82, 488, 1970), Robinson and Wampler (*Publ.A.S.P.*, **84**, 161, 1972), McNall (*Publ.A.S.P.*, **84**, 182, 1972) and Cullum (*ESO Technical Report* No. **11**, 1979).

IV. Implications

At first glance the nonlinearity reported here seems to have little importance for the average observation. Error estimates quoted for line ratios measured in H II region spectra and in the absolute flux calibration are usually of the order of 10 per cent or larger. However, these error estimates concern the random errors. The power law nonlinearity reported here will produce a systematical deviation of 17 per cent for intensity ratios of 100 and 9 per cent for intensity ratios of 10. Though this might be negligible for observations of continuum sources, the effects on H II region line spectra are far reaching. For an electron temperature of 10,000 K and a density of 100 electrons per cubic centimetre the intrinsic ratio of the [O III] lines 5007/4363 is 170. The observed ratio will be 210 and a temperature of 9,350 K will be derived. Together with the overestimated ratios of the strong oxygen lines over Hβ an oxygen abundance too high by a factor of two or more will result. This systematic effect will be present in investigations based on large samples of H II regions or planetary nebulae—for example in abundance gradient studies.

Last but not least I would very much appreciate any comments, in particular to know about similar findings with the detectors on La Silla or anywhere else. The growing confidence in the reality of the nonlinearity reported here has benefitted by discussions with a large number of observers, engineers, technicians and theoreticians, who deserve my thanks.

The Local Stellar Environment (LSE) — The B Emission-Line Stars

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Observations made during the last decade outside the visual region—in the X-ray, far UV, far IR, and radio regions—have profoundly modified our understanding of the LSE. Historically, from only visual observations, the LSE was considered as either the locale of protostellar material surrounding stars in their early evolutionary stages, or as a product of mass ejection during only the late stages of stellar evolution. However, we know from all these new observations that a mass outflow is observed from a variety of stars, during a variety of evolutionary stages, all across the HR diagram; and that there exists a continuous interaction between the mass outflow at a given epoch, and either (i) the general ISM; (ii) the prestellar nebula; or (iii) the mass outflow at a preceding epoch, i.e. a self-interacting variable mass outflow. Thus, the picture of a static LSE enveloping a thermally structured star is replaced by a dynamic LSE enveloping a nonthermally structured star in continuous interaction with the LSE. From this viewpoint, the outermost layers of the star are to be considered as a major component of the local environment; and the structure of both the outermost layers and the local environment reflects the properties of the mass flux. For this reason, progress in our understanding of the LSE is intimately linked to progress in understanding stellar atmospheric structure and stellar evolution.

The LSE may be either observed directly as nebulosity whose association with star(s) in its vicinity has been established; or inferred from the presence of spectroscopic features that imply the existence of an extended atmosphere. Examples of an observed LSE are: (a) pre-main-sequence (PMS) stars, identified by Herbig (1960), still embedded in the primeval nebulosity—Herbig Ae, Be, T Tauri—(b) the planetary nebulae which, on the contrary, have manufactured their own local environment, and represent late stages of stellar evolution. Examples of inferred LSE come from the presence of low-excitation/ionization emission lines (relative to photospheric conditions) such as observed in the visual spectrum of Be and P Cygni stars. These are to be contrasted with chromospheric-coronal, high-ionization emission lines, such as seen in the Sun and in WR stars. Low-ionization emission, especially in the Balmer lines, implies, for these hot stars, the existence of an extended, cool, outer atmosphere. Our understandig of each of these types of stars, whose LSE is observed or inferred, has strongly evolved during the last decade. But, undoubtedly, it is for the Be stars that our picture has changed the most. Be stars are probably the best observed objects in the Galaxy, after the Sun. In the same way as the Sun has served as a guide for understanding stellar chromospheres and coronae, Be stars may help us to understand that broad class of emission-line objects, observed across the whole HR diagram, which, in addition to having hot, rapidly expanding regions, also possess cool, extended, low-velocity regions which define their peculiarity.

