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MAXIMUM SEPARATIONS AMONG CATALOGED BINARIES

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ABSTRACT

We classified many of the widest common-motion binaries listed in the Aitken catalog and list 72 physical pairs with known photoelectric photometry, 31 physical pairs without good photometry, and 27 optical pairs. We find that as a function of primary types, the physical systems have upper limits to their separations that are exceeded by some of the optical pairs. The fact that optical pairs occur with larger separations implies that the limits are real ones and not just catalog limitations. Those limits (in AU) are expressed by 2500 $\mathscr{M}_1^{1.54}$ for B5–K0 main-sequence primaries. The same limits hold for the Trapezium and hierarchical systems studied previously.

Subject headings: stars: binaries — stars: spectral classification — stars: visual multiples

I. INTRODUCTION

The maximum separations of visual binaries are of interest in assessing the effects of chance encounters with neighboring stars and molecular clouds, and the effects of the general galactic potential. Theoretical studies of gradually increasing sophistication (Ambartsumian 1954; Heggie 1975, 1977; Retterer and King 1982; Hut and Bahcall 1983; Hut 1983) show that during the lifetime of the Sun, binaries in the solar vicinity should have maximum separations of 10,000–20,000 AU. Observations obtained or used by Ambartsumian (1954), Bahcall and Soneira (1981), Retterer and King (1982), and Latham *et al.* (1984) confirm those estimates. The broader question of maximum separations for all ages, not just for older stars, has been treated by Öpik (1924) and Abt (1986), who found separations of 20,000–115,000 AU for OB primaries, 10,000–20,000 AU for A dwarfs, and 2,000–5,000 AU for FGK dwarfs. Qualitatively, those results seem logical because one would expect that in open clusters, whose outer diameters are 20–25 pc or 4–5 × 10^6 AU, binaries of a few percent of those diameters can form and then can exist in the field for short times.

We should be careful to distinguish between stable physical binaries and comoving pairs. There are known comoving stellar pairs (Vandervoort 1968; Lü and Upgren 1973; Eggen 1986, 1987; Luyten 1987) with separations up to 20 pc. Most of these components have similar, but not identical, motions; that is, the differences are often larger than the observational errors. Evidence of similar metallicity within pairs (Eggen 1987) confirm the probability arguments (Vandervoort 1968) that they have common origins. These are probably common members of disintegrating open clusters. Because of the velocity dispersion within clusters, cluster members have similar, but not identical, space motions.[2] They are not binaries because they probably do not exhibit closed orbital motions. Although they are useful for evolutionary studies because of their common origins, they should not be used as evidence for the dynamical stability of very wide (> 1 pc) pairs for long time intervals.

There is one objection to the evidence by Öpik (1924) and Abt (1986) for an evolutionary decrease in binary separations with primary type.[3] Both those authors depended upon published catalogs of known binaries. But conservative catalogers, such as Aitken (1932), did not include pairs above certain limits (roughly 20″) on grounds that most such systems are only optical ones. More specifically, at $V = 8$ mag the limit used by Aitken was 16″. For B0 V and G0 V primaries, that separation limit corresponds to 35,000 and 800 pc, respectively, for no reddening. So perhaps the limits found by Öpik and Abt are catalog limits, rather than physical limits to binary separations.

One approach to determining the separation limits in binaries is to avoid using cataloged pairs. That approach is being used in a current project on Selected Area 57 in which Bahcall, Soneira, Latham, Mazeh, etc. are searching for wide binaries by obtaining new photometric, radial velocity, astrometric, spectroscopic, etc. data and are not depending upon cataloged data. Another approach is the one described below.

While it is true that Aitken did not include pairs with separations greater than 10″–40″ for primary magnitudes in 6–9 mag, he did violate those limits for triple systems. That is, if a close pair fell within his limits and it had a third companion outside the limits, he published the data for all three stars. Thus one can find in his catalog systems with up to 5 times larger separations than his quoted limits.

The reason for studying cataloged pairs is because they usually have data for long time intervals that show whether the members have common motions. A common motion (i.e., no significant variation in separations and angles that cannot be attributed to orbital motion) is good evidence for a physical association among nearby stars; however, for distant pairs (for which most proper motions are small), it is a necessary but not sufficient evidence for a physical association.

Specifically we will select pairs and triplets in the Aitken

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[2] A good example is ADS 12913A = 17 Cyg and ADS 12889AB at 792″; they have proper motions of $\mu = 0\overset{''}{.}445 \pm 0\overset{''}{.}002$ and $0\overset{''}{.}431 \pm 0\overset{''}{.}004$ per year as given by the SAO catalog.

