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STARS WITH STRONG CYANOGEN ABSORPTION

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ABSTRACT

This investigation attempts to define the properties of G8–K4 giants with abnormally strong CN (Miss Roman's "4150 stars"). Slit spectrograms were obtained of stars that had been suspected to have strong CN on objective-prism plates or that were noted in the literature as having strong CN. A list of 146 stars with strong CN is given.

Five groups (all G8–K2 stars, G8–K2 III–IV stars, G8–K2 stars with moderately strong CN, G8–K2 stars with quite strong CN, and K3–K4 stars) have been formed from these stars, and for each group a statistical parallax and a mean visual absolute magnitude were calculated. Visual absolute magnitudes of $+1.3 \pm 0.4$, $+1.5 \pm 0.6$, $+1.4 \pm 0.5$, $+1.3 \pm 0.5$, and $+1.0 \pm 0.7$ (m.e.), respectively were found for the above groups.

The low absolute magnitude of the strong-CN giants places them, in the H-R diagram, near the loci for old open clusters. Spectroscopically they appear similar to the red giants in the old open clusters. Evidence indicates that they have masses near 1 $\mathfrak{M}_\odot$. Elemental abundances are discussed, but no conclusion is reached.

I. INTRODUCTION

a) *History*

Lindblad (1922) discovered that the λ4216 and λ3889 band sequences of cyanogen increase in strength with luminosity in late-type stars. In further work, Lindblad and his collaborators (Lindblad and Stenquist 1943; Lindblad 1946) used the CN bands extensively as an indicator of luminosity in objective-prism spectra. An independent study of the CN bands in stellar spectra was made by Keenan (1941). Basic for this investigation is the work of Roman (1952). She noted that some stars had abnormally strong cyanogen absorption for their spectral type and luminosity. Twenty-five of these G and K giants, called "4150 stars," are listed in her paper.

Individual "4150 stars" have subsequently been discussed in several papers in the literature. Bidelman (1957, 1958) discovered several "4150 stars" in visual binaries, and he discussed their absolute magnitudes. Stephenson (1960) found more "4150 stars" in binaries. Yoss (1961, 1962) discussed stars of all strengths of cyanogen absorption. Greenstein and Keenan (1964) found giants with strong CN in NGC 188. Spinrad (1966) commented on the possible relation of field giants to the giants in NGC 188. Conti *et al.* (1967) examined the [O I] lines in α Ser.

I have attempted to determine the properties of the stars with abnormally strong cyanogen bands (illustrated in Fig. 1 [Pl. 1]). The name "strong-CN star" is used in this work as it identifies the phenomenon more clearly than "4150 star." The working definition is: a "strong-CN star" is a star whose spectrum shows more absorption in the 0–1 sequence of the CN band with its head at λ4216 than the average MK standard shows at the same spectral type and luminosity class. The λ4216 band of CN is used because I have not investigated the CN band sequences in other regions of the spectrum and cannot with the present material. The definition refers to "average MK standard" to include cases such

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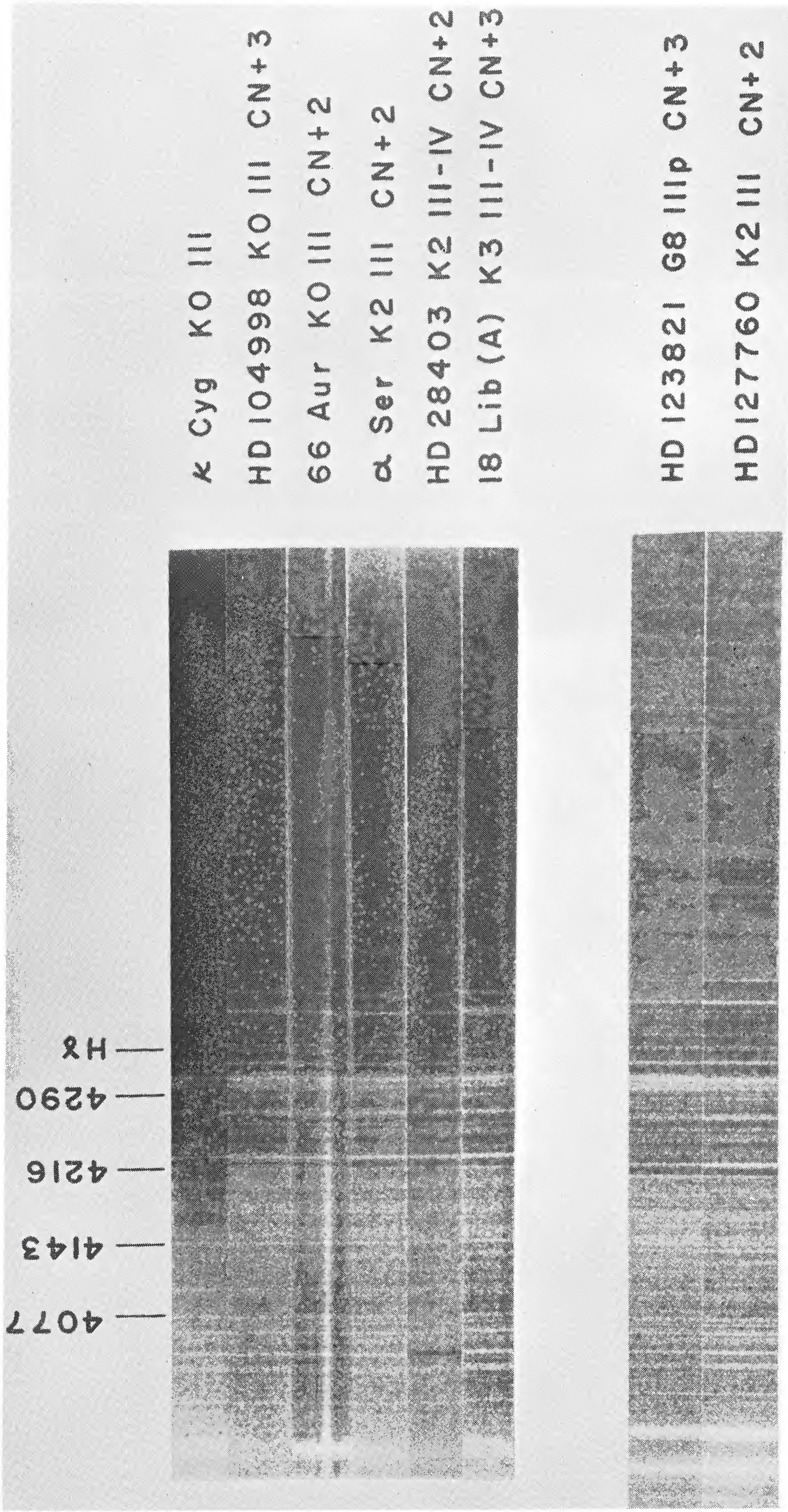

FIG. 1.—Spectra of strong-CN stars. The star κ Cyg is a K0 III star with normal CN.

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as γ Cep, which is an MK standard but which nevertheless shows strong CN absorption for its type and luminosity.

b) *Outline of the Investigation*

I have compiled, from various sources (see § II*a*) a list of approximately 300 suspected "4150 stars." Slit spectrograms of approximately 200 stars were classified on the MK system. In addition, CN-band strengths were estimated for all stars. Having used spectroscopic criteria to isolate a homogeneous group of strong-CN stars, I then used available proper motions and radial velocities to compute their absolute magnitudes and space motions.

II. DATA

a) *Sources of Suspected Strong*-CN *Stars*

Most suspected strong-CN stars were found on objective-prism plates in the University of Michigan collection. I examined approximately 300 plates; no new ones were taken. Most of these plates were circular, covered an area of the sky 5° in diameter, and were taken with both the 4° and 6° prisms on the telescope (the 10°-prism combination [Bidelman 1966]). The dispersion is 108 Å mm^{-1} at $H\gamma$. Many of the plates were taken in pairs; a 10-minute exposure and a 30-minute exposure of the same region of the sky. These were taken by various observers, under the direction of Dr. F. D. Miller, for survey purposes at declinations +52° and +57°. Stars fainter than photographic magnitude 9.5 were usually ignored.

