AUTOMATIC MK SPECTRAL CLASSIFICATION. I. EARLY TYPE STARS

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ABSTRACT

A scheme of automatic MK spectral classification is presented. It is based upon standard spectrograms obtained for visual spectral classification. Computer results are given for all the MK standard stars earlier than B1. They are well correlated with the MK system. However, the results might be improved by using a rapid-scanning Michelson Fourier Transform Spectrophotometer to obtain the stellar spectra. The analysis of the interferograms should also be made by a computer.

1. INTRODUCTION

The MK system has been the key in the solution of a number of important astronomical and astrophysical problems. However, reliable MK spectral classification is made by only a very few people, mainly because visual spectral classification is difficult. This statement is supported by the fact that there exist many discrepancies among the published spectral types and luminosities classes. Differences by the same author are not particularly uncommon.

Herein we present a preliminary outline of automatized MK spectral classification based upon standard slit-spectrograms obtained for visual spectral classification. We have been unable to complete the system because of a series of problems which prevented us finishing the observations. Nevertheless, we feel that our results clearly indicate the procedures to follow for classifying other spectral types. The main purpose of this work

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is to provide an easy technique that can be used to re-classify consistently and quickly most of the existing slit spectrograms, having a scale on the plate between 80 and 150 Å/mm, approximately.

2. THE OBSERVATIONS

Spectrograms of 43 stars listed by Morgan (Morgan and Keenan 1973) from O4 to G2 were secured with the grating spectrograph attached to the 33-inch reflector of the Observatorio Astronomico Nacional at San Pedro Martir, B.C. (Mexico) during 1976 and 1977. The dispersion of the spectra is 80 Å/mm, approximately. The plates were obtained on Eastman Kodak IIa-O emulsion and were developed in D76 for twelve minutes at 20°C. The projected slit-width on the plate was 12μ; the projected spectrum-width on the plate was 650μ. No plate was calibrated; moreover, 40% of the spectrograms have no comparison spectrum.

We include in this work only all the MK standard stars earlier than B1 (cf. Table I: Morgan and Keenan, 1973). This is due to the fact that our collection of plates is not complete. Therefore, the derived algorithms for automatically classifying stellar spectra are valid for the O4-B0.5 spectral range. For later spectral types slight modifications have to be done.

3. DIGITIZATION OF THE OBSERVATIONAL DATA

We have selected 21 spectrograms on 17 plates of the 14 MK standard stars earlier than B1. They are of good and poor quality; well, over and under-exposed; with and without comparison spectrum.

All the spectrograms have been digitized by using the Perkins-Elmer microdensitometer system (model 1010) of the Latin-American Scientific Center, IBM de Mexico. A window of 10 (width) by 400 (height) microns was used to record the spectra on a magnetic tape. The wavelength coverage of these discrete spectra is from 3700 Å to 5000 Å, approximately, resulting in 1551 points.

A glance at the raw data indicate three sources of misleading information, (1) unskillful use of the microdensitometer. Several recorded spectra became saturated on the edges, especially at the long wave-lengths; (2) dust or dirt deposited on the spectrograms during digitization or developing. Emission-like features were produced by this; (3) tiny scratches on the spectra. Absorption-like features were produced by this. To minimize some of these effects we have measured each spectrogram three times. It takes

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approximately one second to record the whole spectrum on the magnetic tape.

4. PREPROCESSING TECHNIQUES AND CLASSIFICATION CRITERIA

All the algorithms to analyze the data obtained with the microdensitometer were written in APL (Iverson 1962; Falkoff and Iverson 1968). All the computations were carried out at the IBM Scientific Center with an IBM 360/MVT system in 1977 and with an IBM 370/155 system in 1978. In both computers we have used the IBM's APLSV Program Product.

We find that using the microdensitometer's raw data directly the results are unsatisfactory. Therefore, we decided to study three different preprocessing techniques to derive a self-consistent system. They were Fourier filtering, Lorentz (and Gauss) curve-fitting and splines. Since through splines we obtained the best results, for the sake of briefness, it will be the only technique to be described below. However, it should be pointed out that it took us quite some time to test the other two, and decide in favor of the splines technique.

It was stated above that several spectrograms were obtained at the telescope with no comparison spectrum. Because of this, all the plates were set on the microdensitometer directly on the stellar H_{13}-line to start the measurements.

The MK system is a phenomenology of spectral lines, blends and bands defined by a list of standard stars. Thus, any scheme in the MK system has to take all this into account. For an automatic spectral classification made by a computer, two main steps have to be made, namely, (1) define a continuum; (2) derive line-ratios, which should be independent of atmospheric extinction and sensitivity of the equipment. This will be achieved if the pair of lines under study are properly chosen.

For most spectra a continuum can be defined by fitting a polynomial of third degree. For those with saturated edges a satisfactory continuum can be found also by fitting a polynomial of third degree to the unsaturated wavelength interval. For very poor spectra with small undamaged intervals a "continuum" can be obtained by fitting a straight line for each undamaged spectral line or blend, from a selection of the nearby points on each side of it.

