ABSOLUTE MAGNITUDES OF STARS IN THE SCORPIO-CENTAURUS ASSOCIATION*

F. C. Bertiau, S.J.†
University of Louvain and Vatican Observatory

Received June 10, 1958

ABSTRACT

Absolute magnitudes for well-established members of the Scorpio-Centaurus association have been determined from newly derived proper motions and recently published photoelectric and photographic photometry Radial velocities and spectral classifications based on new observations collected by the author at the McDonald Observatory have also been incorporated The analysis of the proper motions and the radial velocities and the determination of the absolute magnitudes are based mainly on the expansion hypothesis The conventional type of treatment, involving the assumption that the various parts of the association participate in differential galactic rotation, has also been carried out However, its results are rejected on the basis of various arguments, one of which is the large and unexplained K term in the radial velocities The individual absolute magnitudes are given in Table 1 The mean values per spectral class, in Table 7, are only slightly different from provisional values communicated earlier by Blaauw Apart from the relative motions of the members of the association due to the general expansion, the internal motions are found to be of the order of 1 0 km/sec or less The age of the association, or rather of its oldest parts, is estimated to be about 20 million years From the proper motions and the spectral classifications of the faint B-type stars in the densest part of the association, that is in Scorpius, it is concluded that the association contains a large number of late B-type stars These spectral classifications are based on observations with the Yerkes 40-inch refractor The details of the computation of the proper motions are described in the appendix at the end of the article

I. INTRODUCTION

The Scorpio-Centaurus association is the principal source of information on accurate absolute magnitudes for individual early B-type stars. Consequently, it plays a fundamental role in the calibration of the luminosity criteria for these types. The importance of accurately determined absolute magnitudes has been emphasized particularly by recent developments in the photoelectric and photographic measurements of line intensities. Since the extensive investigation of the association by Blaauw (1946), it has become possible to improve the proper motions of the members of the association by means of new series of meridian observations. These allow a more accurate selection of the stars belonging to the association and a more precise determination of their parallaxes. Further, the Cape Observatory has published accurate photographic magnitudes and photoelectric colors of most of the members of the association, and photoelectric photometry has been published by Oosterhoff.

The Scorpio-Centaurus association lends itself excellently to the study of the properties of young groups of stars. The emphasis of the present paper will be on the computation of the parallaxes and luminosities of the stars in those parts of the association where these quantities can be determined with the highest precision and with the least amount of ambiguity as to the question of membership in the association. The problem of the structure of the association and of its dimensions will be only briefly referred to. In the course of the investigation, it appeared desirable to improve upon the radial-velocity determinations for some of the stars and to extend the spectral and luminosity classifications in the Yerkes system. New observations were therefore made at the McDonald and Yerkes Observatories.

A limited exploration of the membership of faint stars in a small, but suitably located, part of the association has also been carried out.

* *Contributions from the McDonald Observatory, University of Texas,* No 291

† Most parts of this investigation were carried out during a stay at the Yerkes Observatory in 1954 and 1955

II. THE OBSERVATIONAL DATA

a) The Proper Motions

The determination of the proper motions on which the present investigation is based is described in the appendix to this article. The following stars were included in the computation of the proper motions: (1) the 114 stars in Blaauw's lists of "certain," "probable," and "doubtful" members (Blaauw 1946); and (2) the stars HD 127972 (η Cen), 142378 (47 Lib), 147084 (o Sco), 147888, and 148478 (α Sco = Antares), which are also members of the association.

All new proper motions are given in Table 11. They are in the system of N30 (H. R. Morgan 1952), except that precessional corrections were applied as given by Morgan and Oort (1951). The proper motions in galactic components are given in column 5 of Table 1, except for a number of stars which are now considered to be field stars and some stars outside region (1), described in Section II*e*.

The average weight per proper motion is about twice that for the *GC* proper motions used in Blaauw's analysis. This increase in weight is due mainly to the excellent series of meridian observations carried out at the Cape Observatory around the year 1940. This series included almost all the stars in Blaauw's lists, with about ten observations per star in each co-ordinate (Jackson 1953). For the majority of the new proper motions the probable errors are between 0″.0010 and 0″.0030, i.e., of the order of about 10 per cent of the proper motions.

b) The Radial Velocities

Most of the radial velocities were taken from Wilson's catalogue (Wilson 1953). Since, however, these are rather poor for a number of stars in the association, additional observations were made with the D camera of the coudé spectrograph at the 82-inch telescope of the McDonald Observatory (dispersion about 35 A/mm). The results of these measures will be published elsewhere by van Hoof, Bertiau, and Deurinck. The velocities adopted in the present investigation are in Table 1; they are weighted means of the new determinations and the values in Wilson's catalogue. We have maintained the quality classes of Wilson's catalogue, except in a few cases where the new results were based on many more spectrograms than were used for the Wilson values.

A correction of −1.0 km/sec for gravitational red shift has been applied in the analysis of the radial velocities for the stars of spectral type B0 and one of −0.5 km/sec to stars of type B1.

c) The Apparent Magnitudes and Colors

Nearly all our stars occur in *Cape Mimeograms*, No. 1 (1953), which contains accurate photographic apparent magnitudes, *BPg*, and photoelectric colors, *Cpe*, determined at the Cape Observatory. These were reduced to the *U*, *B*, *V* system by means of the relations

$$V = BPg - 1.29\, Cpe - 0.02\,, \quad B - V = Cpe + 0.19\,,$$

which are, with slight revisions, the provisional relations given by Cousins and Stoy (1954). If no Cape photometry was available, we used values derived from Oosterhoff's (1951) photoelectric photometry or from Schilt and Jackson (1949). These cases are referred to in the notes to Table 1.

d) The Spectral Classifications

Spectrograms for spectral classification in the MK system were obtained by the author with the 110-mm camera on the Cassegrain spectrograph at the McDonald 82-inch telescope (dispersion near 120 A/mm at Hγ) for all stars in Table 1 north of −51° declination. Spectra of standard stars were also obtained in the course of this program, and the classifications were carried out under the supervision of Dr. W. W. Morgan. They are given in column 20 of Table 1.

For some of the bright stars not accessible from the McDonald Observatory, spectra occur in McClean's atlas, *Spectra of Southern Stars* (1898), and these were provisionally classified by Dr. Morgan from the atlas. These classifications cannot, of course, be given the weight of normal classifications based on the actual spectrograms. Four of these occur in column 20 of Table 1, where they are printed in italics.

Since the McDonald observations were collected, spectral classifications of Scorpio-Centaurus stars have also been published by Woods (1955) and by de Vaucouleurs (1957). The first are based on Mount Stromlo objective-prism spectra, the latter on microphotometer tracings of Mount Stromlo slit spectra. The classifications by de Vaucouleurs are given next to the McDonald classes in column 20 of Table 1. A comparison between the two reveals that many of the McDonald B2 stars are classified as B3 by de Vaucouleurs, whereas around B5 the Mount Stromlo classifications tend to be earlier than the McDonald classes. A similar trend, though less pronounced, was noticed in a comparison of the McDonald classes with those of Woods. These systematic differences do not seem to depend on the luminosity class. The H-R diagrams and the mean absolute magnitudes per spectral class in Section IV will be given separately for the McDonald classes and for those of de Vaucouleurs. For one star, HD 147888, the spectral type has been taken from Feast, Thackeray, and Wesselink (1957). For the faint B-type stars in the Upper Scorpius region, spectral classifications were made from spectrograms obtained with the 40-inch Yerkes refractor. These are used in Section VII.

e) Stars Selected for Analysis

Figure 1 shows the distribution, in galactic co-ordinates, of all stars for which the new proper motions were computed, except for HD 170740 at $l = 349°$. The various symbols will be explained below. Lines drawn from the positions of the stars represent the proper motions with a mean probable error of the two components smaller than 0".0027; proper motions with larger probable errors are represented by dashed lines. The scale is indicated in the upper right corner of the diagram.

Previous investigations (e.g., Blaauw 1946) have shown that the boundaries of the association are well defined at the higher galactic longitudes, where most of its members are at relatively high galactic latitude and well detached from the general background of field stars. At the lower longitudes it merges into the field-star population. In the latter part the proper motions become smaller because of the vicinity of the antapex of the solar motion. Blaauw (1946) adopted a provisional boundary at galactic longitude 240°. Since we are concerned mainly with obtaining accurate individual absolute magnitudes for stars of well-established membership in the association and not so much with its true dimensions, the following analyses will be confined to the region at longitudes higher than 260° and the following latitudes:

$$l = 260°\text{–}280° , \qquad -15° < b < +35° ,$$
$$l = 280°\text{–}330° , \qquad 0° < b < +35° . \qquad (1)$$

The new proper motions, with their small accidental errors, bear out the remarkable parallelism of the majority of the proper motions, known from earlier investigations. This, together with the conspicuous clustering of the stars, is unmistakable evidence that we are not dealing with a sample of field stars but with a group of stars of common origin.

For a small number of stars in the region (1), mostly at the periphery and all classified by Blaauw as doubtful members, the new proper motion indicates that the star is not a

TABLE 1

OBSERVATIONAL DATA, PARALLAXES, AND VISUAL ABSOLUTE MAGNITUDES FOR STARS IN THE SCORPIO-CENTAURUS ASSOCIATION

No	Name	HD No	l	b	μ_l	μ_b	p e μ_l	p e μ_b	υ	τ	Radial Vel (km/sec)	Quality	Residual (km/sec)
					(0″001)		(0″001) ±		(0″001)				
(1)	(2)	(3)	(4)		(5)		(6)		(7)		(8)		(9)
1		103079	264°4	− 3°2	−35	−15	3 4	2 8	38	+ 3	+25 5	b	+ 5 8
2		103884	264 5	− 0 4	−17	−12	3 6	3 1	21	− 2	+16 0	c	− 3 1
3		105382	264 0	+11 5	−27	−12	3 1	2 7	28	+ 3	+16 5	b	− 0 4
4	δ Cen	105435	264 0	+11 5	−24	−14	1 7	1 6	28	+ 3	+ 9	c	− 7 9
5	ρ Cen	105937	264 8	+ 9 9	−32	−19	2 4	2 1	38	+ 2	+21	c	+ 4 0
6	δ Cru	106490	266 1	+ 3 6	−28	−11	1 8	1 7	30	+ 5	+26 4	b	+ 8 6
7	ζ Cru	106983	267 0	− 1 6	−34	−18	3 3	2 4	39	0	+18 7	b	+ 0 2
8		108257	267 1	+11 0	−28	−22	3 4	2 6	35	− 3	+24	d	+ 8 0
9	σ Cen	108483	267 2	+12 2	−16	−16	2 5	2 0	22	− 5	+12	d	− 3 8
10	γ Mus	109026	269 0	− 9 6	−44	− 6	2 5	2 1	43	+13	+14	c	− 5 1
11	α Mus	109668	269 2	− 6 6	−30	− 9	2 6	2 2	29	+ 4	+18	c	− 0 6
12		110956	270 2	+ 6 1	−31	−24	3 5	2 7	38	− 5	+16 7	b	+ 0 7
13	β Cru	111123	270 3	+ 2 9	−32	−15	1 5	1 4	36	+ 3	+20 0	a	+ 2 9
14	λ Cru	112078	271 2	+ 3 4	−22	−17	3 6	2 7	27	− 4	+16	c	− 0 2
15	μ_2 Cru	112091	271 3	+ 5 4	−21	−25	3 7	2 6	25	− 4	+19	c	+ 3 2
16	μ_1 Cru	112092	271 3	+ 5 4	−19	− 6	2 6	2 1	25	− 4	+11 9	b	− 3 9
17		113703	273 6	+14 0	−24	−20	3 1	2 5	31	− 4	+ 9 0	b	− 4 3
18	ξ_2 Cen	113791	273 6	+12 5	−18	− 6	2 3	2 0	18	+ 4	+14 3	a	+ 0 7
19		115823	275 4	+ 9 4	−22	−13	3 1	2 6	26	0	+ 6 2	b	− 7 4
20		116087	274 5	+ 1 3	−20	−10	3 8	2 7	23	+ 1	+26	d	+10 5
21	ϵ Cen	118716	278 2	+ 8 2	−17	− 9	1 7	1 8	19	0	+ 5 6	b	− 7 8
22	ν Cen	120307	282 6	+19 3	−25	−11	2 3	1 8	28	+ 2	+ 9 0	a	− 0 2
23	μ Cen	120324	282 4	+18 6	−15	−12	2 5	1 9	19	− 3	+11 4	b	+ 2 0
24	3 Cen	120709	285 7	+27 6	−36	−25	2 0	1 9	43	− 6	+ 7 1	b	+ 0 4
25		120908	280 2	+ 7 9	−23	−12	5 7	4 0	26	0	+ 8 0	b	− 4 2
26	4 Cen	120955	286 4	+28 5	−10	− 7	2 4	2 0	12	− 2	+ 5 2	b	− 1 0
27	ϕ Cen	121743	284 1	+18 4	−24	−11	2 2	2 1	26	+ 1	+ 8 6	b	− 0 2
28	υ_1 Cen	121790	283 4	+15 8	−24	−12	2 4	2 0	27	+ 1	+ 5 6	b	− 4 0
29	χ Cen	122980	285 9	+18 9	−23	−11	2 4	1 9	26	+ 1	+ 9 8	b	+ 1 6
30		125823	289 8	+19 3	−31	−16	2 4	2 1	35	0	+ 6 6	b	− 0 2
31	η Cen	127972	290 9	+15 9	−34	−20	1 4	1 4	39	− 2	− 0 2	b	− 7 1
32	α Lup	129056	289 6	+10 7	−19	− 6	2 0	1 8	20	+ 3	+ 7 3	a	+ 1 6
33		129116	294 0	+19 1	−31	−15	2 3	2 1	35	− 1	+ 8	c	+ 2 6
34	o Lup	130807	292 9	+13 2	−31	−10	2 5	2 2	32	+ 4	+ 7 0	b	+ 0 3
35	β Lup	132058	294 3	+13 0	−48	−14	1 8	1 6	50	+ 8	− 0 6	b	− 6 9
36	κ Cen	132200	294 9	+13 8	−18	− 7	2 0	1 9	19	+ 1	+ 8 6	a	+ 2 7
37		132955	300 9	+21 5	−23	−13	2 8	2 5	26	− 3	+ 5 5	b	+ 2 9
38		133937	296 0	+12 2	−24	− 5	6 5	5 7	24	+ 6	+ 2	d	− 3 8
39	λ Lup	133955	294 8	+10 2	−19	−11	2 4	2 2	22	− 2	+18	c	+11 4
40	δ Lup	136298	299 3	+12 8	−20	− 8	2 2	2 2	22	+ 1	− 4 2	c	− 8 8
41	ϕ_1 Lup	136664	301 9	+15 6	−21	− 7	2 2	2 2	22	+ 2	− 1 2	b	− 4 4
42		137432	302 6	+15 3	−26	−15	3 0	2 8	30	− 4	+ 7	c	+ 4 1
43	ζ Lib	138485	317 5	+29 8	−17	− 4	1 5	1 5	18	0	+ 6 2	c	+ 9 9
44	γ Lup	138690	301 2	+10 8	−18	−13	1 7	1 6	22	− 5	+ 9 9	c	+ 5 7
45		138764	324 2	+35 0	−31	− 6	2 3	2 3	32	− 2	− 2 0	b	− 7 9
46		138769	298 9	+ 7 8	−22	−12	3 1	2 9	25	− 1	+ 7 9	b	+ 2 3
47	τ Lib	139365	309 2	+19 3	−27	−11	1 6	1 7	29	0	+ 0 8	c	+ 0 7
48	ψ_2 Lup	140008	306 5	+14 9	−28	− 6	2 4	2 5	28	+ 5	+ 8	c	+ 6 3
49	1 Sco	141637	314 2	+20 5	−27	− 7	1 7	1 6	28	− 2	− 4 2	c	− 2 5
50	λ Lib	142096	318 8	+24 1	−24	−10	1 1	1 1	26	− 2	+ 4 5	c	+ 8 0

