II CRITERIA AND APPLICATIONS OF MK CLASSIFICATION

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CRITERIA AND APPLICATIONS OF THE MK CLASSIFICATION SYSTEM

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ABSTRACT

A review is given of the present state of MK classification, with a view to future developments in techniques and instrumentation. The principle of the complementarity of quantitative and visual inspection techniques is stressed.

Included in the discussion are examples of problems which are currently outstanding. Among these are variable stars, marginal peculiarities, fundamental standards (with specific reference to the Sun), and representation of the third and higher dimensions.

1. INTRODUCTION

The MK System of spectral classification, since its introduction by Morgan, Keenan and Kellerman in 1943, has been increasingly accepted and used by astronomers in all fields. There are many reasons for this success. One of the most important is that it provides a general reference frame in terms of which all stars can be described. Even peculiar stars and stars from other galaxies can be described in terms of those in the solar neighborhood by the addition of new dimensions.

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Standard stars define the system. It is thus independent of calibration, a factor which contributes greatly to its lasting value. The system has evolved somewhat, but the problems that have arisen have been absorbed into the system without changing it in any fundamental way. The new atlases by Keenan and McNeil and by Morgan, Abt, and Tapscott represent the present state of the system of standards. New dimensions have been added as a result of experience with more and better data, the discovery of new categories of peculiarities and input from theoretical work. The publication of the Houk Catalogue will ensure a long useful life for the MK system.

The MK system represents the ideal compromise between too little information and too much, between high enough dispersion to be able to distinguish the most obvious peculiarities and low enough dispersion to be able to reach very faint objects. For a given telescope, MK classification can be carried out for stars as faint as those which can be reached by intermediate band photometric systems, especially if image tubes or other new detectors are used. Improvements in photographic techniques are to be expected as well.

For specific regions of the HR diagram and for specific research programs, other systems of classification are useful, but it is not clear to me that any refinement of the general reference frame beyond that of the new atlases will be meaningful. There is a fundamental fuzziness among the stellar boxes which is sometimes referred to as "cosmic scatter". From my experience it would be difficult to reduce this uncertainty without adding too many new dimensions. Use of higher dispersion or restriction of the system to a few ratios does not solve this problem. On the other hand, new systems, new techniques, new detectors and new wavelength regions can provide extremely useful information. This information actually complements rather than competes with the MK system. The most information can be obtained by comparing an independently determined MK visual inspection classification with quantitative data of any or all kinds, whether it be photometric, photographic or computer processed data.

At the present time, and presumably in the future, research in spectral classification is mainly concentrated in three areas:

1) maintenance of the general reference frame for use with quantitative methods,
2) reconnaissance and discovery: segregation of peculiar objects which eventually gives rise to new dimensions,
3) spectroscopic parallaxes, characteristics of of black holes, etc.

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The remainder of this discussion will be devoted to an illustrative example of an application of the MK system and brief comments on some problems which are current or which will become important over the next few years.

2. THE SPECTRAL TYPE OF THE SUN

The example I wish to discuss is that of determining a solar sister. The problem is difficult and discussion is developing into an exciting full-scale debate.

We are all very familiar with the Sun. It has the advantage that even theoreticians and those observers unfamiliar with the constellations can pick it out from among the other stars in the sky. Details are relatively easy to obtain. But, when it comes to finding an exact solar analog among the stars or fitting the Sun precisely into a sequence of T, P, or χ, great difficulties are encountered.

The way to approach the problem now is to use, in a complementary way, all the data possible, and to try to fit the puzzle together. It must be done carefully and responsibly, however, and that has been one of the problems.

The Sun is a fundamental standard which is one of the anchor points of the MK system, with Vega and a few other single stars. From these fundamental standards, other standards have been set up around the sky. In addition, the Sun has been used by many people as a standard for abundances and stellar atmosphere studies in general.

Without prejudicing the final result, I must insist on a philosophical point. Even if it turns out that the Sun is later or cooler than other stars well classified as G2, which I doubt, then it is the other stars that should be shifted to G1 or G1.5 rather than the Sun to later type.

The problem, of course, is that the Sun is too bright and is not a point source. It is, therefore, not easily compared with other stars. The most recent discussions of this problem have been those of Hardorp (1978), Barry, Cromwell and Schoolman (1978), and Reitsema (1977), though many people have considered the problem in the past. Notable among them are Stebbins and Kron (1957), Fernie, Hagen, Hagen and McClure (1971) and Croft, McNamara and Feltz (1972). The latter groups have confirmed the spectral type of the Sun whereas the former have suggested that it is cooler than other stars classified as G2V.

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All of the critics have made at least one of the following errors:

1.) Only one feature or ratio has been measured. It is best to use as many line ratios as possible, to avoid wide pairs, and to minimize the energy redistribution effects. Single features are not reliable enough.

2.) A poor source of the solar spectrum has been used. Twilight sky is one of the worst. The Moon, as an extended source, gives a very different appearance to the spectrum and there is considerable danger from scattered light within the spectrograph. The best sources are asteroids, though their colors differ considerably according to composition. Another possibility is to launch a satellite and calibrate it in orbit from the space shuttle, then observe it from the earth as a star.