[3] Öpik's data show clearly that early-type visual binaries have greater angular separations on the average at the same apparent magnitudes than late-type binaries, even though the former are more distant. Therefore their separations in AU are much greater on the average.

catalog with separations in excess of 10″ and astrometric evidence during at least 30 years to show common motions. From MK spectral classification and the resulting spectroscopic distances, we will check on physical versus optical associations. Then we will see whether, at a given primary type, the physical pairs show an upper limit with only optical pairs showing greater separations. We will avoid members of known clusters, associations, and moving groups on grounds that it may be difficult to know the difference between distant binary components and other cluster members.

Some of the results, but not the data, of this study were presented in a symposium talk (Abt 1987).

II. OBSERVATIONAL DATA

The spectra were obtained with the white Cassegrain spectrograph on the Kitt Peak 2.1 m telescope. The reciprocal dispersion was 39 Å mm^{-1}, the resolution was 1.0 Å, and the spectrum width was 1.2 mm for most of the spectra but smaller for stars fainter than $B = 9$ mag. The spectra were classified on a Boller & Chivens spectrocomparator against similar standards listed by Morgan and Keenan (1973), Keenan and McNeil (1976), and Morgan, Abt, and Tapscott (1978).

The 163 new spectral classifications are listed in Tables 1–3, arranged according to Aitken (1932) number (ADS) and component. The second column lists the Henry Draper numbers (HD). The third column gives the MK classification. Some (94) of the types come from published sources; those sources are identified in the footnotes. The qualities of the types are listed in the next column according to spectrum widths: qualities "a," "b," and "c" mean spectra 1.2, 0.6, and 0.3 mm wide, respectively. Quality "a" spectra have classification accuracies (Abt 1983) of ±1.0 subclasses in type and ±0.7 luminosity classes; quality "c" spectra are estimated to have about 1.5 times those errors.

The classifications in Tables 1–3 include newly-discovered Am and Ap stars, λ Boo stars, double-lined spectroscopic binaries, and a strange spectrum (ADS 12259B) that needs confirmation.

The cataloged magnitudes of the fainter visual components are usually based on visual estimates calibrated against BD and CD magnitudes; the latter are systematically too bright near 10th mag. The dispersions are (Abt 1986) typically 0.75 mag, and the systematic errors are similar numbers. Thus it is important to have photoelectric photometry to obtain valid distances. The determination of reddening through such photometry is an important second need. Table 1 lists the 72 physical pairs in which the primaries, at least, have available photoelectric photometry. If the companions have only photographic or estimated photometry, the magnitude differences, ΔV, are quoted to one decimal place only. The photoelectric photometry was taken from the compilation by Blanco *et al.* (1968). Most of those data used here were obtained by Eggen (1963, 1966). Some magnitudes were corrected for the inclusion of a second star. Table 2 lists 31 physical pairs with new MK types but without photoelectric photometry; those data are not used below.

For each MK type we can obtain the average absolute magnitude, M_V, from Blaauw (1963). Because spectral types are binned while absolute magnitudes are continuous, the errors in the latter are partly due to the bin dimensions and partly to the classification errors (as given above). The errors in M_V due to the binning range from about 0.2–1.0 mag near the main sequence and more among supergiants.

Applied to the components in a stellar pair, the two MK classifications can be used to obtain individual reddening-free distance moduli, $M_V - V_0$, or one can compare the differences between the two absolute magnitudes, ΔM_V, and two apparent magnitudes, ΔV_0. The latter portrayal is used in Tables 1–3. Considering the dimensions of the classification errors and bins, we estimate that physical systems should have $\Delta M_V - \Delta V_0 < 1.5$ mag; if the differences are larger, the systems are probably optical. Only in a half dozen systems with $\Delta M_V - \Delta V_0 = 1.5 \pm 0.3$ mag is there ambiguity as to whether the systems are physical or optical. Table 3 lists the 27 pairs judged to be optical. Two triple systems (ADS 12893, 16321) have a physical secondary and an optical secondary each; they are listed in both Tables 1 and 3.

In Table 1 the distances listed are obtained from an average of both components if they both have photoelectric photometry, or from the primary only if only that star has such photometry. The median distance is 88 pc. The separations of the secondaries are given in the last two columns in seconds of arc and AU. These separations average 37″.2 (twice the Aitken catalog limit), and 13 secondaries (18%) have separations greater than 60″.