The computer locates the exact position of H_γ, from there it goes to any lines or blends whose ratios will define one of the classification parameters. The spectral lines are smoothed by two cubic splines (Gilman and Rose, 1974) applied to odd and even points, respectively. The interpolated line is used to derive the area under it. The ratio of a pair of spectral lines is the ratio of the areas of the smoothed lines. This procedure can be done as many times as is necessary. The detailed algorithms for carrying out the procedure are available from the author.

The plot of a recorded spectrogram of 15 Monocerotis in which a polynomial of third degree has been fitted to define the continuum is shown in Fig. 1. This is an average spectrum. A plot of only the wavelength interval around 4471-4542 Å in which two straight lines have been fitted to define the continua of this pair of spectral lines is shown in Fig. 2. This is a poor spectrum outside of this spectral region. Again, the star is 15 Mon but on a different plate.

5. RESULTS

The results for the MK standard stars earlier than B1 are given in Table I. The stellar line and blend ratios listed in this table are based upon good and poor spectrograms. The most accurate values correspond to the ratio HeI 4471 Å/HeII 4542 Å (standard deviations are less than 10%). The ratio CIII + OIII) 4650 Å/HeII 4686 Å is the poorest (standard deviations are between 10 and 20%).

The relationship between the MK spectral type and the logarithm of the ratio HeI 4471 Å/HeII 4542 Å is shown in Fig. 3. It looks quite satisfactory. The plot of luminosity class versus (SiIV + HeI) 4119 Å/HeI 4144 Å for O9 type stars is indicated in Fig. 4; this also appears satisfactory.

6. SPECTRAL CLASSIFICATION OF THE FUTURE

The accuracy and reliability of the system described in the previous section can be increased by avoiding the use of photographic plates, since a major source of noise is the emulsion's grain (see Figs. 1 and 2) in addition to being a poor detector in other ways. Johnson (1977b) has developed a rapid-scanning Michelson Fourier Transform Spectrophotometer, which is superior, on the average, to any other technique for securing stellar spectra. The wavelength coverage of his Atlas of Stellar Spectra (1977a) is from 4800 Å to 10000 Å with a resolution equal to that produced by a coudé spectrograph giving a scale of 10 Å/mm

