Observations at La Silla of Peculiar Emission-Line Objects with Infrared Excesses

Jean-Pierre Swings

HD 45677 may be considered the prototype for these peculiar emission-line stars that are now called B[e]'s, i.e. Be stars whose spectra exhibit forbidden lines as well as permitted lines of H, Fe II, ... HD 45677 has the following coordinates: $\alpha = 6^h26^m$ and $\delta = -13°$. It is therefore ideally located to be observed from La Silla during the summer or early fall in the southern hemisphere. In other words at epochs when the weather is perfect. I should probably mention here that out of the 57 nights that were allocated to me by ESO and by CARSO (ten nights at Las Campanas) between 1972 and 1976, only three could not be used for spectroscopy: that corresponds to a 95 % record!

Dr. J.-P. Swings of the Institut d'Astrophysique of the Liège University studies those rare stars that have emission lines. From an impressive series of observations, carried out in the period 1972–76, important new information has been obtained about the behaviour of dust-shrouded stars. The combination of optical spectroscopy and infrared photometry has allowed a better understanding of the physical processes in these very peculiar objects.

In order to illustrate what is meant by "infrared excess", Fig. 1 reproduces the energy distribution of HD 45677 in the visible and near infrared. For a normal B star the energy should go roughly to zero beyond 1 or 2 microns; on the contrary one clearly sees that in the case shown in Fig. 1 there is a remarkable rise of the energy curve in the near IR, with a maximum somewhere around 5 μ. It is now believed that such a strong infrared excess is to be explained by the presence in the circumstellar environment of solid particles (therefore the expression "dust shell") which absorb the ultraviolet and visible radiations and degrade them to infrared wavelengths. In the case of the prototype HD 45677 one then gets an empirical simple-minded physical model where a dust shell of a radius of about 30 astronomical units, optically thick at 5 μ, surrounds the B[e] star and its extended atmosphere, ring (see Fig. 2), and forbidden line regions. Of course HD 45677 may be regarded as an extreme example of B[e] stars, perhaps even as "an object intermediate between an ordinary Be star and a planetary nebula" using the words of P. Merrill in 1952. This possible

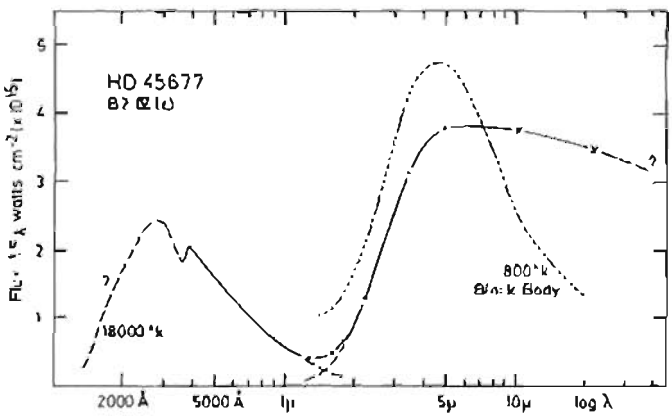

Fig. 1. – Energy distribution of the B[e] star with strong IR excess HD 45677. Wavelength is plotted logarithmically on the abscissa, and flux linearly on the ordinate; on such a graph the area under a segment of the curve represents the energy radiated in that wavelength interval. An 800°K body, shifted by 10^{-15} W cm^{-2}, is shown for comparison.

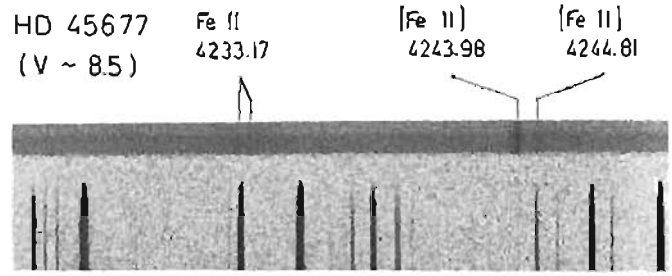

Fig. 2. – In the spectrum of HD 45677 the Fe II emission line λ 4233.17 Å is double with no central absorption, whereas the [Fe II] emissions (λλ 4243.98 and 4244.81 Å) are single (ESO plate, 1.52-m coudé spectrograph, camera III, i.e. original dispersion 3 Å/mm obtained during a 3-night exposure in Feb. 1972). The author has suggested that the Fe II emissions are produced in a rotating equatorial disk (or ring) surrounding HD 45677. A similar doubling of the Fe II lines was discovered in the spectrum of another southern hemisphere star with IR excess: GG Carinae.

