THE ESTIMATION OF THE ELECTRON DENSITY n_e WITH A NARROW-BAND PHOTOMETRIC SYSTEM CALIBRATED BY MODEL ATMOSPHERES

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1. INTRODUCTION

A spectrophotometer was originally designed by Barbier (1960) for the study of early-type stars. The band passes were chosen to measure the features of the hydrogen spectrum. To the first definition of the system (Barbier and Morguleff 1964), two more bands were added, specifically devoted to the peculiar stars of type Ap and Am (Gerbaldi 1972). The interpretation of these observations has already been given separately. We will concentrate here on the calibration of this spectrophotometric system in terms of T_{eff}, log g and electron density n_e.

The properties of this system, including technical details of the equipment, can be found in Gerbaldi (1977). Table I gives, for each band pass, the mean wavelength and the equivalent width. Seven color indices are defined as being the difference between two magnitudes: $C(J) = m(J) - m(2)$, $J \in [1,8]$.

2. CALIBRATION OF THE COLOR INDICES

The principle is the following: knowing the response functions of the system, we calculate color indices for stars for which energy distributions are known, and then we determine the transformation coefficients between those computed color indices and the observed ones.

Table I.

Band passes n°	1	2	3	4	5	6	7	8
Mean wavelength (A)	5937	4951	4859	4350	4043	3946	3753	3618
Equivalent width (A)	93	99	89	70	60	40	60	73

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We determined the response function of this system for each band pass by defining : - the transmission of the atmosphere - the reflectivity of the mirrors of the telescope - the transmission of the optics of the spectrograph - the sensitivity of the photomultiplier (Gerbaldi 1977).

This spectrophotometric system being a narrow band system, we must avoid introducing numerical inaccuracy in the computation of the theoretical color indices by using low resolution energy distributions for the stars. Unfortunately published scanner observations are not continuous and even avoid regions of strong lines so they cannot be used to calibrate the bands centered on hydrogen or calcium lines. For the calibration of thoses bands, we computed the detailed flux of Vega from a model atmosphere (Kurucz 1979).

The relation between the observed and the computed indices is then $C(J) = aC(J)_S + b$. For the parameter a we have the value 1. The values of b are in Gerbaldi (1977).

3. CALIBRATION IN T_{eff} AND LOG G

We have already shown (Gerbaldi and Morguleff 1978) that from these color indices we could define parameters which are related to the MK spectral classification. These parameters are : measurement of the intensity of the H_γ line (HGAMMA) and the Balmer Jump (DB).

$$HGAMMA = C(4) - 0.618\ C(5)$$
$$DB = C(8) - 1.644\ C(5)$$

The theoretical indices and the parameters were calculated using the extensive grid of fluxes of Kurucz (1979) to yield a calibration of these parameters in terms of effective temperature (T_{eff}) and surface gravity (log g). Zero-point corrections were applied. Fig. 1 presents only these calibrations for the early-type stars of types B and A0. We investigated to what extent our theoretical calibration in T_{eff} and log g resembles the observations.

Rapid rotation affects the color of a star. This effect has not been taken into account here, but according to a previous analysis (Gerbaldi 1977) we are confident that the parameters are altered only in case of extremely rapid rotational velocity.

As we do not have enough stars in common with the results of Code (1975), which are as free as possible from theoretical models, we compared the values of T_{eff} and log g, determined from Fig. 1, with the values collected by Cayrel, et al. (1981).

The agreement, based on 6 stars in common : HD 24368, 97633, 147394, 179761, 214994, 216735, is sufficiently good to derive with this grid first-order values of T_{eff} and log g. The star's effective temperature can be determined to within $\sim$ 800 K and its surface gravity to within $\sim$ 0.3 in log g. Such a dispersion between values can also be seen in the fine analyses by different authors.

