SPECTROPHOTOMETRY OF B AND A-TYPE SUPERGIANTS

Luis E. Campusano[+]
Departamento de Astronomia, Universidad de Chile
Casilla 36-D, Santiago

Summary

Continuum fluxes measured with a two-channel spectrum scanner and a 40 A slit are presented, in a differential manner, for six supergiants over the wavelength range 3390-8090 A. Five of these stars presented variability detectable on a time scale of a few days. The stars with the stronger light changes were HD 148379 and HD 160529, both with Hα-emission, whose maximum observed amplitudes amounted to 0.06 and 0.14 mag. The Hα observations done with a 4 A slit gave no indication of strong intensity variations over the same time interval. Some evidence for the presence of a Balmer continuum emission is presented for HD 160529, and we briefly relate it to a possible origin of its Hα-emission profile.

+ Visiting Astronomer, Cerro Tololo Inter-American Observatory, supported by the National Science Foundation under contract No.NSF-C866.

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I. Introduction

Several photometric and spectrophotometric surveys of B and A-type supergiants (Abt,1957;Rosendhal and Wegner,1970;Maeder and Rufener,1972;Sterken,1977) have revealed variability in their spectrum. Individual studies of extreme supergiants have shown some emission features and asymmetries in the absorption lines (Wolf,1972;Wolf _et al_.,1974). Hα begins to show conspicuous emission in stars brighter than a certain limit that depends on spectral type (Rosendhal,1973b). Furthermore, the observed Hα-emission profiles are often found to vary with time in this group of stars (Rosendhal,1973a).

In this communication we present, in a differential manner, the time behavior of the observed spectral energy distributions for a group of southern supergiants over a time scale of several days. In addition, almost simultaneous observations of Hα were performed to detect possible strong intensity variations. The stars for which observations are presented are listed in Table 1. The spectral types and visual magnitudes are from the Photoelectric Catalogue of Blanco _et al_. (1968), excepting the MK-type of HD 125835 quoted from Hiltner _et al_.(1969). The scanner magnitudes AB= $-2.5 \log f_\nu - 48.60$, where f_ν is the flux in erg s^{-1} cm^{-2} Hz^{-1},are such that the value of AB at 5556 A corresponds very nearly to the visual magnitude V. _n_ is the number of continuum measurements.

II. Observations and reductions

The observations were obtained with a low resolution, two-channel spectrometer attached to the 91-cm telescope of the Cerro Tololo Inter-American Observatory,during an observing run (7 nights) in July 1976. The spectrometer uses a plane grating ruled with 600 lines per mm, blazed for 7500 A in the first spectral order. An ITT 130 (S-20) phototube was used for the observed wavelength interval from 3390 to 8090 A. The entrance diaphragm used in the scanner corresponded to 18" , while the exit slits selected for the continuum and line measurements (Hα) gave 40 A and 4 A widths respectively, both at the first and second order.

The observational technique employed to determine the continuous energy distributions of the stars follows mainly

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TABLE 1

PROGRAM STARS

Star	Sp	V	AB	n	Notes
HD 169454	B1 Ia-0	6.61	6.59	4	M_V=-7.9 (a), Hα-em (b , c)
HD 148379	B2 Ia	5.41	5.27	3	M_V=-8.1 (a), Hα-em (d)
HD 167838	B5 Ia	6.73	6.70	4	-
HD 160529	A2 Ia-0	6.67	6.54	6	Hα-em (b , c)
HD 125835	A3 Ib	5.60	5.53	6	-
HD 148743	A7 Ib	6.49	6.48	4	-

References for the Notes: (a) Hutchings 1976, (b) Andrews 1968, (c) Wolf et al. 1974, (d) This work.

TABLE 2

THE STANDARD STARS

Name	HR No.	α_{1900}	δ_{1900}	Sp	V
109 Vir	5511	$14^h\ 41^m.2$	+2°19'	A0 V	3.74
58 Aql	7596	19 49.6	+0 0	A0 V	5.62
29 Psc	9087	23 56.7	-3 35	B8 III	5.11

the procedure of Oke (1965), with specific wavelength bands chosen as to avoid all strong lines and the atmospheric extinction bands. Most of the continuum measurements were followed by observations over a wavelength range which contained often completely the Hα-line, from 6550 to 6580 A, using a 4 A slit width and at intervals of 4 A. The integration times were the same for all stars, 10 or 20-second depending on the wavelength interval. Atmospheric extinction was determined for the observing run using the standard stars listed in Table 2. 58 Aql and 29 Psc, with calibrated energy distributions by Hayes (1970), were employed for conversion of our observations to absolute fluxes after correction to the Hayes and Latham (1975) spectral energy distribution of α Lyrae.

