CRITERIA AND APPLICATIONS OF THE MK CLASSIFICATION (EARLY TYPE STARS)

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ABSTRACT

The fundamental characteristic of the MK classification system is the definition of an array of standard stars, arranged in two dimensions. New techniques and an enormous increase in observational and theoretical work since the original catalog in 1943 have in various ways complicated the problem of spectral classification. Problems discussed are: 1.) The re-examination of standard stars; 2.) The optimum dispersion and the limits of dispersion for MK classification; and 3.) Some groups of peculiar objects.

The MK classification system is two-dimensional. The physical phenomena which give a stellar spectrum its appearance have more than two dimensions and, besides, the parameters describing the stellar atmospheres change in a continuous way. No two-dimensional system can of course reproduce these facts. The great success of the MK system lies in the fact that it is a very practical method to divide the stars into groups from which new investigations of other kinds can be undertaken.

The basic principle behind the MK classification scheme is a comparison between the spectrum of an observed star and a set of standard stellar spectra. By the aid of certain well defined criteria the star can be placed into a "box" to which is assigned a spectral type and a luminosity class. The criteria express comparisons between strengths of various lines and bands and appearances of them. Another criterion is the entire picture of the spectrum in the actual wavelength region which should also be compared to the standards. The criteria can sometimes be somewhat contradictory.

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An important point, which has often been stressed by Morgan, is the differential nature of the MK classification. The system is not meant to give absolute determinations. This implies that the standard stars, which form the reference frame, in principle, must not be changed or revised. Or, if a change of a primary standard star has to be made for some reason which was unknown from the beginning, a new standard should be set up.

The great usefulness of the system is a consequence of the fact that there are two parameters dominating over the others in the characterization of a stellar atmosphere, namely effective temperature and gravity. Another effect from which the system profits is that several characteristics of a stellar spectrum give the same information, so you can use two or more criteria in assigning an MK class to a certain star.

The earliest MK classifications were all made by a small group of astronomers. Later, an increasing number of observers outside the original group has published MK classes. The scattering in various determinations for the same stars, which was a consequence thereof, is sometimes discouragingly large. This is well illustrated in the compilation of MK classifications made in the La Plata catalog (1964). The problem of selecting one class among the various determinations is often difficult for the many investigators who want, for example, to compare indices from some photometric system to MK classes. Usually in such cases, the "original" determinations are preferred, but sometimes it is not possible to find suitable stars classified by the most experienced workers in this field.

It is of course a very unsatisfactory situation if we have several MK systems of which some are made by "well-known" classifiers and considered to be superior to other determinations.

To avoid such a situation and still stick to the original principle of classification it is necessary to have more standard stars giving the reference frame. The standards should be well spread over the sky. These are the most important tasks to be carried out in the near future.

It is very fortunate that Drs. Morgan and Keenan themselves have undertaken the work of a general re-examination of the original MKK atlas of 1943.

The subjective nature of the original MKK classification technique, however, apparently can lead to a situation where only a few classifiers can handle the system. It is therefore well motivated, in my opinion, to support visual inspection of the spectra with some kind of quantitative measurements, from photometric methods or in other ways.

Quantitative measurements are something that is contradictory to the original considerations in the MKK classification system. In the forward to the MKK catalog in 1943 it is stressed that an over-all picture of a stellar spectrum can be obtained by visual inspection alone and a description thereof, or a MK class, can be given in that way. The enormous amount of new data in the field of spectral observation and analysis has, however, complicated the field of spectral investigations and an adaptation of the MK system with its original principles to the new astrophysical discoveries is necessary.

Photoelectric photometric systems can give a sort of quantitative determination. To test a photoelectric system it is usual to compare various indices derived for a group of stars which already have been classified in the MK system with their MK classes. When such a calibration is performed it is possible to go in the other direction: to obtain MK classes from indices determined from photoelectric photometry. Care must be taken, however, in all such calibrations and determinations. For the calibrations only stars which definitely fall in the original reference scheme should be used and, for the determinations, it must be remembered that MK classes derived by means of photoelectric indices are not necessarily more precise than what can be determined from visual inspections of the stellar spectra.

