ROTATION, VARIABILITY AND AGE OF Ap STARS

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ABSTRACT. Photometrically determined gravities for field and cluster Ap stars, together with published periods, show that conservation of angular momentum alone is responsible for the observed increase of the periods with age. New photometric periods of a few cluster stars are presented which independently confirm this result. No outstanding change with age of the amplitude of lightcurves is noted.

1. RESULTS

1.1. Rotation

1.1.1. Ap stars in clusters. Table 1 lists a few periods of cluster stars recently obtained with the Geneva photometry. They confirm the already noticed lack of magnetic braking on the main sequence for CP2 and CP4 stars (Klochkova and Kopylov, 1984; North, 1984).

Table 1. New photometric periods of cluster Si stars

HD/HDE	CLUSTER	PERIOD	NO. OF MEASURES	LOG AGE	AGE REF.
16605	NGC 1039-37	NOT VARIABLE	19	8.3	North & Cramer 1981
45583	NGC 2232-9	1.177 d. or 6.60 d.	44	7.35	Mermilliod 1980
66295	NGC 2516-26	2.454	37	8.1	North & Cramer 1981
66318	NGC 2516-24	NOT VARIABLE	38	8.1	North & Cramer 1981
68074	NGC 2547-5	1.1696 d.	21	7.65	North & Cramer 1981
145102	Upper Sco	1.42 d. (or 3.33 d.?)	38	~7.0	Klochkova et al. 1981
304847	NGC 3114-234	2.3 d.? or 4.6 d.?	25	8.1	North & Cramer 1981

C. R. Cowley et al (eds.), Upper Main Sequence Stars with Anomalous Abundances, 167–170.

References to Table 1

Klochkova, V.G., Kopylov, I.M., Kumaigorodskaya, R.N.: 1981, Sov. Astron. Lett. 7(3), 203
Mermilliod, J.-C.: 1980, Thesis
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1.1.2 Field (and cluster) Ap stars with known gravity. The Geneva photometry gives a statistically reliable estimate of log g for most Ap stars, except for a few exceptionally blanketed ones (North & Cramer, 1984). Gravity is used as an age indicator in Fig. 1 and 2, where all stars with a known period (Catalano & Renson, 1984) and good Geneva colours are plotted. The gravities are probably less reliable in Fig. 2 because of increased blanketing by metallic lines (Teff being smaller) and because of the sensitivity of the Balmer jump to peculiarity (Gerbaldi et al., 1974). A linear least-squares fit through all 92 points of Fig. 1 yields a correlation at the 99% confidence level (r=0.387). Excluding the four anomalous points - whose initial period would be shorter than 0.5 d, while so short periods have never been observed - gives a better correlation (r=0.553) and exactly the same slope (b=-0.64) as that of the theoretical relation for the rather realistic case of rigid-body rotation (Endal & Sofia, 1979). The much greater dispersion of the 89 points of Fig. 2 prevents any fit from being done, but the lower envelope is compatible with the theoretical line.

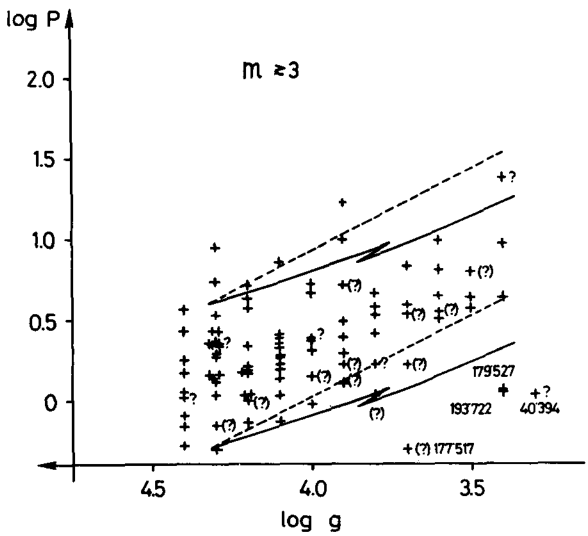

FIG. 1: PERIOD-GRAVITY RELATION FOR CP2 AND CP4 STARS MORE MASSIVE THAN 3 $M_{\odot}$. CONTINUOUS LINES: THEORETICAL RELATIONS FOR A ~4 $M_{\odot}$ STAR WITH COMPLETE RADIAL EXCHANGE OF ANGULAR MOMENTUM, WITH INITIAL PERIODS OF 0.5 AND 4.0 D. BROKEN LINES: THEORETICAL RELATIONS IN THE CASE OF CONSERVATION OF ANGULAR MOMENTUM IN INDEPENDENT SHELLS. QUESTION MARKS ARE FOR UNCERTAIN OR AMBIGUOUS PERIODS.

