ON THE MASS-RATIO OF THE ECLIPSING BINARIES OF W UMa TYPE

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ABSTRACT. The discrepancy between the photometric and spectroscopic mass-ratio in W UMa-type systems is examined by using all the available mass-ratio data derived by modern techniques from photoelectric and radial velocity curves. The new additional data confirm, with few exceptions, the dependence of the discrepancy on the spectral type, first established by Niarchos and Duerbeck (1991). It is suggested that this discrepancy may be due to the influence of a global circulation pattern on the measured radial velocities.

Key words: binaries: eclipsing, stars: mass-ratio, stars: W UMa systems

Introduction

The eclipsing variables of W UMa-type constitute a well-known subclass of close binaries named as late-type contact binaries. In spite of the great amount of theoretical work done so far, our theoretical understanding of the detailed phases of close binary evolutionary sequencing is rather poor and there are enormous obstacles in pursuing close binary evolution in a poorly theoretical approach. According to Leung (1988), a possible solution to this problem could be an observational approach, in which a variety of observed binary systems representing different phases of the evolutionary scheme, could be used to establish an observational evolutionary sequence, which could serve as the constraints for the theoretical model construction.

At present, there is considerable controversy in the theoretical modeling of these systems, such as between the approaches of Lucy (1976), and Shu, Lubow and Anderson (1979). A precise determination of the physical parameters of W UMa stars is needed to check the models and to derive the evolutionary status for these stars.

Determination of the mass-ratio

During the last two decades two distinct developments had a great impact in deriving the basic astrophysical quantities describing the close binary systems. The first was the development of the Roche model for light curve analysis. The modern synthetic light curve codes, based on the Roche model, enable us to derive much more realistic and accurate physical parameters of close binary systems. Among those parameters the one of main interest is the mass-ratio of the system, which is necessary for the calculation of the absolute dimensions for single line spectroscopic binaries. For reasons discussed by Wilson (1978), only for W UMa systems with total eclipses the mass-ratio q_{ptm} can be determined with high accuracy by synthetic light curve techniques.

The second development is the cross-correlation method in deriving radial velocities for close binary systems. This technique has been successfully applied by several groups around the world (see for example Simkin 1974, McLean 1981a,1983a,b, Hrivnak 1993). A method using broadening functions has also been applied by several investigators, e.g. Brault and White 1971, McLean 1981, Becker 1984, Rucinski 1992). By using modern digital reduction methods of radial velocity determinations, it was possible to achieve excellent results in securing accurate radial velocity curves for many close binary systems.

Nevertheless, our knowledge of the radial velocity curves of W UMa systems is still limited. Since the spectral lines are very broad and blended, and since the objects are usually too faint for obtaining good spectral resolution at sufficient time resolution with telescopes of the 2 meter class, spectroscopic studies of contact binaries lack precision. .

Controversy on the mass-ratio

For an understanding of the evolutionary state of the W UMa systems, it is important to know the masses and the mass-ratio, if we hope to understand the evolutionary state of the W UMa systems. When the spectroscopic mass-ratio q_{sp} and the photometric one q_{ptm} differ, it is necessary to clarify the underlying cause. Discrepancies between q_{sp} and q_{ptm} have been noticed since the first determinations of photometric mass-ratios for contact binaries (Mochnacki and Doughty 1972a,b, Wilson and Devinney 1973). It seems that such discrepancies exist for also other W UMa systems, in contrast of Leung's (1988) statement that photometric and spectroscopic mass-ratios agree, when the latter are based on modern methods of radial velocity curve determination. We notice that half of Leung's examples are systems with partial eclipses, where q_{ptm} is determined with no high accuracy (Wilson 1978).

It is generally recognized that the photometric mass-ratio can be determined with high accuracy for systems showing total eclipses (Wilson 1978). An attempt to reconcile q_{sp} and q_{ptm} by a proper simultaneous light and velocity solution has been made by Wilson (1979) and Van Hamme and Wilson (1985) in the case of AE Phe. Nevertheless, they obtained $q_{sp} \# q_{ptm}$. It seems that the simultaneous solution does not really help in understanding the overall situation and very probably systematic effects may seriously influence the results. The problem of compromise between q_{sp} and q_{ptm} remains. If such discrepancies are real, the spectroscopic mass-ratio q_{sp} is likely the quantity which suffers from unexplained systematic errors.