In Table 3 the distances are given from the primaries if photoelectric photometry is available, and only those systems are discussed below. The median distance of those is 88 pc, identical to that for the physical pairs. The last column gives the secondary separations in seconds of arc. The mean is 62″.9, and nine secondaries (33%) have separations greater than 60″. The product of the distances and the separations give the separations in AU *if* the secondary were a physical one; that quantity is used below.

III. DISCUSSION

Figure 1 shows the separations in AU that exceed 1000 AU as a function of the earliest type in each system, or the main-sequence turnoff type in the cases of giants and supergiants. The physical systems (from Table 1) are plotted with open circles. The optical systems (from Table 3) are plotted with Xs with the primary types and with the separations that the secondaries would have if they were physically associated. Optical pairs can occur at any separations.

Note that the physical systems have an upper envelope that is represented by the solid line. Initially a hand-drawn curve was sketched in; then because the spectral type scale is not a smoothly varying function of temperature or primary mass, we converted (Allen 1973) to primary mass and derived the limiting separations as

$$d_{\mathrm{lim}}(\mathrm{AU}) = 2500\mathscr{M}_1^{\,1.54}\,, \qquad (1)$$

where the primary masses, $\mathscr{M}_1$, are in solar units. The conversion back to spectral types results in the sharp bends in the solid line in Figure 1. This relation holds only for B5–K0 main-sequence primaries. It implies that $\mathscr{M}_1^{\,3} d_{\mathrm{lim}}^{\,-2} \doteq$ constant.

Note that above the curve in Figure 1 only optical systems occur. The astrometric observers who measured these systems usually did not know their spectral classifications or distances and therefore did not know which systems are physical or optical. Thus their selection of systems is unbiased by a knowledge of physical association. Therefore if physical systems did exist with separations above the line shown in Figure 1, they would have been observed and cataloged just as the optical

TABLE 1

PHYSICAL SYSTEMS WITH PHOTOELECTRIC PHOTOMETRY

ADS	HD	Classification	Quality	ΔM (mag)	ΔV_0 (mag)	Distance (pc)	Separation (")	Separation (AU)
1A	225009	G9 III	a			125		
B	225010	A1 Vn	a	0.6	1.48		15.2	1900
47A	4	F3 V	a			112		
B	...	F6 V	b	0.6	1.60		12.7	1400
191A	1061	A9 V(SB2)	a			69		
B	...	F3 V	a	1.3	1.61		11.6	800
324A	1942	F7 V	b			73		
B	1941	F8 V	b	0.2	0.24		33.0	2400
426A	2760	A5 IV-V^{a}	...			94		
BC	2761	G1 V	b	2.3	1.59		79.2	7400
903A	6479	F3 V	a			54		
B	6480	F5 V	a	0.3	0.91		33.0	1800
988A	7215	A0 V^{a}	...			204		
B	...	A3 IV^{a}	...	0.2	1.30		19.5	4000
1003A	7439	F6 V^{a}	...			24		
B	7438	G9 V^{a}	...	2.2	2.70		49.7	1200
1040AB	7710	B9.5 V^{a}	...			187		
C	...	Am(K/H/M=A6/A9/F2)^{a}	...	1.8	1.87		10.0	1900
1209A	9311	B5 Iab	a			2520		
B	...	B3 IV	b	3.8	3.2		13.8	35000
1212A	9451	Am(K/H/M=A5/F2/F3)	a			74		
B	...	G2: V	b	1.9	0.7		17.9	1300
1334A	10293	B7 III	a			342		
B	...	Am(K/H/M=A2/A6/A5)	b	3.5	2.4		19.6	6700
1563A	11973	F0 IV	a			42		
B	...	F7 V	a	1.7	2.60		37.4	1600
1630A	12533	K3 IIb^{b}	...			56		
BC	12534	B9 V^{c}	...	1.3	2.58		10.0var	560
1683A	13294	B9 V	a			106		
B	13295	A1 Vn	a	0.9	0.47		16.6	1800
1703A	13612	F8 V	a			30		
B	...	G1 V	a	0.6	2.07		16.2	490
1717A	13633	B8 III^{a}	...			410		
B	...	B9 IV^{d}	...	0.8	1.2		24.1	9900
1752A	14082	F7 V	a			46		
B	...	F9 V	a	0.4	0.75		14.1	650
1763A	14189	F3 V	a			95		
B	...	F3 V	a	0.0	1.06		11.0	1000
1982A	16246	F5 V	a			46		
B	16232	F7 V	a	0.6	0.59		38.6	1800
2042A	16694	B9.5 V	a			232		
C	...	A8 V	b	1.6	2.43		65.7	15200
2048A	16705	B8 III	a			598		
B	16693	B9 IVp(Hg,Mn,Eu)	a	0.8	0.06		20.0	11900

