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IS THERE A MAGNETIC FIELD - PERIOD RELATION FOR THE HOTTER Ap - STARS ?

In two recent papers by P. North (1980) and Cramer and Maeder (1980) a new technique is discussed for a photometric way to detect surface magnetic fields. The Z parameter is a linear combination of the Geneva colours U, B1, B2, V1 and G (Cramer and Maeder, 1979) and is nearly independent of T_{eff} and log g for main sequence stars from about B2 to A5. A linear relation between Z and the surface field Hs is presented. Although no astrophysical argument can be given for the existence of such a relation, there is no doubt that any - even heuristic - photometric technique which allows to pick out candidates for a detailed spectroscopic analysis is highly valuable.

S.C. Wolff (1975) brought up some evidence for a correlation between the radius and period for non-Si stars in the sense that larger radii are correlated with larger periods. Her interpretation of this effect was a deceleration due to magnetic braking, with the increasing radius being a consequence of stellar evolution. If this idea is correct, stars with stronger magnetic fields should rotate slower than equally old but weak magnetic field stars. With more data now available for Hs it was interesting to look again into this problem, which is an aspect of the nature of magnetic fields in Ap stars (Weiss et al., 1976).

Havnes and Conti (1971) and Strittmatter and Norris (1971) derive a rate of loss of angular momentum to:

$$dI/dt = \rho^{1/2} v_f R^3 B_c$$

where ρ is the density of matter which is lost from or accreted by the star, v_f is the relative velocity of the star and interstellar medium or the velocity for mass loss, R is the stellar radius and B_o is the magnetic field strength at the stellar surface. The radius R varies even for our subgroup of hot Ap stars, but the observed range in B_o still exceeds the effect of R on dI/dt.

Table I

Hot magnetic Ap stars

HD	Hs	C	BP	UF	ST	pec.	P^d
9996	.20	B	3	50	B9p	CrEu	36.5
10221	.14			39	A0p	SiSr	3.1848
10783	.24		24		A2p	CrSr	4.14
11502	.18	D	55	51	B9V+Ap		2.6095
12447	.18	DB	92	87	A0P	SiSr	0.7383
18296	.18		22	5	B9p	Si	2.88422
21699	.15			59	B8IIIp	Mn	2.4761
22470	.15			190	A2V	Si	1.9
22920	.16			121	B8IIIp	Si	
25267	.20	B		34	Ap	Si	2.42 (5.74,7.4)
25354	.12		17		A0p	SrCrEu	3.9001
25823	.20	B	21	21	B9p	Si	7.227
27309	.46			46	A0p	Si	1.5691-2.7098
32633	.51		23		B9p	SiCr	6.43
34452	.48	D	62	44	A0p	Si	2.466
34797	.12		80	80	Ap	Si	
35479	.22		82		B9p	Si	
43819	.18			55	B9IIIp	Si(Cr)	1.0785
54118	.18			0	A0p	Si	
74521	.35		19		A1p	EuCr	4.2359
77653	.12	D		0	Ap	Si	3.2
79158	.17			29	B8IIIp	Mn	
90569	.14			90	A0p	CrSr	1.4-7.9
103498	.25		13	≤ 25	A1p	CrEu(Sr)	
112413	.18	D	24	33	A0p	SiEuHg	5.46939
120198	.18			20	B9p	EuCr	1.3799
125248	.20	B	9	59	A0p	CrEu	9.2954
126515	.27		3		A2p	CrSr	~130
133029	.35		20		B9p	SiSrCr	2.8881
134759	.10	D		72	A0p	Si	
136933	.25	D		0	A0p		
140728	.15		75	100	B9p	SiCr	1.30488
142884	.15		200	200	B9p	(Si)	
144661	.13			100:	B7IIIp	HgMn	
145501	.29	D	70	70:	B9p		
147010	.56		25	≤ 50	B9p	SiCr	
147890	.19	D	25	≤ 50	B9p	Si	
148199	.28		25	≤ 50	Ap	SiCr	
153882	.25		26		B9p	CrEu	6.0087
164429	.27			200:	B9p	SiSr	0.51747
168733	.13			0	B8p		6.3
173650	.14		16		B9p	Si(Cr)	9.9748
174933	.15	B	20	20	B9p	Hg	6.36247
175362	.18			0	B8IV	Si	3.682

Table I (cont.)

HD	Hs	C	BP	UF	ST	pec.	P^d
187474	.23	B	4	0	A0p	CrEu	
192678	.50		5		A4p	Cr	18.20, 360?
193722	.13		250		B9p	Si	1.13254
196502	.20		8	0	A0p	SrCrEu	20.2754
203006	.24			48	A2p	CrEuSr	2.1219
204411	.10			32	A6p	Cr(Eu)	~ 360 ?
215038	.39		31		A3p	Si	2.03763
215441	.51		3		A0p	Si	9.4877
220825	.14		35	42	A0p	CrSr	0.5805
223640	.22			64	B9p	SiSrCr	3.73
224801	.18		38	70:	Ap	SiEu	3.73975

HD...HD number, Hs...surface magnetic field in Tesla (1 T = 10000 Gauss), C... Comments (D photometrically unresolved double star, B spectroscopic binary)
BP...v.sin i from Bernacca and Perinotto (1971),
UF...v.sin i from Usuegi and Fukuda (1970) in km/s,
ST, pec...spectral type and peculiarity from North (1980),
P...period in days.

