BOLETÍN DE LOS OBSERVATORIOS DE TONANTZINTLA Y TACUBAYA, VOL. 4, N°27, 1965.

AN INVESTIGATION OF LATE TYPE STARS

Eugenio E. Mendoza V. and Harold L. Johnson***

SUMARIO

Hemos hecho observaciones fotométricas y espectroscópicas de algunas estrellas listadas en el Catálogo de Estrellas Brillantes. La fotometría fue obtenida en el sistema U, B, V, R, I, J, K, L, M, N. Los espectros se tomaron en dos dispersiones, 128 Å/mm y 8.7 Å/mm, en el azul.

Estas estrellas se escogieron por tener paralajes trigonométricas grandes y ser de tipo espectral tardío (K y M en el sistema de Mount Wilson).

Los datos espectroscópicos y fotométricos combinados indican que las estrellas bajo estudio son gigantes amarillas y rojas. La mayoría de ellas posiblemente sean un poco menos luminosas y así pertenezcan a la frontera inferior de la clase de luminosidad III (en el sistema de Yerkes).

En ningún caso se confirmaron las características de estrellas subgigantes, derivadas de las paralajes trigonométricas.

ABSTRACT

We have made U, B, V, R, I, J, K, L, M, and N photometric observations for a group of stars contained in The Bright Star Catalogue. We also have made spectroscopic observations, in the blue region, for most of the stars. We have used 128 Å/mm and 8.7 Å/mm dispersions.

We have chosen this group of stars because of their large trigonometric parallax and late spectral type (K and M on the Mt. Wilson system).

The combined spectroscopic and photometric data indicate that the stars under study are yellow and red giants. Perhaps, the majority of them are lower border-line giants.

Our data do not confirm the subgiant characteristics derived from the measured trigonometric parallaxes.

I. Introduction

During the course of our multicolor photometric observations of red objects, we have noticed that there are some late type stars, contained in The Bright Star Catalogue, which have rather large measured trigonometric parallaxes. We have obtained spectra in the blue region, at The Kitt Peak National Observatory, and photometry covering the spectrum from 0.3 to 10 microns at The Lunar and Planetary Laboratory, University of Arizona and The Observatorio Astronomico Nacional, University of Mexico, for this group of stars.

II. The Observations

Spectra of nine late-type stars, suspected of subgiant characteristics, were taken with the grating spectrograph attached to the 36-inch telescope of the Kitt Peak National Observatory. The dispersion is 128 Å/mm. Spectral types and luminosity classes were assigned to the stars according to the criteria of the Yerkes revised atlas system (MK-type) outlined by Morgan (see Johnson and Morgan, 1953). Spectra of four of these stars were also taken at the Coudè spectrograph of the 84-inch telescope of the Kitt Peak National Observatory. The dispersion is 8.7 Å/mm. All the plates were obtained in May 1965. Unbaked IIa-0 plates were used.

The multicolor photometric data were obtained with the apparatus described elsewhere (see, for example, Mendoza and Johnson, 1965), attached to the 40-inch telescope of the Observatorio Astronomico Nacional, University of Mexico, and the 28-inch telescope of The Lunar and Planetary Laboratory, University of Arizona.

The results of the photometric and spectroscopic observations are given in Tables 1 and 2. The columns of Table 1 contain, first, the numbers (BS) in the Yale University Catalogue of Bright Stars (1964); second, the constellation names; third, the spectral type, as published (Wilson, 1952); fourth, the type on the MK-system; and fifth through fourteenth, the multicolor photometric data. The columns of Table 2 give, first, the BS numbers; second, the intensity of the bright reversals in H and K. These estimates of the emission intensity were made on Wilson and Bappu's (1957) system. Fourth, the measured H and K line widths, in kilometers per second.

* Visiting Astronomer, 1965 at The Kitt Peak National Observatory, U. S. A. and The Lunar and Planetary Laboratory, U. S. A.

