SOLAR CYCLE DEPENDENCE OF SOLAR p MODES

G.R. Isaak, S.M. Jefferies, C.P. McLeod, R. New,
H.B. van der Raay
Department of Physics, University of Birmingham,
Birmingham B15 2TT, England

and P.L. Palle, C. Regulo and T. Roca Cortes
Instituto de Astrofisica de Canarias,
Universidad de la Laguna, Tenerife

ABSTRACT. Data obtained at Izana (Tenerife) and Haleakala (Maui), using optical resonant scattering with a potassium vapour cell over the years 1980-84, are used to determine the frequencies of the low ℓ p modes. Possible variation in these frequencies with the solar cycle are investigated.

1. INTRODUCTION

Possible changes in the internal structure of the Sun over the 11 year magnetic activity cycle could be reflected in the eigenfrequencies of the acoustic p modes. Tentative experimental evidence was first presented in 1984(1) and subsequently analysis of the ACRIM data(2) suggested a decrease in the frequencies of the 5 minute p modes of ~0.1 μHz/year based on 9 discrete frequencies measured in 1980 and 1984. Careful analysis of long data sets obtained at both Izana and Haleakala over the period 1980 to 1984 would tend to throw some doubt on these results.

2. EXPERIMENTAL DATA

Using optical resonant scattering in the potassium 769.9 nm line, the mean line of sight velocity spectra of the full solar disc have been obtained. These data are analysed to yield the daily residuals taking into account the instrumental response. Data available for analysis are summarised in Table 1.

3. ANALYSIS

Iterative sine wave fitting is used with a sampling interval of

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0.01 μHz (except 1980 where 0.1 μHz is used). Where data are available from two sites (1981,1983) each site is analysed separately to determine the consistency of frequency determination and the data from the two sites is further treated as a single data set to improve the window function. Consistent results are obtained.

The precise frequencies of the ℓ_0 and ℓ_1 p modes in the frequency range 2000-3700 μHz are found where possible. Due to the complexity of the ℓ_2 structure precise frequency determinations of these modes are not considered here.

TABLE 1

Year	Site	Dates	Interval (days)	Data (days)
1980	Izana	21/7 – 17/8	28	28
1981	Izana	29/5 – 25/8	89	85
	Haleakala	7/6 – 28/8	83	72
1982	Izana	17/4 – 6/9	142	122
1983	Izana	10/5 – 5/9	116	78
	Haleakala	8/6 – 30/8	84	74
1984	Izana	18/4 – 30/9	166	131

4. RESULTS

The frequencies for each mode for each year are shown plotted in Figures 1 and 2. Treating each single frequency determination as of equal statistical weight, a mean straight line is fitted to each frequency set.

Considering the ℓ_0 modes shown in Figure 1, of the ten sets of results all show an increase in frequency over the period 1980-1984 except one (δf=−0.07 μHz/year for f=2363 μHz). Taking a simple mean of the slopes of the fitted lines an average frequency change of δf_0=0.18±0.05 μHz/year is found for the 10 ℓ_0 modes between 2092 and 3305 μHz.

When the ten ℓ_1 modes shown in Figure 2 are treated similarly, 5 yield positive δf values and the other 5 have negative values (i.e. frequency decrease from 1980-1984) yielding a mean value δf_1=0.01±0.03 μHz/year.

5. DISCUSSION

These results are at variance with those of Woodard and Noyes(2) who when considering the mean frequency of 4 ℓ_0 and 5 ℓ_1 modes in the frequency interval 2800-3400 μHz, find a mean decrease of

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0.42±0.14 μHz over the period 1980-1984 (i.e. $\delta f=-0.11\pm0.04$ μHz/year). This is to be compared with an overall mean value for the ℓ_0 and ℓ_1 modes found presently of $\delta f=0.10\pm0.03$ μHz/year.

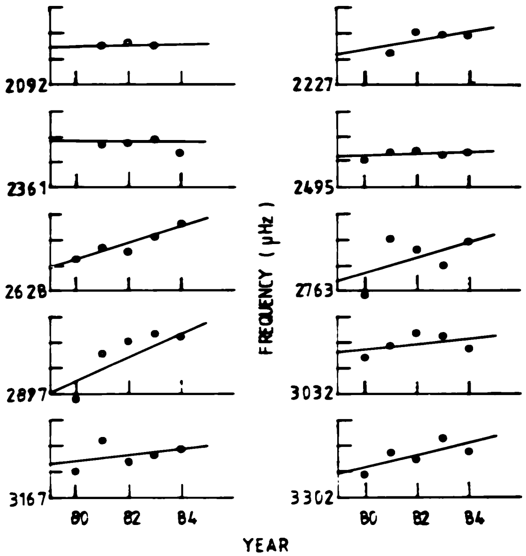

Figure 1. The measured frequencies of ℓ_0 p modes; 1980-84 (vertical scale in steps of 1 μHz), with fitted straight line.

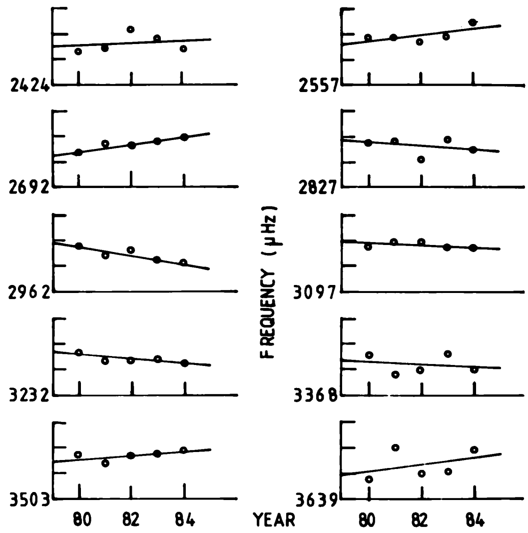

Figure 2. The measured frequencies of ℓ_1 p modes; 1980-84 (vertical scale in steps of 1 μHz), with fitted straight line

Considering the frequency range 2800-3400 μHz, as used by Woodard and Noyes, the values found from the present data are: $\delta f'_0=0.26\pm0.09$ μHz/year and $\delta f'_1=-0.08\pm0.02$ μHz/year.

The earlier analysis of 1980 and 1981 data(1) also indicated a mean increase in ℓ_0 frequencies and no net shift of the ℓ_1 frequencies. The single determination for the frequency difference of the ℓ_1 line at 3098 μHz between 1980 and 1983 indicated a decrease of 0.3 μHz/year. Hence the present analysis is consistent with that found previously.

6. CONCLUSION

The analysis of long stretches of data obtained over the years 1980-84 indicate that the ℓ_0 p modes increase in freqeuncy at the rate of 0.18±0.05 μHz/year whereas no significant shift (0.01±0.03 μHz/year) is found in the ℓ_1 frequency values when considering the frequency range 2000-3800 μHz. Considering a subset of the frequency range (2800-3400 μHz), as studied by Woodard and Noyes, a frequency shift of the ℓ_1 modes consistent with that found by these authors is obtained. In view of the significance of any shifts in the frequencies over the solar cycle, different methods of analysis are at present being investigated.

7. ACKNOWLEDGEMENTS

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8. REFERENCES

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