HR DIAGRAMS DERIVED FROM THE MICHIGAN SPECTRAL CATALOGUE

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In this paper we present some HR diagrams constructed using data from the Michigan Spectral Catalogues. Houk (1975) has been systematically reclassifying the Henry Draper stars on the MK system, from the south pole northward. Objective-prism plates, with a reciprocal dispersion of 108 Å/mm, have been taken with the Michigan Curtis Schmidt telescope at Cerro Tololo Inter-American Observatory in Chile. The spectra are classified visually from the plates, and the results are put onto IBM cards and magnetic tape from which the catalogues are produced.

The data used for this paper are taken from both Volume 1 (Houk and Cowley, 1975) and from part of Volume 2 (Houk, 1978, in preparation). The absolute magnitudes (M_V) were taken mainly from the Landolt-Börnstein tables (Schmidt-Kaler, 1965), with a few being from Blaauw (1963). The values were smoothed and interpolated to get the intermediate luminosity types used in classification such as Ib/II and II/III. More recent work has probably changed some of the values used, but for our purposes the general pattern of the HR diagrams is what is important.

In the plots below only the higher-quality classifications are included: those assigned qualities 1 or 2 in the catalogues. Also all peculiar stars are omitted since reliable luminosity classes can not usually be assigned. Even for spectra of quality 1 and 2, O-type stars earlier than O9 are not normally assigned luminosity types, so are virtually absent from Figs. 1 and 2. Late M stars are also under-represented because of the difficulty of getting good luminosity types when the spectra are often underexposed.

A. G. Davis Philip and D. S. Hayes (eds.), The HR Diagram, 91-98.

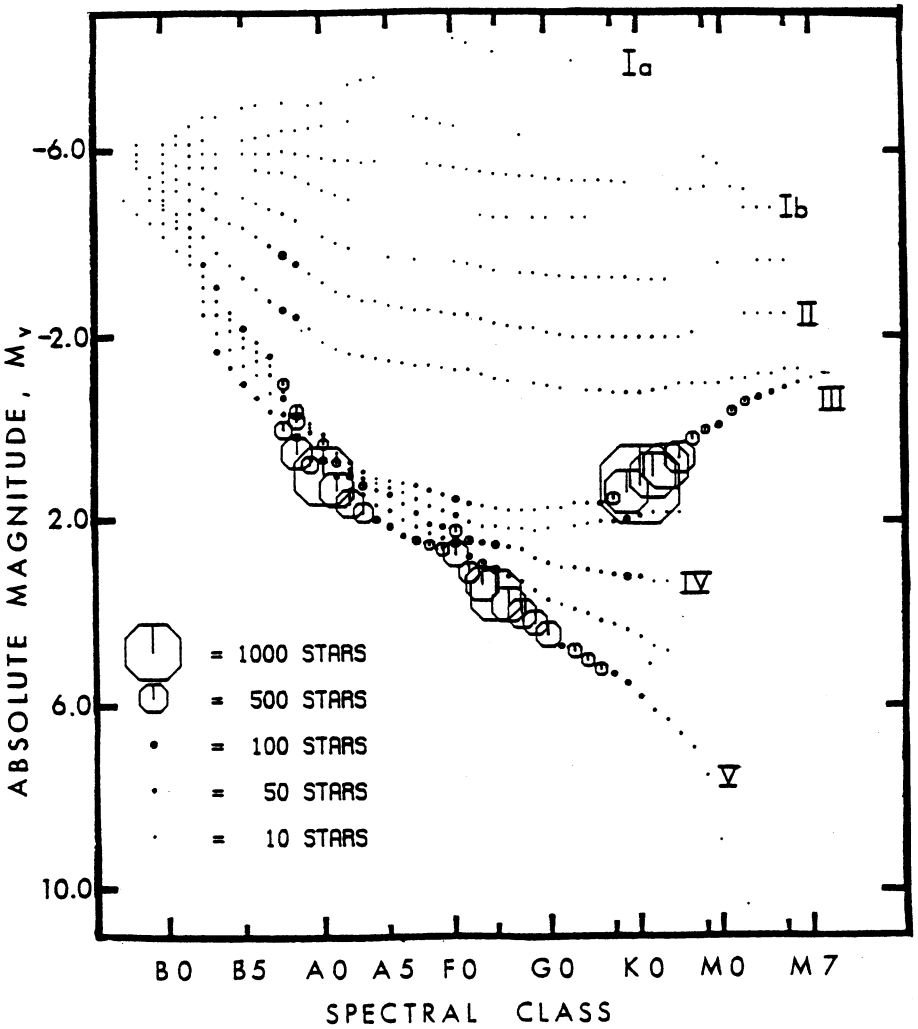

Fig. 1. HR diagram for normal stars of quality 1 and 2 in Volume 1 of the Michigan Spectral Catalogue. The unlabeled subtypes F5, G5 and K5 indicated by the shorter marks are not at the midpoint because only used spectral subtypes are included, all of them being equally spaced. Symbol size is proportional to the number of stars of the particular type. Examples are given in the key.