TABLE 1—*Continued*

ADS	HD	Classification	Quality	ΔM (mag)	ΔV_0 (mag)	Distance (pc)	Separation ('')	Separation (AU)
2270A	18537	B7 V[d]	...			151		
B	18538	B9 V[d]	...	0.7	1.46		12.1	1800
2592A	21769	Am(K/H/M=A3/A7/F0)[e]	...			90		
B	...	F2 V[e]	...	0.8	1.50		20.4	1800
2650A	22399	F5 V	a			40		
BC	...	G8 V	b	2.3	1.93		46.1	1800
2699A	22951	B1.5 IV[d]	...			417		
B	...	A1 Vn[d]	...	4.9	5.09		20.0	8300
3085A	26923	G0 IV[c]	...			42		
B	26913	G3 V[c]	...	2.2	0.63		65.5	2800
3161A	27638	B9 Vnn[d]	...			84		
B	...	F8 V[d]	...	3.7	3.05		19.4	1600
3179A	27778	B3 V[d]	...			206		
B	...	A1 V[d]	...	2.9	1.82		28.9	6000
3318A	29173	Am(K/H/M=A1/A6V/A7)[e]	...			78		
B	29172	A8 V[e]	...	0.2	1.0		12.8	1000
3468A	30584	A0 II-IIIp(Si)[e]	...			788		
B	...	B9.5 V[e]	...	2.8	1.2		10.2	8000
3579A	31764	B7 III[d]	...			266		
B	31747	B8 V[d]	...	1.7	1.50		39.2	10400
C	...	A0 V[d]	...	2.6	2.8		54.4	14400
3910A	34798	B5 Vs[d]	...			260		
B	34797	B7 Vp(He wk)[d]	...	0.6	0.19		39.3	10200
5103A	45542	B7 IIIn + shell(HI)[d]	...			183		
B	...	Am(K/H/M=B9/A0/A1)[d]	...	2.6	3.85		112.5	20600
5166Aa	46136	F8 III[f]	...			108		
B	...	F6 IV-V[f]	...	0.9	0.67		20.0	2200
6208A	60855	B4 III:n + shell(HI)[d]	...			468		
C	...	A0 V[d]	...	3.6	4.01		19.6	9200
6588A	67159	B9.5 IV[c]	...			184		
BC	...	A1 V[c]	...	1.5	1.70		30.9	5700
6746AB	69894	F7 V[g]	...			74		
Cc	...	G7 V[g]	...	1.6	1.29		38.6	2900
7311A	80586	G8 III[c]	...			68		
B	80550	F4 V[c]	...	2.7	2.24		229.4	15700
7705A	88849	Am(K/H/M=A4/F1/F2)[c]	...			82		
B	88850	Am(K/H/M=A5/F0/F1)[c]	...	-0.2	0.70		16.7	1400
8413A	105028	K1 III[g]	...			202		
B	...	G0 V[g]	...	3.6	3.63		10.2	2100
8434A	105422	F8 V[c]	...			60		
B	105423	F9 V[c]	...	0.2	0.59		22.3	1300
8505A	106976	F2 V[c]	...			61		
B	106975	F3 V[c]	...	0.1	0.45		20.1	1200
8600A	109511	K2 III[h]	...			70		
B	109510	A9 Vm[h]	...	1.5	1.54		20.3	1400

