SPLITTING OF THE LOW ℓ SOLAR p MODES

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ABSTRACT. An analysis of full disc line of sight velocity data yield line splitting values of the low ℓ-value non-radial modes. Possible variations of the line splitting with the solar cycle are investigated.

1. INTRODUCTION

In a global measurement of the solar surface line of sight velocity, an average over the spatial distribution of the structure across a hemisphere is obtained. Thus considering a $\ell=1$ sectoral mode ($\ell=m$) the observed signal will vary from a maximum to zero as the observed spatial distribution traverses the field of view. This results in the amplitude modulation of the detected signal with a consequent frequency splitting. Hence by studying the amplitude variation of particular $\ell=1$ modes, the rotational splitting of the lines may be determined(1).

2. METHOD

The analysis requires long data sets in order to effectively determine the frequency of the amplitude modulation; such data are available from observation taken at Izana using a K vapour based resonant scattering spectrometer, over the period 1981-84. This instrument determines the line of sight velocity of the full disc and is therefore particularly sensitive to the low ℓ modes. The daily residuals are determined taking into account the instrumental response profile(2) and these form the basic input data for an interactive sine wave fitting programme ($\Delta f=0.1$ μHz) to determine the frequencies of the $\ell=1$ modes in the 5 minute region. A sub-set of 5 days duration is then considered and the mean amplitude of the particular p mode frequency is found over this period (day 1-5).

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Next, days 2–6 are considered and the mean amplitude for the same frequency is again found. This process is continued, $n_i - n_{i+5}$, until the complete data set is scanned. The intrinsic resolution of 2 μHz associated with a 5 day data span, precludes the necessity of determining the precise frequency of the mode being studied.

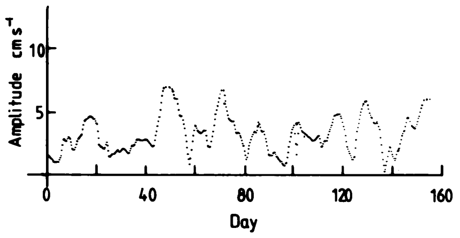

Figure 1 Amplitude spectrum of the ℓ=1 line at 2963.6 μHz

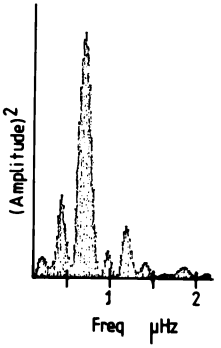

Figure 2 Frequency spectrum of the amplitude modulation of 66 days of data, corresponding to the 2963.6 μHz line

The resulting amplitude spectrum for the ℓ=1 line of 2963.6 μHz determined from 1984 data is illustrated in Figure 1. An analysis of the frequency spectrum of these data yields the results shown in Figure 2. Two prominent lines are visible, at 0.42 and 0.80 μHz, these are presently associated with the motion of large scale solar surface features and rotational splitting of the ℓ=1 modes respectively.

A systematic analysis of the ℓ=1 lines of n values between 16 and 28 over the years 1981–84 yields the results illustrated in Figure 3. Although the splittings appear consistent in any one year, when viewed as a whole it would seem that some systematic changes occur from year to year. Treating each splitting determination as of equal statistical weight, the yearly means for each effect (surface, internal rotation) are found and are tabulated below:

TABLE 1

Year	Surface rotation μHz	Internal rotation μHz
1981	0.41±0.03	0.74±0.03
1982	0.39±0.01	0.59±0.02
1983	0.44±0.01	0.64±0.01
1984	0.44±0.02	0.73±0.03

