A Search for Beta Cephei Stars in the Southern Hemisphere

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The present article is another illustration of new, exciting work in the southern hemisphere which is still largely unexplored when compared to the northern. Drs. Christiaan Sterken and Mikołaj Jerzykiewicz have during the past years been looking for new, relatively bright variable stars of the β Cephei type south of −20°. The observations were made by Dr. Sterken, who was formerly with ESO in Chile, and who will spend another year at the Landessternwarte Heidelberg-Königstuhl, FRG, before he returns to his native Belgium. Dr. Jerzykiewicz made the reductions with the ODRA 1204 computer of the University of Wroclaw, Poland.

One of the main reasons for studying β Cephei-type variables seems to come from the fact that the causes underlying their oscillations are still unknown. Other unsolved problems are the questions why the spectral range in which the β Cephei stars occur is so narrow, and why some of these stars appear to be periodic while others show complex frequency spectra.

The fact that all formerly known β Cephei stars are apparently bright is probably a selection effect, because it is in general relatively difficult to recognize short-period and small-range light or radial-velocity variations in fainter stars. The interesting discovery of the faint β Cephei variable HD 80383 by Haug (*The Messenger* No. 9, June 1977, p. 14), is a nice illustration that β Cephei stars do indeed occur among the apparently less luminous stars.

How to Find More β Cephei Stars?

The possible lines of attack the observers can follow in an attempt to help to solve the above-mentioned problems could either be to observe systematically the individual objects during long observing runs, or to try to increase the number of known β Cephei stars. About 25 β Cephei stars are presently known, and adding even a few ones would significantly increase the statistics of this type of stellar variability. Since the pioneer work of Walker (1952, *Astron. J.* **57,** 227), several programmes aimed at discovering β Cephei stars north of declination −20° have been carried out. However, south of this limit somewhat less effort was directed towards discovering β Cephei stars, and no systematic search of the Walker type has ever been carried out on the southern sky.

In order to fill in this gap, the authors started an observing programme with the purpose of detecting new β Cephei stars among the bright southern stars.

We first compiled a list of all stars south of declination −20°, which appear in the Catalogue of Bright Stars, and whose position in the HR diagram is the same or nearly the same as that of the presently known β Cephei stars. The boundaries of the region considered are shown in Fig. 1. The number of β Cephei stars for each MK type is indicated. Exactly 131 stars with declination south of −20° are situated in the area indicated. Twenty-six of these stars were dropped, either because they are well-known variables, or they were too bright for photometric observation (in this case it was impossible to find suitable comparison stars). For each programme star two nearby comparison stars with similar spectral type and brightness were chosen. Because telescope time was the limiting factor, a number of programme stars were purposely selected as comparison stars.

Observations on La Silla

During the first observing run in the period between November 24 and December 31, 1975 (32 nights) nearly one thousand photoelectric observations of 68 programme stars were obtained with the four-channel uvby photometer attached to the Danish 50 cm telescope at La Silla. The differential observations were programmed in such a way, as to make most likely the discovery of light variation with time scales of about three to seven hours. At least four measurements for the same triplet: "first comparison star – programme star – second comparison star" was obtained during a night, and care was taken that these observations were spaced not closer than about one hour. After some 20 measurements of the same triplet were secured, the star was dropped, and another triplet was selected for observing. In this way all observations of the same triplet were spread over a time span of several days.

Since the relatively large number of observations were obtained on photometric nights only, without changing the equipment, in a fraction of a single season, and by one person (C. S.), one may expect that the errors of observation are normally (Gaussian) distributed. We therefore calculated all standard deviations corresponding to the different series of magnitude differences between programme star and comparison star, and between the comparison stars themselves.

