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Steady part of the sun's internal rotation

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Abstract. It is shown that steady part of rotation in the Sun's convective envelope (*CE*) and radiative core (*RC*) can be determined as an analytical solution of the diffusion equation in an incompressible medium of constant diffusivity. The solution yields isorotational contours similar to helioseimologically inferred rotation. The characteristic time scale of first rotational diffusion eigen mode is estimated to be ~ 10^{13} yrs. The solution also yields toroidal part of the magnetic field whose strength varies from ~ 1 G near the surface, ~ 10^5 G near the base of the convection zone and, ~ 10^3 G near the center.

Key words: sun: interior - sun : rotation - sun: magnetic field

With reasonable assumptions and approximations (Hiremath & Gokhale 1995; Hiremath & Gokhale 1996), we use the full set of Chandrasekhar's MHD equations (1956) and show that steady parts of Sun's internal rotation and magnetic field can be determined as an analytical solution of diffusion equation. We assume that the Sun may be rotating rigidly at the base of the convection zone. From the presently available solar core rotation (Schou *et al.* 1995), we determine the characteristic value of the first rotational diffusion eigen mode and hence it's time scale. By taking average value of viscosity (~ 5 cm^2/sec) in RC, the diffusion time scale of the first eigen mode is estimated to be ~ 10^{13} *yrs.*

The rotational isocontour's for CE (Fig.1) and RC (Fig.2) are presented. The radial variation of rotation in RC is presented in Fig.3. Except near polar regions and outer part of the radiative core, the solution is similar to helioseismologically inferred rotation (Dziembowski & Goode 1989; Antia & Chitre 1996; Schou *et al.* 1995). In CE, the solution yields faster rotation near the polar regions compared to the helioseismologically inferred rotation. The solution also yields a uniform rotation near base of the convection zone. This is in contradiction with the helioseismologically inferred rotation which show that differential rotation extends even just beneath the base of the convection zone. Hence in order to reproduce the rotational isocontours similar to helioseismologically inferred rotation, we may have to change the boundary condition at the base of the convection zone. This indicates that at the base of the convection zone, *differential* rotation is more likely than the rigid body rotation (Hiremath & Gokhale 1996).

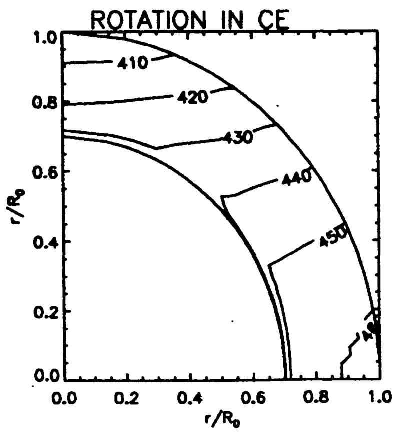

Figure 1. Steady part of Sun's rotation in CE. Rotational isocontours are in nano-Hertz.

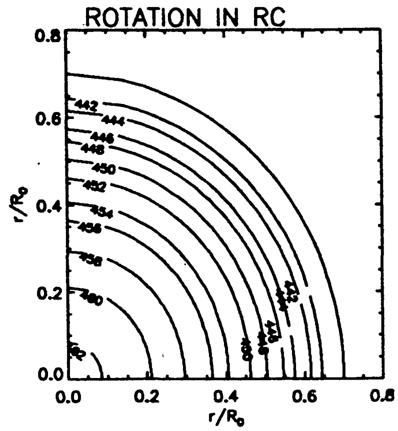

Figure 2. Steady part of Sun's rotation in RC. Rotational isocontours are in nano-Hertz.

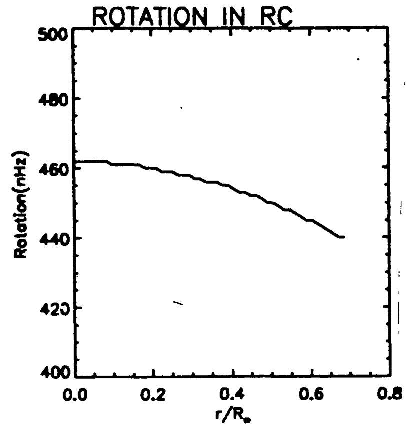

Figure 3. Radial variation of Sun's rotation in RC.

Correspondingly, we get toroidal part of the magnetic field whose strength varies from ~ 1 G near the surface, ~ 10^5 G near the base of the convection zone and, ~ 10^3 G near the center. We assume that steady parts of rotation and toroidal part of the magnetic field have similar evolutionary history and by taking the average value of magnetic diffusivity ~ 34 cm^2/sec (Hiremath & Gokhale 1995) in RC, the diffusional time scale of the first eigen mode for the toroidal part of the magnetic field is found to be ~ 10^{12} yrs. The difference in the estimated diffusion time scales of rotation and toroidal part of the magnetic field indicates that either assumed values of viscosity or magnetic diffusivity in the radiative core may be different. Similar order of diffusion time scales can be obtained either by increasing the viscosity (~ 10 times) or decreasing the magnetic diffusivity (~10 times) in the radiative core.

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