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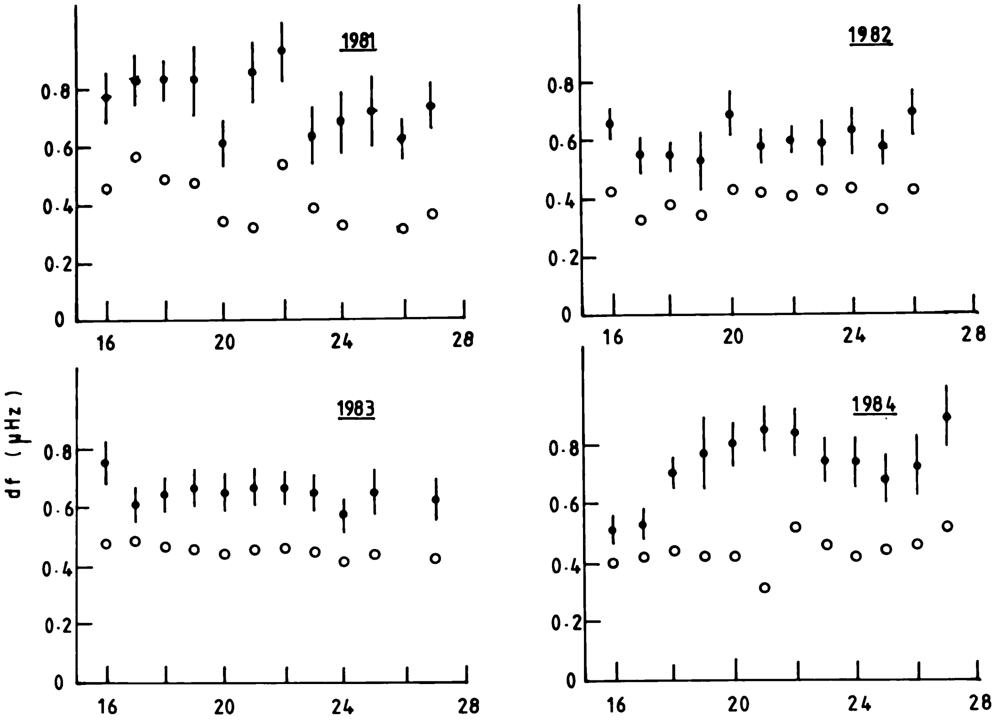

Figure 3 Splitting due to large scale surface effects (O) and internal rotation (ϕ) for the years 1981-84.

3. DISCUSSION

Assuming the two amplitude modulation frequencies to be correctly interpreted as due to solar surface and internal rotation effects, the 'surface' effect would seem to be consistent with the known average surface rotation frequency of 0.43 μHz. However, a surprisingly low value of 0.39±0.01 μHz is obtained from the 1982 data. This could possibly be related to the intense solar activity occurring during this year where the appearance and disappearance of amplitude modulating surface features could well distort the deduced surface rotation rate.

As for the splittings ascribed to internal rotation, these show some systematic behaviour; a sudden drop virtually coincident with the solar activity increase followed by a gradual increase. One interpretation is that of a redistribution of the inner mass of the Sun to larger radii with a consequent decrease in internal rotation rate thus maintaining a constant angular momentum. This is then followed by a return to normal under the influence of gravity with a consequent increase in internal rotation rate.

However, further experimental evidence, now being gathered, is required before definite conclusions may be drawn about the reality of the changes in rotational splittings and possible explanation of the observations.

4. CONCLUSIONS

From an analysis of the time variation of the amplitude of several $\ell=1$ p modes, two discrete frequency components have been found. The first of these is tentatively associated with large scale solar surface features whilst the other is interpreted as rotational splitting. With these interpretations a variation in the rotational splitting is observed with the solar activity cycle and one possible explanation in terms of a sudden outward mass flow followed by a gradual return under the gravitational force is considered.

5. ACKNOWLEDGEMENTS

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6. REFERENCES

1. H.B. van der Raay, P.L. Palle and T. Roca Cortes in Seismology of the Sun and the Distant Stars. (ed. D.O. Gough, NATO ASI *169* (1985) p.215)

2. H.B. van der Raay, P.L. Palle and T. Roca Cortes in Seismology of the Sun and Distant Stars. (ed. D.O. Gough NATO ASI *169* (1985) p.333)