TABLE 1—*Continued*

ADS	HD	Classification	Quality	ΔM (mag)	ΔV_0 (mag)	Distance (pc)	Separation	
							(")	(AU)
8690A	111844	Am(K/H/M=A3/F0/F2)[c]	...			78		
B	111845	F8 V[c]	...	1.6	0.53		16.0	1200
8714A	112515	F3 IV[e]	...			190		
B	...	F6 V[e]	...	1.7	1.02		13.0	2500
9198A	125161	A7 IV[c]	...			34		
B	...	K0 V[c]	...	4.2	3.51		38.5	1300
9258A	126367	A2 V[i]	...			121		
B	126366	A3 V[i]	...	0.3	0.36		35.1	4200
9474A	132910	F0 IV[j]	...			119		
B	...	F2 IV[j]	...	0.0	0.80		40.5	4800
9477A	133029	A0 Vp(Si,Sr,Cr)[e]	...			226		
B	...	F4 V[e]	...	3.4	3.20		35.6	8000
9559A	135722	G8 III-IV[c]	...			38		
B	...	G0 V[c]	...	3.1	4.36		104.9	4000
9626A	137391	F1 V[c]	...			24		
BC	137392	G0 V[c]	...	1.8	2.20		108.3	2600
9716AB	139341	K2 V[c]	...			16		
C	...	K3 V[c]	...	0.2	0.20		121.9	2000
9728A	139461	F8 V[c]	...			32		
B	139460	F8 V[c]	...	0.0	0.02		11.9	370
10129AB	150117	B9.5 Vn[a]	...			86		
C	150118	B9.5 Vs[a]	...	0.0	0.09		90.3	7800
10149A	150378	B9.5 V[a]	...			110		
B	150379	Am(K/H/M=A1/A5/A7)[a]	...	0.7	1.15		69.8	7700
10628A	159560	Am(K/H/M=A4/F2/F3)[e]	...			28		
B	159541	Am(K/H/M=A4/F0/F1)[e]	...	-0.4	0.01		61.9	1800
10759A	162003	F5 IV[a]	...			21		
B	162004	F8 V[a]	...	0.8	1.21		30.3	640
11060AB	165590	G1 V[g]	...			31		
C	...	K7: V[g]	...	3.6	3.55		28.2	870
11061A	166866	F7 V[c]	...			26		
B	166865	F7 V[c]	...	0.0	0.36		20.0var	520
11089A	166045	A3 V	a			71		
B	166046	A3 V(λ Boo?)	a	0.0	0.04		14.2	1000
12893A	186901	B9 III	a			200		
B	186902	A0 V	a	1.2	0.73		15.0	3000
12913A	187013	F6 V	a			21		
B	...	K4 V	b	3.3	3.55		25.9var	540
13574A	192461	F3 V	a			80		
B	...	F5 V	a	0.3	1.16		14.2	1100
13868A	194765	F7 V[a]	...			48		
B	194766	F6 V	a	-0.2	0.80		59.9	2900
13870A	195066	B9.5 V	a			212		
B	...	A2 V	b	1.0	2.04		26.6	5600

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TABLE 1—*Continued*

ADS	HD	Classification	Quality	ΔM (mag)	ΔV_0 (mag)	Distance (pc)	Separation (")	Separation (AU)
13902A	195094	A2 Vn(λ Boo?)	a			87		
B	195093	A5: V	a	0.6	0.80		21.9	2100
15764A	211300	G8 III	a			174		
B	...	A3 V	a	1.1	2.40		28.9	5000
15828A	211797	F1 V	a			65		
B	...	G0 V	b	1.8	2.68		15.6	1000
15863A	212097	B9 III	a			101		
B	...	F2 V	c	3.2	4.39		72.6	7400
16321A	216369	B9 IV	a			258		
C	216353	B9 IV	a	0.0	1.4		82.1	21200

TABLE 2

PHYSICAL SYSTEMS WITHOUT PHOTOELECTRIC PHOTOMETRY

ADS	HD	Classification	Quality	ΔM (mag)	ΔV (mag)	Separation (")
183A	1026	A1 Vn	a			
B	...	A1 Vn	a	0.0	0.7	17.6
487A	3163	A0 Vn	a			
B	...	A0 V	a	0.0	0.4	17.0
742A	5250	F5 V	b			
B	5251	F5 V	b	0.0	0.2	13.0
834A	5910	F4 V	b			
C	5921	F5 V	b	0.1	-0.5	60.6
956A	6872	F4 V	a			
B	...	F5 V	a	0.2	0.5	14.6
1134A	8610	F9 V	a			
C	8624	G3 V	a	0.6	-0.1	56.8
1681A	13247	B8 V	a			
B	...	A0 V	a	1.0	0.8	11.6
1848A	15146	F2 IV	b			
B	...	F5 V	b	0.7	0.0	15.5
1924A	15695	Am(K/H/M=A3/A7/A7)	a			
B	...	F0 V	a	0.4	0.5	13.5
2056A	16760	G2 V	b			
B	...	K2 V	c	1.6	0.3	14.7
2057A	16772	B9.5 Vn	a			
B	...	A1 V	a	0.7	0.7	23.1
2124A	17386	F6 V	c			
C	...	F8 V	c	0.7	0.0	21.0
2494A	20711	F6 V	a			
B	...	G1 V	b	1.1	1.5	10.9
2499A	20873	Am(K/H/M=A3/A7/A7)	b			
B	...	A8 Vn	b	0.1	0.0	10.3

