Rapid Spectral Variations in Be Stars — New Techniques and Results

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Abstract

High resolution spectral scans of some Be stars, taken with an Isocon television camera, show changes in the Hα line profile in times of the order of a minute or less.

Introduction

At this meeting three years ago I spoke of the observation of rapid spectral variations in early type stars — both supergiant and main-sequence Be stars. The technique of spectrum scanning by stepping motor or continuous movement has since been developed in a number of observatories, and extended observational programs have begun on this type of object, amongst others. The Victoria equipment has been digitized, converted to rapid scanning, and recently an image tube introduced to allow red and infrared scans to be made with the same low-noise photomultiplier. These techniques and the results they have yielded have been reported elsewhere (e. g. HUTCHINGS 1970, 1971, BAHNG 1971). Today I wish to discuss a new technique and describe the very spectacular results achieved on its early runs.

Observations

The apparatus was conceived, built and tested at the University of British Columbia, principally by WALKER and AUMAN, and is described in the Edinburgh Observatory publications volume on Automation in Astrophysics (WALKER et al. 1971). Briefly, the detector is an Image Isocon television camera which can integrate a photon-limited light signal for up to some four minutes. The image is then scanned by a 700 line raster and the signal plus accompanying „dark“ reading for each „channel“ recorded on magnetic tape. A computer interface enables signals to be reviewed on an oscilloscope in both channels for single scans and a running mean. The system is very sensitive, has a linear light response over a dynamic range of about 2000, and can be used from λ 7000 down to the ultraviolet limit. For bright objects, time resolution down to 1 second (or less) is possible and for faint objects as many scans as desired may be summed. The photocathode is about 7 cm long and the scan resolution is 100 — 200 μ.

The apparatus was used at the Coudé focus of the Dominion Astrophysical Observatory 48-inch telescope in May and August 1971, and scans were made of various spectral regions of some Be stars. Contrary to expectation based on scanner observations of Balmer emission lines in the blue, the greatest activity was found at Hα, where the emission is strongest, and comes from a larger region of space around the star. In addition, this activity seems to be very rapid and confirms the occasional minute-to-minute changes seen in the previous slow-scan observations.

We present as prime data*) the results of 108 scans at Hα of the B 9 e star HD 142926 ($m_V = 5.6$), with a time resolution of ∼ 40 seconds. Figures 1 and 2 show Hα scans occupying 80 of the 700 scan points, after dark subtraction, three-point running mean smoothing, and normalization to the line-free continuum. Observed at an original dispersion of 5 A/mm, the spectral resolution is 0.2 A (or 0.4 A after smoothing). The upper profile in Figure 1 is the weighted mean of the whole run and indicates a double-peaked structure with a separation of ∼ 2.8 A, and peaks at 1.73 and 1.70 of the continuum. (At the bottom is shown the

*) results of this and other stars in August 1971 are of better quality and confirm the results reported here.

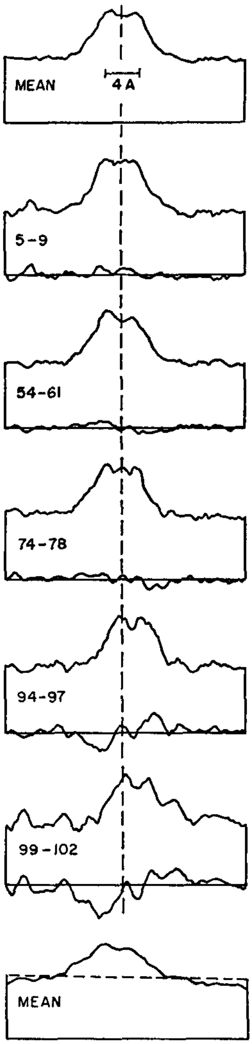

Fig. 1: HD 142926 Hα profiles. Top: mean profile, May 11, 1971. Centre: mean profiles of scans as numbered, May 11, 1971. Scans are 40 seconds apart. Bottom: mean profile June 4, 1971.

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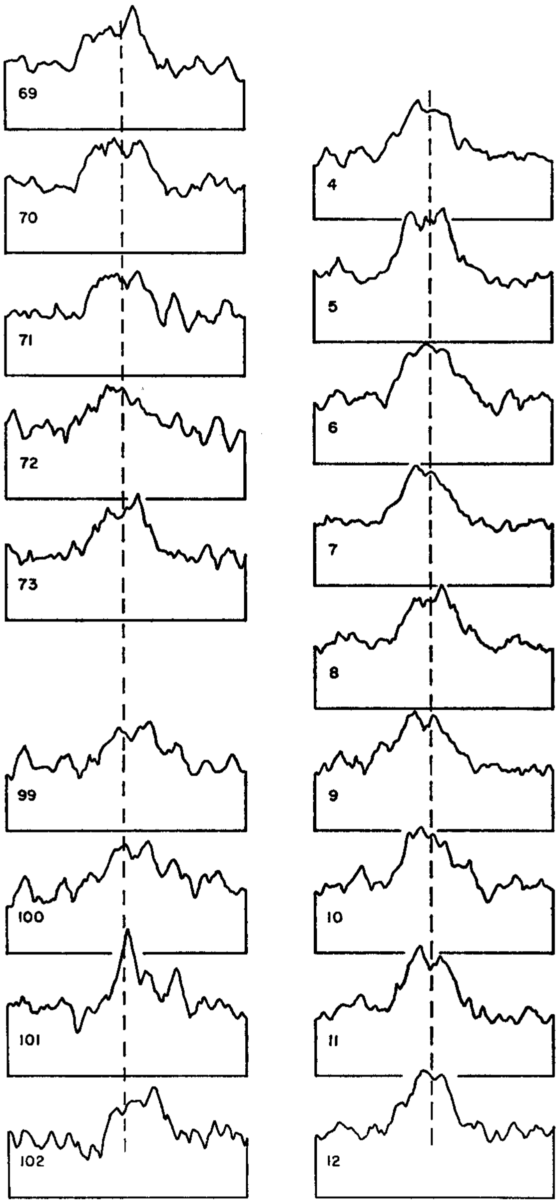

