Model magnetic fields of CP stars with long rotation periods

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Abstract. The formerly adopted hypothesis of loss of rotational momentum in presence of magnetic fields seems to be contradicted by some recently investigated magnetic CP stars. [1]

Key words: Magnetic stars, models, rotation, long periods

1. The problem of slow rotation of CP stars

Considering the statistics of stellar rotational periods there are some difficulties to explain the slow rotation of CP stars. Rather probable prove the hypotheses:

1. The loss of the rotation moment took place under the influence of the magnetic field just before the “pre-main sequence”-phase of evolution.
2. The small rotation moment was taken from protostellar clouds.

The only property of CP stars is in favor of the hypothesis of deceleration - the smaller the mass the greater the difference between their average velocity $v \sin i$ and normal stars (Fig. 1).

2. The influence of the initial rotation on the star formation

On the other hand, there is another property - the lower the velocity of CP stars the greater their proportions among normal stars (Fig. 2). The latter property supports the hypothesis that the lower the initial rotation velocity of a star is when it forms, the greater the probability would be to become a chemically peculiar one. It has turned out that this property is common to chemically peculiar stars - with or without a magnetic field.

Glagolevskij and Chuntonov (2003) suggested that the cause of the slow rotation of CP stars should be searched for at the very initial stages of formation, which is also the reason for the division into CP magnetic, CP nonmagnetic and normal stars, because Ae/Be Herbig stars do not possess any magnetic field of sufficient strength.

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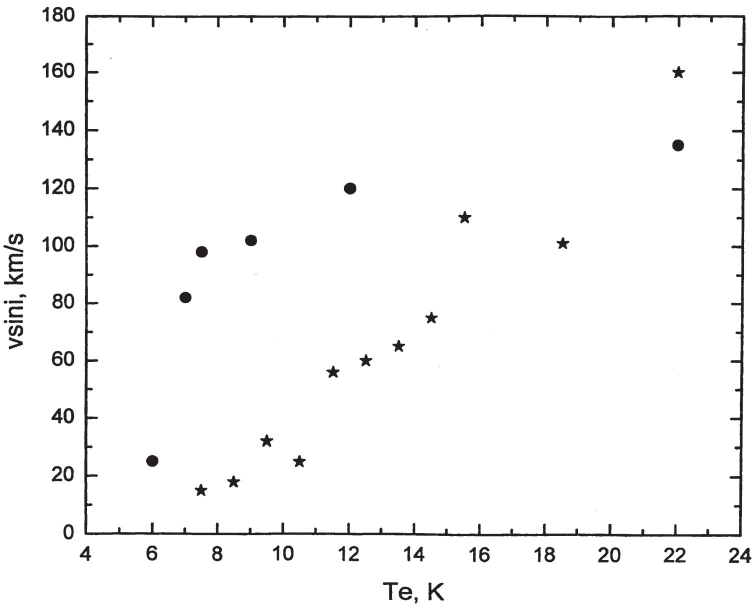

Figure 1. Average values of the rotation velocity $v\sin i$ for normal stars with different temperatures (circles) and chemically peculiar stars (asterisks)

3. The deceleration of the CP stars

In accordance with a statement given by Stępień (2000), the closeness of the dipole and rotational axes (small angles β between them) must be a serious condition for deceleration of CP stars. It is only in this case that conditions arise, under which the loss of the moment of rotation is effective. To clear this up, we investigate in the present paper magnetic configurations of several slow rotating CP stars ($P > 25^d$) for which phase relationships of variation of the effective $B_{\rm e}$ and the mean surface $B_{\rm s}$ magnetic fields are known. For the modeling we used the methods of "magnetic charges" that we have developed (Gerth et al. 1997, Gerth & Glagolevskij 2000, Glagolevskij & Gerth 2004).

4. Modeling of some slowly rotating magnetic stars

Table 1 presents the summary of our results of modeling slow rotators, which shows that they have no predominant orientation of the magnetic dipole with respect to the rotational axis, that is, there is no domination of small angles β as predicted by Stępień (2000).

It turned out that the magnetic field structure in two of the investigated stars is best described by the central dipole model, four of them show a noticeable displacement of the dipole from the center by $\triangle r$ along the dipole axis (in units of the star's radius). The displacement can be both towards the positive and negative charges, i.e. the magnetic field is asymmetric about the magnetic equator. The physics of this phenomenon is not clear yet.

