SPECTRAL CLASSIFICATION OF COMPOSITE SPECTRUM STARS

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INTRODUCTION

Classifying the spectral types of individual components of composite spectrum stars can be a difficult task. Markowitz (1969) discussed the problems of blended and veiled lines associated with the visual assessment of blue spectrograms. Although synthetic spectra (i.e. formed by the intentional superposition of two different spectra) can be used as a means of calibration, the classification of composites with slit spectrograms is a subjective process. Classifications based upon broad- and intermediate-band photometry (Young 1971) can be highly objective, but the lack of spectral resolution introduces other complications. For example, colors in the UBVR system measure the gross behavior of a star's energy distribution. Results based upon this information are not only affected by interstellar reddening but also are incapable of identifying common spectral peculiarities. The use of spectrophotometric indices (Beavers and Cook 1980) avoids the major difficulties of other techniques. The results are not influenced by the veiling or blending of lines, nor are the results influenced by interstellar reddening. If a sufficient number of features are observed, common types of spectral peculiarities can be identified.

OBSERVATIONS

An example of the use of spectrophotometric indices in classifying composites is the application of a subset of the O'Connell (1973) photometry system by Schmidtke (1981). With a photoelectric spectrum scanner, observations are obtained at 48 narrow (i.e. 20-40 Å wide) bandpasses from 3570 to 10400 Å. Line strength indices are calculated for the 20 spectral features in Table 1. A V/R parameter which

TABLE 1

OBSERVED SPECTRAL FEATURES

H	3798	H	3889	H	4340	TiO	7100
He I	3819	Ca II	3933	H	4861	Na I	8190
H	3835	H	4101	Mg I	5175	Ca II	8542
bl#	3835	CN	4200	Na I	5892	TiO	8880
CN	3860	CH	4305	TiO	6180	CN	9190

#A line blanketing index.

approximates a V-R broad-band color is calculated for all comparison

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(i.e. single) stars. For each spectral feature, a plot is produced of index value versus V/R. Calibration curves describing the mean behavior of luminosity class I, III, and V stars are drawn on each plot. Under the assumption that a star's characteristics are uniquely specified by V/R and LUM (a running parameter for luminosity class), a star's index values can be found by linear interpolation of these curves.

MODEL

With an interactive computer program, the observed index values of composites are compared to predicted values of pairs of single stars, and the parameters V/R and LUM for each component are adjusted until a 'best' fit is found. Specifically, the Fortran subprogram CURFIT (Bevington 1969) is used to find a least-squares solution by means of the Marquardt algorithm. Values of V/R_{star1}, LUM_{star1}, V/R_{star2}, and LUM_{star2} are sought so that the quantity

$$\sum_i (\mathrm{Index}_{i,double,obs} - \mathrm{Index}_{i,double,calc})^2 = \chi^2$$

is a minimum. CURFIT requires two supporting subprograms that calculate for any given set of input parameters not only the value of $\mathrm{Index}_{i,double,calc}$ but also its partial derivatives with respect to each parameter. The main program repeatedly calls CURFIT until a stable solution is obtained. It is not necessary to solve for all 4 parameters; some of them can be assigned fixed values. An example is given in the following section.

RESULTS

The star ψ Vir is an MK spectroscopic standard of class M3 III (Morgan and Keenan 1973). Duplicity of this star was discovered by Walker (1975) with a single-channel lunar occultation observation at 6100 Å. The companion was 4.4 magnitudes fainter and was tentatively classified as a late G dwarf. Applying the technique described in the previous sections, the two-star model of Table 2 is derived. The visual magnitude difference of the components is 3.6 for this solution. Note that the luminosity class of the companion is fixed at $LUM_{star2} = 5.0$. A two-star model in which all 4 parameters are explicately calculated yields $LUM_{star2} = 4.3 \pm 2.4$. It is reasonable, therefore, to assign $LUM_{star2} = 5.0$ and to solve for the remaining parameters. Also note that if a one-star model is fit to the data (i.e. solving for V/R_{star1} and LUM_{star2} only), the root-mean-square of the residuals increases to 0.059.

CONCLUSIONS

The use of spectrophotometric indices to classify composite spectrum stars avoids some of the disadvantages of other classification techniques. Composites with large magnitude differences can be resolved by spectral type.

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TABLE 2

TWO-STAR MODEL FOR ψ VIR
MK STANDARD STAR (M3 III)

Index		Obs	Calc	O-C
H	3798	0.102	0.058	0.044
He I	3819	0.089	0.131	-0.042
H	3835	0.225	0.222	0.003
bl	3835	0.361	0.379	-0.018
CN	3860	0.129	0.145	-0.016
H	3889	0.115	0.125	-0.010
Ca II	3933	0.807	0.762	0.045
H	4101	0.014	0.040	-0.026
CN	4200	0.019	0.010	0.009
CH	4305	0.131	0.117	0.014
H	4340	-0.165	-0.140	-0.025
H	4861	0.051	0.040	0.011
Mg I	5175	0.414	0.510	-0.096
Na I	5892	0.442	0.474	-0.032
TiO	6180	0.491	0.434	0.057
TiO	7100	0.383	0.372	0.011
Na I	8190	-0.041	-0.021	-0.020
Ca II	8542	0.147	0.160	-0.013
TiO	8880	0.035	0.040	-0.005
CN	9190	0.006	0.028	-0.022
			rms	0.034

$V/R_{star1} = 1.256 \pm 0.034$
$LUM_{star1} = 3.202 \pm 0.166$
$V/R_{star2} = 0.083 \pm 0.016$
$LUM_{star2} = 5.000$

Spectral type: M2.8 IIIb + F5.9 V

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DISCUSSION

HENDRY: Have you applied your technique to any classical composite systems for which the spectral types of the components are well known spectroscopically, and, if so, with what accuracy of results?

SCHMIDTKE: Yes, my observing list includes a number of composite spectrum stars. There have not been many classifications for these stars, however, because they are mostly southern stars.

POPPER: One aspect of this kind of analysis has always worried me. Your calibrated curves show considerable scatter, yet in your analysis of composite spectra you assume the calibrating relations are known without error. This seems to be a questionable statistical procedure, and I wonder how you allow for the effects referred to.

SCHMIDTKE: One way of getting around this is to use the same modeling technique for a one-star model and to predict spectral types for the comparison stars. I was typically able to predict to about a third of a luminosity class and about one or two subclasses in temperature type. There are a few areas of the H-R diagram that contain systematic errors, such as G subgiants. For double stars it should not be troublesome, because you are measuring differentially from a brighter component.

KREIDL: Is there any significant dependence of accuracy on the spectral type of the primary component? How is line blanketing handled by the models?

SCHMIDTKE: Yes, there is a dependence, but it turns out the technique works very well for classical composite spectra stars containing a cool giant and a hot dwarf. Line blanketing problems are non-existent, because calibrations are empirical

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