Be Stars Observed at La Silla

L. Divan, D. Briot and J. Zorec

Be stars are hot stars with emission lines, but where are these lines formed? Simultaneous spectroscopic observations at La Silla in June 1978 by Drs. L. Divan, D. Briot and J. Zorec from Institut d'Astrophysique (CNRS) in Paris throw new light on the Be phenomenon.

Be stars have been known for a very long time and, as their emission lines could not be formed in the photosphere, these objects were supposed to be surrounded by a thin hydrogen envelope extending to several stellar radii, the emission lines originating from the part of this atmosphere not projected on the central star. This picture explained also the presence in some Be stars of the so-called *shell spectrum* as due to the part of the extended atmosphere projected on the disk of the central star. Moreover, the rapid rotation of most Be stars could at first sight render plausible the formation of this envelope.

But when the details are considered, so many difficulties are encountered that even the reality of the extended atmosphere in which we have believed during more than forty years, now appears questionable. In fact, there is no real correlation between the rotational velocity and the size of the envelope. Difficulties arise also because in the same star, the emission lines and/or the *shell spectrum* can disappear in a few weeks or months and reappear again, more or less rapidly; in the extended-atmosphere picture this is not easy to explain.

On the other hand, the theoretical models for extended atmospheres depend on so many parameters (optically thin or not, dimensions, static or with any form of velocity gradient . . .) that it is impossible to decide if they are or are not in contradiction with the too few observed parameters.

We thought that this bad situation could be somewhat improved if

(1) more parameters were observed,

(2) observations were made of the same stars at the same time,

and this is why simultaneous observations were done at La Silla, by D. Briot with the 152 cm telescope and coudé spectrograph, and by L. Divan and J. Zorec with the 50 cm ESO telescope and Chalonge spectrograph.

Simultaneous Spectroscopic Observations on La Silla

The parameters observed by D. Briot are the equivalent width and profiles of Balmer lines (Hα included); the reduction is made by classical methods but with improved spectral types and effective temperatures thanks to (λ_1, D)-classification obtained for the programme stars with the Chalonge spectrograph.

The Chalonge spectrograph gives interesting and practically never observed parameters in Be stars. The Balmer region is particularly rich in information; in many cases Be stars have quite a normal Balmer Jump but sometimes, as Barbier and Chalonge announced long ago (*Ap. J.* 1939, **90**, p. 627) for ζ Tau, *two* Balmer Jumps occur at wavelengths differing by about 50 Å. The first one is situated like in a normal star and the second one, at shorter wavelengths near the theoretical Balmer limit, like in supergiant stars. Barbier and Chalonge concluded that hydrogen was present in the photosphere of the star and in an envelope at a very low pressure.

The Two Balmer Jumps

Following this idea we assume that the long-wavelength Balmer Jump ($D_\star$ on figure 1) is the Balmer Jump of the central star and that, together with the corresponding λ_1 it gives the λ_1D spectral type (this had been done long ago, by D. Chalonge and L. Divan, *Ann. d'Astroph.* **15**, 1952, 201, to classify four stars with emission in the Balmer continuum: 1 H Cam, 59 Cyg, υ Cyg and 11 Cam) and the effective temperature (the λ_1D spectral type has been calibrated in effective temperature). This assumption is justified by observations made in stars with variable emission (see below).

The second Balmer Jump (d on figure 1) can be either in emission, like in α Ara ($d < o$), or in absorption like in 48 Lib ($d > o$). In all cases the resultant Balmer Jump D is equal to ($D_\star + d$).

These stars are often variable, but the most interesting point is that the variations occur *only* in the short-wavelength Balmer Jump d due to the envelope which may even disappear entirely (1 H Cam, figure 2 or 59 Cyg, figure 3) and reappear again. The long-wavelength Balmer Jump is *constant* and then really defines the spectral type

