ABSOLUTE ENERGY CURVES FROM LATE B-TYPE SUPERGIANTS

Anne B. Underhill
Laboratory for Astronomy and Solar Physics
Goddard Space Flight Center

ABSTRACT

Absolute energy curves for six late B and early A-type supergiants have been determined from IUE data and from other ultraviolet and ground-based photometry. Effective temperatures and angular diameters are presented as well as estimates of the outflow velocity of the wind. All six stars show a strong Balmer continuum in emission; the Ia supergiants also show an infrared excess which reaches into the visible range. Evidence is found for the presence of a warm mantle as well as for wind from the Ia stars.

INTRODUCTION

From ultraviolet spectra it has become clear that O stars and early B stars have an outer atmosphere or mantle in which at least some of the gas is heated to temperatures of the order of 10^5 K and where a rapidly flowing wind is generated. The purpose of this investigation is to see what the evidence is for a mantle for the late B supergiants. The material in the mantle of an O or early B star is seen best by means of the ultraviolet absorption and emission resonance lines.

There is evidence that the mantles of late B and early A stars are seen most easily by means of the continuous spectrum. For instance, Berger et al. (1) showed that the continua of supergiant A stars longward of 5000 Å are usually red, relative to what is seen for main-sequence A stars of the same subtype, and Barlow and Cohen (2) have found that the late B and early A Ia supergiants tend to have a small infrared excess.

The continuous spectrum from the photosphere of an early-type star, that is from the boundary layer of the interior model of the star, can usually be well represented by the predicted spectrum from one of the LTE line-blanketed model atmospheres of Kurucz (3), see Underhill et al. (4). Therefore, comparing the energy distributions of supergiants with the predicted continuous spectra of Kurucz will show whether additional continuous radiation, generated in the mantle of the star, is present or not. Figures 1, 2 and 3 present such comparisons for six B/A supergiants. Solutions for effective temperature and angular diameter have been made for these stars using the methods of Underhill et al. (4) and of Underhill (5) and the results are given in Table 1. The absolute fluxes plotted in the figures have been corrected for interstellar extinction. The adopted values of E(B-V) can be seen to be about correct because no residual effect of the broad interstellar absorption ban centered at 2175 Å is evident in the plotted energy distributions. The relatively sharp dip near 2250 Å is due to blended absorption lines of Cr III formed in the mantle.

DISCUSSION

All of the supergiants studied here show excess emission in the Balmer continuum. In some cases this emission is strong; its presence is the reason why Underhill et al. (4) found that for supergiants the Chalonge and Divan values of D were smaller than the values predicted by means of model atmospheres. All of the Ia supergiants show an infrared excess extending into the visible range. The observations of Barlow and Cohen (2) permit one to trace this excess to longer wavelengths. The wavelength of the "turn-over point" of the infrared excess emission of HD 21291 and 21389 indicates that the electron temperature in the part of the mantle from which the infrared excess originates is near 23000 K.

The effective temperatures given in Table 1 are about correct because the intensity of the stellar light at wavelengths shortward of 1500 Å relative to that at wavelengths near 4100 Å is correctly represented by models having effective temperatures similar to the values given in Table 1. The amount of far ultraviolet light relative to that in the visible is a sensitive indicator of effective temperature for these stars. Near 4100 Å there should be no distortion of the continuum by excess emission due to the gas in the mantle and the Balmer continuous emission from the mantle should be very weak at 1500 Å.

The winds of these six B and A supergiants are easily visible only in the Mg II resonance lines. The terminal velocity estimated from the position of the shortward edge of the Mg II absorption profiles is given in Table 1. These stars do not show P-Cygni-type emission in Mg II.

The mantles of the B/A supergiants appear to be cool, $T_e \approx 23000$ K, but hotter than the effective temperature of the star, and to contain gas flowing at about 250 km s^{-1}. The star HD 21389 sporadically shows sharp C IV resonance lines in emission (Underhill (6)). None of these stars shows obvious absorption in the resonance lines of Si IV and C IV, but all show the resonance lines of Al III and C II as well as those of Al II and Si II.

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REFERENCES

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(3) Kurucz, R. L. 1979, Ap.J. Suppl., 40, 1.
(4) Underhill, A. B., Divan, L., Prévot-Burnichon, M. L. and Doazan, V. M.N.R.A.S., 189, 601.
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Table 1
Effective Temperatures, Radii, Luminosities and Terminal Velocities of B/A Supergiants

Name	Spectral Type	E(B-V) mag	T_{eff} K	Θ 10^{-4} arc sec
53 Cas	B8 Ib	0.41	11600	3.62
β Ori	B8 Ia	0.04	11800	26.67
HD 21291	B9 Ia	0.41	10300[a]	7.27
η Leo	A0 Ib	0.02	9400	6.90
HD 21389	A0 Ia	0.54	9900[a]	8.05
α Cyg	A2 Ia	0.03	8600[a]	21.07

Name	d[b] kpc	$\frac{R}{R_\odot}$	$\log \frac{L}{L_\odot}$	v_∞(Mg II) km s^{-1}
53 Cas	0.93	36	4.33	0[c]
β Ori	0.228	65	4.87	262
HD 21291	1.03	80	4.87	235
η Leo	0.54	40	4.05	>70[d]
HD 21389	1.00	87	4.82	240
α Cyg	0.45	102	4.71	278

[a] Allowance has been made for an infrared excess.

