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Modeling of magnetic fields of chemically peculiar stars. HD 192678

Yu.V. Glagolevskij

Special Astrophysical Observatory of the Russian AS, Nizhnij Arkhyz 369167, Russia

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Abstract. Magnetic field models of the chemically peculiar star HD 192678 have been derived on the assumption of both a central and displaced dipole. The mean parameters of the magnetic field: the angle between the axis of dipole and the rotation axis, $\chi = 70°$, the magnetic field magnitude at the poles, B_p=7300 G, the star rotation axis inclination to the line of sight, $i = 8°$ have been obtained. The measurements are not accurate enough to decide between the two models.

Key words: stars: magnetic fields — stars: chemically peculiar stars: individual: HD 192678

1. Introduction

We pursue the work devoted to the investigation of the structure of magnetic fields of chemically peculiar stars. The technique of modeling and the first results have been published by Gerth et al. (1997) and Gerth, Glagolevskij (2000). Using this technique a researcher consider magnetic monopoles inside the star with a magnetic charge M, with coordinates λ and δ in longitude and latitude, respectively, and computes the results of addition of the fields of the monopoles over the surface and also the relationship curves of the effective B_e and the mean surface B_s fields with the phase P of the rotation period. By selecting appropriate parameters one can achieve a good fit of the observed curves $B_e(P)$ and $B_s(P)$ to the computed ones. In principle, any field configuration can be specified, but not only central or displaced dipole, or quadrupole, or octupole, which are used in the existing models. All these methods provide the distribution of the field analytically. In our technique the field distribution is computed at each point as a result of addition of fields of the specified magnetic monopoles. This is why this technique, in our opinion, is more flexible as compared to others, although experience of comparison with other methods is insufficient yet. One of the goals of the present paper is comparison of the parameters of the star HD 192678 obtained using our technique and that described by Wade et al. (1996). In the paper a model of HD 192678 is considered. The star has already been simulated by other techniques. It is interesting to compare the results obtained independently and to attempt to utilize the distinguishing features of our method.

2. Models of the star HD 192678

Observational data on variations of the effective magnetic field B_e (Wade et al., 1996) and of the surface field B_s (Mathys, 1997) with phase of the period P are available for the star and presented in Fig. 1. These two relationships allow determination of both the star rotation axis inclination angle to the line of sight i and the dipole axis inclination angle to the axis of rotation χ. Unfortunately, the measurement accuracy is insufficient to make a reliable choice of the type of model: central dipole, displaced dipole, superposition dipole+quadrupole, or a model with a more complex structure. In this case one can suggest with assurance only the first approximation model — central dipole. Our calculations resulted in the magnetic field parameters (1st model) given in Table 1, where i is the inclination angle of the star, χ is the angle between the dipole and rotation axes, B_p is the magnetic field intensity at the pole. From the table it is seen, that the dipole lies in the plane inclined to the equator at an angle of 18°, i.e. close to the equatorial plane. The star is viewed pole-on, therefore the amplitude of magnetic field variations is small. As the star rotates, the magnetic poles are always near the edge of the disk, which results in low accuracy of magnetic field measurement. It is only a model computation that can give an idea of the real B_e variation amplitude; it is close to 100 G. The computed curves of $B_e(P)$ and $B_s(P)$ are shown in Fig. 1 (upper and lower panels) with a solid line.

The magnetic field of HD 192678 has been simulated in the paper by Wade et al. (1996) using a different technique. This is why comparison of our results is intriguing. They also used a central dipole model and derived the parameters presented in Table

