COMPARISON OF SOLAR OSCILLATION DATA OBTAINED FROM A STUDY OF THE Na AND K FRAUNHOFFER ABSORPTION LINES

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ABSTRACT. Two independent resonant scattering spectrometers one using a sodium and the other a potassium vapour cell, were operated simultaneously at the same site. Due to the differing abundances of ground state atoms of these two elements different depths of the photosphere are sampled. An inter-comparison of solar p modes obtained with these spectrometers is given.

1. INTRODUCTION

Data taken at Izana, Tenerife over the period 12th August to 16th September 1985 using two independent resonant scattering spectrometers(1) operating in the K and Na resonances lines, are compared. A total of 27 days of useful data were obtained over the 36 day span of observation. These data consist of the line of sight velocity between the observer and the integrated solar disc. After subtraction of the velocity components due to the Earth's orbital motion and spin velocity, plus a constant term associated with the gravitational red shift, residuals are obtained which may be analysed to yield the solar p mode (5 minute) oscillation spectrum. Typical daily curves plus residuals are illustrated in Figures 1a and 1b.

It should be noted that a larger change in the observed signal is obtained when using K than Na, reflecting the relative sensitivities of these two lines. This arises due to the greater slope of the K line as compared with the Na line. Further, the results obtained with Na show greater long period variations than those derived from the K data, reflecting the greater dependence of Na data on atmospheric conditions. The presence of an atmospheric water vapour line and high altitude Na vapour are deemed responsible for this instability.

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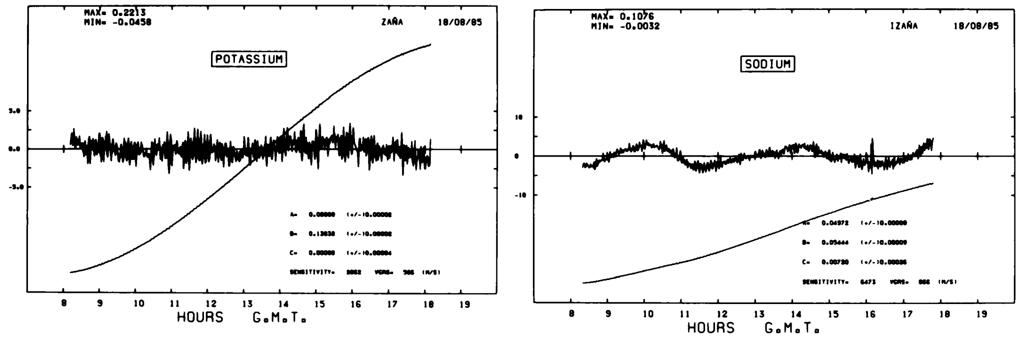


Figures 1a and 1b Diurnal variation of the line of sight velocity signal and residuals.

2. APPARATUS

The two spectrometers used are completely independent, each is fed by its own coelostat separated by ~30 m from the other. Both spectrometers use optical resonant scattering[1] one with a (769.9 nm) cell and the other with a Na (589.0,589.6 nm) cell. Other differences include the method of input beam modulation; an electro-optical light modulator (Pockels cell with KDP crystal) is used in the case of K whereas a liquid crystal modulator[2] is used with the Na based spectrometer. In both cases primary data are logged on a BBC micro-computer, the sense of input light circular polarisation being switched every second. Single photon counting is used in both instruments and the basic data, resonant scattering intensities in the red and blue wings of the appropriate line, together with time and total incident light intensity are recorded on magnetic tape for subsequent analysis. The micro-computer serves as a diagnostic tool displaying information such as illustrated in fig.1 in real time.

3. THEORY

Since ground state K atoms are less abundant than Na ground state atoms in the solar photosphere, for the same optical thickness, K velocity signals originate from greater depths than the Na signals. As a consequence the velocity signals from Na atoms will have greater amplitudes than those from K atoms[3]. The frequencies of individual modes should correspond for K and Na observations and the signals should be in-phase if the pressure wave corresponding to the 5 minute p modes is considered to be a pure standing wave.

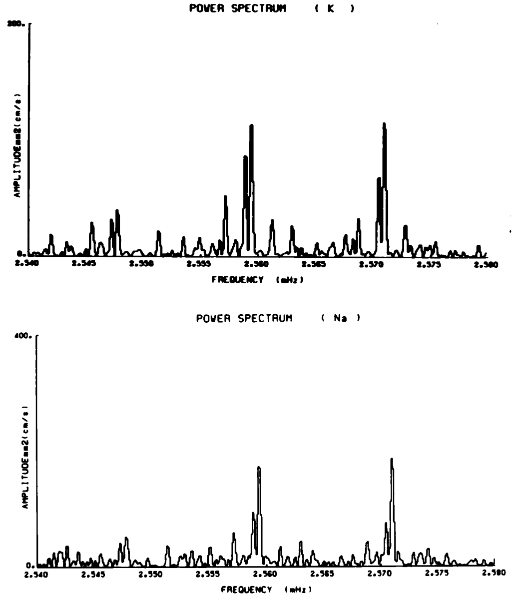
Accurate determinations of the relative amplitudes of the signals derived from these two sets of observations should yield information on the structure of the outer regions of the solar photosphere.

