IV REUNION COMMUNE DES COMMISSIONS 27 ET 29, CONSACREE AUX SPECTRES DES ETOILES VARIABLES

INTRODUCTION

Par P Swings, *président de la Commission* 29

Le présent colloque a été suggéré par Monsieur P W Merrill, président de la sous-commission des spectres d'étoiles variables. Il a été organisé par le président de la Commission 29, avec l'appui, non seulement de Monsieur Merrill, mais encore de MM. Danjon, Struve, Oosterhoff et Kopal. Les communications ont été groupées d'après leur sujet général:

variables spectroscopiques (communications 1 et 2);
type RW Aurigae (3),
type β Canis Majoris (4);
céphéides, RR Lyrae, variables d'amas (5 à 11);
variables à longue période (12 à 16),
étoiles S (17, 18);
étoiles carbonées (19, 20);
η Carinae (21);
objets symbiotiques (22 à 25);
objets divers (26, 27).

Le colloque a fait l'objet de deux séances, la première présidée par Dr P Swings, la seconde par Prof. Kukarkin. Dr J. W Swensson a rempli les fonctions de secrétaire des séances et a bien voulu réunir les manuscrits en vue de la publication.

1. THE SPECTRUM VARIABLES OF TYPE A

By Armin J. Deutsch. (*Presented by* I. S. Bowen)

In the spectrum of the fifth-magnitude peculiar A star HD 124224 the absorption lines of He I vary in strength with a period of only 0·52 day. The lines of Si II are always much stronger than in normal stars. They vary out of phase with the helium lines, but in phase with a group of unidentified lines that seem generally to occur in the so-called 'silicon stars'

The lines of this spectrum are shallow and wide, and radial velocity determinations are inaccurate on this account. The hydrogen lines indicate no velocity changes, but He I 4026 is displaced to the violet before maximum strength, and to the red after. The silicon lines, on the other hand, are probably displaced in the opposite sense. These displacements, together with the diffuseness of the lines, strongly suggest that we have to do here with a star that rotates in half a day about an axis perpendicular to the line of sight. If this is so, the helium lines are produced preferentially near the approaching limb before maximum strength, and near the receding limb after maximum strength.

This star has a shorter period than any other known spectrum variable. Table 1 lists the others for which periods have been published. In the spectra of the last four stars on the list, H. W Babcock has observed the Zeeman effect produced by variable magnetic fields.

HD 153882 is not known to be a spectrum variable, but Miss Gjellestad has recently found that the magnetic field reverses itself with the tabulated period. The two periods shown in parentheses were published as doubtful determinations and are probably incorrect; they will be ignored in the following discussion. This leaves us with ten stars having relatively well-established periods, which range over a factor of 40.

We have proposed that the spectrum variation and Doppler displacements in HD 124224 be interpreted as the effects of axial rotation with the period of spectrum variation. We now inquire whether this interpretation can be put upon the other spectrum variables. All these stars are known to be of closely comparable radii. Therefore, we should expect to find that the widths of the absorption lines are inversely proportional to the periods. For a quantitative test of the rotation hypothesis, coudé spectra at 10 A./mm. have been made, and the line λ4481 has been traced, under nearly identical instrumental conditions, for the ten spectrum variables of known period. λ4481 is well suited for this purpose because it is strong and relatively invariable in all these stars. Fig. 1 shows contours of λ4481 in seven of the stars, arranged in order of decreasing period. For comparison, the observed contour of λ4481 in γ Equulei is also shown. No corrections have been made for the instrumental profile, but this should be very nearly the same in all the contours.

The contours have, however, been reduced to the equivalent width of λ4481 in γ Equulei, by scaling the ordinates in inverse proportion to the equivalent widths. The figure designates the actual equivalent widths before scaling.

To find how closely these contours can be matched by rotational contours, the observed profile of λ4481 in γ Equulei has been convoluted with the appropriate rotational profiles. Except for the coefficient of limb-darkening, which is known with sufficient accuracy, the function for rotational convolution of this line contains only one parameter, $V \sin i$, which is the maximum line-of-sight component of the equatorial velocity of rotation. In each case, we have calculated this parameter on the following assumptions: (1) that the radius is 1·9 solar radii—normal for an A0 dwarf; (2) that the period of rotation is the period of spectrum variation; and (3) that the line of sight lies in the equatorial plane. The calculation of the rotational profiles therefore admits *no* disposable parameters.

