

A *UBV* STUDY OF 94 WIDE VISUAL BINARIES

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*Received August 5, 1963; revised January 20, 1964*

## ABSTRACT

Ninety-four visual binaries with separations greater than  $25''$  were observed in three colors. These data, in combination with the spectral classifications available in the literature, led to results which can be summarized as follows: (1) Good confirmation was found for the theories of common origin and evolution. Each component apparently evolved as a single star without close-binary-type interactions. (2) Provisional distances, intrinsic separations, and periods were determined for each system. (3) No correlations were found between separation and absolute magnitude. (4) An upper limit of about 40000 a.u. was found for the intrinsic separations of these systems

## I. INTRODUCTION

In recent years, several studies have been undertaken to investigate the relationship between the magnitudes and spectral types of components of visual binary systems (Struve and Franklin 1955; Bidelman 1958; Stephenson 1960; see also Eggen 1963). In order to extend these studies and to obtain photoelectric magnitudes and colors for such systems, a photometric study has been undertaken at the Dyer Observatory with the 24-inch Seyfert telescope and its associated equipment. While this paper reports only on those systems with separations greater than  $25''$ , it is hoped that the experience gained will make it possible to observe binaries with smaller separations in the near future. Systems with secondaries fainter than about tenth magnitude were excluded from this study.

It was found that systems wider than  $25''$  were easily observed with the available equipment and were free of most guiding and seeing problems. Moreover, these systems proved to be convenient for indicating what modifications to the equipment and the observing technique might be needed before going to smaller separations. After analyzing the results, it would seem entirely feasible to observe, in a rather conventional way, those binaries which are  $15''$  or more apart, provided use was made of a sufficiently small diaphragm (say,  $15''$ ) and the observations were limited to nights of very good seeing. It would also be necessary to conduct a fairly careful study of the effect that the light from the primary has on the measures of the secondary, especially if the difference in magnitude between the components is greater than about 2 mag. For systems even closer than  $15''$ , the major problems which would arise are mainly those associated with the smaller diaphragms required and with guiding and seeing difficulties.

## II. THE SPECTRAL DATA

From the literature and from private communications, it has been possible to obtain a list of ninety-four systems for which the above criteria were satisfied and for which, with a few exceptions, good spectral data were available for both components. Many of these data were received from A. Slettebak (1963) and are part of the Perkins Observatory Double Star Program. Other than this, the data were taken from the published reports of Berger (1962), Bidelman (1958), and Struve and Franklin (1955), and from an unpublished list kindly supplied by G. Bakos. Five systems were classified expressly for this study by A. Heiser, from spectra taken with the KPNO 36-inch telescope. No attempt has been made to trace these data back to the original observer (if different from the authors noted above), and the reader is referred to the indicated

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reports for a complete discussion. Most of the present data are on the MK system, but it was not thought advisable to adjust the data of any one observer to agree with that of another, even though, in some cases, slight differences were evident.

### III. THE PHOTOMETRIC DATA

The photocell and filter combinations used in this study were chosen to coincide as nearly as possible with those of Johnson and Morgan (1953), and all the measures were reduced to the standard *UBV* system. Table 1 gives a summary of the rms deviations in the reduced data, indicating both the external and the internal errors associated with a single observation. Both sets of internal errors are averages of the deviations found among the data for each of the ninety-four systems and show clearly the expected result that the differential measures embody less error than the magnitudes and colors. These differentials are not influenced as strongly by those errors which arise from atmospheric-extinction fluctuations and seeing variations.

The external errors, which are due to inexact matching of the cell and filters to those of Morgan and Johnson and to the nature of stellar spectra, were determined by treating as unknowns fourteen *UBV* standard stars selected at random from among those measured as standard reference stars. Since these reference stars were subjected to the

TABLE 1  
RMS DEVIATIONS PER SINGLE OBSERVATION

	<i>V</i>	<i>B-V</i>	<i>U-B</i>
Magnitudes and colors (external)	±0 022	±0 007	±0 021
Magnitudes and colors (internal)	± 015	± 012	± 018
Differentials (internal)	±0 010	±0 009	±0 012

same internal observation and reduction conditions as the binary systems, it was possible to remove the contribution of the internal errors and obtain an estimate solely of the external deviations, and they are so tabulated.

All the observations were made using a 22" diaphragm, located in the focal plane, which was, in most cases, able to isolate each component so that its measures were not contaminated by the light of the companion. There were, however, a few systems where large differential magnitudes and small separations combined to produce systematic errors in the data of the fainter component. To determine the appropriate correction factors, a study was made of the light scattered into the 22" diaphragm when it was placed in various positions near a bright star. Curves similar to those in Figure 1 were obtained for *V*, *B*, and *U* magnitudes, but they contain scatter of the order of ±1 mag. No measurable color dependence was found. Due to such large scatter, the correction factors determined from these curves involved possible errors of as much as 50 per cent, but were nevertheless applied to the six systems listed in Table 2 in order to remove the systematic errors present. None of the other eighty-eight systems needed correction by as much as 0.01 mag. in either *V*, *B*, or *U*.

With only a couple of exceptions, all the magnitudes and colors listed were derived from at least three separate measures made, when possible, on separate nights and tied in to a variety of *UBV* standard stars. These standard reference stars were measured frequently during the night and were used to follow the variation of the extinction coefficients. It was possible to accomplish this by applying a slight modification to the normal technique for extinction determinations (Hardie 1962). As in the usual method, five or six standard extinction stars were observed at various air masses on one or two occasions during each night, and from these data it was possible to deduce the average extinction coefficients and the equipment zero points, including the adjust-

ments to the standard system. Since there is reason to expect the zero points to be more nearly constant over a period of time rather than the extinction coefficients, the latter were determined frequently during the night from the measures of the standard reference stars, using the previously determined zero points. On an average night, the extinction coefficients would vary about  $\pm 0.05$  mag. during the several hours of observing, and on occasion would change by as much as  $\pm 0.10$  mag. or more. It was decided, therefore, to interpolate these values over the night rather than attempt to use an average value.

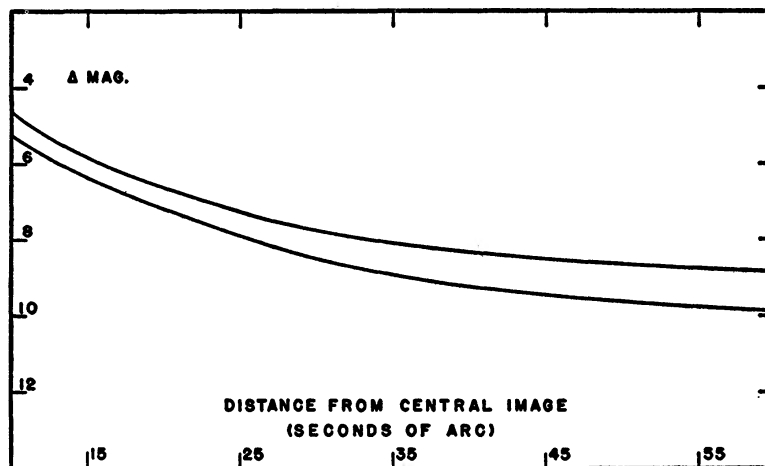


Fig. 1.—An illustration showing the decrease in the magnitude of the light scattered into a  $22''$  diaphragm as a function of distance from the central image. Upper curve obtained on the diffraction spikes produced by the secondary support vanes. Lower curve measured between spikes. No measurable color dependence was found.

TABLE 2  
CORRECTIONS APPLIED TO THE SECONDARY TO ADJUST FOR  
CONTAMINATION FROM THE PRIMARY

System	V	B-V	U-B
ADS 513	+0 01 mag.	0 00 mag.	+0 01 mag.
ADS 2157	+ 02 mag.	- 01 mag.	- 01 mag.
ADS 8695	+ 02 mag.	00 mag.	- 01 mag.
ADS 10786	+ 03 mag.	+ 04 mag.	+ 06 mag.
ADS 12197	+ 01 mag.	00 mag.	+ 01 mag.
ADS 12913	+0 01 mag.	0 00 mag.	+0 02 mag.

The listed magnitudes, colors, and differential measures for each system are the averages of all the observations with appropriate weighting factors applied. In most cases, the measures of a system were interlaced between the components as follows:  $V_A, V_B, B_B, B_A, U_A, U_B$  (in which the subscripts refer to the components of the binary). This technique allowed good differential determinations as well as magnitudes and colors. In some cases, however, each component was measured completely as if it were a single star, and the differentials obtained from these data are consequently less reliable. A weighting factor of 2 or 3 was used in determining the averages, depending on whether the mode of observation yielded better differentials or better magnitudes and colors.

Table 3 is a compilation of the pertinent data available for the ninety-four systems without regard to whether they were found to be physical.

