# SPECTRAL AND LUMINOSITY CLASSIFICATIONS AND MEASUREMENTS OF THE STRENGTH OF CYANOGEN ABSORPTION FOR LATE-TYPE STARS FROM OBJECTIVE-PRISM SPECTRA

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ABSTRACT

Objective-prism spectra of 684 stars of spectral type G8–K2 have been classified for luminosity and cyanogen absorption. The spectra have been obtained with the Curtis Schmidt telescope of the University of Michigan, using the combined 4° and 6° prisms. The luminosity estimate is based on the strength of the λ 4077 line of ionized strontium, while the cyanogen absorption is measured by the break in density at the cyanogen band head at λ 4216. Ten per cent of the giants are classified as "weak CN" stars Slit spectrograms have been obtained for 37 program stars (including 29 weak and slightly weak CN giants) with the 60-inch reflector of Mount Wilson Observatory. Absolute magnitudes were obtained from direct-intensity microphotometer tracings. Space velocities have been determined for over 200 stars, for which radial velocities are available. The frequency distribution of space velocities for the weak CN giants has a higher dispersion than the frequency distribution for giants with normal cyanogen absorption. The weak CN giants are also less concentrated toward the galactic plane than the giants with normal cyanogen absorption.

## I. INTRODUCTION

Late-type stars can be classified into four spectroscopic groups, each characterized by distinct dynamical properties, as shown by the frequency distributions of their space velocities (Roman 1952). Miss Roman's samples are sufficiently large for two of the groups—the "strong-line" and the "weak-line" stars—to define well-determined frequency distributions for space velocity and to determine relative space densities. The samples for the other two groups—the "4150" and the "weak CN" stars—consist of 25 and 12 members, respectively, and therefore only approximately define the properties of these two groups. The present investigation is concerned primarily with the weak CN group, members of which can be detected spectroscopically on objective-prism plates.

A number of methods for measuring the strength of the cyanogen absorption band have been developed, notably the photographic method developed by Lindblad and others (e.g., Ramberg 1941) and more recently the photoelectric methods of Strömgren and Gyldenkerne (1955), Crawford (1960), and Griffin and Redman (1960). In none of these methods, however, is it possible to distinguish between giants with weak cyanogen absorption and normal subgiants or dwarfs.

The Curtis Schmidt telescope of the University of Michigan, with combined 4° and 6° prisms, gives a dispersion of 110 A/mm at Hγ. With this dispersion it is possible to estimate luminosity classes visually from the strength of the λ 4077 line of ionized strontium relative to nearby iron lines, permitting statistical separation of giants and subgiants. Furthermore, the break at the λ 4216 band head of cyanogen is easily visible, and its strength is not greatly influenced by the blending of atomic lines, as is the case with the spectrophotometric cyanogen equivalent or the photoelectric CN measurements.

## II. OBSERVATIONS

Using the combined prisms with the Curtis Schmidt, spectra have been obtained for 87 standard stars classified on the Morgan-Keenan system, from spectral type G5 through K3, and luminosity class I*b* through V. The plates, II*a*-O emulsion, have been developed in a fine-grain developer suggested by Morgan (1937). Three variable factors influence classification of objective-prism spectra: seeing, which influences resolution; sky fog, which affects contrast; and image density, which also affects contrast. The standard star plates, which generally have short exposure times, are usually not heavily fogged. Appreciable systematic error in classification due to variable seeing or density is introduced only in the case of extremely poor plates. Comparison between the published spectral types and luminosity classes and those estimated from the Schmidt plates gives mean errors of one spectral subclass and one half-luminosity class, or, in terms of absolute magnitude, approximately 1 mag.

The measurement of cyanogen absorption consists of an estimate of the difference in density of the continuum on each side of the $\lambda$ 4216 band head and is recorded in five steps, from 0 for equal density to 4 for the strongest differences measured. The CN estimates for the standard stars are given in Table 1. The MK classifications for the stars with asterisks are from Johnson and Morgan (1953) or Morgan and Roman (1950). The remainder are from Keenan and Keller (1953), Roman (1952, 1955), and Halliday (1955). In addition to the MK standards, 16 stars are included for which the spectral types are from Wilson's radial-velocity catalogue (1953). The CN measurements usually depend on one plate, occasionally on two or more, with two or three exposures of varying density per plate.

Seventy-four stars listed in Table 1 have been classified by Griffin and Redman (1960). A linear relationship exists between their measurements and the Schmidt values, notwithstanding the fact that different quantities are measured in the two methods. No noticeable variation with spectral types is evident. The least-squares line of regression is

$$\text{CN (Schmidt)} = -17.81 + 8.95 \text{ CN (Cambridge)}\,,$$

with a mean error in the Schmidt measurements = $\pm 0.5$ step. This value agrees with estimates of the internal mean error based on duplicate plates and reclassifications of the same plates. Thirty-seven of the program stars listed in Table 2 have also been classified by Griffin and Redman. The agreement with the regression line for the standard stars is satisfactory in most cases.

Six of the Schmidt standard stars are included in Keenan's list of CN standard stars (1958*a*), in which the measurement of cyanogen absorption refers to deviation from normal absorption. On the basis of the six stars in common, the Schmidt CN steps 2, 3, and 4 correspond approximately to Keenan's CN $-1$, 0, and $+2$, respectively, for luminosity class III. Thirty-one of the Schmidt standard stars are included in Miss Roman's list (1952), four falling in her weak CN group. All four of these giants show weaker than normal cyanogen absorption on the Schmidt spectra, two being classified as CN 1 and two as CN 2, while most, but not all, of the other 26 stars show normal cyanogen absorption, CN 3.

The distinction between giants with normal and weak cyanogen absorption is arbitrary, but, on the basis of the above comparisons, G8–K2 stars of luminosity class III with CN steps 0, 1, and 2 would be considered weak CN stars. An alternate method of defining "weak CN" stars is based on the frequency distribution of cyanogen absorption for a random sample of luminosity III stars. For the program stars listed in Table 2, the maximum in the frequency distribution for G8–K2 stars with luminosities II–III through III–IV varies from $2\frac{1}{2}$ at G8 to 3 at K2. The distribution is relatively symmetrical for CN 2, 3, and 4, but about 10 per cent of the stars fall into an asymmetrical wing extending to CN 0. Thus, for this spectral and luminosity range, stars with CN 0 and 1 are classified as weak CN stars. In addition, stars with CN $1\frac{1}{2}$ have been included. These are stars for which more than one classification is available and the mean equals $1\frac{1}{2}$. The frequency distribution for luminosity class IV extends from a maximum at CN 0 through CN 2 with little decrease, then drops quickly at CN 3. The majority of luminosity class V stars have been classified as CN 0.

Figure 1 shows Schmidt spectra of several standard and program stars. The standard

TABLE 1

STANDARD STARS FOR SCHMIDT CLASSIFICATION

| HD | Sp | CN | HD | Sp | CN |
|---|---|---|---|---|---|
| 417 | K0 III | 1 | 175751 | K2 III | 4 |
| 2589 | K0 IV | 1 | 176678 | gK1 | 2 |
| 2774 | K2 III | 3 | 180262 | G5 II | 4 |
| 3712 | K0 II-III | 4 | 180809 | K0 II* | 3½ |
| 6186 | K0 III | 2 | 181655 | G8 V | 0 |
| 6582 | G5 VI* | 0 | 182572 | G8 IV | 0 |
| 12929 | K2 III* | 3 | 182762 | K0 III | 2 |
| 17506 | K3 Ib* | 3 | 184406 | K3 III | 3 |
| 20630 | G5 V* | 0 | 184467 | K1 V | 0 |
| 27022 | G5 III | 2 | 185958 | G8 II | 3½ |
| 77912 | G8 Ib-II | 3½ | 188056 | K3 III | 3 |
| 82885 | G8 IV-V* | 1 | 188326 | G8 IV | 1 |
| 101501 | G8 V* | 0 | 188512 | G8 IV* | 1 |
| 137759 | K2 III* | 3 | 188947 | K0 III | 3 |
| 140573 | K2 III* | 4 | 190360 | G6 IV | 1 |
| 141714 | G5 III-IV | 1 | 191026 | K0 IV | 1 |
| 143393 | K2 III | 4 | 194152 | gK0 | 4 |
| 144287 | G8 V | 0 | 195506 | K2 III | 2 |
| 144889 | K4 III | 2 | 196755 | G5 IV | 1 |
| 145148 | K0 IV | 1 | 197989 | K0 III* | 2 |
| 146084 | gK3 | 3 | 198149 | K0 IV* | 1 |
| 149161 | K4 III | 1 | 199191 | K0 III | 1 |
| 150275 | K1 III | 1 | 199580 | K1 IV | 1 |
| 151937 | K1 II-III | 2 | 199870 | gG7 | 2 |
| 152391 | G6 V | 0 | 200577 | gG8 | 3 |
| 152879 | K4 III | 2 | 203344 | K0 III-IV | 2 |
| 153344 | G5 IV | 0 | 203504 | K1 III* | 3 |
| 153472 | K3 III | 3 | 203886 | K0 III | 3 |
| 156283 | K3 II* | 3 | 205512 | K1 III | 3 |
| 157617 | gK1 | 4 | 206078 | G8 III | 1 |
| 157999 | K3 II | 4 | 206778 | K2 Ib* | 4 |
| 160315 | gG9 | 4 | 206859 | G5 Ib* | 4 |
| 160346 | dK3 | 0 | 207089 | K0 Ib | 4 |
| 160781 | gG7 | 4 | 207134 | K3 III | 2 |
| 161096 | K2 III* | 3 | 209747 | K4 III | 1 |
| 161198 | K0 V | 0 | 210745 | K1 Ib* | 4 |
| 163588 | K2 III | 2½ | 212943 | K0 III | 2 |
| 164922 | K0 V | 0 | 215549 | K1 III-IV | 1 |
| 165760 | G8 III-IV | 3 | 218101 | G8 IV | 1 |
| 166229 | K2 III | 2 | 218792 | gK3 | 2 |
| 166460 | gK2 | 3 | 219134 | K3 V* | 0 |
| 166620 | K2 V* | 0 | 219615 | G8 III | 2 |
| 166640 | gG7 | 2 | 219945 | gK0 | 2 |
| 167042 | K1 III | 1 | 219962 | K2 III | 2 |
| 167768 | G8 III | 3 | 220954 | K1 III | 3 |
| 168322 | K0 III | 2 | 221115 | G8 III | 3 |
| 168656 | G8 III | 2 | 221148 | K3 III | 3 |
| 168723 | K0 III-IV* | 2 | 221345 | G8 III | 2 |
| 174980 | gG8 | 4 | 222107 | G8 III-IV* | 1 |
| 175305 | G5 III | 1 | 222404 | K1 IV* | 2 |
| 175515 | gG9 | 3 | 223047 | G5 Ib | 4 |
| 175541 | dK0 | 0 | | | |

* Johnson and Morgan (1953) or Morgan and Roman (1950).

stars are indicated by the designation "MK" following the spectral types. The exposure times for the program stars are 30 minutes in all cases. The spectra of HD 3712 and HD 3681 have been increased to twice their original width by printing two strips side by side, in order to illustrate the spectral features more clearly. The intensity of the $\lambda$ 4077 line of ionized strontium relative to the $\lambda$ 4063 and $\lambda$ 4071 lines of neutral iron increases from dwarf to supergiant. The break in the continuum at the cyanogen band head at $\lambda$ 4216 does not increase uniformly but varies in strength within a given luminosity class. HD 209992 and HD 211153 appear to be more luminous than the standard II–III star HD 3712. The cyanogen absorption in HD 209992 appears normal, but in HD 211153 it is definitely weak. HD 205836, which is underexposed on the original plate, appears brighter than the standard III star HD 12929, yet shows weak cyanogen absorption. HD 208107 and HD 3681 appear to have normal cyanogen absorption for their luminosity, while HD 218935 has weak absorption.