TABLE 1—*Continued*

No	p_v Unit 0″0001	(p e of p_v)/p_v	Adopted p Unit 0″0001	(p.e of p)/p	m_0-M	V	$B-V$	V_0*	M_v*	Internal p e. of M_v	Spect Class† McDonald	Spect Class† Canberra	Notes‡
(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)	(18)	(19)	(19)	(20)	(20)	(21)
1	88	0 090	80	0 067	5 48	4 96	−0 10	*4 72*	*−0 76*	0±14		B4 IV	1, 2, 4
2	47	166	59	097	6 15	5 55	− 14	*5 37*	*−0 78*	20		B3 V	1, 2
3	61	121	66	078	5 90	4 51	− 17:	4 66:	−1 24:	(16)	dB7:	B6 III–IV	
4	61	121	66	078	5 90	2 59	− 15:	2 32:	−3 58:	(16)	B2:V:pe	B3 Vne	
5	82	090	76	067	5 60	3 97	− 15	*3 88*	*−1 72*			B4 V	
6	67	113	69	075	5 81	2 81	− 23	2 78	−3 03	16	*B2 V*	B2 IV	
7	88	088	80	067	5 48	4 06	− 17	*3 97*	*−1 51*	14		B3 IV	
8	76	096	74	069	5 65	4 87	− 33	*4 87*	*−0 78*	15		B4 IV	1, 2
9	48	152	60	091	6 11	3 92	− 20	3 80	−2 31	19	B2 V	B3 V	
10	98	080	84	064	5 38	3 86	− 16	*3 86*	*−1 52*	13		B5 V	
11	65	118	68	077	5 84	2 70	− 20	2 58	−3 26	16	*B2 V*	B3 IV	
12	83	058	78	058	5 54	4 63	− 16:	*4 51:*	*−1 03:*	(12)		B3 IV	
13	77	062	73	060	5 68	1 28	− 25	1 19	−4 49	13	*B0 5 III*	B0 5 IV	
14	58	083	58	075	6 18	4 66	− 17	*4 69*	*−1 49*	16		B5:Vn	
15	54	089	55	079	6 30	5 26	− 17	*5 29*	*−1 01*	17		B5 Ve	
16	54	089	55	079	6 30	4 00	− 17	*3 91*	*−2 39*	17		B3 IV	
17	65	071	63	066	6 00	4 73	− 15	4 70	−1 30	14	B5 V	B4 IV	
18	38	121	42	103	6 88	4 26	− 18	4 08	−2 80	21	B2 V	B2 IV	
19	54	085	55	076	6 30	5 53	− 13	*5 44*	*−0 86*	16		B5 III	1, 2
20	48	098	50	086	6 51	4 53	− 13	*4 44*	*−2 07*	18		B5 V	
21	39	115	43	098	6 83	2 33	− 23	2 24	−4 59	20	*B1 V*	B1 V	
22	56	080	56	073	6 26	3 42	− 22	3 36	−2 90	15	B2 IV	B2 V	4
23	39	115	43	098	6 83	3 12:	− 13:	2 79:	−4 04:	(20)	B2 V:pne	B3 Ve	
24	89	051	83	054	5 40	4 34	− 13	4 25	−1 15	11	B5 III	B5 IV	4
25	54	085	55	076	6 30	5 94	− 04	*5 58*	*−0 72*	16		B5 V	1, 2
26	25	180	31	148	7 54	4 74	− 15	4 71	−2 83	30	B5 III	B5 IV	4
27	53	083	54	075	6 34	3 86	− 22	3 80	−2 54	16	B2 IV	B2 V	
28	55	082	55	074	6 30	3 91	− 22	3 85	−2 45	16	B2 V	B3 IV	
29	53	087	54	078	6 34	4 41	− 21	4 32	−2 02	16	B2 V	B2 V	
30	72	062	69	060	5 81	4 42	− 21	4 45	−1 36	13	B3 V	B6 III	
31	90	057	83	057	5 40	2 33	− 21	*2 36*	*−3 04*	12		B3 III	4
32	40	113	44	097	6 78	2 32	− 22	2 20	−4 58	20	B1 V	B1 III	
33	71	063	68	061	5 84	4 01	− 18:	3 95:	−1 89:	(13)	B3 V	B3 V	
34	67	069	65	065	5 94	4 38	− 18	4 50	−1 44	14	B6 III:	B6 III	
35	101	045	92	050	5 18	2 69	− 23	2 66	−2 52	11	B2 IV	B2 V	
36	40	112	44	096	6 78	3 15	− 21	3 06	−3 72	20	B2 V	B2 III	
37	54	085	55	076	6 30	5 41	− 14	5 23	−1 07	16	B3 V	B4 IV	3
38	49	092	51	081	6 46	5 90	− 10	5 84	−0 62	17	B7:V:nn	B6 V	1, 2
39	45	100	48	087	6 59	4 10	− 19	4 07	−2 52	18	B3 V	B3 IV	4
40	45	100	48	087	6 59	3 24	− 23	3 21	−3 38	18	B2 IV	B3 IV	
41	46	100	48	087	6 59	4 58	− 18	4 64	−1 95	18	B5 V	B3 IV	
42	63	073	62	068	6 04	5 40	− 16	5 44	−0 60	14	B5 V	B4 V	3
43	42	126	54	054	6 34	5 53	− 18	5 35	−0 99	12	B2 Vnn	B3 III	3, 4
44	45	102	48	089	6 59	2 80	− 22	2 74	−3 85	18	B2 Vn	B3 V	4
45	81	070	64	048	5 97	5 12	− 10	5 06	−0 91	10	B7 IV:	B6 IV	3
46	52	088	53	078	6 38	4 56	− 19	4 65	−1 73	16	B5 IV	B3 IV	4
47	62	077	59	048	6 15	3 68	− 18	3 56	−2 59	10	B2 5 V	B4 V	4
48	60	078	60	071	6 11	4 74	− 15	4 77	−1 34	15	B6 V	B6 V	4
49	63	079	59	049	6 15	4 65	− 09	4 26	−1 89	10	B2 5 Vn	B3 V	
50	61	0 085	59	0 049	6 15	5 06	−0 08	4 70	−1 45	0 10	B3 V		3

* Values of V_0 and M_v are printed in italics if the Canberra spectral types were used in computing the corrections for interstellar absorption

† Classifications from McClean's atlas are printed in italics

‡ The notes are as follows:

1 V based on Harvard Revised Photometry
2 $B-V$ based on Schilt and Jackson (1952)
3 V and $B-V$ based on Oosterhoff (1951)
4 The following corrections for duplicity were adopted:

HD	ΔM	HD	ΔM	HD	ΔM
103079	+0ᵐ10	138485	+0ᵐ30	143018	+0ᵐ60
120307	+0 30	138690	+0 66	144217	+0 30
120709	+0 20	138769	+0 10	145502	+0 40
120955	+0 30	139365	+0 30	148184	+0 30
127972	+0 60	140008	+0 60	151890	+0 70
133955	+0 60	142114	+0 10		

1958ApJ...128..533B

TABLE 1—*Continued*

No	Name	HD No	l	b	μ_l	μ_b	p e μ_l	p e μ_b	v	τ	Radial Vel (km/sec)	Quality	Residual (km/sec)
					(0″001)		(0″001)±		(0″001)				
(1)	(2)	(3)	(4)		(5)		(6)		(7)		(8)		(9)
51	2 Sco	142114	315 0	+20 3	−27	−10	1 6	1 5	28	0	−12 2	b	−10 3
52		142165	315 6	+20 9	−30	− 5	2 0	2 0	30	+ 5	+13	d	+15 2
53	. .	142184	316 0	+21 3	−29	−10	2 2	2 1	31	0	−27	e	−24 6
54	47 Lib	142378	319 7	+24 3	−23	−19	2 0	1 9	23	+ 5	− 6	c	− 2 1
55	ρ Sco	142669	312 6	+17 1	−22	−13	1 7	1 6	26	− 3	+ 2 8	b	+ 3 5
56	48 Lib	142983	324 4	+27 3	−22	− 3	1 1	1 2	22	+ 2	− 5 6	b	− 0 1
57	π Sco	143018	315 3	+18 9	−25	−11	1 2	1 2	27	− 1	− 3	c	− 1 6
58	η Lup	143118	306 7	+ 9 8	−26	−10	2 1	2 0	28	+ 1	+ 7	c	+ 4 6
59	δ Sco	143275	318 1	+21 2	−23	−11	0 8	0 7	26	− 3	− 9 0	b	− 7 0
60		143699	307 0	+ 9 2	−34	− 7	2 9	2 9	33	+ 8	− 0 8	c	− 3 2
61	β₁ Sco	144217	321 2	+22 3	−18	−11	0 6	0 5	23	0	− 6 6	b	− 3 5
62	β₂ Sco	144218	321 2	+22 3	−26	− 2	1 4	1 4	23	0	− 3 8	b	+ 0 3
63	θ Lup	144294	308 7	+10 1	−25	−10	2 0	1 9	27	+ 1	+14 6	b	+12 9
64	ω₁ Sco	144470	320 9	+21 4	−24	−10	1 4	1 5	26	− 1	− 4 2	c	− 0 8
65	13 Sco	145482	316 1	+15 5	−22	−11	1 8	1 8	24	− 3	+ 0 5	b	+ 2 2
66	ν Sco	145502	322 7	+21 4	−25	−11	1 0	1 0	27	− 3	− 2 3	c	+ 2 2
67	ο Sco	147084	320 1	+16 8	−20	−13	1 8	1 7	24	− 3	− 8 5	a	− 5 4
68	σ Sco	147165	319 3	+15 7	−20	−10	1 0	0 9	22	− 2	− 0 4	a	+ 1 9
69	. .	147888	321 6	+16 4	−24	−16	3 7	3 4	28	− 7	− 9 6	b	− 6 0
70	χ Oph	148184	326 0	+19 4	−24	−12	1 5	1 5	27	− 4	− 4 0	b	+ 1 2
71	α Sco	148478	319 6	+13 8	−21	−12	0 6	0 7	24	− 3	− 3 2	a	− 0 8
72	22 Sco	148605	321 1	+14 5	−22	−15	1 7	1 6	16	− 6	− 3 8	b	− 0 7
73	.	148703	313 8	+ 8 0	−12	− 5	1 7	1 7	13	+ 1	+ 0 4	b	+ 0 1
74	τ Sco	149438	319 4	+11 5	−20	−10	1 1	1 0	22	− 1	− 1 0	a	+ 0 2
75	μ₁ Sco	151890	313 9	+ 2 7	−21	− 7	1 6	1 7	24	+ 4	−25	d	−26 1
76	μ₂ Sco	151985	314 0	+ 2 7	−25	− 8	1 9	1 9	24	+ 4	+ 2 0	b	+ 0 9
77	θ Oph	157056	328 2	+ 5 1	−16	−13	0 7	0 8	21	− 4	− 3 6	b	+ 0 4