TABLE 3

Star	V	B-V	U-B	n	$E_{B-V}$	Spectral Type	Parallax	$m_v - M_v$ (p.e.)	Comments
ADS 513	A 4.36 B 8.61	-.14 .19	-.54 .08	3	.00	B5 IV A5-6 V			2,CPM,A Spec. *
ADS 899	A 5.34 B 5.56	-.01 -.06	-.07 -.17	3	.03	A0 V B9 V			1,CPM,CRV
ADS 903	A 6.35 B 7.25	.40 .49	-.05 -.02	3	.00	F3-5 IV F6-7 V			2,CPM,CRV *
ADS 1073	A 4.99 C 6.94	.69 .40	.42 -.38	3	.47	F0 Ia B6 Ib			1&2
ADS 1459	A 6.56 B 9.17	2.05 .23	2.30 .07	3	-	K5 Iab-Ib A0 III			5,Optical * 6
ADS 1563	A 4.77 B 7.32	.30 .57	.09 .08	3	.07	F2 IV G0 V	'025	3.01 (±.63)	1,CPM,CRV *
BDS 1094	A 6.47 B 7.17	.24 .30	.07 .08	4	.00	A5 III Am			1, *
ADS 1753	A 6.00 D 9.60	1.10 .27	.79 .16	3	.14	G2 III A4 V			5,Optical * 6
ADS 1982	A 6.50 B 7.09	.42 .51	-.03 .01	3	.00	F4 IV F6 V			1,CPM,CRV A Spec.
ADS 2157	A 3.77 B 8.51	1.68 .14	1.85 -.08	3	.25	K3 Ib B9 V			3,CPM
BDS 1731	A 7.44 B 7.87	.04 .15	-.00 .09	3	.00	A1 V A3 V			1, *
$\gamma$ Tau.	A 2.87 B 6.30	-.09 .01	-.38 -.05	3	.04	B7 III B0 IV			1, *
ADS 3085	A 6.34 B 6.95	.59 .70	.04 .19	3	.00	G0 V G8 V			1,CPM,CRV
ADS 3179	A 6.36 B 8.18	.17 .34	-.35 .22	3	.35	B4-5 IV A0-1 V			2,CPM
$\theta^2$ Tau. $\theta^1$ Tau.	3.41 3.85	.18 .95	.13 .72	1	.05	A7 III K0 III	'029	2.68 (±.96)	1,CPM,CRV * A Spec.
ADS 3317	A 4.26 B 7.82	.18 .55	.07 .03	3	.00	Am V F8 V	'030	2.61 (±.38)	1,CPM,A Spec.
BDS 2313	A 4.28 B 7.16	-.13 .06	-.56 .04	3	.05	B3 V A1 V			1,CPM,CRV * A Spec.
ADS 3579	A 6.10 B 7.60	.05 .06	-.28 -.30	3	.18	B7-8 III B6-7 IV			2, *
ADS 3910	A 6.36 B 6.55	-.13 -.09	-.58 -.44	3	.04	B5 V A0 pec.			1,CPM
ADS 3962	A 5.00 B 7.18	-.16 -.12	-.84 -.62	4	.06	B1 V B3 V:			1&2,CPM
ADS 4000	A 6.55 B 8.38	1.12 .48	1.16 .09	3	.06	K1p III-IV F6 V			3,A Close
ADS 4134	A 2.22 C 6.85	-.22 -.15	-1.00 -.68	3	.06	O9.5 II B2 V			1,CPM,CRV * A Spec.
ADS 4182	A 4.78 B 5.68	-.25 -.22	-.99 -.87	4	.03	B0.5 V B1 V			1&2,CPM,CRV
ADS 4188	A 5.07 B 6.40	-.10 -.12	-.91 -.89	3	.18	O9.5 V B0.5 V			1,CRV,A Spec. *
ADS 4262	A 6.43 B 7.18	-.11 -.04	-.39 -.14	3	.00	B7 V B9.5 V			1&2,CRV *

TABLE 3 - Continued

Star	V	B-V	U-B	n	$E_{B-V}$	Spectral Type	Parallax	$m_V - M_V$ (p.e.)	Comments
ADS 4749	A 5.72 B 6.93	.07 .03	.05 -.06	3	.06	A0-1 III-IV A0 V			2, *
ADS 5103	A 4.17 B 8.00	.13 .10	-.49 -.00	3	.09	B5-6 IV A2 V			2, CPM, A Spec. B Close
ADS 6028	A 7.36 C 7.82	.32 .30	.04 .04	3	.00	F1-2 IV F0-1 IV			2, CPM, A Close
BD +31° 1676-7	6.86 7.75	.18 .18	.09 .06	3	.00	A6-7 III-IV A5-6 IV			2, *
ADS 6588	A 6.23 B 7.93	-.06 -.03	-.12 -.08	3	.00	B9 IV B9-A0 IV			2, CPM, B Close
ADS 6617	A 4.36 C 8.80	.96 1.42	.71 1.72	4	.00	G2 Ib			MK Std., Optical *
ADS 6783	A 7.70 B 9.41	.65 1.00	.18 .77	4	.00	G2 V K2 V			6, CPM
ADS 6913	A 7.25 B 8.41	.60 .81	.09 .45	4	.00				CPM, CRV
ADS 6988	A 4.02 B 6.57	.99 .04	.77 .03	4	.00	G8 III A3 V			1, CPM
HR 3590	A 6.06 B 7.19	1.10 .31	1.03 .04	4	.00	K1 II-III F3 IV			3, CPM *
ADS 7311	A 4.79 B 6.95	.90 .40	.66 -.04	4	.00	G8 III F5 V;			1&3, CPM, B Close
ADS 7438	A 6.76 B 8.07	.36 .44	-.01 -.03	4	.00	F2-3 V F5-6 V			2, *
ADS 7654	A 1.36 B 8.13	-.12 .87	-.36 .52	4	.00	B7 V K0 Vb	'039	2.03 (±.40)	1, CPM, CRV B Close
ADS 7967	A 6.10 B 8.71	.90 .55	.59 .00	4	.00	K0 III G0 V			3,
ADS 8001	A 7.12 B 8.95	1.20 1.14	1.25 1.12	4	.00				CPM
BDS 5652	A 1.80 C 7.15	1.08 .52	.89 -.03	4	.00	K0 II-III F7 V	'031	2.54 (±.36)	3, CPM, A Close
ADS 8162	A 6.49 B 7.56	.80 1.03	.49 .93	4	.00		'053	1.38 (±.28)	CPM, CRV
ADS 8347	A 6.54 D 7.03	.11 .02	.08 .01	5	.00	A3 V A2p			1, CPM, CRV * A Close
ADS 8470	A 6.89 B 8.78	1.13 .57	1.07 .05	3	.00	K2 III F8 IV			5, CPM, CRV
ADS 8530	A 4.79 C 8.55	.51 .53	.26 .02	4	.00	F5 V G0 V			5, A Spec. *
ADS 8568	A 5.28 B 6.63	-.04 .23	-.13 .09	4	.00	A0p Am			1, CPM, CRV * B Close
ADS 8695	A 4.91 C 9.74	.91 .74	.68 .34	4	.00	G8 III G3 IV-V			3, A Close
ADS 8735	A 6.22 B 9.50	.45 .54	.01 .04	3	.00	F7 V G0 V			5, B Close, Optical *
ADS 8883	A 7.06 B 7.36	.78 .83	.38 .51	5	.00	K0 III K2 III			4, CPM
BDS 6498	A 6.66 B 7.04	.38 .40	.00 -.02	4	.00	F2 V F3 V			1, CPM, CRV

