The magnetic field structure of the slow CP star rotator HD 188041

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Abstract. The slowly rotating CP star HD 188041 is subjected to an analysis of its magnetic field structure by the modelling method of the *Magnetic Charge Distribution* (MCD), using the photographic measurements of Babcock. The first attempt to fit Babcock's observational results to a model of a central magnetic dipole gives – as usual because of the ambiguous aspect at the north or south hemisphere of the star – two possible solutions of the distance angle of the magnetic and rotational axes $\beta_1 = 6°$ or $\beta_2 = 76.8°$ corresponding to the inclination angles $i_1 = 80.5°$ and $i_2 = 14°$. Admitting a decentralization of the dipole, the fitting of the phase curve of B_e to the data by minimizing the sum of the quadratic deviations could be improved, making thus the decentered dipole probable, but changing the angles β and i only slightly. The results are compared to those of a series of eight other slowly rotating CP stars.

By this paper we bring to an end a series of investigations on the magnetic field configuration of CP stars with long rotation periods ($P > 25^d$). Some previous papers [1–4] contain already the investigational results of 7 stars of that kind. The main problem is the comparison of the fundamental properties of magnetic fields at fast and slow rotators, for having to explain the possibility of influence of the magnetic field configuration onto the preliminarily assumed degree of braking at CP stars.

Our method of modelling is founded on the imagination of sources of the magnetic field in the form of magnetic monopoles [5]. Differing from some other methods of modelling stellar magnetic fields, our method has the physical meaning that every vector field – including the magnetic field – must have a source. With the coordinates of the monopoles (λ - longitude, δ - latitude), the magnetic moment M and the inclination angle i to the line of sight, we calculate the phase relations of the effective field strength $B_e(\Phi)$ and the average surface field $B_s(\Phi)$, which we compare with the observed relations. The best coincidence is achieved by the method of iterative approximations. The inclination angle i is obtained automatically in the case that the phase relations are known.

For the construction of a model field of the star HD 188041, at first we looked all papers [6-11] through, in which measurements of B_e and B_s are contained. It turned out that all of them are characterized by a rather large scatter of the field values. The only series of measurements, containing a considerable quantity of B_e data, belongs to Babcock [6]. The measurements of B_s we took from [12,13]. For convenience of comparing the phase curves of the calculated and the observed relations, we drew them in the form of smoothed mean values, which we obtained by the method of sliding averaging over 4 points.

The values B_e and B_s are plotted in Fig. 1 and Fig. 2 by points. The minimum of the field strength is found at the ephemeris JD 2432323 + 226*E*.

As usual, the first approximation is carried out on a concept of a central dipole – with a small angle β and a large one. The outcome is, that none of the two variants corresponds to the observed relation $B_s(\Phi)$ according to the form of the phase curve. This means that the star does not possess a magnetic field of a central dipole.

The following step is that there should be found such positions of the magnetic charges inside the star, by which both calculated phase relations correspond to the observation. First we try to get coincidence for the relation $B_e(\Phi)$. Then, taking different parameters and applying the method of consecutive approximations, there are obtained two solutions – with small and with large angle β. In Fig. 1 the first variant is marked by a solid line and the second one is done by a broken line. It can be seen well, that the variant with a large angle β totally does not correspond to the observation according to the form of the phase curve. There fits only the variant with a small angle β. The parameters, by which these two solutions are obtained, are quoted in Tab. 1, A and B. By this way it turns out that the star HD188041 possesses the structure of a magnetic dipole, shifted from the center along an axis in direction to the negative monopole by a magnitude 0.07 of the star's radius.

The accuracy of the obtained parameters is estimated by ours for i, β and δ to ± 1°, for λ to ± 10°, and for B_p to ± 50 Gauss.

In Tab. 2 are shown all results obtained by ours investigating the orientation and the structure of the magnetic field of slowly rotating magnetic stars. On the table we can see that the orientation of magnetic dipoles inside the stars could be arranged any way, without any preference.