[b] From an adopted M_V.

[c] No sign of a wind in Mg II.

[d] Displacement of the deepest point of the Mg II resonance lines.

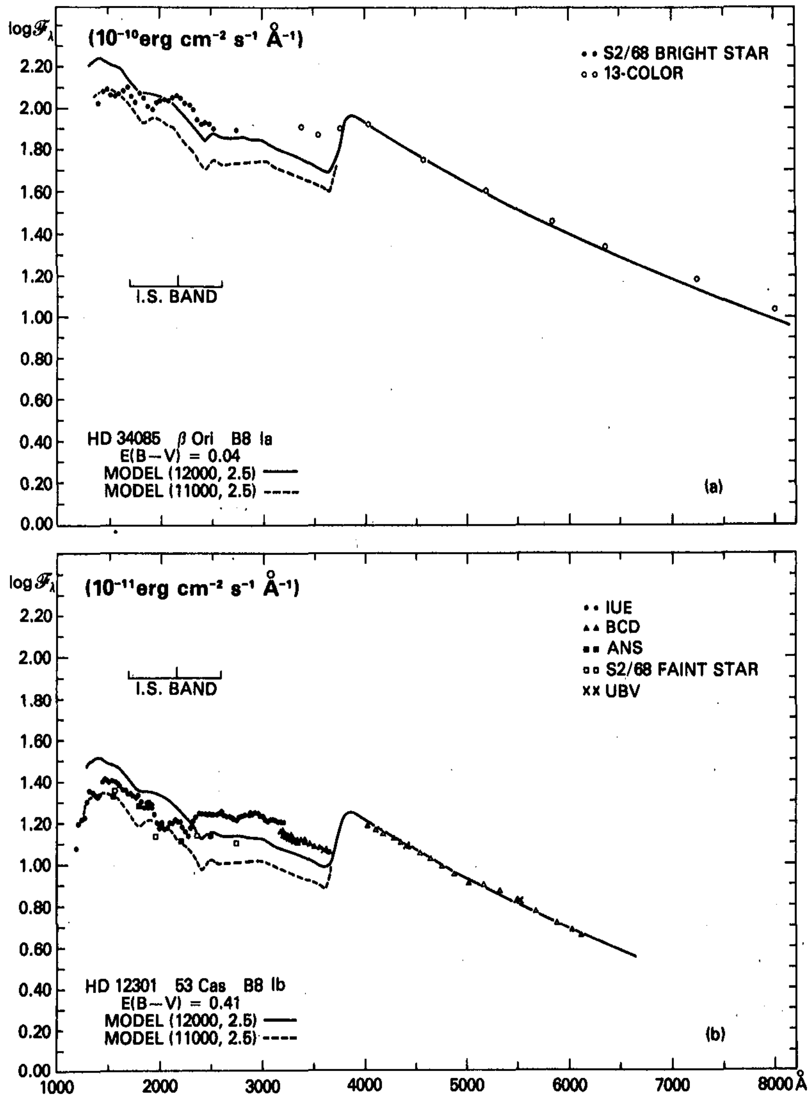

Fig. 1 - The energy curves, corrected for interstellar extinction, of the B8 supergiants 53 Cas and β Ori. The sources of photometric data are indicated in the figure.