Fig. 2: HD 142926 Hα profiles. Groups of successive scans showing development of profile changes.

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mean profile from a run on June 4 1971. This shows a weakening in the overall emission strength and the appearance of broad absorption wings, extending beyond the range of the diagram. These are typical of the „slow" changes in these features.)

Figure 1 also shows mean profiles of scans as numbered. They are selected as those showing systematic variations in the spectrum. The difference between the scan and the mean is shown below each profile. It can be seen that

(1) the differences outside the profile are generally much smaller and more evenly scattered about zero than inside the profile;

(2) systematic effects are present in the differences, within the profile, often in the form of S shapes. These indicate a shift in the whole profile. Check scans on the emission-line comparison spectrum indicated that such shifts are not instrumental.

Occasionally, systematic changes from profile to profile can be seen, and these are illustrated in Figure 2.

Discussion

The mean double-peaked profile can be understood in terms of the model developed by HUTCHINGS (1971) for this star. The rapid changes are predominantly in the form of

(1) growth of a third component of emission (as, e. g. on the right side in scans 99—101, or the centre in scans 69—72) which fades and/or merges with the permanent peaks;

(2) a weakening of one of the permanent peaks (as, e. g. in scans 7—9). When both changes occur together the difference shows the S-shaped distortion seen in scans 54—61, 74—78, 94—102. Changes in emission strength during these times are typically up to 20 per cent of the mean emission strength above the continuum.

Two possible causes may be suggested for the phenomenon.

(1) The extended equatorial envelope is thought to contain „knots" of higher density material released at the photosphere (HUTCHINGS 1970, BOHLIN 1970). If there are rapid fluctuations of light from points along the equator, associated with this activity, the flashes of radiation will take a minute or two to traverse the extended envelope. As they do so they may excite Hα emission in the knots, whose different radial velocities and intensities may cause the rapid profile changes observed.

(2) The flashes may be localized events in the knots themselves, excited by local conditions, or radiative events on the stellar surface, and the duration of the flashes will then be determined by the excitation mechanism.

Both these hypotheses are consistent with the observation of this activity optimally at Hα, since its emission region is larger than that of other Balmer lines. The slower changes thought to be associated with the rotation of the envelope with steadily emitting knots, are optimally observed in smaller emission regions where the size of the knots is larger relative to the whole.

Other Observations

Similar observations have been made on the Be stars 48 Lib and $\varkappa$ Dra (Figures 3, 4). In the case of 48 Lib the emission was double-peaked and stronger than HD 142926, and indicated more activity. The 48 Lib observations were, however, of lower quality. The star $\varkappa$ Dra had still stronger Hα emission, which was single-peaked, and showed signs of variation in total strength. As no structure change was detected, the results depend on the normalization, and further confirmation is sought for this effect*). This program of observation is being continued an Be stars and OB supergiants.

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*) confirmed August 1971.

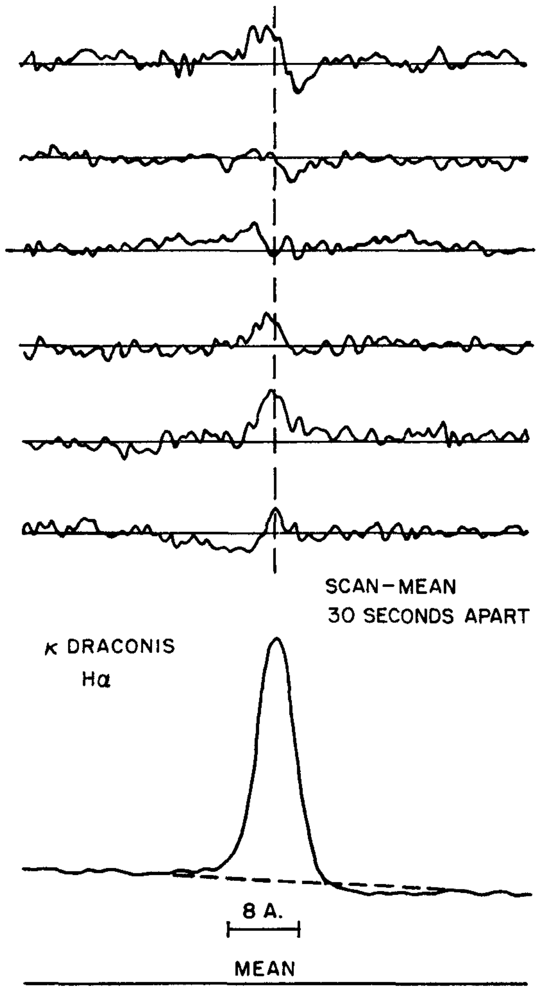

Fig. 3: $\varkappa$ Dra Hα profiles. Mean scan and a series of successive scans-mean differences showing systematic changes.