** Lunar and Planetary Laboratory, University of Arizona.

TABLE 1

The photometric and the spectroscopic data

BS	Name	Spectral Type Mt. W.	Spectral Type MK	V	U–V	B–V	V–R	V–I	V–J	V–K	V–L	V–M	V–N
1355	ε Ret	Sg K5	–	4.44	2.16	1.06	0.83	1.37	1.87	2.47	—	—	—
4671	ε Mus	Sg M6	–	4.16	—	1.55	—	—	—	—	—	—	—
4949	40 Com	Sg M5	M5 III	5.62	3.22	1.58	2.03	3.85	4.73	5.86	6.19	5.91	—
5192	2 Cen	Sg M6	M4 III	4.20	2.92	1.49	2.14	4.01	4.52	5.79	5.96	5.64	5.45
5603	σ Lib	Sg M4	M4 III	3.26	3.63	1.69	1.59	2.82	3.54	4.72	4.79	4.47	—
5824	42 Lib	Sg K4	K4 III	4.95	2.84	1.32	0.94	1.62	2.08	2.84	2.97	2.74	—
5924	—	Sg M0	K4 III	5.45	3.54	1.58	1.25	2.22	2.94	3.93	4.13	3.81	—
5932	2 Her	Sg M3	M3 III	5.37	3.62	1.63	1.49	2.76	3.56	4.61	4.84	4.40	—
7120	ν^2 Sgr	Sg K5	K3 III	4.98	2.84	1.33	0.93	1.60	2.18	2.90	3.07	2.91	—
7317	—	Sg K4	K3 III	6.08	3.00	1.44	1.13	1.96	2.65	3.58	3.65	3.38	—
7429	μ Aql	Sg K4	K3 III	4.44	2.41	1.18	0.86	1.45	2.00	2.73	2.82	2.44	—
8061	—	Sg K6	G3 IV*	5.67	1.69	0.60	—	—	—	—	—	—	—
9089	30 Psc	Sg M3	M3 III**	4.41	3.47	1.63	1.56	2.97	3.77	4.85	5.03	4.87	4.67

* Cousin and Stoy, 1963.

** Keenan, private communication.

TABLE 2

High Dispersion Spectroscopic Data

BS	Int.	W(Km/sec)
5192	2	91
5603	3	76
5932	3	82
7429	2	70

III. The observed spectral energy distributions

The observed spectral energy distribution for several stars selected from Table 1 have been plotted in Figures 1 and 2. Figure 1 shows the spectral energy distributions relative to that of an M0 III