A similar source of suspected strong-CN stars was an unpublished list compiled by Drs. J. J. Nassau and W. W. Morgan and made available to me by Dr. W. P. Bidelman. These stars were found about 15 years ago on objective-prism plates of the Warner and Swasey Observatory. In addition, published work of the Warner and Swasey Observatory sometimes indicated other possible strong-CN stars.

In the publications of the Uppsala and Stockholm Observatories, CN indices are given for many thousands of stars. A high CN index, by itself, can mean that the star is either a late-type supergiant or a strong-CN star. Since supergiant K stars are found only near the galactic plane, high-latitude stars with a high CN index should be strong-CN stars. This is indeed the case for the few stars in the publications that I was able to observe. However, in most cases, the numerous suspected strong-CN stars were too faint to observe with available equipment. References to additional possible strong-CN stars were also found in various other sources in the literature.

The above sources revealed about 300 suspected strong-CN stars. Of these, I observed approximately 130: slit spectrograms were taken of seventy stars with the Michigan 37-inch telescope and of sixty with the Kitt Peak 36-inch telescope. About ninety-five spectrograms taken some years ago with the Lick 36-inch refractor and the McDonald 82-inch reflector were obtained from Dr. W. P. Bidelman. These latter included Roman's "4150 stars" and many of the brighter stars in the unpublished Nassau and Morgan list, as well as a few strong-CN stars discovered by Bidelman (1957, 1958).

Of the stars observed, approximately one-half of the objects noted on the Michigan objective-prism plates proved to be strong-CN stars.

b) *Slit-Spectrogram Observations*

The source of the slit spectrogram used for each star is given in Table 1. Spectrograms noted "Mich" were taken with the Michigan 37-inch reflector with the two-prism spectrograph. Most were taken with the 3-inch camera, which gave a dispersion of 142 Å mm^{-1} at $H\gamma$; the spectra are 0.5 mm wide. The spectrograms from the Lick 36-inch refractor ("Lick") were taken with a single-prism spectrograph with a 6-inch camera. They have a dispersion of 150 Å mm^{-1} at $H\gamma$ and are 0.5 mm wide. The McDonald 82-inch spectrograms ("McD") have a dispersion of 75 Å mm^{-1}.

The plates obtained with the Kitt Peak 36-inch reflector ("KPNO") have a dispersion of 128 Å mm^{-1} and a width of 0.6 mm. The resolution on these plates is excellent, but the spectral classification was nevertheless rather difficult. All the above spectrograms were taken on Kodak IIa-O emulsion and developed in D-19.

c) Sources of Proper Motions

The proper motions used are from the *Smithsonian Astrophysical Observatory Star Catalog* (1966), the N30 catalog (H. R. Morgan 1952), and from the preliminary *Dritter Astronomische Gesellschaft Katalog* (AGK3p) (Dieckvoss 1967). The Smithsonian Catalog contains few new proper motions; it is a collection of proper motions taken from the Boss *General Catalogue*, the Yale zone catalogs (e.g. Barney, Hoffleit, and Jones 1959), and FK4 (Fricke and Kopff 1963), and several other catalogs. Also, it contains some proper motions obtained by comparing the AGK1 with the AGK2. The N30 catalog is not included in it. All the above catalogs, incorporated in the Smithsonian Catalog, were corrected by the catalog compilers to the FK4 coordinate system by means of published tables of systematic differences (e.g., Brosche, Nowacki, and Strobel 1964).

The AGK3p proper motions were graciously sent to me by Dr. W. Dieckvoss of the Hamburg Observatory. They were computed by comparing the positions in a newly reduced AGK2 with those in the AGK3p. The AGK3p positions are derived from a preliminary reference system. For twelve stars, N30 proper motions (corrected to the FK4 system) were available. The mean error in the AGK3 proper motions is $\pm 0\overset{''}{.}008$ $year^{-1}$ (Dieckvoss 1957). The mean error for the average Smithsonian proper motion is probably considerably larger.

d) A Listing of the Data

Information on all the stars studied that proved to have abnormally strong CN is given in Table 1 and the remarks that follow it. The following statements describe this table.

Col. (1).—The HD number, or lacking this, the BD number of the star.

Col. (2).—The spectral type assigned by the writer. An asterisk indicates that the star was not used in a statistical-parallax determination.

Col. (3).—Estimated relative CN strength. Units are those of Keenan (1955, 1958*a*, *b*): a value of 1 indicates slightly strong CN; 2, noticeably strong CN; and 3, exceptionally strong CN.

Col. (4).—Photographic magnitude. In most cases this is taken from the AGK2. For stars not in the AGK2, magnitudes were taken from the *Catalogue of Bright Stars* (Hoffleit 1964) or from the HD.

Col. (5).—Corrected proper motions in units of $0\overset{''}{.}001$ $year^{-1}$ as taken from the Smithsonian Catalog or the N30. An asterisk indicates a proper motion taken from the N30.

Col. (6).—Corrected proper motions in units $0\overset{''}{.}001$ $year^{-1}$ as obtained from the AGK3p. Proper motions are given only for stars used in determining a statistical parallax. If a proper motion is not given for a star used for a statistical parallax, either the star is not in the AGK3p (such as stars south of $\delta = -2°$) or the AGK3p has an uncertain proper motion for this star.

Col. (7).—Radial velocity of the star taken from Wilson's (1953) radial-velocity catalog unless otherwise noted in the remarks. An asterisk following the radial velocity indicates that the star has been used in the determination of the solar apex from radial velocities.

Col. (8).—Source of the slit spectrogram used to classify the star. The abbreviations have been given previously.

Col. (9).—Source of the suspected strong-CN star. The most common sources are as follows: "Case" indicates that the star was originally found on a Warner and Swasey Observatory objective-prism plate; "Mich" indicates that the star was found on a University of Michigan Observatory objective-prism plate; "Ro" indicates that the star occurs in Miss Roman's (1952) list. Other sources are given in the remarks.

Col. (10).—This column lists other names of the star.

TABLE 1

STRONG-CN STAR DATA

HD or BD	Spectral Type	CN	m_{pg}	Sm. or N30 $\mu_\alpha \cos\delta$ μ_δ	AGK3p $\mu_\alpha \cos\delta$ μ_δ	R. V. (km/sec)	Plate Source	Star Source	Name, HR, ADS
2535	K2 III	1	8.0	57 - 6			Lick	Case	
3681	K0 III-IV	1	7.7	12 -22	34 -42	-12*	Lick		
8491	K0 III	1	6.0	78 27	75 27	-11.5*	Lick	Ro	ψ Cas, ADS 1129A
8701	*K2 Ib-II		8.3	-15 41		+0	Lick	Case	
9057	K0 III	2	6.1	10 -43	0 -61	-11.3*	Lick	Ro	49 And
9852	K1 II-III	2	8.6	5 -40	0 9		Lick		
12623	K0 III	1	8.4	104 -14		+77	Mich	Case	
13530	*K0 III	2	6.4	348 -169	336 -165	+27.3*	Lick	Ro	HR 645
14519	K1 III	1	8.3	-29 24	16 15		Mich	Case	
14617	K2 II-III	2	8.6	-17 8	1 -10		Lick	Case	
16039	K1 III:	2	8.4	-14 - 4	-29 - 8		Mich	Mich	
16448	K1 III	1	7.7	45 -64	76 -53	-15*	Mich	Case	
+48°936	K2 II-III	2	8.6	5 -19	10 - 4		Lick	Case	
22427	K2 III-IV	1	7.9	-17 7	-13 14	-32*	Mich	Mich	
25150	K0 III-IV	1	8.8	37 -44			Mich	Case	
27224	K1 III	2	8.1	8 - 6	-19 -17		Mich	Mich	
27348	*G8 III	1	5.9	-24 - 4	-16 2	-27.4*	Lick	Ro	54 Per
28403	K2 III-IV	2	8.9	20 -23	20 -21		Mich	Mich	
29122	K2 III-IV	2	7.6	7 -59	0 -77		Lick	Case	
30793	K1 III-IV	2	9.0	55 -37	52 -39		Mich	Case	
33618	K2 III-IV	1	7.4	11 -14	16 -21	+4.2*	Mich		HR 1688
34190	K3 III	2	8.6	9 -18	10 - 6		Lick	Case	
35295	K1 III-IV	2	7.6	- 7 -39		-15.4*	Mich		HR 1779 ADS 4000A
35620	K4 IIIp	1	6.3	- 4 -47	-10 -47	+31.0	Mich	Ro	φ Aur