TABLE 3 - Continued

Star		V	B-V	U-B	n	$E_{B-V}$	Spectral Type		Parallax	$m_V - M_V$ (p.e.)	Comments
HR 5114	A	6.49	1.04	.91	4	.00	K1	III			3,CPM
	B	8.94	.48	-.02			F6	V			
ADS 9258	A	6.62	.13	.08	3	.00	A2	V			1,CPM,B Close
	B	6.98	.12	.07			A4	V			
ADS 9277	A	7.12	-.02	-.04	4	.00	A0	V			1,CRV *
	B	7.62	.00	-.01			A0	V			
9-8 $\alpha$ Lib.	A	2.75	.14	.10	3	.00	A3	V	"045	1.68 ( $\pm$ .56)	1,CPM,CRV
	B	5.15	.41	-.02			F2	V			
ADS 9474	A	6.84	.32	.03	3	.00	F0	IV			1,CPM *
	B	7.64	.30	.02			F2	IV			
ADS 9559	A	3.46	.96	.66	4	.00	G8	III	"028	2.76 ( $\pm$ .48)	3
	B	7.82	.59	.02			G0	V			
ADS 9626	A	4.29	.32	.04	4	.00	F0	IV	"030	2.61 ( $\pm$ .44)	1,CPM,CRV B Close
	B	6.50	.60	.12			G1	V			
ADS 9951	A	4.03	.07	-.64	4	.31	B2	V			1,CPM,A and C Close
	C	6.30	.14	-.38			B9p	V			
ADS 10022	A	3.76	.29	.15	4	.08	A9	III			5,Optical *
	B	9.57	1.09	.93							
ADS 10129	A	5.08	-.03	-.16	4	.04	B9	V			1,CPM,CRV A Close
	C	5.53	-.06	-.16			B9.5	V			
ADS 10149	A	5.78	-.01	-.08	4	.00	A0	V			1,CPM,CRV *
	B	6.93	.13	.08			A5	V			
ADS 10535	A	6.28	.89	.53	4	.00	G5	III			5
	B	9.97	.46	-.02			F0	V			
ADS 10628	A	4.87	.32	.06	3	.20	Am		"026	2.92 ( $\pm$ .52)	1,CPM,CRV
	B	4.91	.28	.03			Am				
ADS 10635	A	5.81	.03	-.01	6	.04	A2	V			1,CPM *
	B	7.81	.30	.05			F0	IV			
HR 6575	A	6.27	1.05	.82	6	.00	K0	III			3,CPM
	B	7.74	.42	.05			F4	IV			
ADS 10759	A	4.58	.45	-.01	3	.00	F5	IV	"046	1.68 ( $\pm$ .24)	1,CPM,CRV *
	B	5.79	.54	.02			F8	V			
ADS 10786	A	3.42	.77	.35	4	.00	G5	IV	"108	-0.16 ( $\pm$ .12)	3,CPM,CRV B Close
	B	9.76	1.52	.98			dM4				
ADS 10966	A	3.95	.03	-.60	5	.11	B5	Ib			1&2,CRV,A and C Close
	C	8.12	-.02	-.57			B3	V			
ADS 11336	A	4.98	.08	.02	3	.00	A1	V	"031	2.54 ( $\pm$ .50)	1,A Close
	C	7.88	.50	-.04							
ADS 11593	A	6.46	-.12	-.56	3	.04	B3	V			1,CPM *
	B	8.05	-.05	-.25			B8	V			
ADS 11639	A	4.31	.22	.14	3	.00	Am		"025	3.01 ( $\pm$ .44)	1&2,CPM,CRV * A Spec.
	D	5.70	.31	.06			F0	IV			
ADS 12197	A	4.37	-.15	-.64	3	.03	B4-5	III			2,Optical *
	B	8.58	.08	-.06			A1-2	V			
HR 7300	A	5.57	1.09	.86	3	.02	G5p	II			3
	B	7.66	.08	.02			A1	V			
ADS 12693	A	5.64	1.05	.78	3	-	G8	III			5,Optical *
	B	8.29	.49	-.18							
ADS 12750	A	6.40	2.07	2.33	3	.44	M0	Iab-Ib			3
	B	9.47	.26	-.33			B3	V			

TABLE 3 - Continued

Star	V	B-V	U-B	n	$E_{B-V}$	Spectral Type	Parallax	$m_V - M_V$ (p.e.)	Comments
ADS A 12767 C	5.30 8.14	1.14 .56	1.06 .07	4	.06	K2 III F6 IV-V	"030	2.61 ( $\pm$ .68)	3,CPM
ADS A 12815 B	5.95 6.21	.67 .69	.17 .19	3	.00	G2 V G5 V	"034	2.34 ( $\pm$ .31)	1,CPM,CRV
ADS A 12913 B	4.96 8.53	.50 1.06	-.01 .91	3	.00	F5 V	"047	1.63 ( $\pm$ .24)	5,CPM,CRV
BDS A 9705 B	7.13 7.32	.14 .31	.03 .05	3	.18	A1 V Am			1,CPM
ADS A 13087 B	5.70 6.48	-.08 -.04	-.48 -.26	4	.14	B6 V B8 V			1,CPM,CRV
ADS A 13379 B	7.14 7.59	.13 .18	.02 .07	3	.09	A1 V A3 V			6,CPM
ADS A 13554 C	3.76 6.99	1.29 -.14	.44 -.58	3	-	K2 II + B3 V B5 V			1,CPM *
ADS A 13870 B	6.37 8.40	.02 .10	-.02 .06	3	.00	A2-3 IV A2-5 V			2
ADS A 14101 C	5.05 8.50	.72 .92	.24 .68	3	.00	G5 IV dK1			3,CPM,CRV
ADS A 14345 B	6.51 10.30	1.63 .58	1.63 .01	3	.00	M3 II-III F8 V			5, * 6
ADS A 14636 B	5.22 6.04	1.21 1.38	1.14 1.24	3	.00	K5 V K7 V	"292	-2.33 ( $\pm$ .03)	1,CRV *
ADS A 14720 C	6.45 7.29	.01 1.55	-.35 1.38	3	.14	B5 V M5 III			1,A Close *
ADS A 14909 B	4.08 9.19	1.13 .85	1.04 .54	3	.00	K1 III K0 V			3
ADS A 15147 B	6.19 7.67	.02 .37	-.01 -.01	3	.00	A1 V F2 V			1,CPM *
ADS A 15434 B	5.76 6.66	-.15 -.37	-.86 -1.00	3	-	B0.5 V B1 V			1,CPM *
ADS A 15764 B	6.10 8.49	1.04 .15	.84 .07	3	.00	K0 II-III A3 V			3
ADS A 16481 B	6.74 9.52	-.01 .09	-.62 -.25	3	.21	B3 IV B8 V			2
ADS A 16611 B	7.55 8.18	.56 .69	-.03 .11	3	.00	F7 V G0 V			6,CPM,CRV *
ADS A 16633 B	4.23 9.18	1.12 1.06	1.00 .92	3	.00	K0 III dK6			3,CPM,CRV * B Close

1. A.Slettebak (1963)
2. J. Berger (1962)
3. W.P. Bidelman (1958)
4. O. Struve and K.L. Franklin (1955)
5. G. Bakos (Private Communication)
6. A. Heiser (Private Communication)

## NOTES TO TABLE 3

The arrangement of the table should be clear with the possible exception of the following:

Col. (8) trigonometric parallax from the *Yale Catalogue* if greater than  $0''.025$ .

Col. (9) distance modulus determined from the parallax and the probable error associated with it.

Col. (10) comments: (a) the number refers to the spectral observer noted at the end of table, (b) "CPM" and "CRV" refer to common proper motion and common radial velocity, respectively, (c) "Spec" and "Close" indicate the component is a spectroscopic or close binary system itself, (d) an asterisk (\*) indicates a remark in the notes that follow here.

*ADS 513*.— $\Delta M_v$  determined from the luminosity calibration is 0.7 mag. Spectral classification possibly in error or system may be optical.

*ADS 903*.—Struve and Franklin (1955) list F4 V and F6 V for components.

*ADS 1459*.—See reddening discussion.

*ADS 1563*.—Berger (1962) lists A9–F0 IV and F7–8 V for components.

*BDS 1094*.—Two spectra visible for secondary.

*ADS 1753*.— $\Delta M_v$  determined from the luminosity calibration is 1.5 mag. *D* shows relative motion. System probably optical.

*BDS 1731*.—P.M. and R.V. both somewhat different for the components. System possibly optical.

$\eta$  *Tau*.—In Pleiades. Spectral data from Slettebak (private communication).

$\theta$  *Tau*.—Hyades cluster members. Spectral data from Slettebak (private communication).

*BDS 2313*.—Berger (1962) lists B5–6 V and A2–3 V for components.

*ADS 3579*.—P.M. slightly different; however, system likely physical.

*ADS 4134*.—Berger (1962) lists B3 V for secondary.

*ADS 4188*.—See *ADS 3579*.

*ADS 4262*.—See *ADS 3579*.

*ADS 4749*.—Slettebak lists primary as A1 V (shell).

*BD + 31°1676–7*.— $\Delta M_v$  determined from the luminosity calibration is  $-1.0$  mag.; however, the spectral data may be in error. System probably physical.

*ADS 6617*.—Pair noted as optical by Bidelman in private communication.

*HR 3590*.— $\Delta M_v$  determined from the luminosity calibration is 3.6 mag. Spectral data may be in error or system may be optical.

*ADS 7438*.—See *ADS 3579*.

*ADS 8347*.—Berger (1962) lists A1–2 V and A0–1 for the components.

*ADS 8530*.— $\Delta M_v$  determined from the luminosity calibration is 0.9 mag. Spectral type of primary probably discordant. System likely physical.

*ADS 8568*.—Berger (1962) lists A7–9 V for secondary.

*ADS 8735*.— $\Delta M_v$  determined from the luminosity calibration is 0.6 mag. System probably optical. See also *ADS 6617*.

*ADS 9277*.—P.M. slightly different, but R.V. measures in good agreement. System physical.

*ADS 9474*.—Berger (1962) lists F0 IV for secondary.

*ADS 10022*.—See *ADS 6617*.

*ADS 10149*.—Berger (1962) lists A2–3 IV and A2 V for the components.

*ADS 10635*.—Berger (1962) lists A2–3 IV and A7–9 V for the components. R.V. slightly different, but system likely physical.

*ADS 11639*.—Struve and Franklin (1955) list dA9 and A3n for components.

*ADS 12197*.—Both P.M. and R.V. differ between the components. System optical. See also *ADS 6617*.

*ADS 12693*.—Reddening discordant. P.M. not common. System optical. See also *ADS 6617*.

*ADS 13554*.—Bidelman (1954) also lists K2 II + B3 V for primary. Reddening indicates system optical (see reddening discussion), but it has CPM. Physical reality indefinite, but will assume physical. Use reddening of secondary:  $E_{B-V} = 0.02$ .

*ADS 14345*.— $\Delta M_v$  determined from the luminosity calibration is 5.5 mag. Spectral data may be in error or system may be optical.