Long exposures, using the combined prisms, have been obtained over a number of years with the Curtis Schmidt, primarily in four declination zones, $+23°$, $+27°$, $+53°$, and $+58°$. The plate centers are such that about 10 per cent of each 5° circular field overlaps the next field. Generally a 10-minute and a 30-minute exposure have been obtained for each center. Additional plates have been obtained for many of the centers; the result is that 42 per cent of the stars classified have been exposed on two or more plates. The quality of the spectra is relatively independent of exposure time. On nights of good seeing, the 30-minute plates have resolution essentially equal to that of the 10-minute plates, as is well illustrated in Figure 1, where the standard star exposures are very short. Comparison of the long- and short-exposure plates shows no systematic effect in classification due to exposure time or, more specifically, due to sky fog and resolution. The internal accuracy for spectral and luminosity classification is in agreement with that found for the standard stars.

Eight hundred and seventy-one stars brighter than photographic magnitude 9.5, primarily in the three declination zones, $+23°$, $+27°$, and $+58°$, have been classified within the spectral range G8–K2. The results for 684 are given in Table 2. The number of plates and the average quality of the classification are given in the fourth column. Quality "a" implies plates of good definition and well-exposed images, while quality "b" implies lower definition and/or faint images. The additional 187 stars have not been included because the images, although classifiable, are underexposed. Classifications from poor-quality plates have been excluded entirely. One hundred and forty-nine of the program stars in Table 2 have been classified on the MK system elsewhere, primarily at David Dunlap Observatory (Heard 1956). These stars have asterisks following their classifications. Comparison of the Schmidt and Dunlap spectral classifications gives a mean error of $\pm 0.9$ subclass for one Schmidt spectrum and a small systematic difference, the Schmidt spectra being one half-subclass earlier. Sixty per cent of the luminosity classifications agree, 35 per cent disagree by one half-luminosity class, and 5 per cent disagree by one or two luminosity classes. A few stars included in Table 2 have been classified outside the G8–K2 limit. In these cases, the mean of the Schmidt and the Dunlap classifications is within the limit.

Of the 684 stars included in Table 2, 31 have been classified from faint images but were included either because they have been classified as weak CN stars or because they have published radial velocities. These are designated quality "c." Of the 653 stars classified from well-exposed plates, 3 per cent are luminosity classes V and IV–V, 15 per cent are luminosity class IV, 83 per cent are luminosity classes III–IV, III, and II–III, and 6 per cent are luminosity classes II and I. Of the stars in luminosity classes II–III through III–IV, 10 per cent are classified as heaving weak cyanogen absorption (CN 0, 1, and $1\frac{1}{2}$).

### III. DISTRIBUTION PERPENDICULAR TO THE GALACTIC PLANE

If a correlation exists between cyanogen absorption and space velocity, it will be evident in the density distribution as a function of distance from the galactic plane for

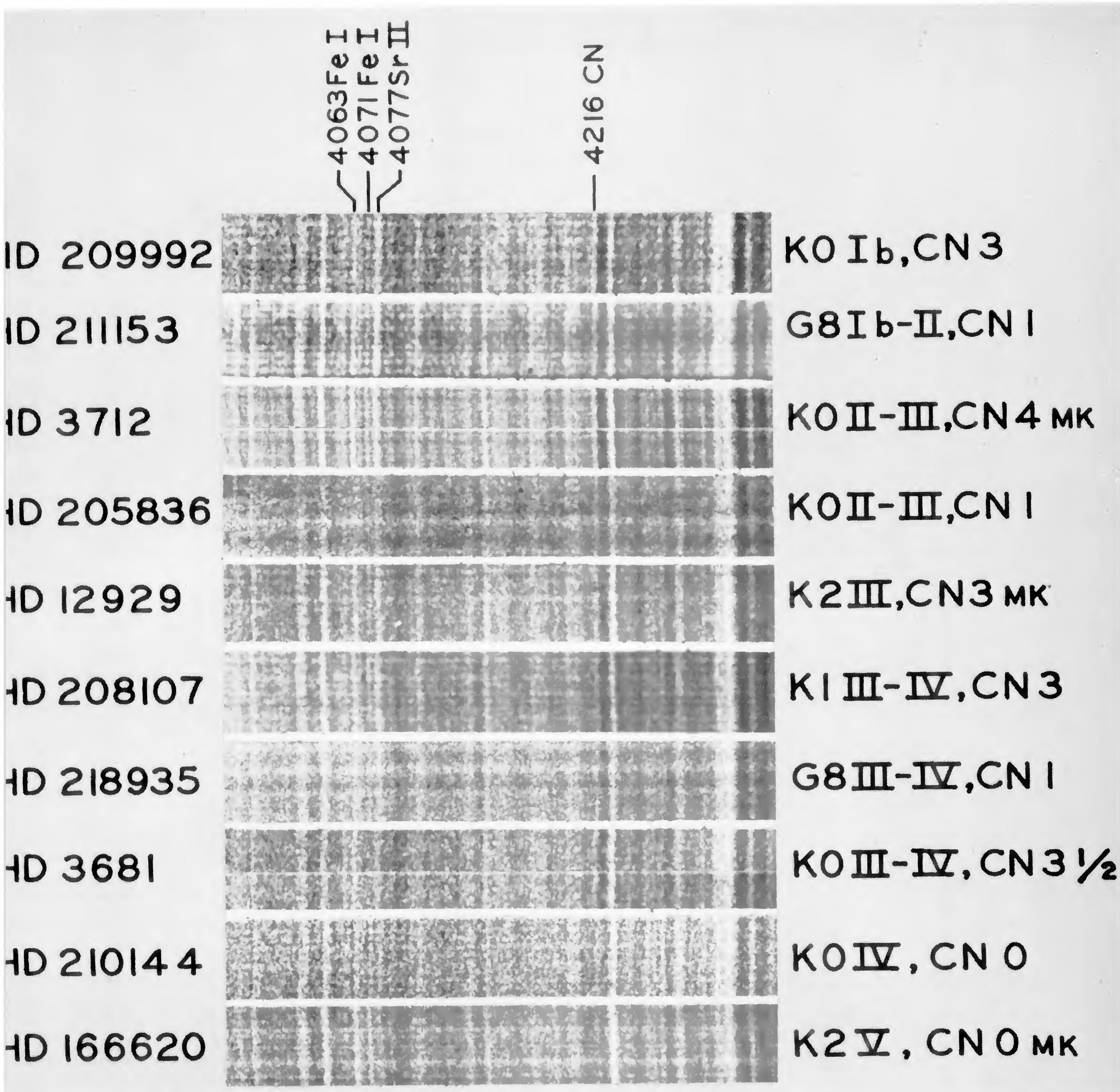


FIG. 1.—Schmidt objective-prism spectra of three standard stars, designated by MK after the spectral types, and seven pro-
am stars, showing luminosity criteria and cyanogen absorption.

TABLE 2

PROGRAM STARS

| HD or BD | Sp | CN | Number; Quality | S (km/sec) | HD or BD | Sp | CN | Number; Quality | S (km/sec) |
|---|---|---|---|---|---|---|---|---|---|
| 71 | K0 III | 4 | 1-a | 19 | 6634 | K0 III-IV | 1 | 1-a | |
| 112 | K1 III-IV | 3 | 2-a | | 6833 | K0 III* | 0 | 1-b | 249 |
| 417 | K0 II-III* | 2½ | 1-b | 98 | 6999 | K2 III | 3½ | 1-b | |
| 554 | G8 III | 4 | 1-c | | 7087 | K0 Ib* | 2½ | 1-b | |
| 638 | K2 III | 2 | 1-a | | +56°221 | K1 II-III | 3 | 1-a | |
| 663 | K1 III | 3 | 1-a | | 7318 | G8 III-IV* | 3 | 1-b | 12 |
| 697 | G8 III | 3 | 1-b | | +56°232 | K2 II-III | 3 | 1-a | |
| 756 | K0 III | 2½ | 3-b | | +56°234 | K2 III | 3½ | 2-a | |
| 1254 | K0 III-IV | 2½ | 3-b | | 7666 | K1 III-IV | 4 | 1-a | |
| 1449 | G9 III | 1 | 2-b | 51 | +22°205 | K1 III | 3½ | 1-b | |
| 1535 | G9 III | 2 | 1-b | | +56°242 | K1 III-IV | 2 | 1-b | |
| 1583 | K1 III | 4 | 2-b | | +55°300 | K1 II-III | 2½ | 2-b | |
| 2234 | G9 III-IV | 2½ | 2-b | | 8200 | G8 III-IV | 2½ | 1-b | |
| 2372 | K0 III | 3 | 1-b | | +57°277 | K0 IV-V | 0 | 2-b | |
| 2469 | G8 III-IV | 2 | 2-a | | +57°280 | G8 III-IV | 4 | 1-a | |
| 2824 | K2 III | 3 | 1-a | 30 | +56°279 | K1 Ib | 2 | 1-a | |
| 2925 | G8 III* | 1 | 3-b | 155 | 8997 | K2 V | 0 | 2-b | |
| 3250 | K0 II-III | 3 | 1-a | | 9033 | K2 III | 3 | 2-b | |
| 3253 | K2 III | 2 | 1-b | | 9109 | K0 III | 0 | 1-c | |
| 3293 | K2 III | 2½ | 2-b | | 9277 | K0 III-IV | 1 | 1-b | |
| 3323 | K1 III | 3 | 1-b | | 9493 | G8 II-III | 1½ | 3-b | 118 |
| 3409 | K1 III | 3 | 1-a | | 9900 | K1 Ia | 4 | 2-a | |
| 3411 | K2 III | 3½ | 3-b | 42 | 9939 | K0 IV | 1 | 1-b | 100 |
| 3468 | K1 III | 3½ | 1-b | | 10309 | G8 III-IV | 2 | 2-b | |
| 3651 | K2 V* | 0 | 1-b | | 10437 | K1 III | 2½ | 2-a | |
| 3681 | K0 III-IV | 3½ | 2-a | 19 | +57°375 | G8 IV | 1 | 1-c | |
| 3690 | K0 III-IV | 2½ | 1-b | 21 | +55°402 | K0 III-IV | 3 | 2-a | |
| 3757 | K0 III | 2½ | 2-b | | 10680 | G8 III-IV | 2½ | 2-a | |
| 3767 | K0 III-IV | 2 | 3-b | | +58°295 | G9 III-IV | 2 | 1-a | |
| 3828 | K1 III | 3 | 1-b | | +58°296 | K0 IV | 0 | 1-a | |
| 3943 | G9 III | 1 | 2-b | 52 | 10806 | G9 Ib | 3 | 4-b | |
| 4029 | G8 III-IV | 2 | 1-b | | 11043 | G8 III | 2 | 2-b | |
| 4105 | K0 III | 3½ | 2-b | | 11103 | K2 II | 3½ | 2-b | |
| 4407 | K0 III | 3 | 1-b | | 11363 | K0 III | 1½ | 2-b | 34 |
| 4688 | K0 III | 1 | 1-b | | 11383 | G9 III-IV | 4 | 2-b | |
| 4719 | K0 III | 2 | 2-b | | 11763 | K1 III | 3 | 3-b | 14 |
| +55°175 | K1 III | 2 | 1-a | | 12139 | K0 III-IV | 2½ | 2-a | 44 |
| 4831 | K0 III* | 1 | 2-b | 51 | 12202 | G8 III-IV | 3 | 1-a | |
| 4832 | K2 III | 3 | 3-b | | 12306 | G8 III | 2 | 2-a | |
| 4833 | G8 III | 2 | 2-b | | 12494 | G8 IV | 1 | 1-b | |
| 4934 | K0 III | 2 | 3-b | | 12772 | K0 III | 2 | 2-a | |
| 5197 | K0 III | 2 | 1-b | | 13056 | K1 IV | 0 | 1-a | |
| 5234 | K2 III* | 3 | 1-b | 34 | 13149 | K2 III | 4 | 2-b | 44 |
| +55°200 | G8 III-IV | 2 | 1-a | | 13437 | G9 II | 3½ | 2-b | |
| 5286 | K1 IV | 2 | 2-b | 7 | 13482 | K1 III-IV | 0 | 2-a | |
| 5361 | G9 III-IV | 1 | 1-b | | 13982 | K2 III | 3 | 4-b | 22 |
| 5395 | G8 III-IV* | 3 | 1-b | 57 | 13994 | G8 II-III | 3 | 4-b | 31 |
| 5396 | K2 III | 4 | 1-a | | 14039 | K1 V | 2 | 1-b | |
| 5430 | G8 IV | 2½ | 1-a | | 14346 | K0 II | 3 | 4-b | |
| 5516 | G8 III* | 2 | 1-b | 32 | 14571 | K1 III | 3 | 2-b | |
| 5556 | K2 III | 2½ | 1-b | | 14914 | K0 III-IV | 2 | 2-b | 48 |
| +58°146 | G8 III | 3 | 1-b | | 15449 | K2 III | 2 | 2-b | |
| 5747 | K0 III | 3 | 2-a | 19 | 15498 | K1 III | 3 | 2-b | 11 |
| 5981 | K1 III | 3½ | 2-a | | 15619 | G9 III | 2½ | 2-b | |
| 6009 | G9 III-IV | 0 | 2-b | 74 | 15665 | G8 Ib | 2½ | 1-b | |
| 6098 | K0 III-IV | 3½ | 1-a | | 15673 | K2 III | 2½ | 1-b | |
| 6238 | G8 II-III | 3 | 2-a | 39 | 15734 | K0 III | 2½ | 1-b | |
| +56°195 | G8 III | 3 | 1-a | | 15953 | K0 III | 1 | 1-b | |
| 6555 | K0 III-IV | 2 | 1-b | | 16039 | K1 III | 4 | 2-b | |
| +58°176 | G8 III-IV | 2 | 1-a | | 16293 | G8 III | 2 | 2-b | |