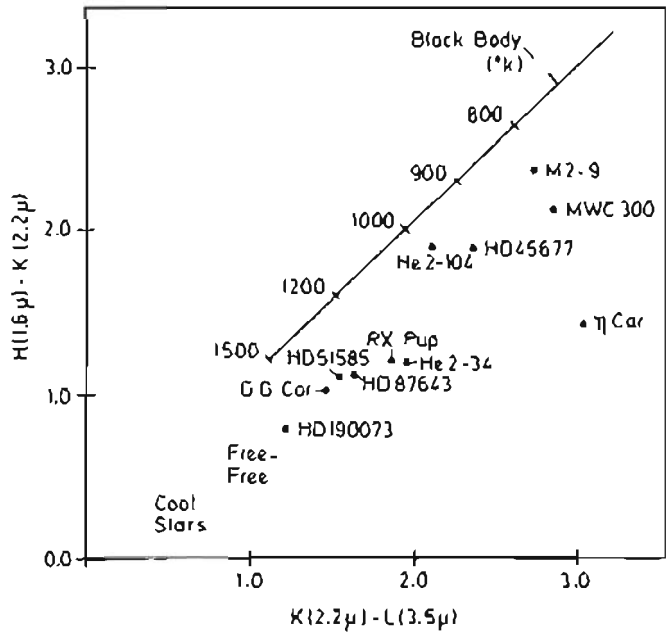

Fig. 3. – The near IR colours of a few peculiar emission-line objects observable on La Silla are plotted on an H-K/K-L diagram. Temperatures of idealized dust shells are marked along a "black body" line. The locations of normal cool stars and of stars whose IR continuum is due to free-free emission are indicated for comparison.

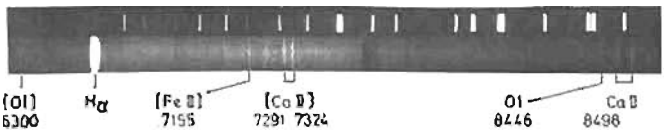

Fig. 4. — *The spectrum of RX Puppis from 6300 to 8600 Å obtained with the Boller and Chivens spectrograph at the 1-m telescope (80 Å mm^{-1}).*

connection between evolved Be's and young planetary nebulae leads me to introduce an interesting colour-colour diagram on which one may plot the position of emission-line stars with IR excesses: the H (1.6 μ) – K (2.2 μ) versus K – L (3.5 μ) diagram. On such a diagram (see Fig. 3) one sees immediately that the colours of a variety of objects (observable from La Silla) are similar: η Carinae, the well-known nova-like, M 2–9, the "Butterfly nebula", dense planetaries such as He 2–104, B[e] stars like HD 87643 or GG Carinae, an ex-symbiotic star, RX Puppis (Fig. 4). It is interesting to note that the spectra of most of those objects reveal low excitation emission lines of e.g. [O I], [S II], and [Fe II], as pointed out by Dr. David Allen and the author.

The study of the spectra of the peculiar emission-line objects of the southern hemisphere is performed on La Silla with the use of the coudé spectrograph of the 1.52-m telescope and of the Boller and Chivens image-tube spectrograph at the 1-m telescope. It covers the wavelength region between the near UV to about 8600 Å. The reduction of the data is often a collaborative venture between myself and colleagues in Liège such as Miss M. Klutz and Dr. J. Surdej, who is now with ESO in Chile, or students writing a dissertation for their master's degree.

The aims of these investigations are (1) the detection of low excitation emission lines in the spectra of those faint objects for which near infrared photometry has revealed excess continuum radiation (following the correlation mentioned above), (2) the study of the emission-line intensities in order to derive physical parameters concerning the extended atmospheres of the B[e] stars or dense planetaries, (3) the monitoring of line-profile variations such as changes from night to night or during the course of the night in the Balmer lines in HD 45677 and RX Puppis (Fig. 4) or from one observing run to the other in the Fe II lines of GG Carinae that give an idea of what happens in the extended atmosphere around the stars, (4) the study of P Cygni profiles in e.g. HD 87643 or CD –52°9243 (Fig. 5) that should lead to an understanding of how the mass loss occurs in these stars, (5) the structure of emission lines such as Fe II in HD 45677 (Fig. 2) or [O III] in HD 51585 (Fig. 6) that give us some indication about the structure and possible heterogeneities in the atmospheres of these stars: in the case of HD 190073 the observation of the evolution of the Ca II complex line profiles can be interpreted in terms of resonance scattering phenomena.

