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Solar Internal Rotation and Dynamo Waves: A Two-Dimensional Asymptotic Solution in the Convection Zone

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Extended abstract

Here we outline how asymptotic models may contribute to the investigation of mean field dynamos applied to the solar convective zone. We calculate here a spatial 2-D structure of the mean magnetic field, adopting real profiles of the solar internal rotation (the Ω-effect) and an extended prescription of the turbulent α-effect. In our model assumptions we do not prescribe any meridional flow that might seriously affect the resulting generated magnetic fields. We do not assume apriori any region or layer as a preferred site for the dynamo action (such as the overshoot zone), but the location of the α- and Ω-effects results in the propagation of dynamo waves deep in the convection zone. We consider an axially symmetric magnetic field dynamo model in a differentially rotating spherical shell. The main assumption, when using asymptotic WKB methods, is that the absolute value of the dynamo number (regeneration rate) $|D|$ is large, i.e., the spatial scale of the solution is small. Following the general idea of an asymptotic solution for dynamo waves (e.g., Kuzanyan & Sokoloff 1995), we search for a solution in the form of a power series with respect to the small parameter $|D|^{-1/3}$ (short wavelength scale). This solution is of the order of magnitude of $\exp(i|D|^{1/3}S)$, where S is a scalar function of position.

To use the helioseismological data on the solar internal rotation rate (e.g., Schou *et al.* 1998) we approximate the angular velocity **Ω** by an analytic fitting function. For the latitudinal dependence of the α-effect we adopted the estimate given by Krause that is proportional to sin θ (θ latitude). For the radial dependence we assumed that the α-effect changes its sign near the bottom of the convection zone. There are two maxima of the generation sources which are situated at latitudes 16° and 61°. For the first one, the radial gradient of **Ω** is positive, while, for the second one, is negative. In our approach, we find two distinct independent non-overlapping dynamo waves: the first wave in low latitudes propagates equatorwards and the second one in high latitudes propagates polewards. The approximate solution of this two dimensional problem is represented in Fig. 1. One can see that, at low latitudes, the dynamo wave propagates mainly equatorwards with some inclination with respect to the bottom of the solar convection zone. The location of the maximum of the generated magnetic

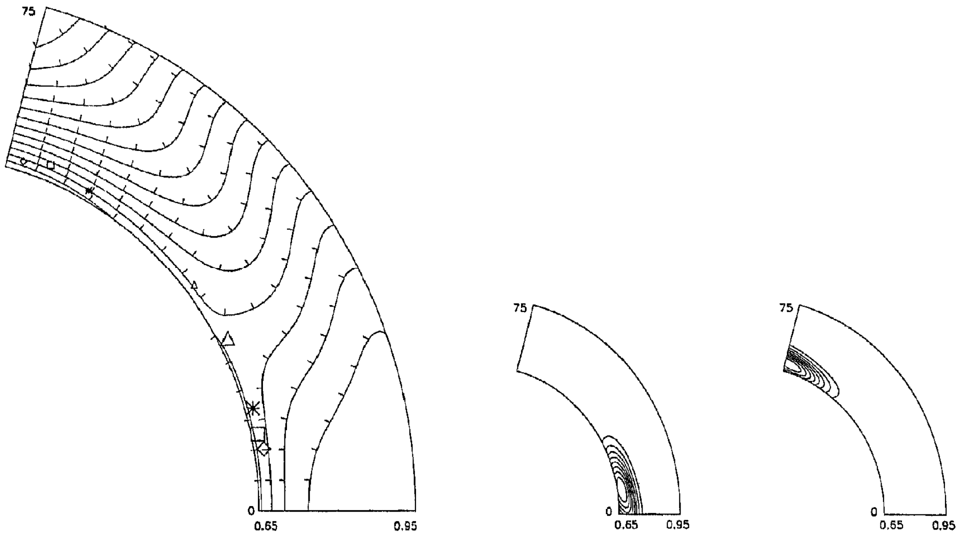

Figure 1. Contour plot of the angular velocity versus radius ($0.65 \leq r \leq 0.95$ units of the solar radius) and latitude ($0 \leq \theta \leq 75°$) after the data obtained by helioseismologists (Schou *et al.* 1998). The points of the dynamo wave maxima are shown as diamonds. Stars indicate the maxima of the sources asymptotic solution (left panel). Contour plots represent the envelope of the asymptotic solution in low (middle) and high (right panel) latitudes.

field is shifted towards the direction of the dynamo wave propagation, and is consistent with the results of (Kuzanyan & Sokoloff 1995) for the one dimensional model. It appears to be beneath the convection zone at the location $\theta = 12°$. For the poleward wave, we obtain similar properties, with the maximum located at $\theta = 68°$.

Summarizing, our analysis reveals two centers of dynamo wave generation: one at low latitudes and the other at high latitudes. The solution was found in the form of a travelling wave, which is shown to possess properties consistent with Yoshimura law (Yoshimura 1975) (dynamo waves propagate mainly along the lines of constant angular velocity).

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