The minimum standard deviations (σ) inferred from the total number of photons counted in the star and sky channels were much less than 0.01 mag for the great majority of the continuum observations of the program stars. The internal accuracy of our absolute flux measurements of the continuum was estimated using all our observations of 58 Aql. The actual standard deviations computed for this star are listed in Table 3, which in fact proved to be larger, at all wavelengths, than the σ_s inferred from photon counts for the faintest program stars. Thus, the variations of the spectral energy distributions were evaluated with the σ_s of Table 3.

In order to evaluate the Hα observations we mention both the constancy of the wavelength scale and the photon statistics. Line shifts of few angstrom detected with a 4 A slit width are within the precision of this kind of instrument, and such effects cannot be established. Therefore, the comparison of the Hα profile measurements was done considering the overall flux distributions only. The minimum σ_s inferred from photon counts can be estimated directly from the data in Figure 2, considering that a derived flux of 1x 10^{-22} erg s^{-1} cm^{-2} Hz^{-1} corresponds roughly to 10000 counts. Then, in most cases the minimum error is of the order of 0.01 mag, excepting some measurements of the following two stars: HD 167838 and HD 148743.

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TABLE 3

STANDARD DEVIATIONS OF FLUXES

λ (A)	σ (mag)	λ (A)	σ (mag)
3390	0.009	4785	0.006
3448	0.013	5000	0.007
3509	0.009	5263	0.005
3571	0.010	5556	0.006
3636	0.008	5840	0.006
3704	0.013	6054	0.007
4036	0.007	6790	0.010
4167	0.008	7100	0.010
4255	0.008	7550	0.016
4464	0.009	7780	0.017
4566	0.006	8090	0.029

III. Results and discussion

Figure 1 shows the differential behavior of the spectral energy distributions of the program stars. Each plotted distribution was obtained averaging two consecutive measurements of the continuum. Variations greater than 1.5 σ at either side of the reference energy distribution are considered to be significant. The systematic behavior of the variations, when present, was considered as further indication of their real character.

Detectable continuum variations are observed in all the stars over intervals of a few days, except in HD 167838. The stronger variations were observed in HD 148379 and HD 160529 (both Hα emission objects), whose maximum amplitude

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in the Balmer continuum amounted to 0.06 and to 0.14 mag approximately. There seems to be a wavelength dependence in the variations of these stars, in the sense of being stronger in the violet.

Figure 2 shows the derived fluxes from the Hα measurements in erg $s^{-1}cm^{-2}Hz^{-1}$. No significant variations in the flux distributions are detectable in any of the stars over intervals of a few days, within the precision mentioned in § II.

The continuum variations in B and A-type supergiants have studied exhaustively by Sterken (1977) using the uvby photometric system, concluding that vibrational instability does not seem to be a suitable mechanism to explain his observations. In particular, some evidence for the presence of a velocity field and the possible role of a chromosphere have been discussed for one of the program stars, HD 160529 (Wolf et al.). We shall briefly relate our absolute spectral energy distribution derived for this star with a possible explanation for the presence of its Hα-emission profile.

S.Dumont et al.(1973) have shown that Hα-emission profiles in T Tauri stars can be explained without recourse to an extended envelope hypothesis: the Hα-emission being related to the observed emission in the Balmer continum, the latter supposed to have a chromospheric origin. In order to have an indication whether Balmer continuum emission is present in the supergiant HD 160529, we have corrected its energy distribution for line blocking and for reddening,using Nandy's law for the Cygnus region (1964), such as to obtain E_{B-V}= 1.23 (Hiltner,1954). The measured Balmer discontinuity (in mag) was 0.46, which turned out to be roughly 0.5 mag smaller than a value implied from a Mihalas (1965) model. On the other hand, we calculated the implied radiative temperatures (T_r) at two wavelengths,representative of the Balmer and Paschen continuum, using the measured fluxes and estimates of the distance and radius of this star. Choosing λ_1 =3571 A and λ_2 =7100 A, we obtained a higher Balmer T_r than the Paschen T_r , with differences amounting approximately to $\Delta T_r \approx 800$ K. Thus, at least for this supergiant, there seems to be some evidence for a Balmer continuum emission. Detailed

