SPECTROSCOPIC INVESTIGATIONS OF HERBIG-Ae-Be-STARS

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ABSTRACT

"Herbig-Ae-Be-Stars" are assumed to be pre-main sequence objects of moderate mass with line emitting envelopes of an unknown nature. From our present theoretical knowledge it is not clear whether the physical structure of these envelopes is dominated by mass accretion or mass loss induced by a stellar wind or radiation pressure effects. Radial velocities and remarks on peculiarities are given for the star HD 200 775, which seems to represent a typical Herbig-Ae-Be-star fairly well. A catalogue of about 60 supposed Herbig-Ae-Be-stars is presented and comments, in particular on the brighter members, are invited.

I. INTRODUCTION

At Landessternwarte Heidelberg high resolution spectroscopic work on Herbig-Ae-Be-stars (HBe's) is in progress. Spectra of about 35 stars are already available and are currently being reduced. Though these objects are not 'classical' Be-stars, it is intended to give Be-observers some insights into the spectral appearance and invite critical comments on a preliminary Herbig-Ae-Be-star catalogue since that list may include related objects as well.

According to model computations of star formation, for mass values of 3-4 $M_{\odot}$ the time scale of the accretion phase of the protostellar envelope is equal to the core age at which hydrogen burning begins (Larson 1969). Present theoretical considerations cannot predict whether the circumstellar envelope is affected by mass accretion processes or by mass loss incuced by a stellar wind or radiation pressure effects. In 1960 G. Herbig made a first discussion of 'Spectra of Be- and Ae-type Stars associated with Nebulosity' (Herbig 1960). In a more recent paper it is demanded that

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the following criteria should be fullfilled by HBe's (Strom et al. 1972):

- presence of emission line spectra
- association with regions of heavy obscuration
- illumination of fairly bright (reflection) nebulosity.

II. HD 200775: A TYPICAL HERBIG-AE-Be-STAR.

Since HD 200775 seems to be representative of the bulk of HBe's this star was chosen to illustrate the work on radial velocities and to show spectral peculiarities which seem to be present in other HBe's as well (see also contribution No. 69). 9.5 Å/mm coudé plates, obtained by Appenzeller and Bertout in June 1977 at the Observatoire de Haute Provence, France, and 42 Å/mm plates from Calar Alto Observatory, Spain, were considered. In the latter case three tracings were superposed in the computer to improve the signal to noise ratio (see Fig. 1).

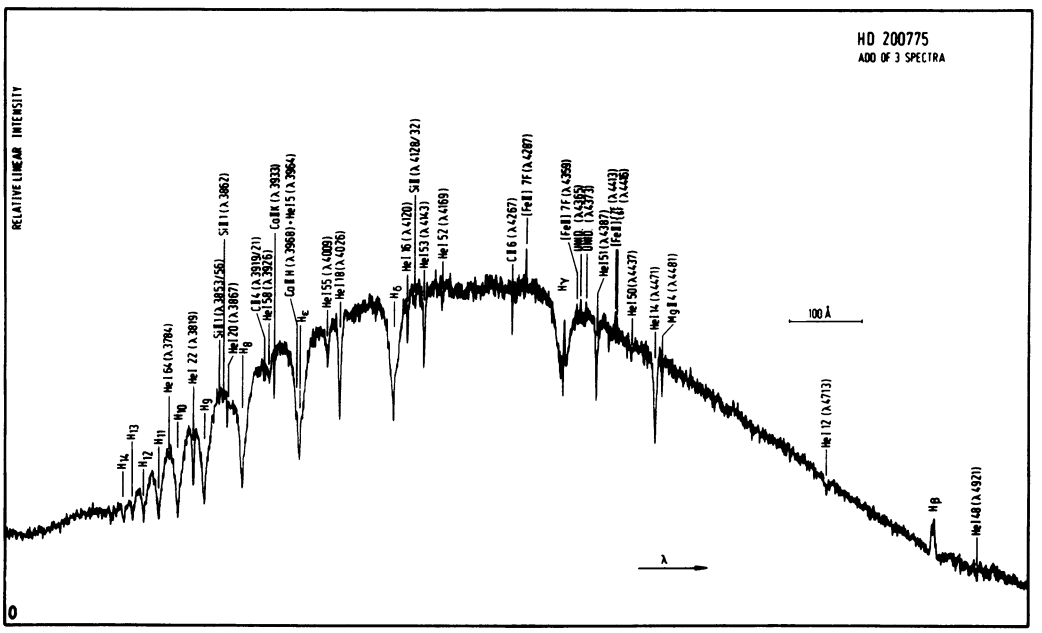

Figure 1. A spectrum of HD 200775, obtained from 3 42 Å/mm spectra taken at Calar Alto Observatory, Spain, on June 30th, 1980. (Since only radial velocities and relative intensities are considered no corrections for the instrument sensivity were applied).