*ADS 14636*.—Struve and Franklin (1955) list dK6 and dM0 for components. Orbit data available (Strand 1957a).

*ADS 14720*.—See reddening discussion.

*ADS 15147*.—Berger (1962) lists A2–3 V and F1–2 V for the components.

*ADS 15434*.—Reddening indicates system optical (see reddening discussion), but it has CPM. Physical reality indefinite, but will assume physical. Use average reddening,  $E_{B-V} = 0.43$ .

*ADS 16611*.—Struve and Franklin (1955) list dF and dG2 for components.

*ADS 16633*.— $\Delta M_v$  determined from the luminosity calibration is 8.2 mag. Possibility of wrong spectral type. P.M. and R.V. indicate system probably physical.

Where the differential magnitudes do not agree with those which would be determined from the spectral data and Arp's (1958) calibrations (see discussion to follow) to within  $\pm 1.5$  mag., the system in question is discussed in the notes to Table 3.

#### IV. THE REDDENING

The reddening correction for each of the ninety-four systems was determined by comparing the data for both components with the color-color curves listed by Arp (1958). A reddening slope of 0.72 was assumed in all cases, and for the later analysis of

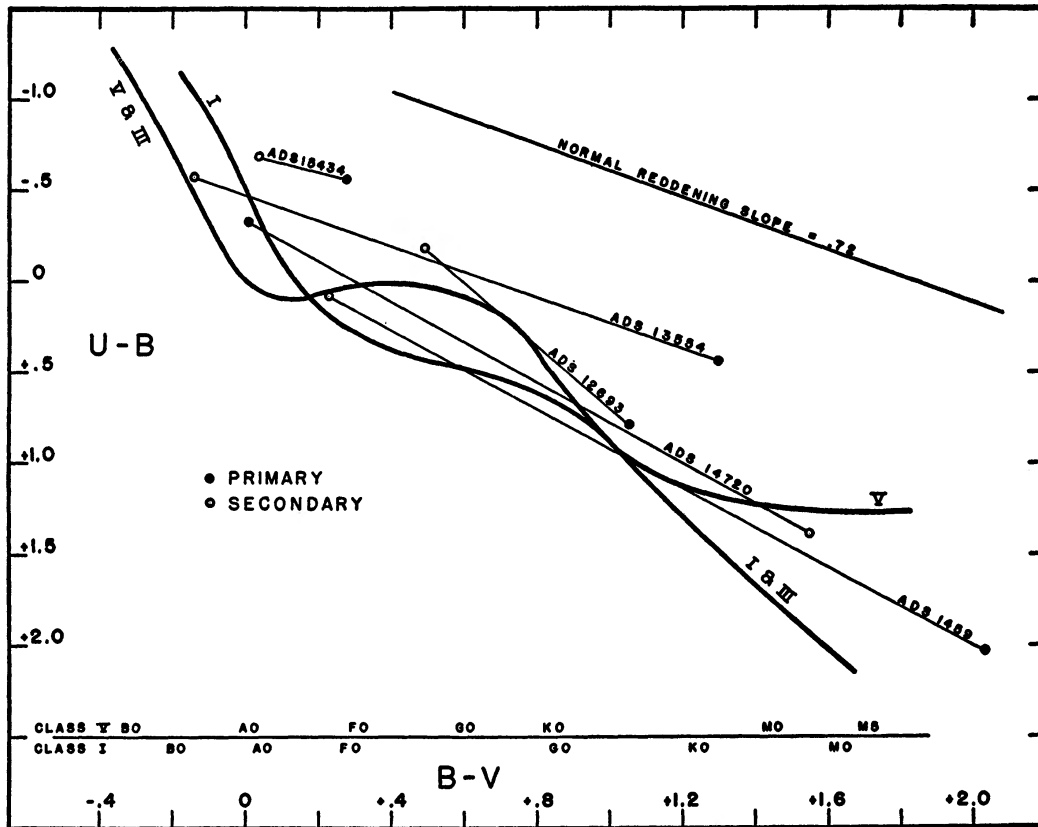


FIG. 2.—Color-color diagram. The spectral calibrations for classes I and V are indicated in the lower portion of the figure. See text for full discussion.

the data, the absorption in  $V$  was taken to be  $3 E_{B-V}$ . The well-known ambiguities in reddening arising from the position of some stars in the color-color diagram were greatly reduced by referring to the spectral data for the star and by assuming that both components of a binary system should be reddened similarly. While there was the possibility that the components might be differentially reddened, this was considered so slight that large reddening discrepancies were treated as indications that the systems were likely to be optical.

The several binaries which revealed such discrepancies are shown in Figure 2 and are discussed as follows:

*ADS 1459.*—The primary is a K5 Ib and appears quite reddened ( $E_{B-V} = 0.55$  mag.) both from its spectral type and its position in the color-color diagram. The secondary's spectral type is A0 III, and it appears reddened by about 0.25 mag. System probably optical.

*ADS 12693.*—The primary is G8 III and only slightly reddened. The secondary is B8 (HDE 231829), and it appears quite reddened. System probably optical.

*ADS 13554.*—Both the spectral and photometric data indicate only slight reddening for the secondary. The primary has a composite spectrum (K2 II + B3 V). By using the luminosity and color calibrations given by Arp (1958), the composite colors would be roughly  $B - V = 0.3$  and  $U - B = -0.4$  which would imply considerable reddening in relation to the star's actual position in the diagram. On the basis of the colors, therefore, the system appears optical, but see notes to Table 3.

*ADS 14720.*—The primary (B5 V) is reddened by  $E_{B-V} = 0.14$ , and the secondary (M5 III) appears discordant. However, the class III curve is poorly defined for these late-type stars, and the  $(B - V)$  color agrees well with the spectral type. System assumed physical and the reddening of the primary adopted.

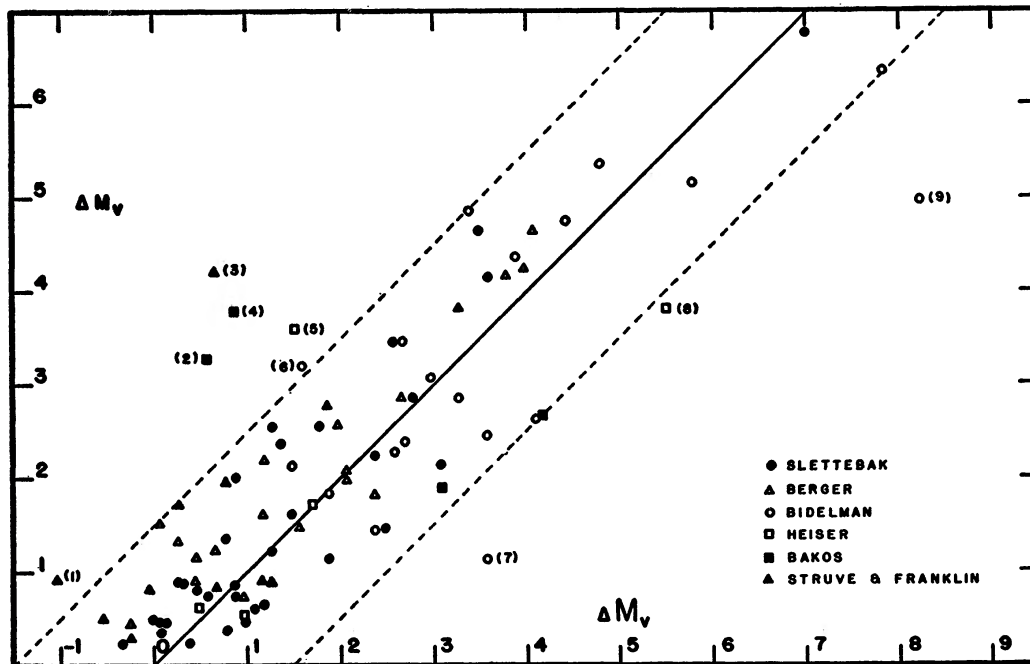


FIG. 3.—Comparison of differential magnitudes.  $\Delta m_v$  was determined photoelectrically, while  $\Delta M_v$  was determined from the spectral data and the luminosity calibration. Those systems with deviations greater than 1.5 mag. are (1) BD+31°1676-7, (2) ADS 8735, (3) ADS 513, (4) ADS 8530, (5) ADS 1753, (6) ADS 13554, (7) HR 3590, (8) ADS 14345, and (9) ADS 16633. The various spectral observers are indicated.

*ADS 15434.*—The primary (B0.5 V) is reddened by  $E_{B-V} = 0.54$ , but the secondary (B1 V) is reddened by only  $E_{B-V} = 0.32$ . On the basis of the colors, therefore, the system appears optical, but see notes to Table 3.

It should be pointed out that, while discrepant reddening may be an indication that a system is optical, similar reddening is not an indication that a system is physical. Manifestly, if the obscuring matter is between the Sun and both components of a binary system, the reddening will appear accordant even if the system is optical. It is necessary, therefore, to consider other parameters as well, such as proper motion, radial velocity, etc., to determine the physical reality of such systems.