The agreement of the rotational profiles with the observed ones is seen to be satisfactory, on the whole. There is a discrepancy in the case of α^2 Canum Venaticorum, but this can be understood in terms of the relative weakness of the line in that star as compared to γ Equulei: it is clear that in the absence of rotation a line much weaker than the standard will have much less pronounced wings. A more serious discrepancy exists in the case of 56 Arietis, for which the observed and predicted profiles are in total disagreement.

It can only be said of this discrepancy that the published period of 56 Arietis rests upon a determination much weaker than any of the others. Observations will be made this fall to ascertain whether the period is really only about eight hours, as the profile seems to indicate.

The line λ4481 is a compound doublet, comprising two nearly equal components separated by 0·4 A. For this reason, the line is intrinsically wide compared to many others, and is not suitable for the detection of the small rotational disturbances we expect in the spectrum variables of long period. A line which is very much sharper in γ Equulei, relatively free from blends, and not subject to large intensity variations, is Fe II 4576. This line has been studied on coudé spectra at 5 A./mm. Fig. 2 shows the contour of the line in γ Equulei and in the four spectrum variables of longest period, excepting one. Just as before, these contours have been compared with the rotationally-disturbed contours of the standard line in γ Equulei. The large discrepancy in the case of ϵ Ursae Majoris is again attributable to a large difference in line strength, and the smaller discrepancies in the other cases can be similarly understood. Incidentally, in a magnetic field of two kilogauss, the most displaced sigma-component of the line is shifted by only 0·04 A.

Figs. 1 and 2 together account for all the ten spectrum variables of known period excepting only 73 Draconis. Being north of the limit for the 100-inch telescope, this star has not been observed on the present programme. However, from inspection of Babcock's Palomar coudé plates, we may state that in its spectrum the lines are narrower than in any of the other nine spectrum variables. Its period is also the longest.

The conclusions to be drawn from these observations are the following: first, that there is a close relation between line-width and period in the spectrum variables; and, second, that the observed profiles of selected lines are duplicated in a normal star of equal size, which rotates about an axis perpendicular to the line of sight, with a period equal to the period of spectrum variation. We infer that in the spectrum variables we observe the rotation of A stars that exhibit intensely magnetic areas, within which the peculiar line strengths are produced. The large proportion of peculiar A stars in which spectrum variation has not been observed are probably similar objects viewed more nearly along the axis of rotation. These magnetic areas are not necessarily dark; they are very large