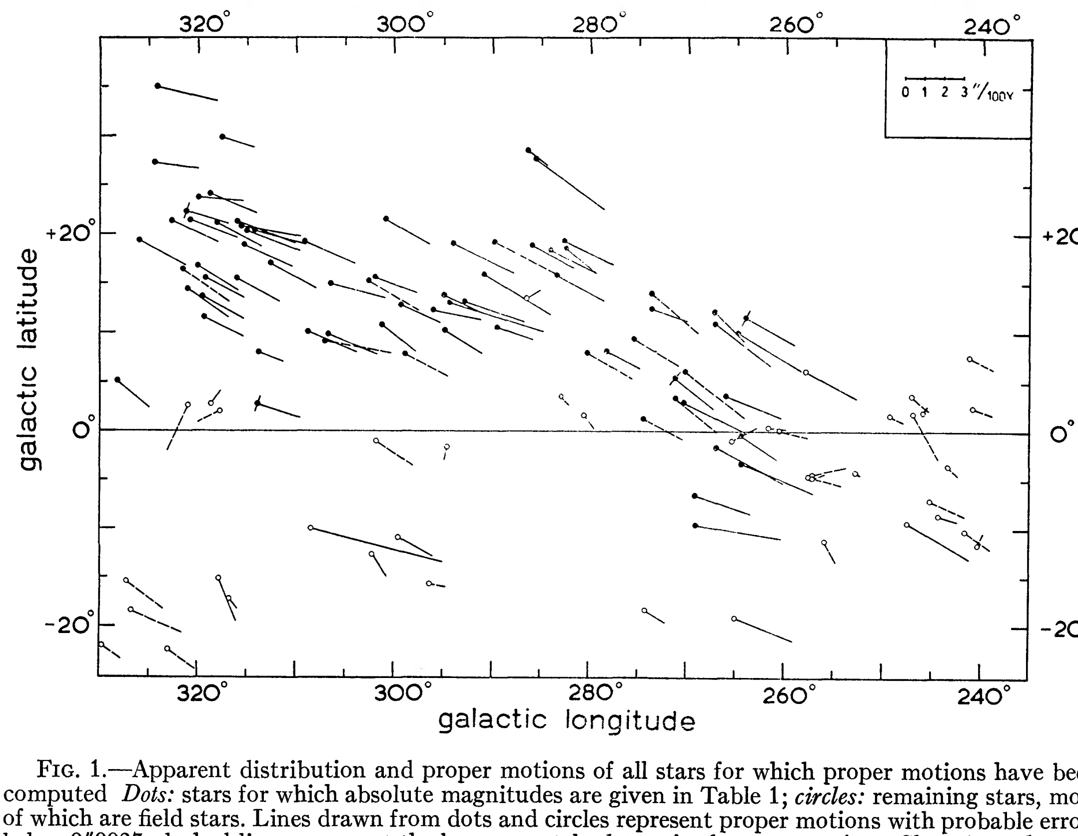

FIG. 1.—Apparent distribution and proper motions of all stars for which proper motions have been computed *Dots:* stars for which absolute magnitudes are given in Table 1; *circles:* remaining stars, most of which are field stars. Lines drawn from dots and circles represent proper motions with probable errors below 0″0027; dashed lines represent the less accurately determined proper motions Short bars through dots indicate double stars for which the average proper motion has been drawn. The scale of the proper motions is in the upper right corner.

TABLE 1—*Continued*

No	p_v Unit 0″.0001	(p.e. of p_v)/p_v	Adopted p Unit 0″.0001	(p.e. of p)/p	m_0-M	V	$B-V$	V_0*	M_v*	Internal p.e. of M_v	Spect Class† McDonald	Spect Class† Canberra	Notes‡
(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)	(18)	(19)	(19)	(20)	(20)	(21)
51	65	0 077	60	0 048	6 11	4 63	−0 11	4 30	−1 81	0±10	B2 5 Vn	B3 Vn	4
52	69	072	61	048	6 07	5 42	− 06:	5 18:	−0 89:	(10)	B6 V	B6 Vn	3
53	71	070	61	048	6 07	5 45	− 09	5 00	−1 07	10	B2 Vnn	B3 Vne?	3
54	54	096	57	050	6 22	5 96	− 01	5 51	−0 71	11	B5 V:	. . . .	
55	56	086	58	049	6 18	3 90	− 21	3 81	−2 37	10	B2 V	B3 IV	
56	55	100	57	051	6 22	4 96	− 08	4 84	−1 38	11	Bp	. . .	
57	61	082	59	049	6 15	2 92	− 19	2 71	−3 44	10	B1 V	B2 IV	4
58	58	079	58	072	6 18	3 45	− 23	3 42	−2 76	15	B2 V	B3 V	
59	60	085	58	049	6 18	2 34	− 13	1 83	−4 35	10	B0 V	. . .	
60	71	066	68	063	5 84	4 91	− 15	5 00	−0 84	13	B7 IV:	B5 V	
61	55	096	57	050	6 22	2 64	− 08	2 04	−4 18	11	B0 5 V	B1 V	4
62	55	096	57	050	6 22	4 92	− 02	4 26	−1 96	11	B2 V	. . .	
63	57	081	57	074	6 22	4 25	− 20	4 13	−2 09	15	B2 Vn	B3 IV	
64	63	084	59	049	6 15	3 96	− 07	3 39	−2 76	10	B1 V	. .	
65	54	091	57	050	6 22	4 60	− 17	4 45	−1 77	11	B2 5 Vn	B3 Vn	
66	67	081	60	049	6 11	3 97	+ 04:	3 25:	−2 86:	(10)	B2 IV–V	B3 V	4
67	56	091	58	050	6 18	4 54	+ 78	2 65	−3 53	11	A5 II	A5 III	
68	53	098	57	051	6 22	2 86	+ 14	1 66	−4 56	11	B1 III		
69	67	078	60	049	6 11	6 76	+ 32:	5 20:	−0 91:	(10)	B3 V:	. .	
70	67	082	60	049	6 11	4 30	+ 23:	2 89:	−3 22:	(10)	B2 V	B3 V:e	4
71	56	091	58	050	6 18	0 92	+1 84	. . .	−5 4	11	M2 I		
72	60	087	58	050	6 18	4 80	− 15	4 53	−1 65	10	B2 V	. .	
73	29	169	51	061	6 46	4 25	− 17	4 04	−2 42	13	B2 IV	B2 V	
74	52	098	56	051	6 26	2 85	− 25	2 70	−3 56	11	B0 V	. .	
75	52	092	56	050	6 26	3 04	− 20	2 92	−3 34	11	B1 5 V	B3 Vp	4
76	52	092	56	050	6 26	3 57	− 22	3 51	−2 75	11	B2 IV	B2 IV	
77	51	0 106	56	0 052	6 26	3 29	−0 22	3 23	−3 03	0 11	B2 IV	B2 IV	

member. These are:

$$\begin{aligned} &\text{HD } 104841, & l &= 265.^\circ 4, & b &= -\ 1.^\circ 0;\\ &\text{HD } 125238, & l &= 286.^\circ 5, & b &= +13.^\circ 5;\\ &\text{HD } 154090, & l &= 318.^\circ 6, & b &= +\ 2.^\circ 9;\\ &\text{HD } 154368, & l &= 317.^\circ 8, & b &= +\ 2.^\circ 0;\\ &\text{HD } 155450, & l &= 321.^\circ 0, & b &= +\ 2.^\circ 6. \end{aligned}$$

Their proper motions deviate considerably from the direction of parallelism. For HD 154090 and HD 154368 the non-membership is confirmed by the spectroscopic distance estimate (both stars are of luminosity class I, which is incompatible with the distance of the association).

The following stars, all but one classified by Blaauw as doubtful members, have also been excluded from the further analysis. Their proper motions, though in the right direction, are all considerably smaller than those of the remaining stars in the region considered. All are at very low latitudes and are probably field stars whose proper motion reflects the normal solar motion:

$$\begin{aligned} &\text{HD } \ \ 99556, & l &= 260.^\circ 6, & b &= +0.^\circ 1;\\ &\text{HD } 100929, & l &= 261.^\circ 7, & b &= +0.^\circ 4;\\ &\text{HD } 123335, & l &= 280.^\circ 5, & b &= +1.^\circ 6;\\ &\text{HD } 125288, & l &= 282.^\circ 9, & b &= +3.^\circ 7. \end{aligned}$$

These nine stars inside the region (1) and all stars outside it are represented by open circles in Figure 1. The remaining ones, represented by dots, form the basis for the analyses in the following sections.

III. THE MOTION OF THE ASSOCIATION

a) Method of Analysis

In an analysis of the stream motion of the Cassiopeia-Taurus group, Blaauw (1956*a*) has pointed out that the treatment of a group of stars of common origin should be different in several respects from the conventional analysis for solar motion of a sample of field stars. Stars with a common origin may be expected to show a certain amount of expansion from the originally smaller volume occupied by the group at the time of its formation, whereas the ordinary effect of differential galactic rotation may not (yet) be exhibited by the relative motions. Referring to Blaauw's article for the detailed reasoning, we summarize here only the main points relevant to the method of analysis.

First, assume that the association shows only linear expansion—i.e., expanding velocities of the members with respect to one another proportional to their distances—and no differential galactic rotation. In that case the proper motions will show exact convergence; the convergent point does not give, however, the direction of the velocity with respect to the sun for the association's center but the direction of the velocity, S, with respect to the sun for an imaginary member of the association coinciding in position with the sun. Denoting by λ the angular distance of a star in the association from this convergent point, by v its proper-motion component in the direction toward the convergent point, and by p its parallax, we have

$$v = \frac{pS \sin \lambda}{4.74}, \tag{2}$$

S being expressed in kilometers per second.

The radial velocity, ρ, of the star will contain two terms, one due to the relative velocity, S, and one due to the expansion. If r denotes the distance of the star from the sun ($r = 1/p$) and k is the rate of expansion expressed in kilometers per second per parsec, we have

$$\rho = S \cos \lambda + r k . \tag{3}$$

If r_0 represents the distance of the center of the association, then its velocity relative to the sun is given by the vector sum of the velocity S toward the convergent point and the velocity $r_0 k$ in the direction from the sun toward the center.

On the other hand, if the stars have a common motion with respect to the sun plus differential galactic rotation, then, after correction of the proper motions and the radial velocities for the latter effect, the proper motions will converge toward a convergent point corresponding with the direction of this common stream motion; counting the angular distance λ and the (corrected) v component with respect to this convergent point, we have

$$v = \frac{pS \sin \lambda}{4.74}, \tag{4}$$

S being the velocity of the stream motion. Further, for the (corrected) radial velocity we have

$$\rho = S \cos \lambda . \tag{5}$$

The two cases described here may be considered as the extremes between which the true state of motion will probably lie. If the age of the association is not more than a few tens of million years, differential galactic rotation effects will still be negligible (Blaauw 1952), and the first alternative must give a sufficient description. If, on the other hand, the age is of the order of 100 million years, differential galactic rotation will be quite noticeable. Hence, for a proper analysis of the proper motions and radial velocities, one would require a priori information on the age.

Since we do not want to introduce any assumption with regard to the age of the association, we shall submit the observational data to two procedures of analysis, corresponding to the two extreme assumptions. As the results point in favor of the first hypothesis, this will be discussed in more detail. We shall show in Section IV*b* that the resulting mean absolute magnitudes per spectral subclass differ by about 0 3 mag. for the two cases.

The solutions resulting from the two different procedures will be denoted as follows: solution I, referring to the assumption of linear expansion, and solution II, referring to the case of common stream motion plus differential galactic rotation. In the latter case the proper motions and radial velocities are always freed first from the differential galactic rotation, for which the following values of the constants A and B have been used:

$$A = +0\overset{''}{.}0043 = +0.020 \text{ km/sec per pc} ,$$

$$B = -0\overset{''}{.}0015 = -0.007 \text{ km/sec per pc} ,$$

as recommended by Morgan and Oort (1951). For the galactic longitude of the center of rotation we adopted $l = 328°$.

b) Determination of the Convergent Point

In principle, one might reason that, if assumption I (expansion) is correct and the proper motions, uncorrected for differential galactic rotation, converge toward a convergent point, then they will no longer converge after the corrections for differential galactic rotation have been applied, as is required for assumption II—and vice versa. Thus, from the degree of convergence of the proper motions with and without these corrections, one might get an indication as to which interpretation is the better one. Unfortunately, this criterion cannot be applied because the corrections affect the directions of the proper motions very little, though they do change their sizes. This is due to the fact that the proper motions make small angles with the direction of increasing longitude, in which the corrections are much larger than those in latitude.

Though the association extends over almost 90° of the sky, the convergent point cannot be very accurately determined because of the unfavorable direction of elongation of the association. The directions of the proper motions, as may be seen from Figure 1, define quite accurately a great circle on which the convergent point must be located; it will be denoted by C. The situation is illustrated in Figure 2.

The indeterminateness of the convergent point is due to the fact that this circle C happens to be nearly coinciding with a great circle that would roughly represent the positions of the stars in the sky. The position of the convergent point *on* the circle C will, by necessity, be rather uncertain, but it *cannot* deviate appreciably from this circle.

This latter uncertainty would be removed if the size of the proper motions could also be taken into account. However, this would involve an assumption with regard to the relative distances of the stars in various parts of the association, which we shall avoid in order not to bias the results for the absolute magnitudes. We shall rather investigate the dependence of the luminosities on various possible positions of the convergent point along the great circle C. This will be discussed in Section IV*b*. The position of the convergent point could not be improved appreciably from an analysis of the radial velocities.

The following procedure was adopted for finding the convergent point from the proper motions. For each star the direction of the proper motion defines a great circle with pole P. If all proper motions pointed exactly to the convergent point, all poles P would exactly lie on a great circle, Cp, the pole of which is the convergent point. Because of the accidental errors in the proper motions and the peculiar motions of the stars, the poles P are scattered around the circle Cp. Moreover, they are located only along a relatively short stretch of this circle because of the unfavorable direction of elongation of the association, referred to above. There is, therefore, some uncertainty in the direction along which the circle Cp runs through the poles P. However, we can be sure that it must run very closely along the mean position, P_0, of all poles P. This latter fact corresponds to the remark made before, that we can define quite accurately a great circle C on which the convergent point must lie, whereas the lack of precision of the *direction* of Cp through P_0 corresponds to the uncertainty of the position of the convergent point *along* the great circle C. Thus, in Figure 2, the dashed circles might be possible variations of the best-fitting circle Cp, and the corresponding solutions of the convergent point are indicated by the dashed crosses.