TABLE 2—*Continued*

ADS	HD	Classification	Quality	ΔM (mag)	ΔV (mag)	Separation (")
2677A	22733	A7 V	a			
B	...	F5 V	b	1.2	1.5	19.8
2851A	24297	G7 IV	b			
B	...	F5 V	b	0.2	0.5	11.9
11072A	166655	A1 V	a			
C	...	F6 V	c	2.7	2.5	23.1
11624A	173384	A1 V	a			
B	...	A1 V	b	0.0	0.7	22.4
12322A	181386	G2 II	a			
B	...	G2 III	b	2.4	0.6	12.1
12472A	183107	F2 V	a			
B	...	F3 V	b	0.1	0.1	11.4
11518A	183518	A6 V	a			
B	...	F2 V	b	0.9	1.8	22.8
12561A	184106	F6 IV	b			
C	...	F6 V	b	1.6	0.4	52.8
13176AB	189214	B9 V	a			
C	189236	B9.5 V	a	0.2	-0.1	93.2
13228A	189507	F2 V	b			
B	189508	F3 V	c	0.1	0.0	16.3
13630A	193010	B9.5 V	a			
B	...	Am(K/H/M=A2/A7/F0)	b	1.8	1.8	51.1
14299A	198063	G8 III	a			
B	...	G2 III-IV	b	1.2	1.9	15.8
14490A	199722	B7 V	a			
B	199721	B9 V	a	1.0	1.0	14.9
15630A	209845	Am(K/H/M=A2/A7/F2)	a			
B	...	G5: V	b	3.1	1.7	19.8
15716A	210686	F2 V	a			
B	...	K1 V	b	3.3	4.8	10.5
16069A	213892	B9.5 V[a]	...			
B	...	A7 V	b	1.8	1.1	13.6
16260A	215714	F5 V	b			
C	...	G0 V	c	1.2	1.0	30.9

[a] Abt 1985.
[b] Morgan and Keenan 1973.
[c] Abt 1981.
[d] Abt and Cardona 1983.
[e] Abt and Cardona 1984.
[f] Hoffleit, Saladyga, and Wlasuk 1983.
[g] Abt 1986.
[h] Hoffleit and Jaschek 1982.
[i] Cowley *et al.* 1969.
[j] Slettebak 1963.

systems were. That is why we believe the line to represent physical upper limits.

Although relation (1) represents the separation limits as a function of mass, we do not know whether it is basically a function of age (since the systems left their cluster environments) or stellar mass or some other physical parameter. But although all B primaries are young, not all these F dwarfs are necessarily old, so it seems likely that binary age is not the determining parameter. But in the pairs that we observed (roughly comparable in brightness and hence mass), the early-type systems will have the greater binding energies at the same separations or the same binding energies at greater separations, so the functional limits seem to be dynamical, rather than evolutionary.

The data on the Trapezium and hierarchical multiple-star systems studied by Abt (1986) are shown in Figure 2 (with a compressed vertical scale), together with the limiting line taken from Figure 1. Those data[4] show that the Trapezium and hierarchical systems also obey the limits represented by relation (1).

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[4] One system, namely Trapezium 320 = BUP at A1 V and 23,700 AU, has been dropped because it is at the heart of the Praesepe cluster, in violation of our attempt to exclude cluster members.

