THE INTERNAL ROTATION RATE INFERRED FROM LOWL AND GONG DATA

Using a Forward Method

LI, Y. AND P. R. WILSON
The University of Sydney
School of Mathematics and Statistics,
The University of Sydney, NSW 2006, Australia

Recently the LOWL Group has made available 2-year averages of frequency splitting data obtained mainly for low values of the degree ℓ. Charbonneau *et al.* (1997) find a nearly flat rotational curve in the deep radiative core from these data using a Genetic Forward Modeling method. Subsequently, they test the assumption of latitude independence for $r < 0.5$ by performing a 1.5-D inversion, and find a rotation rate which is 25% greater at the pole than at the equator for $0.1 < r < 0.2$.

Here we use a different forward modelling approach, in which the LOWL data are analysed in conjunction with the GONG data, using a modified version of the method described in Wilson, Burtonclay and Li (1996a).

We selected 998 multiplets from the LOWL data and 957 multiplets from 4-month GONG data (calculated by J. Schou) consisting of the Clebsch-Gordon (C-G) coefficients, $a_i^{n\ell}$, i=1, 3, 5, at frequency range $1500 < \nu < 3500$ nHz. To achieve a self consistent solution from the outer regions through to the radiative core, we combine these two data sets . There are 610 multiplets common to both sets. Thus the combined set includes 1345 multiplets. Differential mean C-G coefficients $\alpha_{2s+1}^{n\ell}$, s=0,1,2 are derived for each corresponding $a_i^{n\ell}$, i=1, 3, 5 using the same method as in Wilson, Burtonclay and Li (1996a).

To avoid the effects of possible systematic difference between the two data sets, we seek a difference d_{2s+1}, which minimizes the sum $S_{2s+1} = \sum_j \{a_{2s+1}^j(GONG) - a_{2s+1}^j(LOWL) - d_{2s+1}\}^2$ where the summation includes only the common multiplets, and j has replaced the multiplet identifier *nl*. It is given by $d_{2s+1} = \sum_j (a_{2s+1}^j(GONG) - a_{2s+1}^j(LOWL))/610$. We increase all coefficients in the LOWL data set by this amount, and take the average for the common multiplets.

If the rotation rate $\Omega(r,\lambda)$ at fractional radius r and latitude λ is expressed as, $\Omega(r,\lambda) = \sum_{s=0}^{s_{max}} W_{2s+1}(r)\psi_{2s+1}(\mu)$, where $\mu = \sin\lambda$, and $\psi_1(\mu) = 1, \psi_3(\mu) = 1 - 5\mu^2$, and $\psi_5(\mu) = 1 - 14\mu^2 + 21\mu^4$, then the rotation coefficients $W_{2s+1}(r)$ may be found by solving the integral equations

$$\alpha_{2s+1}^j = \int_0^1 W_{2s+1}(r)\frac{1}{j}\{\sum_{j'=1}^{j} K_{2s+1}^{j'}(r)\}dr \tag{1}$$

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where $K^j_{2s+1}(r)$ is the kernel.

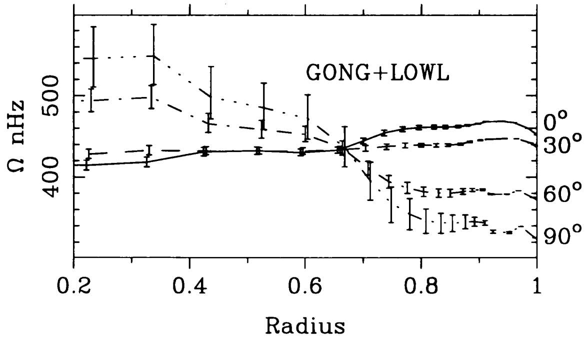

Figure 1. Rotation profiles from combined GONG and LOWL data.

To solve Equation (1), the solar interior is divided into 20 concentric shells. The rotation coefficients at the surface are set equal to values consistent with the plasma rotation rates measured by Snodgrass (1984). Initially, estimates for rotation coefficients at each shell boundaries are given. Between any two shell boundaries, a linear interpolation is carried out to give the rotation coefficients. The initial estimates are then adjusted beginning at the first shell boundary next to the surface and proceeding deeper, till the theoretical differential mean C-G coefficients fit the observations within 1-σ uncertainty range.

The solutions are shown in Figure 1. The error bars were derived by a method described in Wilson, Burtonclay and Li (1997).

The solutions show a flat equatorial angular velocity below $r = 0.66$ and an increased angular velocity at high latitudes, which are in qualitative agreement with Charbonneau *et al.* (1997).

In order to test the solution further, we consider a solution which is independent of latitude (setting $W_3(r)$ and $W_5(r)$ to zero) for $r \leq 0.66$. The corresponding theoretical differential means fall outside the 1-σ uncertainty intervals for $r < 0.5$ and outside Simultaneous Coverage Probability intervals (Wilson, Burtonclay and Li, 1996b) at a deeper layer.

We conclude that a latitude dependent rotation profile below $r = 0.66$ is a significant feature of this inversion of the combined LOWL-GONG data set.

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References

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