#### V. DISCUSSION

Figure 3 is a comparison of the photoelectric differential measures ( $\Delta m_v$ ) with the differential absolute magnitudes ( $\Delta M_v$ ) derived from the spectral data and from Arp's

(1958) luminosity calibrations. While it is natural to expect some scatter about the  $45^\circ$  mean due to the higher probable errors of the spectral classifications, inaccuracies in the calibrations, etc., very large deviations might well indicate optical systems. To investigate this, an arbitrary range of  $\pm 1.5$  mag. (about 1 standard deviation) was allowed, and all systems which exceeded this boundary were noted and discussed separately in the notes to Table 3. The fact that most of the data fall within the boundary lends credence to the luminosity calibrations, at least to within  $\pm 1.5$  mag. Unfortunately, the present data do not cover a sufficient range in luminosity classes to allow improvements in the calibrations. It would be very useful to pursue similar photoelectric studies of systems with good spectral data which cover a wider variety of luminosity classes, as such data would allow better calibrations of the higher classes relative to the main sequence (Stephenson 1960).

Figure 4 is a comparison of the present differential magnitudes ( $\Delta m_v$ ) with those of Wallenquist (1958) and Johnson (1953). The deviations are plotted against the present

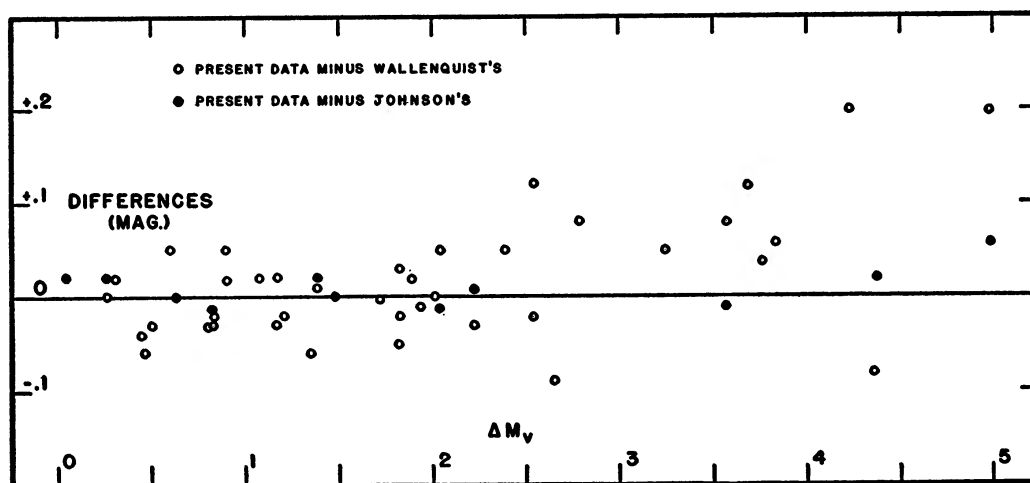


FIG. 4.—Differences in differential magnitudes between the present data and those listed by Wallenquist and by Johnson. The differences are plotted against the present data.

differentials. The scatter with respect to Wallenquist's data is no doubt due, partly, to its not being reduced to the  $UBV$  system, which would also account for the increase in the differences with increasing differentials. It was not possible to convert Wallenquist's data to the standard system because they had an insufficient range in differential color.

The average deviations found in the differentials in relation to the various other observers are as follows:

Present data versus the spectral data	...	...	$\pm 0.80$ mag.
Present data versus Wallenquist's data	.	..	$\pm 05$ mag.
Present data versus Johnson's data	..	: ...	$\pm 02$ mag.

## VI. EVOLUTIONARY EFFECTS

It is of definite interest to investigate the location of these binary systems in a H-R diagram, for it is only here that one may relate the theories of stellar evolution with the assumptions of common origin. To accomplish this investigation, it was assumed that all the secondaries of luminosity class V had absolute magnitudes which rigorously placed them on the main sequence. This technique can be justified, somewhat, in the present case, since the problems inherent in it are reduced with the good luminosity classifications which are available and the unambiguous determinations of the inter-

stellar reddening. It was then possible to locate accurately the positions of the primaries from the differential magnitudes and colors. A similar assumption was made for those systems with class IV, class III, or Am-type secondaries in relation to their appropriate luminosity sequence. The luminosity sequences used were taken from Arp (1958), with the exception of that for the Am-type stars which was taken from Jaschek and Jaschek (1959). The sequences were all slightly idealized to straight-line segments for convenience in plotting.

Figure 5 is the H-R diagram for the sixty-eight systems with class V secondaries. The results indicate good agreement with the hypothesis that, initially, an evolving star moves upward and to the right of the main sequence (Johnson and Hiltner 1956) and that the primaries, being more luminous and more massive, evolve at a greater rate than do the secondaries. The fact that most of the class V primaries lie above the main sequence and that class III primaries exist in systems with main-sequence objects can well be taken as evidence of the more rapid evolution of the hotter stars. Those few primaries which fall below the curve are well within the scatter of the main sequence itself with the possible exceptions of the following: ADS 15147 and BDS 1731 with  $M_v$  about 1.7; ADS 10635 whose class IV primary is at  $M_v = 0.7$ ; and ADS 3910 at  $M_v = -1.2$ . The discrepancies of these systems can probably be explained, however. The primary of ADS 10635 may be a class V object (see notes to Table 3), and ADS 3910 has a secondary which is an A0p star and whose placement on the main sequence is, therefore, doubtful. It appears likely that the discrepancies of BDS 1731 and ADS 15147 have been exaggerated somewhat by using straight-line segments, since, when the components are plotted on the main sequence given by Burbidge and Burbidge (1958), the apparent error is greatly reduced.

It seems evident that binaries cover a wide range of ages (see also Struve and Franklin 1955), with systems like ADS 513 and ADS 7654 being quite young since their primaries are still near the main sequence while being much brighter than their companions, and systems like ADS 14909 and ADS 16633 being rather old with giant primaries and late-type secondaries. All the primaries lie above the NGC 188 boundary (Sandage 1962) with the exceptions of ADS 10786, ADS 14345, and ADS 16633, which fall just below the cutoff, and could be, therefore, extremely old systems.

The systems with secondaries having luminosities brighter than class V are indicated in Figure 6, *A* and *B*. Here again, most of the systems agree well with the evolution hypothesis, but there are two deviations. For  $\theta^1$ ,  $\theta^2$  Tau and ADS 14720, both with class III secondaries, it appears that the secondary has evolved more rapidly than the primary. Since this situation is in conflict with the previously stated notion of evolution, it might be assumed that these are optical systems. However,  $\theta^1$ ,  $\theta^2$  Tau are known members of the Hyades (Johnson and Knuckles 1955), and even if they are not a binary system, they are physically related, and the conflict would remain. It is significant that the differential magnitudes for these two binaries are small and probably fall within the uncertainties of the evolutionary predictions. It cannot be said whether this conflict is evidence of very bright stars becoming slightly fainter as they evolve or of stars evolving off the main sequence in a manner not quite proportional to their brightness. However, since these are the only two cases found among the many which have been studied, it would not seem prudent to attach too much significance to them.

The results of earlier studies such as those of Stephenson (1960) and Bidelman (1958) regarding evolutionary effects are, therefore, well supported and confirmed by the more extensive and reliable photometric data made available here.

#### VII. ESTIMATED PHYSICAL PARAMETERS

Before beginning this discussion, it should be stressed that all the analysis to follow depends strongly on the validity of the assumptions made in the previous section, since it will be necessary to use the distances which were determined there. These distances,

