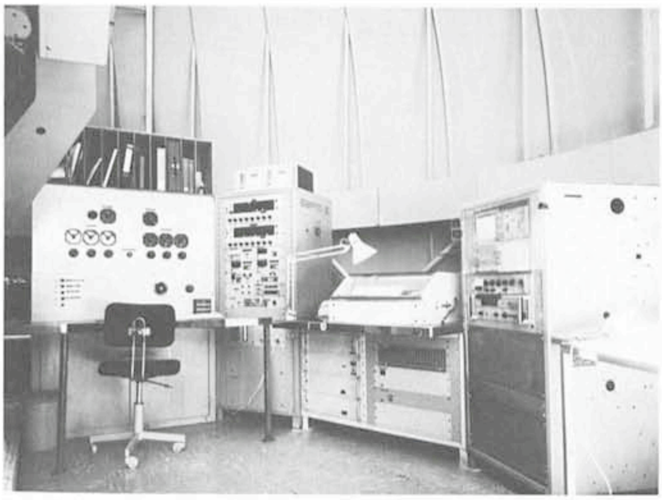

Fig. 3: *Overview of telescope control and data acquisition. To the left the telescope controls; in the middle the data-acquisition rack—on top of which the two cassette-units—and the IBM typewriter/printer.*

The filter system was conceived by Dr. Walraven in order to be able to measure properties of the continuous and line spectrum in stars of spectral type O to middle G which relate directly to effective temperature and surface gravity and, as it turns out, also to heavy-element-line blanketing. The central wavelengths of his five bands were chosen to match the well-known Paris (or Barbier-Chalonge-Divan) classification based on spectrophotometry on photographic spectrograms. Not surprisingly, the possibilities with the VBLUW or Walraven system are in many ways the same as with the well-known Strömgren uvbyHβ system. I refer to the above-mentioned paper by Lub and Pel for more details. Important applications have been to pulsating variable stars (Pel, Lub); the highly luminous OB supergiants in the Magellanic Clouds (Walraven and Walraven) and X-ray binaries (van Genderen and van Paradijs). References may be found in my paper in the 1979 Albany Workshop on *Problems of Calibration of Multicolour Photometric Systems,* edited by A.G. Davis Philip, Dudley Observatory Report No. 14.

I hope to have given a flavour of the possibilities of the present instrumentation on the Dutch telescope. Before long, ESO will install a computer, tape unit and fast printer for faster data acquisition and, possibly, on-line reduction. However, the complete reduction, including the analysis of the linearity of the digital voltmeter still has to be done in Leiden. During 1980 ESO will construct a (high-speed) one-channel photometer for the standard photometric systems such as UBVRI (Cousins) or uvbyHβ. Compatibility with other equipment on La Silla will be assured. Until this is finished the Walraven photometer is the only instrument available to visitors.

Acknowledgements

We wish to thank the Board of Directors of the Stichting Leids Sterrewacht Fonds for permission to give new life to the *Lightcollector* on La Silla. We would like to mention in particular the support given by Prof. A. Blaauw and Dr. J. Tinbergen of Leiden Observatory. The collaboration of Messrs. A. de Jong and G.v. d. Nagel during the reconstruction phase was always a great pleasure; they cheerfully and ably solved all arising small mechanical problems. Dr. J.W. Pel did a fantastic job on the photometer and the optics. ESO staff did as much as they could to provide additional support.

28 Canis Majoris—a Short-period Be Star

D. Baade

Are Be stars nothing but β Cephei stars? This far-reaching possibility is supported by new observations of the Be star 28 CMa, which shows spectral variations with a period of 1.36 days. Dr. Dietrich Baade of the Astronomical Institute of the University of Münster, FRG, recently obtained spectra of this star with the large coudé spectrograph at the ESO 1.52 m telescope. Here is his report about this important discovery.

Among the confusing variety of stars with unusual properties, Be stars probably form the group with the largest number of known members. This is in part due to their high intensive brightness. But the fact that 10 to 15 per cent of all non-supergiant stars of spectral type B exhibit emission lines also shows that the Be phenomenon is important. Moreover, Be stars are quite attractive objects for observations, since most of them undergo unpredictable spectral and photometric variations, which in some cases are fairly drastic. Nevertheless, Be stars are far from being understood.