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TABLE 2 - continued

| HD or BD | Sp | CN | Number; Quality | S (km/sec) | HD or BD | Sp | CN | Number; Quality | S (km/sec) |
|---|---|---|---|---|---|---|---|---|---|
| 16448 | K2 III | 3½ | 2-b | 56 | 46316 | K2 III | 2½ | 2-a | |
| 16644 | G8 III-IV | 0 | 1-c | | 46607 | G8 III | 2½ | 2-a | |
| 16843 | G8 III-IV | 2 | 1-b | | 46702 | G8 III-IV | 2 | 1-a | |
| 17046 | G8 III-IV | 1 | 2-b | | 47254 | G9 III-IV | 2½ | 2-a | |
| 17190 | K2 IV* | 0 | 2-b | 126 | 47586 | G8 III-IV | 1 | 1-c | |
| 17309 | K0 III | 2 | 3-b | | 47587 | K2 III | 1 | 1-c | |
| 17346 | G9 II | 3½ | 4-a | | 47726 | K0 III | 2 | 2-a | |
| 17675 | G9 III | 1½ | 2-b | 58 | 48091 | K1 III | 3½ | 2-a | |
| 18560 | K1 III | 2½ | 1-a | | 48432 | K0 III-IV | 3 | 2-a | 18 |
| 18749 | K0 II | 2½ | 1-a | | 49116 | K0 III | 2 | 1-a | |
| 18991 | K0 IV | 2½ | 2-a | 15 | 49237 | K2 III | 3 | 1-a | |
| 19077 | K1 III | 3 | 1-a | | 49399 | K1 IV | 1 | 1-a | |
| 19089 | K0 II | 2½ | 1-a | | 58680 | G8 III | 4 | 1-b | |
| +58°569 | K2 III | 2 | 1-a | | 58944 | G8 III-IV | 3 | 1-b | |
| 20524 | K1 III-IV | 1 | 1-a | | 59506 | K0 III | 3 | 2-b | |
| 20762 | K0 II-III | 3½ | 1-a | | 59621 | K1 III-IV | 1½ | 2-b | |
| 20930 | K1 III | 2 | 1-a | 61 | 59642 | K1 III-IV | 2 | 2-b | |
| 22400 | K1 III-IV | 2 | 1-a | | 60252 | K0 III | 3 | 2-b | |
| 22844 | K0 III-IV | 0 | 1-b | | 60272 | G9 V | 0 | 2-b | |
| 22886 | K2 III | 3 | 1-b | | 60294 | K2 III | 3 | 2-b | 12 |
| 24154 | K0 II-III | 1 | 1-b | 61 | 60982 | K2 III | 3 | 2-b | |
| 25877 | G8 Ib-II* | 3 | 1-a | | 62564 | K0 III | 3 | 1-b | |
| 26755 | K2 III | 3½ | 1-a | 42 | +57°1104 | G8 II-III | 2 | 1-b | |
| 27029 | K1 III | 3 | 2-b | | 62808 | K0 III-IV | 3 | 2-b | |
| 27224 | K0 III | 3½ | 1-a | | 63628 | K1 III | 3 | 3-b | |
| 27371 | K0 III* | 3 | 6-a | 33 | 66660 | K1 III-IV | 3 | 2-b | |
| 27697 | K0 III* | 3 | 3-a | 33 | 67368 | K1 III | 3½ | 2-b | |
| 28085 | G8 II | 2½ | 1-b | | 68077 | G9 III | 3 | 2-b | 13 |
| 28100 | G9 II-III* | 2 | 5-a | 23 | 68193 | K2 II-III | 2 | 1-b | |
| 28307 | G9 III* | 2½ | 6-a | 35 | 68638 | G8 V | 0 | 2-b | |
| 29117 | K0 III | 2 | 1-b | | 68683 | G8 III-IV | 3 | 1-b | |
| 30166 | K0 III | 2 | 2-b | | +55°1275 | G8 III-IV | 3 | 1-b | |
| 31324 | K1 III | 2 | 2-b | 46 | 70918 | K0 III | 1½ | 2-b | |
| 31646 | G9 III-IV | 3 | 2-b | | +57°1141 | K0 V | 0 | 1-b | |
| 31757 | G9 III | 3 | 2-b | | 70985 | G8 III | 3 | 2-b | |
| 32547 | G8 III | 3 | 2-b | | 71111 | K0 III | 2½ | 1-b | |
| 33618 | K2 III | 3 | 2-b | 12 | 71224 | K1 III-IV | 3 | 2-b | |
| 34786 | K1 III | 3½ | 1-b | 21 | +56°1305 | K0 III | 3 | 1-b | |
| 34853 | K0 II-III | 3 | 1-b | | 71905 | G9 III-IV | 3½ | 2-b | |
| 36770 | G8 II-III | 3 | 1-b | | 72003 | K1 III-IV | 2½ | 2-b | |
| 36850 | K1 III | 2½ | 1-b | | 72604 | K1 III | 3 | 3-a | |
| 37007 | G9 III | 3 | 1-b | | 72742 | K0 II | 4 | 1-b | |
| 37601 | K0 III | 2 | 1-b | 49 | 73469 | G8 III-IV | 3 | 2-b | |
| 39628 | K2 IV | 3 | 1-b | | 73553 | G8 III | 3 | 1-b | |
| 40141 | K2 III | 2½ | 1-b | | 73598 | G8 III-IV | 3½ | 4-b | 28 |
| 40827 | K2 III | 3½ | 1-b | | 73665 | G9 III | 3½ | 4-b | |
| 40872 | K0 II-III | 4 | 1-b | | 74150 | K0 III-IV | 0 | 1-c | |
| 41589 | K0 III | 4 | 1-b | | 74379 | K0 III | 3 | 1-b | |
| 41597 | K0 III* | 3 | 1-b | 37 | 74442 | K1 III-IV* | 2½ | 3-a | 43 |
| 41783 | K0 III | 3 | 1-b | | 74908 | K0 III | 2½ | 1-b | |
| 42721 | G8 II-III | 3 | 1-b | | 75697 | K0 III-IV | 3 | 1-b | |
| 43352 | K1 III | 2½ | 2-a | | 76428 | G8 III-IV | 2 | 2-a | |
| 44061 | K1 III | 3 | 3-a | | 78249 | K1 III-IV* | 2½ | 2-a | 86 |
| 44123 | K1 III | 3 | 3-a | | 78865 | K1 III | 3 | 2-a | |
| 44647 | G9 III | 3 | 2-a | | 78937 | K1 III | 3 | 2-b | |
| 44648 | G8 III-IV | 1½ | 2-a | | 79675 | K1 III | 3½ | 4-a | |
| 44649 | G8 III-IV | 3 | 1-a | | 79702 | K1 IV | 2 | 1-b | |
| 45388 | K2 III | 4 | 1-a | | 80792 | K0 III-IV | 3 | 2-b | |
| 45410 | K0 III-IV | 2½ | 2-a | 123 | 81338 | K2 III | 4 | 1-b | |
| 45636 | K2 III | 4 | 1-a | | 83285 | K0 III | 3 | 2-b | |
| 45742 | K1 III-IV | 3 | 2-a | | 83491 | G8 III | 1½ | 2-b | |
| 45878 | G8 III | 1 | 1-c | | 83564 | K2 III-IV | 3 | 2-a | |