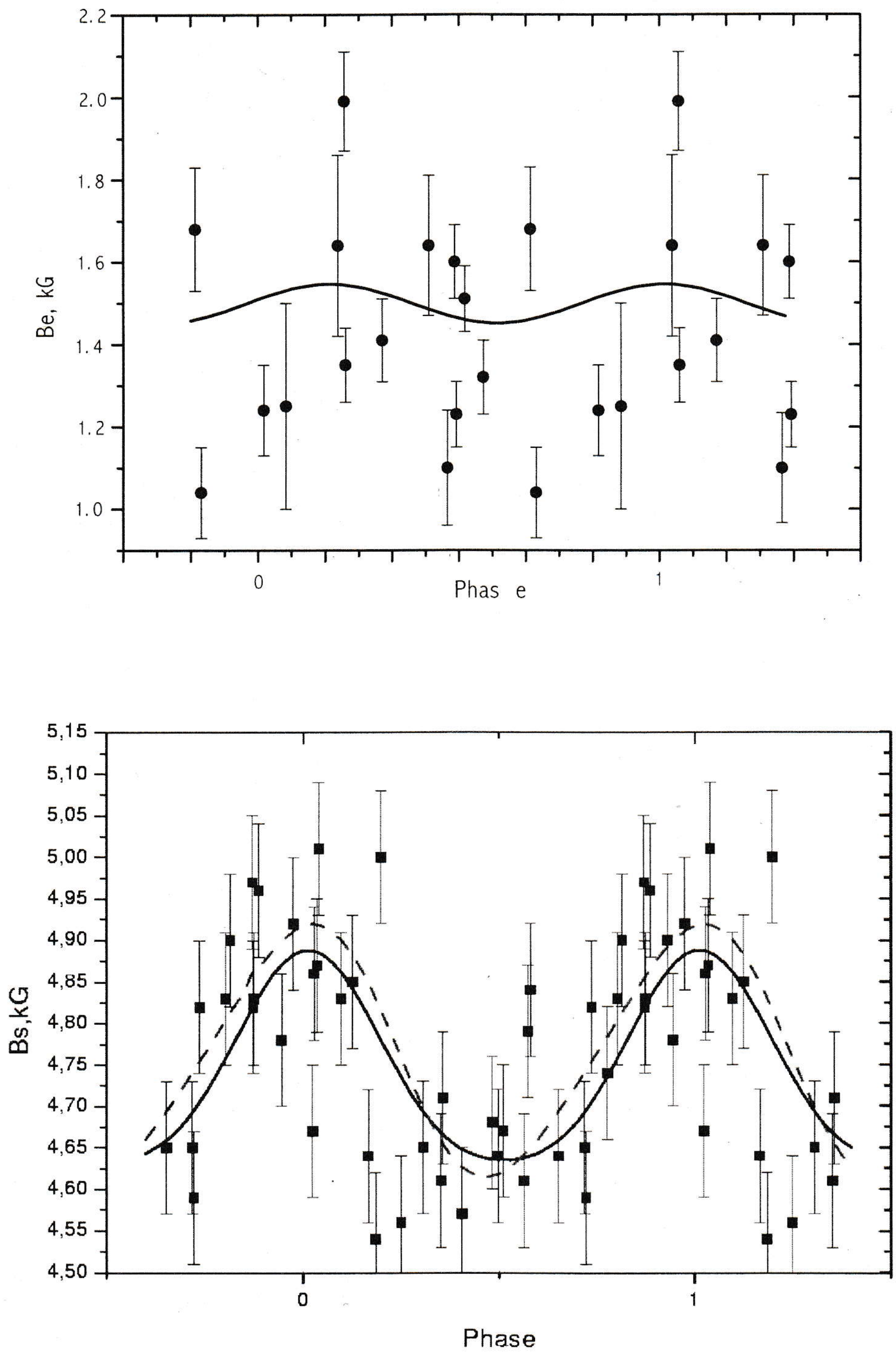

Figure 1: *The relationships between the effective and surface magnetic fields of the star HD 192678 and rotational period phase. The solid line is one computed with the central dipole model, the dashed line presents the displaced dipole model.*

