* This paper is dedicated to my father, William Thomas Morgan (1877-19??). You will never know what I owe you.

THE MK SYSTEM AND THE MK PROCESS

W.W. MORGAN*

Yerkes Observatory
University of Chicago

At some point one has to pass from
explanation to mere description.
L. WITTGENSTEIN, *On Certainty*

Abstract. A methodology is described that permits the development of new spectral classification systems that would supplement the MK System by making possible accurate classification of Population II stars, and other eccentric categories of stellar spectra.

Table of Contents

Next Contents

1. INTRODUCTION

This paper is based on the conviction that a greater degree of discrimination is possible in spectral classification than that now obtainable with the MK System. This is due principally to incompleteness in the system itself. The MK System furnishes a satisfactory frame of reference for stars of Population I in the solar neighborhood; but when we consider the variety of stellar spectra encountered in our galaxy and in other stellar systems we are unable to classify many stars satisfactorily from the MK standards alone.

What we now require is a more general frame of reference - or frames of reference - that will accept with precision a greater variety of ``specimens'' (stellar spectra). To bring these into existence, we propose to supplement the MK System with additional systems that will be constructed according to what we shall label the MK Process.

Next Contents Previous

2. THE MK PROCESS

By ``MK Process,'' we label a specific methodology that makes possible the construction and use of systems of classification based on the particular observed characteristics of stellar spectra that have been selected to define the frames of reference. These systems must be autonomous; that is, they are to be defined completely by the appearance of the spectral features in arrays of standard stellar spectra, in a specified interval of wavelength.

Each of these autonomous systems must also be self-consistent; that is, the array of individual standard stars must constitute - and define - an orderly assemblage, from the point of view of the behavior of the spectral lines, bands and patterns, within the spectral intervals of the standard array. The interval $\lambda\lambda$3850-5000 has been used most commonly in the past.

The autonomy of each array is achieved through its liberation from dependence on the results of stellar-atmospheric computations - or on any other theoretical models.

For such systems to be completely autonomous, we cannot require them to be attachable to the MK System - or to each other. They complement each other; but they each must live separate, independent lives.

Each new system is to be defined by a network of boxes (as in the MK System); and each of the boxes is to be defined by a specific stellar spectrum in a specific wavelength interval.

The increasing use of *patterns*, in place of the line ratios used principally earlier, can increase the discrimination in classification from both stellar spectrograms and stellar scans.

Next Contents Previous

3. MACROSCOPIC PROPERTIES OF THE MK PROCESS

Some general characteristics of the MK Process are:

1. An apparent simplicity.

2. An ill-defined complexity, which reveals vistas of major expansions and great richness.

3. The realization that no precise definition of the MK Process can be accepted, because of the intrinsic scope and generality that are implicit in the process itself.

The only satisfactory ways of defining the MK Process are (*a*) by examples of its use; (*b*) by isolated statements concerning aspects of its nature; and (*c*) by developing sequences of questions [not answers!] that are capable of transporting the observer into a mental climate that is, identically, the only complete form of the MK Process itself.

Among the isolated statements that can be made is the following:

The MK Process is a procedure, a methodology, an operator, that makes possible the arrangement (classification) of stellar spectra into prepared structures that are defined by the spectra of arrays of individual standard stars.

Next Contents Previous

4. THE ACT OF SPECTRAL CLASSIFICATION ACCORDING TO THE MK PROCESS

We are given a two-dimensional array of boxes - each box defined by a single stellar spectrum, or spectral scan.

The classification of an unknown stellar spectrum makes use of all features (lines, bands, blends, patterns) within the specified wavelength interval. The classification act itself consists of comparisons with the series of standard spectra that define the boxes, with the question: ``Is the unknown spectrum (x) `like' or `not like' this particular standard spectrum?"

A ``like" classification does not imply identity in the appearance of x and the comparison spectrum. On the other hand, the resemblance is close; after a certain amount of experience, the ``like" judgment becomes stabilized.

