MEAN COLORS AND EFFECTIVE TEMPERATURES OF K AND M DWARFS

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Many applications of multicolor wideband photometry depend upon the existence of a table of mean colors, i.e. a listing of the average values of the color indices B-V, V-R, etc. for each spectral type. Such a table relates the observed colors of unreddened stars to their temperature classes and enables one to draw a reference line representing the main sequence on any color-color diagram.

The table of mean colors provided by Johnson (1966), which is based on Johnson's (1965) own observations of some 40 K and M dwarfs, has been (and still is) extensively used. There is, however, a problem with Johnson's mean colors which arises from the spectral classifications which he took from the literature. These are of widely varying precision and are expressed on several scales having large systematic differences. Hence the meaning of Johnson's mean colors is somewhat ambiguous.

Some time ago the writer drew attention to the need for improved spectral classifications for M dwarfs and suggested that narrow-band photometry of a TiO band be used to establish a consistent set of classification standards (Wing 1973). Subsequently more than 100 M dwarfs — including nearly all those for which Johnson (1965) obtained wideband photometry — have been observed by C. A. Dean and the writer on an eight-color system of narrow-band photometry in the near infrared. The spectral classifications derived from this photometry, based on the 7100 Å band of TiO, have an internal precision of one-tenth of a subclass and are expressed on the same scale as the MK types for M giants.

A spectroscopic study of M dwarfs has been carried out by Boeshaar (1976), who also expressed her types on the giant scale. Several of Boeshaar's classifications are given in the Atlas of Keenan and McNeil (1976), where they are adopted as standards for the MK system. Wing and Yorka (1979) have shown that the spectral types for M dwarfs obtained from eight-color photometry are in excellent agreement with Boeshaar's types and are thus on the MK scale.

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Table 1. MEAN COLORS AS A FUNCTION OF MK SPECTRAL TYPE

Sp. Type	U-V	B-V	V-R	V-I	V-J	V-K	V-L
K3 V	1.94	1.02	0.92	1.50	1.95	2.68	2.84
K4 V	2.42	1.22	1.06	1.80	2.22	2.99	3.16
K5 V	2.62	1.38	1.18	2.05	2.49	3.30	3.49
M0 V	2.68	1.46	1.28	2.28	2.76	3.61	3.82
M1 V	2.70	1.50	1.40	2.50	3.04	3.92	4.16
M2 V	2.70	1.50	1.52	2.72	3.35	4.24	4.50
M3 V	2.74	1.56	1.66	3.04	3.74	4.58	4.92
M4 V	2.92	1.66	1.84	3.50	4.28	5.15	5.64
M5 V	3.25	1.82	2.20	4.10	5.04	5.90	----
M6 V	3.60	2.00	2.74	5.10	5.90	6.70	----

Table 1 is a new compilation of the mean colors of K3 - M6 dwarfs, obtained largely from the photometry of Johnson (1965) by sorting the stars he observed according to their new spectral classifications from the eight-color photometry. For each color index, a plot was made of color vs. spectral type and a smooth curve was drawn through the data. With the new spectral types, these curves are very well determined.

There are substantial systematic differences between the new mean colors and those of Johnson (1966), especially toward the later types. For example, the mean colors given by Johnson for an M7 dwarf are nearly the same as those given here for an M5 V star on the MK scale. Thus it is important to use the new tabulation of mean colors whenever classifications on the MK system are employed.

Another use of wideband multicolor photometry is to estimate stellar temperatures, and the compilation of mean colors allows the derivation of a relation between spectral type and temperature. Johnson (1966) listed "effective temperatures" for each spectral type by comparing the calibrated flux curves corresponding to each set of mean colors to a family of blackbody curves. New temperatures based on the mean colors of Table 1 are now being derived with allowance for TiO blanketing at several of the filters, which has been evaluated quantitatively as a function of MK spectral type by Smak and Wing (1979).

Boeshaar, P. C. 1976, Ph.D. thesis, Ohio State University.
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DISCUSSION

Mullan: Could you comment on one of the conclusions which arose from the earlier classification by Joy and Abt namely that all stars considered by them of spectral type M 5.5 or later were emission-line stars? With your revised classification is that conclusion still valid?

Wing: The conclusion remains the same except that maybe instead of calling it 5.5 I would call it 5.0. There is a half spectral class difference in that spectral region between myself and Joy. Generally however the correlation between our two classifications are good. So any general conclusions like that should still pertain.

Linsky: Would anyone else like to comment on that particular point because so far as I know Mark Giampapa has observed some stars of later spectral type still which show no Hα emission.

Mullan: But that is the point of the question. What was the basis of those later spectral types?

Wing: I don't know which stars they were so I am not sure whether I have observed them or not.

Worden: Van Biesbrock 10 is one of the stars which Mark (Giampapa) observed.

Wing: I cannot give a good spectral type for that. I observed it once about 20° from a Full Moon and so cannot give a good spectral type. But I believe it is about M6.

Linnell: In your abstract you had something to say about the temperature scale. Could you expand on that a little?

Wing: What I did was to follow the procedure of Johnson in his 1966 review paper. He compared each set of colours for each spectral-type to an absolute calibration of the photometry and then compared these to black body curves. The result is a temperature index which he called effective temperature. I am not sure that this is the best way of defining effective temperatures but at least it gives a temperature index. I thought that I could do somewhat better by making a quantitative allowance for TiO from my measurements. This work is not finished however and so I do not have figures to hand.

Linnell: Effective temperatures or absolute fluxes which are equivalent can only be determined in a fundamental way through determining of angular diameters or their equivalent. At this end of the scale there are only two good points i.e. γγGem and CM Dra. Between these and the middle A-types, where one can use intensity interferometers, there

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are only two other good points viz. the Sun and Procyon, each of which has special problems. So the temperature scale is not well established at the M stars.

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