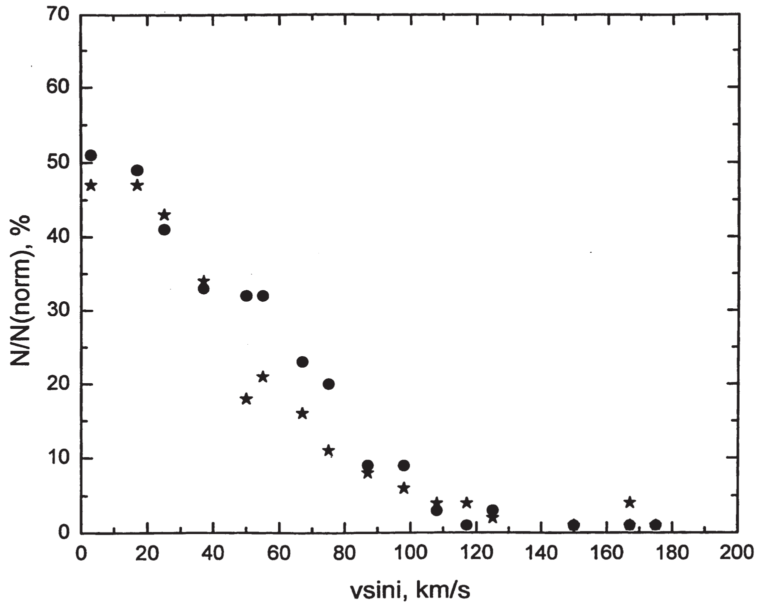

Figure 2. Relative amount of CP stars with different rotation velocities with a magnetic field (circles) and without a field (asterisks)

The angles β between the rotational axis and the dipole axis proved to be considerable in all cases, apart from HD2435. It is known from literature data that the quantity of the photometric variability $\triangle V$ of the investigated stars is rather large, although in the case of small β the variability must be practically imperceptible.

Table 1

Star HD	P[days]	i	β	Δr	B_p[Gauss]	Reference
2453	547	14°	80°	0.00	±6560	Glagolevskij, Gerth, 2004
12288	35	24°	66°	0.00	±13400	Glagolevskij, Gerth, 2004
9996	8000	89°	10°	0.00	±8100	our last results
201601	3800	34°	85.5°	0.00	±6210	Glagolevskij, Gerth, 2006
116458	4600	75°	12°	0.07	+ 9510 – 6220	Glagolevskij, 2005a
126515	12300	22°	86°	0.24	– 45800 +11100	Glagolevskij, 2005a
187474	5000	86°	24°	0.10	+ 6300 – 11600	Glagolevskij, 2005b
200311	8600	30°	86°	0.08	+18520 – 11420	Glagolevskij, Gerth, 2004
	Average:	47°	56°			

Results of modeling magnetic fields of CP stars with long rotation periods.
i - inclination of the star. β - angle between the dipole axis and axis of rotation. Δr - value of the dipole shift from the star center (partial radius). B_p - magnetic field at the poles