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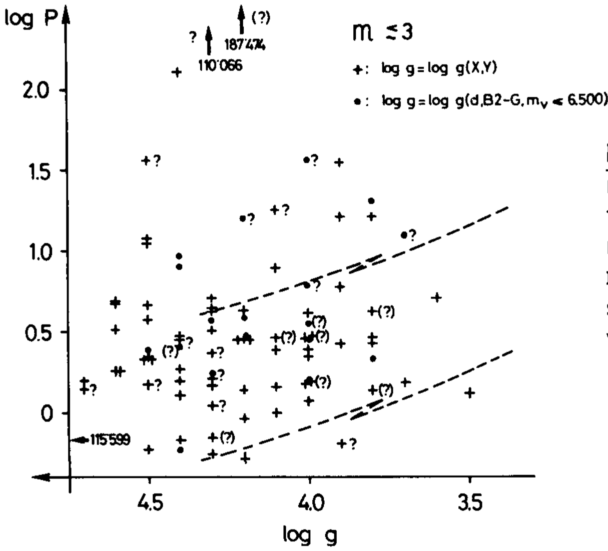

Fig. 2: Same as Fig. 1, for CP2 stars less massive than 3 $M_\odot$. The continuous lines of Fig. 1 are reproduced as broken lines here since they are not strictly valid for low mass stars.

1.1.3 Initial distribution of periods. Neglecting the influence of the initial rotational velocity on its subsequent evolution, one may estimate the period each star had on the ZAMS from its present period and evolutionary state. The distribution of initial periods is shown in Fig. 3 for stars with $M>3M_\odot$ and compared with the distribution for normal dwarfs. It is consistent with the observed periods of Ap stars in young associations.

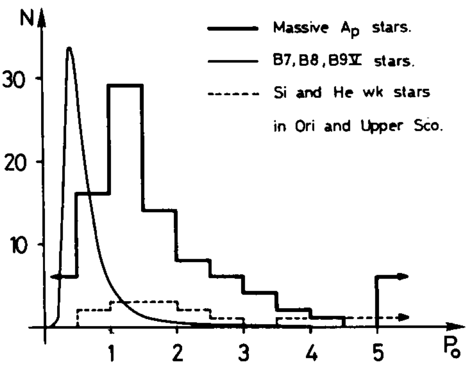

Fig. 3: Distribution of the initial periods of CP2 and CP4 stars with $M > 3\ M_\odot$, deduced from Fig. 1. The distribution of normal class V stars is shown for comparison.

1.2. Lightcurve amplitudes

Plots of the peak-to-peak amplitudes of an homogeneous sample of uvby lightcurves of 44 stars with any mass (Mathys & Manfroid, 1985) vs log g shows no significant trend, except perhaps in the u band, where less variation occurs at small gravities (Tables 2 to 5). More data are clearly needed.

Tables 2 to 5. Contingency tables for amplitudes in the u, v, b and y passbands. The χ^2 value and corresponding level of significance at which the null hypothesis can be rejected are indicated and show no significant correlation

TABLE 2 : U

A(U) \ LOG G	>3.9	≤3.9	TOTAL
> .06	15	3	18
≤ .06	15	11	26
TOTAL	30	14	44

$\chi^2 = 3.22$, ~ 92%

TABLE 3 : V

A(V) \ LOG G	>3.9	≤3.9	TOTAL
≥ .03	16	8	24
< .03	14	6	20
TOTAL	30	14	44

$\chi^2 = 0.06$, ~ 20%

TABLE 4 : B

A(B) \ LOG G	>3.9	≤3.9	TOTAL
≥.035	17	6	23
<.035	13	8	21
TOTAL	30	14	44

$\chi^2 = 0.73$, ~ 60%

TABLE 5 : Y

A(Y) \ LOG G	>3.9	≤3.9	TOTAL
≥ .03	16	5	21
< .03	14	9	23
TOTAL	30	14	44

$\chi^2 = 1.19$, ~ 70%

2. CONCLUSION

No significant braking (magnetic or other) occurs during the MS phase of field as well as cluster magnetic Ap stars in the range 2.5 to $6M_\odot$. Conservation of angular momentum alone accounts for the change of period on the MS. Slow rotation of Ap stars is thus related to stellar formation.

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Discussion appears after the Musielok paper.