TABLE 1--Continued

HD or BD	Spectral Type	CN	m_{pg}	Sm. or N30 $\mu_\alpha \cos\delta$ μ_δ	AGK3p $\mu_\alpha \cos\delta$ μ_δ	R. V. (km/sec)	Plate Source	Star Source	Name, HR, ADS
36040	K0 III	2	7.1	7 -40	3 -30	+14.1*	Lick		HR 1824
38751	G8 III-IV	1	6.0	- 1 -26	- 1 -20	+16.4*	Lick	Ro	132 Tau
39628	*K2 IV	2	7.9	42 -95			Mich	Mich	
40083	K2 III	2	7.2	9 -35	-18 -37	- 5.6*	Mich	Mich	HR 2080
40827	K1 III-IV	2	7.3	4 -50	9 -45	+31.4*	Mich	Mich	HR 2121
41430	K2 III-IV	1	8.5	30 -41	26 -41	+21.1*	Mich	Case	
+12°1069	K1 II-III	2	10.0	3 - 7	- 5 -13		Lick	Case	ADS 4833
43299	K3 III-IV	1	8.0	-29 -36	- 1 -19		McD	Case	
44123	K1 III	1	8.6	4 0	-14 6		Mich	Mich	
45512	K2 III-IV	2	7.3	26 -39	44 -46	-20.3*	Lick	Case	HR 2342
46709	K4 III	1	7.3	-14 3	11 -11	+38.6	Lick	Case	HR 2406
56711	K2 III	1	8.7	8 -13	16 - 3		KPNO	Mich	
57669	K0 III	2	6.3	- 7 -25	-10 -22	+21.2*	Lick	Ro	66 Aur
61912	K1 III	2	8.7	- 1* -22	9 -35		KPNO	Mich	
66660	K1 III	2	8.0	3 2	13 - 9		KPNO	Mich	
67368	K2 III	1	9.0	15 17	-10 18		KPNO	Mich	
69698	K2 III	1	8.7	- 3 - 9	-21 - 1		KPNO	Mich	
69787	K2 III	2	8.7	21 -15	29 -32		KPNO	Mich	
72292	K3 III	1	6.5	-41 -45	-42 -39	+23.8	Mich	Mich	η Cnc
74379	K0 III	1	9.0	-18 -33	-18 -37		KPNO	Mich	
76294	*G8 III-IV	1	4.3	-98 12		+22.8*	Lick	Ro	ζ Hya
76921	G8 III:	1	8.4	-10 -19	-42 -11		Mich	Mich	
78865	K1 III-IV	2	8.1	-36 -11	-31 -17		Mich	Mich	
79675	K0 III-IV	2	8.6	-59 9	-39 - 2		Mich	Mich	
83564	K1 III-IV	2	7.6	-53 -48	-28 -34		Mich	Mich	

TABLE 1--Continued

HD or BD	Spectral Type	CN	m_{pg}	Sm. or N30 $\mu_\alpha \cos\delta$ μ_δ	AGK3p $\mu_\alpha \cos\delta$ μ_δ	R. V. (km/sec)	Plate Source	Star Source	Name, HR, ADS
84779	K0 III	1	8.7	2 -38	16 -33		Mich	Mich	
85425	K0 III-IV	1	9.5	-11 -42	-33 -41		KPNO	Mich	
85503	*K0 III	1	5.1	-214 -56	-219 -77	+13.8*	Mich		μ Leo
87583	K1 III	2	9.0	-25 -13	-26 -11		KPNO	Mich	
88284	*K0 III	1	4.8	-201 - 93		+19.4*	Lick	Ro	λ Hya
88630	K1 III	2	8.9	3 15	- 8 0		KPNO	Mich	
91810	K1 III	2	7.8	-48 - 8	-56 - 9		Mich	Mich	
92811	K1 III	2	7.9	-16* 16	4 8		Mich	Mich	
93727	K0 III	2	9.5	-27 -17	-16 -23		KPNO	Mich	
95272	*K0 III	2	5.4	-459 126		+46.9*	Lick	Ro	α Crt
95405	*G8 IIIp	3	9.8	37 -25		+12	Lick		
96126	K3 III	1	8.3	-63* 25	-58 4		Mich	Mich	
98214	K0 III	1	8.4	-18 0	-15 - 5		Mich	Mich	
103643	K3 II-III	2	9.3	-14 0	-23 -14		KPNO	Mich	
104998	K0 III	3	9.4	-20 16	-11 2		Lick		
105057	K2 III	2	9.3	-56 -15	-35 -14		KPNO	Mich	
105632	K1 III	2	8.8	-31 -20	-30 - 3		KPNO	Case	
105879	K1 III	3	9.0	-12 - 6	-16 - 4		KPNO	Mich	
106102	K2 III-IV	1	8.2	-143* - 30	-142 - 21		Mich	Mich	
107484	K0 III	1	8.6	-20 -15	-46 -28		KPNO	Case	
108078	K2 III	1	8.8	-48 4	-51 5		KPNO		
108174	K1 III	1	8.5	9 -38	- 6 -25		KPNO	Case	
108381	K1 III-IV	2	5.6	-88* -78	-103 - 70	+ 3.9*	Lick	Ro	15 γ Com
109702	K2 III	1	8.4	10 -38	10 -29		KPNO	Mich	ADS 8607
109981	K1 III	2	9.0	-19 3	5 -32		KPNO		

TABLE 1--Continued

HD or BD	Spectral Type	CN	m_{pg}	Sm. or N30 $\mu_\alpha \cos\delta$ μ_δ	AGK3p $\mu_\alpha \cos\delta$ μ_δ	R. V. (km/sec)	Plate Source	Star Source	Name, HR, ADS
110801	K2 III	1	9.6	-13 -41	11 -42		KPNO	Mich	
112127	K2 III	2	8.2	-11 - 5	14 14	+ 2*	Lick		
113064	K2 III	2	9.5	- 6 1	- 8 15		KPNO	Mich	
115202	*K1 IV	1	6.4	310 -118		+34.1	Lick	Ro	57 Vir
116976	K1 III	2	6.0	-120 22		-14.1*	Lick	Ro	69 Vir
119425	K1 III	2	6.8	-291 - 71	-300 -72	-42.4*	Lick		84 Vir A ADS 9000A
120682	K2 III	1	9.5	-15 23	1 - 7		KPNO	Mich	
122546	K2 III	2	9.3	-46 - 2	-44 - 2		KPNO	Mich	
123821	*G8 IIIp	3	9.4	10 -10	10 - 1		KPNO	Mich	
125260	K1 III	1	8.2	44 -33	20 -45		Mich	Mich	
125454	G9 III	1	6.6	-119* - 70	-121 - 81	-27.1*	Lick	Ro	ν Vir
127760	K2 III	2	9.4	-23 36	-31 28		KPNO	Mich	
128091	K3 III	2	9.2	-48 25	-39 8		KPNO	Mich	
130705	K4 II-III	3	7.6	-47 -81	-50 -87		McD		
131445	K3 III	1	9.3	-15 - 9	-21 -14		KPNO	Mich	
132345	K3 III-IV	3	7.0	-104 - 64		-11.5	Lick		18 Lib A ADS 9456A
+58°1541	K1 III	2	9.5	-38 25	-22 28		KPNO	Mich	
137717	K1 III	1	8.9	-11 21			KPNO	Mich	
+78°518	K3 III	1	9.2	- 8 -22	- 2 6		KPNO	Mich	
138716	*K1 IV	1	5.8	305 -239					37 Lib
139663	K3 III	3	7.0	-18 -16		-21.8	Lick		42 Lib
140117	K1 III	1	7.3	-10 14	- 6 3	- 7.7*	Mich	Mich	HR 5841
140573	*K2 III	2	3.8	137 46		+ 2.9*	Lick		α Ser
148513	K4 III	1	7.3	- 5 -65	15 -59	+ 7.3	Mich	Ro	HR 6136
154277	K1 III	2	9.0	-14 -26	-34 -11		KPNO		

