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UBV photometry of wide visual double stars. V. Double stars with mainly K- and M- type primaries*,**

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Abstract. — We present UBV photometric observations of 55 wide visual double stars with K- and M- type primaries. Our observations have been compared and combined with information available in the literature. At least 58% of them are optical pairs.

Key words: stars: binaries: visual

1. Introduction

Many UBV observations of wide visual double stars have been performed in the sixties and early seventies by various observers.

In addition, Oblak (1978, 1980, 1989), Olsen (1982), Lindroos (1984, 1985), and Sinachopoulos (1989-1991) have also observed many wide visual binaries using the $uvby$, β system, starting from different motivations.

However, photometric information on wide visual binaries available in the literature is still very poor and fragmentary.

In a previous paper (Sinachopoulos & van Dessel 1993), we presented photometric observations of wide visual double stars with G - type primaries. We have concluded there, we could not exclude that 70% of the pairs presented are physical. This conclusion was based on the fact, that binaries' components observed, found to have similar astrophysical parameters (MK - classification, M_V, $\Delta(M_V)$ and $\log T_{\rm eff}$) and their magnitude difference is small.

We present here observations of wide visual double stars with K- and M-type primaries. The angular separation of the double star components in our sample has been again at least ten and usually less than twenty arcseconds.

2. Observations and photometric data

For the measurements of the present work, we have used the 50 cm telescope of ESO, La Silla. Fifteen nights have been allocated to our programme in October 1992, and eleven of them were photometric. Typical exposure times have been of the order of fifteen minutes for a full measurement of both components.

We decided to use the UBV system, although it does not provide luminosity class information, because its broad-band filters are more suitable for the B and U observations of about tenth V magnitude red stars at a 50 cm telescope.

The Johnson UBV system at the ESO 50 cm telescope is implemented with a blue-sensitive EMI 9789QB tube and a 2 mm UG2 as U, a 1 mm BG12 + 2 mm GG385 as B and a 2 mm GG495 as a V filter (Lindgren 1992).

While the blue end of the U band filter is determined by the atmosphere and depends on its transparency, the red end of the V band filter is determined by the EMI 9789QB, which is slightely less red-sensitive than the RCA type 1P 21 photomultiplier used originally by Johnson (1963).

A diaphragm of fifteen arcseconds has been used.

More than 30 UBV standard stars have been observed each night. We selected them from several publications, in an attempt to use a sample of photometric standard stars having almost uniform distribution in spectral types.

We checked the atmospheric extinction coefficients for variability during each night, but we did not find any significant. Therefore, SNOPY software has been used for the data reduction, which determines and uses only an average value of atmospheric extinction per night.

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*Based on observations made at ESO La Silla, Chile

**Tables 1 and 2 are also available at the CDS via anonymous ftp cdsarc.u-strasbg.fr or 130.79.128.5

All double star components have been observed in at least two different nights. In case that some of them were suspected to be variable, they were observed in addition twice or even more often in the same night.

Table 1 contains the photometric results and the number of observations of each component (last column).

It contains two lines per double star, one for each component. The second column in Table 1 contains the component designation and the following columns the mean values of the photometric measurements and their standard deviation.

The first column of the line of the component A contains the IDS1900 code of the double star as listed in WDS (Worley & Douglass 1984). The first column of the line of the component B on the other hand contains spectral type of component A and angular separation of the components in arcseconds as listed in WDS as well. Sometimes the spectral type of component B is also known and then it is given after the spectral type of component A.

Figure 1 gives the two colour diagram of our observations. The location of unreddened stars of luminocity class Ib, III, and V are indicated by dashed and full lines. The location of primaries is given by filled squares and of secondaries bye open ones. Error bars have been drawn and correspond to the values listed in Table 1.
We selected our targets from WDS taking into account the spectral types of the primaries listed there and choosing wide visual double stars with K and M type primaries. We remark that only five primaries (10%) in our sample have actually colours corresponding to stars of spectral type earlier than K0. On the other hand, 23 secondaries (40%) are stars earlier than K0. Fourteen giant or supergiant primaries (25%) can be clearly seen on the same diagram.