Some Empirical Aspects of Be Stars

The main reason for this lack of comprehension is exactly the irregularity in the behaviour of nearly all Be stars. Thus, observations of individual stars normally are not expected to contribute much to the improvement of models for Be stars. Only statistical treatment made it possible to derive several types of variability representative for the Be phenomenon. Erratic long- and short-term photometric variations with amplitudes up to several tenths and a few hundredths of a magnitude, respectively, are common. Most important, however, are the spectroscopic changes, among them the characteristic V/R variations, i.e. the changing relative equivalent widths of the blue and red components of double-peaked emission lines.

V/R variations are in many cases cyclic but not strictly periodic. The duration of a (long) cycle differs from star to star within the range of 100 days to several years. The longer the cycle, the fewer cycles occur before the variation ceases gradually or abruptly. Short cycle lengths in the range of minutes or even seconds are reported for an increasing number of stars. They are, however, even less stable and have in no case been confirmed by a second series of observations.

Only one other type of variability of Be stars is correlated with the V/R variations: the radial velocities (RV) of the emission lines and their central reversals. But their interpretation is rather doubtful, and it cannot be ruled out that the RV variations are simply observational consequences of the V/R variations.

Effects on Models for Be Stars

The numerous irregularities and the, nevertheless, marked uniformity of the observations, if only the few properties common to the great majority of Be stars are considered, make their interpretation quite uncertain. Hence there are few observational restrictions for model building on the basis of the V/R variations and consequently a great variety of such models has been suggested—double star, elliptical ring, radial pulsation, stellar wind, ... A convincing decision between different models is seldom possible, since contradictions between models and observations can only be found in a few cases. An additional disadvantage of some of these models is that they put the origin of the variability into the shell or extended atmosphere of the star rather than into the star itself.

Observations of 28 Canis Majoris

With an average visual magnitude of $m_v = 3^m.8$, 29 ω CMa (B2 IVe) belongs to the apparently brightest Be stars. It is largely due to this circumstance that its very remarkable variability has been detected. Because of the short exposure time (5 minutes on baked IIIa-J plates, 12 Å/mm) at the coudé spectrograph of the 1.52 m telescope, I obtained in November 1976 within 6 nights more than a dozen spectra of this star in addition to an extensive observational material on a large number of other stars. When I was back in Münster and measured the radial velocity of the star it turned out to be variable due to an unusual circumstance. The reason was not a shift of the entire lines but a changing asymmetry in the moderately broadened ($v_{rot} \sin i \approx$ 100 km/s) profiles of *all* absorption lines (cf. fig. 1). This was connected with a weak V/R variation of the emission lines HI and FeII). Such observations are not known for Be stars: even similar ones of other stars are extremely scarce. The time scale of this variability was less than a few days.

These findings are remarkable (1) because they reveal a new phenomenon correlated with the V/R variations and (2) because they place the time scale of the variability of 28 CMa into the large gap between the observed spectroscopic cycle lengths of several minutes to a few hours and 100 days.

Another observing run, which was conducted in January 1978 by Dr. Duerbeck, Bonn, using the same equipment, confirmed the preliminary results and added considerable detail. The most important outcome is the strict periodicity of all variations with a period of $P = 1^d.36$. This period has probably been stable over more than 9 years, since it was also found from an examination of 6 ESO spectra taken by Prof. Van Hoof, Leuwen, and kindly lent to me. It is by far the shortest stable period so far observed in Be stars.

There are many further details, which are quite interesting, but only a selection can be presented here. To avoid a lengthy description the reader is referred to figure 2. Note that the radial velocity curves of absorption and emission lines are 180 degrees out of phase.

