AN ATTEMPT TO DETECT THE MAGNETIC FIELD OF A WHITE DWARF

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Summary

A series of slitless spectra of the 11th mag. white dwarf Wolf 1346 has been taken with and without polarizing apparatus to test Blackett's prediction of large magnetic fields in such stars. No systematic Paschen-Back pattern can be detected in the hydrogen lines with an experimental error of the order of 8 A., corresponding to an upper limit of 10^6 gauss. The need for greater spectral purity is emphasized in a discussion of an apparent structure in the lines which is independent of the polarizing analyser.

Blackett * has suggested that the angular momentum of a white dwarf is associated with a magnetic field of several million gauss. Such a field should lead to Paschen-Back splitting of the hydrogen lines of the order of 50 A. which should be perceptible even on quite low dispersion. It was therefore decided to attempt to test the suggestion at the Solar Physics Observatory, Cambridge, using the 36-inch Common reflector (refigured by Burch) or the Newall 25-inch refractor.

The number of known white dwarfs suitable for the experiment is extraordinarily small. The companions of Sirius and Procyon are too near their primaries; 40 Erid. B ($9^m.6$) was not accessible at the time of Blackett's prediction. The next star, Wolf 1346 ($11^m.3$) was reckoned to be beyond the grasp of the 25-inch refractor with its slit spectrographs, but to be attainable with a 1-prism slitless spectrograph attached to the 36-inch reflector.

This spectrograph has a 2-inch negative collimator of the same focal ratio as the 36-inch mirror. As camera lens a 2-inch $f/1$ aspherical singlet, figured and kindly lent by Dr C. R. Burch, was used. The mount for this lens with adjustable tilt for the plate-holder was made in the Observatory workshop. The camera reduced the scale on the plate in the ratio 3·6 : 1 compared with direct photography; guiding errors and atmospheric unsteadiness were thus diminished in the same proportion. The combination proved extremely fast and it was possible to register the spectrum of Wolf 1346 on Ilford Zenith plates in exposures of the order of 15 to 20 minutes. The hydrogen lines $H\gamma$, $H\delta$ and $H\epsilon$ could be detected although sky-fog naturally proved to be a rather severe limitation, especially in July when the first successful plates were obtained. Experience showed that when working so close to the sky-fog it was preferable to use rather slower plates with longer exposures but higher contrast. The dispersion attained, 450 A./mm., at $H\gamma$, was considered adequate to reveal the presence or absence of fields of the order of 10^6 gauss.

The spectrograph in its original design permitted guiding on the star by means of its image reflected off the first unsilvered face of the prism. But since it proved impossible to guide on a star fainter than 8th mag. in this way, a small

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area of about 1 cm.^{2} of the prism was silvered; with this, Wolf 1346 could be comfortably seen in the guiding field, but even so it was only used for guiding in R.A.—the direction in which the spectrum could be widened perpendicular to the dispersion. The guiding in declination, carried out on a neighbouring star of 10th mag., was far more critical since (*a*) any error appeared directly in the spectrum contour, (*b*) the tilt of the plate being about 30° a *zero-error* in declination put the whole spectrum out of focus. The field of good definition was in fact extremely small, much more so than for the usual field for direct photography. The collimator lens was suspected as primarily responsible. However, when plenty of light was available and contrasty fine-grain plates were used the definition was satisfactory; it was possible in such circumstances to detect the K line in α Lyrae, which is known to be less than 2 A. wide. (This must not however be taken as a measure of the resolving power which was about 400.)

As polarizing apparatus a sheet of mica quarter-wave plate was used in front of the polaroid placed between the prism and camera lens, with suitable relative orientation. Column 5 of Table I, which lists the material on which this note is based, indicates the orientation used for the various plates; *A* or α will transmit

TABLE I

Diary of Observations of Wolf 1346

Plate No.	Date	Time (U.T.) h m	Exp. (min.)	Polarizer	Emulsion
18	Aug. 10	22 54	82	*A*	Zenith 700
19	Aug. 10	23 55	30	...	Sp. Rapid 270
20	Aug. 11	23 10	120	*B*	Sp. Rapid 270
21	Aug. 12	00 38	30	...	Sp. Rapid 270
22	Aug. 12	22 48	120	β	Sp. Rapid 270
23	Aug. 13	00 57	120	α	Sp. Rapid 270
24	Aug. 13	23 30	240	α	Sp. Rapid 270
25	Sept. 5	21 30	25	...	Empress
26	Sept. 9	22 32·5	17	...	Zenith 700
27	Sept. 9	22 51·5	17	...	Zenith 700
28	Sept. 9	23 15	18	...	Zenith 700

circularly polarized light in one sense, *B* or β in the opposite. *A*, *B* refer to a quarter-wave plate suitable for $H\gamma$; α, β to another suitable for $H\delta$. The relative senses of these two plates were determined in a laboratory test after the measures of the spectra had been completed.