TABLE 1--Continued

HD or BD	Spectral Type	CN	m_{pg}	Sm. or N30 $\mu_\alpha \cos\delta$ μ_δ	AGK3p $\mu_\alpha \cos\delta$ μ_δ	R. V. (km/sec)	Plate Source	Star Source	Name, HR, ADS
156349	K0 II-III	2	6.6	-54 -10		-29.2*	Lick		o Oph A ADS 10442A
156774	K2 III	1	8.5	-28* -23	-29 -29	-48.3*	Mich	Mich	
156841	K1 III	1	8.7	19 10	0 14		Mich	Mich	
164349	*K0 II-III	2	5.9	- 4 -10	-11 - 4	-23.4*	Lick	Ro	93 Her
165687	K1 III	1	6.8	-100 57		-32.4*	Lick	Case	HR 6769
166284	K2 III	2	8.7	13 -17	23 -19	- 6.8*	KPNO	Mich	
167472	K1 III	2	7.8	-13 -34	2 -31	- 2.2*	Mich	Mich	
169113	K1 III	2	8.5	- 3 - 4	12 0	-31.8*	Lick		
170474	K0 III	1	6.5	32 -33	33 -35	+27.5*	Lick	Ro	60 Ser
171443	*K2 III	2	5.4	- 18 -313		+35.8*	Lick	Case	α Sct
171745	G8 III	2	6.8	7 8	12 16	+15.9*	Lick		HR 6980 ADS 479
171767	K1 III	2	7.6	22 -26	15 -13		Lick	Case	ADS 11494
174350	K1 III	2	8.8	1 25	27 -11		Lick	Case	
174487	K4 III-IV	1	7.8	- 4* -40	- 4 -35	- 2	Lick		
176408	K1 III	1	6.7	-29* -58	-29 -48	-34.0*	Mich	Mich	48 Dra
177198	K2 III	2	9.7	-24 -40	16 -18		KPNO	Mich	
178555	K1 III	1	7:3	19 -81			Lick		HR 7265 ADS 12096
178637	K1 III	2	7.5	-11 - 8	- 4 -12	+ 8*	Lick	Case	
180006	G8 III	2	6.2	39* 52	42 57	-15.8*	Lick	Ro	53 Dra
180352	K0 III	1	8.2	13 -11	- 3 21	-27*	Lick	Case	
181098	K1 III-IV	2	7.8	88 150	80 176	-74.0	Lick	Case	
181603	K1 III	1	9.1	-19 4	6 - 8		KPNO	Case	
182572	*G8 IV-V		6.0	726 640		-99.8	Lick	Ro	31 Aql
184492	G8 III	2	6.1	9 - 5		-30.8*	Lick	Ro	37 Aql
184944	K0 II-III	2	7.6	36 -21	9 -31	-42.0*	Lick		HR 7449

TABLE 1--Continued

HD or BD	Spectral Type	CN	m_{pg}	Sm. or N30 $\mu_\alpha \cos\delta$ μ_δ	AGK3p $\mu_\alpha \cos\delta$ μ_δ	R. V. (km/sec)	Plate Source	Star Source	Name, HR, ADS
185055	K2 III-IV	2	8.4	13 -40	5 -25		Mich	Case	
189751	K1 III	1	8.0	17 - 1	23 3	-15*	Lick	Case	ADS 13240A
190147	K1 II-III	2	6.3	22 8	16 12	+ 0.9*	Lick	Ro	26 Cyg ADS 13278A
190227	K1 III	2	7.8	15 1	10 13	-19.8*	Lick	Mich	
191067	*K1 IV	1	6.8	116 - 69		- 4.2	Lick		64 Aql
194152	K1 III	2	6.9	31 48	21 44	-26*	Lick		HR 7798
199442	K2 III	2	7.2	19 -63	19 -89	-25.6*	Lick		HR 8017 ADS 14457A
200060	K2 III	1	8.4	-33 4	-22 - 2	-23*	Lick	Case	
200970	K2 III	1	8.3	66 -21			McD		
202987	K3 III	2	7.3	22 18	15 25	-18.8	Lick	Case	HR 8150
205512	K1 III	2	6.0	127 101	135 78	-65.9	Lick	Ro	72 Cyg
206349	K1 II-III	1	7.9	4 7	21 - 3		Lick	Case	
206834	G8 II-III	2	6.4	22 - 5		- 4.9*	Lick	Ro	46 Cap
207130	K0 III	2	6.4	-40 -33	-44 -28	-38.5*	Lick	Ro	HR 8324
210905	K0 III	2	7.5	134 86	149 103	-28.3*	Lick	Case	HR 8476
211833	K2 III	2	7.2	38 21	42 10	- 2.4*	Lick	Case	25 Cep
217730	K4 III	1	8.5	- 6 -14	22 -16	-21	Mich	Case	
220954	*K1 III	2	5.3	-117 - 44	-116 - 40	+ 5.8*	Lick	Ro	θ Psc
222404	*K1 IV	1	4.4	-60 152		-42.4	Mich	Ro	γ Cep
222455	K3 III-IV	1	8.6	-92 -41	-87 -24	- 2.2	Lick		ADS 16919
222682	K2 III	1	7.6	57 - 7	59 -18	-15.5*	Lick	Case	HR 8990
224116	*K2 IV:	1	8.4	28 81			Mich	Case	

REMARKS TO TABLE 1

HD 3681. Good case of weak hydrogen lines (Bidelman 1957).
8701. Bidelman (1957).
9852. Bidelman (1957).
12623. Radial velocity: Boulon (1963).
13530. Spectroscopic binary.
14617. Bidelman (1957).
16039. Strong Hg in spectrogram. Hδ moderately strong; possible class II.
25150. Hg strong in spectrogram.
27224. Hg strong in spectrogram.
28403. Hg very strong in spectrogram (see Fig. 1).
30793. Hg strong in spectrogram.
33618. Radial velocity: Young (1939).
35295. Bidelman (1958).
35620. A peculiar star (Roman 1952).
36040. Bidelman (1957).
44123. Hg strong in spectrogram.
72292. Ljunggren and Oja (1961).
76921. Hg in spectrogram.
83564. Hg strong in spectrogram.
84779. Hg strong in spectrogram.
85503. Spinrad (1966).
88284. Spectroscopic binary.
95405. Possibly weak C_2 at λ4737. May be very early carbon star; intermediate between K and R star in HD.
104998. Keenan (1958*a*); Upgren (1962).
105632. Upgren (1962).
107484. Upgren (1962).
108078. Upgren (1962); Malmquist (1960).
109981. Upgren (1962); Malmquist (1960).
110801. Upgren (1962). Break at λ4216 weak, but λ4150 region strong.
112127. Keenan (1958*a*); Upgren (1962).
123821. Peculiar star; possibly very early carbon star. Very strong CN and weak lines. Illustrated in Fig. 1.
130705. Strong CN noted in HD.
132345. Bidelman (1958).
138716. The spectral type is taken from Keenan (1955).
140573. Keenan (1955). AGK3p proper motion uncertain.
148513. A peculiar star (Roman 1952).
156349. Bidelman (1958).
169113. Lindblad (1922).
170474. Spectroscopic binary.
171745. Visual binary with orbit.
174487. Bidelman (1957).
194152. Bidelman (1957). Spectroscopic binary.
199442. Bidelman (1957).
200970. Strong CN noted in HD.
202987. Bidelman (1957).
211833. Bidelman (1957).
224116. Hg strong in spectrogram.