Observations with the ESO 50 cm telescope as well as earlier measurements of other authors show that 28 CMa does not display night-to-night variations exceeding $0^m.03$

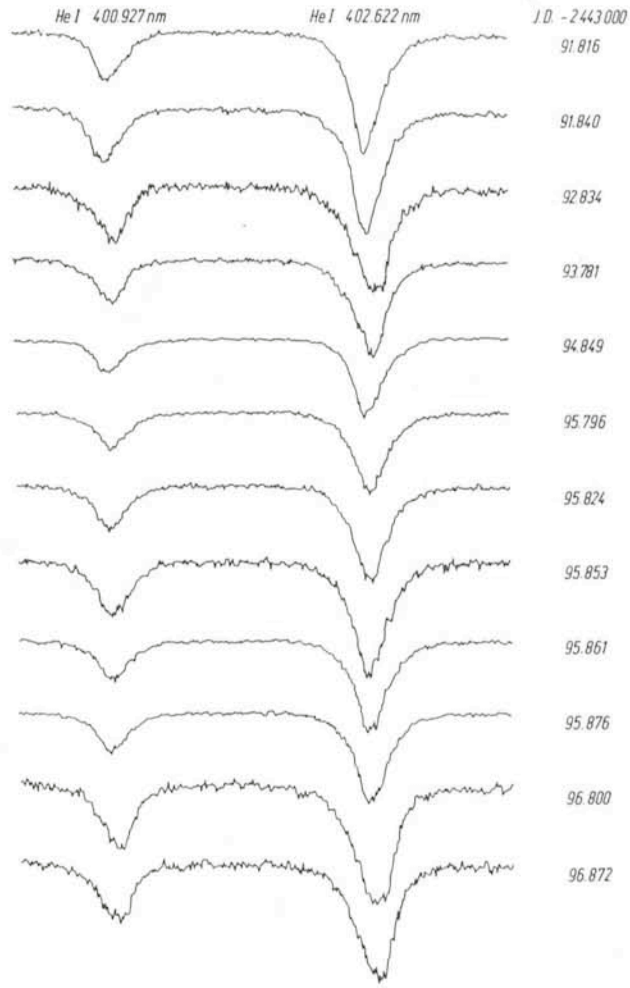

Fig. 1: *Variability of absorption lines in the spectrum of 28 CMa with time. As typical representatives the He I lines near 4009 and 4026 Å are shown.*

in the uvby passbands. A correlation to the spectroscopic period has not been found.

The Interpretation

It can be shown that all above-mentioned models of Be stars lead to unsurmountable difficulties, when used to explain the observed variability of 28 CMa. This is mainly due to the short period, the asymmetric line profiles and the missing photometric variability. On the other hand, the sequence of line profiles shown in figure 1 resembles very much those of β Cephei stars. This small group of stars is the only one in the immediate vicinity of Be stars in the Hertzsprung-Russell diagram, which shows a well-defined type of variability. A connection between Be stars and β Cephei stars has, therefore, sometimes been suggested, though observational evidence was never found. Now it seems possible that 28 CMa constitutes the "missing link".

β Cephei stars are nonradially pulsating stars with fundamental oscillation periods of 4–6 hours. If they and 28 CMa have similar internal structures, one should expect a similar period for 28 CMa. And indeed, under the assumption that 28 CMa undergoes nonradial pulsations of the P_2^2-type this can be shown to be true. The expression P_2^2-pulsation symbolizes a double wave which is symmetric with respect to the equator and travels azimuthally along

