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About the Dependence of the Rotation Velocity of CP Stars on the Magnetic Field

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Abstract. Based on the observational data of the average magnitudes of the surface magnetic field strength B_s for a number of chemically peculiar stars we investigate the dependence of the rotation period on the magnetic field. As a consequence of the B_s dependence on the stellar age (at the expense of radius alteration) they have moved to the Main Sequence luminosity class V. The obtained dependence is described with a sufficient reliability by a polynomial of second degree, the maximum of which is in the range of periods $P=10^d$. We assume that this dependence is a result of superposition of different processes, which took place at the early stages of evolution.

Key words: stars: CP stars – rotation – magnetic fields – evolution

The problem of the dependence of stellar magnetic fields on the rotation of stars has been frequently discussed. In publications, supporting the mechanism of magnetic field generation by the action of a magneto-hydrodynamic dynamo, proportionality of the magnitude of the magnetic field and the speed of rotation was predicted by Moss in 1974 and Mestel in 1975. If the field has a relic origin, i. e. if it has evolved by compression from the magnetized interstellar clouds, such a dependency should not be expected. Lower speeds of rotation can be explained by loss of torque momentum due to "magnetic braking". In this case one should expect a reciprocal proportionality between the magnitude of the magnetic field and the rotation velocity.

Now the periods of rotation P and the average values of the surface magnetic field B_s are known for more than 50 magnetic stars. Therefore, it is recommended reconsider the interdependence between them, as it is shown in Fig. 1. As well as in some previous investigations, the reverse correlation is appreciable — at least for stars with the rotation period $P>25^d$ (bordered by the vertical shaped line). The linear regression expressed by the formula

$$B_s = [(9694 \pm 1686) - (1342 \pm 599) \cdot \log P] \text{ Gauss}, \quad (1)$$

however, still does not show a 100% confidence of the angle of inclination. Its magnitude of dispersion exceeds 2σ. It is remarkable that in the diagram the positions of the white circles are somehow distinguished from the black ones.

The distribution of stars on the values B_s is shown in Fig. 2a for fast and in Fig. 2b for slow rotators. Obviously, a lack of slow rotators in Fig. 2b with field values of $B_s>5$ kG is essential for the problem considered. Most likely, this is connected to the observational selection owing to insufficient sensitivity of the measurement methods. If it is so, then adding the stars with small values of the magnetic field should increase the gradient of the function $B_s=F(\log P)$ in the range of $P>25^d$. Then the reverse relationship of (1) can become significant.

It is, however, necessary to take into account the following circumstance: The magnetic field B_s decreases in the process of evolutionary movement across the MS–band owing to an increase of the

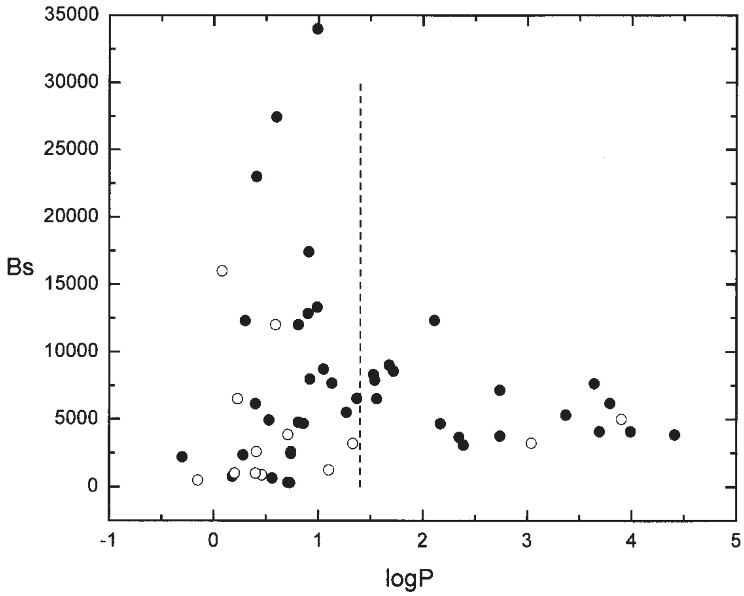
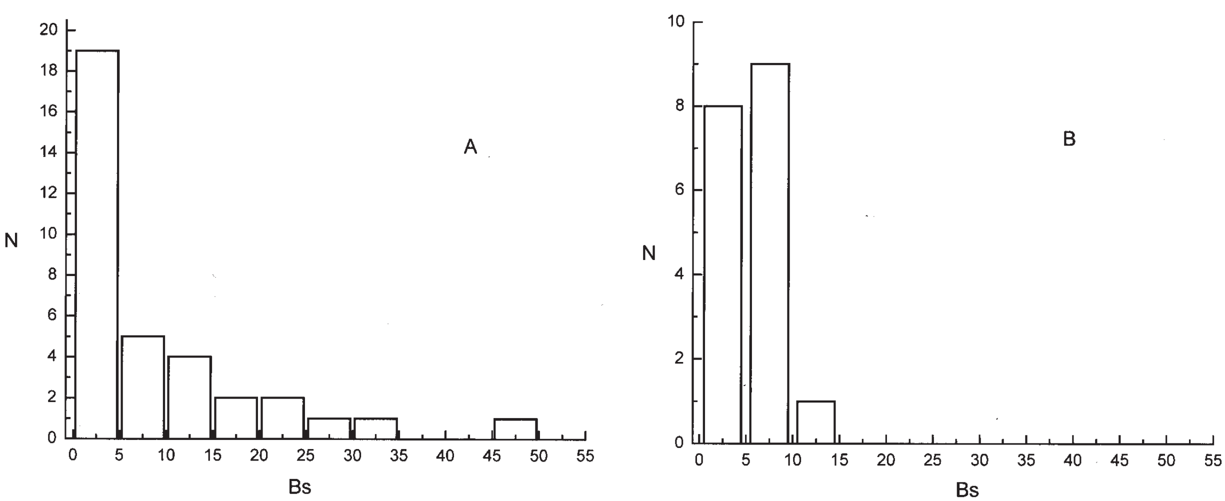


