REVISED MK SPECTRAL ATLAS FOR STARS EARLIER THAN THE SUN

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To ANTONIA C. MAURY
(1866 – 1952)

Master Morphologist
of
Stellar Spectra

Preface to the ULO Version

This version of the Revised MK Atlas was produced by M. M. Dworetsky and W. R. Reece at the University of London Observatory, University College London, with permission from one of the authors, H. A. Abt.

While every effort has been made to ensure that this version of the Atlas is a faithful copy of the original, mistakes may have occurred. Please submit corrections to mmd@ulo.ucl.ac.uk.

This version includes a table of contents and a star name index not included in the original version of the Atlas.

High resolution scans of the catalogue plates are available on the World Wide Web. The home page for these is:

www.ulo.ucl.ac.uk/catalogues/mkrevised/

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I Introduction

Terminology: MK Diagram: The two–dimensional diagram relating MK spectral type and luminosity class.

The present Atlas was prepared to satisfy three requirements: (1) To furnish an improved version of the out–of–print **Atlas of Stellar Spectra** by Morgan, Keenan, and Kellman (University of Chicago Press, 1943) for stars earlier than the Sun; it thus complements the Keenan–McNeil Atlas for the stars of later type. (2) To decrease the classification "noise", for the sake of determining spectral types and luminosity classes as precisely as possible from plates of relatively low dispersion. (3) By means of (2), to demonstrate how rich the prospects can be for classification in the future, by making use of conceptual improvements developed here, and incorporating them in what we describe as the MK–78 system. These processes, when taken together, will have the result of introducing a finer structure over that part of the MK Diagram occupied by stars earlier than the Sun.

The process described under (3) brings us to a major characteristic of the present Atlas: it is by no means a definitive work. In the early stages of its preparation there was a feeling that it might furnish all that needed to be said about its field for an indefinite period or even forever. As the work of preparing the Atlas plates progressed, however, it became clear that the field was being opened up increasingly to new fine structure in the MK Diagram, and to new localized third dimensions. These developments now indicate convincingly that there can be no such thing as a "definitive" spectral atlas so long as a body of unrecognized, and uninvestigated, specimens exists in the observable region of the universe.

When we label the revised system defined by this Atlas as the MK–78 system, we are taking a step that requires further comment. The earlier MK "domain" has been the spectral region Hβ – Ca II K; here, we extend the spectral range used to the neighborhood of λ 3500 in the cases of certain categories of stars. The Atlas plates show the spectral range used, by the features marked. This increase in spectral range has been possible because of the remarkable quality of the low–dispersion spectrographs designed by a great astronomical instrumentalist, Dr. A. B. Meinel, the first director of the Kitt Peak National Observatory. These spectrographs were installed on several of the smaller reflectors at Kitt Peak and at the Cerro Tololo Inter–American Observatory, and were used by Dr. Abt to obtain all of the spectrograms of lower dispersion illustrated here. Such spectrograms, having dispersions in the range 63

and distances — and for adding the greatest amount of justified detail to the MK Diagram.

VI Spectral Classification in Globular Clusters and in Galaxies

It can be seen from the preceding section that the present Atlas is not adequate to deal with the classification of stellar populations like globular clusters and the Galactic halo population. It is also not suited to precise classification of stars in extragalactic systems which are at differing evolutionary stages from our own Galaxy. In the general case of classification of stars in other galaxies, the most crucial requirement is to retain as much particular information as possible. To guarantee this, we should not take for granted *any* similarities with stars in the solar neighborhood, and should: (1) Create a new, self–consistent classification from the stellar spectra available in each object, using a notation completely different from that of the MK system; (2) when this is finished, we should confront the resulting classifications with the MK classifications as illustrated in the present Atlas; (3) from this confrontation, we should then assess the differences and similarities between the stars in the other galaxy and those in our own. The above procedure can be used only if a considerable number of stars have been observed in the particular galaxy; when only small numbers of spectrograms are available, they must be referred to the MK standards, and their similarities and differences noted.

VII A Note on Classification in the Satellite Ultraviolet

A classical example of the approach to spectral classification in any new spectral region is furnished by Bidelman's recent paper on spectral classification from Copernicus ultraviolet data (*Highlights of Astronomy, Vol. 4, Part II*, 355–359, 1977). The approach described by Bidelman is a model for a procedure that guarantees preservation of the maximum justified information — and for a careful, descriptive comparison with spectral types from the normal MK spectral region.

VIII Conclusion

We present herewith a revised structure for the classification of stars earlier than the Sun. The structure has greater precision than that of the MKK Atlas of 1943, partly because of the use of single standard–stars to define each classification box. There are still important problems awaiting attention: (1) The classification of very broad–lined early–type stars is intrinsically less exact than that of the narrower–lined objects; what is needed here is a frame of reference consisting entirely of very broad–lined stars, with this frame fitted to the standard MK–78 boxes by the use of low–dispersion ($\sim$150 Å/mm), fine–grain, high–contrast spectrograms, which would minimize differences in appearance between n and s stars. (2) The MAT Atlas is applicable only to Population I stars; still needed is a general classification that would include Population II stars. (3) The calibration of the MK Diagram for the determination of physical parameters will have to await classification of large numbers of stars on the MK–78 system.