The plot for Volume 1 is shown in Fig. 1 (also on cover of this book). It contains the HD stars between $\delta = -90^{\circ}$ and -53°0. This diagram includes more than 24,000 stars -- about 2/3 of the total in Volume 1, the others being of too low quality or peculiar.

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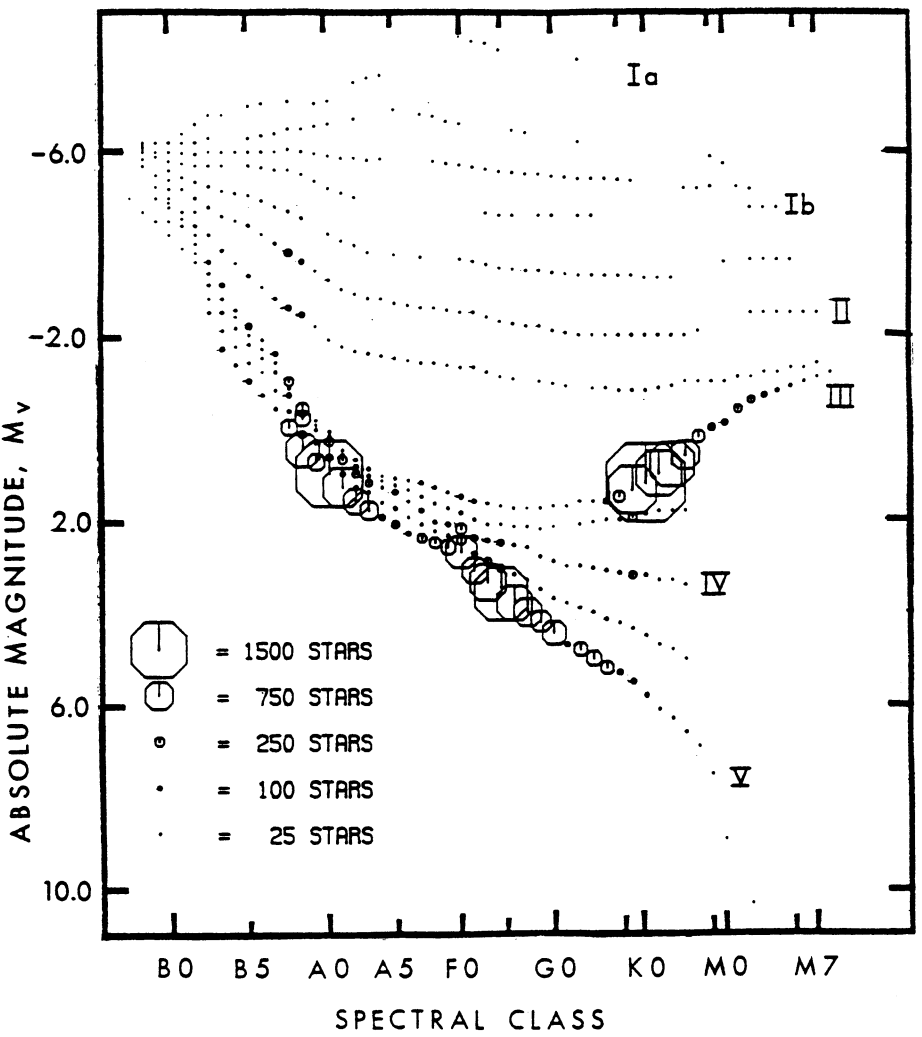

Fig. 2. HR diagram for normal stars of quality 1 and 2 in Volume 1 plus part of Volume 2 of the Michigan Spectral Catalogue.

Note that K0 III stars are most numerous, A0 V next, and then F5V. A similar pattern is seen in Fig. 2 which adds the stars that were on tape in August for Volume 2, bringing the total stars on this plot to 36,382. For the Volume 2 sample alone the A0 V types slightly exceed the number of K0 III's, but this will change when the omitted regions far from the galactic plane are added.