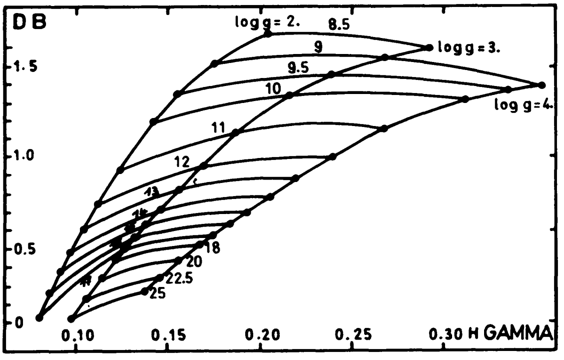

Fig. 1. The calibrated DB vs HGAMMA diagram, for models with [m/H] = 0.0. The grids are identified according to the value of log g and Teff (in 10^3 K).

4. CALIBRATION IN ELECTRON DENSITY n_e

In large-scale programs, it is customary to apply the Inglis-Teller formula (1939) or the Unsöld method (1955) to derive a mean electron density. In our spectrophotometric system, we can, with the band pass (7) measure the intensity of the confluence of the Balmer series. The corresponding reddening-free parameter is : DELTA = C(7) − 1.421 C(5).

We correlate this parameter with the electron density n_e given by the model atmosphere calculations of Kurucz (1979). As the optical depth $\tau \sim 0.1$ corresponds, for B type stars, to the layers where weak and moderate strength lines are formed, we took the value of n_e at $\tau_{5000} = 0.1$.

Figure 2 presents the theoretical relationship between log n_e and DELTA, for the early type stars B and A0.

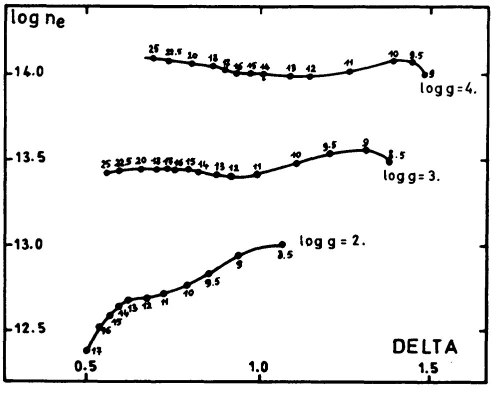

Fig. 2.- The calibration log n_e vs DELTA diagram for models with [m/H] = 0.0 and values of n_e at τ_{5000} = 0.1. The points are identified according to the value of log g and Teff (in 10^3 K).

We cannot compare directly the values of n_e obtained with this grid to other ones because of the sensitivity of n_e to the value of τ. Nevertheless we shall mention the extensive work performed by Kopylov (1961, 1966) in this field.

By entering Fig. 1 with observed values of DB and HGAMMA, an estimate of T_{eff} and log g can be made.

Fig. 2, with observed values of DELTA, permits a determination of n_e, corresponding to the preceding values of T_{eff} and log g. But with Fig. 2 we can also detect inconsistencies between the T_{eff} and log g values from Fig. 1 and those which could be determined from DELTA. From the sample of stars previously mentioned we have pointed out such an inconsistency for HD 214994, which cannot be attributed to observational errors.

5. CONCLUSIONS

Spectrophotometric measurements of the features of the hydrogen spectrum, such as H_γ equivalent width, the Balmer jump and the confluence of the last Balmer lines have been calibrated in terms of T_{eff}, log g and log n_e for the early-type stars B and A0.

Intercomparison between these three parameters have shown that some stars do not have a value of n_e compatible with their values of T_{eff} and log g. Such a situation has been detected for the first time by Fischel and Klinglesmith (1973) for some helium-weak stars. We have observed six HeW stars : HD 21699, 49606, 51688, 182568, 183339, 212454. Three of them (HD 21699, 49606, 183339) have values of Teff and log g obtained from spectroscopic observations and collected by Underhill and Doazan (1982), which are compatible with our determination from Fig. 1. But the value of n_e from Fig. 2 is inconsistent with values of T_{eff} and log g from Fig. 1 for HD 21699, 49606 and 212454.

This means that the behavior of these three hydrogen features can be properly reproduced by model atmospheres in some cases, but that these models can fail in other situations.

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