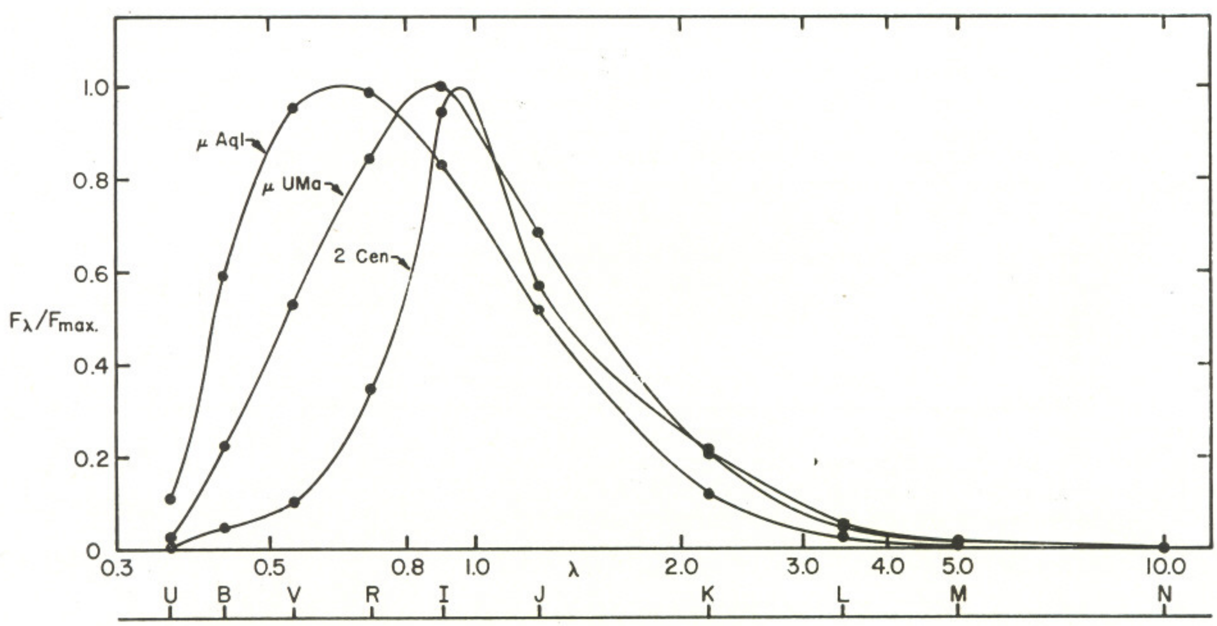

Fig. 2.—*The spectral energy curves for stars selected from Table 1 and μ U Ma (M0 III).*

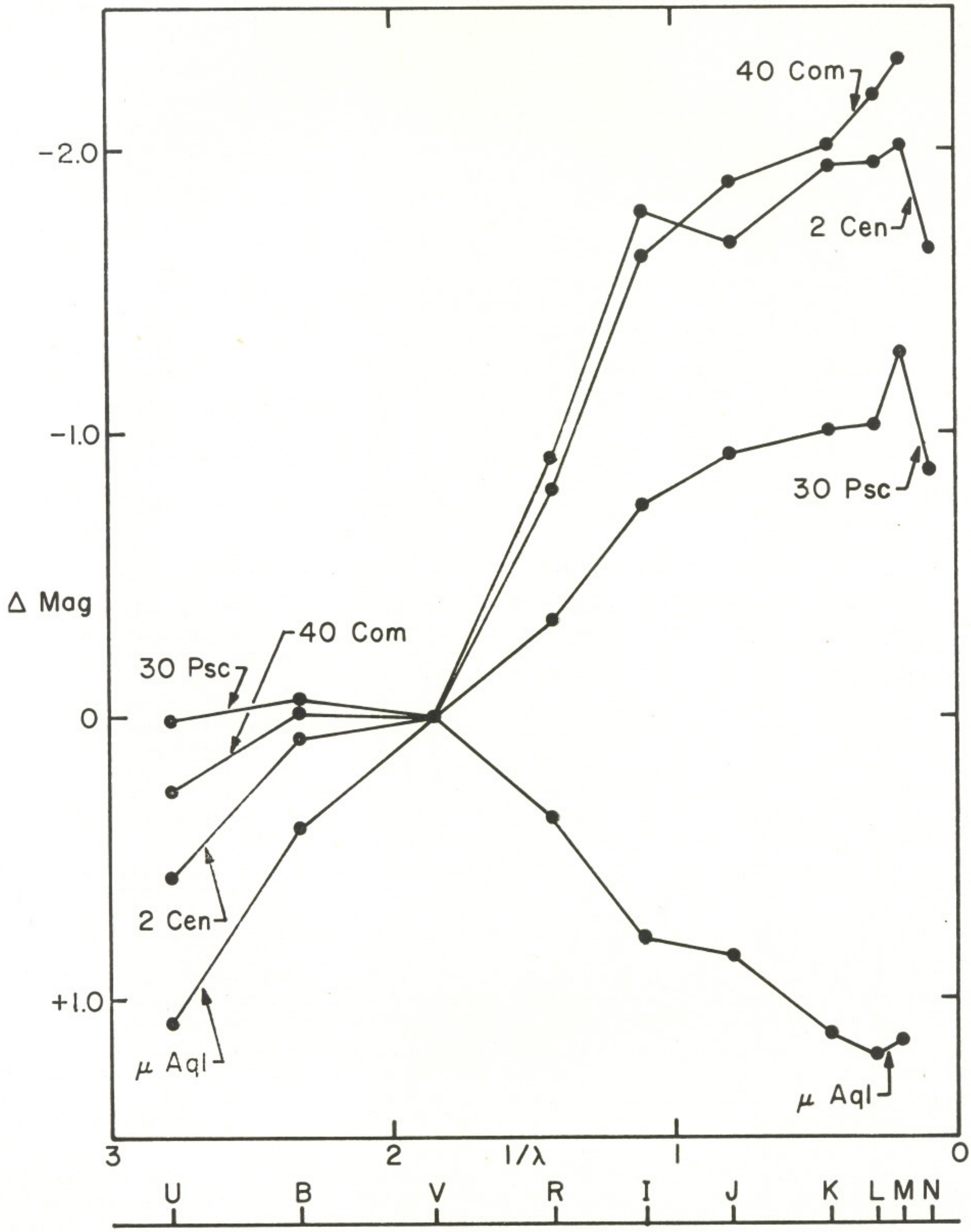

Fig. 1.—*The spectral energy curves for stars selected from Table 1. These data are relative to that for an M0 III star.*