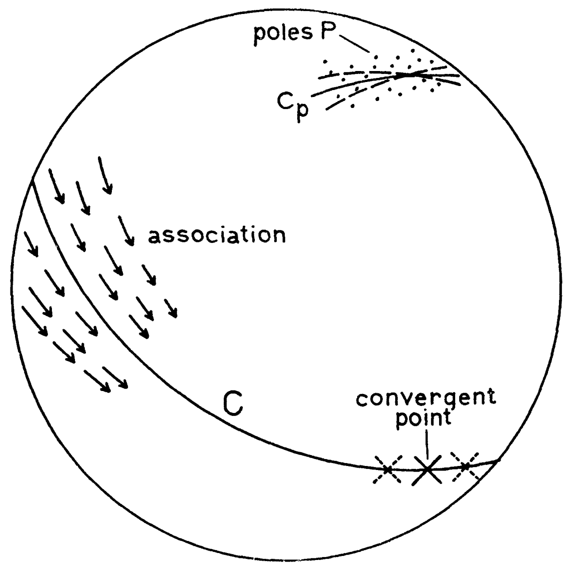

FIG 2—Schematic representation of the convergent point, considered as pole of the great circle C_p running through the poles P, the poles P being defined by the directions of the proper motions.

For the actual determination of the convergent point, the poles P were arranged in seven groups. These were chosen so that the corresponding stars in each group would lie approximately on the same circle through a provisionally chosen position of the convergent point, $l = 210°$, $b = -24°$. Thus in each group the stars may be at widely different distances from the convergent point, but, if the proper motions pointed exactly to the convergent point (i.e., not being affected by accidental errors and peculiar motions), their poles would all fall within a small area, the mean position of which would lie on the circle Cp. By computing the mean position of the poles for each group, we obtained seven normal points to define the great circle Cp. These seven positions are given in Table 2. In computing these means, the stars were weighted according to the probable error, ϵ, of the proper motions: weight 3 for $\epsilon \leq 0''.0015$; weight 2 for $0''.0015 < \epsilon < 0''.0025$; and weight 1 for $\epsilon \geq 0''.0025$.

Figure 3 shows the distribution of the seven mean poles in gnomic projection on a plane, tangent to the sphere at $l = 180°$, $b = +60°$. This tangent point is very close to the weighted mean position of all poles: $l = 180°$, $b = +61°$. The circles indicate the probable errors of the mean poles. The straight line best fitting the projection of the seven mean poles according to a least-squares solution is considered to be the projection of the great circle Cp sought for. The pole of this great circle, then, is the convergent point of the proper motions, whereas the mean of all poles at $l = 180°$, $b = +61°$ defines the great circle C through the convergent point along which the uncertainty in its position is greatest.

This procedure was followed for solutions I and II; the results are in Table 3. The uncertainty in the position of the convergent point is about five times larger along the

TABLE 2

MEAN POSITIONS OF POLES P IN SEVEN SUBGROUPS

(n Is Number of Stars Included)

Subgroup	l	b	n	Subgroup	l	b	n
1	226°5	+62°8	9	5	170°2	+60°3	26
2	204 1	+62 3	20	6	161 7	+57 1	21
3	189 8	+61 8	24	7	160 4	+50 0	5
4	176 1	+62 5	38				

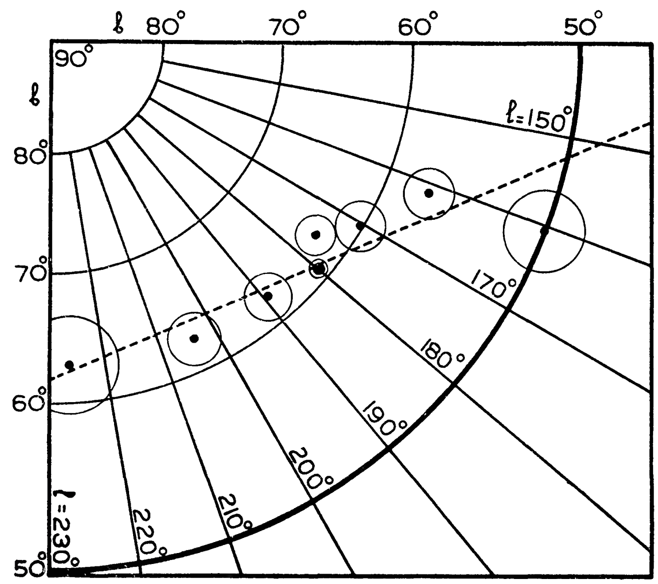

FIG 3 —Gnomic projection of the mean poles of the proper motions in seven subgroups of the association (see also Table 2) *Circles:* sizes of the probable errors; *large dot:* mean position; *dashed line:* projection of great circle C_p

TABLE 3

SOLUTIONS I AND II FOR CONVERGENT POINT

	Solution I: Expansion Hypothesis	Solution II: Differential Gal Rotation Eliminated
Convergent point	$l=205°$, $b=-27°$	$l=217°$, $b=-25°$
Probable error along circle C	±3°5	±3°5
Probable error perpendicular to circle C	±0°7	±0°7

circle C than perpendicular to it. The difference between the two positions I and II is about two and a half times its probable error.

c) Analysis of the Radial Velocities

Solution I, which appears to be relevant to the Scorpio-Centaurus case, will be discussed first. Strictly, each star provides an equation of condition (3) with the unknowns S and k, λ being counted from the convergent point derived from the proper motions. This requires knowledge of the individual distances, r, which we do not possess. We have, however, taken advantage of the fact that (1) the mean distance of the stars in the association at different longitudes is approximately the same, and (2) the spread of the individual distances around these means is only a small fraction of these mean distances (see, e.g., Blaauw 1946, pp. 78 ff.). Therefore, no significant error is made if we assume the value of rk to be the same for all stars (what really counts in the solution is only the variation of r with λ). This constant value of rk will be denoted by r_0k, and r_0 may for our purposes with sufficient approximation be taken to represent the mean distance of all stars from the sun.

Weight 3 was assigned to quality class a; weight 2 to quality class b; weight 1 to classes c and d, whereas stars of class e were discarded. The results of the least-squares solution are in the left-hand division of Table 4. The solution is also represented by the dashed

TABLE 4

SOLUTIONS FROM RADIAL VELOCITIES

Solution I	Solution II
$S=$ 23 3 km/sec $\pm$0 9(p e)	$S=$ 26 4 km/sec $\pm$0 9(p e)
$r_0k=+$ 8 3 km/sec [$\pm$0 3(p e)]	$K=+$ 6 4 km/sec [$\pm$0 3(p e)]

line in Figure 4, which shows the radial velocities, corrected for gravitational red shift, plotted against cos λ. In order to investigate the significance of this solution, we have repeated it, assuming different convergent points along the great circle C referred to in the preceding section. The following characteristics were found:

a) The velocity S is practically independent of the position of the convergent point, within the range of its uncertainty. For instance, for a convergent point at $l = 210°$, $b = -26°$, we find $S = 23.0$ km/sec, and even for shifts of 10° the changes in S remain below 1 km/sec. This is a most important result, for it means that the mean parallaxes to be computed later will not be significantly affected by a possible error in the convergent point.

b) The value of the quantity r_0k is very sensitive to changes in the convergent point. A shift of 5° along the circle C toward higher longitudes corresponds to a change of -1.5 km/sec in r_0k. While the probable error derived from the residuals in the least-squares solution is only ± 0.3 km/sec, as indicated in Table 4, the true probable error must accordingly be taken to be somewhat less than 2 km/sec.

The motion of the center of the association with respect to the sun has been computed according to the procedure mentioned in Section III*a*. The center has been adopted at a distance of 170 pc in the direction $l = 285°$, $b = +10°$. We then find a velocity of 25.3 km/sec toward $l = 225\overset{\circ}{.}0$, $b = -21\overset{\circ}{.}2$.

The radial velocities, treated according to the procedure of solution II, show that the assumed state of motion underlying this solution does not apply to the Scorpio-Centaurus association. We have not used equation (4) for this solution, but added a K term:

$$\rho = S \cos \lambda + K . \tag{6}$$

This K term should be found to be small, of the order of its probable error. We find, however, $K = +6.4$ km/sec. Additional solutions show that K can be reduced to $+3.6$ km/sec if the convergent point is shifted by 8° toward higher longitudes, that is, by 2.3 times the probable error of the convergent point. Even then its value is more than can be accounted for. The inference is that this solution does not account for the state of motion of the Scorpio-Centaurus association.

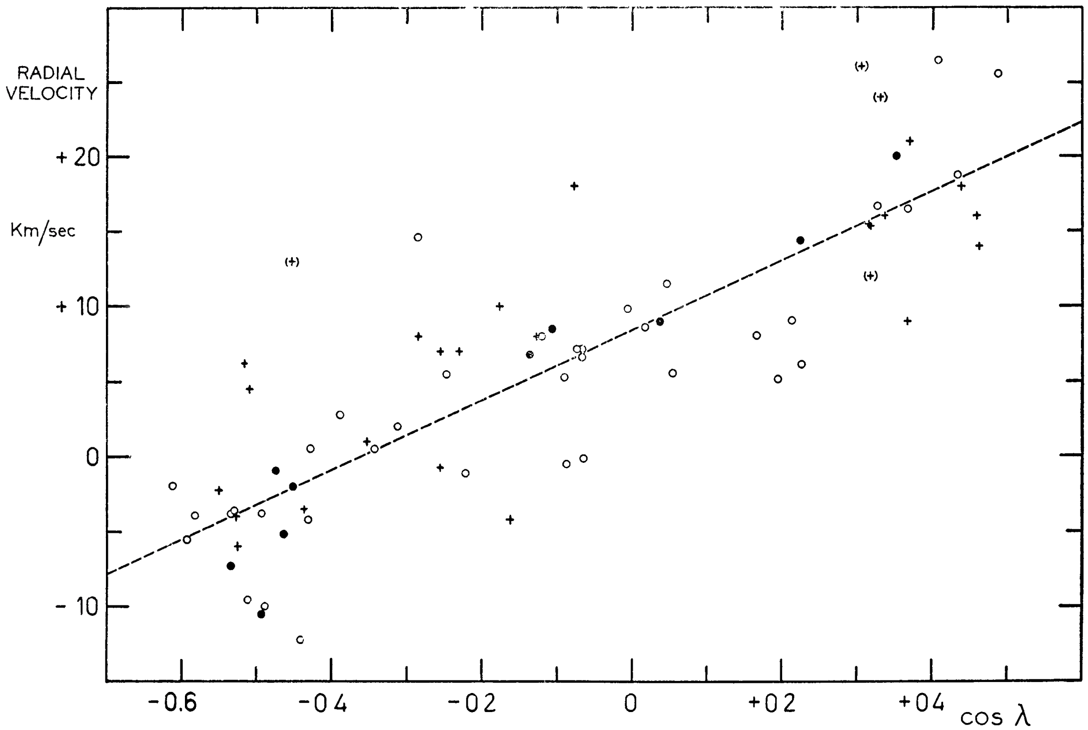

FIG 4—Radial velocities plotted against cos λ, λ being the angular distance from the convergent point of solution I. *Dots:* quality class a; *circles:* class b; *plus signs:* class c; and *plus signs in parentheses:* class d The dashed line represents solution I from the radial velocities

IV. PARALLAXES AND ABSOLUTE MAGNITUDES

a) *Parallaxes and Their Accuracy*

In determining the parallaxes for the members of the association, two procedures can be followed: (*a*) Formula (2) is used, with the values of v, S, and λ referring to the elements of the motion of the association as given under solution I in Tables 3 and 4. Parallaxes thus determined will be denoted by p_v; they are given in column 11 of Table 1. (*b*) All members in a certain region of the association are assumed to be at their mean distance, which can be accurately determined from the mean proper motion. Such parallaxes will be denoted by p_l.

For the following discussions we shall subdivide the association into five regions according to galactic longitude, as given in Table 5. The first line gives the intervals of longitude. The first vertical division refers to the most concentrated part of the association; this will henceforth be called the "Upper Scorpius region." The remaining parts are given the names "Lupus region," "Upper Centaurus region," and "Lower Centaurus regions I and II," although these constellations do not completely cover the various parts. For the parallaxes p_l we adopt the mean values of p_v for the five longitude divisions. They are given in line 8 of Table 5.

We shall first consider the errors in these two kinds of parallaxes, p_v and p_l. First, consider the parallaxes based on formula (2). The values of v used contain, in addition to the group motion S, observational errors in the proper motions and the component of the peculiar motions in the v direction. Both will cause accidental errors in the parallaxes p_v. The parallaxes are, further, systematically affected by a possible error in S and in the adopted position of the convergent point.

The amount of the accidental errors in the parallaxes can be estimated by means of the τ components perpendicular to the v components. It will be assumed that the peculiar motions, as well as the observational errors of the proper motions, are the same in the v as in the τ directions. (The systematic difference between the probable errors in v and τ is only about 5 per cent, on the average.) Thus the square of the combined cosmic and

TABLE 5

QUANTITIES REFERRING TO FIVE LONGITUDE DIVISIONS

	Longitude Division				
	Upper Scorpius (1)	Lupus (2)	Upper Centaurus (3)	Lower Centaurus I (4)	Lower Centaurus II (5)
1 Limits of galactic longitude	309°–330°	292°–309°	281°–292°	270°–281°	260°–270°
2 Root-mean-square value of τ	0″.0031	0″.0040	0″.0027	0″.0031	0″.0050
3 Root-mean-square value of $v - \langle v \rangle$	0″.0038	0″.0072	0″.0093	0″.0064	0″.0069
4 $[\langle (v - \langle v \rangle)^2 \rangle - \langle \tau^2 \rangle]^{1/2}$	0″0022	0″0060	0″0089	0″0056	0″0047
5 Mean of internal (p e of p_v)/p_v according to formula (7)	0 091	0 085	0 089	0 087	0 112
6. External (p e of p)/p according to formula (8)	0 041	0 041	0 041	0 041	0 041
7 External (p e of p)/p according to formula (9)	0.033	0.011	0.003	0.017	0.027
8. p_l	0″0058	0″0058	0″0057	0″.0057	0″0071
9 (p e of p_l)/p_l according to formula (10)	0 060	0 148	0 211	0 142	0 100

observational mean error in v is taken to be equal to $\langle \tau^2 \rangle$. It will be shown in Section V that the observational errors contribute most to $\langle \tau^2 \rangle$. The root-mean-square values of τ are given in line 2 of Table 5. The probable error of an individual parallax, p_v, is given by

$$\frac{\text{p.e. of } p_v}{p_v} = 0.674 \frac{\langle \tau^2 \rangle^{1/2}}{v}. \qquad (7)$$

A Gaussian distribution of the τ components has been assumed. This probable error includes only peculiar motion and observational errors in v and will therefore be called the "internal probable error" of p_v. The values of (p.e. of p_v)/p_v, given in column 12 of Table 1, are based on formula (7), with a root-mean-square value of τ of 0″.0032 for the first four longitude groups ($l > 270°$) and 0″.0050 for the last division. The mean values of (p.e. of p_v)/p_v for the five longitude divisions are in line 5 of Table 5.