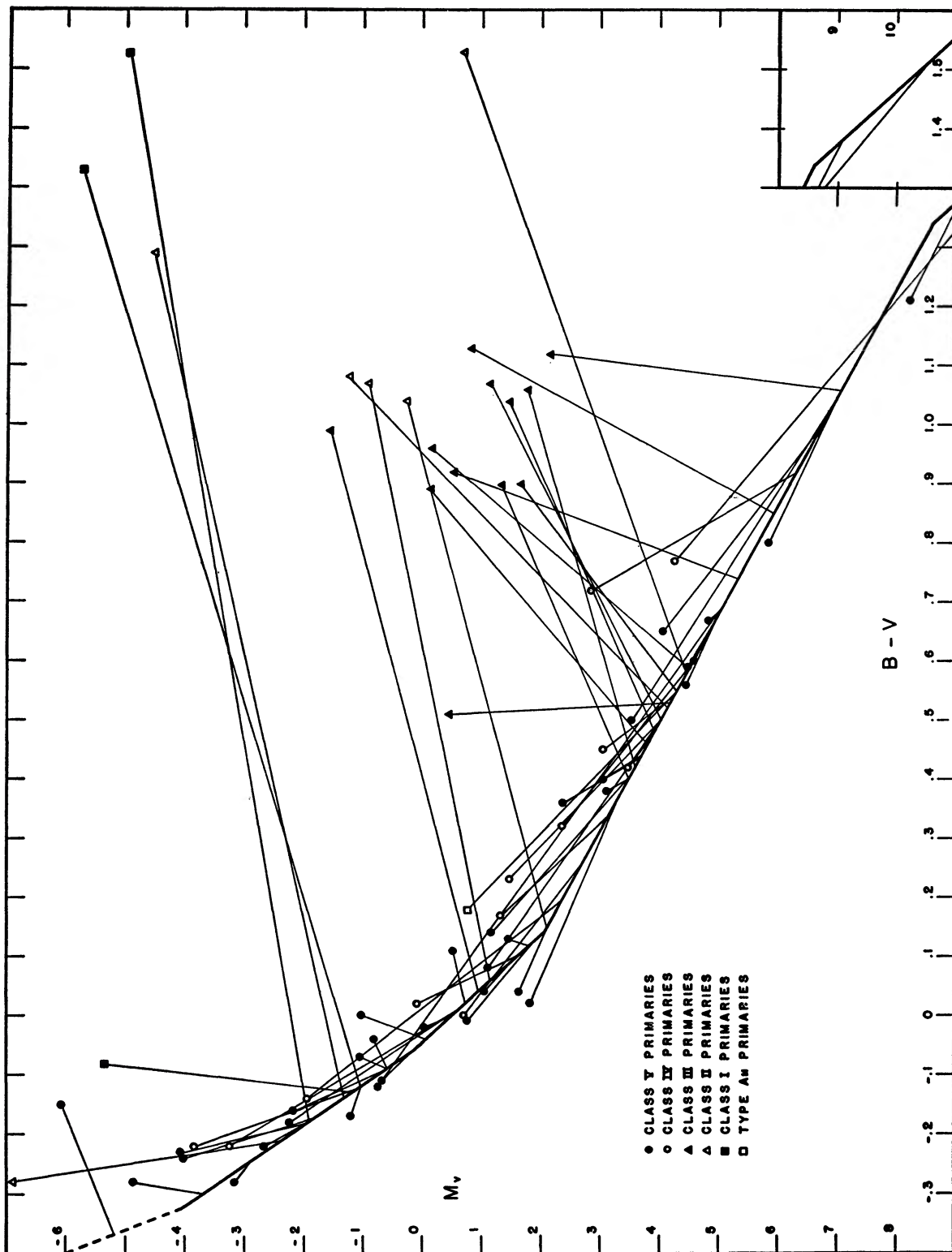


FIG. 5.—H-R diagram for systems with class V secondaries. All secondaries were placed on the main sequence

in parsecs, are listed in Table 4, along with the absolute magnitudes of the components of the eighty-seven systems which were considered to be physical. They range from as close as 2.5 pc to as distant as 2,200 pc, with the average being about 150 pc.

By using these distances and the apparent separations taken from Aitken (1934), it was possible to determine the intrinsic separation of each system in astronomical units (Table 4). This separation is, of course, only the projection on the plane of the sky of the true separation, and, as such, should be considered as a minimum value.

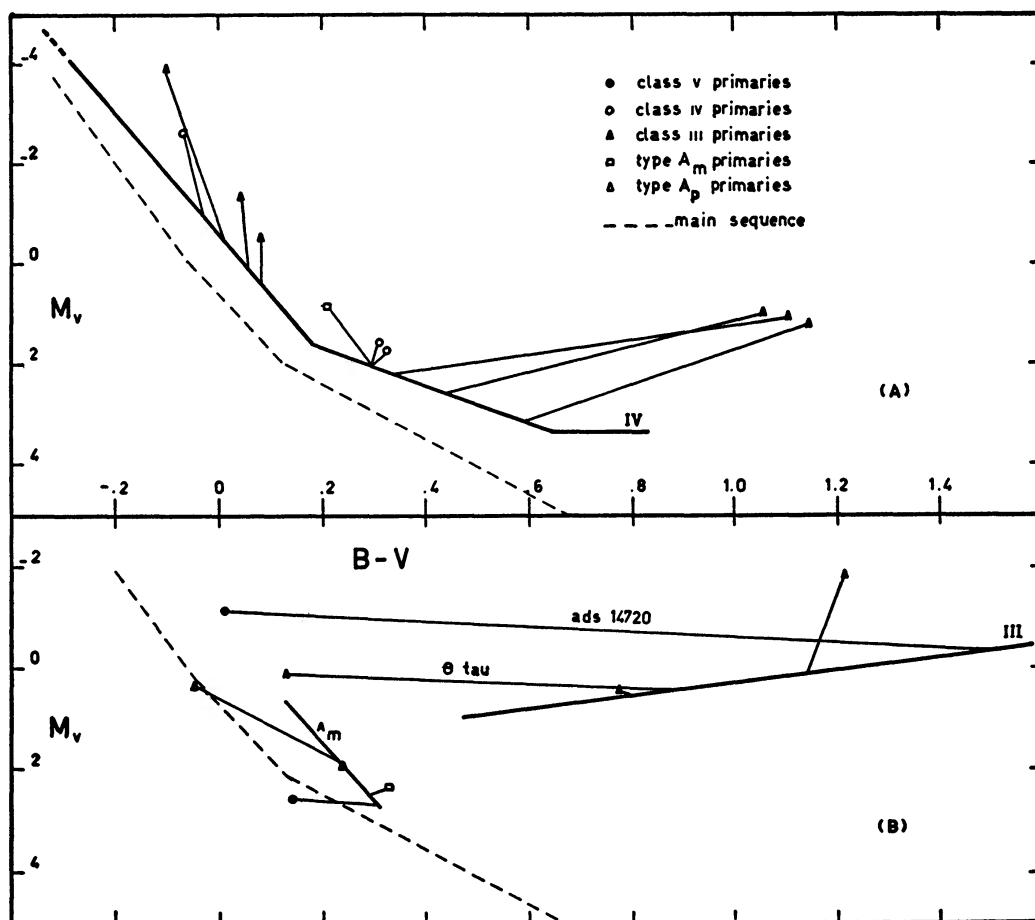


FIG. 6.—H-R diagram for systems with non-class V secondaries *A*, systems with class IV secondaries, located on the class IV sequence; *B*, systems with type  $A_m$  or class III secondaries, located on their respective sequences.

Figure 7 shows an apparent correlation of the intrinsic separation with the absolute magnitude of the primary, but it can be shown that this is due to selection effects. At the beginning of the study definite limits were placed on the apparent brightness and separations, these limits corresponding to the cut-off lines in Figure 7. The present data, however, fell well within these bounds so that the actual cut-offs restrict the data to the much narrower region indicated in the figure. Therefore, this apparently strong correlation is seen to be solely the reflection of the selection effects inherent in the study. Figure 8, which involves differential magnitudes, is free from these selection effects and exhibits no correlations.

Since orbital data were not available for these systems, it was impossible to improve the mass-luminosity relation. On the other hand, it was possible to proceed the other

TABLE 4

System	Name	Secondary		Primary		Distance (Parsec)	Projected Separation (A.U.)	Total Mass <sub>☉</sub>	Period (10 <sup>6</sup> Years)
		M <sub>v</sub>		M <sub>v</sub>	Luminosity Class				
<u>A. Class V Secondaries</u>									
ADS 513	π And.	2.32		-1.94	IV	182	6,600	8.0	190
ADS 899	ψ Psc.	-.58		-.80	V	158	4,700	8.3	110
ADS 903	77 Psc.	3.98		3.07	V	46	1,500	2.6	36
ADS 1563	λ Ari.	4.03		1.49	IV	42	1,600	3.2	36
ADS 1982	30 Ari.	4.09		3.49	IV	40	1,600	2.4	41
ADS 2157	71 Per.	-1.01		-5.74	Ib	575	16,000	10.4	630
BDS 1731	HD 21700	2.10		1.67	V	144	6,300	4.0	250
ADS 3085	HR 1322	5.12		4.50	V	23	1,500	1.9	42
ADS 3179	62 Tau.	3.16		1.34	IV	100	2,900	3.6	82
ADS 3317	88 Tau.	4.30		.73	Am	50	3,500	5.1	97
BDS 2313	τ Tau.	.63		-2.25	V	66	4,200	10.0	84
ADS 3910	HR 1753	-1.02		-1.20	V*	316	12,000	10.4	410
ADS 3962	23 Ori.	-1.90		-4.08	V	603	19,000	18.3	610
ADS 4000	HR 1779	3.60		1.77	III-IV	83	2,600	3.2	74
ADS 4134	δ Ori.	-2.34		-6.97	II	631	33,000	31.9	1,100
ADS 4182	HR 1887	-2.90		-3.18	IV	501	18,000	19.3	550
ADS 4188	θ <sup>2</sup> Ori.	-3.65		-4.87	V	780	41,000	26.6	1,600
ADS 4262	HR 1945	.09		-.66	V	263	6,800	7.8	200
ADS 4749	HR 2174	.09		-1.02	V	209	6,100	7.4	180
ADS 5103	ν Gem.	.62		-3.21	IV	263	30,000	12.2	1,500
ADS 6783	HD 70516	6.76		5.05	V	33	990	1.6	25
ADS 6913	HD 73668	5.73		4.57	(V)*	35	910	1.8	20
ADS 6988	ι Cnc.	.96		-1.58	III	132	4,100	7.1	98
ADS 7311	27 Hya.	3.48		1.32	III	50	11,000	3.6	1,900
ADS 7438	HR 3811	3.70		2.39	V	76	1,900	2.9	49
ADS 7654	α Leo	6.05		-.72	V	26	4,600	5.3	140
ADS 7967	HR 4249	4.30		1.69	III	76	2,700	3.2	78
BDS 5652	α U.Ma.	4.14		-1.21	II	40	15,000	5.4	790
ADS 8162	83 Leo	6.92		5.84	(V)*	13	380	1.4	6.2
ADS 8347	65 U.Ma.	.73		.23	V	182	11,000	5.7	480
ADS 8530	12 Com.	4.20		.44	(III)*	76	4,900	3.7	180
ADS 8695	35 Com.	5.34		.51	III	76	2,200	3.6	54
BDS 6498	HR 5074	3.49		3.11	V	52	3,600	2.7	130
HR 5114	HD 118266	3.92		1.47	III	100	6,000	3.4	250
ADS 9258	HR 5397	1.82		1.46	V	110	3,800	4.2	110
ADS 9277	HR 5415	.52		.02	V	263	6,800	6.2	230
HR 5531	α Lib.	3.54		1.15	V	21	4,900	3.7	180
ADS 9559	δ Boo.	4.51		.15	III	46	4,800	4.0	170
ADS 9626	μ Boo.	4.58		2.37	IV	24	2,600	2.7	81
ADS 9951	ν Sco.	-1.74		-4.01	V	263	11,000	17.2	280
ADS 10129	17 Dra.	-.58		-1.03	V	158	14,000	8.8	560