TABLE 3

OPTICAL SYSTEMS

ADS	HD	Classification	Quality	ΔM (mag)	ΔV (mag)	Primary Distance (pc)	Separation (")
1030AB	7471	F3 V[a]	...			71	
C	7505	B9.5 IV:[a]	...	-2.9	-0.5		130.3
1901A	15407	F5 III	a			...	
B	...	K3 V	b	5.5	1.8		21.2
2094A	16965	A0 II-III	a			...	
B	16964	A0 V(λ Boo)	a	2.8	0.3		15.8
2365A	19426	A0 Vs	b			...	
B	...	K0 Vs	c	5.1	0.5		27.2
2605A	21984	A4 Vn(λ Boo)	a			...	
B	...	K0 III	a	-0.8	3.0		9.5
2691A	22764	K4 III	a			120	
D	22763	B8.5 II:	a	-3.7	3.0		54.7
2849A	24550	F2 V	a			84	
BC	...	A7 V	b	-0.8	2.23		59.2
3824A	33959	A9 V[e]	...			42	
C	...	F4 V[e]	...	0.8	2.93		14.6
11213A	168092	F0 V + F0 V	a			88	
BC	...	F5: V	c	0.8	3.10		95.6
11423A	...	G9 IV-V	b			...	
C	...	M5 III	b	-4.8	-1.0		77.1
11448A	171247	B9 IIIp(Si)	a			222	
B	...	G8: III	c	0.8	3.28		38.7
11468A	171779	K0 III[h]	...			73	
C	...	A5 V	c	1.0	3.44		25.7
11616A	173399	G8 IV	a			62	
B	...	F4 V	b	0.1	1.71		25.8
11695A	174005	Am(K/H/M=A2/A8/A5)	a			74	
B	...	F4 V	c	1.0	3.09		37.9
11916A	176485	K3 III	a			...	
B	...	B9 V	b	-0.1	1.4		16.9
12259A	180660	K0 IV	b			...	
B	...	A2 IIp(3760 OIII st)	b	-5.9	0.6		19.6
12540A	183912	K0 III + A	a			24	
B	183914	B8 V	a	-1.3	2.03		34.3
12767A	185644	K0 III	a			68	
C	185673	F9 IV	b	1.4	3.6		45.6
12893A	186901	B9 III	a			200	
F	...	K3 V	b	6.9	2.57		43.3
13050A	188060	B9 Vs	a			...	
C	...	F5 V	a	3.2	1.2		31.1
13092A	188772	G9 V	a			...	
B	...	F2 V	b	-2.9	2.2		27.8

TABLE 3—*Continued*

ADS	HD	Classification	Quality	ΔM (mag)	ΔV (mag)	Primary Distance (pc)	Separation (")
13554A	192577	K2 II + B2.5 V[a]	...			122	
D	192514	A3 IV	a	3.0	1.04		337.5
13767A	193967	F3 V	a			...	
C	...	K2 V	a	3.4	0.3		76.0
13909A	195323	G8 III	a			293	
C	...	B7 V	b	-0.8	1.46		87.1
13921A	195358	A0 Ib-II	a			...	
C	195341	B7 V	a	3.8	0.4		105.9
16321A	216369	B9 IV	a			258	
E	216341	B9.5 Vn	a	0.4	2.1		118.3
16393A	217085	A6 V	a			117	
D	217049	A1 V	b	-1.1	0.63		120.8