Fig. 2 shows the frequency histogram of the standard deviations of all "b" measurements taken at airmasses not exceeding 1.3, i. e. within 40° from zenith. The distribution shows a fast increase from nearly zero to a quite well-defined maximum, followed by a much slower and rather

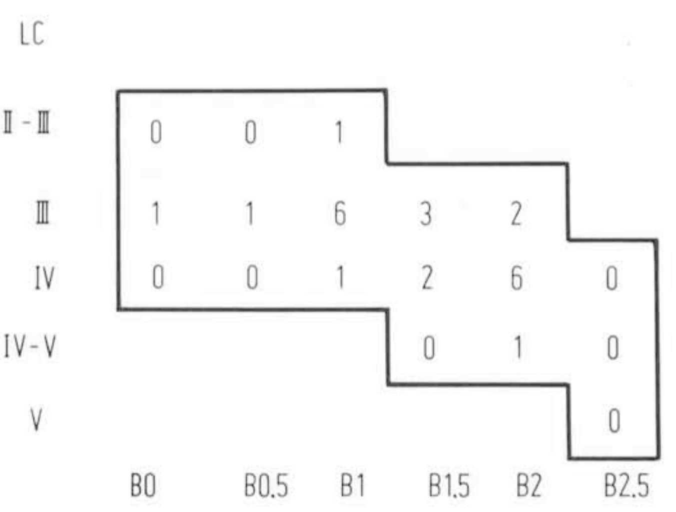

Fig. 1. — *The distribution of known β Cephei stars in the spectral type luminosity class diagram. Numbers of β Cephei stars for each MK type are indicated.*

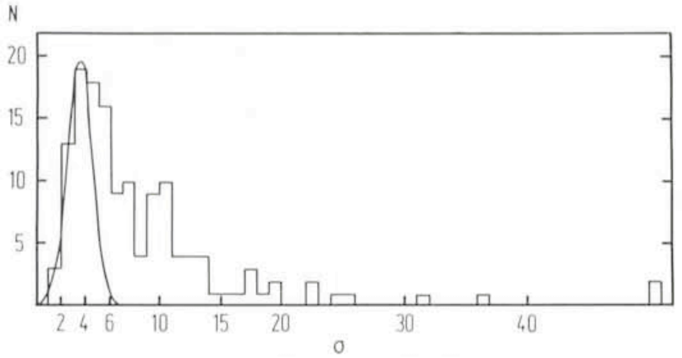

Fig. 2. — *Frequency histogram of standard deviations of the magnitude differences in the "b" filter obtained from observations taken at airmasses smaller than 1.3 (the unit of σ is 0.001 mag).*

irregular descent. The diagram can be regarded as a combination of a normal frequency curve, with its centre located at the observational average mean error, and a flatter, somewhat irregular one, generated by the observed distribution of intrinsic variability. Assuming that the portion of the frequency histogram to the left of maximum gives a reasonably good approximation of the observed error distribution, we estimate that the average mean error of a single magnitude difference is equal to 0^m0035.

Sorting Out the Variables

Once the average mean error of a single measurement was known, we were able to classify the magnitude differences into three categories, viz. *constant, doubtful* and *variable,* according to the size of the largest deviation from the mean. We considered as constant such series of magnitude differences in which the deviation never exceeded two average mean errors. If in a series of magnitude differences there occurred deviations equal to or greater than three average mean errors, we classified the magnitude difference as variable. The intermediate cases were labeled as doubtful.

Next we identified as constant all stars which occur in magnitude differences classified "constant". Many of these constant stars were also included in the "variable" magnitude differences, so we could in some cases unambiguously identify the stars causing the variations. However, an unambiguous assessment of the degree of variability was not always possible, and we have to wait for more information from future observing runs. It must be stressed that only measurements obtained at airmasses smaller than 1.3 were used for deciding about the variable or non-variable character of a star. Measurements taken at high airmasses (but not exceeding 2.0) were only used to complete the light-curves and to get a better idea about the character of variability present.