If only ``not like" judgments are obtained for all boxes in a system, it is necessary to go on to comparison with the boxes in other systems.

The procedure outlined above implies the availability of a number of classification arrays (compatible with the MK Process) that include all types of stellar spectra frequently encountered in our Galaxy and in other nearby galaxies. The preparation of the arrays is a pressing problem for the immediate future.

Next Contents Previous

5. FRAGMENTS OF TWO NON-MK SYSTEMS

The spectrum of HR 4049 = HD 89353. This spectrum is under investigation by Helmut Abt; I am indebted to Dr. Abt for permission to include the following observations.

The only lines visible on 39 Å/mm plates in the range λλ3900-4900 are rather narrow H lines and a weak Ca II K line. Abt has assigned a type of A0 Ib-II, with marked peculiarities. The He I lines at λλ4026 and 4471 (which are easily visible in the A0 Ib standard η Leo - and are strong in the B7 III standard β Tau) are absent; also absent are the strong lines of Fe II and Mg II, which are outstanding in η Leo. On a coudé spectrogram, the K line is resolved into two components: one stellar and one apparently interstellar. The spectrum of HR 4049 is illustrated in figures 1 and 2 [plates 1 and 2] from Dr. Abt's spectrograms.

It can be seen from the above that there is no MK box that can accept the spectrum of HR 4049 satisfactorily; the line weakening is pronounced.

The spectrum of HD 22879. This spectrum is reproduced in the Morgan-Abt-Tapscott *Revised MK Spectral Atlas for Stars Earlier than the Sun*; it is in plate 31 therein.

Here, we have a smaller degree of line weakening than in the case of HR 4049; however, it is great enough to bar satisfactory classification in any box of the MK System.

Next Contents Previous

6. TERMINOLOGY FOR WEAK-METALLIC-LINE CLASSIFICATION SYSTEMS

These non-MK types consist of two parts: (1) a notation for the particular system, which depends on the degree of line weakening - we adopt here three systems, (m-1), (m-2), and (m-3), for progressively greater line weakening; and (2) a spectral type in the particular system. The latter is evocative of the MK System, but uses small letters instead of capitals, and the type is enclosed in square brackets; these emphasize the fact that the types are not on the MK System.

The types then are:

HR 4049: (m-3) [a0 ib-ii]
HD 22879: (m-1) [f8 v]

Dr. Abt and the writer are now engaged in setting up complete systems for the above three categories of line weakening. In this connection, it must be emphasized that such types as those shown above are independent of similar MK types; these types *cannot* be used with the calibrations for MK types; and completely new calibrations for luminosity and intrinsic color will have to be carried out when a sufficient number of stars have been classified on the new system.

Next Contents Previous

7. AN ALTERNATIVE PROCEDURE IN SPECTRAL CLASSIFICATION

The new classification systems just outlined have two strong similarities to the MK System: the boxes that comprise them are defined in each case by the spectrum of a single star; and the occupants of each box resemble each other closely in their spectral appearance. There are, however, certain categories of stellar spectra that could require a different approach; these categories could be labeled as stellar spectra which contain an outstanding feature (line, blend, pattern) that discriminates them from the ordinary inhabitants of the boxes of the MK System.

In such cases, it could be of considerable importance to make the first stage in classification a simple segregation of all spectra containing such a feature into a single ``basket.'' The inhabitants of such a basket could represent wide varieties of stellar spectra, but would have the single property - the outsanding feature - in common.

Next Contents Previous

8. SPECTRA SHOWING THE STELLAR-WIND LINE HE I 3888

Figure 3 [plate 3] shows the spectrum of the WN star HD 192163, together with the Of star λ Cephei (the plate has been adapted from plate 2 of the Morgan, Abt, and Tapscott Atlas of 1978). The normal position of He I 3888 has been marked by small black triangles; the radial velocity of the strong, shifted absorption line in HD 192163 is - 1,400 km/s. One WN star, HD 191765, shows a somewhat weaker λ3888 at a radial velocity of 1,600 km/s.