In this connection it is worth mentioning that spectral work is not always more time consuming than photometry. It requires larger instruments and perhaps more time at the telescopes but many nights can be used for photographing spectra but not for photoelectric photometry.

An investigation carried out by Dr. Sinnerstad (1979) at Stockholm Observatory illustrates what has been said above. In this work, which will be presented later, a comparison is made between the MK classes and the atmospheric fundamental parameters (effective temperature and gravity) which have been obtained from measurements of equivalent widths and line profiles. The 75 stars considered are all B stars on the main sequence. There are good relations found for θ_{eff} and log g and MK classes for the primary MK standard stars. A comparison is also made between the derived θ_{eff} and log g and the average indices in the uvbyβ system for various MK types, taken from Crawford (1978). From this comparison it is seen that the photometric parameters for luminosity class V seem to fall in the region for luminosity class IV of the standard stars, as derived by Sinnerstad. Also the parameters for luminosity class III are generally displaced towards the region for luminosity class IV of the standard stars. A natural explanation is that the MK classes for luminosity used in these investigations are not in the original system but have been displaced during the processes of new MK classifications outside the range of the original standard stars.

The energy maximum for the earlier type stars lie in the ultraviolet region. Spectra in the wavelength regions 1300 to 2500 Å have now been obtained for several thousands of stars from satellite observations. Attempts to separate these stars according to temperature and gravity from spectrophotometric criteria or from color indices derived entirely from the ultraviolet spectrum have been made (Cucchiaro 1976, Nandy et al. 1976). Preliminary comparisons between these new criteria and MK spectral types and luminosity classes have been derived. New MK classifications for 250 stars with satellite observations have recently been published by Roman (1978). These new MK values will give a better base for such comparisons.

The original MK catalog used slit spectra at a dispersion of 125 Å/mm. Applications of the criteria to other dispersions and to objective prism work are natural extensions of the system.

It is well known that the number of stars with designation "p" for peculiar increases when you go to higher dispersions. Both "peculiarities" and "normal" features in stellar spectra can look very different in various dispersions. Some good indicators of luminosity are best seen in low dispersion. A good example on this effect is the appearance of the hydrogen line wings, which are broader for stars of lower luminosity. This effect is more difficult to see by visual inspection in higher dispersion.

Earlier investigations, quoted in the MKK catalog, point to a minimum dispersion of about 140 Å/mm for good accuracy in a two-dimensional classification when objective prism material is used. If this low dispersion limit should be used, the plates must be of good quality and the widening should be optimal.

On the other hand, for more detailed studies it is necessary to use higher dispersions than 125 Å/mm, in which you can see the lines better defined. Especially when peculiar types are studied a dispersion of about 60 Å/mm is needed. Sometimes still higher values are desirable. The most difficult stars to classify are the B8 - A2 stars; the whole group can easily be isolated even at low dispersions but it is impossible to trace peculiarities even at 60 Å/mm (Osawa 1965).

Several spectral workers have tried to apply MK classification to low dispersion objective prism work. In the Bonner spectral atlas compiled by W. Seitter (1976) MK standards and known peculiar objects have been observed at the dispersions 240, 645 and 1280 Å/mm. It seems to be clear that part of the MK classification scheme can be used even at the lowest of these dispersions. It is for example possible to detect class Ia supergiants from the material. It was found empirically that the equivalent width of the faintest visible feature in mÅ should be approximately equal to the dispersion in Å/mm. It is also required that the broadening should be of the order of 1 mm and of course that the line width should be smaller or about equal to the spectral resolution.

In the Stockholm spectral survey of the Southern Milky Way (1976), which up to now contains 18000 early type stars, the dispersion is 240 Å/mm at H_γ and the useful spectral range is 3900-4900 Å. The plates have been taken with the ADH telescope at Boyden Observatory in South Africa. In taking a large plate material it is seldom possible to cover the whole survey with plates of optimum quality. On the best plates we considered it possible to obtain a two-dimensional classification from visual inspection from MK criteria usable at this dispersion. The criterion used is then, mostly, the appearance of the hydrogen line wings.