Perhaps the most surprising feature is the paucity of main sequence stars from A4 to A9, evident in Volumes 1 and 2. This is not an artifact of the classification scheme: a plot versus

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(B-V) or temperature shows this same effect. This deficiency of later A stars is not new, being present, at least to some extent, in most HR diagrams of field stars, including early ones by Russell. The large amount of data here makes it more conspicuous. Also, in the past it has often been de-emphasized by adjusting the horizontal scale. We have no space to show an example here, but see the often-shown HR diagram prepared by Gillenberg, on p. 259 of Astronomy of the 20th Century (Struve and Zebergs, 1962). Note that there would be a gap if the scale were the same throughout the A's. Interestingly, both Mendoza (1956) and Böhm-Vitense and Canterna (1974) have found similar gaps in the (B-V)'s of field stars. They were not seen very convincingly in clusters, however, which may be one reason the finding was neglected. The latter paper includes a discussion of some possible causes of such a gap.

The sort of HR diagram given in Figs. 1 and 2, which contains stars down to a very rough limiting magnitude, is admittedly of limited usefulness compared with a diagram of a single cluster or of stars within a certain volume of space. When our paper was placed in the Solar Neighborhood session, we decided it would be appropriate to try to obtain HR diagrams for our HD stars within 25 pcs and within 100 pcs.

This first required an evaluation of the magnitudes in the Henry Draper Catalogue before using them to obtain distances. Photoelectric magnitudes are available for about 4500 of the 36,400 HD stars we used south of $\delta = -40^{\circ}$. Using these we found systematic errors in the HD magnitudes which depend, among other variables, on the position in the sky, especially on R.A. By visual examination of the errors lists we divided the area from -90° to -40° into 8 regions which required somewhat different corrections. In most regions the magnitude error is a strong function of magnitude, as is shown in Fig. 3. In that region the errors are also dependent on spectral type or color, so we made different corrections for the G-M stars than for the O-F stars. As is clear from Fig. 3 there are also large random errors even for the brighter stars, making the individual distances we obtain very uncertain. The corrections used, though of limited accuracy, are given in Table I. In the fourth column the Δm is in the sense (HD pg mag - p.e. B mag) and is the value Δm has at the brighter magnitude given in column 3. The slope, given in the last column, can then be used to calculate the Δm at any m. Outside the magnitude ranges given no corrections are needed.

The resulting HR diagrams for the 184 normal, quality-1-and-2 stars in Volumes 1 and 2 computed to be within 25 pcs and the 4700 stars within 100 pcs are shown in Fig. 4. Only the general picture is significant since the distance to any particular star is so uncertain. The majority of the HD stars within 25 pcs are early G dwarfs, with incompleteness setting in for later types. For HD stars within 100 parsecs note that the maximum is at G0 and there

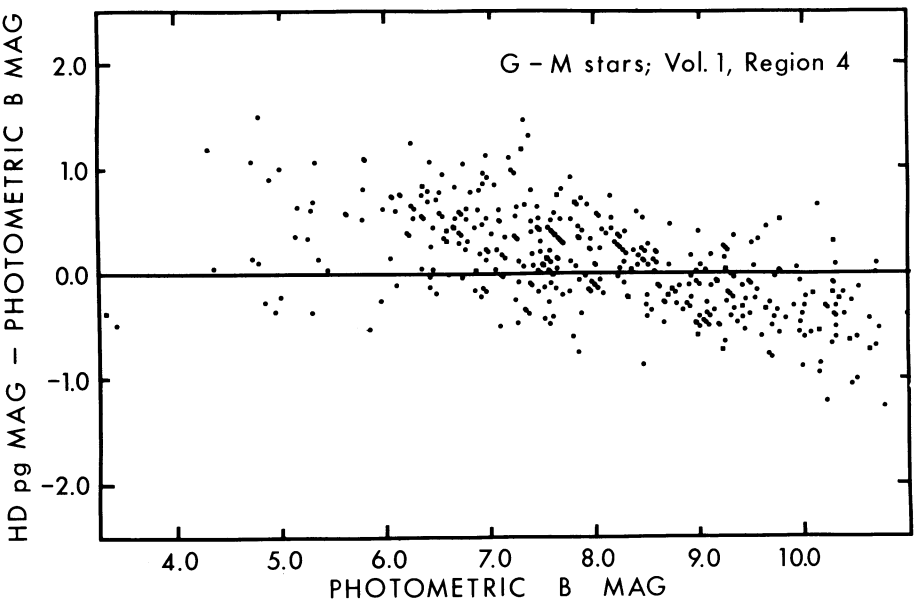

Fig. 3. Errors in HD magnitudes as a function of p.e. magnitude.