Table 1 gives the distribution of light variability obtained so far. The doubtful cases also contain the 20 cases for which the magnitude differences show that at least one or

Table 1. — *Distribution of light variability from the first sequence of measurements obtained in 1975*

	constant	variable	doubtful
68 programme stars	21	13	34
42 non β Cep box stars	23	11	8

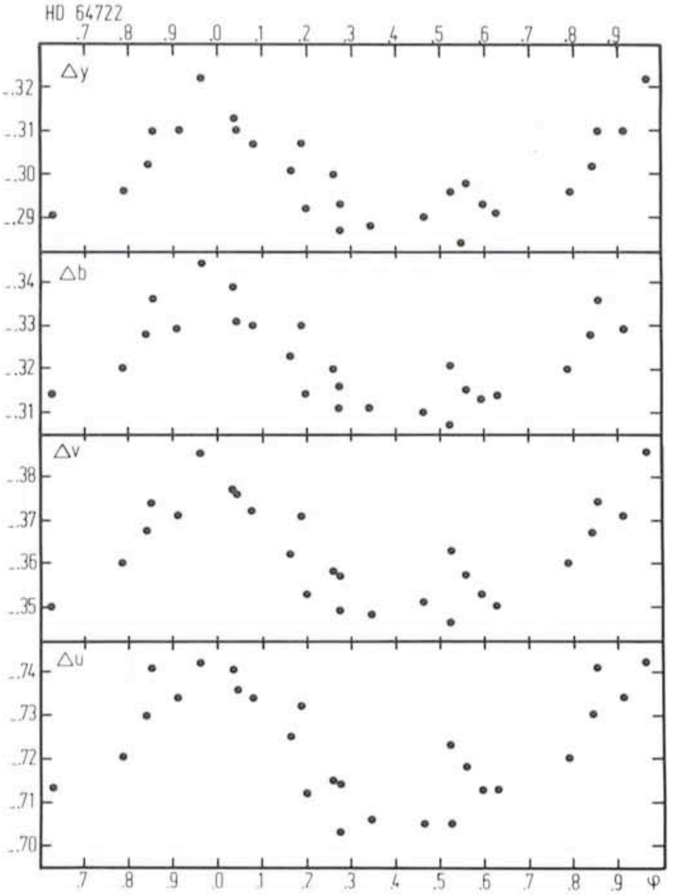

Fig. 3. — *y, b, v and u differential observations of HD 64722 plotted as a function of phase in the 0^d1160 period. Zero phase corresponds to JD 2442742.*

two stars from the triplet are variable, but where we could not decide *which* of the three stars cause the variability.

The amplitudes and the time scales of the variations present in the 13 variable programme stars indicate that probably no more than four stars are serious candidates for β Cephei membership. One of them (HD 64722; B1.5 IV) shows typical β Cephei-type light variation with a very short period of 0^d1160. The observations of HD 64722 are shown in Fig. 3 as a function of phase in the 0^d1160 period. Zero phase corresponds to Julian Date (JD) 2442742.

The 37 remaining programme stars were observed in a similar way during 18 nights between June 15 and July 3, 1977. Unfortunately the weather conditions were rather poor during the run, and we could not obtain a similar amount of measurements as earlier. However, the material is also homogeneous (for every programme star about eight to ten measurements were obtained), and we expect to derive preliminary conclusions very soon.

Future Plans

So far the first goal of the project has been reached: the variable and non-variable objects in the β Cephei box were singled out. The second part of the programme consists of a systematic follow-up of the candidates which we found during the first runs, in order to get a complete description of the light-curves (eventual beat periods). A first attempt will be undertaken during an observing run at La Silla between November 27 and December 17, 1977. We hope to be able to confirm the β Cephei membership of some of the candidates by means of simultaneous spectrographic and photometric observations.

Besides valuable information about β Cephei stars, our programme has yielded an enormous amount of data concerning other types of new variables. Until now at least 30 new bright, variable stars have been discovered, and we hope to be able to get complete light-curves in the near future. Further observation runs are planned for April 1978, December 1978 and April 1979.

