BASIC PARAMETERS OF THE STAR HD 60848

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RESUMEN. Usando el sistema espectrofotométrico BCD, se calculan los parámetros básicos de la estrella Oe HD 60848. Se discuten en particular, la temperatura efectiva y la luminosidad total. Con los parámetros físicos obtenidos y usando modelos de estructura de estrellas en rotación, se discute la distribución del momento angular en la estrella.

ABSTRACT. We calculate the basic physical parameters of the Oe star HD 60848, by using the BCD spectrophotometric system. In particular, we discuss its effective temperature and its luminosity. Using the parameters here obtained and stellar rotating models, we discuss the angular momentum distribution in this star.

I. INTRODUCTION

The basic parameters of O stars, such as they can give us their position in the HR diagram, can be directly determined only in a very few cases. However, these quantities can be rather well determinated for those O stars having no spectral peculiarities, so that they can be analysed using classical model atmospheres (Conti 1973, 1975, Underhill 1982). Nevertheless, these methods are not applicable to HD 60848, which is an O star showing Be phenomena (Divan *et al.* 1983). So, we present in this paper a way suitable for obtaining basic parameters of Be stars, which avoids the mentioned spectral restrictions, and which can be used for O stars of later spectral classes having Be type emission phenomena. Actually, because of the number of uncertainties which we are dealing with in this type of stars, the method gives us a useful first approximation of their basic parameters.

II. PRIMARY PARAMETERS OF THE STAR

We call primary parameters of the star, all those quantities which come directly from observations, and in terms of which, the basic parameters such as the bolometric magnitude, the effective temperature, ... are calibrated. The primary parameters to which we refer to in this paper, are the Balmer jump D of the central star and the parameter λ_1 which gives the position of this discontinuity. These parameters were obtained with the BCD spectrophotometric system (Chalonge and Divan 1952). We consider also as primary parameter, the apparent visual magnitude of the star at a non-emission phase.

It was shown by Divan (1979) and Divan *et al.* (1982), that the Balmer discontinuity of Be stars presents two components: one depending mainly on the central star and the other, wich is variable, characterizing the outer layers located above the photosphere. Nevertheless, because of the low dispersion of the spectra used (150 Å/mm at the Balmer discontinuity), to obtain properly the parameters describing the energy distribution of the central star, we have to analyse a great number of observations corresponding to different states of the Be star variation.

Once the behaviour of the BCD colour gradient ϕ_{rb}, on the red side of the Balmer jump, as a function of the total Balmer discontinuity is known (a linear relation), the energy distribution of the central star around the Balmer jump, is easily determined. For that, we firstly obtain the Balmer discontinuity of the central star, by intersecting the (ϕ_{rb}, D) curve of the Be star with a (ϕ_{rb}, D) curve of normal B stars, corresponding to the luminosity class defined by the λ_1 parameter of the Be star. The (ϕ_{rb}, D) curve of the Be star is a dereddened one, so we need for that an estimation of the interstellar extinction E(B-V) of the star. Secondly, once the ϕ_{rb} colour gradient of the central star and its Balmer discontinuity are known, we obtain the near-ultraviolet colour gradient from the (ϕ_{uv}, D) correlation.

The variation of the colours of HD 60848 as well as its interstellar E(B-V) colour excess have been recently discussed by Divan *et al.* (1983). The calibration of the intrinsic colours ϕ_{rb} in terms of the λ_1D parameters, was already given by Chalonge and Divan (1973).

Actually, the λ_1D parameters so obtained, correspond to a non-emission phase of the object, which we assume they represent the central star.

Divan *et al.* (1983) have also studied the variation of the visual apparent magnitude of HD 60848, as a function of the total Balmer jump. So, once the Balmer jump of the central star is determined, the apparent magnitude corresponding to the non-emission phase of the object, is readily obtained.

III. PHYSICAL PARAMETERS OF THE STAR

Assuming that the primary parameters obtained as described in section II, represent a normal-like star, we can derive a set of physical quantities, from the calibrations given by Chalonge and Divan (1973) and Divan and Zorec (1982).

