SOME NOTES ON STARS NEAR K0

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Abstract. Two hundred giant and subgiant stars near K0 were classified twice by somewhat different techniques. The resulting types were in excellent agreement but a comparison of the assigned types with *U, B, V* colors indicated both an intrinsic scatter in the colors for stars of similar spectroscopic appearance and a problem in either the luminosity classifications or the standard colors or both. Several peculiar stars and a luminous supergiant were also detected.

Photoelectric *UBV* photometry and slit spectra with dispersions and resolutions near that of the MK system have been obtained for more than 700 stars brighter than twelfth magnitude, photographic, in Kapteyn Selected Areas. The majority of the areas studied are at high galactic latitudes since the intent of the program was to provide homogeneous data for a large random sample of moderately faint stars for studies of population effects. These data may also serve as standards for photographic photometry and, particularly, objective prism spectroscopy.

In general, the observed spectral types agree well with those predicted from the photometric colors, but near K0 the scatter is larger than would be expected from the internal consistency of either the photometric measurements or the spectral classification. Individual outstanding cases of disagreement were reclassified with no significant improvement in the agreement and, usually, no change in the assigned types. The 200 stars of luminosity classes III and IV and spectral classes G8, K0, and K1 were then arranged in groups of about 25 in a two-dimensional array on the basis of intercomparisons only among the stars being classified. Since the original types were determined by the direct comparison of each spectrogram with those of standard stars, the arrangements in a two-dimensional array, was independent of my earlier classifications except for the use of the same classification criteria.

More than 85% of the newly derived types were identical to those I had assigned previously. The scatter in the colors for stars of the same type was unaffected. The 15% of the stars for which the new types differed by one classification interval from the earlier ones indicates a reasonable uncertainty, considering that the spectral classes are quantized. Finally, all of the G8 stars were again intercompared and arranged in order of apparent luminosity and the class III stars were again arranged in order of spectral type. These intercomparisons yielded no deviations from the assigned classifications.

The mean colors of the stars at latitudes more than 45° from the plane were then examined. Table Ia lists the mean colors for each class of stars. It is clear that, contrary to expectations, there is no difference in mean color as a function of luminosity. Table Ib shows the same thing in a different way. The G8 stars have been divided into groups of two or three, and the groups paired by $(B-V)$ color. Again, there is no difference between the brighter and the fainter members in each color grouping.

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TABLE I

Average colors for the faint stars

(a)				(b)		
Type	No. of stars	$B-V$	$U-B$	Luminosity	G8 Stars $B-V$	$U-B$
G8III	4	0.94	0.57	BR	0.85	0.44
G8IV	12	0.92	0.61	FT	0.88	0.52
K0III	32	1.00	0.75	BR	0.93	0.56
K0IV	13	0.98	0.74	FT	0.94	0.57
K1III	32	1.09	0.99	BR	0.99	0.72
K1IV	2	1.18	1.09	FT	1.03	0.76

Average $(U-B)$ excess 0.05.

Thus, the observations show two effects which are larger than the accidental errors of measurement. There is a spread in colors for the same spectral type and the expected correlation of luminosity class and color does not appear. The colors of the stars assigned to G8IV can be explained if the stars are actually G9III–IV stars. This is not entirely unreasonable since the hydrogen lines decrease in intensity with both decreasing luminosity and increasing spectral type and the CN and λ4077 of Sr II become slightly weaker with advancing type as well as much weaker with decreasing luminosity. However, the strontium line should be enough weaker at G8IV than at G9III–IV to make it unlikely that a systematic classification error of this magnitude would have survived the arrangement of the spectra in a two-dimensional array. Moreover, the effect at K0 cannot be explained as simply.