A possible solution

Despite the use of cross-correlation methods to obtain good spectroscopic orbits and mass-ratios, some systems yield noticeably differing qs which cannot be explained by observational scatter. A hint towards the solution of the q-discrepancy was given by Niarchos and Duerbeck (1991). If the discrepancy is plotted as $\Delta q/q = 2(q_{sp} - q_{ptm})/(q_{sp} + q_{ptm})$ for systems with total eclipses as a function of spectral type, it is noted that q_{sp} is systematically larger than q_{ptm} for early spectral types (A, F), while it is smaller for types G and K.

The sample in Table 2 of Niarchos and Duerbeck (1991) was relatively small and the conclusion was not very convincing. We are able to enlarge our sample substantially so that we can reassess the validity of this discrepancy, and to test the Niarchos and Duerbeck (1991) hypothesis, whose main idea is as follows: in early type A systems, the smaller, cooler component 2 is irradiated by the hotter component 1, and the radial velocity amplitude K_2 is measured too small, resulting in $q_{meas} > q_{true}$. While, in late type W systems, the larger, cooler component 1 is irradiated and K_1 is measured too small, resulting in a $q_{meas} < q_{true}$.

In Table 1, some parameters for W UMa systems derived from light and radial velocity curves are listed. These data were taken from a recent work of Maceroni and Van't Veer (1996) and from Niarchos and Duerbeck (1991). The column "class" of Table 2 of Maceroni and Van't Veer (1996) should serve as a reference to judge the quality of the photometric solution and of the spectroscopic orbit. Only systems with four out of five classes of decreasing quality in radial velocity curve determinations and with three out of four classes of decreasing quality in light curve solutions were considered.