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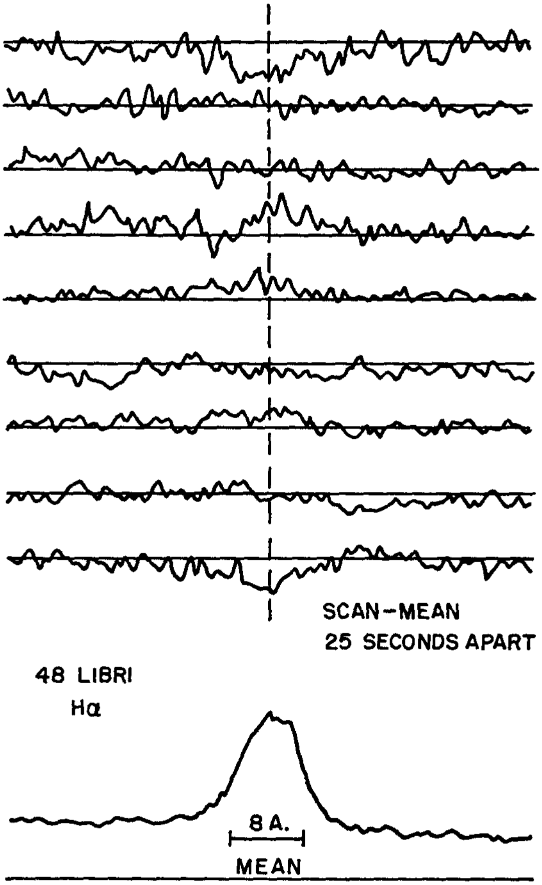

Fig. 4: 48 Librae Hα profiles. Mean scan and successive scan-mean differences.

The star HD 142926 has been followed intensively with a four-channel photometer to search for continuum intensity changes which may be associated with the line changes. A preliminary analysis shows no definite persistent effects, although occasional rapid changes may be present.

Finally, it is worth mentioning a few other observational programs undertaken with this apparatus:

(1) rapid changes in β Cephei star spectra — e. g. the „standstill" phase in BW Vul;
(2) polarization curves of reddened stars;
(3) the interstellar extinction curve for reddened stars;
(4) photometry of nebular and nova emission lines;
(5) a helium variable star;
(6) a rapid emission-line variable star;
(7) Seyfert galaxy line-profiles;
(8) very accurate profiles of close-binary component spectra for distortion effects;
(9) changes in Ca II H and K central reversals.

Acknowledgements

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Discussion to the paper of HUTCHINGS, WALKER and AUMAN

WALKER: Since information tends to become lost these days in the literature, it may be well to remind ourselves that a very good example of a Be star in which material is ejected at irregular intervals, rotates with the star, and than dissipates is HD 217050, whose variations I discussed photoelectrically in 1951. I have always been a little surprised that no one now continued to observe this star, since it provides an excellent object in which to study the mechanism of ejection of material from the equatorial zones of a star rotating close to the limit of stability.

HUTCHINGS: Thank you.

H. J. WOOD: With the Doppler rotational separation of individual blobs as shown in the profiles you may be able to study these variations for periodicities. Have you done any power spectrum analysis of these observations yet?

HUTCHINGS: No, we intend to do this when we have longer trains of observations.

SAHADE: Your third star was 48 Lib, isn't this true? ADELA RINGUELET found several years ago that 48 Lib is probably a spectroscopic binary with a period of a few hours. This was found by measuring the position of the edges of the H_δ absorption. Perhaps one should take into account this fact in interpreting whatever you find in the behaviour of the envelope.

HUTCHINGS: I would suspect periodicities of hours in these stars to be either a pulsation or a rotational phenomenon of the stars themselves, since any companion with this period would be in contact with if not inside the B star itself.

Models for Contact Binaries

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The well-known problem one has in constructing zero age contact binaries stems from the fact that given two mass values, the ratio of the radii for zero age stellar models differs from that derived from the Roche model (KUIPER 1941). Therefore one cannot achieve contact by adjusting just the distance of the two stars, since if for instance the distance would be such that the critical equipotential surface is of the right volume for the primary to fill it completely, then the secondary would be smaller than its critical equipotential surface and one would end up with a semidetached system. LUCY (1968) has shown that this argument does not hold if both stars are surrounded by a common convective envelope, since then an energy exchange is possible in the convective zone which will increase the stars radius if it

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