would allow to observe a few systems simultaneously.

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