Besides these internal errors, all parallaxes are systematically affected by (a) the error in S, corresponding to

$$\frac{\text{p.e. of } p}{p} = \frac{\text{p.e. of } S}{S} = 0.041 \text{ (according to Table 4)}, \qquad (8)$$

and (*b*) the possible error in the convergent point. This gives rise to a systematic error varying with λ, the angular distance of the star from the convergent point, according to

$$\frac{\text{p.e. of } p}{p} = |\cot \lambda| \epsilon_c \ . \tag{9}$$

Here ϵ represents the probable error of the longitude of the convergent point, which is to be taken equal to $\pm 3\overset{\circ}{.}5 = \pm 0.061$ radians, according to Table 3.

The mean values of (p.e. of p)/p according to formulae (8) and (9) are given in lines 6 and 7 of Table 5 for the five longitude intervals.

Let us now consider the alternative procedure, which is based on the assumption that all stars in a certain region of the sky are at the same distance. For stars at a certain longitude the spread in the parallaxes can be determined from the relation

$$\langle (v - \langle v \rangle)^2 \rangle = \langle \tau^2 \rangle + \left(\frac{S \sin \lambda}{4.74}\right)^2 \langle (p - \langle p \rangle)^2 \rangle ,$$

and hence, with sufficient approximation,

$$\frac{\langle (p - \langle p \rangle)^2 \rangle}{p^2} = \frac{\langle (v - \langle v \rangle)^2 \rangle - \langle \tau^2 \rangle}{v^2} .$$

Hence, by assuming for each star the mean value $\langle p \rangle$ instead of the true p, we introduce such errors that

$$\left(\frac{\text{p.e. of } p}{p}\right)^2 = 0\ 674^2 \frac{[\langle (v - \langle v \rangle)^2 \rangle - \langle \tau^2 \rangle]}{v^2} . \tag{10}$$

In addition, these parallaxes will be affected by errors in S and in the position of the convergent point in exactly the same way as described by formulae (8) and (9).

The root-mean-square values of $v - \langle v \rangle$ and the values of $[\langle (v - \langle v \rangle)^2 \rangle - \langle \tau^2 \rangle]^{1/2}$ are in lines 3 and 4 of Table 5. The near-equality of the dispersions in the τ and in the v components in the Upper Scorpius division confirms Blaauw's conclusion (1946) that in this part of the association the dispersion of the v components due to the spread in distances of the stars is almost negligible. In the second to fourth longitude divisions, however, it must have caused most of the dispersion of the v components, whereas in the Lower Centaurus II region the contributions by the spread in distance and by the peculiar motions and observational errors are about equal. The values of (p.e. of p_l)/p_l, according to formula (10), are in line 9 of Table 5.

For the finally adopted parallaxes we have taken weighted means of p_v and p_l. These are given in column 13 of Table 1; they were computed by means of the following relations:

$$p = \frac{3p_l + p_v}{4} \text{ for the Upper Scorpius division;}$$

$$p = \frac{p_l + 4p_v}{5} \text{ for the divisions Lupus, Upper Centaurus, and Lower Centaurus I;}$$

$$p = \frac{p_l + p_v}{2} \text{ for the Lower Centaurus II division.}$$

The values of (p.e. of p)/p for these adopted parallaxes in column 16 of Table 1 are based on the values of (p.e. of p_v)/p_v of column 12 and on smoothed values of (p.e. of p_l)/p_l. It should be borne in mind that these probable errors do not represent the external uncertainty in the parallaxes due to possible errors in S and in the position of the convergent point.

b) *Absolute Magnitudes and H-R Diagram*

The visual absolute magnitudes, M_v, in column 19 of Table 1 have been computed with the adopted parallaxes, p, in column 13 and with the visual absolute magnitudes, V, of column 16. A correction for interstellar absorption has been applied, based on the intrinsic colors for the various spectral types as given by Morgan, Harris, and Johnson (1953, Table 3) and the ratio 3.0 between visual absorption and the color excess in the B, V system. The corrected visual magnitudes, V_0, are in column 18. In those cases where the adopted intrinsic colors were based on de Vaucouleurs's spectral classes, the values of V_0 and M_v are printed in italics.

TABLE 6

ESTIMATION OF ACCIDENTAL AND SYSTEMATIC ERRORS IN VISUAL ABSOLUTE MAGNITUDES DUE TO ERRORS IN PARALLAXES

	LONGITUDE DIVISION				
	Upper Scorpius (1)	Lupus (2)	Upper Centaurus (3)	Lower Centaurus I (4)	Lower Centaurus II (5)
1 Average probable error in M_v, corresponding to internal probable error of the parallaxes	$0^m.11$	$0^m.16$	$0^m.17$	$0^m.16$	$0^m.16$
2 Probable systematic error in M_v, corresponding to probable error of stream velocity S	0 09	0 09	0 09	0 09	0 09
3 Probable systematic error in M_v, corresponding to probable error of position of convergent point	0 07	0 02	0 01	0 04	0 06
Average changes in M_v, corresponding to:					
4 5° increase of galactic longitude of convergent point	−0 11	−0 05	0 00	+0 05	+0 08
5 10 per cent increase in stream velocity, S	−0 20	−0 20	−0 20	−0 20	−0 20
6 Change in proper motions due to application of corrections for differential galactic rotation	+0 19	+0 16	−0 02	−0 14	−0 21
7 Transition from solution I to solution II	−0 33	−0 22	−0 28	−0 28	−0 28

Next to the values of M_v are their internal probable errors. These correspond to the internal errors in the parallaxes p and, therefore, do not contain errors in the photometry (which for most of the stars are negligible) or the systematic effects of errors in S and in the position of the convergent point. The mean values of these internal probable errors of M_v for the five longitude groups are in line 1 of Table 6. The probable systematic errors corresponding to the two external causes just mentioned have been derived from lines 6 and 7 of Table 5 and are shown for the five longitude groups in lines 2 and 3 of Table 6. We further give in Table 6 some quantities which allow a rapid estimation of the changes in the absolute magnitudes, if these were computed on the basis of somewhat different elements of the motion of the association than those used here:

a) Line 4 gives, for each of the five longitude divisions, the average change in the absolute magnitudes, which corresponds to an increase in the longitude of the convergent point by 5°.

b) Line 5 gives the average change in the absolute magnitudes, which corresponds to an increase in the stream velocity S by 10 per cent.

c) Line 6 gives the average change in the absolute magnitudes which would result from a correction of the proper motions—and hence of the υ components—for the effect of differential galactic rotation. For this computation we used the same values of the constants A and B as for solution II. By means of these quantities and those of the two preceding lines in Table 6, it is possible to estimate how much the choice between solutions I and II affects the resulting absolute magnitudes. Suppose we had applied corrections for differential galactic rotation and obtained solution II ignoring the fact that the K term remained unexplained and passing over also the question of why the internal motions of the association should correspond to those of differential galactic rotation; if we then compute parallaxes with the elements of solution II according to Tables 3 and 4, we will obtain a set of absolute magnitudes which differs from those in Table 1 by an amount corresponding to Δl(conv.p.) $= +12°$, $\Delta S/S = +0.13$, plus the values of line 6. The result is in line 7 of Table 6. The combined effect of the various corrections appears to give rise to an approximately constant increase in the luminosities by about -0.28 mag.

In the column "Notes" of Table 1 we refer to the corrections for duplicity in cases of spectroscopic binaries and visual double stars, for which the photometry refers to the pair.

The Hertzsprung-Russell diagram is shown in Figure 5, *a*, *b*, and *c*. Figure 5, *a*, is based on the author's spectral classifications and the absolute magnitudes, M_v, of Table 1, uncorrected for duplicity. Figure 5, *b*, is based on the same spectral classes but on the corrected absolute magnitudes. Figure 5, *c*, also uses the corrected absolute magnitudes, but here we have used the spectral classes according to de Vaucouleurs. Unreliable absolute magnitudes are represented by open circles. Emission stars are marked *e*.

Table 7 gives the mean absolute magnitudes and the average deviations from these means for each spectral subclass, together with the numbers of stars used, except for types B5 and later, where our data are incomplete for the lower luminosities. Provisional values of the mean absolute magnitudes per subclass in the Scorpio-Centaurus association were communicated by Blaauw (1956*a*) in the context of a more general discussion of the calibration of the MK luminosity classifications. The finally adopted values in the present paper differ only slightly from those earlier values, so that a new discussion of the calibration seems superfluous.

The distribution of the stars of Table 1 on the sky is shown in Figure 6. Dots surrounded by circles represent stars brighter than $M_v = -3.5$; dots those between -3.5 and -2.0; and circles the fainter ones. The brightest stars are marked by their Bayer letters and Flamsteed numbers, and the boundaries of the constellations are drawn as adopted by the International Astronomical Union.

V. PECULIAR MOTIONS

An accurate determination of the average peculiar velocity of the members of the association, i.e., of their individual velocities after elimination of the stream motion and of the expansion, is not feasible because these velocities are small compared to the accidental errors of the proper motions and of the radial velocities. We have therefore derived only an upper limit of the peculiar velocities.

Combining the data for the regions 1 to 4 of Table 5, for which the mean parallaxes are approximately the same and which together contain 66 of the 77 stars of Table 1, we find the root-mean-square τ component to be

$$\langle \tau^2 \rangle^{1/2} = \pm 0\overset{''}{.}0033 .$$

The contribution to this quantity by the accidental errors of the proper motions must be approximately equal to 1.48 times the root-mean-square value of the probable errors in the components μ_b; for this we find, from the same 66 stars,

$$1.48 \times \langle (\text{p.e. of } \mu_b)^2 \rangle^{1/2} = \pm 0\overset{''}{.}0031 .$$

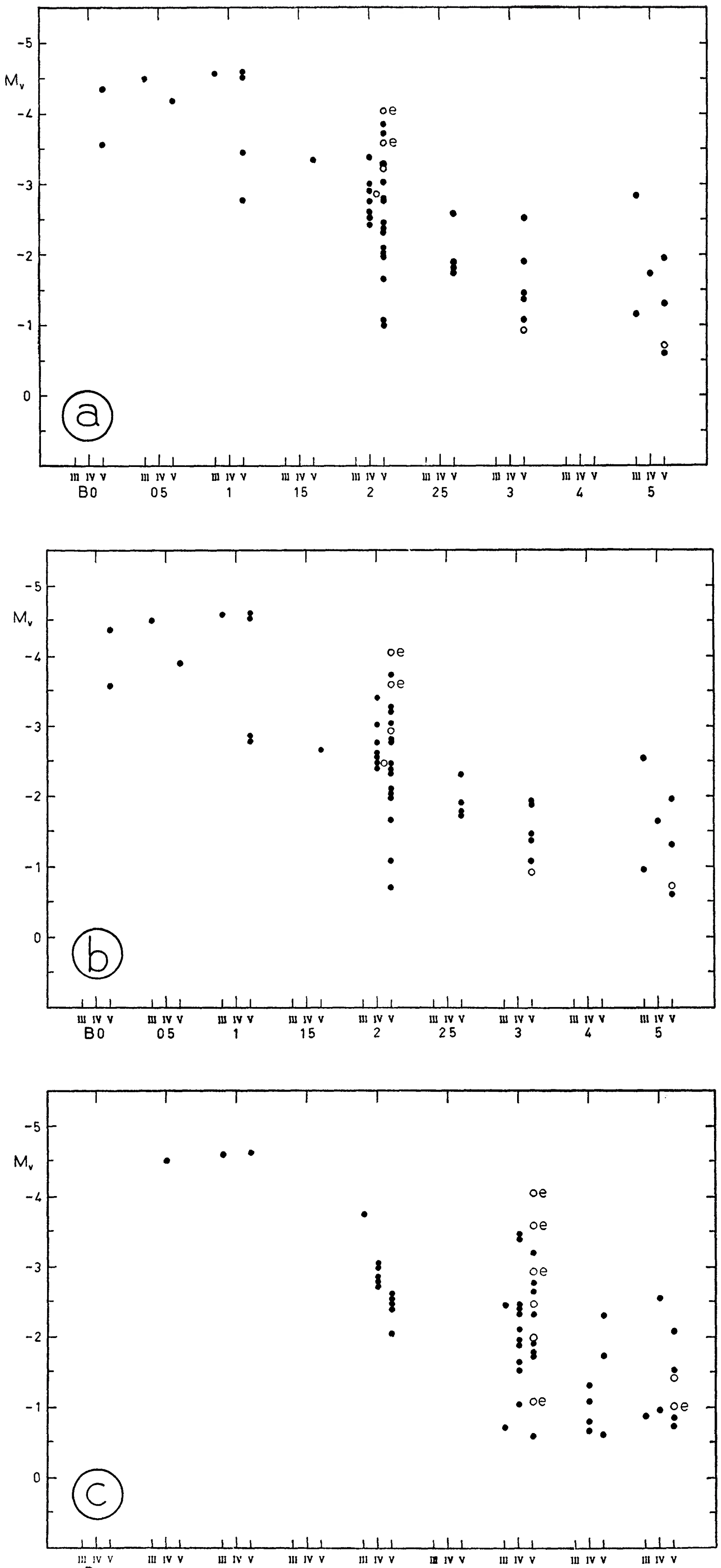

FIG. 5.—Luminosity–spectral type diagrams. The top diagram is based on the McDonald spectral classes and the values of M_v in Table 1; the middle diagram is based on the same spectral classes and absolute magnitudes corrected for duplicity; the bottom diagram is based on de Vaucouleurs's spectral classes and absolute magnitudes corrected for duplicity Circles represent doubtful values. Emission objects are marked *e*.