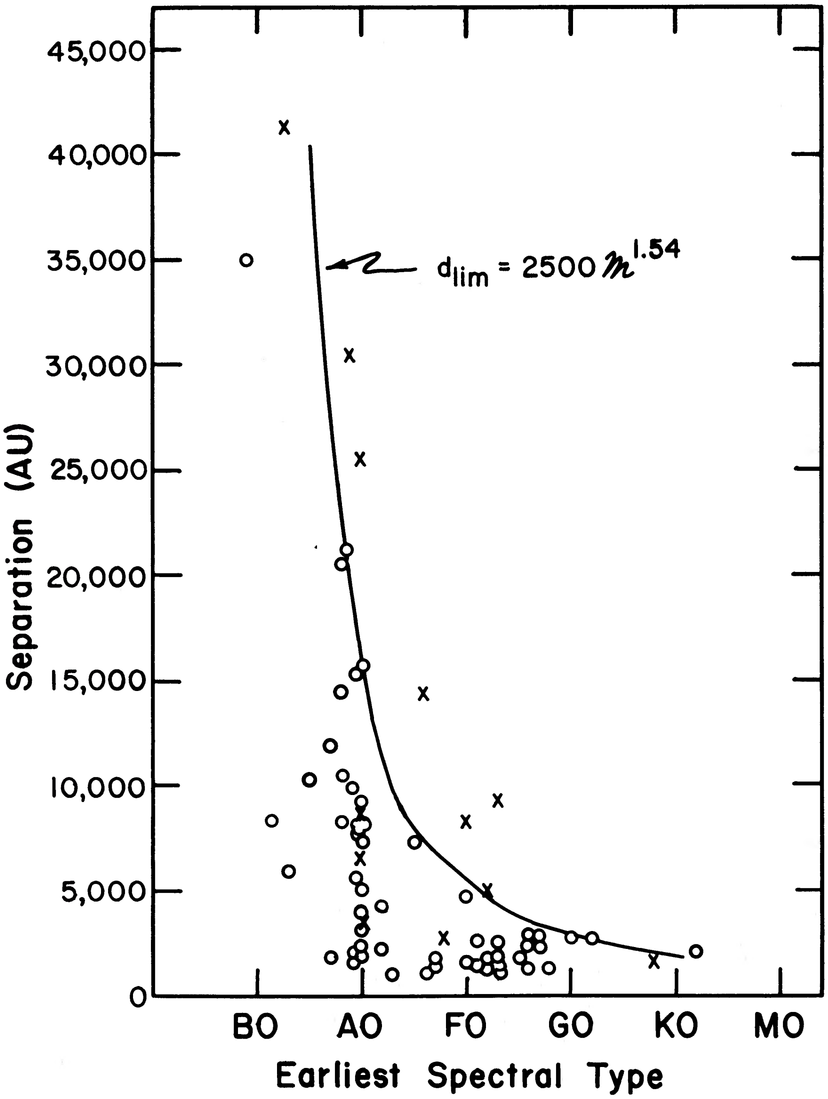

FIG. 1.—The separations of pairs are plotted as a function of earliest spectral type in each system (or the main-sequence turnoff type for giants and supergiants). All pairs have photoelectric photometry and reddening determinations for at least the primaries. Only pairs with separations greater than 1000 AU are plotted. Physical pairs are represented with open circles and optical pairs with Xs. The curve represents the upper limits to physical pairs.

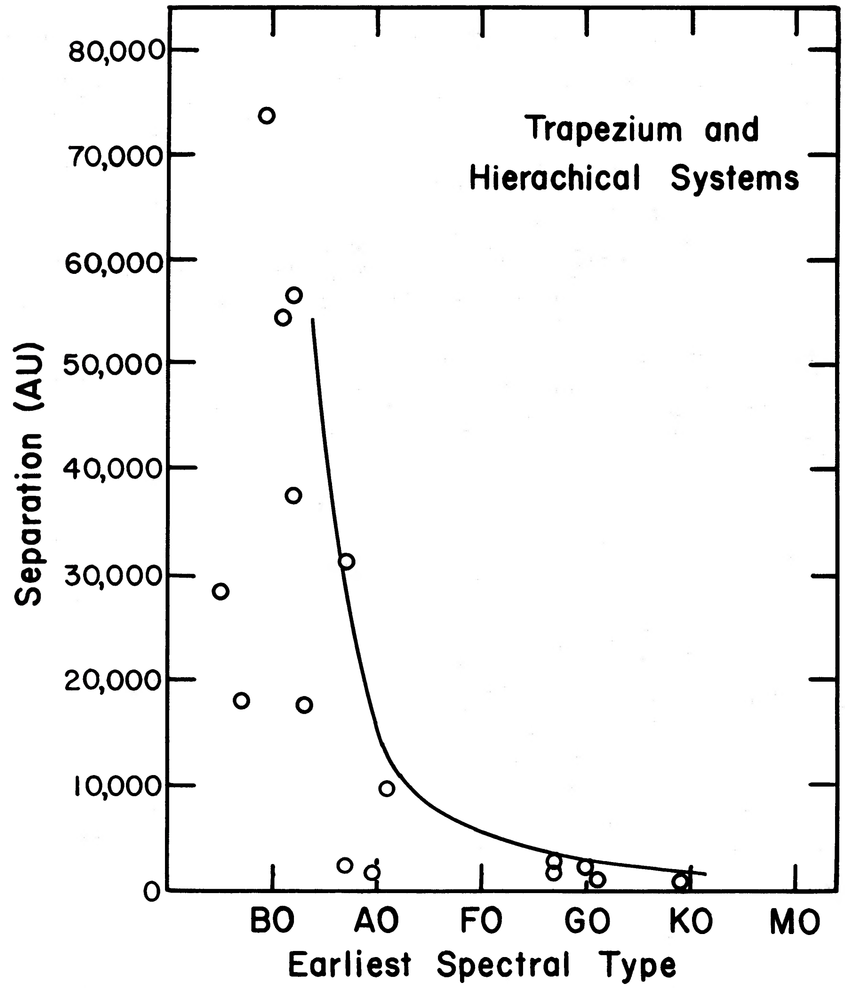

FIG. 2.—Separations in Trapezium and hierarchical systems studied by Abt (1986) and with photoelectric photometry (for at least the primaries) are plotted against earliest spectral type. Only physical pairs are shown. The curve is taken from Fig. 1 and again represents the upper limits to the separations.

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