TABLE I

CORRECTIONS TO HD PG MAG AS A FUNCTION OF R.A. AND MAG

Volume 1 (-90° to -53°)			Correction Δ mag at	
Zone	R.A. Limits	HD pg mag Range	brtest mag	slope
1	$0^h.0$ - $5^h.0$ +$21^h.5$ - $24^h.0$	all magnitudes	no correction	
2	5.0 - 9.0	6.0 - 10.0	+.50	-.20
3	9.0 - 10.5	7.0 - 10.2	+.40	-.19
4	10.5 - 21.5	O-F stars 6.5 - 10.7	+.25	-.24
		G-M stars 5.0 - 6.99	.00	+.35
		G-M stars 7.0 - 10.7	+.50	-.27
Volume 2 (-53° to -40°)				
1	$0^h.0$ - $8^h.0$	5.8 - 8.49	+.50	-.26
	+$17^h.5$ - $24^h.0$	8.5 - 11.5	-.20	+.20
2	8.0 - 12.0	8.5 - 11.5	-.30	.00
		O-F stars 6.2 - 8.49	+.40	-.26
		G-M stars 6.2 - 8.49	+.70	-.44
3	12.0 - 15.0	3.0 - 6.49	-.30	+.23
		6.5 - 11.5	+.70	-.30
4	15.0 - 17.5	3.0 - 6.49	-.20	+.23
		6.5 - 7.99	+.80	-.80
		8.0 - 10.5	-.20	.00

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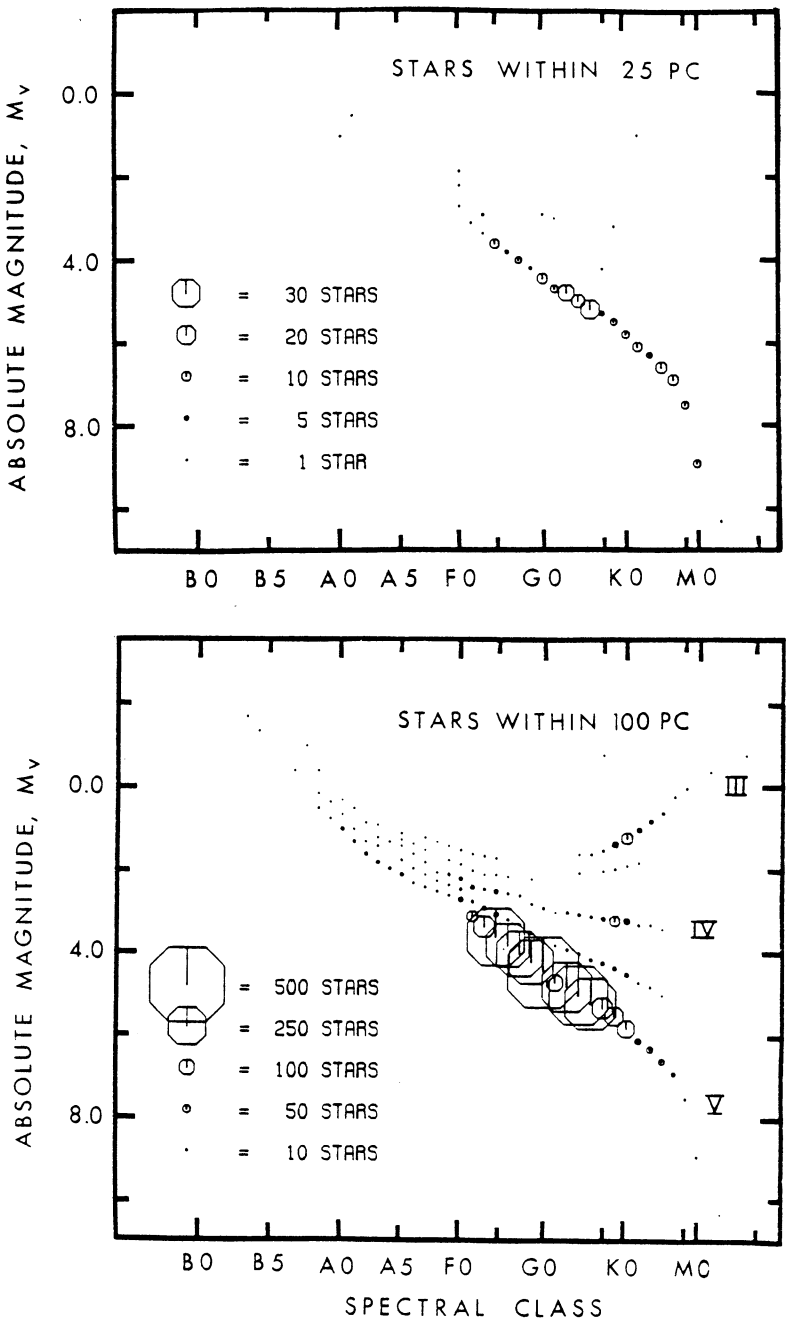

Fig. 4. HR diagrams for HD stars from Volumes 1 and 2 of the Michigan Spectral Catalogue computed to be within 25 pcs and 100 pcs.

