THE 13 DAY PERIOD OSCILLATION AND THE SOLAR CYCLE

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ABSTRACT. From the analysis of radial velocity measurements of the Sun, obtained at Izaña during long observing seasons covering ten years, from 1976 to 1985, stable periods longer than 1 day, have been found in the observed signal. In particular the appearance of an oscillation with a 13 day period, discovered by Claverie et al (1982), has been confirmed. The comparison, for 1981 - 82 - 83 and 84, of the observations with a calibrated numerical model of the passage of inhomogeneities (spots and plages) on the solar surface, shows that the signal is not only due to this effect. The obtained signal from the model has a phase lag of almost two days relative to the observed one . So, it is believed that another velocity field, probably related to the surface inhomogeneities, contributes to the observed signal.

1. OBSERVATIONAL MATERIAL AND METHOD

The observations have been carried out at the Observatorio del Teide of the I.A.C. at Izaña (Tenerife) during the summer seasons of 1976 to 1985 with the exception of 1979 (Table 1). In 1983 some faults in the electronics were found and therefore data from this year should be taken with caution. Integral sunlight was used to measure the radial velocity between the Sun and the observer by means of a resonant scattering spectrometer. The spectrometer selects the KI 7699 Å solar line and, by alternately measuring the intensities on either side of the line (N_R and N_L), the relative position of the solar and laboratory lines can be found, $r=(N_R-N_L)/(N_R+N_L)$, and the doppler velocity shift measured: $V_{ob}= K\cdot r$ if the line is symmetric and linear. V_{ob} is the observed radial velocity and K the calibration constant.

The velocities which contribute to the radial velocity observed are : $V_{ob}= V_{orb}+ V_{grs}+ V_{spin}+ V(t)$, where: V_{orb} is the radial orbital velocity of the Earth around the Sun; V_{grs} is the red shift velocity due to the difference between the gravitational fields of the solar surface and the laboratory; V_{spin} the observatory's rotational velocity component around the Earth's axis. The last term V(t),

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includes all effects that produce an observable velocity variation and is the quantity in which we are interested.

TABLE 1

YEAR	OBSERVING INTERVAL	NUMBER OF DAYS	HOURS/DAY
1976	27-7 to 19-10	38	7.0
1977	12-7 to 25-8	37	8.9
1978	31-7 to 9-9	26	9.6
1980	21-7 to 17-8	28	8.5
1981	29-5 to 25-8	82	9.7
1982	17-4 to 5-9	125	9.8
1983	10-5 to 31-8	92	9.1
1984	21-4 to 30-9	147	9.8
1985	3-5 to 30-9	126	10.2

Assuming that the solar line shape is symmetric and linear, the ratio $r = a+b(\lambda-\lambda_0)$, being λ_0 the wavelength of the centroid of the line. Obviously: $K \cdot r = K(a + b\Delta\lambda) = V_{orb} + V_{spin} + V_{grs} + V(t)$. The a and b values can be calculated using a least squares fit, and their values are related to the terms $(V_{orb} + V_{grs})$ and V_{spin}, respectively.

If the line shape is assumed to be non linear, but symmetric, it is possible to express $V_{ob} = K \cdot r'$, where $r' = r(1 + C_2 r^2 + C_4 r^4)$. The coefficients can be calculated theoretically, but they have been obtained from the experimental data; they are chosen so that the

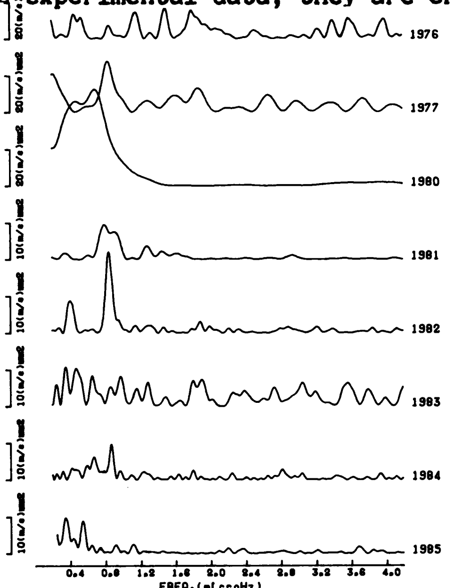

FIGURE 1. Power spectra calculated from V(t) using an iterative sine wave fit. Given the frequency, the amplitude and phase are least squares fitted to the data and by changing the frequency the power spectrum can be calculated. The frequency interval scanned goes from 0.2 μHz to 4.2 μHz with steps of 0.005 μHz.