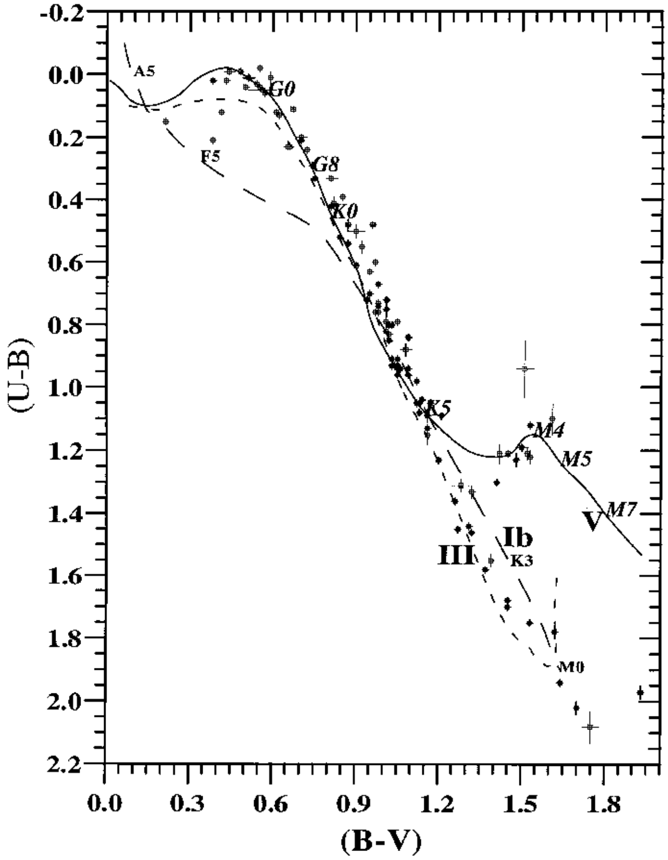

Fig. 1. The two colour diagram of our observations

We found in the literature *UBV* values of only six stars of our sample.

As these six stars have been observed more than once by different observers in the past, we were able to calculate the accuracy of the literature values, which was found: $\sigma_V = 0.03$, $\sigma_{(B-V)} = 0.04$, and $\sigma_{(U-B)} = 0.03$. The deviation of our *UBV* photometry of these six stars from the calculated literature mean values is $\sigma_V = 0.03$, $\sigma_{(B-V)} = 0.03$, and $\sigma_{(U-B)} = 0.03$ mags as well.

3. Discussion

In the Univ. of Michigan Catalogue (Houk & Cowley 1975), the 7th Catalogue of MK Spectral Classifications (Buscombe 1988), and the SIMBAD data bank in Strasbourg, we found two - dimensional Spectral classification of 26 double star components in our sample (25%).

We combined this information with the physical parameters of the stars given by Schmidt-Kaler (1982), in order to get the average M_V, $(B-V)_0$, and $(U-B)_0$ values of these objects. Estimates of reddening indices $E(B-V)$ and $E(U-B)$ have been then calculated. From the formula $A_V = 3.2\ E(B-V)$, we derived A_V values and then distances of the pairs as well as their projected linear separation were estimated. Of course, this projected linear separation is meaningless for the optical pairs.

Since a large percentage of wide double stars is considered to be optical pairs, we examine whether it is possible that the two components of each one of them are at the same distance from the Sun, so that they have probably a common origin. In addition, if the components are at the same distance and their projected separation is not larger than a few hundred astronomical units (AU), the pairs can be considered to be physical.
For investigating that, we combined the results of our observations (components magnitudes and colours) with the "physical parameters of the stars" listed in Schmidt-Kaler (1982). From this paper, we made wide use of the "absolute magnitudes of the MK system" (Table 13, page 18), the $(B-V)_0$ (page 15) and the $(U-B)_0$ (page 16) in the MK system. The absolute magnitudes there have a precision of 0.3 mags, the $(B-V)_0$ values of 0.02 mags and the $(U-B)_0$ ones of 0.03 mags.