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is a quite abrupt cutoff at F3, the earlier-type stars mainly being further away than 100 pcs. In considering total numbers of stars it should be remembered that only 2/3 of the HD stars in Volume 1 and even fewer in Volume 2 were part of the reference population used to obtain Fig. 4 since poor quality, peculiar, and unprocessed (i.e., not yet on tape) stars were excluded.

HR diagrams constructed from stars divided into galactic-latitude groups might well be of interest. We did not look into this because Ochsenbein's paper, later withdrawn, was to have been along those lines. After Volume 2 of the Michigan Spectral Catalogue is complete other such correlations and statistical studies will be undertaken.

We would like to thank F. Ochsenbein and the Centre de Donnees Stellaires (Stellar Data Center) at Strasbourg for providing a tape of the available photoelectric magnitudes for HD stars south of $\delta = -40^{\circ}$. Thanks also to S.W. McCuskey for helpful discussions and suggestions. We are especially grateful to the National Science Foundation for their continuing support of this work through a series of grants.

REFERENCES

Blaauw, A. (1963). In Stars and Stellar Systems, Vol. III, Basic Astronomical Data, K. Aa. Strand, ed., Univ. of Chicago Press, Chicago, p. 383.

Böhm-Vitense, E. and Canterna, R. (1974). Astrophys. J. 194, 629.

Houk, N. and Cowley, A.P. (1975). University of Michigan Catalogue of Two-Dimensional Spectral Types for the HD Stars, Vol. 1, Dept. of Astronomy, Univ. of Michigan, Ann Arbor.

Houk, N. (1978). University of Michigan Catalogue of Two-Dimensional Spectral Types for the HD Stars, Vol. 2, Dept. of Astronomy, University of Michigan, Ann Arbor.

Mendoza, E.E. (1956). Astrophys. J. 123, 54.

Schmidt-Kaler, Th. (1965). In Landolt-Börnstein New Series, Group 6, Vol. 1, Astronomy and Astrophysics, H.H. Voigt, ed., Springer-Verlag, N.Y., p. 298.

Struve, O. and Zebergs, V. (1962). Astronomy of the 20th Century, The MacMillan Co., N.Y., p. 259.

DISCUSSION

UPGREN: I would like to direct this question to you and to Dr. Gliese. The numbers of stars in each spectral class which you find in your Volume I to be closer than 20 parsecs could be extrapolated to cover the whole sky since the nearby stars should be uniformly distributed. This would give expected numbers of stars closer than 20 parsecs in each class earlier than M. Have the numbers of stars of each class in Gliese's catalog been compared to these to detect the degree of incompleteness in each spectral class?

HOUK: I have not done this but am sure it would be very incomplete, at least from mid-G later. Extrapolating over the whole sky, I expect to find about 1100 stars within 25 parsecs, lower than Gliese's figures.

GLIESE: I use the Michigan Spectral Catalogue, Vol. 1 to search for late type nearby stars. Does it seem necessary to calibrate the mean relation between Michigan objective prism spectral types the absolute magnitudes for main sequence stars by trigonometric parallaxes?

HOUK: It might be a good idea. I don't think there are any systematic errors in that spectral region but we have not made very extensive intercomparisons.

GLIESE: It's difficult to find accurate apparent magnitudes for many of these stars which seem to be nearby objects.

HOUK: Yes, our results show rather large errors, even for stars as bright as 6th or 7th magnitude. Of the 67,000 HD stars south of declination -40°, only about 4500 have photoelectric magnitudes in the Strasbourg data file.

GLIESE: Can you give any estimate of time of the publication of further volumes of the Catalogue?

HOUK: Lets limit that to Volume 2. (Declination -53° to -40°, $\sim$ 31,000 stars.) It should be ready early in 1978. The magnetic tape version will probably be available in February; the availability of the volume depends on the printer.

GREENSTEIN: Will your catalogues and tapes include new magnitudes (determined from the spectra) and improved positions?

HOUK: We will continue to print the original HD pg magnitudes. The corrections discussed here are too uncertain and difficult to make, since they differ so much with region in the sky. Volume 2 will, however, have improved 1900 positions and precession provided by the Strasbourg Stellar Data Center. The right ascension will be given to a tenth of a second of time, the declination to one second of arc.