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TABLE I

Heliocentric Radial Velocities [km/sec] of HD 200775

Line	Plate W 6421 9.8 Å/mm		Plate N 740 42 Å/mm	
H_{12}	-		- 7 ± 30	
H_{11}	-		+ 2	
H_{10}	-		+14	
He I 3819	-		- 9	
H_9	-41 ± 7		-41	
He I 3867	-		-16	
H_8	(-66)		- 2	
Ca II K	-14	X	- 5	X
He I 3964	-		+26	X
H_ε	-10		+ 3	
He I 4026	-25	X	-10	X
H_δ	- 1		-16	
He I 4120	-16	X	+ 3.5	X
He I 4143	-		-10	
C II 4267	+ 2	X	+ 0	X
He I 4387	- 9	X	+13	X
He I 4471	+ 0	X	- 5	X
Mg II 4481	-10	X	- 8	X
He I 4713	-23		- 1	
Mean	-16.2 ± 6.0	-7.7 ± 4.5	-3.6 ± 3.1	+1.8 ± 4.3
[FeII] 4243.98	-11		-	
4276.83	- 4		-	
4287.40	- 9		+ 2	
4352.78	- 8		-	
4359.24	-		-	
4413.78	+ 0		+20	
4416.27	-14		- 3	
Mean	-6.3 ± 2.8		+6.3 ± 4.9	
H_γ Blue Peak	-119		-103	
Red Peak	+102		+120	
Central Abs.	0		+ 13	
H_β Blue Peak	118		- 60	
Red Peak	84		+111	
Central Abs.	- 8		+ 20	

The crosses indicate lines which are generally accepted for system velocity determination (see for example A. Underhill, The Early Type Stars, Dordrecht, 1966, p. 121). These values compare well with those of the forbidden lines.

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The photospheric spectrum can be estimated as B3 IV - B3 V. The following points seem to be noteworthy:

- H_β and H_γ possess complex emission components with a central absorption. The emission on the red side is the stronger one. At H_δ and H_ε a disturbed red slope can be discerned. The Balmer series can be followed up to H_{14}. HD 200775 has extremely broad shallow absorption wings of about 80 Å total width at H_β.
- Most of the HeI lines show a disturbed blue wing. The perturbations are not restricted to triplet transitions but can be observed in singlet transitions as well.
- There are several lines of [Fe II] present, the strongest of which is [Fe II] 4287. Forbidden lines of other elements and ionization stages were not observed. Two sharp emission lines, probably originating in the envelope, could not be identified (4365.5 and 4373.1).

Since the structure of many lines is complex and asymmetric one should be cautious when assigning radial velocities. For that reason each line is listed separately. For the determination of the system velocity Balmer lines were not considered. The system velocity of -7.7 + 4.5 km/sec compares fairly well with literature values (Plaskett & Pierce 1931) who give the mean of -6.1 (1925), -1.8 (1927), +4.2 and +5.9 (1928) as +0.6 $\pm$ 1.8 km/sec.

Thus the visual and blue spectrum is dominated by features that appear rather static. Only the asymmetry of the He I lines may indicate mass loss, which has been determined by various authors and different techniques to be in the range of 10^{-7} $M_\odot$ yr^{-1} (Garrison 1978, Altamore 1980). Theoretical models should explain the strong, basically unshifted central absorption phenomenon of the Balmer lines. No prominent variations of the spectrum of HD 200775 have been found or are known in the literature.

III. OTHER HERBIG-Ae-Be-STARS

From the observational material available at present (35 objects out of about 65 are covered by spectra with ≈10 Å/mm dispersion) we feel that most of the HBe's are like HD 200775, i.e. they show in the lower Balmer lines a double peaked emission feature with a sharp central absorption. About 65% fall into that category. Another group (≈ 15%) displays prominent P-Cygni profiles, e.g. BD +61°154 or HD 250550. A third group consists of stars which have an emission line rich spectrum very similar to T Tauri stars, e.g. T CrA or HK Ori.