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variation in K, due to the non linearities in the line shape, is as small as possible. Then C_2= 0.7 and C_4= 1.0 . With the new r' ,the values K and V(t) can be obtained from the parameters of the linear fit.

The behaviour of V(t) can be studied from its power spectrum (Figure 1). In some of them a 27 and 9 day period appear which are identified as the Sun's rotation period and its second harmonic. Virtually in every year a signal with a period of 13 days appears but its power seems to decay with the solar cycle. The existence of this oscillation was established by Claverie et al. in 1982 and has been interpreted in various ways.

The experimental results can be compared to a numerically simulated model in which the rotation of active regions and spots on the solar surface has been simulated (Herrero et al.,1983). Only years 1981 to 84 are used, as longer observing periods have been obtained (Figure 2).

Notice in figure 1 that the power level of the simulated signal is 25% of the observed one. Simulated and observational results are compared calculating the normalized cross correlation between them (Figure 3).

DISCUSSION OF THE RESULTS

The observed and simulated series are correlated when the observed signal advances approximately 2 days. This is clearly shown for the years 1981, 1982 and 1984, in which, the correlation exceeds the 99% confidence level. It is also particularly noticeable that in 1981 and 1982 there is a periodicity of 13 and 27 days. There is no correlation for 1983, as for this particular year there is a high noise level registered in the observed data. In order to explain the observations attempts have been made to obtain a unique 13 day signal leading to the conclusion that no signal can fit all the data.

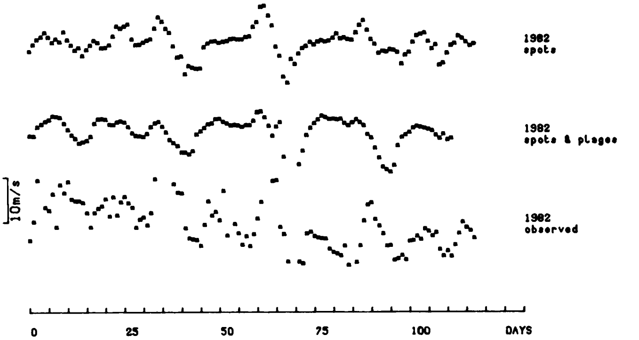

FIGURE 2. Shows the result of the numerically simulated model for 1982 when using only the information on spots and when using spots and plages. For comparison,the experimental results for the same period at the same scale are also plotted. The information on solar activity was obtained from the data available in the Prompt Reports of the Solar Geophysical Data from Boulder.

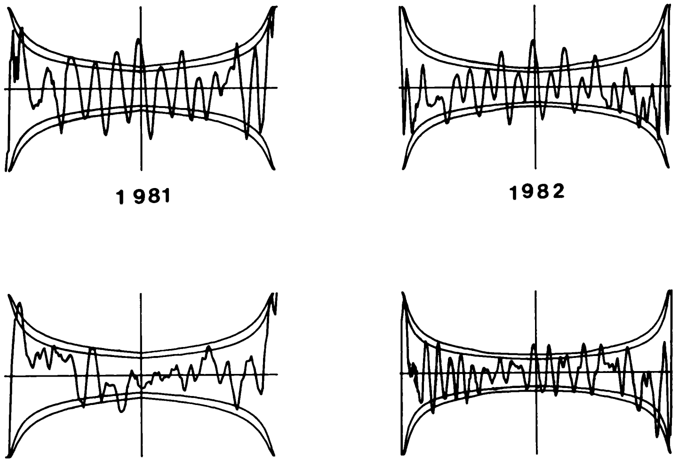

FIGURE 3. Crosscorrelation between simulated and experimental data for different years: 1981 to 1984. For 1981 and 1982 the numerical model uses information on plages and spots. For 1983 and 1984 only information on spots are available. In these figures two levels of a confidence test for the obtained values are also plotted. This is a null test and, therefore, if the correlation function has a value for certain lags, smaller than the corresponding absolute value of the test function, then there is no correlation for this lag.

The existence of this 2 day phase lag on the correlation supports the fact that it is not only the rotation of inhomogeneities on the solar surface that generates the observed 13 day oscillation. We must consider the presence of another contribution like, for instance, an ascending velocity field associated to the spots, or even, the existence of giant convective cells with the sunspots situated in its lanes.

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