I. The Be Stars as Seen in the Visible—A Variable, Cool, Extended Outer Atmosphere

Be stars show a B-type spectrum of luminosity class III-V accompanied, in the visible region, by emission in the Balmer lines, and often in the singly ionized metallic lines whose presence is expected only at later spectral types.

The origin of emission lines in B-type spectra was attributed by Struve, in 1931, to the presence of an extended, cool atmosphere. The question to be answered, at that epoch, by the existence of Be stars was: Why do only some stars of the B-type class possess an extended atmosphere? On the basis of observed line widths, interpreted as rotational, Struve hypothesized that the presence of emission lines in the spectrum and the rapid rotation of the star were two connected phenomena. At that epoch, rotation at break-up velocity was believed to produce equatorial mass ejection. Thus, a star rotating at such velocity would form an extended, cool, rotating, equatorial gaseous disk. This was the model of Be stars proposed by Struve. Subsequent studies showing that v. sini values are higher, statistically, for Be stars than for normal Bs, strengthened this picture.

However, it was realized that critical rotation by itself could not produce a mass ejection. Moreover, the observations did not provide any basis for justifying the assumption of critical rotation for these stars. Finally, it was recognized that v. sini values for Be stars are rather uncertain. Given these uncertainties, only ad hoc models of the Be phenomenon have been constructed. They retained the two basic assumptions of Struve's rotation model: (i) Be stars rotate at the critical rotational velocity; and (ii) they possess a mass flux restricted to the equatorial region only.

The rotation model stood up to nearly half a century of new observations; as long as the observations were restricted to the visible or infrared regions, it provided a convenient picture into which a large amount of new data could be fitted.

However, even in the visible region, it was possible to guess that the suggested picture was too narrow for describing the richness and diversity of the properties of the Be stars, especially their striking variable behaviour.

II. The Be Stars in the Far UV—A Variable, Hot, Rapidly Expanding Outer Atmosphere

The real contradiction between the rotation model and the observations comes from the far UV, where there is evidence for a new region in the outer atmosphere of Be stars, which no theory, or model, has predicted. In this spectral region, instead of a cold, low-excitation, low-velocity atmospheric region, one observes a hot, superionized region, with expansion velocity higher than escape. Instead of mass ejection restricted to the equatorial region, one observes high expansion velocities in stars classified as pole-on—that is, in the presumed direction of the axis of rotation—as well as in stars classified as equator-on. Not only was the possible existence of such phenomena ignored in the construction of the models, but the models were actually constructed on the assumption that such a possibility was actually excluded. The hypothesized picture of a cool, rotating equatorial disk is confronted with the actual picture of a hot superionized atmosphere in violent expansion. The rotation model is shaken by these new observations. It is clear now that any Be-star model must represent all the observed atmospheric regions within a coherent, self-consistent framework.

But, such far UV observations have not been genuine surprises for only Be-star models. Those spectral features which indicate the presence of an outer atmosphere of high ionization, and rapid expansion—i.e. the existence of a mass flux and a nonradiative energy flux—are equally observed among both normal B and Be stars. Any distinguishing difference between these 2 types of objects is a matter of degree and temporal behaviour of these 2 nonthermal fluxes rather than existence. It is, thus, in the *presence* of the *cool,* subionized regions and in the *behaviour* of the *hot* superionized regions that B and Be stars differ. Now, the problem raised by the existence of the Be phenomenon is to understand: (i) how do Be stars, and not "normal" B stars, produce, in addition to their superionized regions, slowly moving, subionized, extended atmospheres, (ii) what specific differences exist between the superionized rapidly expanding regions of B and Be stars.