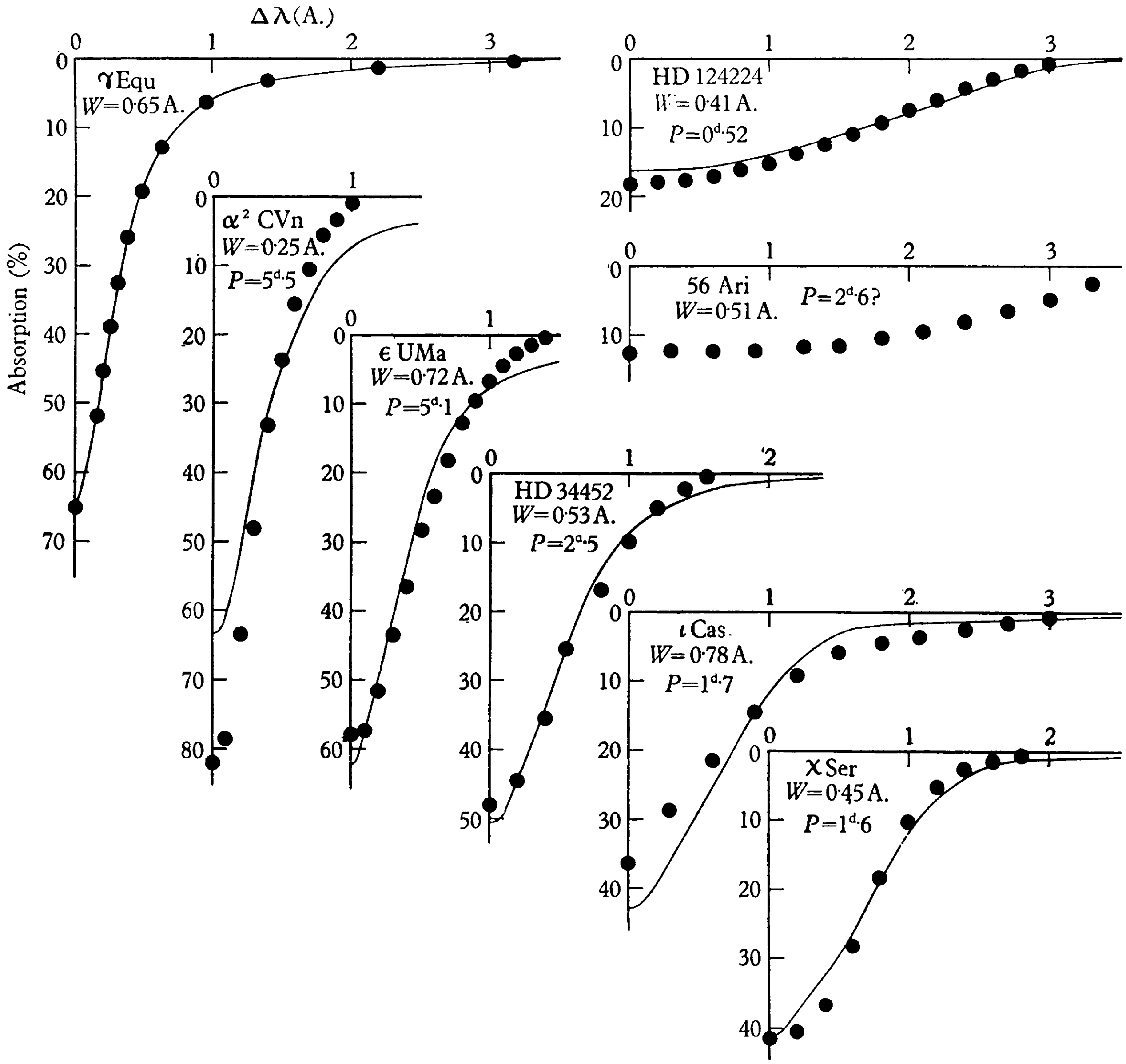

Fig. 1. Observed contours of Mg II 4481 (dots) in seven spectrum variables, compared with the rotationally distributed contour of the same line in γ Equ.

compared with sunspots, but they may still be small compared with the area of the star. Thus, consider a magnetic area that covers 15% of the area of the star. When it lies at the center of the disk, its projected area is 50% of that of the disk; with normal limb darkening, it contributes 60% of the light.

On this model, it is possible to give at least a qualitative explanation of the radial velocities measured by Struve and Swings in α^2 Canum Venaticorum; of the doubling of certain lines observed by Hiltner in the same star; of the non-zero mean magnetic field observed by Babcock in many magnetic variables; and of the 'cross-over' effect observed by Babcock in the profiles of some lines in the spectrum variables with relatively sharp lines. The magnetic field and the spectroscopic peculiarities appear to reach their extremes near antipodal points on the star. However, a model comprising a dipole configuration, with axis perpendicular to the axis of rotation, appears to be seriously oversimplified. For the detailed interpretation of the velocities in HD 125248 and α^2 Canum Venaticorum, we seem to require the additional hypothesis of mass motions of gas in the vicinity of the spots.

With magnetic fields of the order of a kilogauss, and rotational velocities of the order of 100 km./sec., the induced electrical force on an electron exceeds the gravitational force by a factor of 10^{13}. The induced electric field is neutralized, however, by an excess of only 10^8 electrons over each square centimeter of surface, i.e. by a negligible increase in the number density of free electrons.