TABLE 4 - Continued

System	Name	Secondary	Primary		Distance (Parsec)	Projected Separation (A.U.)	Total Mass <sub>☉</sub>	Period (10 <sup>3</sup> Years)
		M <sub>v</sub>	M <sub>v</sub>	Luminosity Class				
ADS 10149	37 Her.	1.94	.78	V	100	7,000	4.8	270
ADS 10535	HR 6491	3.81	.12	III*	174	5,700	4.2	210
ADS 10635	53 Oph.	2.71	.71	IV	100	4,100	4.3	130
ADS 10759	ψ Dra.	4.25	3.05	IV	20	620	2.5	9.8
ADS 10786	μ Her.	10.60	4.26	IV	6.9	230	1.3	3.0
ADS 10966	67 Oph.	-1.16	-5.32	Ib	603	33,000	16.4	1,500
ADS 11336	39 Dra.	4.03	1.13	V*	58	5,200	3.6	200
ADS 11593	HR 7033	-.58	-2.18	V	501	13,000	11.0	450
HR 7300	HD 180262	1.16	-.93	II	191	17,000	6.4	870
ADS 12750	HR 7475	-1.90	-4.97	I <sub>ab</sub>	980	27,000	20.9	970
ADS 12767	54 Sgr.	4.03	1.19	III	60	2,800	3.6	78
ADS 12815	16 Cyg.	5.08	4.82	V	17	650	1.9	12
ADS 12913	17 Cyg.	7.09	3.53	V*	19	490	1.9	7.9
ADS 13087	57 Aql.	-1.90	-2.67	V	398	14,000	14.9	430
ADS 13379	HD 190850	1.50	1.05	V	144	9,400	4.7	420
ADS 13554	31 Cyg.	-1.30	-4.53	II*	457	49,000	14.1	2,900
ADS 13870	HR 7827	1.94	-.09	IV	200	5,200	5.3	160
ADS 14101	K Del.	6.32	2.87	IV	28	6,000	9.7	160
ADS 14345	HD 198624	4.47	.68	II-III	144	15,000	4.9	830
ADS 14636	61 Cyg.	9.03	8.21	V	2.51	63	1.0	0.5
ADS 14909	1 Peg.	5.94	.83	III	44	1,600	3.5	34
ADS 15147	3 Peg.	3.32	1.84	V	76	3,000	3.5	88
ADS 15434	HD 208392	-5.18	-6.08	V	2,230	140,000	35.0	8,900
ADS 15764	HR 8493	2.10	-.29	II-III	191	5,500	5.2	180
ADS 16481	HR 8777	-1.03	-3.81	IV	940	32,000	15.0	1,500
ADS 16611	HD 219175	5.07	4.44	V	42	1,000	2.0	7.1
ADS 16633	91 Aqr.	7.08	2.13	III	26	1,300	2.6	9.2
<b>B. Class IV Secondaries</b>								
HR 1165	71 Tau.	-.37	-3.80	III	216	25,000	10.5	1,200
ADS 3579	HR 1600	.25	-1.25	III	295	12,000	6.8	500
ADS 6028	HD 57044	2.10	1.64	IV	138	4,400	3.8	150
BD+31.1676	HD 63610	.40	-.49	III	302	23,000	6.1	1,400
ADS 6588	HR 3174	-.95	-2.65	IV	597	19,000	9.2	860
HR 3590	HD 77250	2.15	1.05	III	100	27,000	4.3	2,100
ADS 8470	HD 106365	3.05	1.16	III	138	3,700	4.0	110
ADS 9474	HD 132910	2.10	1.78	IV	126	5,200	3.7	200
HR 6575	HD 160315	2.50	1.03	III	110	12,000	4.1	650
ADS 11639	ξ Lyr.	2.15	.76	Am	52	2,300	4.3	53

TABLE 4 - Continued

System	Name	Secondary $M_V$	Primary $M_V$	Luminosity Class	Distance (Parsec)	Projected Separation (A.U.)	Total Mass $_{\odot}$	Period ( $10^3$ Years)
<u>C. Class III Secondaries</u>								
HR 1412	O <sup>2</sup> Tau.	.45	.01	III	46	16,000	5.9	840
ADS 8001	HD 95098	.15	-1.68	(III)*	575	20,000	8.2	990
ADS 8883	HD 116442	.55	.25	III	229	6,200	5.4	210
ADS 14720	HR 8107	-.30	-1.14	V	330	45,000	8.1	1,100
<u>D. Class Ib Secondaries</u>								
ADS 1073	$\phi$ Cas.	(-5.6)	(-7.5)	Ia*	1,620	220,000	29.6	1,900
<u>E. Type Am Secondaries</u>								
BDS 1094	HD 12927	2.70	2.00	III	79	4,400	3.4	160
ADS 8568	17 Com.	1.90	.55	AOp	87	12,000	4.9	590
ADS 10628	Dra.	2.60	2.56	Am	29	1,800	3.2	43
BDS 9705	HD 188212	2.87	2.68	V	78	3,300	3.1	110

\* ADS 1073 Absolute magnitude of secundar taken from Arp's (1958) calibration.

ADS 3910 Secondary is AOp, but assumed on main sequence.

ADS 6913 Both components assumed Class V from color-color diagram.

ADS 8001 Both components assumed Class III from color-color diagram.

ADS 8162 See ADS 6913.

ADS 8530 Primary assumed Class III.

ADS 10535 }  
 ADS 11336 } Secondary assumed Class V.  
 ADS 12913 }

ADS 13554 Primary composite - listed as K2 II + B3 V by Bidelman (1954).

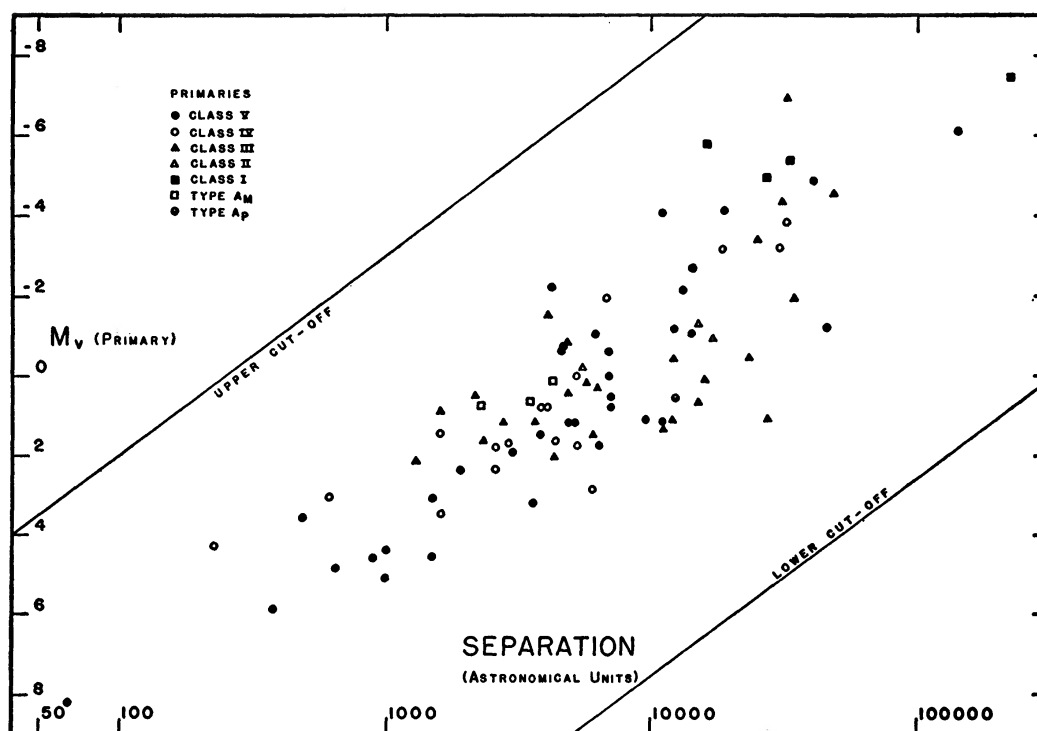


FIG. 7.—Absolute magnitude of the primary versus the intrinsic separation. The upper cutoff corresponds to conditions of 0th apparent magnitude and  $25''$  apparent separation. The lower cutoff corresponds to conditions of 10th magnitude and  $300''$  separation.