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TABLE II

LIST OF SUPPOSED HERBIG-Ae-Be-STARS

Star	α(1900)	δ(1900)	m_{pg}	References
Lk H_α198	$0^h06.1$	$+58^\circ17'$	15	(1)
BD $+61^\circ154$	0 37.5	+61 22	10.6	(1)
BD $+30^\circ549$	3 23.2	+31 05	9.5	(2)
XY Per A+B	3 42.9	+38 40	8.8-10.1	(3)
Elias 1	4 12.5	+28 04	15	(4)
AB Aur	4 49.4	+30 23	7.2-8.4	(1)
HK Ori	5 25.9	+12 05	4.4-12.5	(1)
BD $+9^\circ880$	5 29.2	+ 9 58	9.3	(5)
T Ori	5 30.9	- 5 32	9.5-12.6	(1)
V380 Ori	5 31.6	- 6 47	9.7-10.3	(1)
BF Ori	5 32.4	- 6 39	9.8-13.4	(6)
RR Tau	5 33.3	+26 19	10.2-14.2	(1)
HD 37490	5 33.9	+ 4 04	4.37	(2)
HD 250550	5 56.2	+16 31	9.7	(1)
Lk H_α208	6 02.1	+18 42	13.0	(1)
MWC 137	6 13.0	+15 19	11.2	(6)
Lk H_α341	6 25.3	+10 37	13	(6)
HD 46060	6 26.0	- 9 36	8.6	(2)
Lk H_α215	6 27.2	+10 14	10.7	(1)
HD 259431	6 27.6	+10 24	8.7	(1)
R Mon	6 33.7	+ 8 50	11.3-13.8	(1)
$LH_\alpha25$	6 35.2	+ 9 53	13.0	(1)
HD 52721	6 57.2	-11 09	6.40	(2)
Lk H_α218	6 57.5	-11 17	12.2	(7)
ZCMa	6 59.0	-11 24	8.8-11.2	(1)
Lk H_α220	6 59.6	-11 18	12.3	(7)
HD 53367	6 59.7	-10 18	7.0	(1)
CoD $-44^\circ3318$	7 16.4	-44 24	10.4	(8)
HD 76534	8 51.5	-43 05	7.5	(2)
RCW 34	8 52.8	-42 43	11	(2)
RCW 36	close to RCW 34		11	(2)
Herbst 28	8 54.8	-43 03	11.5	(2)
HR Car	10 19.4	-59 07	8.2-9.6	(1)
Anon.	10 50.0	-59 55	10.5	(1)
GG Car	10 52.0	-59 52	9.1-9.5	(1)
AG Car	10 52.6	-59 55	7.1-9.0	(1)
HD 97048	11 05.3	-77 07	8.4	(6)
CED 110	11 03.4	-76 50	11.3	(9)
HD 97300	11 06.8	-76 04	9.2	(9)
Anon.	11 11.9	-77 14	11.5	(9)
HR 5999	16 01.9	-38 50	6.44	(10)
HD 150193	16 34.3	-23 42	8.6	(4)
Herbst	16 49.6	-40 06	10.5	(2)

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TABLE II (continued)

CoD -42°11721	16 52.0	-42 33	11	(11)
KK Oph	17 03.9	-27 08	11.8-12.7	(6)
HD 163296	17 50.3	-21 56	6.8	(12)
Lk H_α118	17 59.7	-24 16	12	(6)
Lk H_α119	18 05.0	-24 17	13	(13)
MWC 297	18 22.4	- 3 55	11.0	(1)
VV Ser	18 23.7	+00 05	10 - 13	(6)
MWC 300	18 24.1	- 6 09	10 - 13	(6)
AS 310	18 28.0	- 5 03	10	(6)
R CrA	18 55.2	-37 06	10.0-13.6	(1)
TY CrA	18 54.9	-37 01	8.9-12.1	(6)
T CrA	18 55.0	-37 06	11.8-13.6	(1)
BD +40°4124	20 17.0	+41 03	10.6	(1)
BD +41°3731	20 20.8	+41 58	9.9	(1)
HD 200775	21 00.4	+67 47	7.4	(1)
V645 Cyg	21 36.4	+49 47	15.1	(14)
BD +65°1637	21 40.6	+65 39	11	(1)
Lk H_α234	21 40.8	+65 39	11 - 13	(1)
BD +46°3471	21 48.7	+46 46	10.1	(1)
Sh -125	21 49.1	+46 27	10.5	(15)
Lk H_α257	21 50.5	+46 43	13.5	(6)
Lk H_α233	22 30.3	+40 08	14.5	(1)
HD 216629	22 49.4	+61 36	9.0	(16)
Sh -158	23 08.9	+61 06	10.8	(15)
MWC 1080	23 12.9	+60 18	13.0	(1)

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A catalogue of Balmer line profiles at $\approx$10 Å/mm for as many HBe's as possible is in preparation and will allow discussions on a more quantitative and representative basis.

The accompanying list contains supposed HBe's and related objects. The brightest members are HD 37490, HD 52721, HD 53367, HD 76334 and HD 163296. It is hoped that future research will take these objects into consideration.

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DISCUSSION FOLLOWING THE PAPER PRESENTED BY U. FINKENZELLER

SWINGS: What is the origin of your catalogue, since I recognize several B [e] stars, and at least one symbiotic?

FINKENZELLER: Entries are from various sources. Among the most important are Herbig's original work, the Herbig-Rao Catalogue of Emission-Line stars of the Orion Population, a paper of Herbst from 1975 on the Vela R2 Association, and various private communications with G. Herbig and I. Appenzeller.

SWINGS: The sample seems very heterogeneous: there are objects at very different stages of evolution.

FINKENZELLER: I agree that, due to the selection criteria applied, objects other than HBe's may be included. However, it is hoped to cancel some when all the spectroscopic material is available and compared accurately.