Plates were first examined in a Hilger measuring micrometer and later on microphotometer tracings. In view of the extreme difficulty of measuring the diffuse lines which barely stood out against sky-fog background, the plates were measured a second time (a week later) in a Zeiss micrometer with variable magnification. On this occasion the plates were placed in the micrometer by an independent observer who recorded the plate number.

Since no terrestrial comparison could be impressed on these slitless spectra, a field star with practically the same declination was used as a standard; this 10th mag. star (the same as that used for guiding in declination) showed the hydrogen lines rather more clearly and sharper than Wolf 1346. Normally three measures were made on the white dwarf lines in each of the two orientations of the plate in the micrometer, and two on the field star.

Table II lists the various measures of Δx, the relative displacement of the hydrogen lines in the spectra of the two stars, in units of 0·01 mm. on the plate; this quantity includes (*a*) the relative displacement in declination of the two stars (calculated to be 0·11 mm. on the scale of the plate), (*b*) curvature of the spectrum lines, (*c*) all displacements due to differences in radial velocity, relativity shift, Zeeman patterns, etc. in the two stars.

Table II

Micrometer measures of Wolf 1346 *and Field Star.* Δx *in units of* 0·01 *mm.* (*see text*)

Plate	Pol. *A* or α			No Polaroid			Pol. *B* or β		
No.	$H\gamma$	$H\delta$	$H\epsilon$	$H\gamma$	$H\delta$	$H\epsilon$	$H\gamma$	$H\delta$	$H\epsilon$
18	19 (1)	17 (1)							
					31 (1)				
19				18 (6)	20 (4)	25 (2)			
				8 (4)	13 (2)	14 (2)			
20							14 (6)	15(2)	21 (2)
								12 (1)	12 (2)
21				23 (6)					
				14 (6)	14 (4)	13 (1)			
22							14 (6)	11 (4)	20 (2)
									8 (2)
23	14 (2)	14 (1)	[29]						
24	[18]	[11]							
	16 (3)	16 (2)			[31]			15 (2)	20 (4)
				20 (12)	20 (4)	25 (2)	14 (12)	11 (5)	10 (4)
				11 (10)	14 (6)	13 (3)			

Figures in round brackets give the weight of the relevant observations.
Figures in square brackets refer to observations considered to be of negligible weight.

Correction for curvature is particularly troublesome as it varies rapidly in the field. It probably accounts for most of the excess of the mean value of Δx over the shift in declination. But all plates quoted in Table II were taken with identical setting of the spectrograph and position of the star in the field; in these conditions a change in Δx which shows correlation with the orientation of the mica plate could only be attributed to the operation of a stellar magnetic field.

Some plates gave signs of structure within the hydrogen lines and although it is felt that such structure might well be attributed to grouping of plate-grain, it is remarkable that it was noted in the white dwarf spectrum and *not* in the field star; (this precludes an explanation in terms of guiding errors*); it was moreover more frequently noted in the short exposures taken without polaroid. In these cases Δx was measured for each apparent component and these are listed separately in Table II, together with the sum of the weights of the measures which were allotted at the time of measurement.

At the foot of Table II are given weighted mean values of Δx, the various "components" being treated as permanent features for this purpose. From the

* The absence in the field star is explicable in terms of plate-grain in that Wolf 1346 was always less densely exposed.

inter-agreement of the two series of measures (with Hilger and Zeiss micrometers) a standard error of ±0·018 mm. for one plate was obtained. It is clear that there is no systematic difference between the spectra with opposite orientations of the polarizing analyser. In other words Paschen-Back splitting of $H\gamma$ is unlikely to exceed 8 A. in Wolf 1346, and can scarcely be a major factor contributing to the observed line-width of about 50 A. in this star.*

Fig. 1 gives microphotometer tracings of a selection of the material used.