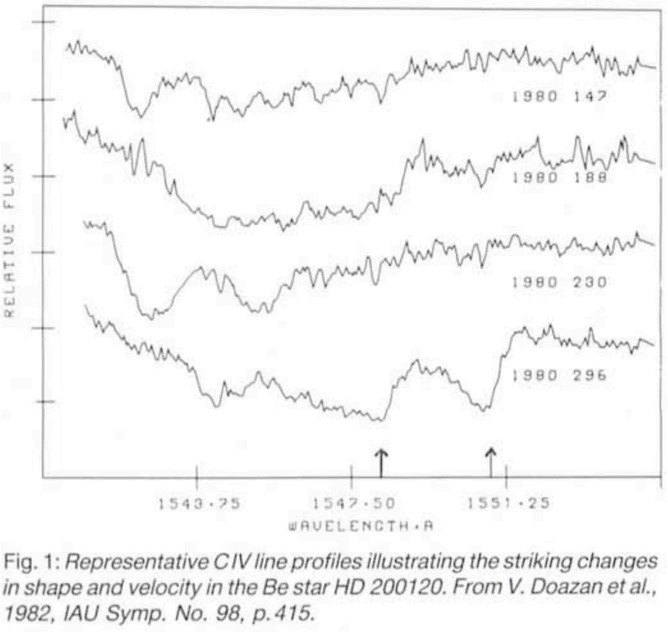

Fig. 1: *Representative C IV line profiles illustrating the striking changes in shape and velocity in the Be star HD 200120. From V. Doazan et al., 1982, IAU Symp. No. 98, p. 415.*

Before trying to find the physical causes of the Be phenomenon, it is first necessary to be more precise on what *is* the Be-behaviour in these various atmospheric regions. Because the outstanding property of Be stars is their variability, it is necessary to observe *simultaneously* such variability in the different atmospheric regions in order to provide the observational basis necessary for modelling the whole atmosphere.

III. Variability of Be Stars—A Variable Mass Flux and/or a Variable Nonradiative Energy Flux

As a general rule, Be stars are variable in their line spectrum, as well as in the continuum, in the visual region. The variability of Be stars can manifest itself in various ways depending on the star in question. In some cases a Be star loses its emission characteristics and becomes a normal B spectrum, and vice versa.

From the first far UV observations, it was quickly recognized that Be stars are also variable in this spectral region. After one decade of far UV observations, it is clear that Be stars are, among the hot stars, those which exhibit the largest, and the most striking, variations there. These large variations are exhibited by the resonance lines of the most highly ionized species present in the IUE spectral range, as C^{+++} and N^{++++}. On the contrary, the Mg II resonance lines in Be stars behave like the Balmer emission lines, in reflecting conditions in the cool regions of the outer atmospheres, and thus do not help in studying the highly ionized rapidly expanding atmospheric regions.

Long-term programmes of simultaneous observations made in the far UV and in the visual, for a few Be stars, have shown that the superionized lines, C IV and N V, are highly variable in velocity, shape and strength—in association with the visual phase. Fig. 1 shows some C IV profiles observed in HD 200120, at an epoch where emission in the Balmer lines begins to develop in the visual. That is, after having shown only absorption lines, the star entered what we have called a "new Be phase". Our regular monitoring of this star during seven years has shown, correlated with changes in the Balmer lines, the most remarkable sequence of changes in the C IV lines ever observed in a Be star. A synthesis of all the data obtained so far shows a striking correlation between the long-term behaviour in the visual and in the far UV. Fig. 2 illustrates another type of variability which affects mainly the strength of the C IV resonance lines: they appear and disappear at varying and irregular time scales. These 2 kinds of variability have been observed in other Be stars of our programme list, so they should not be considered as exceptional. We believe, on the contrary, that the only exceptional aspect of these results is their demonstration of associations between visual and far UV phenomena that became apparent only because of the regularity of our survey during a sufficiently long time.