The calibration of visual absolute M_V in terms of λ_1D parameters made by Chalonge and Divan (1973), and the calibration of bolometric absolute magnitudes done by Divan and Zorec (1982), are presented here together in Fig. 1, which is useful, due to its resolution, for low values of the Balmer discontinuity.

The set of physical parameters for HD 60848 derived in this way, are given in Table 1.

TABLE 1

BASIC PARAMETERS OF HD 60848 OBTAINED USING THE BCD SYSTEM

T_{eff}(K)	$L/L_\odot$	d (pc)	$R/R_\odot$	$M/M_\odot$
35100	7.2×10^4	1250	7.2	30

The radius is calculated by supposing the star is spherically symmetric.

To define the position of the star in the HR diagram, we need a good estimation of the effective temperature T_{eff} and of the total luminosity $L/L_\odot$. So, we test the validity of the values obtained above, by using another independent method.

To examine the effective temperature, we proceed as follows

a) We determine the visible energy distribution for the stellar non-emission state. The flux distribution of this phase is obtained from the correlation both of the visual colour gradient and of the apparent magnitude, as function of the total Balmer discontinuity.

b) We calculate then, the visible angular diameter θ_{vis}, by comparing the flux distribution obtained in a), corrected for interstellar extinction, to a model atmosphere (Kurucz 1979) defined by the parameters given in Table 1.

c) Following the same arguments as those developed by Zorec and Briot (1984) in this issue, we suppose that the total luminosity of the star does not change during its variations. Then, the effective temperature can be calculated from the relation

$$\sigma_R\, T^4_{eff} = \frac{\theta^2_{vis}}{4} \int_0^\infty f_\lambda\, d\lambda \qquad (1),$$

where σ_R, is the Stefan-Boltzmann constant, θ_{vis}, is the angular diameter of the star in the visible range, assumed to be the same at all wavelengths, and f_λ, is the monochromatic flux from the star observed at the earth and corrected for interstellar extinction. The f_λ fluxes correspond to an emission phase of the star (the epoch of the TD-1 satellite observations).

The integral over the non-observed spectral regions is evaluated by means of the relation

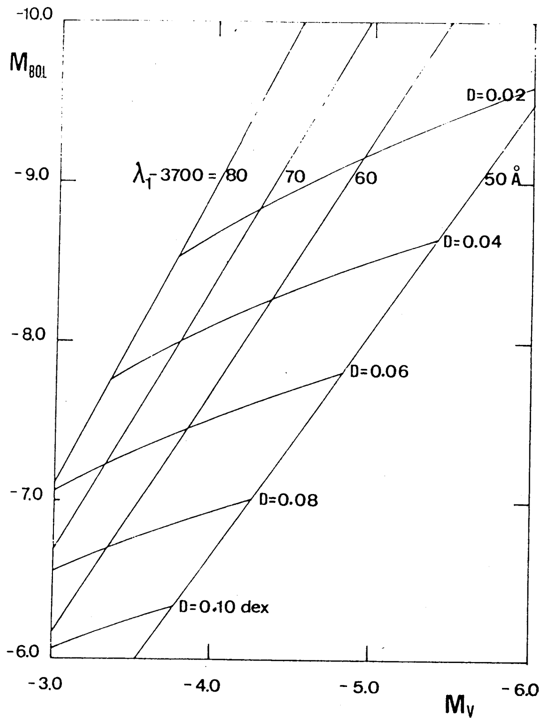

Fig. 1. Calibration of the BCD $\lambda_1 D$ parameters in absolute visual (M_v) and bolometric (M_{bol}) magnitudes.

$$\int_{\lambda_1}^{\lambda_2} f_\lambda \, d\lambda = \frac{\theta^2_{vis}}{4} \int_{\lambda_1}^{\lambda_2} F_\lambda(\text{model}) \, d\lambda \qquad (2)$$

The far-ultraviolet part of the integral in (1) was calculated from data of the TD-1 satellite (Macau-Hercot *et al.* 1978). The visible and near-ultraviolet integral was estimated using the BCD ϕ_{rb} and ϕ_{uv} colour gradients and the visual magnitude at the time of TD-1 observations. These last quantities were deduced from a study of the stellar line emission behaviour as function both, of the magnitude and of the emission in the Balmer continuum.

d) We iterate the steps b) and c).