Figure 1: The dependence of the surface magnetic field strength on the rotation period. Black circles represent the reliable values of B_s. White circles — approximate values of B_s.



(a) (b)

Figure 2: The distributions for fast (a) and slow (b) rotators

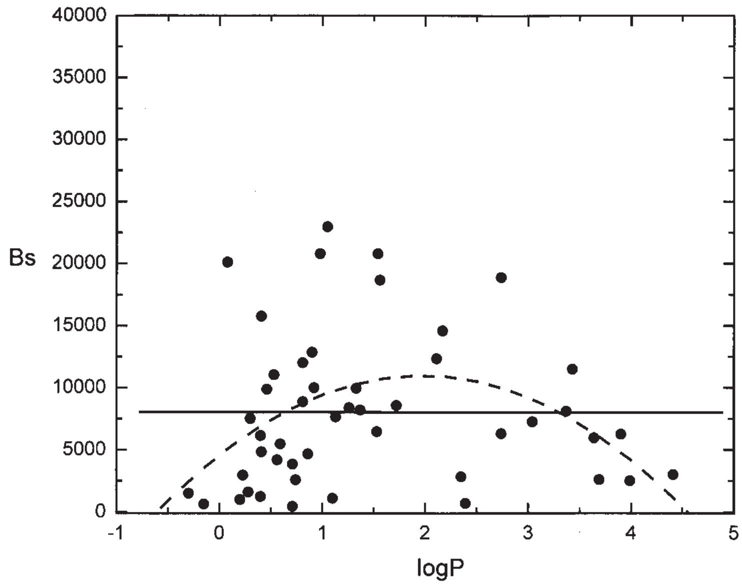


Figure 3: Calculation of the arch from the field values B_s by a polynomial of second degree

radius (Glagolevskij & Gerth, 2005) with a cubic dependence (in case of a dipole field). On the upper limit of the MS–band, the stars have the radii 3 times larger than on the ZAMS. Concurrently, a full magnetic stream is kept during all the lifetime of stars on the MS (Glagolevskij & Gerth, 2005). Therefore, the investigated dependence in Fig. 1 is deformed by the changes in the star's condition in the progression of the evolutionary age. To eliminate this influence all measured values B_s are converted into those of one relative radius, corresponding to the average size of the luminosity class V stars by a technique, described by Glagolevskij & Gerth, 2006. This procedure leads to a minor reliable magnitude of inclination angle:

$$B_s = [(819 \pm 161) - (62 \pm 86) \cdot \log P] \text{ Gauss} \tag{2}$$

The corrected variant is demonstrated in Fig. 3. It is clear that the bias of stars with extreme magnetic fields has disappeared a result of the performed procedure in the left panel of Fig. 1. The points are now settled in more regular intervals.

Such a uniform distribution of points corresponds to the hypothesis of a relic field much more. Formally carrying out the derivation of a polynomial of the second degree leads to a curve, looking like an arch, as represented in Fig. 3 by the shaped line. The coefficients are quoted in the following table:

	Coefficient	Error
A	659	223 (3σ)
B1	243	300 ($<1\sigma$)
B2	−78	75 (1σ)

Thus it would be interesting to search for different magnetic field dependencies on the effect of age. Owing to a large dispersion of points (which occurs not only because of errors) the obtained dependence is not reliable enough, and efforts are necessary for its specification and confirmation. It is possible to make the preliminary assumption that the obtained dependence is the sum of two dependencies — direct and reverse ones. Some hypotheses claim that the reverse correlation corresponds to a dynamo, but the straight one — to "magnetic braking". The weakness of correlation corresponds to the hypothesis of a relic field. However, it should be taken into account that the known randomness of the observed inclination angles β of the dipole axis to the axis of rotation (Glagolevskij, 2011) contradicts to the hypothesis of a dynamo, nevertheless, it confirms the assumption of a primary quantity of stars lying by $\beta \approx< 90°$. However, these data are inconsistent with respect to the proven connection between the rotation of CP stars with magnetic fields. Additional data are in urgent need.

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