stars (Johnson, 1964, Table 3). Figure 2 shows the spectral energy curves computed with the aid of the absolute calibration derived by Johnson (1965) and have been normalized to unity at the maxima. The curve for μ U Ma (data from Johnson, 1964, Table 2), M0 III, is shown for comparison. We notice, from both figures, the similarities among the stars, taking into account the different effective temperatures.

TABLE 3

Derived data

BS	*π (")*	*Absolute Visual Magnitude, M_v* *Trig.*	*Ca II*	*MK*	*B. C.*	*T_e (°K)*
1355	0.058	+2.8	—	—	−0.40	4530
4671	0.038	+2.1	—	—	—	—
4949	0.042	+3.7	—	−0.5:	−2.88	2830
5192	0.025	+1.2	−1.1	−0.5:	−2.79	3075
5603	0.056	+2.0	+0.4	−0.5:	−1.80	3230
5824	0.042	+3.1	—	−0.3	−0.54	4310
5924	0.023	+2.3	—	−0.3	−1.22	3500
5932	0.031	+2.8	−0.2	−0.5	−1.76	3200
7120	0.034	+2.6	—	−0.3	−0.58	4140
7317	0.033	+3.7	—	−0.2	−0.99	3670
7429	0.038	+2.3	+1.2	−0.2	−0.46	4240
8061	0.040	+3.7	—	+3.1	—	—
9089	0.007	−1.4	—	−0.2	−1.94	3110

IV. The bolometric corrections and effective temperatures

We have computed the bolometric corrections, BC, for the stars in Table 1, following the procedure outlined by Johnson (1964). This procedure consists primarily of a simple numerical integration under the spectral energy distribution, after conversion to absolute units. The results of this integration are then compared with the corresponding value for the sun.

We have also computed the effective temperatures, Te, by the procedure of Johnson (1964). This procedure, which uses a color index, (R + I) − (J + K), centered around the wavelength of one micron, was derived from the total fluxes, as computed above, and the measured angular diameters of ten stars. The effective temperature calibration depends for the cooler stars, primarily upon K and M giants. Such stars have effective temperatures in the range around 3000 °K, and the peak radiation of a black body of this temperature falls in the neighborhood of one micron. Therefore, this techniques should give us good effective temperatures for the stars in Table 1.

These bolometric corrections and effective temperatures are listed in the last two columns of Table 3.

V. The absolute bolometric magnitude-effective temperature diagram

Since the trigonometric parallaxes of all the stars in Table 1 have been measured (Jenkins, 1952 and 1963), we were able to compute the absolute visual magnitudes, M_v. This quantity also can be obtained for the stars in Table 2 with the aid of the calibration by Wilson and Bappu (1957).

The derived data are given in Table 3. The columns of this Table contain, first, the BS numbers; second, the trigonometric parallax (Jenkins 1952, 1963); third, fourth and fifth, the computed absolute magnitudes from the trigonometric parallaxes, from the widths of the bright reversals in H and K, and the MK types (see Keenan, 1963), respectively; sixth, the bolometric corrections; and seventh, the effective temperatures.

The absolute bolometric magnitude-effective temperature for the stars in Table 3 is shown in Figure 3. The lines represent, the zero-age main sequence (ZAMS) from Johnson (1964) and the Luminosity Class III (giant) sequence, computed from the bolometric corrections and effective temperatures of Johnson (1964, Table 3) and the absolute visual magnitudes of Keenan (1963). We notice from this figure that the data from the trigonometric parallaxes (filled circles) lie mostly below the giant sequence, in agreement with the Mt. Wilson types. The data from the Ca II emission lines (open circles with a central dot) lie closer to the giant sequence. The data from the MK types (crosses) lie quite near to the giant sequence.