We have interpreted the large changes of the C IV velocity, measured at maximum depth, as reflecting mainly the variability of the mass flux; and the large changes in strength of the C IV lines as reflecting mainly the variability of the nonradiative energy flux. Clearly, it is not possible to decide, from far UV observations alone, which of these fluxes are variable, but the whole set of data obtained so far points toward our interpretation. It is obvious that X-ray, far IR and radio data are necessary to complete the observations.

IV. A Tentative Model for Be and Similar Stars

In a first, wholly empirical, attempt to use all the available observational data on Be and similar hot, emission-line stars, we asked, free from historical preconception: what actually is the outer atmospheric pattern common to all these stars? We recognized, first, what is becoming apparent all across the HR diagram: the outer atmospheric structure is dynamic and nonthermal. Second, that in the Be and similar stars the highly ionized species showed the largest nonthermal velocities, while the subionized ones, formed in the more distant regions of the outer atmosphere, showed the lowest nonthermal velocities. Finally, that variability is always associated to emission-line stars.

Combining far UV and visual observations for Be and similar stars, we concluded that a decelerated outflow, which may occur as close as a few stellar radii from the photosphere, characterizes the stars. We proposed that a deceleration of such a superthermic flow, expanding at velocities higher than the escape velocity, can come only from its interaction/collision with either a preceding slowly moving flow—in the case of a Be star—or with the stellar primeval environment—in the case of Herbig Ae, Be stars; and concluded that mass outflow variability is a sufficient condition to produce a deceleration. If after such a deceleration, the flow velocity is smaller than the escape velocity at that point, then the outflowing material will ultimately fall back on the star. In this picture, both expanding and infalling flows may occur. We did not impose any, a priori, asymmetry to the model. But any asymmetry that the observations may demand may be introduced in a self-consistent way.

The variability of the mass flux is at the basis of our empirical model for Be and similar stars where, after the photosphere, the following radial sequence of atmospheric layers are defined: a chromosphere, a corona with its pre- and post-coronal regions, an Hα-emitting envelope, a cool shell, and a dust shell.

V. The Structure of the LSE—A Reflection of the Nonthermal Properties of the Subatmosphere

The new data (visual observations obtained with highly-performing instruments, and data obtained in the newly observeable spectral regions), synthesized in the NASA-CNRS Monograph Series on Nonthermal Phenomena in Stellar Atmospheres, indicate that nonthermal fluxes (mass flux, nonradiative energy flux) exist, at varying degrees, in a variety of objects, including those associated with an LSE. In our approach for modelling Be and similar stars, we have adopted the suggestion that such nonthermal fluxes are produced by subatmospheric nonthermal modes, due to rotation, convection, pulsation (radial or nonradial). Under such a hypothesis, the structure of the LSE is linked to the nonthermal properties of the subatmosphere.

High-quality observations of variable photospheric line profiles show evidence for nonthermal motions in the subatmospheres of a large variety of stars. From studies of precisely