TABLE II

Mean colors of bright stars

Type	No. of stars	$B-V$	$U-B$
G8II – III	6	1.01	0.79
G8III	47	0.94	0.67
G8III – IV	15	0.97	0.74
G8IV	4	0.86	0.52
K0II – III	5	1.15	1.06
K0III	80	1.02	0.86
K0III – IV	6	1.02	0.86
K0IV	2	0.99	0.85
K1II – III	1	1.12	1.02
K1III	28	1.00	0.99
K1III – IV	2	1.12	1.08
K1IV	2	1.04	0.98

The mean colors are listed in Table II for the stars brighter than 5.5 and north of declination $-20°$, which are in the *Naval Observatory Catalogue* (Blanco *et al.*, 1968). The mean $B-V$ colors for each spectral type agree well with those given in Table I for the fainter stars. The $U-B$ colors for the G8 and K0 giants are about 0.1 mag. redder than those for the faint high-latitude stars although the colors for the K1 giants agree perfectly. The brighter U magnitude for the high-latitude giants is interesting but hardly surprising in view of earlier evidence that high-velocity stars appear brighter in the ultraviolet than low-velocity stars. Although, particularly at G8, Table II gives an indication of the expected luminosity effect in the colors, it is far

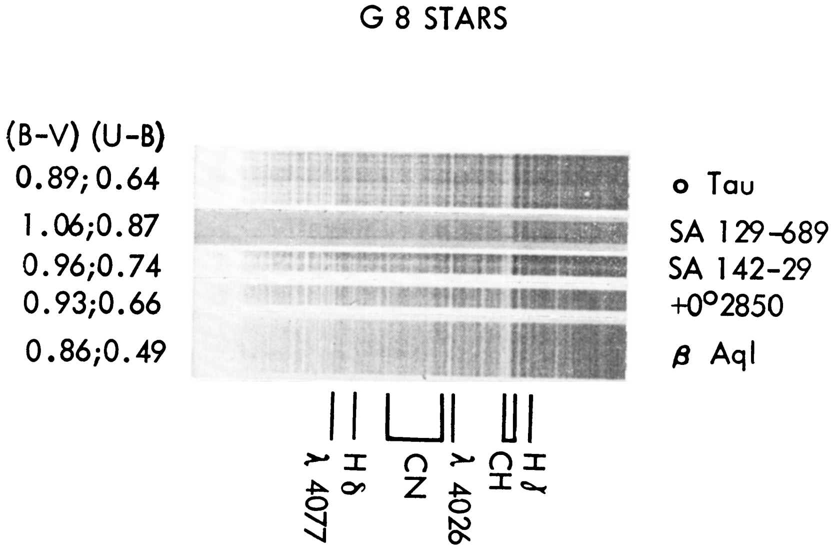

Fig. 1. The G8IV stars SA 129 – 689 (BD – 14°3683), SA 142 – 29 (CPD – 29°233) and BD + 0°2850 are arranged in order of $B-V$ colors between the G8III and G8IV standards, *o* Tau and *β* Aql respectively.

less marked than one would expect (see, e.g., Fitzgerald, 1970). In addition, as for the fainter stars, the scatter in each spectral type is significantly larger than would be expected.

It appears probable that the mean colors of stars near K0 should be revised. It is also possible that most of the stars observed in surveys to a limiting apparent magnitude are basically evolved stars and, hence, that the subgiants are closer to the giants than to the dwarfs. Nevertheless, it is also possible that the large individual residuals reflect a problem with the classification criteria. Near K0, the classification criteria in the MK system are based on the strength of the hydrogen lines, the strength of Ca I, λ4226, and the appearance of the G band of CH; the luminosity criteria are based on the strength of Sr II, λ4077 and of CN. It is well known that CN is often weak in high-velocity stars and it was given relatively little weight in the present classifications.

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Strontium is an element which often appears in anomalous strength in earlier stars as well as in such stars as the BaII stars. I suspected some time ago that there are variations in the strength of the strontium line among the high-velocity stars which are uncorrelated with luminosity and the present study appears to confirm this. It also is well known that, among the high-velocity stars, the hydrogen lines are often strong compared to the strength of the metallic lines and the CH strength is frequently anomalous. Thus, all of the classification criteria are suspect, at least for stars which are not bonafide members of the spiral-arm population.