We discuss below each wide double star separately.
00072S3201: component A is a K2III star. Since

Table 1. UBV photometry of wide double stars with K- and M- type primaries

IDS_{1900}	Co.	V	σ_V	$(B-V)$	$\sigma_{(B-V)}$	$(U-B)$	$\sigma_{(U-B)}$	$N_{\mathrm{obs.}}$
00072S3201	A	9.70	.01	1.06	.01	.94	.01	3
K0 14.9	B	11.54	.01	1.16	.01	1.15	.03	4
00149N0544	A	11.89	.01	.51	.02	.01	.01	4
K0 20.5	B	13.09	.02	.90	.03	.50	.02	2
00283S2003	A	8.56	.01	1.20	.01	1.23	.01	2
K0 18.6	B	12.29	.02	.73	.01	.25	.02	4
00347S6322	A	9.66	.01	1.18	.01			4
K0 26.0	B	12.43	.02	.56	.05	.05	.01	7
00355S0056	A	10.59	.01	.70	.01	.21	.01	4
K 14.1	B	11.01	.01	1.02	.01	.83	.01	4
00422S5233	A	8.67	.01	1.02	.01	.80	.01	2
K0G 27.5	B	10.40	.01	.55	.01	-.02	.01	2
00543N0015	A	7.66	.01	1.45	.01	1.70	.01	4
K0 18.3	B	8.91	.01	.98	.01	.73	.01	4
00543S2530	A	9.16	.01	1.13	.01	1.05	.01	2
K0 28.7	B	12.28	.01	1.01	.01	.75	.03	7
01135S0123	A	8.04	.05	.81	.01	.42	.01	3
K0 27.8	B	10.70	.01	1.42	.01	1.21	.03	8
01284S4146	A	9.17	.01	.95	.01	.70	.01	2
K0G 18.5	B	10.39	.01	.61	.01	.12	.01	2
01304S5950	A	8.36	.01	1.01	.01	.72	.01	4
K0 22.5	B	11.96	.01	1.01	.01	.79	.03	7
01345S4545	A	10.37	.01	1.50	.02	1.19	.01	4
K 15.4	B	10.62	.01	1.52	.01	1.21	.02	4
02068S3608	A	10.15	.01	1.48	.01	1.23	.02	2
K0 14.1	B	11.79	.01	1.53	.01	1.22	.02	6
02086S6330	A	9.33	.01	.98	.01	.67	.01	2
K0 18.1	B	12.46	.01	.95	.01	.63	.01	6
02142S0718	A	9.07	.01	1.13	.01	1.08	.01	2
K0 23.9	B	12.16	.01	.70	.02	.20	.01	5
02320S6938	A	9.03	.01	1.21	.01	1.09	.01	4
K0 16.3	B	12.20	.02	.85	.01	.39	.01	4
02324S4852	A	8.25	.01	.98	.01	.74	.01	2
K0 24.2	B	11.74	.01	.97	.01	.76	.01	4
02362S4926	A	10.36	.01	.38	.01	.02	.01	4
K2 15.1	B	10.69	.01	.48	.01	-.01	.01	4
02516S6445	A	9.56	.01	.84	.01	.52	.01	2
K0 12.7	B	10.24	.03	1.01	.01	.82	.01	2
03077S0317	A	8.68	.01	1.09	.01	.96	.01	2
K0 20.2	B	11.52	.01	1.08	.02	.88	.02	4
03173S1338	A	8.84	.01	1.16	.01	1.13	.01	4
K0 21.0	B	11.54	.01	.50	.01	.04	.01	4
03186S1036	A	8.92	.01	1.32	.01	1.46	.01	2
K0 24.3	B	11.60	.02	.44	.02	-.01	.01	3
03202S5021	A	8.56	.01	1.09	.01	.94	.01	4
K0 14.7	B	10.17	.01	1.45	.01	1.21	.01	7
03285S0253	A	8.70	.01	1.02	.01	.85	.01	4
K0 25.8	B	10.64	.01	.43	.01	.02	.01	4
03312N0555	A	10.11	.01	.74	.01	.29	.01	4
K0 22.4	B	11.89	.01	.81	.02	.33	.01	5
03454S5045	A	9.24	.01	1.31	.01	1.44	.01	2
K2 14.0	B	10.83	.02	.51	.01	.01	.01	2
04082S3402	A	8.94	.01	1.14	.01	1.04	.01	7
K0 29.8	B	10.15	.01	1.39	.01	1.55	.02	6