3.) Poor resolution has been used by many investigators. The results are thus affected by the energy distribution of the reflection or scattering source. The best solution is to use as high resolution as practical and combine it with classification resolution in a complementary way.

4.) Stellar spectral types for comparison have usually been taken from the literature indiscriminately. This has caused serious systematic effects, especially in the work of Hardorp (1978). For example, in his Table I section 7, where he lists stars with much weaker absorption features than Solar, there are 39 stars which have types ranging from G0 to G5. Ten have spectral types by Morgan or Keenan, of which seven are G0, one is G1 and two are G2; i.e. they should have much weaker lines than Solar! Eight others have types by Roman of G2. Those classified later are from radial velocity spectra by Evans in South Africa and can be considered less reliable. In a problem of this importance, it is essential to use good data for discussion because serious systematic effects result.

The issue of the solar analog is important enough that I have started a program to gather as much quantitative information as possible as carefully as possible, and in as many wavelength regions as possible. So far, the only results are from the Wampler scanner at Lick Observatory in a program being carried out jointly with Joe Wampler. A second order grating was used to give a resolution of 2.5A. Spectra of 10 Hyades stars were compared with the spectrum of Callisto. Other programs using reticon observations, high dispersion spectra, classification spectra of clusters, ultraviolet spectra from IUE, and infrared spectra are underway.

3. CLASSIFICATION OF VARIABLE STARS

Variable star research is a field in which the classification orientation can be used profitably. For example, the best work on Cepheids is still that of Code (1947). Since then the concentration has been on detailed studies or single features. One of the students at Toronto is beginning a project to include more stars. Mira variables in the southern hemisphere and especially in the Magellanic Clouds are relatively untouched. The Clouds are an ideal place for calibration of absolute magnitudes of Miras, but first they must be compared with Galactic Miras by means of spectral classification such as was done by Keenan, Garrison and Deutsch (1974) for the northern stars. There is a student at Toronto involved in that problem.

4. NEW DIMENSIONS

The problem of marginal peculiarities is difficult. Obviously all stars are peculiar in some sense and there is a continuous variation from extremely peculiar stars to "normal" stars. Ap stars are a good example. Perhaps the solution is to introduce a system similar to that of Keenan for the later type stars, giving a strength parameter. For the Am stars, the new atlas by Morgan, Abt and Tapscott proposes a viable refinement of the previous system. Similar problems are encountered throughout the HR diagram. We must be careful, however, not to introduce so many new dimensions that a classification becomes too cumbersome.

From this brief summary, with highlights from a few problems and a detailed look at the problem of the search for a solar sister, it is possible to see that spectral classification work is lively and exciting. As always in astronomy, the direction that spectral classification of the future takes will depend on the people involved and the instrumentation available.

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DISCUSSION

Feast: I am intrigued by your reference to Miras in the Magellanic Clouds. Do you know of some new ones? So far as I am aware there are only one or two known.

Garrison: No. In fact, we have only just started this project and I believe that Corbally has written to you about it. We were hoping that you would have some new data. Gaposhkin has published lists of variables, but I do not know how usable they are.

Gratton: Population II stars are difficult to classify because the features are often very different from those of Population I stars. Another difficulty arises from the fact that, because of instrumentation limitations, a different wavelength region must be used. A careful comparison of other wavelength regions to that of the MK system is urgently needed.

Garrison: In the new atlas by Keenan and McNeil an attempt has been made to consider Population II stars and several comments are offered therein for future research. The problem of different wavelength regions is a serious one and will be the topic of several other discussions at this meeting.

Mendoza: In 1969 I published a paper in which I derived solar colors from 0.3 to 3.4μ. These colors agree very well with solar parameters (Pub. Astron. Dept. Univ. of Chile, No. 7, 1969).

Walborn: I think that, with dispersions near 100 Å mm^{-1}, consideration of the entire spectrum is probably the best way to determine MK types. The disadvantage of this method is that, if systematic peculiarities exist in a group of spectra, one may integrate over them and eliminate the possibility of discerning these peculiarities. I would, therefore, make a distinction between the determination of MK types, and the application of the MK technique to discover and describe new phenomena. In the latter case it may be advantageous to use a somewhat higher dispersion and some specific criteria for the two-dimensional types, so that other spectral features may be described relative to them.

Code: I would like to make an historical note on the Stebbins and Kron measurement of the Sun. This, of course, consisted of six color photoelectric photometry of stars, standard lamps, and the Sun by use of an effective neutral Sun reducer. Observations were carried out very carefully over an extended period of time. When colors were compared with the older Mount Wilson types of the solar analog stars the correlation was poor. Stebbins asked Morgan

to classify the stars without telling him why. Inspection of the published paper of Stebbins and Kron shows that the MK spectral types are exactly ordered in terms of colors and discriminate as small a difference as $0^{m}.02$ in color. The spectral types of these stars were totally consistent with a spectral type of G2V for the Sun.

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