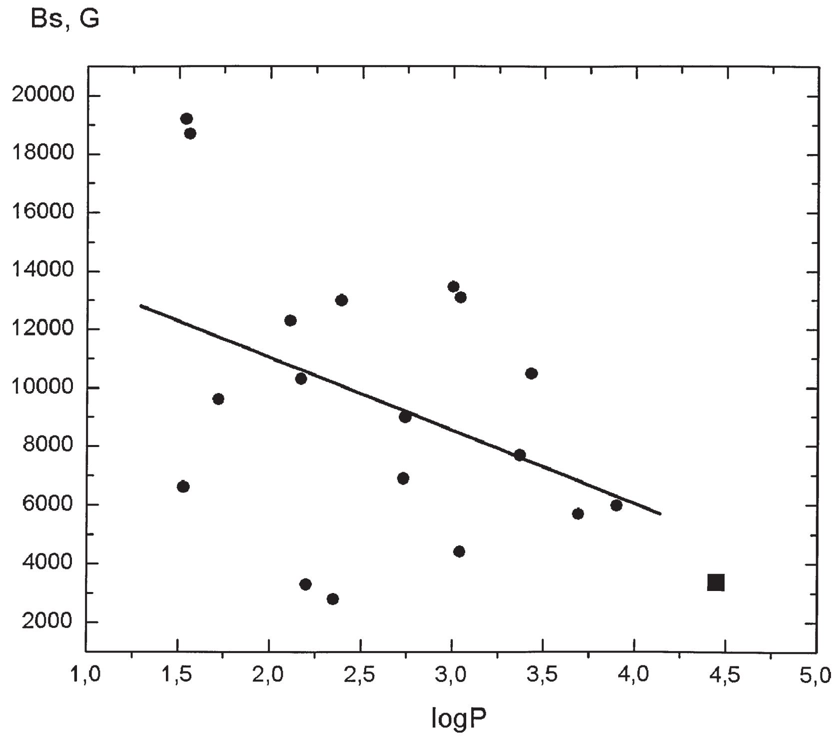

Figure 3. Dependence of the average surface magnetic field of CP stars on their period of rotation. In case of “magnetic” braking the period would be the longer the stronger the magnetic field is.

5. Slowing down by magnetic magnetic fields?

One more argument against the magnetic deceleration is that the relationship between the average surface magnetic field of slow rotators and the rotation period proves to be opposite to the expected one (Fig. 3). Nevertheless, the “slowest” star γEqu has a rather weak magnetic field. “Magnetic braking” would be an interaction between the own magnetic moment of the star rotating in the environment of an interstellar magnetic field. It is not improbable that the magnetic field has played an important role only in the diminishing of the moment of rotation of the protostellar clouds.

6. Asymmetry of the magnetic dipole field

It can be seen from the Table that in some cases the dipole is shifted along the axis by a considerable value up to $\Delta r = 0.24$ of the radius of the star, which seems to be quite noteworthy. It is not clear yet to what extent the magnetic field configuration of CP stars is asymmetric in reality and to what degree the field measurements are distorted by the influence of inhomogeneous distribution of chemical elements. In the stars considered the average angle of the diverging axes is $\beta = 56°$, which corresponds approximately to the mean value that must be the case for an arbitrary orientation of the magnetic dipoles.

7. Conclusions

1. The fact that the axes of rotation and of the dipole are not parallel is one of the indications that the deceleration at the "pre-main sequence" stages is absent. This verifies the hypothesis of an initial slow rotation of CP stars as the result of a small moment of rotation for protostellar clouds.

2. The absence of sufficiently strong magnetic fields in Ae/Be Herbig stars (see Glagolevskij & Chuntonov 2003, Glagolevskij & Gerth 2006) also poses difficulties for the hypothesis of "magnetic" deceleration at "pre-main sequence" stages of evolution.

3. The known considerable photometric variability of the investigated CP stars is a further argument against the closeness of the axes.

4. The axes of the magnetic field dipoles in slow rotators are oriented randomly with respect to the rotational axes, as being in the case of fast rotators.

5. The inverse relationship $B_{\rm S}(P)$ to the rotational velocity at some stars contradicts to the assumption that the magnetic field is involved in the deceleration.

6. The same relation between the relative number of chemically peculiar stars and nonmagnetic stars is inconsistent with the assumption that the magnetic field is involved in the deceleration.

7. The loss of the moment of rotation with the magnetic field involved could hardly occur at "pre-main sequence" evolutionary stages, the slow rotation is most likely due to its origin from protostellar clouds.

References

1. Glagolevskij Yu.V., Chuntonov G.A., 2003, Bull. Spec. Astrophys. Obs., **55**, 38

2. Stępień K., 2000, A&A, **353**, 227

3. Gerth E., Glagolevskij Yu.V., Scholz, G.: 1997, Stellar Magnetic Fields, Proc. Intern. Conf., eds. Yu.V. Glagolevskij and Romanyuk, 13–18 May 1996, Nizhnyj Arkhyz, 67

4. Gerth E., Glagolevskij Yu.V., 2000, Magnetic fields of chemically peculiar and related stars, Proc. Intern. Conf., Nizhnij Arkhyz, eds.: Yu. V. Glagolevskij, I.I. Romanjuk, Nizhnij Arkhyz 24–27 Sep.1999, 151

5. Glagolevskij Yu.V., Gerth E., 2004, Bull. Spec. Astrophys. Obs., **58**, 1

6. Glagolevskij, Yu.V., 2005a, Astron. Zhurnal, **82**, 1119

7. Glagolevskij, Yu.V., 2005b, Astrofizika, **48**, 575

8. Glagolevskij, Yu.V., Gerth, E., 2006, Astrofizika, **49**, 252