Table 1. continued

IDS_{1900}	Co.	V	σ_V	$(B-V)$	$\sigma_{(B-V)}$	$(U-B)$	$\sigma_{(U-B)}$	$N_{obs.}$
04096S1648	A	8.50	.02	1.64	.01	1.94	.01	5
M1 16.4	B	10.91	.01	.87	.01	.48	.02	5
04183S0514	A	7.62	.01	1.27	.01	1.45	.01	2
K2 17.4	B	9.66	.01	.66	.01	.23	.01	2
04488N0713	A	8.20	.01	.87	.01	.54	.01	2
K0 16.6	B	8.36	.01	.90	.01	.61	.01	2
05016S1534	A	9.02	.01	1.45	.01	1.68	.01	4
K0 28.8	B	11.26	.01	.96	.01	.48	.01	5
05037S3946	A	9.45	.01	1.12	.01	1.05	.01	2
K0G5 24.4	B	9.93	.01	.92	.01	.55	.02	2
05351S4116	A	9.72	.01	1.03	.01	.93	.01	2
K 20.7	B	11.78	.01	1.05	.01	.79	.01	4
05418S0318	A	8.50	.01	1.03	.01	.80	.01	4
K 25.0	B	8.87	.01	.38	.01	.21	.01	4
06155N0547	A	8.08	.01	1.93	.01	1.97	.02	7
M 28.7	B	10.28	.01	.21	.01	.15	.01	4
06165S2934	A	7.93	.02	1.05	.01	.96	.01	2
K0 13.2	B	9.34	.01	.62	.01	.13	.01	2
06214S0146	A	9.17	.01	1.09	.01	.84	.01	6
K0 25.4	B	10.39	.01	.54	.01	.03	.01	8
06216N0408	A	8.63	.01	1.03	.01	.91	.01	4
K0 13.8	B	8.86	.02	1.75	.03	2.08	.05	18
06225S2645	A	9.55	.01	1.05	.01	.93	.01	3
K2 10.9	B	9.75	.02	.98	.01	.76	.01	4
06297S5732	A	7.87	.01	.94	.01	.72	.01	2
K0 18.8	B	11.41	.01	.67	.01	.11	.01	3
06523S2231	A	7.33	.01	1.26	.01	1.36	.01	2
K0F 23.2	B	8.47	.01	1.05	.01	.91	.01	2
19181S3305	A	9.18	.01	1.17	.01	1.05	.01	4
K0F8 25.8	B	9.85	.01	.41	.01	.12	.01	4
19276S2716	A	8.88	.02	1.53	.01	1.75	.01	4
K0G5 24.0	B	9.63	.01	.97	.01	.60	.01	4
20166S2033	A	9.50	.01	1.12	.01	.98	.01	4
K0 17.6	B	10.21	.01	.72	.01	.24	.01	4
20298N0453	A	8.29	.02	1.62	.01	1.78	.02	3
M 24.3	B	10.21	.01	1.28	.03	1.31	.02	4
21369N0640	A	9.92	.01	1.70	.01	2.02	.02	5
M2 25.6	B	11.59	.01	.82	.01	.41	.02	6
21399S1407	A	8.58	.01	1.37	.01	1.58	.01	3
K0 26.8	B	11.60	.01	.57	.01	.06	.01	3
22140S1118	A	8.78	.02	1.16	.01	1.09	.02	7
K2 11.7	B	9.94	.01	.55	.01	.04	.01	4
22333S2108	A	9.11	.01	1.53	.01	1.12	.01	4
M1 21.4	B	11.47	.02	1.61	.01	1.10	.05	9
22512S3928	A	10.24	.01	1.04	.01	.93	.01	4
K0 11.8	B	12.63	.04	.59	.01	.01	.02	7
22534S5354	A	9.52	.01	1.05	.01	.91	.01	4
K0 18.1	B	11.59	.01	1.32	.01	1.33	.02	4
23171S1331	A	9.65	.01	1.01	.01	.75	.02	4
K0K0 20.	B	10.48	.03	.65	.01	.23	.01	5
23309S4909	A	1.07	.01	1.41	.01	1.30	.01	4
K7 29.	B	12.33	.02	1.51	.03	.94	.09	9
23325N1203	A	10.31	.01	.75	.01	.33	.01	2
K0K0 20.4	B	10.42	.01	.80	.01	.36	.01	2