This leaves, for the root-mean-square peculiar motion, a value which must certainly be below $\pm 0\farcs002$. With the mean parallax of $0\farcs0058$, this would correspond to a linear velocity of ± 1.7 km/sec. However, it is more likely below ± 1 km/sec.

A similar estimate follows from the residuals of the radial velocities in Table 1. The average residual without regard to sign is ± 1.7 km/sec for the 9 stars in quality class a; ± 3.4 km/sec for the 38 stars in class b; and ± 4.4 km/sec for 23 stars in class c. The probable errors of these quality classes suggested by Wilson (1953) would correspond to average residuals of ± 0.7, ± 1.4, and ± 3.0 km/sec, respectively. Considering the possible presence of unrecognized spectroscopic binaries, we find that the root-mean-square peculiar motion in the radial component must be below 2 km/sec and more likely does not exceed ± 1 km/sec.

TABLE 7

MEAN VISUAL ABSOLUTE MAGNITUDES AND AVERAGE DEVIATIONS FOR McDONALD AND FOR DE VAUCOULEURS'S CLASSIFICATIONS
(Emission Objects Excluded)

Spectral Type	McDonald Spectrograms					de Vaucouleurs's Classifications		
	M_v Not Corrected for Duplicity		M_v Corrected for Duplicity		No of Stars	M_v Corrected for Duplicity		No of Stars
	Mean M_v	Average Deviation	Mean M_v	Average Deviation		Mean M_v	Average Deviation	
B0 III								
IV	.			. .				
V	−3 95	0 40	−3 95	0 40	2			
B0 5 III	−4 49		−4 49		1			.
IV	. .		. . .			−4 49		1
V	−4 18		−3 88		1			
B1 III	−4 56		−4 56		1	−4 58		1
IV	. .		.	. . .			. . .	.
V	−3 84	0 74	−3 69	0 89	4	−4 24	0 35	2
B1 5 III								
IV	.							
V	−3 34		−2 64		1			
B2 III						−3 72	. . .	1
IV	−2 79	0 26	−2 74	0 26	7	−2 88	0 10	5
V	−2 47	0 67	−2 39	0 62	16	−2 42	0 16	5
B2 5 III								
IV		.						
V	−2 02	0 29	−1 92	0 19	4			
B3 III						−1 56	0 88	2
IV						−2 18	0 54	11
V	−1 66	0 44	−1 54	0 29	5	−2 14	0 53	10
B4 III						.	. . .	
IV						−0 95	0 23	4
V						−1 54	0 61	3

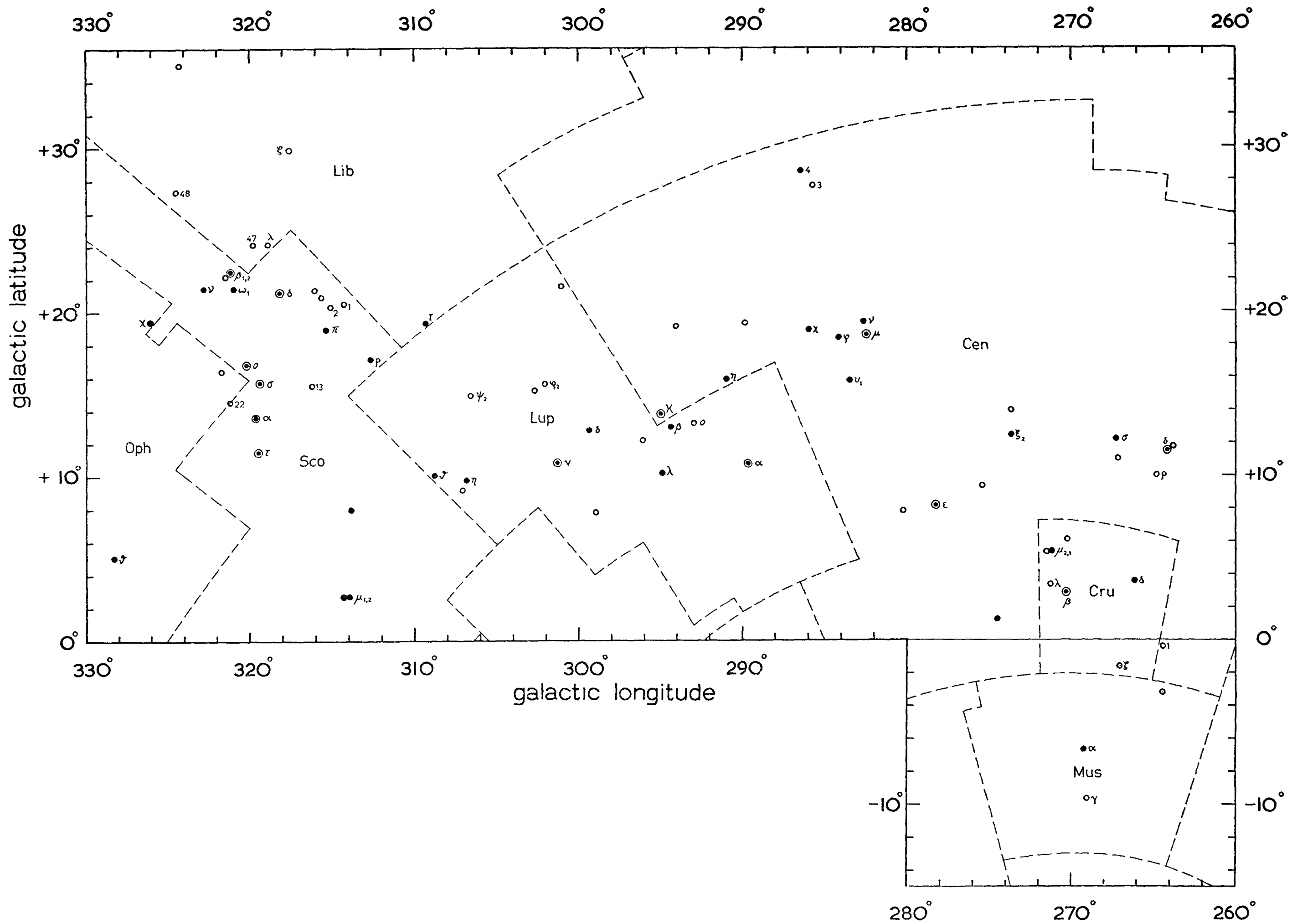

FIG. 6.—Distribution on the sky for the stars in Table 1. *Dots surrounded by circles:* stars with M_v brighter than −3.5; *dots:* stars with M_v between −3.5 and −2.0; *circles:* stars fainter than −2.0.

VI. THE AGE OF THE ASSOCIATION

The term r_0k found in solution I, according to Section III*c*, represents the product of the mean distance of the association members from the sun and the rate of expansion of the association. According to Table 5, the mean parallax may be taken to be 0″.0060, and hence $r_0 \simeq 170$ pc. Thus we find $k = 0.05$ km/sec per pc, or 5×10^{-8} yr^{-1}.

Hence, if we assume the association to have expanded uniformly since its formation, we find its expansion age to be 20×10^6 years. It is unlikely that the galactic gravitational field of force during the first 20 million years of the existence of an association changes the rate of expansion appreciably (Blaauw 1952), so that in this respect the age estimate may be reliable. However, as has been pointed out in Section III*c*, the value of r_0k is rather sensitive to changes in the adopted convergent point, and therefore its probable error is rather large—about 25 per cent. This, then, also applies to the age determination.

Finally, we should like to mention that there are indications of systematic differences in the H-R diagram of different parts of the association, which may be due to differences in the ages of the stars in different parts. In particular, it appears that the main-sequence stars in the Upper Scorpius region are of lower luminosity than those of other parts of the association, and this difference may be interpreted as indicating more recent formation of the Upper Scorpius part. These properties will be dealt with in more detail in a forthcoming discussion of some characteristics of the nearest associations by Blaauw (see also Blaauw 1956*b*). The age of 20 million years referred to above then probably applies to the oldest members of the association.

VII. FAINTER MEMBERS IN THE UPPER SCORPIUS REGION

As a first step in the exploration of fainter members of the association, we have investigated the region between R.A. 15^h30^m and 16^h30^m and between Dec. $-19°$ and $-31°$. This comprises the most densely populated part of the association.

A plot of the B8 and B9 stars in the *Henry Draper Catalogue* shows immediately that the number of these stars in the region just mentioned is far greater than in the adjacent region between the same declinations and R.A. 16^h30^m and 17^h30^m. The R.A. 16^h30^m approximately marks the sharp boundary of the association at the high-galactic-longitude end in Figure 1. In the case of a population of field stars, one would expect to find more B8 and B9 stars in the adjacent region because of its lower galactic latitude. There is, therefore, strong evidence of a considerable membership of the association among the fainter stars.

A thorough investigation of the faint membership should be based on objective-prism plates, covering the large part of the association located north of the galactic circle, where the association is well detached from the background population. Such a study should include accurate photometry and a determination of the motions of the stars. Our brief exploration has been confined to only the following: (*a*) Classification in the MK system of all B0–B9 stars brighter than apparent magnitude 8.0 in the *Henry Draper Catalogue* and of a few fainter ones in the region just mentioned. Some of these stars had been classified already from the McDonald spectrograms described before. The remaining ones were observed with the 40-inch Yerkes refractor. (*b*) The computation of improved proper motions for those stars which have a sufficient number of meridian observations, i.e., in practice, the stars occurring in the *GC*. All these stars, with the exception of those occurring in Table 1, are in Table 8. The spectral classifications are in the seventh column, and the proper motions, insofar as they could be determined, in the next one. These are in the system of N30, and the probable errors apply to both components.

All stars are plotted in Figure 7: those without proper motions as crosses and the other ones as circles, with the proper motion as a dashed line. We have added the stars of Table 1, plotted as dots, with lines drawn to represent the proper motions.

The character of these proper motions confirms the provisional conclusion that most of these stars must belong to the association. One obvious exception is HD 140543, the spectral type of which indicates a much larger distance than that of the association. A doubtful case is HD 147889, which, although very faint, may be a member of the association; a provisional measurement of its color kindly provided by Dr. W. A. Hiltner indicates considerable reddening. The absolute magnitude of this star would then be rather faint for its spectral class ($M_v = -1.6$, B1.5 V), but perhaps not quite impossible.

Among the brightest stars of the list are ρ Oph, B2 V, and its companion HD 147934 and the two B3:V stars HD 142883 and 142990, which did not occur in Blaauw's list and therefore were not included in the investigation from the outset. The remaining stars are

TABLE 8

FAINT B-TYPE STARS IN UPPER SCORPIUS REGION

Name	HD No	GC No	R A 1900	Dec 1900	Ptm mag.	Spec Class	μ_α Unit 0ˢ0001	μ_δ Unit 0″001	p e. Unit 0″001
	139094	20982	15ʰ31ᵐ1	−26° 10′	7 2	B8 IV	− 6	− 3	6
	139160	20993	31 5	−25 57	6 0	B8 V	− 4	−22	3
	139486		33 3	−19 24	8 0	B9 5 V			
	140543		39 1	−21 30	8 5	B0.5 III			
	141404		43 8	−20 28	7 4	B9 V			
	141774	.... .	45 7	−20 16	7 3	B9 V	.	..	.
	142250	21352	48 4	−27 03	6 0	B7 V	− 8	−27	3
3 Sco ..	142301	21355	48 7	−24 57	5 9	B7 IV:	− 3	−13	2
	142315	21356	48 8	−22 29	6 7	B9 V	− 8	−18	4
	142805	21413	51 4	−21 11	7 0	B9 V	−12	−22	3
	142883	21420	51 9	−20 41	5 9	B3: V	− 5	−23	3
	142990	21442	52 6	−24 32	5 4	B3: V	−10	−23	3
	143567		56 0	−21 42	7 2	B9 V			
	143600	. .	56 3	−22 24	7 7	B9 V	.	..	
	144334	21620	16 0 2	−23 20	5 9	B9: III	− 5	−28	2
	144661	21668	1 9	−24 11	6 2	B7 IV:	− 7	−21	4
	144844	21694	2 8	−23 25	5 8	B9 V	− 9	−22	3
	145102	21737	4 1	−26 39	6 7	B9 Vp	− 4	−27	3
	145353	21757	5 4	−26 53	6 8	B9 V	−15	−15	3
12 Sco .	145483	21776	6 1	−28 9	5 7	B9 V	−20	−41	3
	145554		6 5	−19 19	7 7	B9 V	.	.	
	145631	21795	6 9	−19 14	7 5	B9 5 V	− 2	−37	6
	145792	21814	7 7	−24 10	6 3	B7 IV	+ 3	−16	3
	146001	21845	8 8	−25 13	6 2	B8 IV	− 1	−16	3
	146029	21847	9 0	−22 8	7 1	B9 V	− 6	−24	3
	146284	21873	10 4	−24 2	6 6	B8 V	−11	− 6	3
	146285	.... .	10 4	−24 44	8 1	B8 V	.	.	.
	146332	21878	10 7	−29 30	7 5	B5 II:	−12	−16	7
	146416	21883	11 1	−21 3	6 4	B9 5: V	− 9	−19	4
	147009	21958	14 2	−19 48	8 8	B9 5 V	+ 2	−25	6
	147196	21992	15 3	−23 28	7 0	B5 V	−14	−22	6
	147889		19 4	−24 14	8 0	B1 5 V			
	147890	.	19 4	−29 11	7 6	A0 (Si II)			
ρ Oph	{147933	22079	19 5	−23 14	5 2	.	.	.	
	{147934	22078	19 6	−23 14	5 9	B2 V	− 3	−34	2
	148579	22170	23 9	−24 56	7 3	B9 V			
	148594	21178	24 0	−27 41	6 8	B9: V	− 4	−22	2

all of types B5 and later. This shows that, for practically the whole region considered in this section, the survey extends well beyond the limit of completeness for type B3 and earlier.