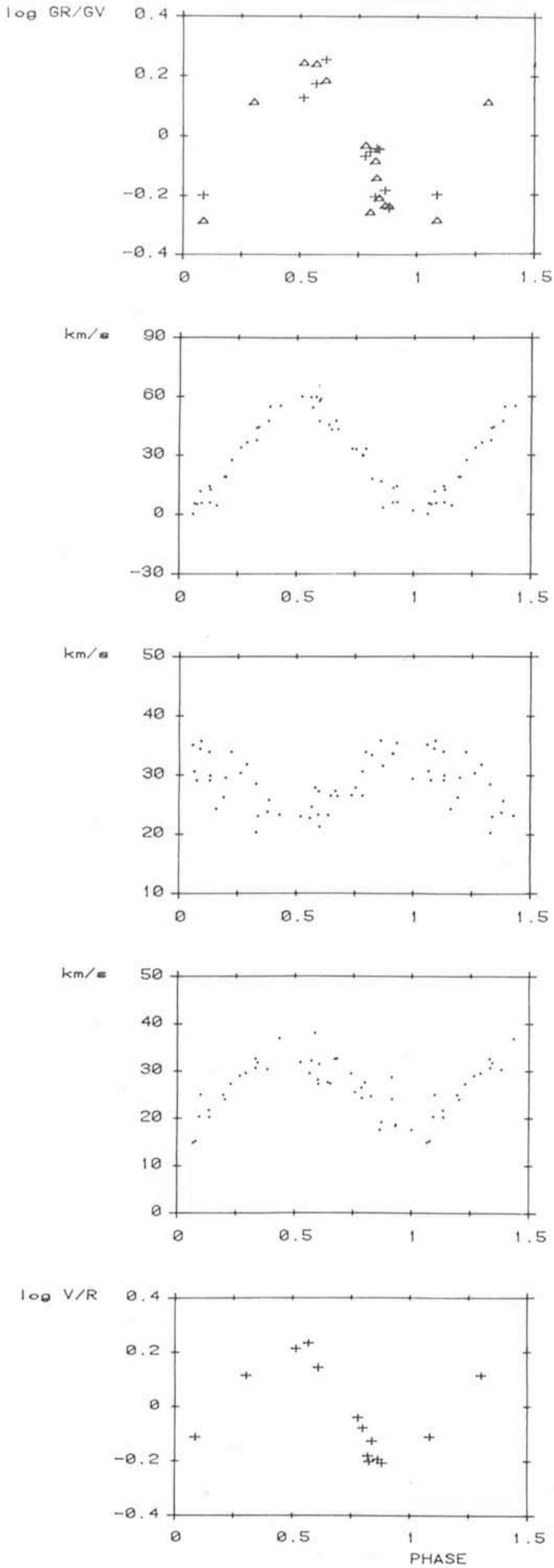

Fig. 2: *The principal spectral variations of 28 CMa: (a) ratio of the gradients of the red (GR) and the violet (GV) wings, crosses: He I 4009 Å, triangles: He I 4026 Å, (b) RV curve of the He I singlets, (c) RV curve of the total emissions in Hβ and Hγ, (d) RV curve of the central reversals of the emissions in Hδ to H10, (e) V/R ratio in Hδ.*

the stellar surface in opposite sense to the direction of the stellar rotation. It is this direction of propagation of the waves which, together with the rotation, makes the actually observed period of the star appear longer than the one which would be observed in the rotating frame of the star.

The travelling wave itself is the cause of the variable asymmetric absorption-line profiles. Furthermore, since its velocity of propagation exceeds the speed of sound in the stellar atmosphere, an additional emission produced in the wake of the corresponding shockwaves can account for both, the V/R variation and the variable radial velocity of the total emission of a given line. The V/R variation is probably strengthened by the 180 degree phase shift between the RV curves of the emissions and the central reversals (cf. fig. 2).

A Few Conclusions

Keeping the "corotating" period constant, calculations show that the observed period is very sensitive to even small differences in stellar rotational periods and radii. With other words, one can expect for different stars periods as short as the one of 28 CMa or shorter and others which are longer, up to many years. Thus the explanation of the behaviour of 28 CMa provides an interesting working hypothesis for additional future examinations of other Be stars. In particular, nonradial pulsations may enable a Be star—in connection with its high rotational velocity—to maintain its envelope.

To verify nonradial pulsations in Be stars spectroscopically may be somewhat difficult because of the generally strong rotational broadening of their spectral lines. On the other hand, one is encouraged by the increasing number of known line-profile-variable B stars in all luminosity classes. This leads to the supposition that a surprisingly high fraction of all early-type B stars undergoes nonradial pulsations. Therefore, the observations of 28 CMa, which are until now in several aspects more or less unique for Be stars, will hopefully contribute to overcome the isolation of Be stars from other stars, which is probably a major reason for the above-mentioned, current unsatisfactory situation of the investigation of Be stars.

List of Preprints Published at ESO Scientific Group

September–November 1979

68. L. WOLTJER: High Energy Astrophysics and Cosmology (IAU Proceedings). September 1979.
69. G. CONTOPOULOS: The 4:1 Resonance. October 1979. *Celestial Mechanics.*
70. E. ATHANASSOULA: Bar-driven Spiral Structure. *Astronomy and Astrophysics.* October 1979.
71. J. MATERNE: Mass-to-light Ratios of Nearby Groups of Galaxies. *Astronomy and Astrophysics.* October 1979.
72. J. BREYSACHER and N. VOGT: Spectroscopy of Ex Hydrae. *Astronomy and Astrophysics.* November 1979.