Table 2. The astrophysical data

No.	IDS_{1900}	Co.	MK-class.	$E(B-V)$	$E(U-B)$	A_V	M_V	Dist. [pc]	Separ. [AU]	Nature
1	00072S3201	A	K2III	-0.10	-0.22	-0.32	0.5	800		OPT
2	00283S2003	A	K1III	0.13	0.22	0.42	0.6	290	5400	CO?
		B	G0V							
3	00347S6322	A	K0III/IV	0.18		0.58	0.7	475		OPT
		B	F3/4V						12400	CO?
4	00422S5233	A	G8III	0.08	0.10	0.26	0.8	330	9000	CO?
5	00543N0015	A	K5II	-0.04	-0.04	-0.13	-2.3	1040		OPT
6	00543S2530	A	K0III	0.13	0.21	0.42	0.7	400		OPT
7	01135S0123	A	K1V	-0.04	-0.12	-0.13	6.15	25	700	PHY(?)
8	01284S4146	A	K1III	-0.12	-0.31	-0.38	0.6	610		OPT
9	01304S5950	A	G6III	0.13	0.13	0.42	0.9	260		OPT
10	02516S6445	A	K4V							
		B	G8V	0.26	0.22	0.83	5.5	45	570	PHY?
		B	K0V	0.19	0.07	0.61	5.9	40	500	
11	03077S0317	A	K1III	0.01	-0.06	0.03	0.6	410		OPT
12	03202S5021	A	K3V	0.13	0.14	0.42	6.65	20	300	PHY?
		A	K5V	-0.06	0.16	-0.19	7.35	20	300	PHY?
		B	K7V-M0V							
13	03454S5045	A	K2:III	0.15	0.28	0.48	0.5	450	6300	
14	04082S3402	A	K3III	-0.02	-0.35	-0.06	0.3	550		OPT
15	04096S1648	A	M2III	0.04	0.07	0.13	-0.6	620		OPT
16	05016S1534	A	K2III	0.29	0.52	0.93	0.5	330		OPT
17	05037S3946	A	K2III	-0.04	-0.11	-0.13	0.5	650	15900	CO?
		B	G0/4III							
18	05351S4116	A	K2III:	-0.13	-0.23	-0.42	0.5	850		OPT
19	06155N0547	A	M3Ib	0.24	0.01	0.77	-4.8	2600		OPT
	06155N0547	A	M3II	0.33	0.20	10.06	-2.6	840		OPT
20	06165S2934	A	G8III	0.11	0.26	0.35	0.8	225		OPT
21	06297S5732	A	G8III	0.00	0.02	0.00	0.8	310	5800	CO(?)
		B	G1V							
22	19181S3305	A	K0III	0.17	0.21	0.54	0.7	390	10000	
23	19276S2716	A	K3III	0.26	0.36	0.83	0.3	360		OPT
	19276S2716	A	K4III	0.13	0.16	0.42	0.0	430		OPT
24	21399S1407	A	K3III	0.10	0.19	0.32	0.3	390	10400	CO?
		B	F V							
25	22333S2108	A	M0Vpe	0.13	-0.10	0.42	8.8	9.5	200	PHY
		B	M4V							
26	22534S5354	A	K0III	0.05	0.07	0.16	0.7	540		OPT