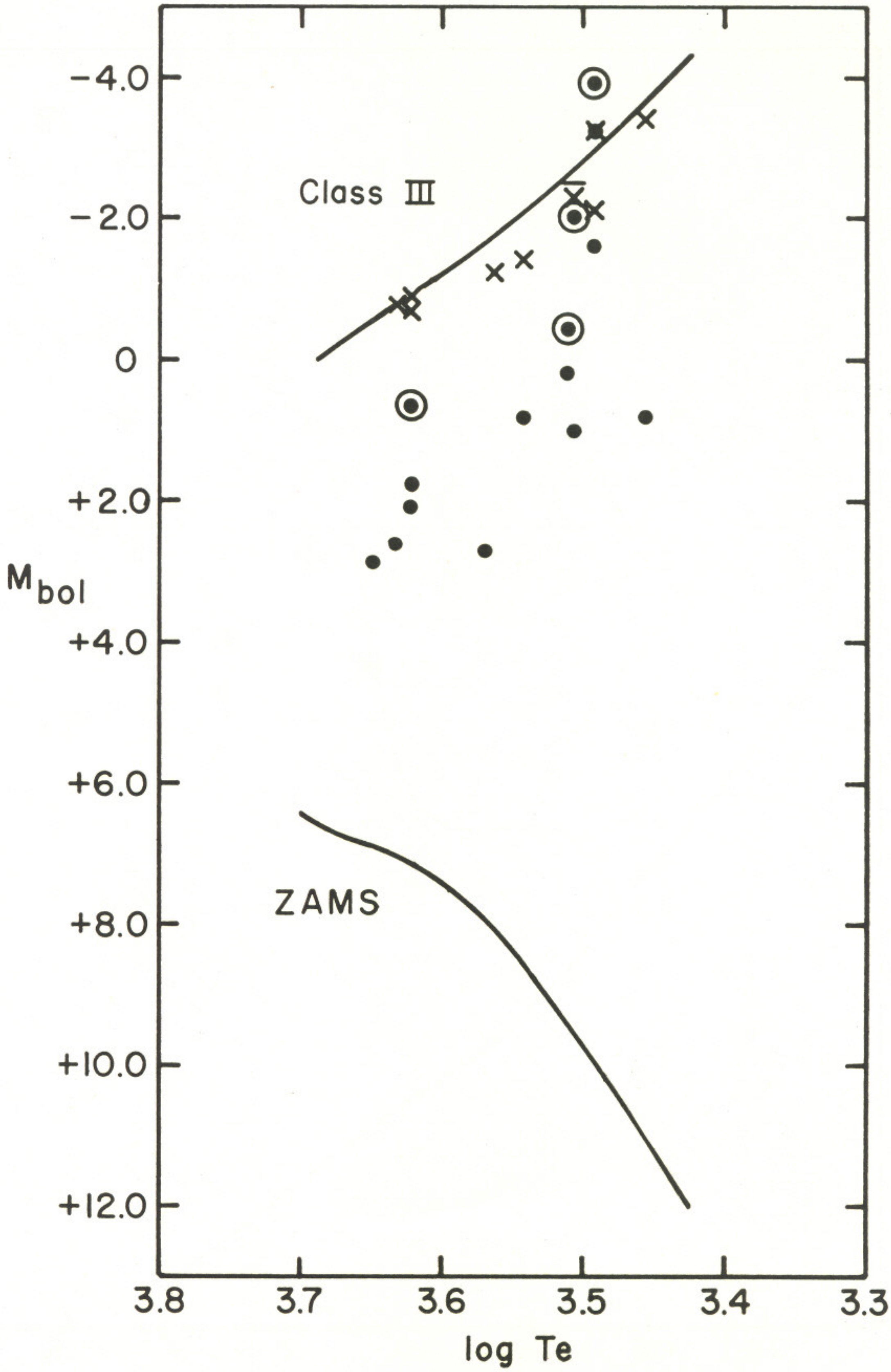

Fig. 3.—*The BT diagram for stars in Table 1. The lines are the zero-age main sequence (ZAMS) and the sequence of K and M giants of Luminosity Class III. Filled circles represent the data derived from the trigonometric parallaxes. Circles with a central dot represent the data from the H and K line widths. Crosses represent the data from the low dispersion spectra.*