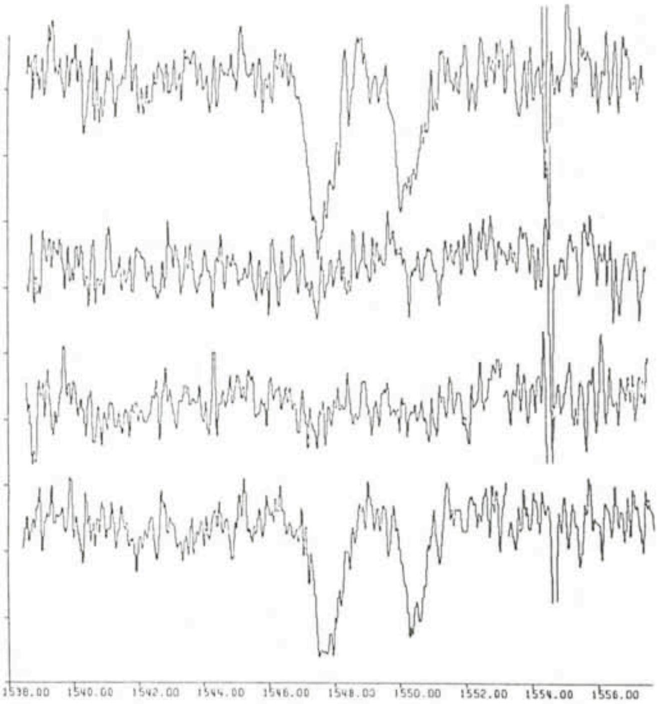

Fig. 2: *Representative C IV line profiles illustrating the changes in strength in the Be star HD 138749. From bottom to top: August 2, 1982; December 17, 1982; January 27, 1983; April 6, 1983. From Doazan et al., 1984,* Astron. Astrophys. **131,** *210.*

that variability of photospheric line profiles, various kinds of photospheric and subphotospheric pulsations have been diagnosed. The next step will be to identify which of these nonthermal modes (rotation, convection, pulsation, or any combination of them) is associated with the observed variety of structures of the LSE. From this viewpoint, any study of the LSE must include a simultaneous investigation of the subatmospheric properties of the stars associated with it. Such a study is currently being made for Be and similar stars.

(The above approach to the study of atmospheric structure and local environment, and the conclusions on the required subatmospheric structure have been abstracted from Volume 2 [B Stars With and Without Emission Lines, by A. B. Underhill and V. Doazan] and Volume 4 [Stellar Atmospheric Structural Patterns, by R. N. Thomas]).

An important collaborative programme based on simultaneous ground-based observations at La Silla, and space observations with EXOSAT and IUE, has been organized recently by Dr. Thé and Dr. Tjin a Djie of Amsterdam for the study of the Herbig star HR 5999. This programme illustrates well the necessity to study simultaneously the whole atmosphere by observing the high- and the low-energy parts of the spectrum. On September 11, 1983, several instruments at La Silla were pointing towards the same star, together with EXOSAT and IUE. We ourselves were observing it in the red and in the blue with the IDS at the 1.5 m telescope. Visual observations alone, which show the presence of Hα emission, and Fe II and Na I shell absorption lines, would only imply the presence of a cool extended atmosphere. But far UV observations, which show the presence of Si IV and C IV resonance lines in the spectrum, and X-ray observations, which imply a hot corona, show that the whole outer atmosphere is composed of multiple, strongly differing, atmospheric regions. These are the data which are needed for modelling the star. But, in order to understand the dynamic interaction of these several atmospheric regions, further repeated observations are still necessary over a significant time-scale. Finally, in order to link the observed properties of the LSE to the properties of the subatmosphere, we have undertaken at La Silla a study of the behaviour of the photospheric lines of the star with the CES. This programme is currently in progress.

The Multi-Faceted Active Galaxy PKS 0521-36

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The southern active elliptical galaxy PKS 0521-36 exhibits a range of nuclear and extranuclear phenomena which is remarkable in a single object which has only been observed in any detail over the last few years. Indeed, if it were situated significantly closer than its 330 Mpc (H_o = 50 km/s/Mpc), it would probably attract more observational and theoretical attention than Centaurus A and M 87 combined. The relationships between its many manifestations of high-energy activity will be the subject of intensive study as new observational techniques become available.

As has so often been the case for southern active objects, attention was first drawn to the galaxy by its optical identification with a Parkes radio source (Bolton, Clarke and Ekers 1965). Higher resolution images suggested an elliptical morphology, but the broad-band colours were anomalously blue, giving the first reason for special interest. The photometric observations of Eggen (1970), showing that it varied by more than one magnitude on a time scale of months, supported the earlier spectroscopic observations of Westerlund and Stokes (1966) and Searle and Bolton (1968), which showed an almost featureless continuum with only very weak emission lines, suggesting a close relationship to BL Lac objects.