The creation of CP stars is connected with their initial slow rotation - as schown already by Landstreet and Mathys [14].

Table 1 A. Variant with small angle β

Sign of monopole	Longitude λ	Latitude δ	Angle β	Angle i	Field B_e on the poles
−	0°	–83°	7°	83°	–7400 Gauss
+	180°	83°			+4850 Gauss

Shift of the dipole from the center of the star Δa = – 0.07

B. Variant with large angle β

Sign of monopole	Longitude λ	Latitude δ	Angle β	Angle i	Field B_e on the poles
−	0°	–10°	80°	16°	–7540 Gauss
+	180°	10°			+5580 Gauss

Shift of the dipole from the center of the star Δa = – 0.05

Table 2 List of investigated slow CP star rotators

HD	B_s, G	P, days	β	Structure	Source
2453	547	521	80	central dipole	1
9996	8000	4800	10	central dipole ?	1
12288	35	7900	66	central dipole	1
116458	4600	148	12	decentered dipole	2
126515	12300	130	86	decentered dipole	2
187474	5000	2345	24	decentered dipole	3
188041	3600	224	20	central dipole ?	this paper
200311	8600	52	86	decentered dipole	1
201601	3800	72 years	50	decentered dipole	4

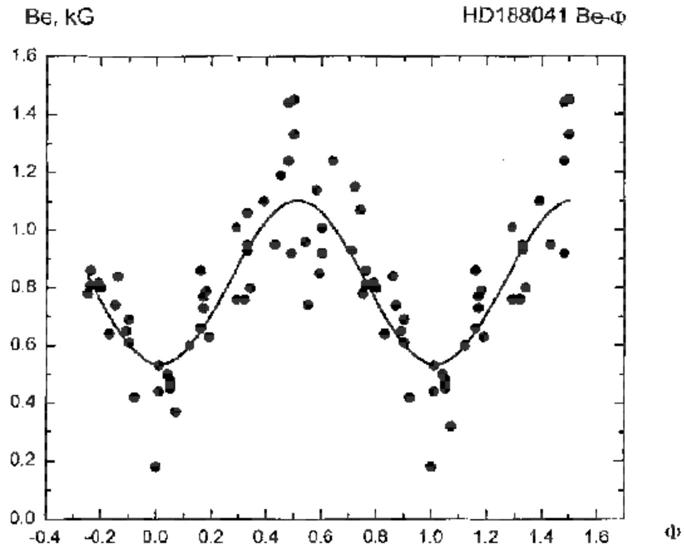

Fig. 1. Phase arrangement of the measuring B_e data of Babcock

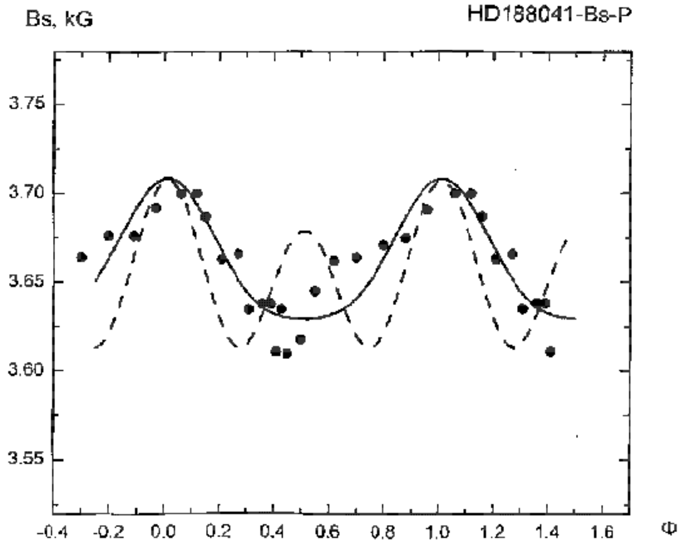

Fig. 2. Phase arrangement of the measuring B_s data of Babcock

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