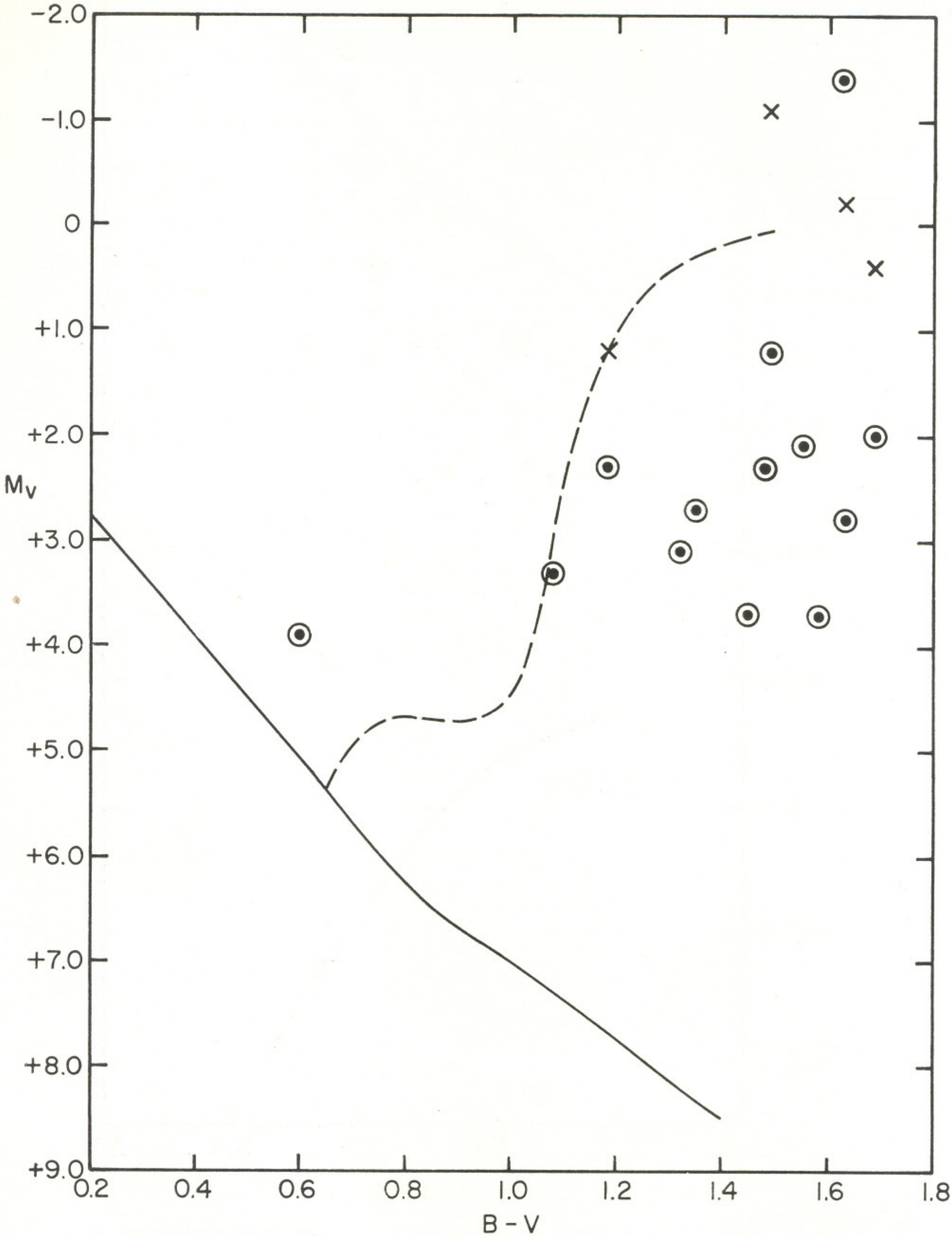

Fig. 4.—*Color-magnitude diagram for the stars in Table 1. Heavy and dotted lines are from Wilson (1959). Circles with a central dot have M_v from trigonometric parallaxes. Crossen have M_v from Ca II emission-lines.*

VI. Discussion

We have presented multicolor data, over the range in wavelength from 0.3 to 10 microns, and high and low dispersion spectra for a number of late type-stars. If we could accept the absolute magnitudes derived from the trigonometric parallaxes as the best ones, most of the stars in Table 1 would fall well to the right and below Wilson's (1959) dotted boundary line, when plotted in Wilson's (M_v, B−V)-diagram (see Figure 4), Wilson (1959) concl ded from his dotted boundary line that the age of the oldest stars in our galaxy is about 10^{10} years.