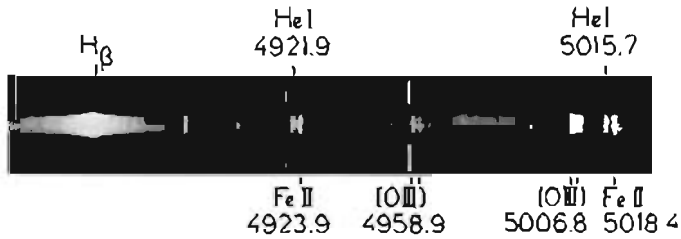

Fig. 6. — *The spectrum of HD 51585 in the region of Hβ and [O III] λλ 4959 and 5007 Å (coudé spectrogram, original dispersion 20 Å mm^{-1}). The two [O III] emissions are clearly double, while He I and Fe II lines are single.*

It is therefore clear that for peculiar emission-line objects of our galaxy there exist many interesting problems to be tackled on the basis of data gathered, or to be gathered, at the ESO telescopes. The next steps will of course contain the study of peculiar emission-line galaxies with IR excesses as well as the extension of the observations of B[e]'s and planetaries to the near infrared once a spectrograph designed for this spectral region (8000–12000 Å) will become available.

The author is most indebted to ESO since the work very briefly described here could not have been possible without the generous allotment of time on the telescopes at La Silla nor without the help of the staff in Chile, in the offices, in the labs, in the domes and ... in the kitchen!

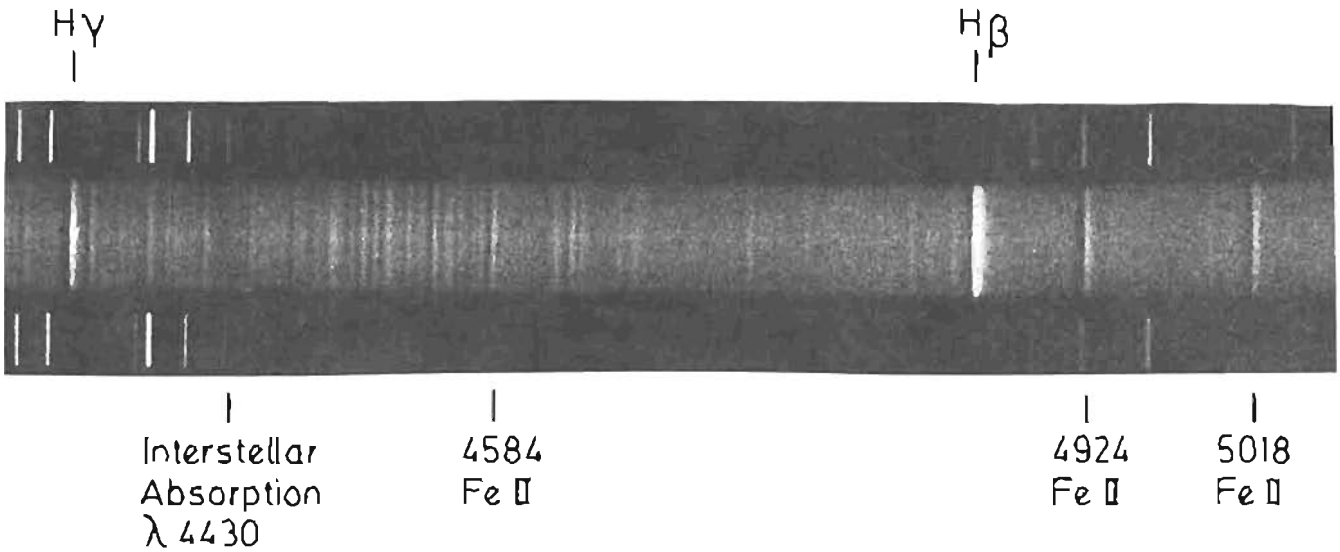

Fig. 5. – *Strong P Cygni profiles in the spectrum of CD –52°9243 (original dispersion 40 Å mm^{-1}; Boller and Chivens spectrograph, 1-m telescope).*