The following stars are in Yoss's (1961) list: HD 3681, 16039, 16448, 27224, 33618, 39628, 40827, 44123, 66660, 67368, 74379, 78865, 79675, 83564, 84779, 91810, 98214, 106102, 109702, 125260, 127760, 156774, 156841, 167472, 180006, and 224116.

III. DATA REDUCTION

a) *Spectral Classification*

The spectral types given in Table 1 were determined by visual comparison of spectrograms of the strong-CN stars with those of standard stars.

The stars classified were in the range G8–K4 and of luminosity classes II–IV, and thus the number of spectral criteria used is small. The criteria were basically those of the MKK system (Morgan, Keenan, and Kellman 1943). The spectral type was found primarily from the strength of λ4290 (Cr I). The ratio of λ4290 to λ4300 (Ti I, Ca I, Fe I) was used for types K0–K5. At G8 one must use Hδ and its ratio to λ4143 (Fe I), since λ4290 is about as strong as at K0. However, one must be careful since Hδ is also luminosity-sensitive. For classes K2–K5 the ratio λ4227 (Ca I) to λ4325 (Fe I) is also useful for spectral type; however, as for Hδ, λ4227 is luminosity-sensitive.

The principal luminosity criterion used was the strength of the Sr II line λ4077: the ratio of this line to the neutral iron lines at λλ4045, 4063, and 4071 is a sensitive indicator of luminosity. In addition, one must check the strength of the hydrogen lines to be certain that they agree with the luminosity class as determined from λ4077.

It is important to realize that the spectrum of a star should match that of a standard star in all respects before it can be said to be of the same type as the standard. This is especially important in this investigation since many of the stars have slight spectral peculiarities (e.g., I found, as did Roman [1952], that the strong-CN stars tend to have strong Ca I λ4227 and a strong G-band). Thus, while the above criteria were the main ones checked while classifying the spectrograms, I have always looked at the entire spectrum before making a final classification; I have also made comments when appropriate. I have independently discovered and classified stars that appear in the list by Yoss (1961) (a list is given following Table 1). The agreement between my classification and his is usually within 1 spectral subclass and 1 luminosity class. Also, reasonable agreement exists in the estimated CN strengths.

In the process of classification, two interesting problems were encountered. The Lick 36-inch telescope is a visual refractor, and the amount of blue light focused on the spectrograph slit depends strongly on the position of a correcting lens. Thus one must not allow a star's energy distribution to influence the classification. The second problem stems from the location of the Michigan 37-inch telescope. One usually finds Hg I emission lines from the city street lights appearing on long exposures. Figure 1 (Plate 1) includes one spectrogram with an exceptional amount of Hg I emission (HD 28403). At first sight it appears that this star is a dwarf since λ4077 of Sr II is not present. Actually, λ4077 is filled in by one of the weaker Hg I emission lines!

An indication of the strength of the CN absorption in each star is given in Table 1. Eye estimation of the strength of the CN bands in a spectrogram is difficult. One must use wide spectrograms of low dispersion so that the bands are compact and can be seen as integrated bands rather that as groups of partially resolved lines. Also, the apparent CN strength is very sensitive to the density of the spectrogram.

Exactly what is meant in the literature by CN absorption is not entirely clear. Often each investigator has estimated or measured a different quantity. For example, Griffin and Redman (1960) do not include most of the region centered on λ4150 in their measurement bands.

I have used the amount of the "break" at λ4216 as my criterion of CN strength. Keenan (1958*b*) defines this as the difference between the intensity in the range λλ4211–4213 and that in the range λλ4219–4221. I compared the region from Ca I λ4227 to the blend of Sr II λ4215 and the CN band head at λ4216 with the region from λ4216 to approximately λ4210. The region λλ4216–4227 is relatively smooth and free of strong atomic or molecular lines. The region λλ4210–2416 is almost entirely populated with rotational lines of CN and is not affected appreciably by atomic lines. I found this criterion of CN strength easier to use and more easily reproducible from different spectrograms than the general appearance and strength of the λ4150 region. Also, the λ4150 region does contain atomic lines that could substantially influence its appearance.

The strengths have been estimated by reference to Keenan's (1958*a*) standard numerical estimates. Ideally, one should have a standard for each spectral type and luminosity for various strengths of CN. However, Keenan lists only four strong-CN stars that can be used as standards for CN strength. His list of stars with normal CN covers G8–K2 giants with one bright giant. However, at a most critical spectral type, K2 III, he has only one normal standard, and on my spectrogram this star (ξ Dra) appears to show somewhat more CN absorption than other K2 III standards.

In view of the above, I suggest that the proper interpretation of the number given in column (3) of Table 1 is as follows: a CN strength of 1 indicates slightly stronger CN than normal; a CN strength of 2 indicates a certain case of abnormally strong CN; and a CN strength of 3 indicates an excellent case of abnormally strong CN. Several strong-CN stars with spectral classifications and estimated CN strengths are shown in Figure 1.

b) Proper-Motion Studies

It is essential to correct proper motions for errors in the adopted values of the constants of precession and for the effects of galactic rotation. In addition, their reference coordinate system should be the FK4 system (Fricke 1966). Fricke (1967*a*) gives the following equations for the corrections to proper motions due to errors in the precession constants:

$$\Delta\mu_\alpha(\text{prec}) = \Delta n \sin\alpha \sin\delta + \Delta k \cos\delta\,,$$

$$\Delta\mu_\delta(\text{prec}) = \Delta n \cos\alpha\,,$$

where $\Delta\mu_\alpha(\text{prec})$ = the correction in right ascension (in seconds of arc per year); $\Delta\mu_\delta(\text{prec})$ = the correction in declination (in seconds of arc per year); $\Delta n = \Delta p_1 \sin\epsilon$, the correction to lunisolar precession times the sine of the obliquity of the ecliptic; and $\Delta k = \Delta n \cos\epsilon - (\Delta\lambda + \Delta e)$, where $\Delta\lambda$ = the correction to planetary precession and Δe = the motion of the equinox originating from other effects than precession (rotation about the polar axis of the Earth). I have used $\Delta p_1 = 0\farcs0110$ year^{-1} and $(\Delta\lambda + \Delta e) = 0\farcs0121$ year^{-1}, which are the values suggested by Fricke (1967*b*). The usual equations have been used to correct the proper motions for the effects of galactic rotation (e.g., Fricke 1967*a*). The values $A = +15$ km sec^{-1} kpc^{-1} ($+0\farcs0032$ year^{-1}) and $B = -10$ km sec^{-1} kpc^{-1} ($-0\farcs0021$ year^{-1}) (Schmidt 1965) were used for Oort's constants. Both of the above corrections are incorporated in the proper motions given in Table 1. Presumably, aside from errors, the proper motions listed in Table 1 reflect only the solar motion and peculiar motions and unknown stream motions of the stars. The peculiar motions are assumed to be random; one cannot, of course, correct for unknown stream motions.

The numerous G8–K2 stars of luminosity classes III–IV to II–III (107 stars) were divided into groups of approximately the same apparent magnitude, and statistical parallaxes were calculated for each group. I have also calculated statistical parallaxes for the K3 and K4 stars, the G8–K2 luminosity class III–IV stars, the G8–K2 CN +2 and +3 stars, and the G8–K2 CN +1 stars listed in Table 1. These smaller groups could not be subdivided into different apparent-magnitude groups, and thus in these cases the method of "reduced" proper motions was used.