4. RESULTS

An analysis of the residuals shows excellent agreement in the frequency structure of the data obtained with the two spectrometers; Figure 2 illustrates the ℓ_1 line at 2559.4 μHz and in Figure 3 the ℓ_0 (3033.9 μHz) and ℓ_2 (3025.1 μHz) lines are compared. The change in vertical scales should be noted, reflecting the greater amplitude of the velocity signals originating from Na atoms.

The actual frequencies (μHz) and amplitudes (cm s^{-1}) obtained for the ℓ_0, ℓ_1, ℓ_2 and ℓ_3 modes in the 5 minute region for both K and Na are given in Tables 1a and 1b. The agreement in frequency is consistant to 0.1 μHz over the entire frequency range considered and on average the Na amplitudes are $\sim 1.5 \times$ those of the K signals.

Finally a direct comparison of the phases of the K and Na signals is considered. Where a difference in measured frequency was



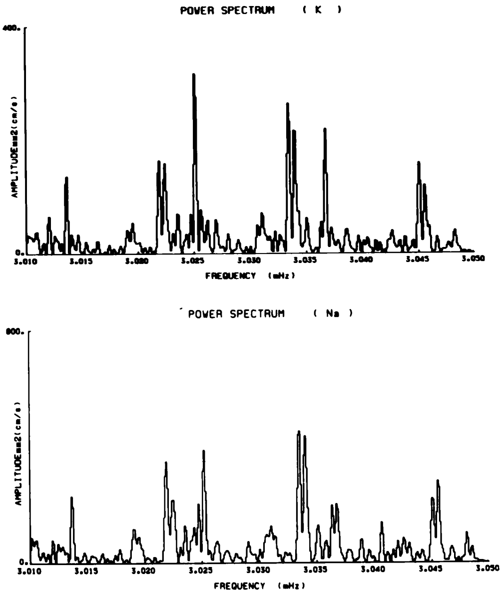


Figure 2 Comparison of frequency spectra in the region of the ℓ_1 line for K and Na.

Figure 3 Comparison of frequency spectra in the region of the ℓ_0 and ℓ_2 lines for K and Na.

TABLE 1. Frequencies (μHz) and amplitudes (cms^{-1}) of p modes obtained with (a) K and (b) Na

n\ℓ	0		1		2		3	
(a) K								
11					1815.8	1		
12	1822.0	3	1885.2	2	1946.9	2	2002.7	2
13	1958.3	3	2020.9	3	2082.8	4	2138.2	2
14	2093.6	2	2156.8	5	2217.9	5	2274.5	2
15	2228.8	5	2291.9	4	2353.3	5	2409.7	3
16	2362.8	6	2424.9	6	2485.7	6	2541.9	4
17	2496.3	5	2559.4	11	2619.5	10	2677.1	5
18	2629.2	5	2693.9	9	2753.6	11	2811.5	7
19	2764.8	8	2827.7	18	2890.1	11	2947.9	6
20	2898.8	10	2963.3	13	3025.1	18	3083.5	9
21	3033.9	15	3098.6	10	3160.1	16	3218.8	8
22	3169.0	17	3233.1	13	3295.6	14	3354.4	7
23	3303.9	11	3368.3	12	3430.2	9	3489.1	5
24	3439.2	13	3503.7	11	3567.4	6	3626.1	5
25	3576.2	6	3639.9	6	3703.6	6	3760.9	3
26	3712.1	5	3777.5	6	3837.6	4	3898.1	4
27	3847.5	4	3914.2	7	3975.6	2	4035.1	4
28	3984.5	3	4051.6	4	4113.4	4	4172.1	3
29	4122.4	3			4249.3	2		
30			4325.3	3	4387.0	2		
31	4395.3	3	4464.0	2	4523.9	2	4583.5	2
32	4533.1	3						
33	4669.0	2	4739.1	3				
(b) Na								
11					1815.8	4		
12	1822.0	4	1885.2	5	1946.9	5	2002.7	2
13	1958.5	3	2021.0	5	2082.8	6	2138.3	5
14	2093.5	4	2156.9	5	2217.9	6	2274.5	5
15	2228.8	5	2291.9	6	2353.3	4	2409.7	4
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22	3169.0	27	3233.1	18	3295.6	19	3354.4	6
23	3303.9	16	3368.3	17	3430.2	12	3489.1	8
24	3439.3	16	3503.7	17	3567.4	10	3626.0	8
25	3576.2	9	3639.9	7	3703.6	6	3761.0	4
26	3712.2	7	3777.5	11	3837.8	6	3898.2	7
27	3847.6	10	3914.2	8	3975.6	5	4035.0	6
28	3984.5	9	4051.6	6	4113.4	3	4172.0	7
29	4122.3	8			4249.2	6		
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32	4533.1	8						
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obtained the phase difference corresponding to the frequency determined for the K signal has been used. Neglecting three points with $|\Delta\phi|\geq 0.5$, where $\Delta\phi = \phi_{Na} - \phi_K$, a small (0.06±0.03 rad) phase difference exists.

5. CONCLUSIONS

(1) The individual p mode frequencies for velocity signals observed from K and Na atoms agree to 0.1 μHz over the range 1800 to 4800 μHz. (2) The amplitudes of the Na velocity signals are ~1.5 × those of the K signals. (3) The phase difference $(\phi_{Na} - \phi_K)$ is small (0.06±0.03 rad) and positive. (4) The Na derived signals are more sensitive to atmospheric conditions than the K signals. (5) The velocity response of the K based system is ~2.5 times that of the Na system.

6. ACKNOWLEDGEMENTS

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