Figure 1 illustrates three stars near G8, arranged in order of decreasing redness

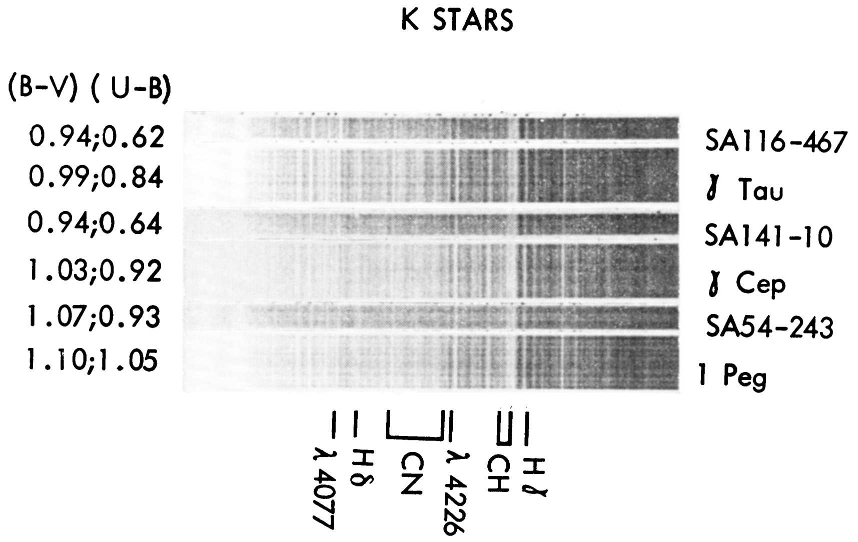

Fig. 2. The standard stars γ Tau, γ Cep and 1 Peg are K0III, K1IV and K1III respectively. SA 141 − 10 (CPD −29°108) and SA 54 − 243 (BD +30°2022) are apparently normal K0III stars although CN is weak in SA 141 − 10. Sr II λ4077, is abnormally strong in SA 116 − 467 (BD −15°43).

between a G8III and a G8IV standard. It is clear that the ratio of Ca I/H indicates that SA 129 − 689 (14°3683) is no later than *o* Tau in spite of its substantially redder color. The spectrum bears little resemblance to a star as late as K1. Similarly, BD +0°2850 has weaker Sr II than β Aql in spite of its redder color. Both the hydrogen-line strength and the appearance of the G band would be hard to reconcile with a type much later than G8 for any of these stars. Figure 2 illustrates these discrepancies for three stars at K0 and K1, compared with standard stars at K0III, K1IV and K1III. Although SA 54 − 243 (+30°2022) is nearly as red as 1 Peg, neither the strontium nor the CN is significantly stronger than in γ Cep. By comparison, SA 141 − 10 (CPD − 29°108) appears both later and brighter than SA 54 − 243 but is substantially bluer. In SA 116 − 467 (−15°43), the strontium line is obviously too strong. If this were really a luminosity class II star, it would be more than three kiloparsecs below the galactic

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TABLE III

Peculiar giants near K0

−15°564	CH strong, Ba II star
−15°43	Sr strong, CH normal
−15°3440	CH strong, remaining spectrum normal
+45°1951	CH strong, remaining spectrum normal
+0° 2971	CH normal, all other features weak
−0° 294	Lines washed out, CN probably weak
+45°1764	CN weak
−14°6438	Sr normal, no CN, other lines weak (G8IV)
+30°3866	4150 star (K1IV)

Fig. 3. SA 64 − 382 (BD +29°3865) is compared with three other supergiants.

plane. There are no other indications of high luminosity. The strength of the strontium line resembles that in the Barium II stars, but there is no trace of the Ba II line and CH is normal in intensity. Table III lists nine other obviously peculiar stars observed in this study. Again, the tendency for CH, CN, and Sr II to be abnormal is clear.

These results indicate that both the standard classification criteria and the predicted colors for stars near K0 must be re-examined. Until these problems are understood, narrow-band colors must be used cautiously. It may be possible to test the luminosity discrimination in the present material through the computation of secular parallaxes but the small proper motions and tendency for these stars to have large space-velocity dispersions will make this difficult.

Figure 3 illustrates another unusual star near K0, a Ia supergiant. While SA 64 − 382 (+29°3865) is slightly later than RW Cep, the strength of the hydrogen lines indicates that it cannot be much later than K0. It appears much more luminous spectroscopically

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than either ε Gem (G8Ib) or ζ Cep (K1Ib). Thus it adds another star to a very sparsely settled region of the HR diagram.

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