In what concerns the total luminosity of the star, we compare the value presented in Table 1, which was derived from the calibration of M_{bol} in Fig. 1, with the luminosity calculated from

$$L = 4\pi d^2 f \qquad (3)\ ,$$

where d is the distance of the star and f is the integral entering relation (1).

The values of the effective temperature and of the luminosity obtained by this method, are given in Table 2.

TABLE 2

EFFECTIVE TEMPERATURE AND LUMINOSITY OF HD 60848 OBTAINED USING MEASURED FLUXES

T_{eff}(K)	$L/L_\odot$
34900	4.6×10^4

IV. DISCUSSION

We note that there is a good agreement between both temperature determinations, but that there exists an important difference in the luminosities: of the order of 0.5 mag. in M_{bol}.

To explain such a discrepancy, two kinds of reasons may be evoked, namely,

a) The errors in the calibrations of the absolute visual and bolometric magnitudes may affect the determination of the distance which enters in relation (3) or the luminosity, given in Table 1. In the first case, because relation (3) gives a lower value of the luminosity, the difference would represent an underestimation of the distance of about 60%, which implies an error of 1 mag. in the BCD calibrations. This is probably not so, as this calibration was proved to be particularly well adapted for early type stars (Underhill *et al.* 1979, Underhill 1982). In the second case, if we consider that we have an overestimation of the luminosity, an error of about 0.5 mag. in M_{bol} is implied. This error is far from being excluded, as it can be seen when we compare the bolometric magnitudes of Divan and Zorec (1982) with those determined by Code *et al.* (1976) or by Habets and Heintze (1981) for early type stars.

b) As the star HD 60848 is a rapid rotator (V sin i = 275 Km/sec: Uesugi and Fucuda 1982), we may then claim for an additional, physical reason, which can produce a lowering of the f entering formula (3). In fact, a rapid rotation of the star may produce a lowering of the total luminosity, as compared to a non-rotating star having the same mass (Bodenheimer 1971).

Nevertheless, due to the plausible uncertainties in the M_{bol} calibrations, the determination of the luminosity from relation (3) seems to be the more probable one. Using this luminosity and the effective temperature, we obtain a mean radius of the star which agrees well with the mean radius predicted from Bodenheimer's (1971) stellar rotating models.

With the parameters obtained here, by interpolating among the Bodenheimer's models, we see that HD 60848, a star of 30 $M_{\odot}$, should have a high concentration of angular momentum towards the core (case C of Bodenheimer's calculations). This result seems contrary to which we should expect if the rotation is an important factor for the stellar mass-loss phenomena, as it was thought for Be stars. In such a case, a high concentration of angular momentum towards the stellar surface is expected. It is interesting to note, that HD 60848, due to its high rotation, and as it follows from the parameters and models used here, will remain as a main sequence star, nearly three times longer than a non-rotating star having the same mass.

V. CONCLUSIONS

Studying the correlations determined both of the colour gradient on the red side of the Balmer jump and of the visual magnitude with the total Balmer discontinuity of HD 60848, we obtained a set of primary parameters which describe the energy distribution of the central star. From the various calibrations of these parameters, we obtained the basic physical parameters of the central star, on the assumption, that the central star behaves like a normal O star. We discussed in more detail the value of the total luminosity of the star and its effective temperature. Owing to the overestimation of M_{bol} from the calibration of λ_1 and D, the BCD parameters, at the moment we cannot conclude that the measured luminosity of the central star of HD 60848 agrees with that of a normal O star, but we can say that there is a high probability that they have nearly the same value.

Comparing the parameters obtained with those predicted by stellar rotating models, we conclude that HD 60848 seems to present a high concentration of angular momentum towards its core. Owing to this, the star will stay about three times longer on the main sequence than a non-rotating star having the same mass.

These results will be discussed again in a forthcoming paper, where we also analyze the effects of rotation on the primary parameters, λ_1, D and V, of the central star. The same study will be done for a high number of Be stars.

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