At the time when this long-range programme will be accomplished, almost all northern and southern B0 – B2 stars brighter than magnitude 6.5 will have been checked for β Cephei membership, and a more homogeneous sample will then be available for statistical investigation.

Vertical Extinction on La Silla

H. Tüg

Among the many factors that determine the quality of an observatory site, two are crucial. These are the seeing *(how much the light from a celestial object is spread out during the passage through the Earth's atmosphere) and the* extinction *(how much the light is weakened during the passage). It has long been known that La Silla is among the best sites in the world what concerns seeing but it is only recently that a major study has revealed that the La Silla extinction is very small on good nights. Dr. H. Tüg from the Astronomical Institute of the Ruhr University in Bochum, FRG, spent several months on La Silla in 1974–76 with his "black-body" platinum oven which will still be remembered as the "new star" next to the water tanks, where the Swiss telescope is now situated. As a result of his work, we can now give quantitative figures for the extinction at ESO.*

"Bad data are better than no data!", says the desperate visiting astronomer attempting photometric work through clouds. Scheduled only for a few nights, weather always becomes important. The measurements of vertical extinction are the best indicator for the quality of a night. From this point of view we try to give an answer to the questions "What is a good night on La Silla?" and "How good is good?".

For the last decade, ESO meteorological reports show a mean of 225 photometric nights per year, which is 62 % of the total number of nights. A photometric night is characterized by ESO as "six or more hours of uninterrupted clear sky". For La Silla extinction coefficients were only known from measurements in common filter bandpasses (e. g. C. Sterken, M. Jerzykiewicz, *Astron. Astrophys. Suppl.* **29,** 319, 1977) but not over the whole optical region.

During calibration work from 1974 to 1976, when the spectral energy distribution of southern standard stars was measured by comparison with black bodies, extended extinction measurements were undertaken with the 61 cm Bochum telescope using a photoelectric rapid spectrum scanner. The high accuracy of the experiment demanded excellent nights. Normally three extinction stars of early type were observed between airmasses 1 to about 2.5, one star rising, one star setting, and a third star, close to $\delta = -60°$, observable almost the whole night and which passed the meridian at about midnight. The wavelength region was 3000–9000 Å with a bandpass of 10 Å in the blue und 20 Å in the red region. The extinction coefficients were calculated in steps of 50 Å using the Bouguer method. Regions with strong lines were omitted.

Neglecting also the absorption bands of atmospheric oxygen and water vapour, the total extinction of even a clear, cloudless sky consists of three components: Rayleigh scattering, ozone absorption and aerosol scattering. Each component has its own wavelength characteristic. The amount of Rayleigh scattering depends only on air pressure and therefore on the altitude of the observatory. The ozone is concentrated in the stratosphere between 10 and 35 km, so that its contribution is independent of the observatory point, but the concentration varies with latitude and season, sometimes over time scales of hours. The aerosol scattering is due to solid particles and liquid droplets of any size which remain suspended in the air. Most of these particles are small liquid droplets resulting from condensation of water on very small hygroscopic nuclei. Others are the solid or liquid products of combustion not acting as nuclei. The size of aerosol particles cover the range from 10^{-3} to 10 μ, which indicates that their behaviour in incident light cannot be described by a simple theory.

The extinction due to Rayleigh scattering and ozone can be calculated quite accurately for any observatory location. So the aerosol scattering is determined by subtracting these two amounts from the total observed extinction. This procedure, which is described in more detail by Hayes and Latham (*Astrophys. J.* **197,** 593, 1975) was applied for calculating the aerosol extinction for La Silla. The figure shows the extinction coefficient in mag/airmass for all three components separately against wavelength. The sum is given by a least square fit of the measured values. While the aerosol extinction changes slowly by wavelength, ozone shows a sharp cut-off at 3200 Å and an additional bump at 6000 Å. This bump deforms the resultant curve in a manner which cannot be seen in extinction curves resulting from filter measurements.

Extinction measurements were made during three observing periods with a total number of 41 photometric