However, to derive a statistical parallax from proper motions requires knowledge of the solar motion. Listed in Table 1 are fifty-five stars of spectral types G8–K2 with published radial velocities less than 65 km sec^{-1}. Using these stars, I obtained the following values for the solar motion: $X = +4.3 \pm 4.1$ km sec^{-1}, $Y = -15.0 \pm 5.0$ km sec^{-1}, $Z = +11.9 \pm 4.1$ km sec^{-1}, and $K = +0.5 \pm 5.6$ km sec^{-1} (total motion 19.6 ± 4.8 km sec^{-1}). The K-term can, of course, be ignored. The solar apex is at the position $A = 286° \pm 16°$ and $D = +37° \pm 3°$. All errors are mean errors.

Delhaye (1965) lists two determinations of the solar apex for K0–K2 giants: Vyssotsky and Williams (1948) found $A = 278°$ and $D = +32°$ ($l^{\text{II}} = 61°$, $b^{\text{II}} = +17°$) from proper motions of 2525 stars, and Delhaye (1951) found $A = 278°$ and $D = +37°$ ($l^{\text{II}} = 66°$, $b^{\text{II}} = +19°$) from the proper motions of 4439 stars. From my determination and the above results, I have adopted $A = 280°$ and $D = 35°$ for the solar apex and 19.5 km sec^{-1} for the magnitude of the solar motion.

I have chosen in most cases to use the so-called υ-component of the proper motions to determine the mean parallaxes. The results of the several solutions by this method are given in Table 2. The mean errors have been calculated by Gauss's method. One should note in Table 2 that the mean parallaxes from Solutions 7, 8, and 9 are very similar. In

TABLE 2

MEAN PARALLAXES AND ABSOLUTE MAGNITUDES

Solution number	No. of stars	Apparent magnitude range	Mean AGK2 apparent magnitude	Proper motion source	Mean parallax	$\bar{M}_{pg}$*	$\bar{M}_v$*
			All G8 - K2 Stars (ν components)				
1	19	6.0 - 6.9	6.5	AGK3p	0.0160 ± 0.0053	+2.1 ± 0.7	+1.1
				Sm. + N30	0.0158 ± 0.0051	+2.1 ± 0.7	+1.1
2	26	7.0 - 7.9	7.5	AGK3p	0.0120 ± 0.0024	+2.7 ± 0.4	+1.6
				Sm. + N30	0.0116 ± 0.0022	+2.6 ± 0.4	+1.7
3	41	8.0 - 8.9	8.5	AGK3p	0.0048 ± 0.0010	+1.7 ± 0.5	+0.7
				Sm. + N30	0.0044 ± 0.0012	+1.5 ± 0.6	+0.5
4	20	9.0 - 10.0	9.3	AGK3p	0.0061 ± 0.0012	+3.0 ± 0.4	+2.0
				Sm. + N30	0.0064 ± 0.0020	+3.2 ± 0.7	+2.2
			G8 - K2 Stars (τ components)				
5	19	6.0 - 6.9	6.5	AGK3p	0.0128 ± 0.0098	+1.8 ± 1.7	+0.8
6	19	7.0 - 7.9	7.5	AGK3p	0.0052 ± 0.0040	+0.8 ± 1.8	-0.2
			G8 - K2 III-IV Stars (ν components)				
7	21	6.0 - 10.0	8.0	Sm. + N30	0.0088 ± 0.0026	+2.5 ± 0.6	+1.5
			G8 - K2 CN +1 Stars (ν components)				
8	44	6.0 - 10.0	8.0	Sm. + N30	0.0082 ± 0.0019	+2.4 ± 0.5	+1.4
			G8 - K2 CN +2 and +3 Stars (ν components)				
9	63	6.0 - 10.0	8.0	Sm. + N30	0.0079 ± 0.0020	+2.3 ± 0.5	+1.3
			All K3 and K4 Stars (ν components)				
10	18	6.0 - 10.0	8.0	AGK3p	0.0078 ± 0.0031	+2.4 ± 0.9	+1.1
				Sm. + N30	0.0077 ± 0.0030	+2.1 ± 0.8	+0.8

* -0.2 magnitude correction incorporated for dispersion in distance

addition, attention is called to the excellent agreement between the mean parallaxes resulting from the Smithsonian and N30 proper motions and those resulting from the AGK3p proper motions (Solutions 1, 2, 3, 4, and 10).

As a check on the calculations using the υ-components, mean parallaxes which use the τ-components for the two apparent-magnitude groups that have the largest proportions of published radial velocities have been computed and are also given in Table 2. The method commonly used is to assume that the motions are isotropic and to equate the dispersion in the tangential velocities to that in the radial velocities. My calculation for the solar velocity gave a radial-velocity dispersion of 20.7 km sec^{-1}. As an estimate of the dispersion in the τ-component of the proper motions, I have used the square root of the sum of the squares of the individual components divided by the number of individual components. However, both of these dispersions are larger than their true values because of observational error. Hence the radial-velocity dispersion has been corrected for an estimated "error" dispersion of 8 km sec^{-1}. The τ-component dispersion has been similarly corrected for an estimated "error" dispersion of 0".010 year^{-1}. Unlike the proper motions, the radial velocities are not corrected for galactic rotation, but this is unnecessary. To derive the error for the τ-component mean parallaxes, I assumed that the radial-velocity dispersion is a well-known number. I then computed the mean error for the dispersions in the τ-components alone and considered this as the source of error for the mean parallax.

The mean parallaxes found from the τ-components (Solutions 5 and 6 in Table 2) agree moderately well with those found from the υ-components (Solutions 1 and 2). However, the errors of the τ-component solutions are surprisingly large; and these solutions will not be considered further.

IV. CONCLUSIONS

a) *Absolute Magnitudes*

The derivation of the mean absolute magnitude of a group of stars from its mean parallax involves the assumptions that all the stars in the group have approximately the same absolute magnitude and that the dispersion in the distances to the stars is Gaussian. With these assumptions van de Kamp (1967) gives the following expression for the mean distance, $\langle r \rangle$, computed from the mean parallax, $\langle p \rangle$:

$$\langle r \rangle = \langle p \rangle^{-1} \exp (0.21\sigma^2) .$$

where σ is the rms deviation in the absolute magnitude of the group of stars. One then uses $\langle r \rangle$ to compute the absolute magnitude in the usual manner.

I have used spectroscopic criteria to isolate groups of stars of about the same absolute magnitude, and have assumed that the dispersion in distance for each group is Gaussian. However, to use the formula one must estimate the value of σ. This is difficult to do accurately. The dispersion obtained directly, by taking the absolute magnitudes from Blaauw's (1963) calibration for each individual star, is only 0.4 mag. However, the mean errors of the absolute magnitudes derived in Table 2 are somewhat larger than this, and I have adopted $\sigma = 0.6$ mag, which leads to a correction for distance dispersion of -0.2 mag; this correction has been incorporated in the values of the photographic absolute magnitudes given in Table 2.

To convert photographic to visual absolute magnitudes, the color index is needed. Allen (1963) gives the following formula: $C = B - V - 0.11$, where C is the color index, which equals $m_{pg} - m_v$. I have taken $B - V = +1.11$ as a convenient value for the G8–K2 stars and find $C = +1.0$ for them. For the K3 and K4 stars I have used a color index of $+1.3$. The last column in Table 2 gives the visual absolute magnitude corresponding to each mean parallax.

A correction that has not been incorporated in these absolute magnitudes is given by Malmquist's (1922) formula: ($\langle M \rangle$ of stars in a given volume of space) = ($\langle M \rangle$ of stars brighter than a given apparent magnitude) + 1.4 σ^2, where σ is the dispersion in absolute magnitude. Since it is almost impossible to derive a reliable estimate of σ, I have not applied to this correction, which is probably of the order of $+0.3$ mag, to my mean absolute magnitudes. However, one should note that Blaauw's (1963) calibration for the G and K stars is also based upon stars selected according to apparent magnitude. Therefore, while a comparison between my absolute magnitudes and those given by Blaauw is valid, strictly speaking my absolute magnitudes are systematically somewhat brighter than they would be if they referred to all stars within a given volume of space (e.g., a cluster).

