# STUDY OF ε DEL: REDUCTION AND ELABORATION OF THE OBSERVATIONS BY THE ELECTRONIC COMPUTER IBM 1620

Nota di Massimo FRACASSINI e Laura E. PASINETTI (*)
(*Osservatorio Astronomico di Merate - Centro di Astrofisica del C. N. R.*)

Riassunto. — Si danno i risultati relativi all'analisi quantitativa di ε Del ottenuti mediante riduzione dei microfotogrammi al calcolatore elettronico IBM 1620. Nella prima parte del presente lavoro si sottolineano differenze relative alla discontinuità di Balmer, rispetto ai dati forniti da Chalonge e Divan, dovuti probabilmente alla maggiore dispersione usata nei nostri spettri. Si danno poi i valori per la densità elettronica, la temperatura, la abbondanza dell'idrogeno e dell'elio. Viene inoltre eseguito un controllo di classificazione in base ai diversi risultati ottenuti. Nella seconda parte si danno brevi notizie sui programmi compilati per il calcolatore IBM 1620, allo scopo di ottenere le curve di calibrazione, le profondità centrali, e le larghezze equivalenti, direttamente dai microfotogrammi.

Abstract. — Results of the quantitative analysis of ε Del obtained with the reduction of stellar spectrograms by an IBM 1620 electronic computer, are given. In the first part of this paper we emphasize some differences in the Balmer discontinuity, relative to the data given by Chalonge and Divan, probably dued to the greater dispersion used by us; after, the values of the electron density, the temperature, the hydrogen and helium abundances, are given; in addition a classification control is made, following the various results obtained. In the second part we give concise information about the programs compiled for the IBM 1620 electronic computer, by means of which it is possible to have the curves of calibration, the central depths and the equivalent widths directly from the spectrograms.

## The quantitative analysis

In the present work we have reduced some spectra taken in the violet, by means of the grating spectrograph at the Zeiss reflector of the Merate Observatory, using the dispersion of 34 A/mm and 23 A/mm (respectively in the second and third order).

Our results derive from the average of five spectra, whose spectrograms

(*) Ricevuta il 27 febbraio 1964.

have been reduced by means of the IBM 1620 electronic computer of the Brera Observatory in Milano, as it will be explained later on.

The star ε Del, HD 195810, is classified B5 according to the Yerkes classification, and B5 IV according to the $\lambda_1$, D classification by Chalonge and Divan (1).

All the spectral lines, with exception of the Balmer lines, are very weak. We could measure only the He lines 3820, 4026 and 4471; the Si II lines 3856, 3863, 4128 and 4131 have been only identified; while the Mg II line 4481, whose intensity is like the 4471, has been also measured. The Balmer lines have been identified up to the $H_{17}$.

By means of the Holtsmark and Inglis-Teller formulae we have obtained the following values of the electron density:

$$\log N_e = 14{,}64$$
$$\log N_e = 14{,}03$$

The temperature from the colour has been determined with the value of the gradient given by the Greenwich Observatory (2) and it is resulted T = 18 500.

We have adopted the value of the gradient $\varphi_b = 0{,}89$ from Chalonge and Divan (1) to compute the electron pressure and the abundances, obtaining T = 19 600, in good agreement with the previous value. Adopting the averaged value of the log $N_e$ reported above, we have obtained log $P_e = 2{,}76$.

A remarkable difference has been found between our measurements of the Balmer discontinuity and those of Barbier-Chalonge (3) and Chalonge-Divan (1); our values from the various spectra are in good agreement but they are lower than those given by the above mentioned Authors: that is probably to be accounted to the different dispersion used by us. Indeed, while the above mentioned Authors extrapolate the continuum between the lines $H_8$ and $H_9$, we have extrapolated it from the line $H_9$ to $H_{11}$, where is not overlapping of the line wings.

Nevertheless the main share to this difference is to be attributed to the violet side of the Balmer discontinuity. Indeed, the very low dispersion used by Chalonge and Barbier, blending completely the Balmer lines which are left on the ultraviolet side of $\lambda_0$, makes the continuum considerably higher than in our spectra, and therefore gives a larger discontinuity.

Further, Chalonge and Barbier give a $\lambda_0 = 3700$ A for the beginning of the discontinuity, and this value falls between the lines $H_{16}$ and $H_{17}$ which are still well separated in our spectra. Our value for $\lambda_0$ is about 3692 A, which implies also a different value for $\lambda_1$.

From the above arguments we may infer that this difference between our measurements of the discontinuity and those found by Barbier, Chalonge and Divan is general. Therefore a revision of the measurements of the Balmer discontinuities should be necessary using spectra having a mean dispersion of about 30 A/mm.