Table I gives a subset of stars from Cramer and Maeder (1980, op.cit.) for which v. sin i and/or a rotational period is determined. F. Catalano (Catania) kindly contributed 5 periods from his catalog.

Double stars not separated during the measurements and spectroscopic binaries (circles in Figure 1) obviously do not differ systematically from single Ap stars. Therefore all objects from Table I are used for the following discussion.

A comparison of the integral probability distribution for all Ap stars with known rotational period (adapted from Catalano and Strazzulla, 1976) with those for which Hs is measured by the Geneva group give no evidence for a different parent distribution for both samples (Figure 2). We can therefore hope that the objects from Table I are characteristic at least for the group of hot Ap stars. The median rotational period is 2.56 days.

Large Hs values are found in Figure 1 for all periods almost equally frequent. This result does not change even if all pure Si stars from Table I are excluded, as did S. Wolff for her investigation (Figure 3). Hs obviously does not correlate with the period.

On the basis of the still rather limited material it can be concluded:

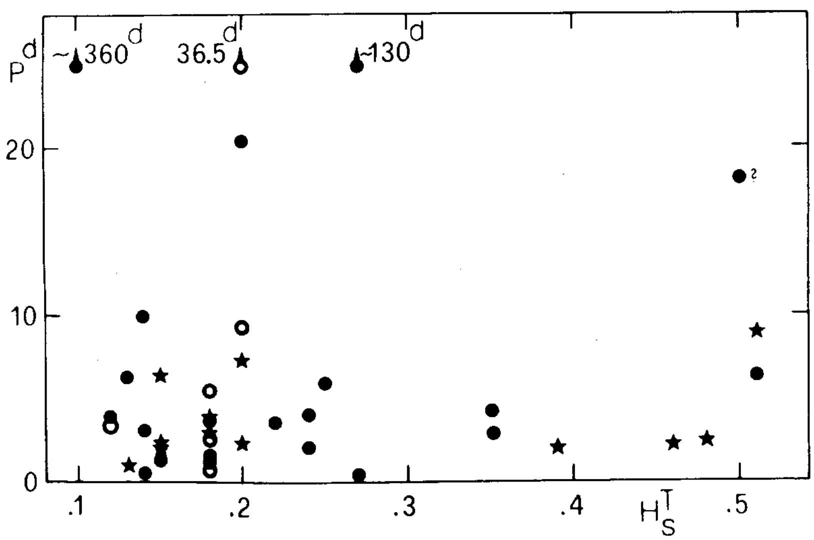

Figure 1: Hot Ap stars with known period P (in days) and photometrically determined surface magnetic field (H_S^T) in Tesla (1 T = 10000 Gauss). Asterisks: Si stars, one Hg and one Mn star. Circles: double stars not separated during Hs measurement and spectroscopic binaries. Points: hot single Ap stars.

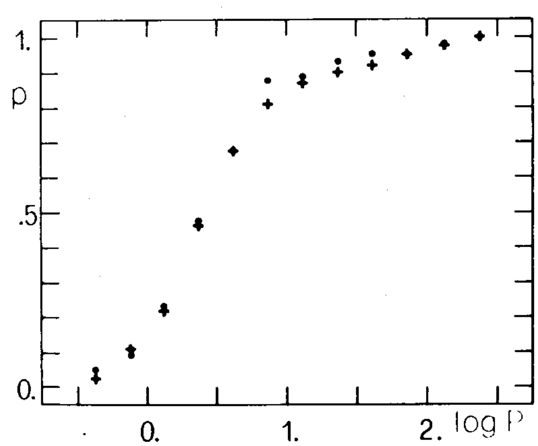

Figure 2: Probability function p for all Ap stars (crosses) with known period (P in days), adapted from Catalano and Strazzulla (1976) and for Ap stars with photometrically determined surface magnetic fields (dots).

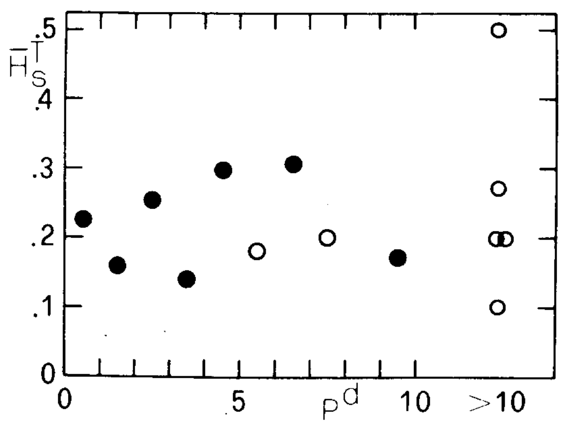

Figure 3: Mean photometrically determined surface magnetic fields ($\bar{H}_S^T$ in Tesla, 1 T = 10000 Gauss) for Ap stars within a given period interval (P in days). Filled symbols: arithmetic mean, open symbols: individual stars.

i) The quantity Hs, as determined by Cramer and Maeder photometrically, shows the same distribution for P (and v.sin i) as is known to be typical for Ap stars.

ii) No evidence can be found for a correlation of Hs with the rotational period. Thus, at least for the hotter Ap stars, magnetic braking needs further investigation.

iii) Only 34 more or less reliable periods are known for more than 140 bright magnetic Ap stars from the list of Cramer and Maeder. Much more telescope time should be devoted to the determination of basic Ap star parameters, such as is the rotational period.

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