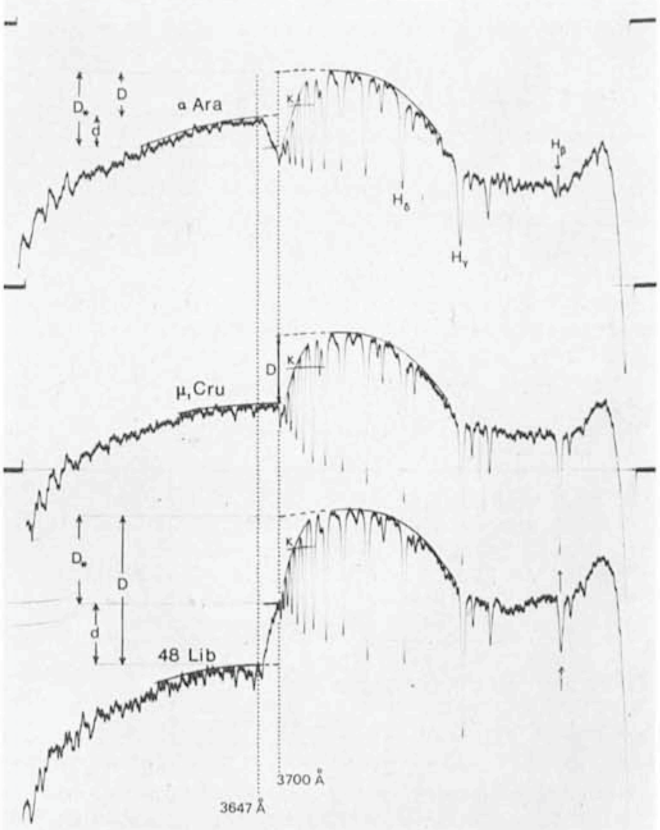

Fig. 1: *Microphotometer tracings of α Ara, μ_1 Cru and 48 Lib. μ_1 Cru is a normal B star showing a unique Balmer discontinuity, D. In α Ara and 48 Lib two Balmer discontinuities can be seen, a long-wavelength one, $D_\star$, which is due to the central star, and a short-wavelength one, d, corresponding to the envelope.*

d is in emission for α Ara ($d < o$) and in absorption for 48 Lib ($d > o$). In the two cases $D = D_\star + d$.

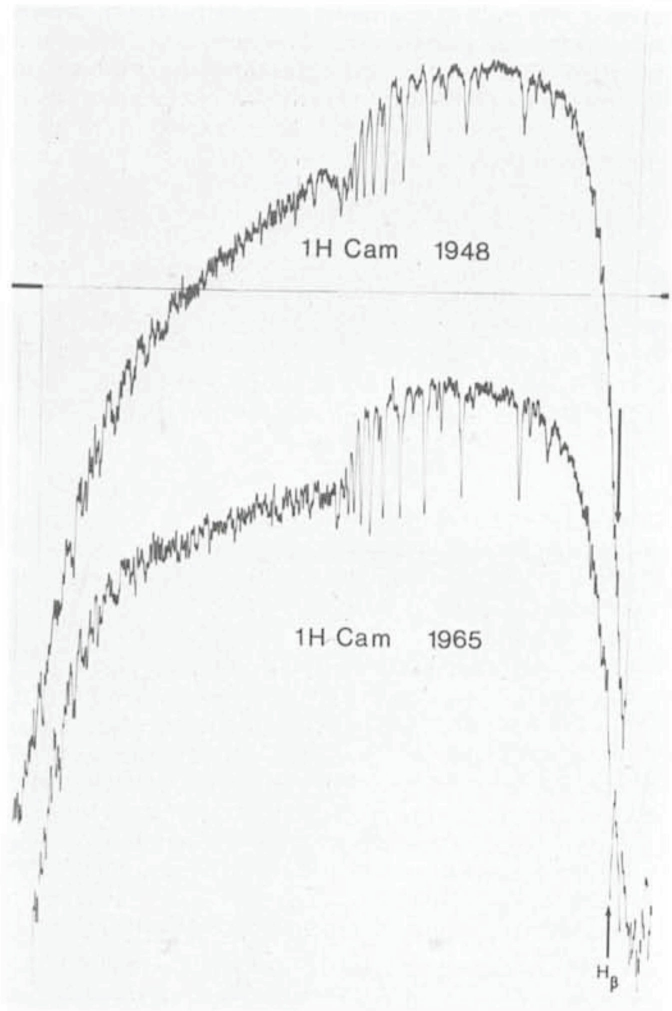

Fig. 2: *Emission in the Balmer continuum which was clearly visible on the 1948 spectrum has disappeared in 1965. Note also the Hβ line, absent in 1948 (filled in by emission) and normal in 1965.*