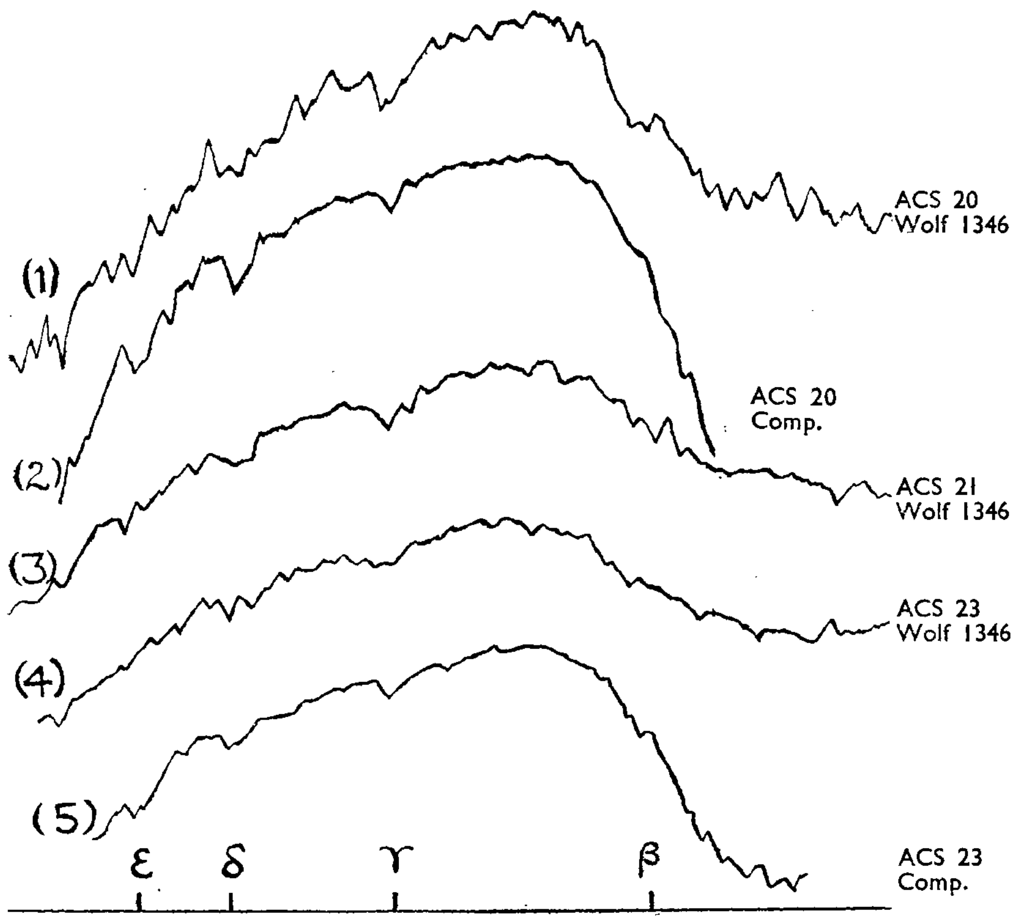

FIG. 1.—*Microphotometer tracings of slitless spectra.*
(1), (4) *Wolf* 1346 *through oppositely polarizing analysers.*
(3) *Wolf* 1346 *without analyser.*
(2), (5) *Field star on same plates as* (1) *and* (4) *respectively.*

The reality of the "components", separated by about 0·1 mm. or 45 to 50 A. (as may be seen in Table II), remains a matter of doubt, which requires further study with higher spectral purity. In order to test the possibility that they represent real features which vary over periods of the order of 1 hour (i.e. less than the exposure times of the plates taken with the analyser) a series of three plates was taken, without polaroid, in immediate succession on the same night, but no systematic trend in the measured Δx or in apparent structure could be detected.

* The test is most suitable to the case where the lines of force are predominantly parallel to the line of sight. If the magnetic axis is at right angles to the line of sight, one might expect a narrowing of the lines with an orientation of the analyser which cuts out both outer σ components. For the pair of plates 18, 20 (orientations "A" and "B") the polaroid was rotated through 90° but no pronounced narrowing of the lines is detectable on either plate. The author is indebted to Professor Blackett for drawing his attention to this point.

40 *Erid. B.*—This star began to be accessible in September and the Burch camera lens was attached to the Newall refractor for an attempt with the Wood aluminized grating spectrograph; this combination gave a dispersion of about 360 A./mm. with rather greater spectral purity than the slitless. A successful 1-hour exposure without polaroid was obtained on 1947 September 25 (showing $H\gamma$ only), but exposures of 1 hour (September 25) and 3½ hours (September 27) through the analyser both failed owing to thick haze forming during exposure.

The writer is deeply indebted to Professor Blackett for his untiring encouragement and assistance in this interesting experiment. It was due to his initiative that the camera lens and the quarter-wave plates which were used were obtained so expeditiously. I am also grateful to Mr L. J. Stanley of the Solar Physics Observatory for providing the short-focus lens with a rigid camera mount, complete with the necessary adjustments, at very short notice.

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