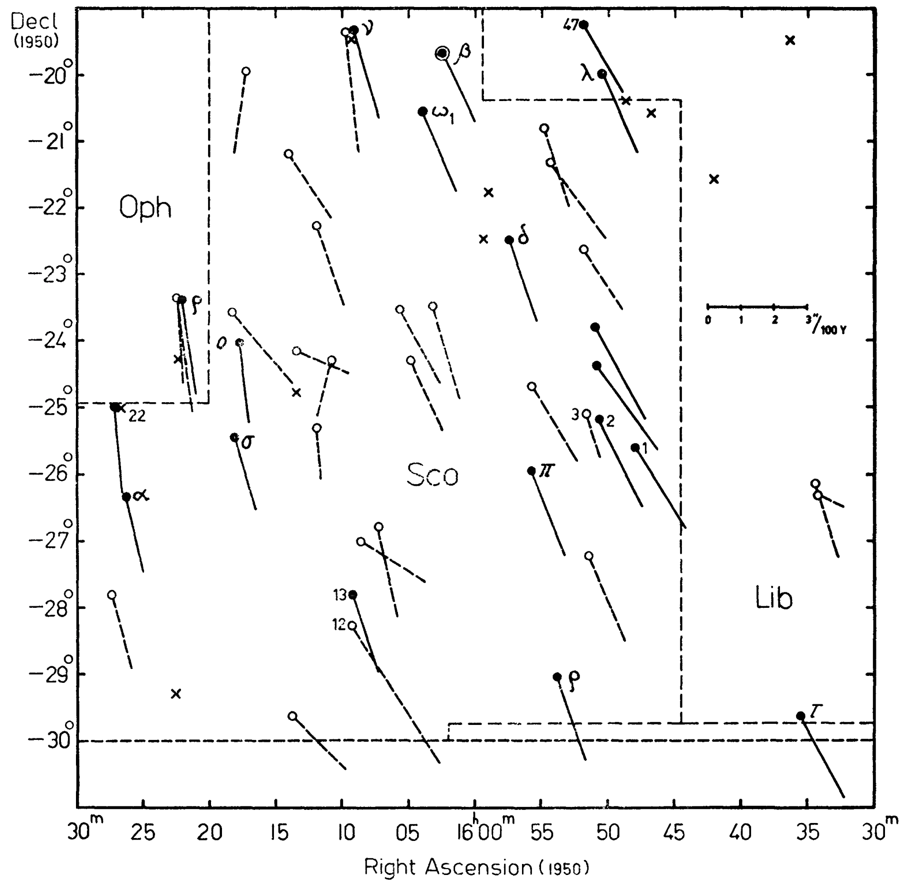

FIG. 7 —Bright and faint B-type stars in the densest part of the Upper Scorpius region *Dots:* bright stars according to Table 1, with drawn lines representing their proper motions; *circles:* faint stars according to Table 8, with proper motions represented by dashed lines; *crosses:* faint stars with undertermined proper motions. The scale of the proper motions is indicated near the right edge of the diagram.

APPENDIX

The Computation of the Proper Motions

The determination of the new proper motions involved two steps: (*a*) For the stars not occurring in the N30 catalogue, proper motions in the system of N30 were derived from recent meridian observations, combined with the position of the star at the mean epoch of the *GC*. The procedure followed was similar to that applied by H R. Morgan for the N30. (*b*) These proper motions and the N30 proper motions already available were combined with those of the *GC* into weighted means, the system of N30 being retained.

In the first step the following recent meridian catalogues, which contain at least two of the Scorpio-Centaurus stars, were used in Table 9:

Cape 1st 25 (*First Cape Catalogue of Stars for the Equinox of 1925 0;* epoch 1922)

Cape 2d 25 (*Second Cape Catalogue of Stars for the Equinox of 1925 0,* Part I: *Stars South of Declination −30°*; Part II: *Zodiacal Stars;* epoch 1928)

Wash XIV, 1 (*Publications of the United States Naval Observatory, Second Series,* Vol **14,** Part I: *Catalogue of 3520 Zodiacal Stars,* epoch 1929)

LaPl XII (*Observatorio Astronomico de la Universidad Nacional de La Plata, Publicaciones*, Vol. **12**; epoch 1933)
LaPl F (*Observatorio Astronomico de la Universidad Nacional de La Plata, Publicaciones*, Vol **13**; epoch 1935)
Cape 1st 50 (*First Cape Catalogue of Stars for the Equinox of 1950.0;* epoch 1940)

In order to make sure that in the first step the N30 system of proper motions would be reproduced, we have selected about 90 N30 stars in the interval of right ascension 8^h to 18^h occurring in one or more of these catalogues. Their positions in the various catalogues were reduced to the N30 epoch with the N30 proper motions and Newcomb's precession, and the differences from the N30 position were computed. Smoothed values of these differences were subsequently used for the application of systematic corrections to the various catalogues. The dependence of these corrections on right ascension was found to be negligible. The corrections as a function of declination, $\Delta\alpha_\delta$ and $\Delta\delta_\delta$ are given in Table 9, except for Cape 1st 25, for which they occur in Part I of the *GC*. For Cape 2d 25, only 17 stars common with the N30 catalogue were available. A curious, but apparently well-established, reversal of the corrections to LaPl XII occurs in the zones $-35°$ and $-40°$.

TABLE 9

SYSTEMATIC CORRECTIONS TO CATALOGUE RIGHT ASCENSIONS (UNIT 0^{s}001) AND DECLINATIONS (UNIT 0".01)

Declination	Cape 2d 25 Part I		Cape 2d 25 Part II		Wash XIV, 1		LaPl XII		LaPl F		Cape 1st 50	
	$\Delta\alpha$	$\Delta\delta$	$\Delta\alpha$	$\Delta\delta$	$\Delta\alpha$	$\Delta\delta$	$\Delta\alpha$	$\Delta\delta$	$\Delta\alpha$	$\Delta\delta$	$\Delta\alpha$	$\Delta\delta$
−15°			+6	+29	−10	+10	+41				+3	
−20°			+5	+30	− 7	+10	+35	−16			−1	+ 7
−25°		.	+4	+30	.	.	+26				−2	. .
−30°	+ 6	+28	+6	+28	− 5	+ 8	+14	− 7			0	+10
−35°	. .				.	.	−18				+4	.
−40°	+12	+17			− 2	+ 2	− 6	− 4			+3	+14
−45°	.	.			.		+13	.	. .	.	.	.
−50	+ 8	+11			0	− 2	+28	− 2	+20	−10	+2	+14
−55°	. .	. .					+35				.	. .
−60°	+13	+13					+32	− 4			+8	+11
−65°	. .	.					+19					.
−70°	+10	+14					− 8	−14			+4	+ 3

Next, Table 9 was used for the application of systematic corrections to the catalogue positions of those stars of our program not occurring in the N30 catalogue. From these corrected positions we have derived mean positions at the mean epoch. The weights attached to the various catalogues were the same as those given in Table 1 of the Introduction to the N30 catalogue These mean positions were reduced to 1950 with the proper motions and with Newcomb's precession The resulting positions are given in Table 10; they form a system equivalent to that of the N30 catalogue. The weights of the new positions are in the fourth column, and the mean epoch is in the next one. As in the *GC*, weight 1 corresponds to a probable error of 0".30 For most of the stars the epoch is around 1935, a little later than that of the bulk of the stars in the N30 catalogue. This is due largely to the great weight attached to the Cape 1st 50 observations, made around 1940.

The proper motions were computed in the same way as those of the N30 catalogue, i e , from the corrected recent positions and the *GC* position at the mean epoch of the *GC*. Since these *GC* positions are virtually independent of the *GC* proper motions, we obtain in this way a set of proper motions independent of those of the *GC* In accordance with the procedure of H R Morgan, systematic corrections were applied to the *GC* positions, as recommended on page xvi of the Introduction to the N30 catalogue. The new proper motions, derived from least-squares

TABLE 10

PROPER MOTIONS, DERIVED FROM MODERN MERIDIAN OBSERVATIONS, FOR STARS NOT IN N30 CATALOGUE

GC No	R A 1950 0	Dec 1950 0	w	Epoch 1900+	μ_α Unit 0.0001	μ_δ Unit 0″001	p e (Unit 0″001) 15 μ_α cos δ	p e (Unit 0″001) μ_δ
11796	8h 34m 05s 976	−58° 03′ 03″43	9	36 7	− 9	0	55	45
12707	9 09 08 749	−62 06 40 77	9	37 0	−50	+12	38	33
12879	9 18 00 760	−54 58 27 47	3	28 0	−26	− 2	103	67
13637	9 52 19 319	−45 02 47 72	12	34 2	−13	+ 5	42	31
13792	9 59 51 604	−53 07 20 62	3	25 8	− 9	− 4	112	72
14055	10 11 43 408	−61 24 37 80	3	29 5	+12	−12	101	80
14087	10 13 25 278	−54 43 29 53	3	29 8	− 9	− 2	87	67
14769	10 42 03 124	−63 59 10 25	3	30 8	− 9	+ 3	93	81
14778	10 42 18 074	−63 41 53 77	9	38 4	−38	+10	50	43
14850	10 45 01 671	−64 07 10 43	9	38 8	−33	− 5	50	41
15708	11 24 19 879	−60 50 23 59	3	38 0	−22	− 1	44	38
15913	11 34 01 736	−60 46 32 44	9	38 5	−11	− 6	55	48
16241	11 49 23 717	−64 55 39 12	12	34 4	−69	− 7	44	37
16357	11 55 08 505	−62 10 12 65	9	36 9	−37	−11	49	44
16490	12 01 43 913	−62 53 14 04	9	38 0	−20	+ 7	45	36
16651	12 09 01 728	−52 05 24 10	10	37 8	−47	−17	35	32
16785	12 15 42 770	−63 43 30 87	9	38 4	−53	−22	46	37
16954	12 23 49 093	−51 10 25 48	9	38 1	−26	−27	46	36
17352	12 43 29 689	−56 12 55 47	9	36 9	−38	−24	51	39
17514	12 51 40 158	−58 52 31 74	9	38 5	−26	−30	47	39
17513	12 51 39 725	−56 53 50 61	9	37 3	−24	−27	43	33
17750	13 03 22 211	−48 11 44 24	10	36 7	−25	−25	45	36
18034	13 17 34 714	−52 29 07 62	9	36 6	−24	−18	46	39
18724	13 48 56 007	−32 44 48 61	9	36 9	−20	−35	31	29
18757	13 50 27 440	−53 07 37 29	3	26 9	−37	−11	104	64
18874	13 55 13 329	−41 51 26 15	9	37 1	−22	−24	34	31
19017	14 02 59 038	−40 56 27 24	9	36 6	−25	−27	35	30
19073	14 05 23 632	−59 02 22 55	3	26 5	−40	−11	107	79
19305	14 16 13 359	−79 52 48 01	9	37 5	−15	− 7	40	38
19304	14 16 11 484	−45 49 42 00	9	37 7	−11	− 9	36	29
19377	14 19 56 861	−39 17 03 84	9	37 3	−22	−27	34	32
19779	14 38 50 734	−37 34 47 81	9	37 8	−23	−31	24	32
19977	14 48 21 886	−43 22 10 69	9	38 1	−32	−30	39	31
20350	15 05 20 558	−42 40 35 82	3	28 8	−16	−25	97	73
20356	15 05 27 937	−45 05 19 57	12	34 9	−11	−24	30	24
20756	15 24 05 549	−36 35 36 58	9	36 9	−18	−28	45	41
20887	15 30 05 457	−16 41 04 51	12	35 5	− 9	−15	27	23
20923	15 31 44 312	− 9 00 59 32	9	38 5	−15	−31	38	36
20943	15 32 26 120	−44 47 32 84	9	37 5	− 4	−22	49	38
21106	15 39 29 445	−34 33 04 47	9	38 1	−16	−23	34	35
21285	15 47 57 976	−25 36 02 51	15	34 7	−13	−25	26	25
21329	15 50 36 295	−25 10 45 42	15	34 2	−11	−28	25	23
21339	15 50 54 396	−24 23 08 10	15	34 6	−12	−26	28	29
21341	15 50 57 002	−23 49 50 06	15	34 8	−12	−30	30	29
21364	15 52 06 716	−19 14 12 50	15	33 9	− 9	−19	30	29

TABLE 10—*Continued*

GC No	R A 1950 0	Dec 1950 0	w	Epoch 1900+	μ_α Unit 0ˢ0001	μ_δ Unit 0″001	p e (Unit 0″001) 15 μ_α cos δ	μ_δ
21398	15ʰ53ᵐ47ˢ504	−29°04′ 10″36	12	37 6	−13	−26	30	29
21548	16 00 04 232	−38 27 52 80	9	37 4	−17	−33	48	38
21610	16 02 31 893	−19 39 59 55	15	33 8	−12	−20	24	19
21639	16 03 52 651	−20 32 06 94	15	34 1	−14	−28	26	25
21778	16 09 13 120	−27 47 53 37	15	34 5	− 6	−23	28	27
21773	16 09 05 106	−19 19 56 07	15	34 1	− 9	−32	21	21
21969	16 17 37 383	−24 03 01 24	15	33 5	− 4	−24	27	21
21997	16 18 43 296	−49 27 17 38	10	36 6	− 4	−28	42	37
22070	16 22 24 133	−23 20 46 78	3	31 4	+17	−15	54	52
22117	16 24 07 318	−18 20 39 68	12	34 7	− 5	−25	26	25
22691	16 48 56 606	−37 56 03 16	9	37 4	−16	−35	35	30
23063	17 03 08 435	−35 23 04 41	6	28 6	+ 4	+ 6	86	79
23209	17 09 43 404	−32 22 46 62	6	29 6	+25	− 1	64	57
23517	17 21 10 791	−56 19 58 94	9	38 0	+ 3	−19	30	26
25273	18 28 20 090	−45 47 37 28	9	38 3	− 5	− 8	39	34
25973	18 53 17 080	−37 24 32 38	9	37 9	−10	−33	42	39
26375	19 06 26 494	−41 58 25 44	3	27 2	− 2	−17	70	65

solutions, are given in Table 10. The probable errors were computed from the weights and the epochs of the corrected positions involved, with the probable error of 0″30 for a position of unit weight They were *not* derived from the residuals in the least-squares solutions, in order to avoid spuriously small values in case of accidental agreement of the catalogues The following formula was used in the computation:

$$\text{p.e. of annual proper motion} = \pm \frac{0''30\sqrt{\Sigma w}}{\sqrt{[\Sigma w \Sigma w j^2 - (\Sigma w j)^2]}},$$

where w = the weight given in the N30 to each catalogue and j = the interval in time, expressed in years, between the mean epoch in the *GC* and the epoch of observation in a new catalogue

The new proper motions and their probable errors were tested by means of a comparison with the *GC* proper motions, after the latter had been reduced to the system of the N30 with the table of corrections of page xiv of the Introduction to the N30 catalogue. The differences between the two proper motions were divided by their probable errors, these latter being based on the probable error of the *GC* proper motion and that of the newly derived value In good agreement with the definition of probable error and a Gaussian distribution of errors, we found 50 per cent of these quotients to be smaller than 1.0

We next combined the new proper motions as well as those already available in the N30 catalogue with the *GC* proper motions, the latter after reduction to the N30 system. The weighted mean values, corrected with precessional corrections according to Morgan and Oort (1951), are given in Table 11, together with their probable errors The table also gives the numbers of the stars in the *GC*, the N30, and the FK3 catalogues.