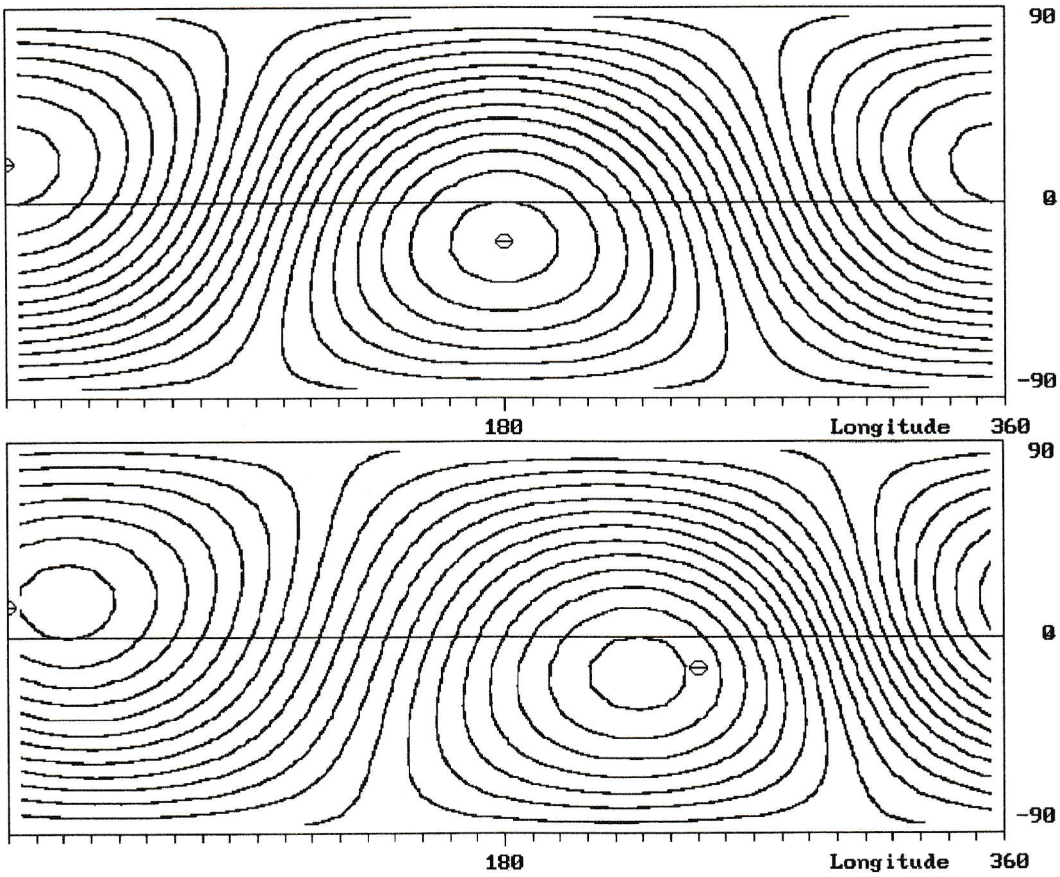

Figure 2: *The distribution of the magnetic field strength over the surface of HD 192678. A — the central dipole model, B — the displaced dipole model.*

1 (2nd model).

As can be seen, the angles i are of the same order, but χ and B_p are markedly different, 12° and 1100 G, respectively. No sufficiently accurate measurements have so far been available, which results in a failure to analyze the causes of these differences.

Angle i can be estimated also from vsin i=4 km/s (Wade et al., 1996). By assuming the parameters β=2.884 (Houck, Mermilliod, 1980) and T_e=9300 K (Glagolevskij, 1994) obtain the absolute bolometric magnitude M_b=0.65. Hence the radius $R = 2.5R_\odot$, $v = 50.6 \cdot R/P = 19.8$ km/s (the rotational period $P = 6.4$ days (Wade et al., 1996)), and $i = 12°$, i.e. very close to what has been derived from the modeling.

The M_b value has been used to calculate the ratio of the star's radius to its radius on the zero age line of the main sequence, $R/R_{ZAMS} = 1.5 \pm 0.2$, which shows that the star is located between the sequences of luminosity classes V–IV in the Hertzsprung-Russel diagram. It may be expected that at this age the magnetic field could keep the elements of the complex structure, which is likely inherent to recently formed CP stars. This is why, it is interesting to attempt to apply the displaced dipole model by considering real asymmetry (saw-toothed shape) of the relationship $B_s(P)$ (see also Fig. 2 in Wade et al., 1996). The maximum asymmetry of the computed curve was achieved with the coordinates of magnetic monopoles indicated in Table 2 (for comparison we present the coordinates of monopoles for the central dipole model).

Note that the point with the longitude λ=0° passes across the central meridian at the phase P = 0.0.

The dipole is displaced perpendicularly to its axis; the maxima of the positive and negative magnetic field at the surface are located closely with respect to one another in longitude — about 150°, but not 180°, as is the case in the central dipole model; the field strength at the maxima is equal. The distribution of field intensity isolines over the surface for models 1 and 3 is shown in Fig. 2 (upper and lower panels). The curves of the relationships $B_e(P)$ and $B_s(P)$ computed in accordance with the central dipole model are shown by a dashed line in Fig. 1 (the curves of $B_e(P)$ for the displaced and central dipoles are virtually co-

Table 1: *Parameters of the magnetic field of HD 192678*

Model	i	χ	B_p	Notes
1	$10° \pm 1°$	$72° \pm 1°$	7900±500 G	Central dipole
2	$7° \pm 5°$	$60° \pm 7°$	6800±200	Central dipole (Wade et al.)
3	$9° \pm 1°$	$76° \pm 1°$	8300±500	Displaced dipole
Mean	$8.7° \pm 1.3°$	$69° \pm 4°$	7366±500	

Table 2:

Model	Sign	Longitude	Latitude
central dipole	(+)	0°	18°
	(–)	180	−18
displaced dipole	(+)	0	14
	(–)	250	−14

incident). It is not improbable that the asymmetry is due not to the magnetic field geometry but to the inhomogeneous surface distribution of chemical elements whose lines have been used to determine the magnetic field. This problem needs further investigation. The magnetic field parameters of the displaced dipole are listed in Table 1 (model 3). The central dipole model seems to be preferable since its curve of magnetic field variations agrees best with the observational data.

We cannot so far give priority to any of the models examined. For this reason it is worthwhile to derive the mean values of the parameters i, χ and B_p which are given in the lower line of Table 1. Further studies have to reveal the properties of each of the methods of modeling applied at present.

3. Conclusions

Investigation of the star HD 192678 shows that it is viewed nearly the rotation pole-on, and the dipole axis lies in the plane close to that of the equator. Such a configuration is unfavourable both from the point of view of modeling and from the point of view of deriving reliable curves of effective and surface field variations from observations. This is why it is impossible yet to define exactly the type of model — whether this is a central or displaced dipole or a more complex configuration. In a first approximation, the model of Wade et al. (1996) or ours give the same values of magnetic field parameters.

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