There are also B-type stars showing this same, blue-shifted absorption line. Merrill (1951) has observed multiple absorption components of He I 3888 in BD + 11°4673; as many as eight components were observed with radial velocities covering the range - 36 to - 428 km/s. The components vary rapidly in position and intensity, and comprise a spectacular example of stellar winds.

The strongest absorption line in the spectrum of the Be star RY Scuti = HD 169515 is He I 3888, and it may be another example of the stellar-wind line.

Next Contents Previous

9. FURTHER CLASSIFICATION OF CATEGORIES LIKE THE HE I 3888 ``WIND-LINE'' STARS

After the identification and collecting together of an appreciable number of members of this group, we are faced with a different kind of problem in deriving a complete spectral classification for them. Their approximate spectral types range from Wolf-Rayet and O at the earlier type to around middle B at the later. The optimum procedure cannot be predicted for such situations in advance; and it does not seem even certain that the spectral-type/luminosity-class parameters used for normal spectra will be the most natural for members of such a group.

Next Contents Previous

10. GENERALITIES CONCERNING THE NATURE OF THE SUPPLEMENTARY SYSTEM

The supplementary systems envisaged above will be usually two-dimensional, and these two dimensions usually will be correlated closely with intrinsic color and luminosity; however, it is crucial not to require such a correlation. In each particular case, it is of prime importance to the autonomy of the particular situation that the most ``natural groupings'' of the spectra be followed - no matter what the physical situation may later turn out to be.

Some of the supplementary systems may incorporate specimens over a great range of intrinsic color and luminosity; others may be located in a limited area of the HR diagram.

In a great majority of the new systems the defining ``boxes'' will resemble the MK boxes in including only spectra that resemble each other closely. However, in the ``baskets'' such as that containing He I 3888 stellar-wind spectra, a wide variety will be found; but one very interesting fact will be true for the inhabitants of each basket: *they will share one outstanding, particular characteristic in common with other specimens in the same basket*.

Next Contents Previous

11. SUMMARY

The writer has outlined a methodology that makes possible accurate classification of categories of stellar spectra not dealt with in detail in the MK System. This has been done by introducing a concept which is labeled the MK Process - a procedure which makes possible the construction of an indefinite number of new systems of spectral classification. Each of these new systems is autonomous, and independent of the MK System - and of each other.

Bringing these new systems into operational existence will make possible precise classification of the very great majority of all stellar spectra in our Galaxy and those observable in the nearest external galaxies.

Next Contents Previous

12. PENDANT: MORPHOLOGY OF SPECTRAL FORMS

The interchange between the spectral forms (spectrograms) and the observer is an individual thing. It could be said, with some truth, that the spectral forms have helped to classify themselves, by showing where they are most comfortable.

Contents Previous

13. ACKNOWLEDGEMENTS

The writer is deeply indebted to many persons for various reasons concerning the present paper:

To Helmut Abt, for making the investigation possible by offering a large number of spectrograms obtained by him at Kitt Peak National Observatory. He has also given valuable suggestions in the course of this work.

To Dimitri Mihalas, for many discussions through the years on problems connected with one of his fields of highest distinction, stellar atmospheres, and for his continuing encouragement of the writer's attempts to explore certain conceptual fields.

To Lewis Hobbs and Al Harper, in their successive periods of Directorship of the Yerkes Observatory, for their support of the writer's efforts to continue creative research; to the University of Chicago for its encouragement of this work.

To Robert Garrison for arranging and hosting the June 1983 conference at the University of Toronto, where the present paper was given.

To Don Osterbrock of the Lick Observatory, for his continued encouragement during the course of this work.

To Richard Kron for discussions of problems.

To Paul Rybski for numerous conversations concerning fundamental issues raised in connection with this paper.

To Richard D. Dreiser for preparing the three illustrations.

To Mrs. E. Cox and Mrs. J. Draeger for stenographic help.

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1. Merrill, P.W. 1951, Ap. J., 114, 338.

Contents Previous