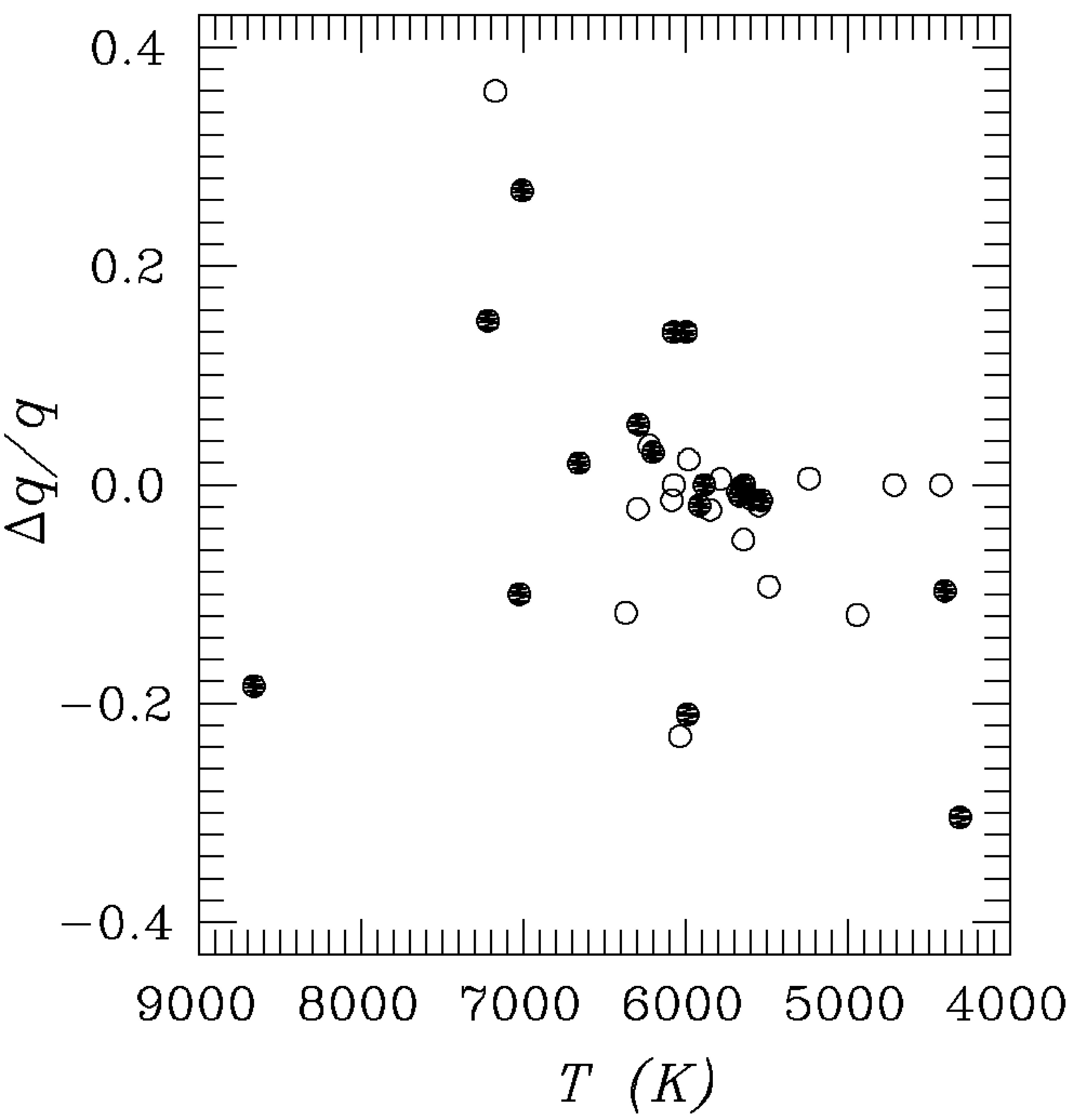

Figure 1: Discrepancy between spectroscopic and photometric mass-ratio of W UMa systems as a function of the mean temperature. Totally eclipsing systems are shown as filled circles, partially eclipsing ones as open circles.

Systems with total eclipses and modern methods of reduction are marked by an asterisk. $T_{\rm mean}$ is the mean temperature of the two components. The q-discrepancy for all systems listed in Table 1, defined in the same way as in Niarchos and Duerbeck (1991), is plotted in Fig. 1 as a function of the mean temperature. Totally eclipsing systems are shown as filled circles, partially eclipsing ones as open circles.

5. Conclusions

An inspection of Figure 1 reveals that the discrepancy between the photometric and spectroscopic mass-ratio changes as a function of the mean effective temperature (or the spectral type). The tendency is more clear for totally eclipsing systems. The most probable explanation of the dependence on the spectral type can be, according to Webbink (1977) and Kähler (1995), the large-scale streaming motions occuring between the luminosity-exchanging components, which distort the simple surface velocity field of two components in bound rotation. It was found that the streaming motion is different for hot and cool systems and this may explain the dependence on the spectral type (Niarchos and Duerbeck 1991). These effects affect the radial velocities and the spectroscopic mass-ratio in a systematic way. By using a much larger sample of W UMa systems with accurate photometric and spectroscopic mass-ratios, it was shown, with a few exceptions, the validity of Niarchos and Duerbeck (1991) hypothesis about the discrepancy between the photometric and spectroscopic mass-ratio.