TABLE 2 - continued

| HD or BD | Sp | CN | Number; Quality | S (km/sec) |
|---|---|---|---|---|
| 83588 | K2 V | 0 | 1-b | |
| 84779 | K0 III | 4 | 2-b | |
| 85459 | G9 III-IV | 2 | 2-b | |
| 85472 | G8 IV | 1 | 3-a | |
| 85945 | G8 III | 2 | 1-b | 78 |
| 86217 | K2 III | 2 | 1-b | |
| 86335 | K1 III-IV | 3 | 2-b | 21 |
| 86661 | G8 IV | 0 | 2-b | 198 |
| 87045 | K1 III | 2½ | 1-b | |
| 87421 | K1 III | 2½ | 2-b | |
| +59°1290 | K0 III-IV | 1 | 1-c | |
| 88800 | K0 III-IV | 3 | 1-b | |
| 88999 | K2 III | 3 | 2-b | |
| 89523 | G8 IV | 0 | 1-c | |
| 89862 | K0 III-IV | 2 | 2-b | |
| 90222 | G8 III | 2 | 1-b | |
| 90715 | G8 III-IV | 2 | 1-b | |
| 90859 | K0 III-IV | 2 | 1-b | |
| 91810 | K2 III | 4 | 1-b | |
| 91971 | G9 III | 3 | 1-b | |
| 93859 | K2 III | 3 | 2-b | 33 |
| 94631 | K0 III-IV | 3 | 2-b | 26 |
| 94862 | G8 III | 2½ | 2-a | |
| 95001 | G9 III-IV | 2½ | 2-a | |
| 95098 | K2 II-III | 3 | 2-a | |
| 95690 | K2 V | 0 | 1-a | |
| 96688 | K0 III | 1½ | 2-b | |
| 96708 | G8 III | 3 | 2-b | |
| 96717 | K0 IV | 2 | 1-a | |
| 97934 | K0 IV | 2½ | 1-a | |
| 98214 | K0 III | 3 | 3-a | |
| 98316 | G8 III | 2 | 1-a | |
| 99283 | K0 III | 3 | 1-a | 41 |
| 99489 | K0 III | 2½ | 2-b | |
| 99807 | K0 III-IV | 2 | 1-b | |
| 100403 | K0 III | 3½ | 2-b | |
| 100615 | K0 III | 3 | 1-a | 38 |
| 101090 | K2 II-III | 4 | 1-b | |
| 102194 | K2 III | 2 | 2-b | |
| 102251 | K0 III | 3 | 1-b | |
| 102569 | K1 III | 2½ | 2-b | |
| 102956 | K0 III | 3 | 3-b | |
| 103605 | K1 III | 3½ | 1-b | 29 |
| 104239 | K1 IV | 1 | 1-b | |
| 105440 | K0 IV | 2 | 2-b | |
| 105719 | K0 IV | 1½ | 2-b | |
| 106102 | K2 III-IV | 3 | 2-b | |
| 106711 | K0 III-IV | 2 | 1-b | |
| 107325 | K2 III-IV | 2 | 4-b | 41 |
| 107468 | K0 III* | 4 | 2-b | 88 |
| 107469 | K0 IV | 1 | 3-b | 73 |
| 107854 | K1 II-III | 2½ | 3-b | 59 |
| 107949 | K2 III | 2 | 1-b | |
| 108123 | K1 III | 2½ | 4-b | 50 |
| 108381 | K2 III* | 3 | 5-b | 22 |
| 108466 | K1 III* | 3½ | 3-b | 44 |
| 108805 | G8 III* | 3 | 3-b | 57 |
| 108861 | G9 III | 3 | 1-b | 41 |
| 109011 | K1 V | 0 | 2-b | |
| 109012 | K2 III* | 2 | 3-b | 77 |
| 109508 | G8 IV | 1 | 1-c | |
| 109627 | K0 III-IV* | 3 | 3-b | 61 |
| 109654 | K0 III | 3 | 2-b | 47 |
| 109702 | K2 III | 3½ | 2-b | |
| 109894 | G9 III | 2 | 2-b | |
| 110463 | K2 V | 0 | 2-b | |
| 110762 | K2 III | 4 | 2-b | |
| 111093 | K1 III-IV | 4 | 1-b | |
| 111094 | K0 IV | 1 | 1-c | |
| 111850 | K0 III-IV | 3 | 2-b | |
| 112395 | G9 III | 1½ | 2-b | |
| 113253 | G9 III-IV | 2½ | 2-b | |
| 114107 | G8 III-IV | 1 | 1-b | |
| 114535 | K1 II-III | 3 | 2-b | |
| 114633 | G9 III | 3 | 2-b | |
| 115019 | K2 II | 2½ | 1-b | |
| 115442 | K0 III-IV | 2½ | 2-b | |
| 115720 | G9 IV | 2½ | 2-b | |
| 115749 | G8 III | 1 | 1-c | |
| 116956 | G9 IV-V | 0 | 2-b | |
| 117417 | K0 III | 2½ | 2-b | |
| 119332 | K0 IV-V | 0 | 2-b | |
| 119347 | K0 IV | 0 | 1-b | |
| 119549 | K1 III | 3 | 2-b | |
| 123338 | K0 III-IV | 3 | 2-b | |
| 123977 | K0 III-IV* | 2½ | 2-b | 94 |
| 124319 | G9 III | 2 | 2-b | |
| 125260 | K2 III | 4 | 2-b | |
| 125918 | G9 II | 3½ | 1-b | |
| 126186 | G8 IV | 1 | 1-b | |
| +57°1509 | K1 III | 2½ | 1-b | |
| 127760 | K2 III | 3½ | 1-b | |
| +55°1691 | K0 IV | 0 | 1-c | |
| 128386 | G9 III | 2 | 1-b | |
| 128781 | K1 III | 3 | 1-b | |
| 129267 | K0 III-IV | 1 | 1-b | |
| 129580 | G8 IV | 0 | 1-b | 69 |
| 129937 | K2 III | 2½ | 1-b | |
| 130499 | K2 III | 3 | 1-b | |
| 131219 | K0 III | 3½ | 2-b | |
| 148228 | G8 III | 2 | 1-b | 27 |
| 152153 | K0 IV | 3 | 1-b | 9 |
| +26°2979 | G8 III-IV | 1 | 1-c | 10 |
| 156774 | K2 III* | 4 | 1-a | 51 |
| 156775 | K1 III-IV* | 3 | 1-a | 41 |
| 156841 | K0 III-IV | 4 | 1-a | |
| 156874 | K0 III | 2½ | 1-b | 19 |
| +28°2720 | G8 II-III | 0 | 1-c | |
| 157150 | G8 III | 1 | 1-c | |
| 157294 | G9 III* | 2½ | 1-a | 110 |
| 158038 | K1 IV* | 3 | 1-a | 47 |
| 158331 | G8 IV-V | 0 | 1-a | |
| 158332 | K1 IV* | 0 | 1-a | 142 |
| 158416 | K2 III | 2 | 1-a | |
| +26°3026 | G8 IV | 0 | 1-c | 26 |
| 158507 | G8 II-III | 2 | 1-a | |
| 159027 | K2 III | 3 | 1-a | |
| 159479 | K2 III* | 3 | 1-a | 19 |
| 162113 | K0 III | 3 | 1-b | 69 |
| 162135 | G9 III | 0 | 1-c | |
| 166070 | K1 III* | 4 | 1-c | 37 |
| 166730 | G8 III* | 3 | 1-c | 58 |
| 166842 | K0 III-IV* | 4 | 1-a | 47 |
| 167132 | G8 IV* | 2 | 1-c | 44 |

TABLE 2 - continued

| HD or BD | Sp | CN | Number; Quality | S (km/sec) |
|---|---|---|---|---|
| 167275 | K0 II* | 4 | 1-a | 93 |
| 167304 | K1 III-IV | 3 | 1-a | 45 |
| 167472 | K1 III* | 4 | 1-a | 58 |
| 168293 | G8 III | 1 | 1-c | |
| 168622 | K0 III* | 3 | 1-c | 37 |
| 169573 | K0 III* | 3 | 1-c | 70 |
| 169797 | G8 III-IV* | 1 | 1-a | 25 |
| 170289 | K1 II | 1 | 1-c | |
| 170737 | G8 III-IV* | 0 | 1-b | 195 |
| 170738 | G8 III-IV* | 3 | 2-b | 92 |
| 171164 | K1 III* | 2 | 1-b | 63 |
| 171830 | G7 III* | 3½ | 2-b | 61 |
| 172132 | K1 III* | 3½ | 1-b | 38 |
| 173132 | G8 II | 2½ | 1-b | |
| 173367 | K0 II-III* | 2 | 1-b | 129 |
| 173435 | G9 III* | 2½ | 2-b | 26 |
| 173702 | G8 III-IV | 2 | 2-b | |
| 173780 | K2 III* | 3 | 1-b | 9 |
| +26°3350 | K2 III | 3 | 2-b | |
| +27°3110 | K0 III-IV | 2 | 1-b | |
| 173909 | K0 III* | 2 | 1-b | 75 |
| +27°3112 | K2 III | 2 | 2-b | |
| 174180 | K1 II-III | 4 | 1-b | |
| 174414 | K2 III* | 3 | 1-b | 36 |
| 174695 | K0 III* | 3½ | 1-b | 36 |
| 174733 | G9 III-IV | 4 | 1-b | |
| 174881 | K1 II-III | 3 | 1-b | 30 |
| 175204 | G8 III-IV* | 1 | 1-b | 42 |
| +26°3394 | G8 II-III* | 3 | 1-b | 45 |
| 175940 | K2 III* | 3 | 1-b | 59 |
| 176230 | K0 III* | 4 | 1-b | 54 |
| 176527 | K2 III* | 2½ | 1-b | 27 |
| +26°3430 | K0 III* | 4 | 1-b | 65 |
| +28°3155 | K1 III | 4 | 1-b | |
| +27°3217 | K0 III-IV | 0 | 1-c | |
| 178276 | K2 III-IV | 3½ | 1-a | |
| 178539 | K1 III | 4 | 1-a | 16 |
| +28°3210 | G8 II | 2 | 1-a | |
| +26°3472 | K0 II* | 2 | 1-a | 50 |
| +26°3485 | K0 Ib | 2 | 1-a | |
| 180006 | K0 II-III | 3 | 1-b | 32 |
| 180161 | G8 V | 0 | 1-b | |
| +28°3245 | K0 III-IV | 3½ | 1-a | |
| +28°3250 | G8 III | 2 | 1-a | |
| 180315 | K2 III | 3 | 1-a | |
| 180656 | K1 II | 3½ | 1-b | |
| +28°3262 | G8 II-III | 3½ | 1-a | |
| 181069 | K1 III | 4 | 1-a | |
| 182218 | K0 Ib-II* | 3 | 2-a | |
| 182617 | K1 III* | 3 | 1-b | 28 |
| 183399 | K1 III* | 3 | 1-b | 26 |
| +28°3339 | G8 IV | 0 | 1-c | |
| 183491 | K0 III | 4 | 1-b | 15 |
| 183753 | K2 II-III* | 1 | 1-b | 141 |
| 183754 | K2 II | 2 | 1-b | |
| +28°3367 | G8 IV | 1 | 1-c | 5 |
| 184010 | K0 III-IV | 2 | 1-b | 16 |
| +27°3426 | G8 III | 1 | 1-c | |
| 184538 | K2 III* | 3 | 1-b | 13 |
| 185241 | K1 III* | 3 | 1-b | 39 |
| 185289 | G7 III* | 2 | 1-b | 12 |
| 185982 | G8 III* | 2½ | 2-b | 55 |

