EVIDENCE FOR THE PHI-DEPENDENT ROTATION-OSCILLATION OF THE SUN (AND FOR THE DRIVING MECHANISM OF THE ASYMMETRIC DYNAMO)*

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Abstract. Longitude-dependent oscillations of the solar rotation are derived from the 27-day averages of the photospheric velocity data. Two pairs of prominent periods are obtained. Their harmonic means correspond to a semiannual variation and to the first harmonic of the latter. To explain the origin of the oscillation the corona and the interplanetary material are supposed to rotate parallel to the planetary plane with an inclination to the solar equator. The non-uniform shearing around the equator is assumed to result in oscillation with a period of half of a year.

A preliminary analysis expressed in terms of an asymmetric solar dynamo suggests the existence of φ-dependent oscillations of the angular velocity (Csada, 1980). In the present report the observational evidence is summarized and a physical explanation of the variation in solar rotation is suggested.

Let us take a model example to understand the basic feature of a φ-dependent oscillation. Consider a fictive external body with a supposed tidal effect acting on the Sun. Alternate increasing and decreasing rotational velocities manifest themselves as φ-dependent oscillations corresponding to the rising and falling of the photosphere. If the external body is supposed to be fixed in space, the oscillations are stationary with respect to an inert frame, and two maxima and two minima will be observed in the rotational velocity over a terrestrial year.

This hypothetical physical mechanism will be used to construct the mathematical form of the variation. It is proposed that the corona and the interplanetary matter rotate parallel to the planetary plane with an inclination to the solar equator. Thus φ-dependent oscillations are induced, but the formulation is much more difficult than that in terms of a solid fictive body. In particular, the driving of the oscillation must be sustained by some energy source which is able to compensate for the decay of the magnetic field.

The oscillations are superimposed on the mean rotation and on random oscillations due to the granular pattern. To eliminate the random term, the daily velocity data were averaged over 27 days. The φ-dependent terms were separated from the mean rotation by taking averages over the solar disc according to scheme

$$\bar{v} = -\frac{1}{2\Delta\varphi} \int_{-A-\Delta\varphi}^{-A+\Delta\varphi} \omega_1 \sin\varphi \, \mathrm{d}\varphi + \frac{1}{2\Delta\varphi} \int_{A-\Delta\varphi}^{A+\Delta\varphi} \omega_2 \sin\varphi \, \mathrm{d}\varphi \, .$$

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On the assumption that the variation of the angular velocity is caused by an elliptical distortion of the photospheric level, we can write that

$$\omega_1 = \omega_0 + B \sin(\lambda + \varphi),$$

$$\omega_2 = \omega_0 - B \sin(\lambda - \varphi),$$

where λ is the (heliographic) longitude of the central meridian relative to the fictive body, and φ is taken increase eastwards from the central meridian.

The photospheric velocity data observed in the Mount Wilson Observatory from 1 January, 1975 to 27 December, 1978 were collected by Dr Howard for the study of long period oscillations. The list constains velocity residuals (obtained after the subtraction of the Earth's motion, the solar rotation, the limb shift and the 'ears') in the azimuth zones $30° \pm 2°$ on either side of the central meridian. The west zone values are subtracted from the east zone values. The residuals were averaged over 27 day intervals. The material was analysed in the Konkoly Observatory to find significant periods from 27 to 250 days. For data fit the formula

$$\langle v \rangle = 0.433 + B \sin 2\omega t$$

was used and ω was tested by steps of $2\pi/100$.

The result of the analysis shows prominent periods of 199.2, 165.1, 93.1, and 86.9 days with a less than 10% error of the printed values in Table I. The method of computation consists in comparing three successive values of the mean deviation of the observed from the calculated values. If the significant periods show normal distribution the interpolation of the logarithm of the mean deviations by a parabola yields the periods.

The harmonic mean of the values printed in the first two columns of Table I is 180.4 days indicating an oscillation of a period of half of a year while the mean value of the last two columns, being 90.2 days, corresponds approximately to periods of a quarter of a year.

Since the velocity residuals are corrected for the Earth's motion, the apparent half year variation and its harmonics are eliminated from the data. However, the double periods suggest that the normal distribution expected in the analysis for the apparent variation is smaller than manifested by the observations. This suggests the existence of yet another mechanism which generates oscillations. This mechanism could be as follows: the corona rotates with the interplanetary material in the planetary plane and thus it is connected to the Sun over a great circle where the rotational displacement on the surface is larger than that of the corona at the nodes and smaller perpendicular to them. A shearing between the photosphere and the corona has a tendency to equalize the motion and results in an oscillation of the angular velocity which is stationnary relative to an inertial frame. The oscillations are fed by the angular momentum of the Sun which is transported via the friction of the interplanetary matter in the shearing area.