Moderately good internal agreement in absolute magnitude is found for the four different apparent-magnitude groups of G8–K2 stars (Solutions 1–4 in Table 4). From these four solutions I find the mean visual absolute magnitude of the G8–K2 stars to be $+1.3 \pm 0.4$. A comparison of the G8–K2 stars of differing CN strength (Solutions 8 and 9) shows that there is no significant difference in the absolute magnitudes of these groups. I found a similar result in comparing all of the G8–K2 stars with the G8–K2 III–IV stars alone (Solution 7). However, this latter result is somewhat questionable since the stars of luminosity classes III–IV are badly distributed in the sky. (Also, I have checked the effect of including G8 giants in the group: No change in absolute magnitude is found if they are not included). I find a mean visual absolute magnitude of $+1.0 \pm 0.7$ for the K3 and K4 stars alone (Solution 10).

It is also of interest to compare these absolute magnitudes above with those available from other sources. Sixteen of the strong-CN stars have trigonometric parallaxes (Table 3) in Jenkins's (1952, 1963) catalogs. As one can see, the scatter is considerable, but one should note that among the stars with more accurate parallaxes, the tendency is toward fainter absolute magnitudes. For the G8–K2 stars, $\langle M_v \rangle = 1.2$. In addition, Table 3

TABLE 3

ADDITIONAL PARALLAXES AND ABSOLUTE MAGNITUDES OF STRONG-CN STARS

Star Name	Spectral Type	Parallax	Visual Absolute Magnitude
Trigonometric Parallaxes			
ψ Cas.....	K0 III	$0''.012 \pm 0''.006$	+0.4
49 And....	K0 III	$0''.015 \pm 0''.006$	+1.0
φ Aur.....	K4 III	$0''.011 \pm 0''.006$	+0.2
η Cnc.....	K3 III	$0''.014 \pm 0''.006$	+0.9
ζ Hya.....	G8 III–IV	$0''.029 \pm 0''.006$	+0.6
μ Leo.....	K2 III	$0''.022 \pm 0''.006$	+0.8
λ Hya....	K0 III	$0''.021 \pm 0''.007$	+0.4
α Crt.....	K0 III	$0''.024 \pm 0''.008$	+2.3
69 Vir.....	K1 III	$0''.051 \pm 0''.010$	+4.5
υ Vir......	G9 III	$0''.013 \pm 0''.008$	+1.2
42 Lib....	K3 III	$0''.042 \pm 0''.010$	+3.8
α Ser.....	K2 III	$0''.046 \pm 0''.006$	+1.1
α Sct.....	K2 III	$0''.013 \pm 0''.004$	+0.0
48 Dra....	K1 III	$0''.020 \pm 0''.006$	+2.2
HR 8324.	K0 III	$0''.014 \pm 0''.006$	+1.1
26 Cyg....	K1 II–III	$0''.014 \pm 0''.007$	+1.0

Star Name	Spectral Type	Visual Absolute Magnitude
Ca II Emission Width Absolute Magnitudes		
α Crt.....	K0 III	+0.9
84 Vir A...	K1 III	+1.3
37 Lib....	K1 IV	+3.0
α Ser.....	K2 III	+1.2
α Sct.....	K2 III	+0.4
HR 6980..	G8 III	+1.7
γ Cep.....	K1 IV	+2.6
Hα Width Absolute Magnitudes		
φ Aur.....	K4 IIIp	+0.1:
ζ Hya.....	G8 III–IV	+1.7:
α Ser.....	K2 III	+1.4:
Absolute Magnitudes from Membership in the 61 Cygni Moving Group		
HR 645...	K0 III	+1.5
α Crt.....	K0 III	+0.9
HR 8476..	K0 III	+0.8

contains ten stars for which Wilson and Bappu (1957), Wilson (1967), and Helfer and Wallerstein (1968) have derived absolute magnitudes from the emission widths ($\langle M_v \rangle = 1.6$) of the H- and K-lines and three stars for which Kraft, Preston, and Wolff (1964) found absolute magnitudes from the widths of Hα absorption. Three members of the 61 Cygni moving group are strong-CN stars, and absolute magnitudes of these are thus available from their group membership (Eggen 1962). These are also given in Table 3. The absolute magnitudes for the G8–K2 giants found in the above ways tend to be fainter than $M_v = +0.8$. This tends to confirm the values found from the proper-motion solutions.

According to Blaauw's (1963) calibration, the visual absolute magnitude of G9–K2 giants should be near +0.8 rather than +1.3; the visual absolute magnitude of K3 and K4 giants should be near 0.0 rather than +1.0. Thus the main conclusion is that the strong-CN stars are somewhat too faint for their mean spectral types: the stars listed in Table 1 have mean visual absolute magnitudes 0.5–1 mag fainter than would be anticipated.

b) *Apparent Distribution in the Sky*

Despite strong observational selection effects inherent in this study, one observes that the stars listed in Table 1 are found in all parts of the northern sky and are not strongly concentrated to the galactic plane. It should also be noted that this reasonably fulfills the requirements for the distribution of stars used for a statistical parallax.

One can very roughly estimate the total number of undiscovered strong-CN stars. About 5 percent of the G8–K5, II–III to III–IV stars in Roman's (1952) list are strong-CN stars. Shapley and Cannon (1921) list approximately 2×10^4 K-type stars in the HD brighter than 8.25 (visual magnitude); a very high percentage of these must be giants. One would thus expect that about 10^3 strong-CN stars remain undiscovered down to magnitude 8.25.

c) Evolutionary History

The absolute magnitudes found in this investigation place, in the H-R diagram, the G8–K2 stars and the K3 and K4 stars near the loci for the old open clusters M67 and NGC 188 (Fig. 2). NGC 188 may have an age from 6 to 10 billion years (Demarque 1968), and M67 an age near six billion years (Iben 1967). These stars are closer in absolute magnitude to the red giants in M67 and NGC 188 than to normal red giants in the field.

A less conclusive indication of the age of these stars is found in their space motions. Space velocities relative to the local standard of rest have been computed for all of the stars in Table 1 that have known radial velocities. The proper motions were corrected for errors in the constants of precession but not for galactic rotation. The motions of these stars in the galactic plane are shown in Figure 3. One notes that about 10 percent of the stars are high-velocity objects.

As previously mentioned, three strong-CN stars belong to the 61 Cygni moving group (Eggen 1962, 1965*a*). Eggen has noted that the H–R diagram of the 61 Cygni moving group is similar to that of M67.

In addition to kinematic evidence, one has spectroscopic evidence. The strong-CN stars tend to have strong Ca I λ4227, a strong G-band, and I have suspected that $H\gamma$ is somewhat weak in certain stars. These properties are similar to those of the red giants in NGC 188 and also, to a lesser extent, to those of the red giants in M67. Greenstein and Keenan (1964) examined spectrograms of eleven red giants in NGC 188 and found that six of them showed strong CN absorption, three showed weak hydrogen lines, and seven had strong Ca I. They also examined spectrograms taken by the Burbidges of six red giants in M67. Two of the six showed slightly strong CN, and one showed strong Ca I. Further evidence on this point has recently been given by the photoelectric work of Spinrad and Taylor (1969). Thus the conclusion that the stars considered in this investigation are similar to red giants in very old open clusters is supported by their absolute magnitudes, kinematics, and spectra.