We give the averaged values, obtained with the following methods: 1st — by extrapolation of the continuum from $H_9$ to $H_{11}$; 2nd — by extrapolation of the continuum from $H_8$, following the french Authors; 3rd — we report the values by Barbier, Chalonge and Divan for comparison.

| | 1st | 2nd | Barbier/Chalonge (1941) | Chalonge/Divan (1952) |
|---|---|---|---|---|
| D = | 0,207 | 0,235 | 0,28 | 0,299 |
| $\lambda_0$ = | 3692 | 3692 | 3700 | |
| $\lambda_1$ = | 3727 | 3732 | 3746 | 3748 |

The hydrogen abundance has been deduced reporting the values of log $N_{0,2}h$ versus the quantum number n. We have log $N_{0,2}h \geq 16{,}50$. By the Minnaert's formula which takes in account the finite thickness of the absorbing layer

$$\log N_{0,2}h = 16{,}86 - \log\left(\frac{1}{R} - \frac{1}{R_c}\right)$$

we have

| | | |
|---|---|---|
| $\log N_{0,2}h$ | = 16,72 | using the value of D, in $R = 1 - 10^{-D}$, from 1st |
| | = 16,81 | » » » » » » » 2nd |
| | = 16,99 | » » » » » » » 3rd |

The total abundances of the neutral and ionized H, adopting for temperature T = 19 600 and for the pressure log $P_e$ = 2,76, result

| | | |
|---|---|---|
| log N h(H) = 18,73 | log N h($H^+$) = 22,71 | from method 1st |
| = 18,82 | = 22,80 | » » 2nd |
| = 19,00 | = 22,98 | » » 3rd |

We have also attempted to estimate the abundance of He, but the lack of lines measurables in the spectra makes the values obtained rather uncertain. Since He appears considerably ionized, (log $He^+/He$ = 1,70), we have adopted the formula of Unsöld to obtain the abundance relative to H, using the 4026 and 4102 lines; in this manner we have obtained log He/H = —1,62. Using the formulae of Boltzmann and Saha we obtain lower values for the above ratio; these values, however, are more uncertain for the uncertainty in the determination of the lower limit in the He abundance in the $2^3P$ level.

A classification check in the diagram discontinuity-spectral class [4], with our value for the Balmer discontinuity, would place ε Del in the B4 area rather than in the B5 area, in a better agreement with the temperature found from the gradient. This result would be confirmed also by the value of the equivalent widths of the 4026 line found by us, compared with those given by Williams [5].

On the contrary, the intensity of the Balmer lines according to Williams [5] and Petrie [6], would lead to classify ε Del in a more advanced type, near B6, B7 and luminosity class V.

The absolute magnitude obtained using the spectroscopic parallax [7] and the relation of Petrie [6], has given respectively the values

$$M = -1,2 \qquad\qquad M = -0,78$$

confirming by this way that ε Del belongs to the main sequence.

## THE REDUCTION OF THE SPECTROGRAMS WITH THE IBM 1620 ELECTRONIC COMPUTER

Two routines have been programmed and are used in the IBM 1620 electronic computer at the Brera Astronomical Observatory of Milano:

— The first is a program for the numerical elaboration of the curve of calibration of the photographic plates: single or averaged curve of calibration (when the single curves are quite parallel).

— The second is a program for the reduction of the spectrogram until to the computation of the equivalent widths.

In the first program the input is: the deviations and the plate background of the various calibration spectrograms. The output is: the transmissions, hundredths by hundredths as usual, and the relative log f(I), printed on the paper, and f(I), punched on the tape; for the single or averaged curve, according to the operator's criterion.

In the second program the computer memorizes the calibration curve Tr/f (I), punched on the tape by the first program and accepts as input: a) — the positions (in cm) and the corresponding wavelength (in A) of three standard lines of the spectrum; b) — the plate back-ground, the abscissae (the positions along the spectrum in cm) and the ordinates (deviations) along the spectrogram profile. The output is: the wavelength, the central depth, the equivalent width, of the various identified spectral lines.

Both these programs have been performed in a general way for using them for similar routine works of spectrogram reduction.

## REFERENCES


(1) D. CHALONGE-L. DIVAN: *Recherches sur les spectres continus stellaires*, Ann. d'Aph, **15**, 201, (1952).

(2) GREENWICH ROYAL OBSERVATORY, *Relative gradients of 250 stars determined at the Roy. Obs. Greenwich*, M. N. of the R.A.S., **100**, 189, (1940).

(3) D. BARBIER-D. CHALONGE, *Etude du rayonnement continu de quelques étoiles entre 3100 et 4600 A*, Ann d'Aph, **4**, 30, (1941).

(4) M. HACK, *Étude du spectre d'absorption de 243 étoiles de types spectraux compris entre 06 et F8, pour la recherche de critères quantitatifs de classification spectrale bidimensionelle*, Ann. d'Aph, **16**, 417, (1953).

(5) E. G. WILLIAMS, *Absorption line intensities in B-type stars, Classification of the B-type stars*, Ap. J, **83**, 279; Ap. J, **83**, 305, (1936).

(6) R. M. PETRIE, *Absolute magnitudes of the B stars determined from measured intensities of the $H\gamma$ line*, Publ. Victoria, **9**, 251, (1953).

(7) F. SCHLESINGER - L. F. JENKINS, *A general catalogue of stellar parallaxes*, Yale Univ. Press, (1935).