The validity of this interpretation depends upon the quality of the trigonometric parallaxes. Three stars in Table 1 appear in both Jenkins (1952, 1963) catalogues of Stellar Parallaxes. These stars are listed in Table 4. The columns of this Table give, first, the BS numbers; second and third, the trigonometric parallaxes, 1952 and 1963, respectively; fourth and fifth, the derived visual absolute magnitudes from these parallaxes; and sixth, the difference between these two visual absolute magnitudes. We notice from Table 4 that all the new parallaxes are much smaller than the older ones making the stars lie closer to the giant sequence.

TABLE 4

Quality of trigonometric parallaxes

BS	$\pi_1('')$	$\pi_2('')$	$M_v(1)$	$M_v(2)$	ΔM_v
5192	0.049	0.025	+2.7	+1.2	+1.5
5924	0.034	0.023	+3.1	+2.3	+0.8
9089	0.043	0.007	+2.6	−1.4	+4.0

There is more evidence which makes us doubt the quality of the trigonometric parallaxes, namely, our own spectroscopic data; firstly, the low dispersion spectra indicate Luminosity Class III; secondly, the H and K line widths suggest lower border-line giants; and thirdly, the intensity of these emissions is not low. If there is the same correlation, in main-sequence stars and the stars in Table 1, in the sense that chromospheric activity diminishes with time (see Wilson, 1963 and Wilson and Skumanich, 1964), then the emission intensities given in Table 2 would not suggest very old stars. Of course, if the stars are spectroscopic binaries which exhibit emission, such stars might have more cromospheric activity than their ages would suggest. As far as we know, BS 7120 is the only spectroscopic binary of the stars in Table 1. Furthermore, it also is a high velocity star.

A statistical analysis of the motions of the stars in Table 1, under way by van de Kamp and Mendoza, gives a secular parallax which is lower than the average trigonometric parallax of this group of stars, suggesting again, that they might be lower border-line giants.

Acknowledgment

We want to express our thanks to Dr. H. A. Abt for his help during the spectroscopic observations and one of us (EEMV) to the Organization of American States for a grant during the last stages of this work. The work at the University of Arizona was supported in part by the National Science Foundation and the Office of Naval Research.

REFERENCES

Cousins, A. W. J., and Stoy, R. H., 1963, *Royal Observatory Bulletins No.* **64** (Photoelectric Magnitudes and Colours of Southern Stars).
Jenkins, L. F., 1952, *General Catalogue of Stellar Parallaxes* (Yale University Observatory).
Jenkins, L. F., 1963, *Supplement of the General Catalogue of Stellar Parallaxes* (Yale University Observatory).
Johnson, H. L., 1964, *Tonantzintla and Tacubaya Observatory Bull. No.* **25**.
Johnson, H. L., 1965, *Comm. Lunar and Planetary Laboratory, No.* **53**.
Johnson, H. L., and Morgan, W. W., 1953, *Ap. J.*, **117**, 313.
Keenan, P. C., 1963, *Basic Astronomical Data* (University of Chicago Press), 92.
Mendoza, E. E., and Johnson, H. L., 1965, *Ap. J.*, **141**, 161.
Wilson, O. C., 1959, *Ap. J.*, **130**, 496.
Wilson, O. C., 1963, *Ap. J.* **138**, 832.
Wilson, O. C., and Bappu, M. K. V., 1957, *Ap. J.*, **125**, 661.
Wilson, O. C., and Skumanich, A., 1964, *Ap. J.*, **140**, 1401.
Wilson R. E., 1952, *General SCatalogue of Stellar Radial Velocities* (Carnegie Institution of Washington).