

DISCOVERY OF MAGNETIC FIELDS IN FOUR SOUTHERN Ap STARS

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A search for magnetic fields in southern Ap stars has been made using a Balmer-line magnetograph. Observations of nine stars were obtained, and definite or probable evidence for the presence of fields ranging from a few hundred gauss to almost four kilogauss was found in HD 54118, HD 94660, HD 133880, and α Cir.

Key words: Ap stars — magnetic fields

I. Introduction

Babcock (1958) has conducted an extensive survey of peculiar A and B stars for magnetic fields, and has identified numerous magnetic stars. Further magnetic Ap stars have been discovered by other observers. However, because magnetic observations have been carried out almost exclusively with telescopes located in the Northern Hemisphere, virtually nothing is known about magnetic fields in Ap stars south of $\delta = -40^\circ$.

In this paper we report the results of a search for magnetic fields in nine southern Ap stars, using an $H\alpha$ magnetograph. Magnetic fields in excess of 1 kG have been detected in HD 54118, HD 94660, and HD 133880, while α Circini appears to have a field of a few hundred gauss.

II. Observations

The observations reported here were obtained in March 1974 with the two-channel photoelectric Pockels cell polarimeter described by Angel and Landstreet (1970), attached to the 1-meter telescope of the Carnegie Institution at Las Campanas. The polarimeter was used as an $H\alpha$ magnetograph, as discussed by Angel and Landstreet (1970) and Landstreet et al. (1975). Circular polarization was measured in the wings of $H\alpha$, which were isolated using 5 Å HPBW interference filters. Points four to six angstroms from the line center were chosen, and the polarization was measured alternately in the red and

blue wings, with at least two separate integrations on each wing. The presence of a longitudinal magnetic field leads to circular polarization equal in magnitude but of opposite sign in the two line wings, and reversal of an observed signal when the line wing is changed is an important test of the reality of a signal which helps to eliminate small systematic and instrumental errors. All observations in both line wings are combined in a mean polarization $\langle V \rangle = (V_r - V_b)/2$, where V_r and V_b are the polarizations measured in the red and blue line wings, and the standard error of this value is computed from counting statistics.

When circular polarization due to the longitudinal Zeeman effect is present, the polarization $\langle V \rangle$ and the average longitudinal magnetic field H_e are related by

$$\langle V \rangle = \frac{ez}{4\pi mc^2} H_e \frac{dI/d\lambda}{I(\lambda)}, \quad (1)$$

where $I(\lambda)$ is the observed profile, z is the Lande factor for the transition, and the other symbols have their usual meanings. The line profile $I(\lambda)$ was measured each night for an A0 V star and for some of the brighter survey stars by tilting the interference filter. Normally these profiles are obtained in a ratio mode, holding the filter for one photomultiplier fixed while the other is tipped to a succession of angles (up to $\sim 10^\circ$ from the beam axis), but during this observing run one of the RCA C31034 (GaAs) photomultipliers had

lost much of its sensitivity, thus reducing the polarimeter nearly to a single-channel instrument, and so profiles were obtained by one-channel photometry. As all the nights were cloudless and of photometric quality, the profiles thus obtained are as good as those usually obtained in the ratio mode. Because of the limited range of spectral classes observed, the $H\alpha$ profile varies little from star to star so a mean profile may be used in equation (1), which becomes

$$H_e(\text{gauss}) = 1.5 \times 10^4 \langle V \rangle (\%) \quad (2)$$

An observing list of southern Ap stars was made up using the catalog of Bertaud (1959, 1960). The observations are given in Table I. The first row for each star observed gives the star name, HD number, V magnitude, and spectral class and peculiarities. Below in one or two columns are given the Julian Dates of observations (less 2440000) and the observed longitudinal fields and their standard errors. Four of

TABLE I
 $H\alpha$ MAGNETOGRAPH OBSERVATIONS OF
SOUTHERN Ap STARS

Star JD	HD $H_e \pm \sigma_H$	V JD	Sp $H_e \pm \sigma_H$
HR 2683	54118	5.30	AO Si
2116.65	-1410±290	2121.37	1040±450
2117.61	1100±270	2123.55	-390±350
2118.64	650±350	2124.58	860±270
2119.68	-1350±260		
HR 4185	92664	5.51	AO Si
2120.72	-170±570		
HR 4263	94660	6.10	AO Si
2124.71	-3300±510		
HR 4327	96616	5.14	A2 Sr
2115.86	90±740		
η Aps	123998	4.90	A2 Cr, Eu?
2115.75	480±530	2120.88	-380±470
α Cir	128898	3.17	F0 Sr Eu
2114.87	30±290	2118.74	-290±200
2115.80	420±240	2119.82	-560±120
2116.81	-450±210	2120.80	-290±170
2117.82	-500±110		
HR 5624	133880	5.78	AO Si
2121.88	-2810±420	2124.86	+1550±380
2123.88	+3680±470		
γ TrA	135382	2.88	AO Eu
2115.83	-290±240	2119.90	120±170
2116.86	210±140	2120.85	-230±210
2117.90	-150±180		
HR 6204	150549	5.12	AO Si
2121.80	480±330		

these stars show evidence of magnetic fields and will be discussed in section III. The others show no indication of fields, and give confidence that the instrument was free of serious systematic zero-point errors during the observing run. The series of null measurements of γ Trianguli Australis, with standard errors of typically 0.01% (150 gauss) is particularly reassuring in this respect.