To verify the reality of the rest of the printed periods (Table I) other material, published at the Stanford Observatory (Scherrer *et al.*, 1980), was chosen for analysis

TABLE I

Significant periods printed for the φ-dependent rotation-oscillation of the Sun as function of the heliographic latitudes. All the periods and their errors are given in days.

40	198.3 ± 21.6	169.4 ± 25.4	151.1 ± 30.6	134.7 ± 24.4		114.8 ± 96.0		92.7 ± 7.5	85.9 ± 7.7
35	199.7 ± 42.6	165.8 ± 20.3	144.7 ± 33.6	133.0 ± 36.2	120.5 ± 16.4		108.8 ± 17.8	96.8 ± 16.3	89.5 ± 12.7
30	206.0 ± 29.4	162.6 ± 10.1	144.3 ± 7.3		124.3 ± 10.1		107.5 ± 7.6	98.8 ± 6.0	87.0 ± 9.3
25	192.1 ± 26.1	160.2 ± 65.8		131.4 ± 17.9		113.1 ± 22.1	103.0 ± 5.4	93.2 ± 5.5	86.0 ± 6.1
20	193.1 ± 71.7	165.7 ± 20.2		132.3 ± 15.0	120.7 ± 39.3			99.4 ± 11.4	83.5 ± 7.8
15	210.2 ± 50.3	163.9 ± 22.4		137.5 ± 24.0	124.6 ± 13.2	114.2 ± 16.7	104.8 ± 8.4	95.7 ± 9.7	85.3 ± 4.4
10	(206.8)	158.3 ± 32.8		136.2 ± 11.7	123.4 ± 11.9	110.5 ± 10.4	100.8 ± 10.0		89.1 ± 8.2
5	202.4 ± 23.8	173.9 ± 16.7		129.3 ± 6.4		112.9 ± 5.6	98.3 ± 5.5	90.7 ± 6.6	83.6 ± 3.9
0	219.7 ± 94.6	159.4 ± 45.4	145.4 ± 87.8	137.0 ± 47.9	122.5 ± 34.6	110.8 ± 20.9	100.6 ± 29.9	95.9 ± 27.5	85.3 ± 15.5
−5	205.3 ± 25.2	181.3 ± 32.0	157.7 ± 11.7	136.1 ± 11.6			104.4 ± 6.6	92.3 ± 14.3	86.7 ± 5.2
−10	212.4 ± 55.3	163.9 ± 17.1		138.7 ± 15.1	119.6 ± 28.4	113.6 ± 23.1	104.1 ± 7.9	95.5 ± 5.0	88.9 ± 6.1
−15	197.6 ± 40.9		149.9 ± 20.7	127.8 ± 28.5		110.8 ± 19.2		95.6 ± 5.9	87.6 ± 10.9
−20	185.0 ± 13.5	161.5 ± 13.3	144.6 ± 14.4	131.6 ± 11.2	119.5 ± 8.6		104.1 ± 12.2	90.4 ± 4.6	84.4 ± 3.8
−25	196.8 ± 78.9		152.3 ± 52.0		123.7 ± 12.7	109.6 ± 10.4		95.9 ± 6.1	88.0 ± 7.0
−30	198.3 ± 38.1		145.4 ± 19.1		124.6 ± 8.3		103.1 ± 5.7	93.7 ± 9.7	86.5 ± 11.1
−35	193.9 ± 22.8	159.5 ± 32.2	141.2 ± 21.0	127.9 ± 98.1	117.6 ± 12.1	107.7 ± 8.1	101.6 ± 15.2	93.0 ± 9.8	83.6 ± 9.1
−40		160.7 ± 18.4		136.4 ± 47.2		112.4 ± 8.1	103.8 ± 9.2	95.9 ± 9.7	86.7 ± 11.1

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in the Konkoly Observatory. The coordinates of the whole disc velocity data were read directly from the diagram and the analysis leads to periods of 90.6, 146.8, and 241.1 days. The oscillation of a quarter of a year, which could be the first harmonic of the model, is confirmed and also the 146.8 day period is printed in the table as 147.8. Since the error of the last value is about 14 days and that of the first data is probably larger, we think that this period also exists but its origin in unknown.

Finally, we note that the 199.3 day period (Table I) is as long as half the Jupiter's synodic revolution time. This permits to see the planetary influence on the solar dynamo. Direct gravitational effect is an absurdity but its trace on the printed periods could be possible. The small deviation of the 180.5 day period from the semiannual value (182.6 days) could be explained in this way.

References

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