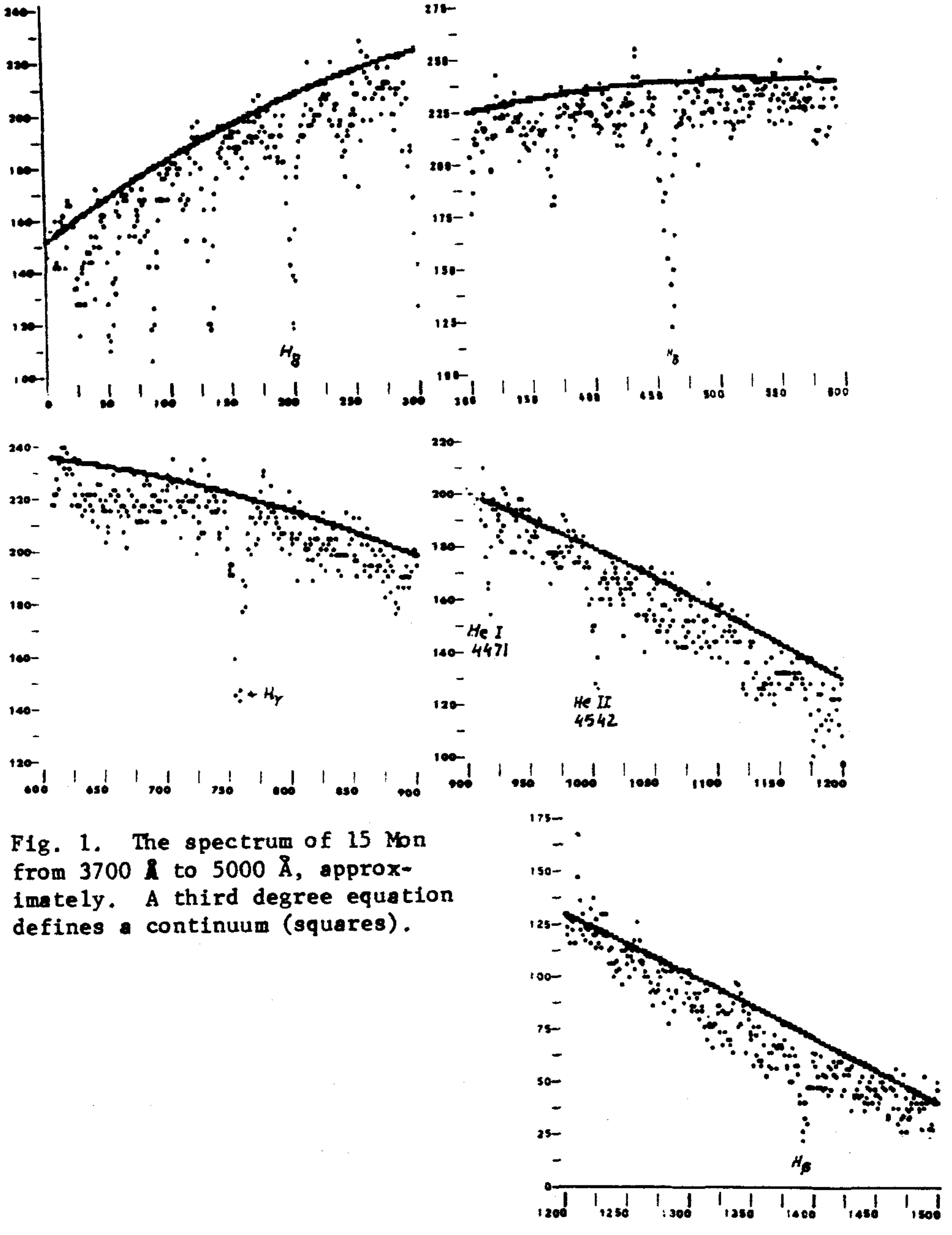

Fig. 1. The spectrum of 15 Mon from 3700 Å to 5000 Å, approximately. A third degree equation defines a continuum (squares).

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TABLE I

STELLAR LINE RATIOS FOR EARLY MK STANDARD STARS

Star		CIII/SiIV (λ4068/λ4089)	(SiIV+HeI)/HeI (λ4119/λ4144)	HeI/HeII (λ4471/λ4542)	(CIII+OIII)/HeII (λ4650/λ4686)
HD 46223	O4	0.32	0.67	0.39	0.7
HD 46150	O5	0.40	0.70	0.51	0.7
ξ Pup	O5f	0.24	0.90	0.24	em.
15 Mon	O7	0.40	0.81	0.95	0.7
10 Lac	O9V	0.57	0.77	2.15	2.0
ι Ori	O9III	0.40	0.83	1.97	1.8
τ CMa	O9Ib	0.45	0.96	2.08	2.8
σ Ori	O9.5V	0.55	0.50	3.20	4.7
τ Sco	B0V	0.50	0.50	5.04	2.3
ν Ori	B0V	0.77	0.66	2.45	4.2
ε Ori	B0Ia	0.71	1.96	3.00	4.2
δ Sco	B0.3IV	0.4	0.5	4.2	5.0
ε Per	B0.5III	0.7	0.4	5.8	4.1
κ Ori	B0.5Ia	0.8	1.0	5.1	9.4

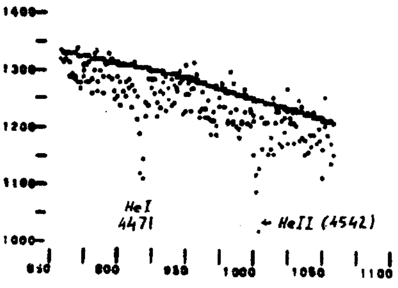

Fig. 2. The spectrum of 15 Mon around 4471-4542 Å. Two straight lines define a continuum (squares).

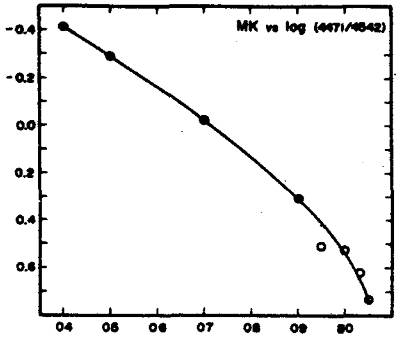

Fig. 3. The relationship between MK spectral type and the ratio He I 4471 Å/He II 4542 Å.

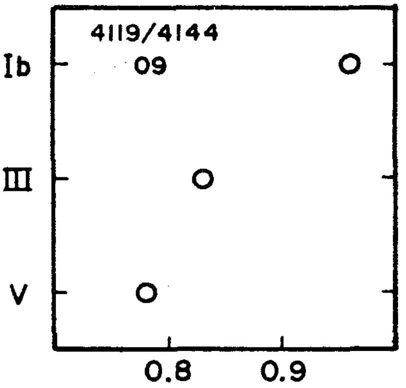

Fig. 4. The relationship between MK luminosity class and the ratio (Si IV + He I) 4119 Å/He I 4144 Å. for O9 type stars.

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(Johnson 1978).

Johnson's system has to be modified only slightly to be used for spectral classification, namely by lowering the resolution and by shifting to shorter wavelengths the interferograms. The analysis of the spectra, again, should be made by a computer.

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DISCUSSION

Mould: How faint can Johnson's instrument go?

Mendoza: At present Johnson is mainly observing bright stars. However, he thinks there is no problem in observing fainter stars.