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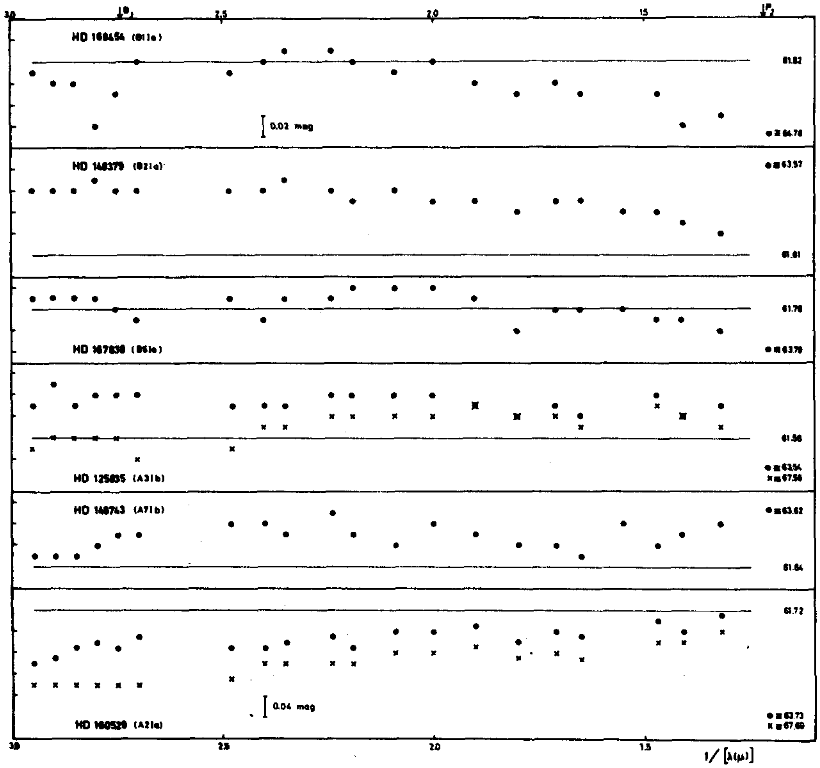

Fig. 1. Differential behaviour of spectral fluxes (40 A bands). The straight lines represent the arbitrary reference continuum. Julian Date of measurements are given in the right-hand side (2 442 900. +). The Balmer and Paschen jumps are indicated in the reciprocal wavelength scale. The magnitude scale used is the same for all stars, excepting the last one where a change by a factor 2 has been applied.

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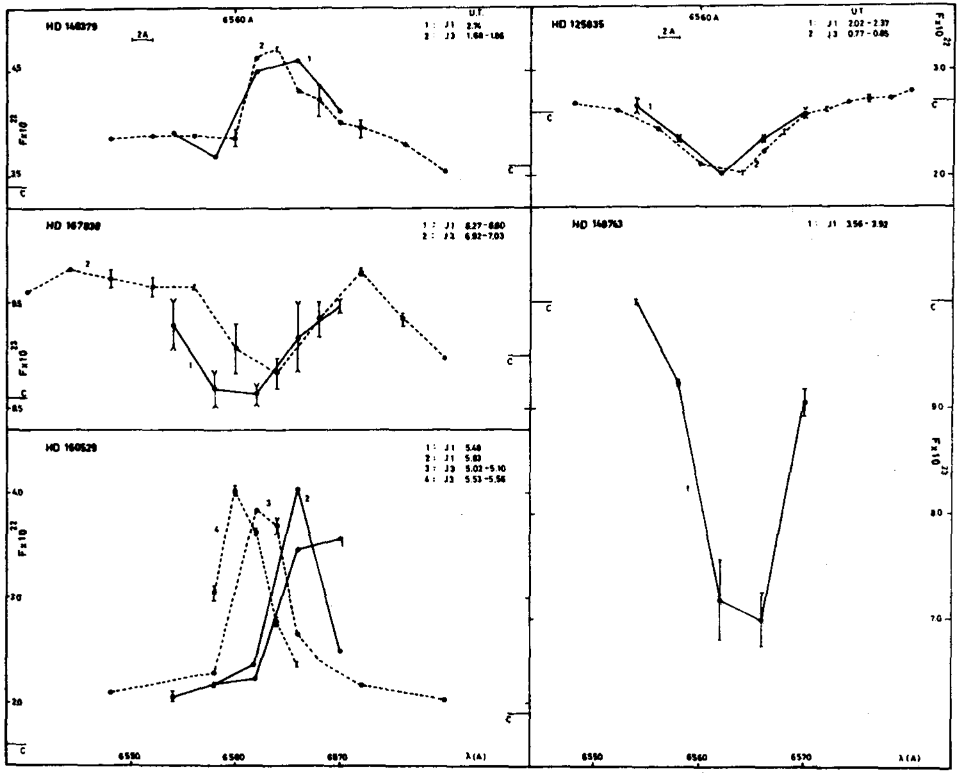

Fig. 2. Flux distributions (4 A bands) in a wavelength interval containing Hα. The fluxes F are in erg $s^{-1}cm^{-2}$ Hz^{-1}. Each plotted distribution is numbered, and the night of July 1976 (Jn) together with the Universal Time (U.T.) of the observation are indicated in the upper left corner of the rectangles. The dots in the middle of vertical bars are the mean of two separate measurements, for which both U.T. are specified. Note that line-shifts cannot be inferred (see text).

calculations of Hα , using Dumont *et al*. approach, have been performed taking into consideration the presence of a velocity field (Cuny,1977) in the case of A-type supergiants.

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