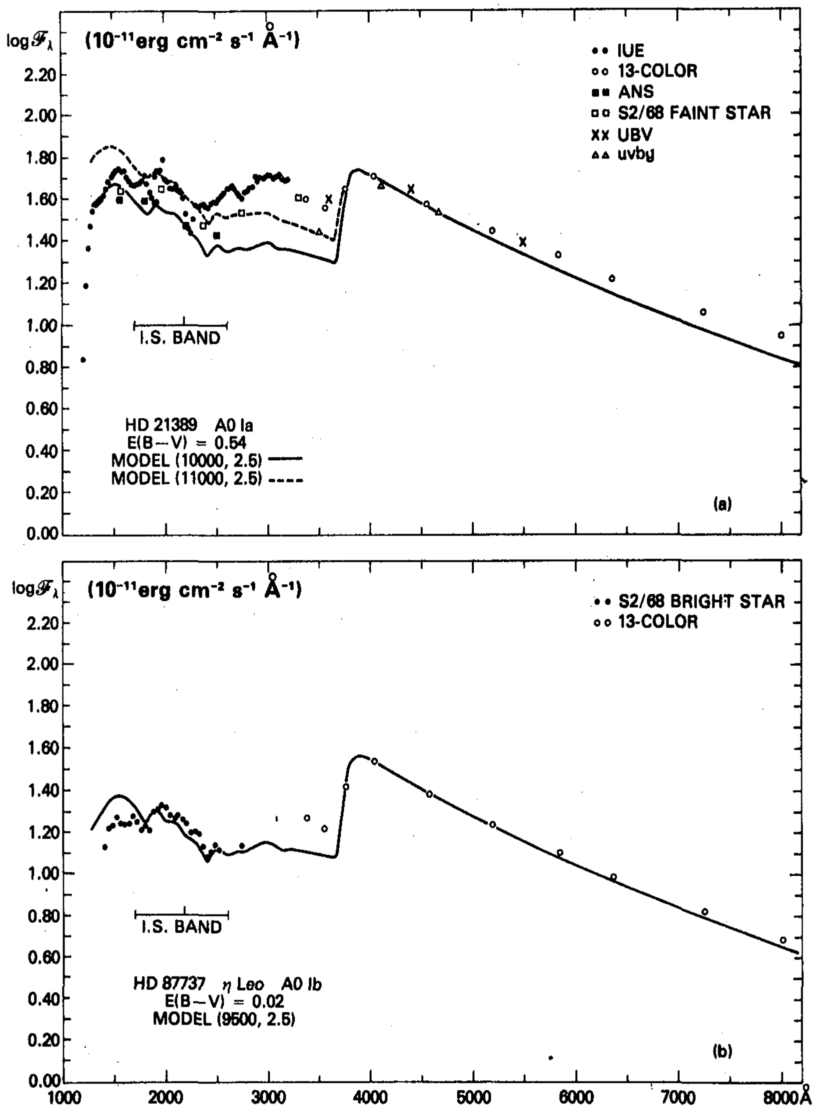

Fig. 2 - The energy curves, corrected for interstellar extinction, of the A0 supergiants η Leo and HD 21389. The sources of photometric data are indicated in the figure.

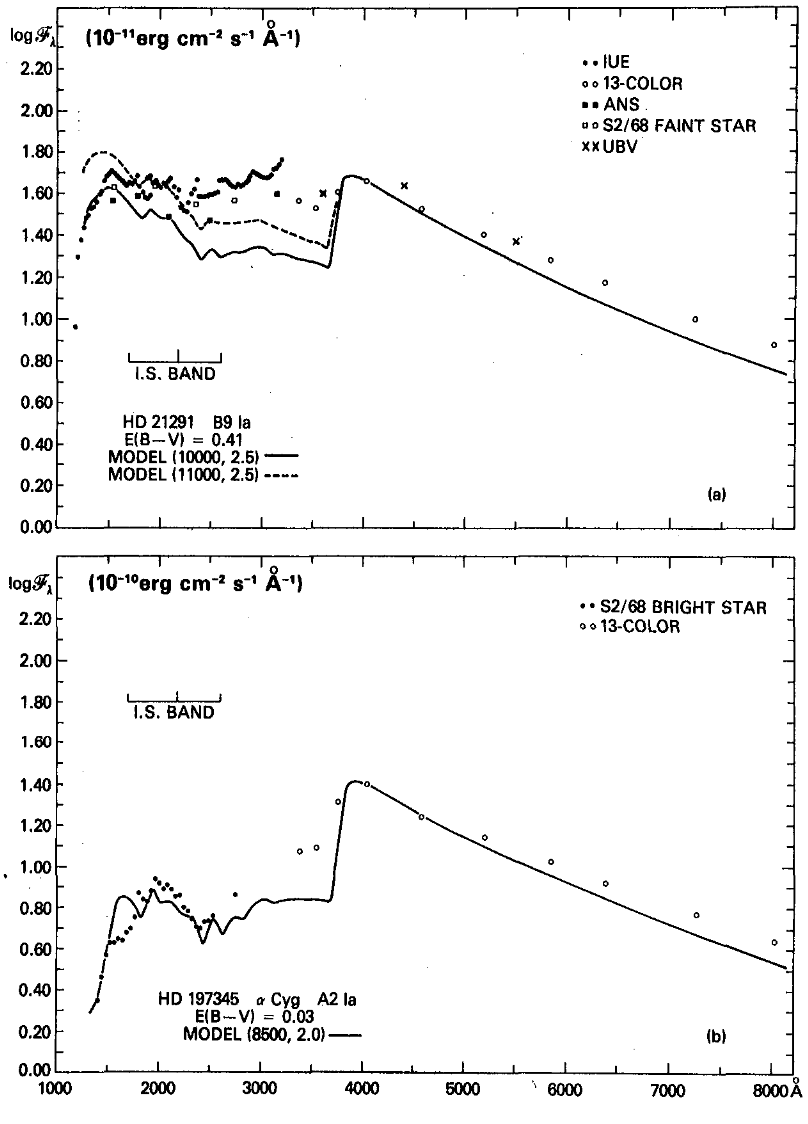

Fig. 3 - The energy curves, corrected for interstellar extinction, of HD 21291, B9 Ia, and α Cyg, A2 Ia. The sources of photometric data are indicated in the figure.