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Fossil magnetic fields of the sun and stars

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Abstract. Using helioseismologically inferred internal rotation given by Dziembowski et al., 1989, in the previous work, we (Hiremath and Gokhale 1995, Hiremath 1995) modelled the steady (fossil) part of the poloidal magnetic field structure as that which isorotates with the sun's internal rotation. In the present study, we use the sun's internal rotation recently obtained by Anita et al., (1998), from the GONG data. The results of the present work are almost similar to our previous work but are much more accurate. It is important to note that it is possible to obtain a high degree of isorotation between an eigen-solution of the diffusion equation and the internal rotation inferred from the latest helioseismic data, by fitting only a few parameters in the eigen-solution. It is found that magnitude of the poloidal magnetic field varies substantially with the radial direction and is nearly independent of latitude. We plan to extend our work to other stars on the main sequence and white dwarfs.

Key words : solar and stellar magnetic fields, rotation

1. Introduction

It is believed that the stars might have retained in their interiors some part of the large scale magnetic field from the protostar phase (Cowling 1953). Such large scale fields are observed to be conspicuous in many stars of early and late spectral types on the main sequence and in white dwarfs. These large-scale magnetic fields play an important role in transferring angular momentum on long time scales and creation of stellar activity and activity cycles on short time scales. Aim of the present study is to model the geometrical structure of the magnetic fields from the solutions of MHD equations (Chandrasekhar 1956).

In a previous work, we first obtained a solution of Chandrasekhar's MHD equations which is embedded in an asymptotically uniform external field. To obtain steady part of the Sun's poloidal magnetic field, we imposed on this solution the condition of isorotation with the Sun's internal rotation. In order to get the relative strengths of different components in the solution, we used the internal rotation inferred by Dziembowski et al., (1989) from earlier helioseismic observations (Libbrecht 1989). Owing to the large uncertainties, at that time, in the inferred rotation near the polar regions and near the center, the uncertainties in our estimates of the relative strengths of the components were rather large. The rotation inferred from present observations (eg. GONG, SOHO, etc.,) is much more accurate. This motivated us to revise our earlier calculations.

2. Results and discussion

In the present work, we use the internal rotation recently inferred by Antia et al., (1998) from the recent GONG data. In the radiative core (RC), the best fit yields a combination of the first two diffusion eigen modes of the magnetic field. In the convective envelope (CE), the best fit yields a combination of dipole-like and hexapole-like magnetic fields. Magnetic field structure obtained from the present work is almost similar to our previous work. However, in the previous work, the uncertainties in the relative strengths of different components of the magnetic field were large (~20%), where as in the present calculations, the uncertainties are smaller (~2%).

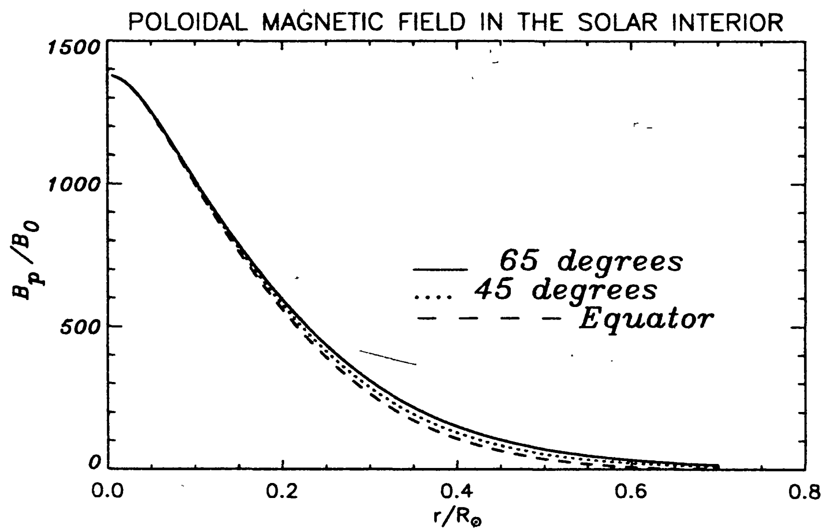

Figure 1. The radial and the latitudinal variations of the magnitude of the poloidal magnetic field B_p normalized to an asymptotic uniform magnetic field B_0 which merges with the interstellar field.

In Fig. 1, we present the radial and the latitudinal variations of the magnitude of the poloidal magnetic field (B_p) normalized to an asymptotic uniform magnetic field B_0. It is interesting to note that the magnitude of the poloidal part of the magnetic field varies substantially in the radial direction and is nearly independent of the latitude. One wonders, how sun might have reached such a field structure and rotation in the interior. This may give us the clue to evolutionary history of the rotational and magnetic field of the sun. For example, in the early history of the sun, strong poloidal magnetic fields might have played dominant role in transferring the angular momentum from the interior to the surface. In later stages, as the field decays, the poloidal field might have reached isorotation with the present day solar rotation as in the calculation of Charbonneau and MacGregor (1993). Hence, it might not be surprising that we obtain a striking similarity between the structure of the poloidal part of the magnetic field and rotational isocontours inferred from helioseismology.

It is tempting to extend our work to other stars. For example, for the *early type main sequence stars*, we can expect the leading terms in the geometric structure of the poloidal magnetic field to be similar to those in the poloidal field in the sun's radiative core. The magnetic structure of *white dwarfs* also could be similar to the filed in the radiative core of the sun. In the case of *G and K type main sequence stars*, which have convective envelope in the outer part and radiative core in the deep interior, one can expect the magnetic field to be similar to that of the whole sun. In the case of *late type main sequence stars* which are almost fully convective, we expect the magnetic field to be similar to the magnetic field in the convective envelope of the sun. In future, we plan to compute the internal magnetic field structures of the afore mentioned stars and use their surface properties to interpret the polarization in line profiles.

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