Generally, however, the plate material does not permit more than a spectral type designation. Thus, in the catalog only the spectral type is given with the obvious risk for misinterpretation of, for example, a B8 star of luminosity class III to be listed, say as a B5 one. In our opinion it is preferable to present the material in this way; all information is now homogeneous in the catalog and it is hoped to be a valuable finding list although the spectral type designation does not uniquely correspond to the same designation in the MK catalog.

A standardization or a comparison of our material to the MK system has not been possible because of the fact that there are very few MK classified stars in the Southern Milky Way; the existing are normally over-exposed on our plates.

A comparison of the Stockholm spectral types O-B5 to HD classes for 1050 stars in common shows that, on the average, the Stockholm classification is systematically shifted towards earlier type with respect to the HD classes. A shift of this kind is also found from comparisons of the HD and MK spectral types in other investigations.

To summarize what has been said about low dispersion (lower than 140 Å/mm) objective prism work: some of the MK criteria can be used, some can be transferred and some new ones can be found (new blends of lines). The eventual MK designation should then always be given together with the value of the dispersion used. Various catalog designations of the same star cannot, of course, be compared directly. The value of such investigations lies in the internal homogeneity of the material included.

Objective prism material with dispersions similar to the recommended MK one has been undertaken in the very extensive work by Dr. Houk (1979), which includes re-classification of all stars in the Henry Draper catalog. When this work is complete we shall have a very large number of stars classified according to the same principles and constituting material for statistical investigations, up to now not possible.

Among the problems which hopefully can be better understood when the re-examination for the early type stars is completed is the varying intensity of helium lines. Abnormally strong lines of He I have been found and reported for some stars. No explanations in terms of differing temperature or luminosity seem to be possible at present.

Another problem to solve is the very broad hydrogen lines found for some stars in the Orion region, an effect that is very obvious also at low dispersion.

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DISCUSSION

Geyer: My opinion is that one should not speak about reciprocal linear dispersion D in A/mm with which MK classification can be done. The essential value is the spectral purity $\delta\lambda$ which is given in objective prism work or slitless spectroscopy by the "seeing" angle β, the angular dispersion of the prism and/or grating and the camera focal length f: $\delta\lambda = D \quad f \quad \beta$. Therefore one may have poor spectral purity (or resolution) though D is small. According to my experience $\delta\lambda$ should be $\leq$ 5 A if MK classification is to be done.

K. Lodén: The dispersion is not the only information necessary for an interpretation of the observations. You have to describe other details of the instrument also.

Walborn: The same comment by Prof. Geyer applies to slit spectrograms. The spectrographs developed at Yerkes and at AURA have higher resolution and consequently for a given dispersion the weak lines are more visible than they are for other spectrographs.

Keenan: I agree with Dr. Loden that more standard stars are needed. There were not enough of these in the Atlas of Keenan and McNeil, but we are preparing a longer list of late-type stars, and hope to publish it by next spring.

Ardeberg: You said that on your best-quality plates you could make two-dimensional classification. What do you actually mean by two-dimensional?

K. Lodén: I mean spectral type and luminosity class in the MK system for the early type stars.

Garrison: With regard to your comment about supplementing visual inspection classifications with quantitative information, I presume you know the way; but just for the record, I wish to remark that it is essential to determine the type by visual inspection independently and then compare it with the quantitative data. It is only in this way that no important information is lost.

With regard to Keenan's remark about new standards in the southern hemisphere, I have good spectra obtained at a minimum of two different dispersions for each star of the 1300 brightest stars in both hemispheres. The classifications are underway and I hope that one of the results will be additional standards in the south.

Gratton: I wish that people who dealt with standard spectral types would pay attention to faint stars. It is often very difficult to compare bright stars with faint stars, not only because of dispersion or resolution, but also because of noise introduced by intensifiers or by sky background etc.

Andersen: I should like to supplement Dr. Garrison's request for observers to determine MK type with care, with a plea to catalogue compliers to be similarly careful in including only "MK-types" which are as a minimum based on inspection of actual spectra, and not on entirely different kinds of information which not infrequently are translated by authors into the MK notation.

Abt: With regard to Dr. Gratton's comment, there should be no problem in comparing bright and faint stars if a high-quality neutral-density filter is used for the spectrograph. With such a filter the spectra of bright stars look identical to faint ones of the same types.

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