Optical Structure

(a) The Jet

Deeper direct imaging obtained by Danziger et al. (1979) showed a jet-like structure extending about 20 kpc towards the north-west. This has a structure somewhat reminiscent of the jet in M87, although a direct comparison is difficult because of the order-of-magnitude difference in linear resolutions available. Sol (1983) has examined the structure of the jet in more detail: as in M87, it consists of condensations of different surface brightness. We are now fairly certain that in the optical region, all sections of the jet are emitting continuum and not line radiation. In deep CCD images of the object in a narrow-band filter isolating redshifted Hα, the jet does not appear. Nor do emission lines appear in the north-west in long-slit spectroscopy aligned along the jet. This spectroscopy does, however, reveal extended emission elsewhere. Nothing is yet known about the polarization of the jet in the optical band although there is associated radio structure which we discuss below.

(b) The Extended Emission

During the course of long-slit spectroscopy of this object with the UCL IPCS on the ESO 3.6 m Boller & Chivens spectrograph, nebular emission was discovered extending about 10 arcseconds to the east and south-east. This is not the source of the relatively weak emission seen in the integrated spectrum, which comes from a compact region at the nucleus.

In Fig. 1, we show the result of a 40-minute exposure taken with the CCD on the Danish 1.5 m telescope on La Silla through an interference filter with a bandwidth of 32 Å and a central wavelength of 6922 Å, corresponding to redshifted Hα. No continuum subtraction has been done. The picture shows a faint filamentary structure extending north of east and then turning towards the south. The reality of this structure has been established by long-slit spectroscopy with the slit in several different positions. In addition to the eastern filament, the picture hints at a more general, irregular filamentary structure. There is perhaps also a very low surface brightness halo extending out to a radius of ~15 arcseconds. These features merit more detailed study with deeper high-resolution imaging and spectroscopy. The picture shows no structure corresponding to the jet.

Spectrophotometry of the eastern filament, Fosbury (1982) and recent unpublished results, show the gas to be in a low state of ionization with [O III] λ 5007 / Hβ ≲ 1.5. This contrasts

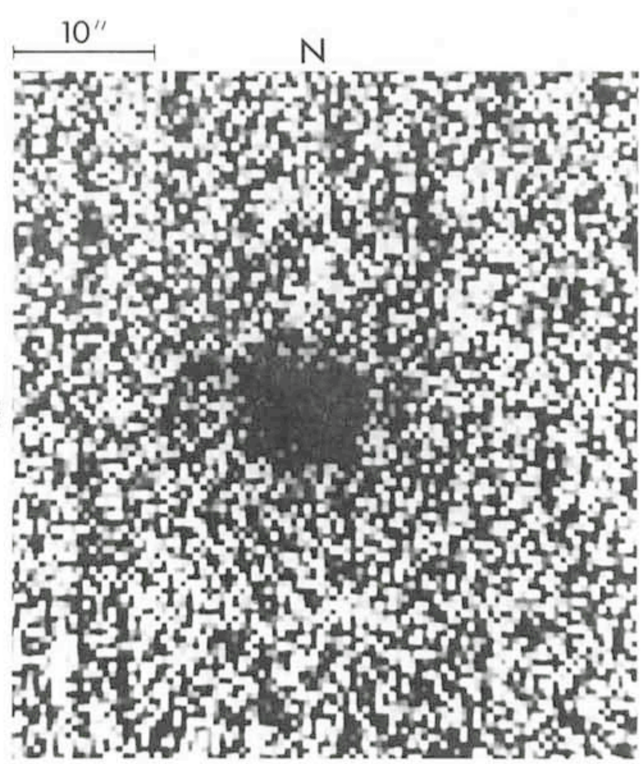

Fig. 1: *A 40-minute CCD exposure of PKS 0521-36 taken with the Danish 1.5 m telescope on La Silla. The filter was a narrow band centred on redshifted Hα (6922 Å). It shows the filament to the east of the galaxy but no feature corresponding to the jet visible on broad-band images in the blue.*