SOLAR ROTATION RATE FROM STABLE SUNSPOT TRACINGS

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Abstract. Positions of sunspots between 1966 and 1976 as observed at Kandilli Observatory were used to determine the differential rotation of the Sun. A total of 202 sunspot groups which were E, F, G, H, and J-types were chosen, and a least-squares solution was calculated with their daily rotations. A gradient difference was found between the two hemispheres of the Sun.

1. Introduction

In the last decades much work has been done in the study of the solar rotation and its dependence on heliographic latitude using different solar phenomena. Determination of the differential rotation of the Sun using the positions of the sunspot groups has been mainly studied by Becker (1954), Godoli and Mazzucconi (1979), Lustig and Dvorak (1984), and Howard and Gilman (1984). Some of them used primarily the data of the Greenwich Photographic Results. Wöhl (1983) pointed out that there could be rather large differences in the rotation velocities of the same sunspot determined at different observatories and by different methods. As an additional interesting result, Eddy et al. (1976) showed that the Sun's differential rotation has not always been the same, but is subject to secular changes over long time intervals. Therefore, we decided to use other data to deduce solar differential rates from sunspot groups. On the other hand, new data sets had to be used to determine the long-term characteristics of sunspot behaviour. Fortunately, there exist the data of sunspot drawings obtained at Kandilli Observatory.

2. Observations and Data Analysis

The solar telescope which is used has a focal length of 3050 mm and an aperture of 200 mm. The observation consisted of drawings of the Sun with a diameter of 250 mm. The accuracy of the drawings of the Sun depends highly on the quality of the picture. To take into account this fact we choose the good quality pictures (on Kiepenheuer scale). The determination of the position of the sunspot never exceeds ±1.0 mm. The position of the center of the umbra was measured with an accuracy of ±0.5 mm. These measured positions were also corrected with a cosine-term according to the angular distance from the central meridian.

In studying the recurrence of long-lived solar activity features, it is usually supposed that these features are sufficiently stable in position during their life-time. Therefore, we used recurrent H- and J-type sunspot groups as well as E, F, and G-type sunspot groups with a distance smaller than 0.85 solar radius from the centre of the solar disk. The criterion for the determination of the type of sunspot was the Zürich-classification. We

only used spot groups with a visibility of more than four days during one passage. For identification of the recurrent spot groups we used the Photoheliographic Results from Greenwich.

For the period 1966–1976 we selected 202 sunspot groups which suited our definitions and measured about 1110 individual sunspot positions. Fifty-three percent of them were from the northern hemisphere, while 47% were measured on the southern hemisphere, in accordance with the actual distribution of the sunspot groups during this period. We made a single measurement for each sunspot group, then fitted all positions over the single passages and calculated a least-square solution of the daily rotation according to their mean latitudes which should correspond to the law

$$w(B) = a + b \sin^2 B,$$

where $B$ is the heliographic latitude; $a$, the angular sidereal rotation velocity at the equator (in deg day$^{-1}$); and $b$, the gradient of the differential rotation.

### 3. Results and Discussion

Calculations were done for the whole Sun, separately for its north and south hemispheres, and for every year by using Equation (1). The sunspot group rotation rate determined for the whole data set (in degrees) is

$$w = (13.09 \pm 0.03) - (2.57 \pm 0.13) \sin^2 B, \quad \text{for } N = 202.$$  \hspace{1cm} (2)

From sunspot groups observed on the northern hemisphere we obtained

$$w = (13.16 \pm 0.04) - (2.47 \pm 0.14) \sin^2 B, \quad \text{for } N = 108$$ \hspace{1cm} (3)

and for the southern hemisphere the rotation rate may be expressed as

$$w = (13.06 \pm 0.05) - (2.33 \pm 0.22) \sin^2 B, \quad \text{for } N = 94;$$ \hspace{1cm} (4)

$N$ being the number of sunspot groups used. Figure 1 shows the graphical results of the 202 sunspot groups. The abscissa gives the mean heliographic latitudes; the ordinate shows the fitted synodic daily rotation rates. The solid line corresponds to the differential rotation curve which was derived according to Equation (2).

Our equatorial velocity agrees well with the result of Lustig and Dvořák (1984). In general our velocities are lower than those of Howard and Gilman (1984), Lustig (1982), and Godoli and Mazzucconi (1979). For equatorial velocities very little difference was found between the northern and southern hemispheres while a notable difference is found in the gradients of the differential rotation. From Equations (3) and (4), the difference in the gradients of the differential rotation between the two hemispheres is

$$b_N - b_S = 0.14,$$ \hspace{1cm} (5)

where $b_N$ is the northern hemisphere's gradient and $b_S$ is the southern hemisphere's one. This result indicates that the southern hemisphere has a smaller $\delta v / \delta B$ ($v$ velocity, $B$ latitude). We did not examine further whether this difference was related to the latitude...