References

Becker H.J.: 1984, *Ap.Space Sci.* **99**, 157.
Brault I.W., White D.R.: 1971, *As.Ap.* **13**, 169.
Hrivnak B.J.: 1993, in: *New frontiers in binary star research*, K.C.Leung and I.S.Nha, eds., *ASP Conf. Ser.* **38**, 269.
Kähler H.: 1995, *As.Ap.* **294**, 497.
Leung K.-C.: 1988, in: *Critical Observations Versus Physical Models for Close Binary Systems*, K.-C. Leung, ed., Gordon and Breach, New York, p. 93.
Lucy L.B.: 1976, *ApJ* **205**, 391.
Maceroni C., Van't Veer F.: 1996, *As.Ap.* **311**, 523.
McLean B.J.: 1981, *MNRAS* **195**, 931.
McLean B.J.: 1983a, *MNRAS* **203**, 341.
McLean B.J.: 1983b, *MNRAS* **204**, 817.
Mochnacki S.W., Doughty N.A.: 1972a, *MNRAS* **156**, 51.
Mochnacki S.W., Doughty N.A.: 1972b, *MNRAS* **156**, 243.
Niarchos P.G., Duerbeck H.W.: 1991, *As.Ap.* **247**, 399.
Rucinski S.M.: 1992, *AJ* **104**: 1968.
Shu F.H., Lubow S.H., Anderson L.: 1979, *ApJ* **229**, 223.
Simkin S.M.: 1974, *As.Ap.* **31**, 129.
Van Hamme W., Wilson R.E.: 1985, *As.Ap.* **152**, 25.
Webbink R.F.: 1977, *ApJ* **215**, 851.
Wilson R.E.: 1978, *ApJ* **234**, 885.
Wilson R.E.: 1979, *ApJ* **234**, 1054.
Wilson R.E., Devinney E.J.: 1973, *ApJ* **182**, 539.

Table 1. Parameters from light and radial velocity curves

n	Name	q_{ptm}	q_{sp}	T(mean) (K)	$\Delta q/q$	type	ref
1	CC Com*	0.518	0.470	4401	−0.097	W	2
2	V523 Cas*	0.571	0.420	4307	−0.304	W	1
3	RW Com	0.343	0.345	5239	+0.006	W	1
4	44i Boo	0.501	0.498	5677	−0.006	W	1
5	BX Peg*	0.371	0.372	5885	0.000	W	3
6	XY Leo	0.500	0.500	4713	0.000	W	1
7	BW Dra	0.280	0.280	6072	0.000	W	1
8	TY Boo	0.467	0.466	5652	−0.002	W	1
9	SW Lac	0.812	0.797	5549	−0.019	W	1
10	YY Eri	0.439	0.400	5487	−0.093	W	1
11	AB And*	0.491	0.491	5636	0.000	W	1
12	W UMa*	0.470	0.488	5997	+0.140	W	2
13	RZ Com*	0.436	0.430	5532	−0.014	W	1
14	BV Dra	0.411	0.402	6295	−0.022	W	1
15	AM Leo*	0.426	0.450	6290	+0.055	W	1
16	V752 Cen	0.300	0.311	6222	+0.036	W	1
17	U Peg	0.331	0.315	5642	−0.050	W	1
18	TX Cnc	0.596	0.530	6369	−0.117	W	1
19	SS Ari	0.302	0.295	5848	−0.023	W	1
20	AH Vir*	0.342	0.300	5592	−0.013	W	1
21	ER Ori	0.610	0.613	5785	+0.005	W	1
22	V502 Oph	0.377	0.370	6084	−0.014	W	1
23	AA UMa	0.551	0.564	5981	+0.023	W	1
24	AE Phe*	0.391	0.450	6073	+0.140	W	2
25	EZ Hya*	0.310	0.350	5988	−0.210	W	2
26	V508 Oph*	0.530	0.520	5915	−0.019	A	1
27	AU Ser	0.800	0.710	4940	−0.119	A	1
28	V566 Oph*	0.239	0.240	6659	+0.020	A	2
29	RZ Tau	0.372	0.540	7173	+0.360	A	2
30	AW UMa*	0.072	0.070	7025	−0.100	A	2
31	TV Mus	0.150	0.119	6034	−0.230	A	1
32	OO Aql*	0.843	0.835	5668	−0.010	A	1
33	AQ Tuc*	0.270	0.354	7007	+0.269	A	1
34	RR Cen*	0.180	0.210	7219	+0.150	A	2
35	V535 Ara*	0.361	0.300	8661	−0.184	A	1
36	VZ Psc	0.920	0.920	4426	0.000	A	1
37	Y Sex*	0.175	0.180	6200	+0.030	A	2

*systems with total eclipses

References:

1. Maceroni and Van't Veer (1996), 2. Niarchos and Duerbeck (1991), 3. Samec and Hube (1991)