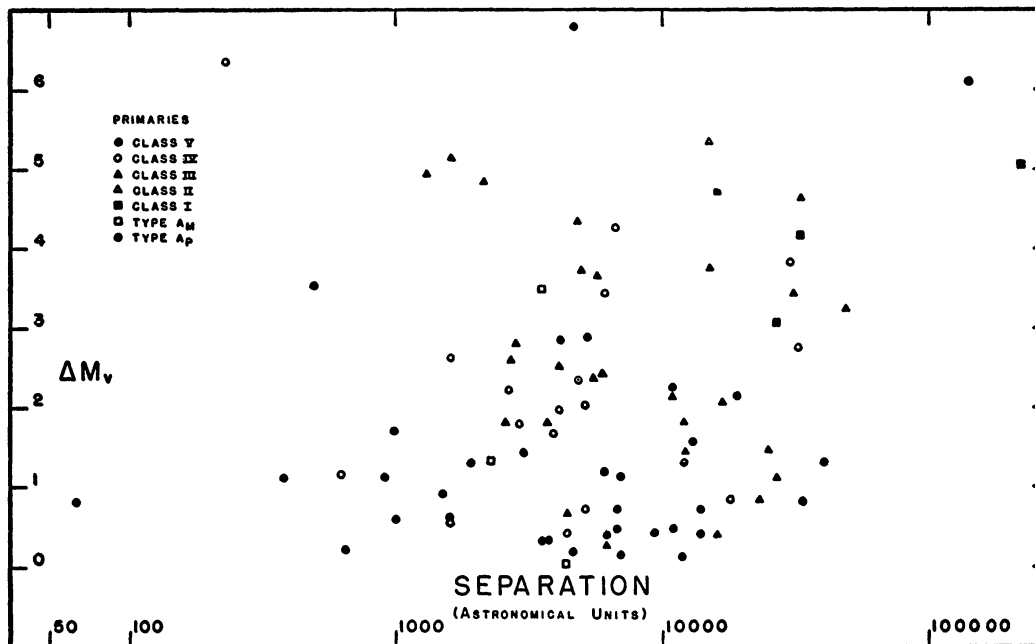


FIG. 8.—Differential magnitude versus intrinsic separation

way and, by using the empirical mass-luminosity relation as quoted by Strand (1957b) and the bolometric corrections of Popper (1959), to obtain masses and provisional periods for the systems. Since the same mass-luminosity relation was used without regard to luminosity class, it is probable that the masses of the giants and supergiants involve somewhat more error than do the masses of the main-sequence objects. The derived masses and periods are listed in Table 4. The periods are minimum values only, since they depend on the projected separations; and they range from 500 years for ADS 14636 to about 9000000 years for ADS 15434. It is clear that observation of orbital motion for most of these systems is out of the question for many years to come, and, moreover the relative radial velocity between most of the components is less than 1 km/sec, so that confirmation from radial velocity observations is also unlikely. It

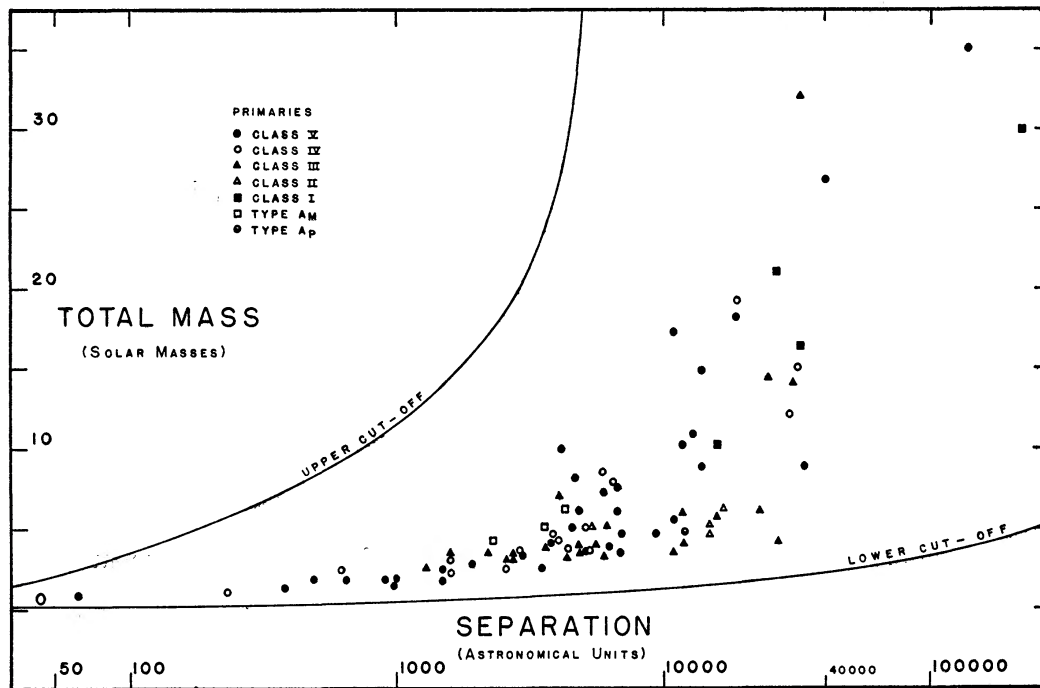


FIG. 9.—Total mass of the system versus the intrinsic separation. The upper cutoff corresponds to conditions of 0th apparent magnitude and 25'' apparent separation. The lower cutoff corresponds to conditions of 10th magnitude and 300'' separation.

should be pointed out that ADS 15434 has been treated as though it were a physical system, even though it exhibits a large reddening discrepancy (see the reddening discussion). Since the average  $E_{B-V}$  was used for the system, the absolute magnitudes and hence the masses for the components appear large.

Figure 9 is a plot of the separations versus the sum of the masses. The boundary lines were established by transferring the cut-off lines from Figure 7 with the assumption that the primary was half as massive as the whole system. They are, therefore, generous outer limits. Again the general trend of the points can be explained by selection effects, but the approximate limit of about 40000 a.u. seems real. The existence of such widely separated systems lends weight to the discussion of "proper-motion pairs" as being physical binaries of great separation (van Biesbroeck 1957; van de Kamp 1961).

The two systems which exceed 40000 a.u. are ADS 1073 and ADS 15434, and the question arises whether such systems are physical, and if they could exist for very long without being torn apart by the stochastic and shear forces of the galaxy. According to Huang (1957), a binary system would not be stable for separations greater than about

one-half of a mean interstellar distance, which would imply stable systems with separations as great as about 1.5 pc (for a mean interstellar distance of 3 pc as given by Chandrasekhar 1942). Both of the systems in question fall within this range of stability, and, moreover, both have extremely massive components, i.e., around  $15 M_{\odot}$ , and would be able to withstand greater disruptive forces. It is very possible, therefore, that these could indeed be physical systems. Both components of ADS 1073 ( $\phi$  Cas) are luminosity class I objects and have been studied as possible members of NGC 457 by Pesch (1959). The components of ADS 15434 are both early B-type main-sequence stars.

#### VIII. CONCLUSIONS

After observing photoelectrically ninety-four visual binaries with separations greater than  $25''$ , the following was found:

1. Systems with separations of about  $15''$  probably could be observed with adequate care using the 24-inch telescope, but systems of smaller separations would require modifications of the observing techniques.
2. Unambiguous reddening determinations were made for all but five of the systems.
3. Seven of the systems were found to be optical.
4. Good confirmation was found for the theories of common origin and evolution. Each component apparently evolved as a single star without close-binary-type interactions.
5. The distances for the systems ranged from 2.5 to 2200 pc.
6. A projected intrinsic separation was determined for each of the systems. They ranged between 63 a.u. and 220000 a.u.
7. The sum of the masses was estimated for each system. The range was from 1 to  $35 M_{\odot}$ .
8. A provisional period was obtained for each system, ranging from 500 to 9000000 years.
9. No correlations were found between separation and magnitude, except those introduced by selection effects.
10. An upper limit of about 40000 a.u. was found for the intrinsic separations of these systems.
11. Two systems were found with exceptionally large separations: 140000 a.u. and 220000 a.u.

The author would like to thank Drs. Robert Hardie and Arnold Heiser for their guidance and advice. Thanks are also due to Dr. William Bidelman for his useful discussion and comments on the problem, and to Dr. Arne Slettebak for kindly providing his spectral data prior to publication. The support of the Natural Science Committee of Vanderbilt University, the Research Corporation, and the National Science Foundation in several phases of this investigation is also greatly appreciated.

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