| HD or BD | Sp | CN | Number; Quality | S (km/sec) |
|---|---|---|---|---|
| 186223 | K2 III* | 3 | 2-b | 47 |
| 186260 | G8 III* | 2½ | 1-b | 65 |
| 186378 | K2 II-III | 4 | 1-b | 68 |
| 186486 | K0 II* | 2½ | 1-b | |
| 186517 | K0 II-III* | 2 | 1-b | 71 |
| +27°3492 | G8 III | 1 | 1-c | |
| 186815 | K2 III | 4 | 2-b | 21 |
| +25°3944 | K0 II-III | 1 | 1-c | |
| 186930 | K0 II-III | 3 | 1-b | |
| 187162 | G8 II-III* | 1 | 1-b | 64 |
| 187193 | K0 II-III | 2½ | 1-b | 72 |
| 187280 | K1 III* | 2 | 1-c | 72 |
| 187614 | G8 III* | 2½ | 1-b | 7 |
| +26°3688 | K2 II-III | 4 | 1-b | ≥ 113 |
| 188258 | K1 III-IV* | 3 | 1-b | 29 |
| 188259 | K0 III-IV* | 3 | 1-b | 36 |
| 188566 | K1 III* | 3½ | 1-b | 50 |
| 189108 | K0 II-III* | 2 | 1-b | 52 |
| 189127 | G9 III | 3 | 3-a | 58 |
| 189251 | G8 II | 3 | 1-b | |
| 189475 | K2 II | 3 | 1-b | |
| 189533 | G9 III | 4 | 2-b | 20 |
| 189843 | G8 III-IV | 4 | 1-b | |
| 190913 | K0 III | 3 | 1-b | |
| 191009 | G9 III | 2 | 1-b | |
| 192491 | K0 III-IV | 3 | 1-b | |
| 192806 | K2 III* | 2½ | 1-b | 26 |
| 192892 | G9 II-III* | 2 | 1-b | 33 |
| 193031 | G8 III | 3 | 1-b | |
| +28°3682 | G8 IV | 0 | 1-c | |
| 193094 | K1 III | 3 | 1-b | 19 |
| 193221 | K2 III* | 4 | 1-b | 24 |
| 193287 | K0 III-IV | 4 | 1-b | |
| 193342 | K1 III | 2 | 1-b | |
| 194033 | K2 II-III | 3 | 1-b | 11 |
| 194071 | G8 II-III* | 2½ | 1-b | 30 |
| 194241 | K1 III-IV | 3½ | 4-a | |
| +28°3729 | K0 III* | 3 | 1-b | 89 |
| 194260 | G8 III-IV | 3 | 5-a | |
| 194403 | K2 III* | 3 | 1-b | 26 |
| 194450 | K1 III | 3 | 1-b | 39 |
| 194759 | K2 II-III | 3 | 1-b | |
| 195100 | G8 III* | 2 | 4-a | |
| 195176 | G8 III | 3 | 4-a | |
| +28°3761 | G8 III | 1 | 1-c | |
| 195273 | K0 II-III* | 3 | 1-c | 52 |
| +41°3775 | K0 II | 2 | 2-c | |
| +27°3773 | K0 IV | 2½ | 1-b | 36 |
| 195509 | G9 III* | 2½ | 1-b | 40 |
| 195647 | K0 III | 3 | 5-a | |
| 195712 | G8 II* | 2 | 1-b | 51 |
| 195790 | G8 III* | 2 | 1-b | 24 |
| 195835 | K0 II | 4 | 1-b | |
| 195987 | K0 IV* | 0 | 5-a | 70 |
| 196134 | K0 III-IV | 1½ | 5-a | 46 |
| 196360 | G8 III | 1½ | 5-a | |
| 197139 | K2 III | 2½ | 4-a | 63 |
| 198821 | K1 III* | 3 | 1-b | 13 |
| +25°4418 | G8 IV | 0 | 1-b | |
| 199375 | K1 III-IV* | 3 | 2-b | 19 |
| 199440 | G8 III* | 2½ | 1-b | 44 |
| 199512 | K1 IV | 2 | 1-b | |

TABLE 2 - continued

| HD or BD | Sp | CN | Number; Quality | S (km/sec) | HD or BD | Sp | CN | Number; Quality | S (km/sec) |
|---|---|---|---|---|---|---|---|---|---|
| 199693 | K2 III | 1 | 1-c | 59 | 208563 | K2 II-III | 2 | 1-a | |
| 199717 | G8 III-IV* | 2 | 1-b | 56 | 208667 | K1 III-IV | 3 | 3-a | |
| 200206 | K1 III | 3 | 1-b | 23 | 208700 | K1 III* | 4 | 2-b | 53 |
| 200491 | G8 III* | 2½ | 1-b | 27 | 208799 | K1 IV | 3 | 1-a | |
| 200578 | K0 II-III* | 3 | 2-b | 28 | 208839 | K1 III | 2 | 3-a | |
| 200679 | K0 Ib* | 3½ | 1-b | | 209180 | K1 III-IV | 2 | 1-b | |
| 200831 | K2 III | 4 | 1-a | 20 | 209181 | K0 III-IV | 1½ | 3-a | 48 |
| 200844 | K0 II | 2 | 2-a | | 209543 | G9 III-IV* | 2½ | 3-b | 58 |
| 201051 | K0 II-III | 2½ | 3-b | 29 | 209694 | K1 IV | 3 | 1-b | |
| +28°3995 | K0 III-IV | 1 | 1-c | | 209761 | K2 III | 3 | 3-b | 29 |
| 201626 | G9 p* | 0 | 2-b | ≥140 | 209992 | K0 Ib | 3 | 1-a | |
| +27°3988 | G8 II-III | 2 | 1-b | | 209994 | G6 III* | 1 | 2-b | 90 |
| 201669 | G8 III* | 2½ | 1-b | 73 | 210026 | K0 III* | 3½ | 2-b | 31 |
| 201890 | K1 III | 3 | 1-a | | 210144 | K0 IV | 0 | 1-a | 253 |
| 202089 | K2 III | 1 | 1-c | | 210211 | G8 III-IV | 1½ | 3-a | |
| 202365 | G9 II-III* | 3 | 1-b | 110 | 210373 | K1 IV | 2 | 3-a | |
| +27°4021 | G8 IV | 0 | 1-c | | +20°5090 | K0 III-IV | 4 | 1-a | |
| 202521 | K2 III* | 4 | 1-b | 71 | 210608 | K0 III* | 3½ | 2-c | 28 |
| 202573 | G8 II-III | 1 | 2-b | 162 | 210685 | K0 III* | 2 | 2-b | 37 |
| 202696 | K0 III-IV | 2½ | 1-b | | 210789 | K1 III-IV* | 1½ | 3-b | 70 |
| 202975 | G8 II-III | 2½ | 2-a | 59 | 210801 | K2 III | 3 | 3-a | |
| 203030 | G8 IV* | 0 | 1-b | 32 | 210925 | K1 III* | 1½ | 2-b | 131 |
| 203344 | K1 III* | 3 | 1-a | 126 | 211006 | K2 III | 3½ | 2-b | 30 |
| 203886 | K0 III-IV* | 2½ | 1-a | 16 | 211153 | G8 Ib-II | 1 | 2-a | |
| 204079 | K1 IV* | 0 | 1-b | 139 | +28°4330 | G8 III | 0 | 1-c | |
| 204415 | K0 III | 2 | 1-a | 28 | +22°4593 | K0 III | 3 | 1-b | |
| +26°4170 | K1 III-IV | 4 | 1-b | | +25°4696 | K2 III | 3 | 2-b | |
| 204539 | K2 III* | 4 | 2-b | 48 | 211407 | G8 III-IV* | 3 | 2-b | 78 |
| 204540 | K2 III* | 4 | 2-b | 17 | 211432 | G9 III | 3 | 2-b | 38 |
| 204642 | K1 III-IV* | 3 | 2-b | 97 | 211460 | G7 II-III* | 1½ | 2-b | 194 |
| 204711 | K1 II-III* | 3 | 1-b | 103 | 211555 | K1 III* | 3½ | 2-b | 44 |
| 204721 | K0 III | 2 | 1-b | | +23°4513 | G8 III | 1 | 1-b | 87 |
| 204878 | K0 II | 1 | 1-b | | 211984 | G8 II-III | 2 | 1-a | |
| 204892 | K0 III-IV | 2½ | 1-b | | 212005 | K0 III-IV | 2 | 1-b | |
| 204923 | K1 III* | 2½ | 1-b | 161 | 212136 | G8 III | 3 | 2-b | |
| 204934 | G8 III* | 2½ | 1-b | 15 | +21°4738 | G8 III-IV | 1 | 1-a | |
| 205011 | G8 Ib | 3½ | 1-a | | 212416 | K2 III-IV | 3½ | 2-a | |
| +26°4191 | G8 II-III | 1 | 1-c | 116 | 212596 | K2 III | 3 | 1-b | |
| 205316 | K0 II* | 1 | 1-b | 106 | 212750 | K0 III* | 3 | 1-a | 65 |
| 205540 | K0 III | 2 | 1-b | | 212833 | K2 III-IV | 3 | 2-a | |
| 205553 | G8 III | 3 | 1-a | | 213013 | K0 IV | 0 | 1-b | 20 |
| 205602 | K0 III | 3 | 2-a | 12 | 213025 | G8 III-IV* | 2½ | 1-a | 49 |
| 205760 | K1 III-IV* | 4 | 1-b | 17 | +20°5162 | G8 III | 1 | 1-a | |
| +29°4458 | G8 IV | 1 | 1-b | 26 | 213178 | K0 III* | 3 | 1-a | 19 |
| 205836 | K0 II-III | 1 | 1-b | 187 | 213179 | K2 II | 4 | 1-a | |
| 206027 | G9 III | 3 | 2-b | 29 | +24°4603 | K0 III | 3 | 1-a | |
| 206169 | K0 III | 3 | 1-b | | 213787 | G9 IV | 2 | 3-b | |
| 206536 | G8 III-IV | 3 | 2-b | | 213803 | G8 IV* | 2½ | 1-c | 36 |
| 206646 | K1 III | 2 | 1-a | 20 | 213930 | G8 III-IV | 3 | 2-b | 24 |
| 206842 | K1 III | 3 | 2-b | 25 | 213994 | G9 III-IV | 1 | 1-a | 24 |
| 206889 | K1 III* | 4 | 1-b | 93 | 214099 | K0 III-IV | 4 | 1-a | |
| 206990 | G9 III-IV | 3½ | 2-b | | 214265 | K0 II-III* | 3 | 1-a | 73 |
| 207086 | G9 III | 2½ | 2-b | | 214434 | K0 III-IV* | 3 | 1-a | 28 |
| 207089 | G8 II-III* | 4 | 1-a | | 214543 | G8 II-III | 1 | 1-c | |
| 207134 | K2 III* | 2½ | 4-a | 114 | 214757 | K0 II-III | 2 | 2-a | |
| 207244 | K0 III-IV | 1 | 1-c | | 215041 | K2 III-IV | 2½ | 2-a | |
| 207470 | G7 II-III* | 2 | 1-c | 44 | 215183 | G9 III | 1½ | 2-a | 65 |
| 207719 | K0 III | 3 | 1-a | | 215361 | K1 III-IV | 3 | 2-a | |
| 207740 | G8 IV* | 0 | 1-b | 32 | 215445 | G9 III-IV | 1½ | 2-a | 12 |
| 208107 | K1 III-IV | 3 | 1-a | | 215522 | K0 III-IV | 0 | 1-c | |
| 208201 | G8 II-III | 1½ | 2-b | | 215567 | K1 III | 3 | 1-b | |
| 208330 | K0 III | 1 | 1-c | | 215771 | K0 III-IV | 2½ | 1-a | |