To further test the instrument, three observations of the known magnetic variable 78 Virginis were obtained. These are given in Table II, where ϕ is the phase calculated from the ephemeris of Preston (1969) and H_{pg} is the magnetic field from a mean curve through Preston's data. H_{pe} is the magnetic field based on unpublished $H\beta$ magnetograph observations made by one of us (J.D.L.), which show a magnetic curve for 78 Vir similar to that obtained by Preston but shifted toward positive field values by 400 to 800 gauss, an effect predicted by Borra (1974). The agreement of these $H\alpha$ observations with the $H\beta$ photoelectric measurements is acceptable if not as good as one might wish.

III. Discussion

Four of the stars in Table I show evidence of magnetic fields, and are discussed individually below.

HD 54118. Of the seven observations obtained for this star, four differ from zero by more than three standard errors, making it virtually certain that the star is magnetic. Plotting the observations against time shows an apparent variation with a period of the order of 3 days, and a few trials lead to the best fit to the data for $P = 3.2 \pm 0.1$. All other plausible periods give substantially poorer fits. The data are plotted in Figure 1 with this period, arbitrarily taking JD 2442116.65 as $\phi = 0$. If this period is confirmed, it will be one of the shortest periods of

TABLE II
 $H\alpha$ MAGNETOGRAPH OBSERVATIONS OF 78 VIR

JD	$H_e \pm \sigma_H$	ϕ	H_{pg}	H_{pe}
2114.79	50±380	0.74	-1400	-600
2115.70	-270±420	0.99	-600	-100
2117.73	-1880±350	0.54	-1400	-1000

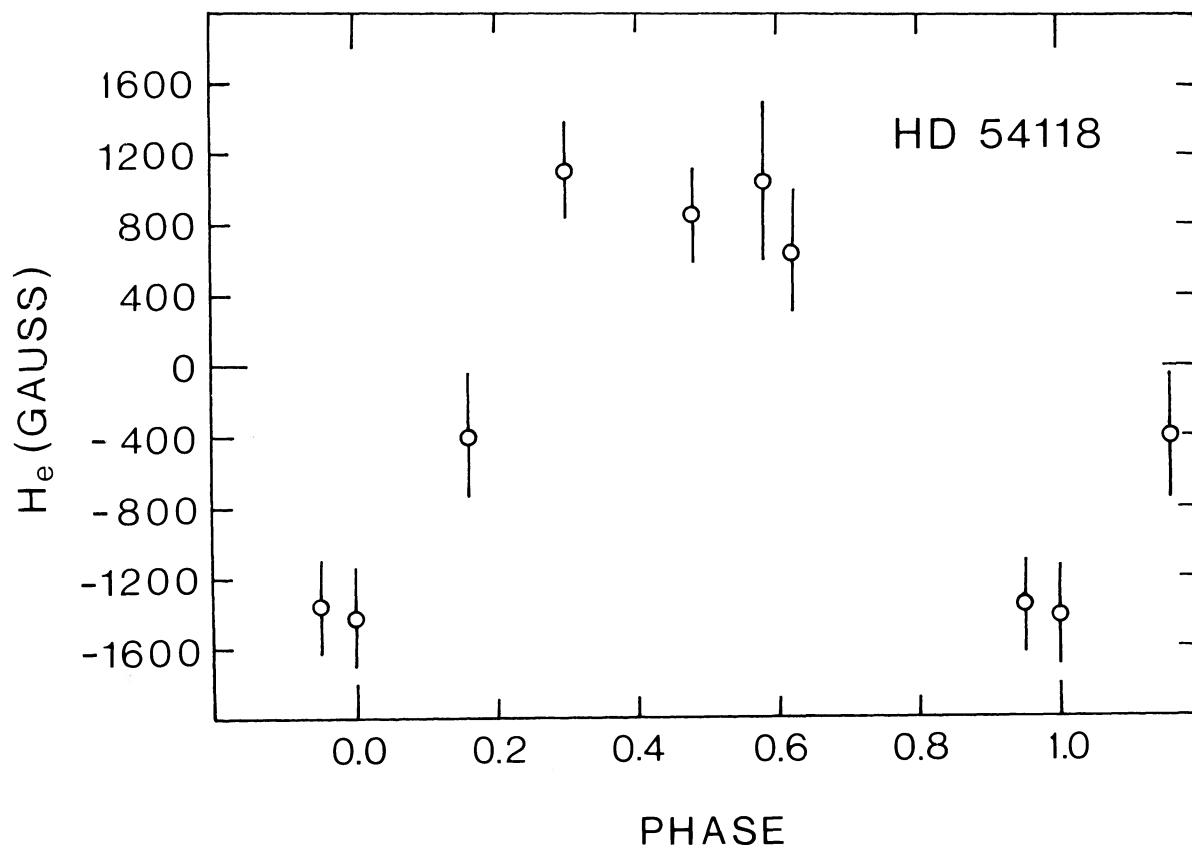


FIG. 1 — All magnetic observations of HD 54118 plotted with a period of $3^d.2$.

magnetic variation found in any Ap star up to the present.

HD 94660. Unfortunately, this star was not observed until the last night of the observing run, so a confirming observation is lacking. However, the size of the effect observed (about 0.22%) makes it unlikely that the observation is spurious. This star is very probably magnetic.

α Cir. For this star, two of the seven observations differ from zero by more than three standard errors, while most of the remaining observations hover around the 2σ mark. The actual signal observed is quite small, however, being only 0.037% (550 gauss) in the highest value recorded, so there is some doubt about the reality of the field. But the series of null measurements obtained on γ TrA with similar errors makes it reasonable to believe that a weak field has in fact been detected in α Cir. A plot of the data

suggests a period of the order of 12 days.

HD 133880. The three observations of this star all show evidence of a large field, in one instance reaching 3700 gauss, so the field is almost certainly real. A period of ~ 4 –5 days seems likely.

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