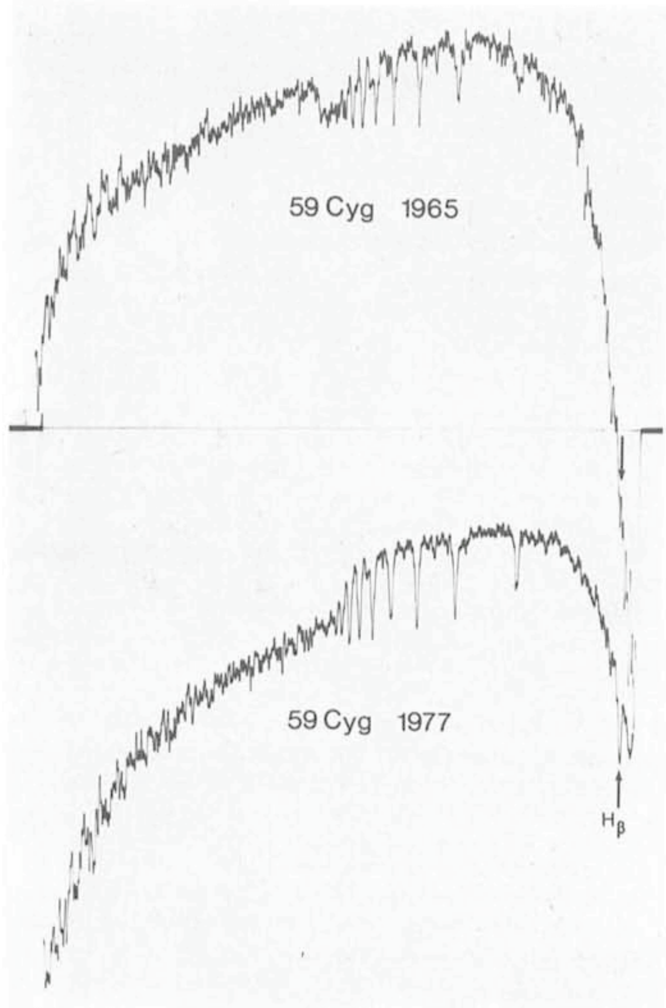

Fig. 3: *Cf. figure 2.*

(and luminosity class) of the central star as was supposed above.

Spectral Variations

Naturally, variations in d are accompanied by variations of the emission in the Balmer lines (Hβ in figures 2 and 3). What is less known (but was discovered by Barbier and Chalonge for γ Cas during its great burst in 1936–37) is that variations in d and Balmer emission lines are accompanied by changes in the colour temperature of the star, on both sides of the Balmer discontinuity. Figure 4 shows the results obtained for HD 24534 (= X Per) by L. Divan at the Haute-Provence and Jungfraujoch Observatories with the Chalonge spectrograph: there is a close relation between the colour of the *star + envelope* and the discontinuity d (D_* being constant) both on the red side (φ_{rb}) and on the ultraviolet side (φ_{uv}) of the Balmer Jump, showing that in this

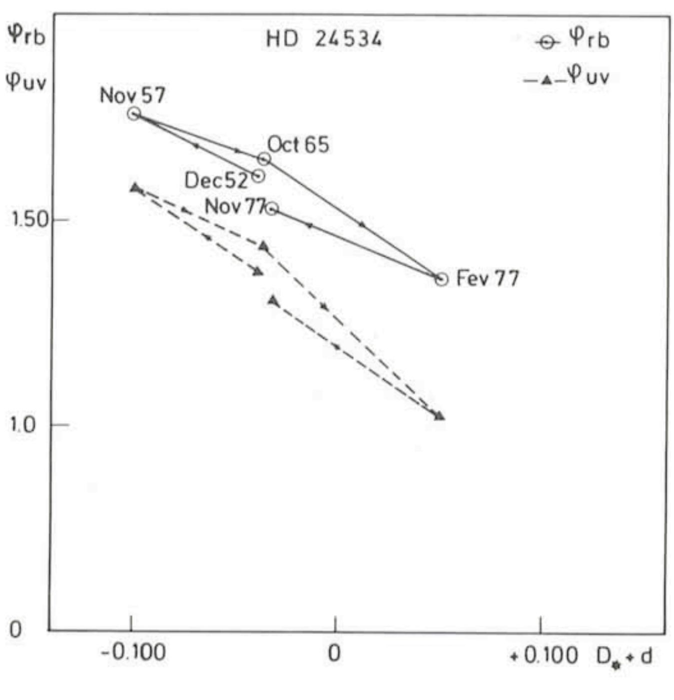

Fig. 4: *Spectrophotometric gradients φ_{rb} (spectral range 6200–4000 Å) and φ_{uv} (3700–3150 Å) for HD 24534 (= X Per) as a function of $D = D_* + d$.*

The emission d in the Balmer continuum of X Per is variable and we can see here that the colour temperatures on both sides of the Balmer Jump are strongly correlated with d.

The normal colour of X Per (spectral type B0) is $\varphi_{orb} = 0.73$. In February 1977, the colour of the star is $\varphi_{rb} = 1.36$ and its spectrum shows practically no emission ($d = O$, $D = D_*$); thus the colour excess $\varphi_{rb} - \varphi_{orb} = 0.63$ is entirely interstellar. In all other cases the colour excess is the sum of two terms, the interstellar colour excess and a colour excess due to the presence of the envelope. Observations of this type permit a clear separation of these two terms. ▶

case the envelope cannot be considered as optically thin in the continuum. Note that the extrapolation of this relation to d = 0 (in fact to the immediate vicinity of the point *Fev 77* for which the emissions have almost disappeared) gives the interstellar colour excess of the star; this interstellar colour excess is the same in all phases and can then be subtracted, to obtain the colour excess due to the envelope alone.