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TABLE 2 - continued

| HD or BD | Sp | CN | Number; Quality | S (km/sec) | HD or BD | Sp | CN | Number; Quality | S (km/sec) |
|---|---|---|---|---|---|---|---|---|---|
| +25°4819 | K0 IIp | 0 | 1-b | | 221293 | G9 III | 3 | 1-a | 20 |
| 216046 | K2 II-III | 3 | 1-a | | 221354 | K1 V* | 0 | 2-a | |
| 216218 | G9 II | 3 | 2-a | | 221364 | G8 IV* | 1 | 1-b | 15 |
| +28°4474 | G8 III-IV | 1 | 1-b | | 221395 | K2 III | 3 | 2-b | |
| 216502 | K1 III-IV* | 3½ | 1-b | 35 | 221639 | K0 III-IV | 1½ | 2-a | 50 |
| 216586 | K1 III-IV* | 4 | 1-b | 60 | 221670 | G9 III | 2½ | 2-a | 24 |
| 216712 | G8 III-IV | 3 | 1-a | | 221786 | K1 III-IV | 2 | 2-b | |
| 216723 | G7 II-III* | 2 | 1-b | 40 | 222067 | G9 III-IV | 3½ | 1-b | |
| 216730 | G8 III | 2 | 2-b | | 222078 | K0 III-IV | 2 | 1-b | |
| +58°2522 | G8 IV | 1 | 1-a | | 222218 | K0 III | 2 | 2-a | 44 |
| 217673 | K0 II-III* | 3½ | 3-a | | 222366 | K0 IV | 0 | 2-b | |
| 217711 | K1 III | 2 | 2-b | 12 | 222390 | K0 II-III* | 4 | 1-b | 49 |
| 217797 | K0 III | 2 | 1-a | | 222618 | G8 III | 3 | 2-a | 16 |
| +57°2673 | K2 V | 0 | 1-a | | 222797 | G9 III | 1½ | 3-b | 16 |
| 217850 | G8 V | 0 | 1-a | | 222842 | K0 II-III* | 3 | 1-b | 26 |
| 217944 | G8 IV | 1 | 4-a | 22 | 222886 | G9 III-IV | 2 | 1-a | |
| 218187 | G8 III | 3½ | 3-a | 26 | 223019 | G8 III-IV* | 3 | 1-c | 78 |
| 218356 | K1 Ib-II* | 3 | 3-b | | 223094 | K2 III | 0 | 1-c | 34 |
| 218468 | K0 III | 3 | 2-b | 14 | 223165 | K2 II-III* | 3 | 1-b | 42 |
| 218660 | K1 III* | 3 | 1-b | 33 | 223211 | K2 III-IV* | 3 | 3-b | 39 |
| 218803 | G8 III-IV | 2½ | 4-a | | +58°2659 | K1 III | 3 | 1-a | |
| +59°2660 | K0 III | 1 | 2-b | | 223792 | G9 III | 2½ | 2-b | 37 |
| 218935 | G8 III-IV | 1 | 1-b | 119 | 223847 | K0 III | 3 | 1-a | 62 |
| 219110 | G8 III | 2 | 1-b | 54 | 224116 | K2 III | 2 | 3-a | |
| 219310 | K2 III | 4 | 2-a | 58 | +56°3112 | K0 III-IV | 3 | 1-b | |
| 219446 | G9 III | 1 | 2-b | | 224355 | G8 Ib | 3 | 1-a | |
| 219800 | G8 III-IV* | 2 | 2-b | 62 | 224784 | G9 III-IV | 2½ | 3-a | 65 |
| 220265 | K1 III | 2½ | 2-b | | 224907 | K2 III-IV | 2½ | 2-a | |
| 220539 | K0 III | 2½ | 2-b | | 224940 | G9 III | 3 | 3-a | |
| 220583 | G8 III | 1 | 1-b | | +59°2815 | G9 II-III | 1 | 1-a | |
| 220952 | K1 IV | 1 | 2-b | 49 | 224981 | K2 II | 4 | 1-a | |
| 221039 | K0 III-IV | 2 | 2-b | | 225170 | G8 IV | 2 | 1-a | |
| 221113 | K1 III-IV | 2½ | 2-b | 58 | 225261 | G9 V | 0 | 2-a | |
| 221204 | K0 III-IV | 2 | 2-b | | 225274 | G9 III | 3 | 1-a | |

* Also classified elsewhere on MK system.

the weak CN stars relative to normal CN stars. The "z" components of distance have been computed for the program stars listed in Table 2 with luminosities II–III through III–IV. The luminosity classes have been converted to visual absolute magnitudes with Roman's calibration (1952). Whenever MK classifications from elsewhere are available, as indicated by asterisks in Table 2, the absolute magnitude depends on the mean of the two luminosity classifications. The *Henry Draper* visual magnitudes have been used when available, with no correction for interstellar extinction. For the BD stars, the magnitudes listed in the proper-motion catalogues have been used. The largest source of error in the resulting "z" distances is the absolute magnitude. Virtually all the program stars are within 300 pc of the galactic plane. For 65 per cent of the stars, the galactic latitude is less than 30°. Thus the error in "z" is less than 50 pc in most cases.

The sampling is not uniformly distributed in galactic latitude, and the depth of the survey is relatively small. Nevertheless, the frequency distributions in "z" for the stars with both normal and weak cyanogen absorption can be approximated by normal distribution curves. The dispersions of the normal curves are 121 and 162 pc for 462 normal CN stars and 84 weak CN stars, respectively. The stars with normal cyanogen absorption actually deviate significantly from their normal distribution curve, but in that an excess of stars are concentrated within 20 pc of the galactic plane. The comparison clearly shows a lower concentration toward the galactic plane for the stars with weak cyanogen absorption.

## IV. SPACE VELOCITIES

Space velocities have been computed for 256 stars with luminosity classes II–III through IV for which radial velocities are available. One hundred and twenty radial velocities are from David Dunlap Observatory (Heard 1956), 113 are from Wilson's catalogue (1953), and an additional 25 are from spectrograms obtained by the author, using the Mount Wilson 60-inch reflector and x-spectrograph. Proper motions for 239 of the stars have been take from the Yale proper-motion catalogues (Barney 1953; Barney, Hoffleit, and Jones 1959), while the remainder are from the *General Catalogue* (Boss 1937). The proper motions from the *General Catalogue* and from the +57° Yale zone have been converted to the FK3 system, using Kopff's corrections (1939). The proper motions for the remaining Yale zones are already on the FK3 system. The resulting space velocities, which have been corrected for solar motion of 15.5 km/sec toward R.A. = 265°, Dec. = +21° (Vyssotsky and Janssen 1951), are listed in the last column of Table 2.

In Table 2, the velocity of HD 201626 is based on its radial velocity alone. This is a CH star (Keenan 1958*b*), with no available absolute magnitude. The velocity of +26°3688 is based on proper motion alone and is included in Table 2 only because it is also listed in Table 4.

The frequency distributions for the space velocities are shown in Figure 2. The stars of luminosity class II–III through III–IV have been divided into three groups, normal and strong CN, slightly weak CN, and weak CN, and are shown in Figure 2, *a*, *b*, and *c*, respectively. Figure 2, *d*, shows the distribution for stars of luminosity class IV with weak cyanogen absorption. Seven stars of luminosity class IV with stronger cyanogen absorption are included in Figure 2, *a* and *b*, shown as crosshatched areas. Figure 2, *e*, will be discussed in Section VI.

The accuracy of individual space velocities is limited by the largest source of accidental error—the absolute magnitude, which is accurate to about 1 mag. and which gives for typical giants an uncertainty of about 20 km/sec, as compared with about 5 km/sec for the uncertainty caused by the error in proper motion. The random errors increase the dispersions of the frequency distributions. Nevertheless, it is evident, even with the low precision of the individual velocities, that the dispersions of the frequency distributions increase with decreasing cyanogen strength.

The frequency distribution for the stars of normal cyanogen strength (Fig. 2, *a*) is similar to the frequency distribution for Miss Roman's strong-line and weak-line stars combined (1952). On the other hand, the space velocities of the subgiants (Fig. 2, *d*) generally are less than those of the subgiants compiled by Eggen (1960).

### V. 60-INCH ABSOLUTE MAGNITUDES

The precision in absolute magnitude has been increased for 37 program stars by means of slit spectrograms obtained with the Mount Wilson 60-inch reflector and x-spectrograph, using both the 4″ and 8″ cameras, with dispersions of approximately 80 and 40 A/mm. This group consists of 29 weak and slightly weak CN giants and subgiants, 6 normal CN giants and subgiants, and 2 weak CN supergiants (one of which is spectral type K3 and thus not listed in Table 2).

In order to establish a calibration-curve for absolute magnitude, spectra were also obtained for 42 standard stars from spectral type G0–K4. All the plates are baked II*a*-O emulsion, standardized with the wedge spectrograph located in the 60-inch dome. The exposure times of the calibration plates are generally about one-third as long as the

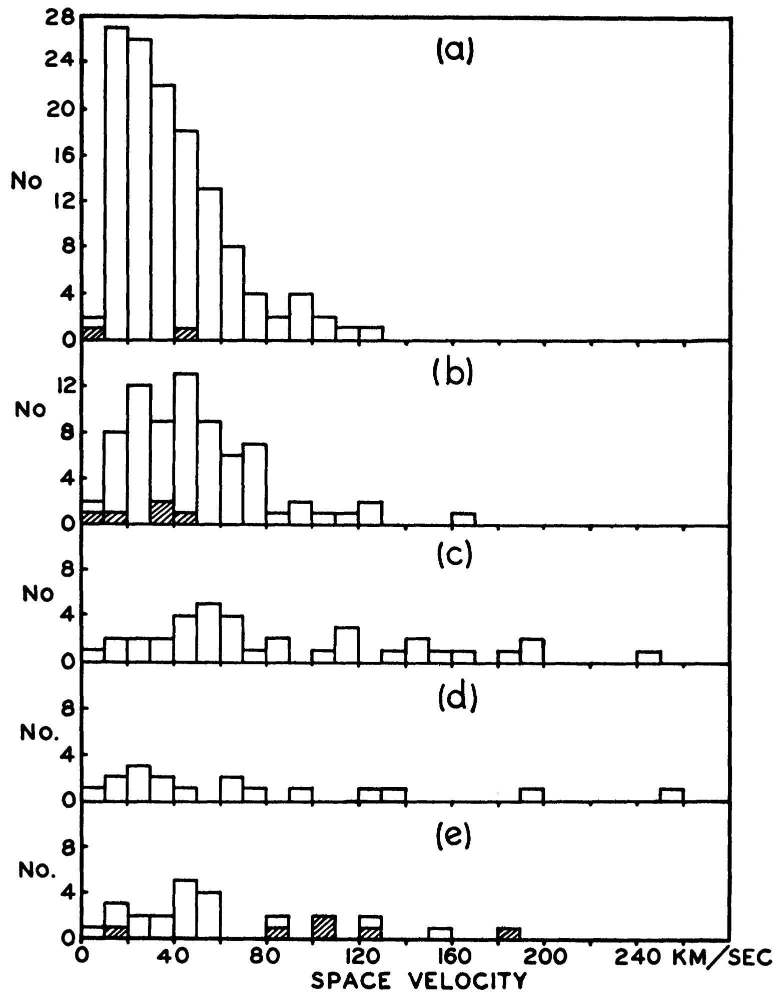


FIG. 2.—Frequency distributions for space velocities of G8–K2: *a*, strong and normal CN giants (CN 3, 4); *b*, slightly weak CN giants (CN 2, $2\frac{1}{2}$); *c*, weak CN giants (CN 0, 1, $1\frac{1}{2}$); *d*, subgiants with weak CN (CN 0, 1); and *e*, weak CN giants, based on improved absolute magnitudes. The crosshatched areas in sections *a* and *b* show stars of luminosity class IV; the crosshatched areas in section *e* show stars from Griffin and Redman's list (1960).

exposure times of the stellar plates, to compensate partially for the intermittency effect due to the multiple trailing of the stellar images along the spectrograph slit. Several calibration plates of varying exposure times were exposed at regular intervals throughout each night. Development times of both calibration plates and stellar spectrograms were $5\frac{1}{2}$ minutes at 66° F in D-19.