component B is a slightely cooler star than A ($\Delta(B-V)$=0.10, and $\Delta(U-B)$=0.21), let us see whether it can be at the same distance with A:

- B cannot be a luminosity class III and at the same distance with A component, because in such a case ΔV should be almost zero and not $\Delta V = 1.84$ mags as measured.
- it cannot be a sub-giant (IV) or a main sequence star because the measured ΔV is too small.
- obviously, it cannot be of luminocity class II or I, because it should be brighter than A.

We conclude that the two components are not in the same distance, what means that the pair is an optical one.

We proceed the other pairs now using similar argumentation. In case that the photometric and spectroscopic parameters of the two components of a double star discussed below are as incompatible as in the above case of 00072S3201, we will simply write that this double star "is an optical pair".

00283S2003: for the same reasons, if the components are at the same distance B cannot be a luminosity III or IV star, but it can be a G0V star, which fits excellently to the observed differences in magnitude and the two colours. It cannot therefore be excluded that the components have

common origin.
00347S6322: if A is a giant (luminosity class III), it cannot be excluded that B is a F3/4V and that the two stars have common origin. Then A is an evolved much more massive star than B does. On the other hand, if A is subgiant the pair is optical.
0042222S5233: A is a G8III type star. B could be an early F-type IV or V star. Given the uncertaintes, it cannot be excluded that the stars have common origin.
00543N0015: is an optical pair.
00543S2530: is an optical pair.
01135S0123: A is a K1V star. It cannot be excluded that B is a M0V star and the pair a physical binary.
01284S4146: the K1III value given in the literature for A is probably erroneous, since it leads to highly negative reddening values. If A is not giant, it cannot be excluded that the stars have common origin. Our observations indicate that B is a G1/2V star and the pair optical.
01304S5950: is an optical pair.
02516S6445: Component B is given in the literature as a K0V or a G8V star. The reddening values calculated on this basis are perplexing, since they are in both colours too high. If we disregard this index, A could very well be a K4V star. In this case, and taking into account the small projected components separation, the system could be physical.
03077S0317: Component A is a K1III star. The two colours of the componets are very similar, which intuitively rizes suspicions of pair's physicity. The large magnitude difference on the other hand, shows that B component is probably an early K-type IV or V star, which proves that the pair is optical due to very different component ages.
03202S5021: its nature depends on the secondary's luminosity class. B is probably a late K-type or M0 main sequence star and the pair is then physical. But it cannot be excluded that B is a giant or a supergiant and the pair an optical one.
04082S3402: is an optical pair.
04096S1648: is an optical pair.
05016S1534: is an optical pair.
05037S3946: B can be an early G-type giant and the pair have then common origin components.
05351S4116: the very negative colour-excess values indicate a probably erroneous primary's MK classification (K2III:). If this value is correct the pair should be optical.
06155N0547: is obviously an optical pair.
06165S2934: is an optical pair.
06297S5732: B is probably a G1V star and the pair has common origin components.
19276S2716: is an optical pair.
21399S1407: it can logically be that B component is an early F-type main sequence star and the pair has common origin components.
22333S2108: it is probably a physical pair with a M4V type secondary and approximately 200 AU projected component separation.
22534S5354: it is one more optical pair.

We present the above astrophysical information in Table 2. In case of optical pairs, we do not give obviously the projected linear separation of the two components.
We see there that at least 15 pairs out of 26 (58%) are optical. Four (15%) could be physical and seven (27%) could have common origin components.

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