The writer is indebted to Dr. A. Blaauw, who suggested and supervised most of the present investigation; to Dr. W. W. Morgan for advice on the spectral classifications; to Dr. D. L. Harris for helpful suggestions concerning the photometric systems; and to Professor A. van Hoof for making the radial-velocity measurements available.

TABLE 11

MEAN PROPER MOTIONS, DERIVED FROM VALUES IN *GC* AND IN N30 CATALOGUE OR IN TABLE 10

HD No	GC No	N30 No	FK3 No	R A 1950	Dec 1950	Proper Motion μ_α 0ˢ00001	Proper Motion μ_α 0″0001	p e (Unit 0″0001) 15 μ_α cos δ	p e (Unit 0″0001) μ_δ
70839	11428	1942		8ʰ20ᵐ1	−57° 49′	+ 40	+ 53	35	29
73390	11796	..	..	8 34 1	−58 3	− 188	+ 48	38	28
77002	12405	2111	1233	8 55 8	−59 2	− 112	+ 52	18	18
79351	12696	2179		9 9 7	−58 46	− 228	+ 73	40	20
79447	12707			9 10 1	−62 7	− 502	+101	26	22
80781	12879	.		9 18 0	−54 58	− 76	− 1	62	44
82984	13219	2282		9 31 9	−48 47	− 95	+ 37	34	27
85980	13637	..		9 52 3	−45 3	− 123	+ 26	36	26
86466	13718	2378		9 55 4	−52 24	− 2	+ 35	43	29
86659	13729	2382		9 55 9	−68 52	− 216	− 54	46	33
87152	13792	.		9 59 9	−53 7	− 259	−115	62	43
88206	13953	2418		10 7 0	−51 34	− 117	− 15	31	25
88907	14055			10 11 7	−61 25	− 31	+ 5	60	47
89104	14087			10 13 4	−54 43	− 81	+ 6	60	46
93163	14769			10 42 1	−63 59	− 67	+ 46	56	50
93194	14778			10 42 3	−63 42	− 211	+111	33	30
93607	14850		.	10 45 0	−64 7	− 260	+ 33	38	30
93845	14863	2554	411	10 45 3	−80 17	−1234	+ 32	16	15
98718	15601	2660	428	11 18 7	−54 13	− 328	− 45	17	17
99556	15708			11 24 3	−60 50	− 203	+ 15	31	26
100929	15913			11 34 0	−60 47	− 115	+ 14	42	35
103079	16241			11 49 4	−64 56	− 583	− 84	34	28
103884	16357			11 55 1	−62 10	− 270	− 85	36	31
104841	16490	..		12 1 7	−62 53	− 165	+ 80	32	25
105382	16576	2810		12 5 5	−50 23	− 295	− 86	31	27
105435	16584	2812	452	12 5 8	−50 27	− 269	−106	17	16
105937	16651	...	.	12 9 0	−52 5	− 375	−148	24	21
106490	16724	2833	455	12 12 5	−58 28	− 372	− 80	18	17
106983	16785			12 15 7	−63 44	− 539	−151	33	24
108257	16954			12 23 8	−51 10	− 314	−197	34	26
108483	16990	2884	464	12 25 3	−49 57	− 173	−157	25	20
109026	17086	2897	469	12 29 5	−71 51	− 931	− 44	25	21
109668	17179	2910	474	12 34 2	−68 52	− 519	− 81	26	22
110956	17352			12 43 5	−56 13	− 367	−240	35	27
111123	17374	2947	481	12 44 8	−59 25	− 419	−155	15	14
112078	17514			12 51 7	−58 53	− 269	−175	36	27
112091	17513	.		12 51 7	−56 54	− 239	−263	37	26
112092	17512	2973		12 51 6	−56 54	− 228	− 68	26	21
113703	17750			13 3 4	−48 12	− 225	−218	31	25
113791	17773	3011	489	13 4 0	−49 38	− 177	− 63	23	12
115823	18034		.	13 17 6	−52 29	− 220	−164	31	26
116087	18087	3062	1347	13 19 4	−60 44	− 255	−126	38	27
118716	18458	3113	504	13 36 7	−53 13	− 127	−123	17	18
120307	18665	3143	..	13 46 5	−41 26	− 189	−177	23	18
120324	18667	3144	508	13 46 6	−42 14	− 102	−157	25	19
120709	18724			13 48 9	−32 45	− 212	−347	20	19
120908	18757	.		13 50 5	−53 8	− 210	−180	58	38
120955	18755	3160		13 50 3	−31 41	− 57	−101	24	20
121743	18874	.		13 55 2	−41 51	− 175	−178	22	21
121790	18883	3174		13 55 6	−44 34	− 184	−184	24	20

TABLE 11—*Continued*

HD No	GC No	N30 No	FK3 No	R A 1950	Dec 1950	Proper Motion μ_α 0ˢ00001	Proper Motion μ_δ 0″0001	p e (Units 0″0001) 15 μ_α cos δ	p e (Units 0″0001) μ_δ
122980	19017			14ʰ 3ᵐ0	−40° 56′	− 157	−182	24	19
123335	19073			14 5 4	−59 2	− 28	− 83	54	41
124771	19305			14 16 2	−79 53	− 266	− 95	25	24
125238	19304			14 16 2	−45 50	− 71	+ 10	25	19
125288	19318	3246	529	14 16 8	−56 9	− 26	− 55	30	24
125823	19377			14 19 9	−39 17	− 196	−269	24	21
127972	19656	3301	537	14 32 3	−41 56	− 290	−224	14	15
129056	19774	3316	541	14 38 6	−47 10	− 141	−136	20	18
129116	19779			14 38 8	−37 35	− 173	−278	23	21
130807	19977			14 48 4	−43 22	− 204	−239	27	20
132058	20128	3380	552	14 55 2	−42 56	− 318	−367	18	16
132200	20146	3383	553	14 55 9	−41 54	− 105	−155	20	19
132955	20225	3391		14 59.9	−32 27	− 98	−230	30	23
133937	20350			15 5 3	−42 41	− 162	−169	70	51
133955	20356			15 5 5	−45 5	− 96	−198	25	20
136298	20620	3450	1402	15 18 1	−40 28	− 99	−181	23	21
136664	20676	3459	1403	15 20 0	−36 41	− 106	−181	23	21
137432	20756			15 24 1	−36 36	− 98	−280	31	27
138485	20887			15 30 1	−16 41	− 68	−145	16	14
138690	20926	3500	575	15 31 8	−41 0	− 50	−214	17	16
138764	20923			15 31 7	− 9 1	− 113	−268	25	22
138769	20943			15 32 4	−44 48	− 101	−227	34	26
139365	21019	3514		15 35 6	−29 37	− 103	−253	16	17
140008	21106			15 39 5	−34 33	− 141	−230	24	25
141318	21273	3557		15 47.2	−54 54	+ 59	− 40	36	30
141637	21285			15 48 0	−25 36	− 108	−238	17	16
142096	21327	3566	1415	15 50 4	−20 1	− 72	−239	11	11
142114	21329			15 50 6	−25 11	− 95	−257	16	15
142165	21339			15 50 9	−24 23	− 133	−247	19	21
142184	21341			15 50 9	−23 50	− 102	−277	22	21
142378	21364			15 52 1	−19 14	− 84	−199	20	19
142669	21398			15 53 8	−29 4	− 57	−246	17	16
142983	21439	3582	1417	15 55 4	−14 8	− 81	−179	12	11
143018	21447	3584	592	15 55 8	−25 58	− 75	−249	12	12
143118	21478	3587		15 56 8	−38 15	− 104	−246	22	19
143275	21489	3589	594	15 57 4	−22 29	− 58	−246	7	8
143699	21548			16 0 1	−38 28	− 170	−279	32	27
144217	21609	3609	597	16 2 5	−19 40	− 30	−213	5	6
144218	21610			16 2 5	−19 40	− 111	−204	16	12
144294	21625	3611	599	16 3 3	−36 40	− 92	−247	20	19
144470	21639			16 3 9	−20 32	− 68	−244	15	14
145482	21778			16 9 2	−27 48	− 51	−234	19	17
145502	21773			16 9 1	−19 20	− 58	−263	10	10
147084	21969			16 17 6	−24 3	− 27	−240	18	16
147152	21997			16 18 7	−49 27	− 36	−220	33	27
147165	21982	3663	607	16 18.1	−25 28	− 42	−217	9	10
147888	22070			16 22 4	−23 21	− 24	−287	37	34
148184	22117			16 24 1	−18 21	− 41	−263	15	15
148478	22157	3686	616	16 26 3	−26 19	− 39	−240	6	7
148605	22179	3693		16 27 2	−25 0	− 20	−260	16	17

TABLE 11—*Continued*

HD No	GC No	N30 No	FK3 No	R A 1950	Dec 1950	Proper Motion μ_α 0ˢ00001	Proper Motion μ_δ 0″0001	p e (Units 0″0001) 15 μ_α cos δ	p e (Units 0″0001) μ_δ
148703	22195	3698	1431	16ʰ28ᵐ1	−34°36′	− 38	−122	18	16
149438	22303	3713	620	16 32 8	−28 7	− 42	−217	10	11
151890	22677	3763	1439	16 48 5	−37 58	− 63	−211	17	16
151985	22691	. . .		16 48 9	−37 56	− 84	−245	23	18
153716	22983	3805		17 0 1	−57 39	− 29	−201	35	31
154090	23019	3808		17 1 5	−34 3	− 58	00	23	19
154368	23063			17 3 1	−35 23	+ 87	+ 53	69	59
155450	23209	. .		17 9 7	−32 23	+ 200	− 49	47	40
156838	23465	3870		17 19 3	−62 49	− 44	− 78	44	32
157056	23451	3869	644	17 18 9	−24 57	+ 13	−211	7	8
157246	23517	.	.	17 21 2	−56 20	+ 78	−127	19	17
158427	23708	3898	651	17 28 0	−49 50	− 214	−658	17	16
168905	25094	4083		18 20 7	−44 8	+ 150	−169	28	23
170523	25273	. .		18 28 3	−45 48	+ 29	− 54	26	23
170740	25282	4109		18 28 7	−10 50	+ 55	−170	26	21
172910	25613	4154		18 41 0	−35 42	+ 46	−230	30	30
175362	25973			18 53 3	−37 25	+ 3	−280	30	27
178322	26375	.	. .	19 6 4	−41 58	+ 45	−163	55	50
180885	26631	4275	1501	19 16 4	−35 31	+ 25	−116	38	35

REFERENCES

Blaauw, A 1946, *Pub. Kapteyn Astr. Lab. Groningen*, No 52

———. 1952, *B A N.*, **11**, 414

———. 1956*a*, *Ap J* , **123**, 408.

———. 1956*b*, Paper presented at the Charlottesville Conference on the Cosmic Distance Scale (in press)

Cape Mimeogram, No 1: *The Magnitudes and Colours of Bright Southern Stars* (Cape of Good Hope, Royal Observatory, 1953)

Cousins, A. W J , and Stoy, R H 1954, *M N* , **114**, 349

Feast, M W , Thackeray, A D., and Wesselink, A J 1957, *Mem R A S* , Vol **68**, Part 1

Jackson, J. 1953, *First Cape Catalogue of Stars for the Equinox 1950 0*

McClean, F 1898, *Spectra of Southern Stars* (London: Edward Stanford)

Morgan, H R 1952, *Astronomical Papers Prepared for the Use of the American Ephemeris and Nautical Almanac*, Vol **13**, Part III.

Morgan, H R , and Oort, J. H 1951, *B A N* , **11**, 379

Morgan, W. W., Harris, D. L , and Johnson, H L 1953, *Ap J* , **118**, 92

Oosterhoff, P. Th 1951, *B A N* , **11**, 299

Schilt, J , and Jackson, C 1952, *A J.*, **56**, 209

Vaucouleurs, A de 1957, *M N* , **117**, 449

Wilson, R E 1953, *General Catalogue of Radial Velocities* (Washington, D C : Carnegie Institution of Washington).

Woods, M L 1955, *Mem Commonwealth Obs* , *Mt Stromlo*, *Canberra*, No 12