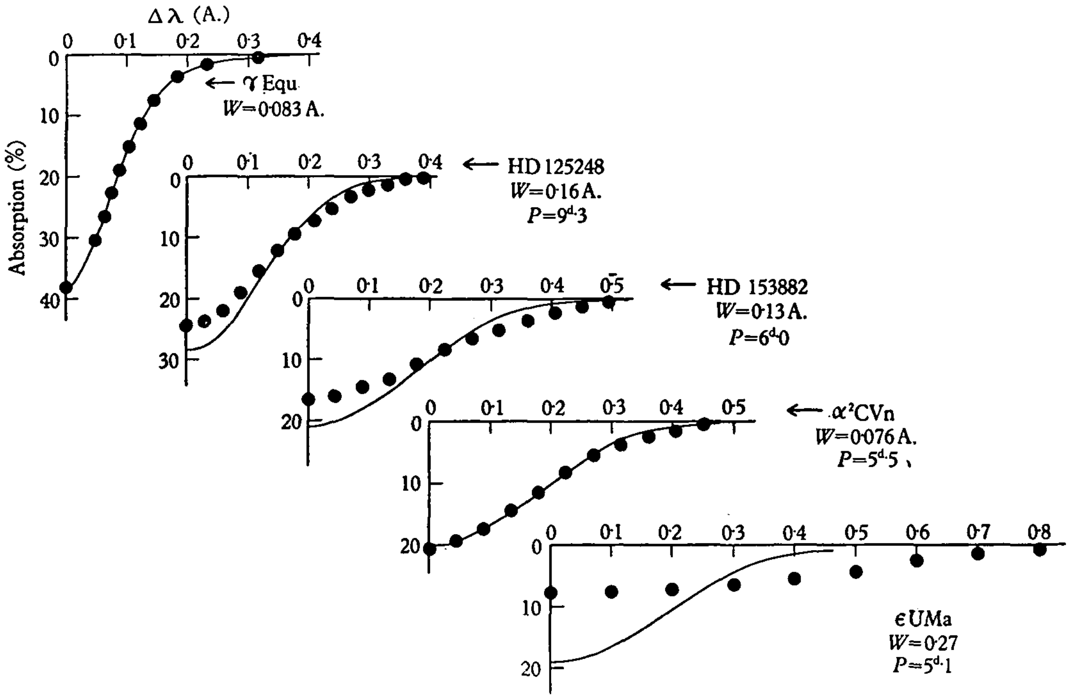

Fig. 2. Observed contours of Fe II 4576 (dots) in four spectrum variables, compared with the rotationally distributed contour of the same line in γ Equ.

Table 1

Periods of spectrum variables

Star	Period	Star	Period
HD 124224	$0^d{\cdot}52067$	γ Ari (s)	(2·607)
χ Ser	1·59584	ϵ UMa	5·0887
ι Cas	1·7405	α^2 CVn	5·46939
π Boo (A)	(2·2445)	HD 153882	6·001
HD 34452	2·4660	HD 125248	9·2983
56 Ari	2·563	73 Dra	20·27

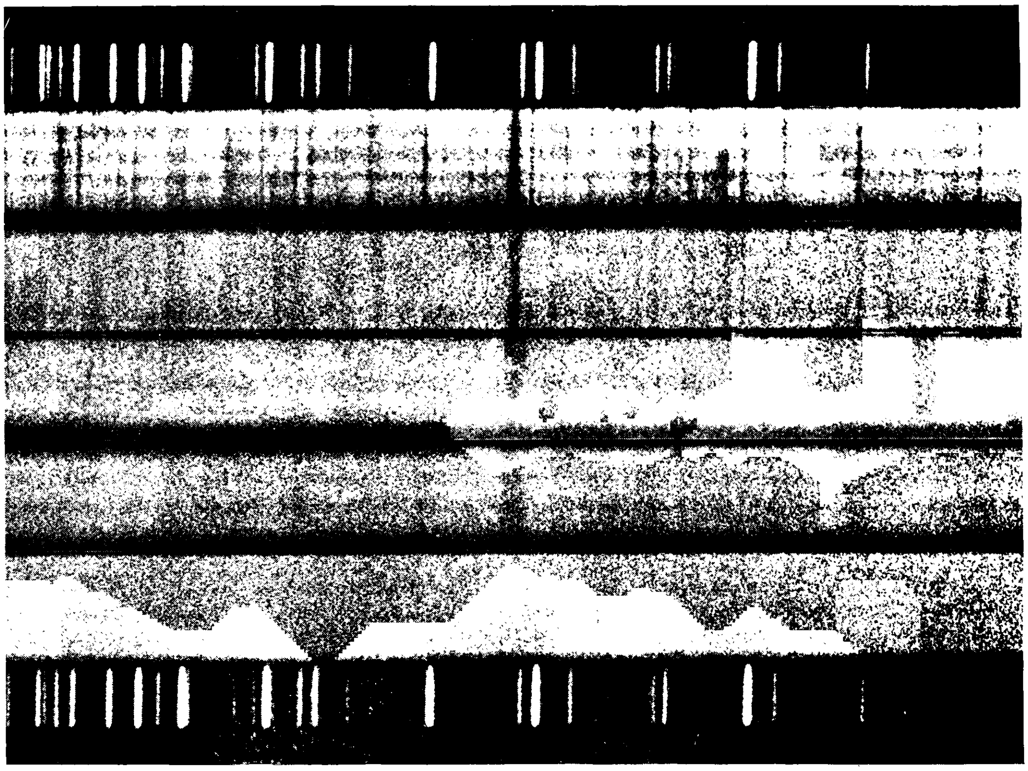

Fig. 3. Line-widths in γ Equ (Fop) and in four spectrum variables.

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