Future Observations

All these observations will be extended to many stars. The fact that the discontinuity D_* as it has been defined on figure 1, is constant, justifies the picture of an *unvariable* central star. But the variable part of the spectrum is still a mystery: extended atmosphere or perhaps a chromosphere? A tentative representation of the Be phenomena by non-thermal phenomena in the stellar atmosphere is in progress (R.N. Thomas and J. Zorec) at the Institut d'Astrophysique in Paris and the present simultaneous observations done by us at La Silla (high dispersion to measure the emission in Balmer lines, low dispersion to measure all the parameters of the continuum: D_*, λ_1, d, φ_{rb}, φ_{uv}) will serve to test new models. Of particular interest are the correlations:

(1) between d and emission in Balmer lines ($W\alpha$, $W\beta$ . . . and Balmer decrements),

(2) between d and the colour temperatures on both sides of the Balmer Jump.

We hope that the large set of new data obtained in June 78 at La Silla together with theoretical efforts will throw some new light on the Be phenomenon!

The Environments of Active Galactic Nuclei

R.A.E. Fosbury

It is becoming increasingly clear that strange things happen in many galaxy nuclei and that their study is of extreme importance for our understanding of the behaviour of matter. Observations from satellites and with large telescopes have yielded new and often unexpected results and the possibility of the existence of black holes (or even more exotic objects) in the centres of active galaxies is now taken seriously by most astronomers. Dr. Robert Fosbury, who joined the ESO Scientific Group in Geneva in 1977, has been pursuing for a long time the study of galaxy nuclei with some of the world's largest telescopes. He gives some examples of recent work with the ESO 3.6 m telescope.

Small regions of intensely energetic activity are known to exist in the nuclei of many galaxies and there are a number of arguments which, taken together, provide rather convincing evidence that QSOs are distant, luminous examples of the same type of phenomenon. Understanding the nature of these energy sources is important because the extreme conditions encountered in them stretch our knowledge of basic physics. Also it would be possible to use the QSOs as cosmological probes with much more confidence if there was a better knowledge of what they were and whether their redshifts were entirely due to the universal expansion.

Aside from the cosmological information implicit in the study of QSOs, by moving a little nearer home and looking at activity in galactic nuclei, we are immediately presented with a number of observational and interpretative advantages. Not least of these is the chance to investigate the relationship between the nucleus and its galactic environment. The interaction between the central energy source (10^{15} cm from variability and other arguments) and its surroundings occurs on a very wide range of spatial scales and, depending on the nature of these surroundings, produces widely different manifestations of what are probably similar phenomena. This range of scales demands the application of a wide range of observational techniques. The radio band does not in general contain a large fraction of the luminosity of active nuclei, radio continuum observations do however provide a means of tracing events from the smallest to the largest angular scales. Optical and ultraviolet spectrophotometry are powerful techniques for studying the continuum radiation emitted from very close to the energy source and also, from the emission lines, the state of the ionized gas which is excited by the activity. Recently obtained X- and γ- ray results are putting very severe constraints on models of the energy source itself.

These are some interesting general correlations between the outward appearance of the nuclear activity we observe and the morphological type of the associated galaxy. For example, classical double radio sources seem only to be found straddling elliptical galaxies, while class 1 Seyfert nuclei (blue continuum, broad permitted emission lines, narrow forbidden lines) exist predominantly in spiral galaxies and are usually not strong radio sources. While correlations of this kind do not have the status of absolute rules, they do provide a starting point for a study of the link between events in the nucleus and the evolution of the galaxy as a whole.

As part of a larger programme studying the morphologies of radio galaxies in the Parkes Catalogue using the SRC IIIa-J sky survey, I obtained in April direct plates of some selected galaxies using the 3.6 m telescope at prime focus. Figure 1 shows the galaxy identified with the inverted-spectrum radio source PKS 1934–63. The radio source itself is worthy of note since it was among the first discovered to show the characteristic low-frequency cut-off due to synchrotron self-absorption (Bolton, Gardner and Mackey, 1963, *Nature*, **199**, 682). It is also extraordinarily powerful as a compact source associated with a galaxy rather than a QSO. Optical spectrophotometry has been published by Penston and Fosbury (1978, *M.N.R.A.S.*, **183**, 479), and figure 1 is a significant improvement over previously published photographs. Rather than being a "double" galaxy it is possibly a giant elliptical girded by a dust belt reminiscent of our nearest radio galaxy NGC 5128 (Centaurus A). As in Cen A, the radio structure, which is known to be a very close double from VLBI observations, would be aligned perpendicular to the dust belt. It is even possible that the dust is hiding a quasar-like nucleus, an idea which could be checked by infrared observations.