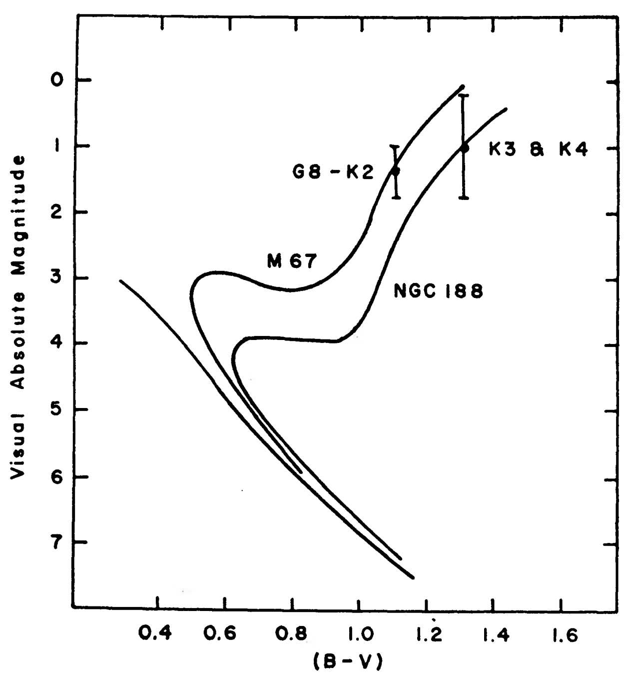

FIG. 2.—An H-R diagram showing the loci of M67 and NGC 188 (Sandage 1962) and the positions of the G8–K2 and K3 and K4 stars in this investigation.

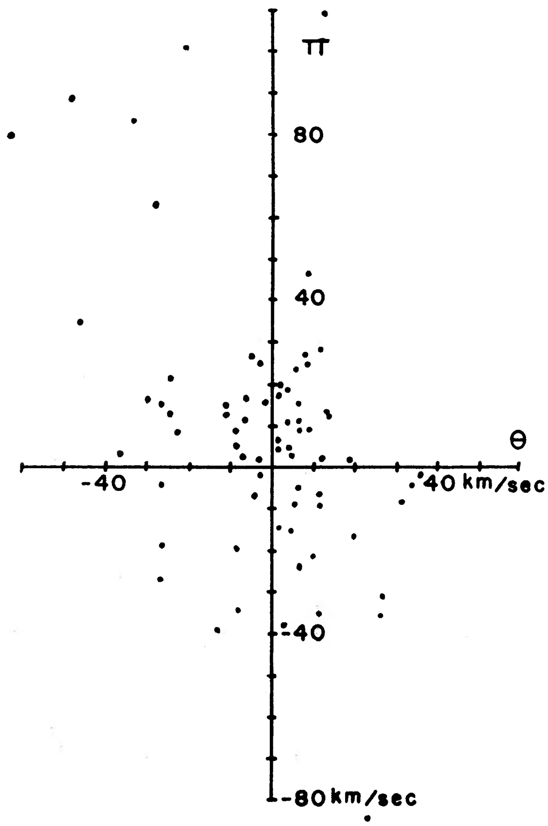

FIG. 3.—Motions in the galactic plane referred to the local standard of rest. The positive θ-direction is in the direction of galactic rotation. The negative π-direction is in the direction of the galactic center.

d) Masses of the Strong-CN *Stars*

The only well-determined orbit found for a visual binary included in Table 1 is that for HR 6980, G8 III CN +2 (ADS 11479) (Arend 1951). The system consists of two G8 III stars (0ʺ.4 binary) of nearly the same apparent magnitude ($\Delta m = 0.2$). Eggen (1965*b*) adopted a parallax of 0ʺ.010 for the system and assumed that each star had the same mass. He concluded that each star is about 1 $\mathfrak{M}_\odot$. However, Wilson (1967) derived an absolute magnitude of $+1.69 \pm 0.10$ from the width of the Ca II emission in HR 6980 and concluded that the mass of each star is approximately 0.7 $\mathfrak{M}_\odot$.

In addition, one should note that, if the strong-CN stars are similar to the red giants in M67 and NGC 188, their masses should be in the neighborhood of 1 $\mathfrak{M}_\odot$ (Iben 1967).

e) Elemental Abundances in the Strong-CN *Stars*

The following observations are relevant to the problem of the light-element abundances in the strong-CN stars. Bidelman and Ratcliffe (1955) found no evidence of an abnormally strong 0–0 band of C_2 at λ5165 in several strong-CN stars. There is little difference in the strength of the NH bands between strong-CN stars and normal stars (Schmitt 1969).

Using high dispersion spectrograms, Conti *et al* (1967) find the [O I] λ6300 line in α Ser to be weaker than expected. They find that an increase in the C/O ratio of 15 percent is sufficient to account for the weakness. Greene (1969), using model atmospheres and 2 and 6 Å mm^{-1} spectrograms, found a C/O ratio slightly higher than that for the Sun.

Also, Greene found nitrogen enhanced. Thus the strength of the cyanogen bands appears to be explained by a small increase in the C/O ratio and a nitrogen enhancement. However, Conti *et al.* and Greene use a mass of 2.5 $\mathfrak{M}_{\odot}$ for α Ser. The results of this investigation indicate a mass near 1 $\mathfrak{M}_{\odot}$.

Published heavy-element abundance determinations are listed in Table 4. Spinrad and Taylor (1967, 1969) interpret the strong metallic lines in the strong-CN stars as high abundances of the metals. They also find the red giants in NGC 188 and M67 to be strong-lined stars. Demarque (1968) has found that the calculated evolutionary locus for NGC 188 will fit the observed locus well if $Z = 0.06$–0.07 in his models.

However, Cayrel de Strobel (1968) has found normal abundances for ϕ Aur, a star which Spinrad and Taylor (1969) find overabundant in the metals. An examination of Table 4 indicates that more good determinations of abundance are needed to resolve the question of the heavy-element abundances in the strong-CN stars.

V. SUMMARY

Through the initial use of objective-prism spectrograms and a later use of slit spectrograms, a list of 146 strong-CN stars has been compiled. Spectral classifications have been given for all these stars.

Statistical parallaxes from proper motions were calculated for various groupings of the strong-CN stars. Table 2 lists the groups and the calculated mean parallax for each group. The resulting mean absolute magnitudes are somewhat fainter than those usually assumed for normal red giants.

The low absolute magnitudes of the strong-CN stars places them in the H-R diagram near the loci of old open clusters. Their spectroscopic features are also similar to the stars in the old open clusters. Evidence indicates that the strong-CN stars have masses near 1 $\mathfrak{M}_{\odot}$. More good determinations of abundance are needed for the strong-CN stars.

TABLE 4

DETERMINATIONS OF HEAVY-ELEMENT ABUNDANCES

Star name	Reference	Remarks
ϕ Aur......	Cayrel de Strobel (1968)	Normal abundances
	Spinrad and Taylor (1969)	[M/H] = +0.4
132 Tau	Wallerstein and Helfer (1966)	[Fe/H] Hyades = −0.11
	Helfer and Wallerstein (1968)	
μ Leo......	Peat and Pemberton (1968)	[Fe/H] = −0.1:
	Spinrad and Taylor (1969)	[M/H] = +0.6
λ Hya.....	Wallerstein and Helfer (1966)	
	Helfer and Wallerstein (1968)	[Fe/H] Hyades = +0.2
α Crt......	Wallerstein and Helfer (1966)	
	Helfer and Wallerstein (1968)	[Fe/H] Hyades = −0.12
α Ser......	Griffin (1969)	[Fe/H] = +0.2 (typical value)
	Spinrad and Taylor (1969)	[M/H] = +0.2
31 Aql.....	Pagel (1963)	[Fe/H] = 0:
	Spite (1966)	[Fe/H] = 0.24
	Greenstein (1966)	Small metal deficiency
72 Cyg.....	Wallerstein and Helfer (1966)	[Fe/H] Hyades = −0.14
	Helfer and Wallerstein (1968)	
	Spinrad and Taylor (1969)	[M/H] = +0.2
γ Cep......	Pagel (1963)	[Fe/H] = 0:
	Spite (1966)	[Fe/H] = 0.92
	Herbig and Wolff (1966)	[Fe/H] = 0.27
	Spinrad and Taylor (1969)	[M/H] = +0.1:

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