The 60-inch standard stars are from the lists of Wilson and Bappu (1957), Oke (1957), and Keenan and Keller (1953). A number of these stars have high space velocities and/or weak cyanogen absorption. The method of Wilson and Bappu is apparently relatively insensitive to abundance differences and has a high internal accuracy. Oke's method depends on line ratios and thus also is relatively insensitive to abundance differences, while Keenan and Keller were concerned specifically with luminosity criteria suitable for high-velocity stars. Other spectroscopic parallaxes are available but generally depend on visual estimates of line strengths or line ratios or are expressed in terms of MK luminosity classes instead of absolute magnitudes. Reliable trigonometric parallaxes are available for the majority of the stars used for calibration, except for the supergiants (Jenkins 1952). For absolute magnitudes fainter than $-1$, each value used for the calibration-curve is the mean of the absolute magnitudes available from the above four sources. For stars brighter than $-1$, the values of Wilson and Bappu are used. The internal accuracy of the absolute magnitudes of both Wilson and Bappu and Oke is $\pm 0.3$ mag (m.e.). The resulting mean absolute magnitudes for the standard stars generally are accurate to $\pm 0.3$ mag. also. The G5–K3 stars are listed in Table 3. The sources for the spectral and luminosity classifications are the same as for the standard stars in Table 1, and the asterisks in Table 3 have the same meaning as in Table 1. For stars in common with Table 1, the Schmidt CN strengths have been repeated in column 3 of Table 3. For an additional seven stars in Table 3, "cyanogen equivalents" have previously been measured (unpublished). The results have been discussed elsewhere (Yoss 1958). These cyanogen equivalents have been included in column 3 of Table 3 and are shown in parentheses. They have been converted to the CN step scale of the present investigation. The seventh and eighth columns of Table 3 give the mean absolute magnitude and the sources of the absolute magnitudes making up the mean.

Microphotometer tracings on a scale of direct intensity were made of all 60-inch spectrograms at the California Institute of Technology. In most cases only one plate per star is available. Therefore, the analyzing slit was set relatively wide—20 and 30 $\mu$ for the 4″ and 8″ plates, respectively—reducing plate grain effect but, at the same time, reducing resolution. Line-intensity ratios involving lines which are luminosity-sensitive have been measured relative to a fiducial continuum. The ratios are relatively insensitive to the exact location of the continuum or zero intensity and also to the calibration-curve used to produce the direct-intensity tracing. Ratios used by Keenan and Keller (1953) and Oke (1957) were measured on the 60-inch tracings. Of these, several have steep calibration-curves, others have relatively large scatter, and two ratios in particular are strongly correlated with cyanogen absorption and therefore cannot be used. These last two ratios, $\lambda$ 4161/$\lambda$ 4149 and $\lambda$ 4196/$\lambda$ 4198, both fall within the cyanogen absorption band. The line ratios found to produce good calibration-curves for the 8″ plates are $\lambda$ 4077/$\lambda$ 4063, $\lambda$ 4077/$\lambda$ 4071, $\lambda$ 4129/$\lambda$ 4127, $\lambda$ 4152/$\lambda$ 4154, and $\lambda$ 4215/$\lambda$ 4250. The line ratios producing useful calibration-curves for the 4″ plates are $\lambda$ 4077/$\lambda$ 4063, $\lambda$ 4077/$\lambda$ 4071, and $\lambda$ 4215/$\lambda$ 4250. These individual ratios have been combined to form mean line ratios for each dispersion. The mean line ratios for the 4″ dispersion are systematically less than those for the 8″ dispersion by 0.07. After this correction has been applied to the 4″ ratios, they have been combined with the 8″ line ratios to form a single calibration-curve relating line ratio and absolute magnitude. The mean line ratios are shown in the sixth column of Table 3, where, in the case of the 4″ plates, the ratios have been corrected to the 8″ system; the number of plates is given in parentheses. The calibration-curve for the G5–K3 stars is shown in Figure 3. The slope changes slightly over

TABLE 3

60-INCH STANDARD STARS FOR SPECTRAL TYPES G5 THROUGH K3

| HD | Sp | Schmidt CN | 60-in. CN | 60-in. △ CN | Mean Line Ratio | $\overline{M}_v$ | Ref ** |
|---|---|---|---|---|---|---|---|
| 3546 | G8 III | (1) | +0.08 | -0.09 | 1.08 (1) | +1.7 | a,d |
| 3627 | K3 III | | .21 | +0.01 | 1.07 (1) | +0.3 | c,d |
| 3651 | K0 V* | (1) | .08 | +0.02 | 0.73 (1) | +5.2 | b,d |
| 4128 | K0 III | | .18 | -0.01 | 1.10 (1) | +0.8 | b,c,d |
| 6582 | G5 Vp* | 0 | .03 | -0.02 | 0.54 (1) | +5.6 | a,b,d |
| 9270 | G8 III* | (3) | .22 | +0.01 | 1.23 (1) | -0.2 | c |
| 27371 | K0 III* | (3½) | .21 | +0.02 | 1.13 (2) | +0.6 | b,c,d |
| 124897 | K2 IIIp* | (2) | .18 | -0.02 | 1.09 (2) | +0.5 | c,d |
| 135204 | G8 V | | .06 | 0.00 | 0.69 (1) | +5.2 | a,b,d |
| 144579 | dG8 | | .03 | +0.01 | 0.56 (3) | +6.3 | b,d |
| 148897 | G8 II | | .09 | -0.11 | 1.12 (2) | +0.2 | c |
| 150275 | K1 III | 1 | .09 | -0.07 | 0.96 (2) | +2.2 | c,d |
| 153210 | K2 III | | .21 | +0.02 | 1.06 (1) | +0.5 | c,d |
| 161797 | G5 IV* | (1) | .07 | -0.04 | 0.88 (2) | +3.7 | d |
| 163770 | K1 II | (4) | .25 | +0.01 | 1.16 (2) | -2.5 | c |
| 167042 | K1 III | 1 | .11 | -0.02 | 0.91 (1) | +3.2 | c,d |
| 168723 | K0 III-IV* | 2 | .13 | -0.03 | 0.95 (2) | +2.0 | b,d |
| 180809 | K0 II | 3½ | .25 | +0.01 | 1.13 (1) | -2.4 | c |
| 182572 | G8 IV | 0 | .08 | -0.03 | 0.86 (1) | +3.9 | a,b,d |
| 184406 | K3 III | 3 | .23 | +0.08 | 0.95 (2) | +2.3 | c,d |
| 185351 | K0 III | | .13 | -0.03 | 1.01 (1) | +1.9 | c,d |
| 186791 | K3 II* | | .20 | -0.04 | 1.07 (2) | -2.1 | c |
| 188512 | G8 IV* | 1 | .07 | -0.05 | 0.86 (2) | +3.5 | b,d |
| 197989 | K0 III* | 2 | .15 | -0.03 | 1.15 (1) | +1.2 | b,c,d |
| 198149 | K0 III-IV | 1 | .12 | -0.02 | 0.88 (2) | +2.8 | a,b,c,d |
| 206778 | K2 Ib* | 4 | .15 | -0.11 | 1.09 (1) | -4.6 | c |
| 206859 | G5 Ib* | 4 | .22 | -0.04 | 1.43 (1) | -4.0 | c |
| 212943 | K0 III | 2 | .11 | -0.04 | 0.93 (3) | +2.3 | c,d |
| 216228 | K1 III | | .19 | +0.01 | 1.13 (1) | +1.2 | b,d |
| 219134 | K3 V* | 0 | .01 | 0.00 | 0.72 (2) | +6.5 | b,c,d |
| 219615 | G7 III | 2 | .07 | -0.12 | 1.12 (1) | +0.8 | a,d |
| 222107 | G8 III-IV* | 1 | .07 | -0.09 | 0.95 (2) | +2.1 | b,c,d |
| 222404 | K1 IV* | 2 | +0.17 | +0.02 | 0.94 (2) | +2.4 | b,c,d |

* Johnson and Morgan (1953) or Morgan and Roman (1950).
** a) Keenan and Keller (1953), b) Oke (1957), c) Wilson and Bappu (1957), d) Jenkins (1952).

the spectral range, but the change is less than the scatter of the points and therefore cannot be clearly defined. The weak CN stars are shown as open circles. No systematic dependence of the line ratios on cyanogen absorption is apparent on the basis of these relatively few data. If only trigonometric absolute magnitudes are used, individual points change, but the mean curve changes insignificantly. The solid line represents a weighted mean least-squares solution for the stars between absolute magnitudes $-1$ and $+5.5$. The mean error of a single determination of absolute magnitude from one plate has been determined by intercomparison of pairs of plates, as well as by the least-squares solution, assuming the mean error of the absolute magnitudes to be $\pm 0.3$ mag. Both approaches give consistent results, the mean error being about $\pm 0.5$ mag. for one 60-inch plate. For stars brighter than $-1$, the scatter is large and the slope steep, and thus the calibration-curve cannot be used. The line ratio used by Oke (1957) for the

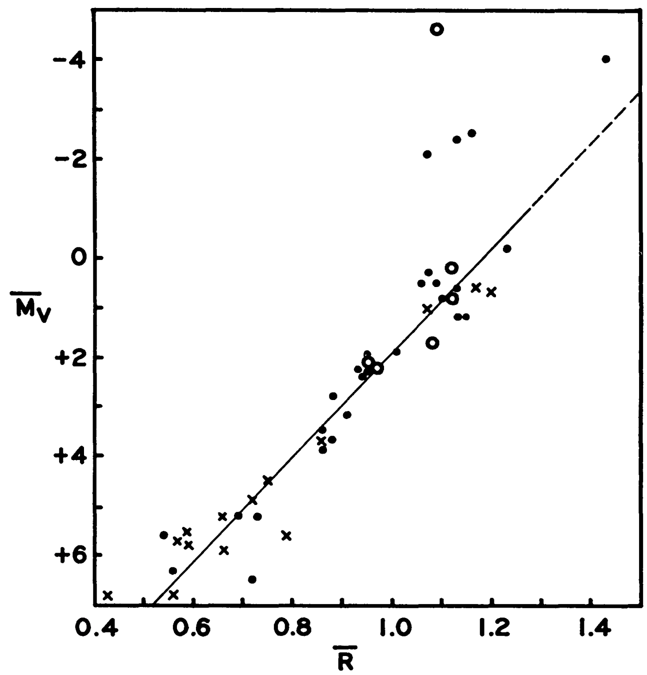


FIG 3 —Calibration-curve, relating mean absolute magnitude and mean line ratio for the 60-inch standard stars The open circles represent stars with weak cyanogen absorption. The crosses represent Oke line ratios (1960), converted to the 60-inch system

bright giants and supergiants, $\lambda$ 4233/$\lambda$ 4236, produces a well-defined calibration-curve for the stars brighter than $-1$.