One of us (W.W.M.) wishes to make the following acknowledgments: for the support of a series of grants from the National Science Foundation, which made possible both the

Notes on Atlas Plates

The dispersion of all spectrograms illustrated is □125 Å/mm, unless otherwise noted.

Plate. 1. Main Sequence O4 – O9

We may obtain spectral types earlier than O4 – O5 by discovering stellar spectra showing a higher level of excitation than the stars of similar luminosity which are MK standards at O4 – O5; we may also obtain earlier types by expanding the scale of classification for the O stars by moving the MK standards toward earlier types. The first procedure is clear; the second tends to distort the scale of the MK system.

An important problem for the future is the spectrographic identification of the ZAMS for the O7 – B2 stars. The brightest members of the Orion Nebula cluster show abnormally broad absorption wings for the Balmer series of H (see Ann. Rev. Astronomy and Astrophysics, Vol. 11, Illustration on page 35, 1973). This phenomenon is not shown by the main–sequence stars illustrated in Plate 1. A question to be answered is: Are the luminosities of the stars in Plate 1 higher than those of similar spectral type in the Orion Nebula cluster (the Trapezium cluster)?

Plate. 2. The O5–O6 Supergiants and Two He I 3888 Wolf–Rayet Stars

The scale of the print of ζ Pup is somewhat more extended in the ultraviolet near N IV

Plate. 7. Three O8 – BO Supergiants

The concluding sentence of the legend should read: "...we consider the ratio O II : O III to be the fundamental discriminant for spectral type for O9 – B0 supergiants."

Plate. 11. Luminosity Effects at B2

The relationship of the Orion "helium stars" to the ZAMS is an interesting problem. In δ Ori (ft) the He I sharp triplet at λ 4121 is much narrower than the He I diffuse singlets at $\lambda\lambda$ 4009 and 4144. He I 4121 is similar in width in the B2 V standard β Sco (ft) and in δ Ori (ft), but the diffuse singlets and triplets are considerably narrower in the former. Can this be considered as indicating a lower spectroscopic luminosity for δ Ori (ft) than for β Sco (ft)?

Plate. 12. Strong Helium Stars in the Orion Association

Plate. 18. Luminosity Effects at A0

The high optical quality of the low–dispersion spectrographs designed by A. B. Meinel makes practicable extremely sensitive discrimination of the extent of the wings of the Balmer lines for stars in the neighborhood of class A0. This has made possible the splitting of MK box A0 V into two: A0 Va and A0 Vb. Stars of the former class turn out to be, in general, main–sequence non–cluster stars (such as the fundamental standard α Lyrae) and main–sequence stars in evolved clusters. Spectral type A0 Vb exhibits markedly broader wings on the H lines, for stars of similar rotational line–broadening; examples are found among clusters having main–sequence turn–offs at B3 and earlier. The star NGC 2516 #29 is located at the extreme edge of the cluster, and does not seem to be a cluster member, since its cluster luminosity would be M_V □ 0; the spectrum does not resemble that of a white dwarf, since many members of the Balmer series are observed. Its true nature remains to be determined.

It appears feasible at the present time to split spectral types B9 V and B9.5 V into luminosity classes Va and Vb. The star HD 19805 (HL 167 in the α Per cluster) is a good candidate for the standard B9.5 Vb; it is illustrated on Plate 13, as of type B9.5 V.

Plate. 20. Three Ap Stars

The discovery by Babcock that HR 2534 is a very rapid spectrum variable (pronounced changes in 24 hours) makes it of importance to obtain a series of low dispersion spectrograms for investigating the behavior of the line patterns with the spectral variations. If these line patterns show great changes in appearance, it may be possible to discover other examples of this uniquely interesting star from low–dispersion plates — or even with objective prism cameras.

Plate. 22. 17 Lep: An A–Type Shell Star

The exceedingly strong shell absorptions of Ti II at $\lambda\lambda$ 3685 and 3759–61 in 17 Lep are from the lower level a^2F, which is metastable and has an E P of 0.6 volt. These same absorptions have been observed as shell lines in rapidly rotating A stars by Abt and Moyd (Ap.J., 182, 814, 1973).

would also have been observed. For this reason, we feel that the diffuse K–line in HR 4369 is probably similar in nature to that observed in so many Sr II stars.

Note on the Spectrum of a Scl

The announcement of α Scl as a member of the peculiar manganese group by Morgan (Ap.J., 73, 109, 1931) was an error, and is withdrawn herewith.

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