For fifteen standard stars which have also been measured by Oke (1957), the 60-inch and Oke line ratios show a linear relationship. The Oke line ratios of stars not included in the present investigation have been transformed to the 60-inch system and are shown as crosses in Figure 3. These points have not been used in the least-squares solution but do show good agreement with the curve.

The "CN discontinuity" has been formed by measuring the ratio of the continuum difference on each side of the $\lambda$ 4216 band head of cyanogen divided by the strength of the continuum on the red side of the band head. The CN discontinuity is given in column 4 of Table 3. The least-squares solution for the linear relationship between the Schmidt CN measurements and the CN discontinuity of the 60-inch plates is

$$\text{CN (Schmidt)} = -0.1 + 15.1 \text{ CN (60-inch)},$$

with a scatter consistent with the accuracy of the Schmidt data.

A calibration-curve relating CN discontinuity and absolute magnitude has been formed for the 60-inch standard stars with normal cyanogen absorption. Following the procedure of Keenan (1958*b*) and Griffin and Redman (1960), the "CN discrepancy," ΔCN, is defined as the difference between the measured CN discontinuity and the value obtained from the calibration-curve for a given absolute magnitude. The resulting CN discrepancies are given in column 5 of Table 3.

On the Schmidt scale, the weak CN stars are defined as those stars with cyanogen absorption weaker than normal by one or more steps. On the 60-inch scale, the weak CN stars thus are defined as those stars with CN discrepancies equal to, or greater negatively, than −0.07. The weak CN stars shown in Figure 3 have been defined in this manner.

A calibration-curve relating spectral type and line ratios has been formed with the mean of the following line ratios: λ 4227/λ 4102, λ 4254/λ 4260, and λ 4325/λ 4340. For the dwarfs and giants, the internal mean error for a single plate is one subclass. The supergiants define a calibration-curve that deviates two subclasses toward later spectral types from that of the dwarfs and giants.

Five of the standard stars also are radial-velocity standards (*Trans. I.A.U.* 1955). Seven spectrograms were obtained of all five standards with the 8″ camera, while four spectrograms were obtained for three of the standards with the 4″ camera. Using the effective wave lengths of Wright (1952), a number of suitable absorption lines were found that give consistent measurements of radial velocity relative to the published values for the standards. The mean errors for a single plate are ±5 and ±10 km/sec for the 8″ and 4″ cameras, respectively. The 8″ radial velocities also require a systematic correction of −7 km/sec. The mean error for the 4″ plates is consistent with that found by Woolley (1959), while the 8″ mean and systematic errors are consistent with those found by Abt (1960).

Spectral types, CN discontinuities, CN discrepancies, radial velocities, and absolute magnitudes have been measured for the 37 60-inch program stars. The results are given in Table 4, where the spectral and luminosity types and CN strengths from Table 2 are also repeated. The radial velocities, reduced to the sun, are given except in the cases when they have been published previously or when the plate is not suitable for measurement. The number of 60-inch plates is indicated in parentheses after the visual absolute magnitude.

The calibration-curve for the absolute magnitudes depends on line ratios measured on tracings of relatively short exposures of bright standard stars. The fact that exposure times are considerably longer for the program stars may possibly introduce a systematic error when the calibration-curve is used for determining absolute magnitudes for the fainter program stars. The measurement most subject to systematic error in the photometry is the CN discontinuity, where any error in slope of the assumed characteristic curve directly affects the measurement. For the standard stars, the relationship between the CN strengths of the Schmidt and 60-inch plates, shown in columns 3 and 4 of Table 3, is approximately linear, with the expected scatter corresponding to the accidental mean errors of the measurements. The scatter is much larger for the program stars, given in columns 3 and 5 of Table 4, and the mean relationship has shifted an amount corresponding to one CN step on the Schmidt scale; the 60-inch measurements are stronger relative to the standard star relationship. The systematic difference is not correlated with luminosity class. No systematic difference is evident between the CN strengths of the Schmidt spectra on the 10- and 30-minute plates or between the stars which have been classified on both program plates and standard star plates of short exposure. Most of the systematic difference therefore probably is in the 60-inch photometry. Line ratios, on the other hand, are relatively insensitive to variations in the slope of the assumed characteristic curve, and when various curves are used to convert the microphotometer signal to direct intensity, the measured line ratios for a given plate show no significant

TABLE 4

60-INCH PROGRAM STARS

| HD or BD | Schmidt Sp | Schmidt CN | 60-in. Sp | 60-in. CN | 60-in. △ CN | 60-in. RV (km/sec) | 60-in. $M_v$ | 60-in. S (km/sec) |
|---|---|---|---|---|---|---|---|---|
| 2925 | G8 III | 1 | G7 | +0.12 | -0.05 | | +1.5 (1) | 126 |
| 3943 | G9 III | 1 | G4 | +0.14 | -0.05 | -40 | +0.8 (1) | 49 |
| 6009 | G8 III-IV | 0 | G6 | +0.05 | -0.06 | +40 | +3.7 (1) | 40 |
| 9493 | G8 II-III | 1½ | G7 | +0.19 | +0.01 | -13 | +1.4 (1) | 46 |
| 9939 | K0 IV | 1 | K2 | +0.09 | -0.02 | -55 | +3.7 (1) | 95 |
| 11363 | K0 III | 1½ | K1 | +0.18 | +0.01 | -17 | +1.5 (1) | 30 |
| 17190 | K2 IV | 0 | K2 | -0.02 | -0.08 | | +5.1 (1) | 38 |
| 17675 | G9 III | 1½ | G8 | +0.12 | -0.06 | -46 | +1.3 (1) | 56 |
| +26°2979 | G8 III-IV | 1 | G7 | +0.12 | -0.04 | -12 | +2.1 (1) | 8 |
| 158038 | K1 IV | 3 | K1 | +0.28 | +0.11 | | +1.7 (1) | 68 |
| 158332 | K0 IV | 0 | G9 | +0.12 | +0.04 | | +4.5 (2) | 66 |
| +26°3026 | G8 IV | 0 | G7 | +0.11 | 0.00 | -37 | +3.9 (1) | 25 |
| 170737 | G8 III-IV | 0 | G6 | +0.05 | -0.08 | | +3.1 (2) | 152 |
| +28°3367 | G8 IV | 1 | G8 | +0.19 | 0.00 | -16 | +0.5 (1) | 8 |
| +26°3688 | K2 II-III | 4 | K0 | +0.35 | +0.17 | | +1.4 (1) | ≥ 37 |
| +27°3773 | K0 IV | 2½ | K2 | +0.23 | +0.05 | +11 | +1.1 (1) | 97 |
| 200831 | K2 III | 4 | K1 | +0.27 | +0.07 | -09 | +0.5 (1) | 22 |
| 202573 | G8 II-III | 1 | G4 | +0.10 | -0.07 | -24 | +1.7 (1) | 57 |
| 203030 | G8 IV | 0 | G8 | +0.03 | -0.02 | | +5.4 (1) | 18 |
| 204079 | K1 IV | 0 | K2 | 0.00 | -0.05 | -36 | +5.4 (1) | 54 |
| +26°4191 | G8 II-III | 1 | G5 | +0.14 | -0.07 | -03 | -0.2 (1) | 84 |
| 205602 | K0 III | 3 | G8 | +0.24 | +0.06 | -17 | +1.4 (1) | 9 |
| +29°4458 | G8 IV | 1 | G6 | +0.11 | -0.03 | -01 | +2.9 (1) | 30 |
| 205836 | K0 II-III | 1 | K1 | +0.13 | -0.03 | -02 | +2.2 (1) | 52 |
| 206114 | K3 Ib | 1 | K2 | +0.15 | -0.07 | -10 | -1.2 (1)* | |
| 209181 | K0 III-IV | 1½ | K1 | +0.21 | +0.04 | +13 | +1.5 (1) | 46 |
| 211153 | G8 Ib-II | 1 | G5 | +0.10 | -0.11 | +12 | -0.2 (1)** | |
| 211460 | G7 II-III | 1½ | G7 | +0.06 | -0.09 | | +2.3 (1) | 51 |
| +23°4513 | G8 III | 1 | G9 | +0.13 | -0.03 | -08 | +1.9 (1) | 41 |
| 213994 | G9 III-IV | 1 | G7 | +0.10 | -0.09 | +16 | +0.6 (1) | 24 |
| 215183 | G9 III | 1½ | G9 | +0.16 | -0.01 | +12 | +1.8 (1) | 42 |
| 215445 | G9 III-IV | 1½ | G8 | +0.18 | 0.00 | -18 | +1.2 (2) | 12 |
| 219800 | G8 III-IV | 2 | K1 | +0.19 | +0.02 | | +1.5 (1) | 53 |
| 220952 | K1 IV | 1 | K2 | +0.14 | -0.02 | -18 | +2.2 (1) | 69 |
| 221364 | G8 IV | 1 | K0 | +0.20 | +0.02 | | +1.3 (1) | 15 |
| 222797 | G9 III | 1½ | G7 | +0.10 | -0.09 | -05 | +0.8 (2) | 11 |
| 223094 | K2 III | 0 | G9 | +0.13 | -0.04 | +26 | +1.6 (1) | 33 |

* $M_v$ is based on the 4233/4236 line ratio.

** The 4233/4236 line ratio gives $M_v$ = +3.5.

variation over the range in slope between the calibration-curves of long and short exposures. The mean difference between the 60-inch and Schmidt spectral types for the program stars is 0.8 subclass. If a corresponding error were present in the line ratios for absolute magnitude, the maximum error would be 0.3 mag.

## VI. 60-INCH SPACE VELOCITIES

Space velocities for the weak CN stars listed in Table 4 have been recomputed, using the absolute magnitudes derived from the 60-inch spectrograms, and are shown in the last column of Table 4. The resulting frequency distribution is shown in Figure 2, *e*. Six stars from Griffin and Redman's list with CN anomalies greater negatively than $-0.10$ are also included in Figure 2, *e*. The absolute magnitudes of five of these stars are accurate to within 0.5 mag. The stars and their space velocities in km/sec are HD 3546, 102; HD 37160, 101; HD 81192, 130; HD 188119, 14; and HD 215549, 90. Although the absolute magnitude of the sixth star, HD 199191, is not accurately known, the star has been included on the basis of its high radial velocity, 185 km/sec. These six stars are shown as crosshatched areas in Figure 2, *e*.

Figure 2, *e*, does not include all known weak CN stars with available space velocities, but the stars in the diagram have been selected from random samples on the basis of their cyanogen strengths alone. The frequency distribution for these 27 weak CN stars includes a large percentage of high-velocity stars; 32 per cent have space velocities greater than 80 km/sec, as compared with 4 per cent for the stars of normal cyanogen absorption.

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