OBSERVATIONAL STUDY OF THE FIVE-MINUTE OScILLATIONS IN THE SOLAR ATMOSPHERE

I. Oscillatory Velocity and Intensity Fields

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Abstract. The 5-min oscillations in the photospheric velocity fields have been studied in detail from measurements on 14 absorption lines from three time sequences of spectrograms of high quality. The lines cover a range of heights in the solar atmosphere from log \( \tau = +0.2 \) to \(-1.2\). Regions oscillating coherently are seen to have an average dimension of 8000 km and the oscillations in general last for 2 to 3 periods. The power spectrum analysis of high resolution enabled to determine the period of oscillation at each level very precisely. The period decreases with increase in height, being 304 s at the level log \( \tau = +0.2 \) and 295 s at the level log \( \tau = -1.2 \). The low level lines possess considerable power in the low frequency range representing the convective overshoot from below. The oscillatory power increases with height, while the low frequency power decreases and the high frequency component remains substantially constant in the heights studied.

The intensity fluctuations in the continuum, the line wing and core of \( \text{Fe I} \) 6358.695 have also been studied. The continuum power spectrum has practically all the power near the zero frequency range, with a very weak oscillatory component. The line wing intensity fluctuations resemble those in the continuum, whereas the line core clearly shows an oscillatory component similar to the velocity oscillations.

1. Introduction

The study of the dynamical characteristics of the velocity fields in the quiet regions on the Sun during the past two decades has enabled significant advancement of our knowledge in this direction. Since the discovery by Leighton et al. (1962) of the small scale vertical oscillations in the velocity fields in the upper photosphere and low chromosphere, Evans et al. (1963), Edmonds et al. (1965) and Frazier (1968) have studied these oscillations using time sequence spectra. The velocity oscillations have also been studied using the one-dimensional scans obtained with a magnetograph in the Doppler mode by Howard (1968), Deubner (1967, 1972), Tanenbaum et al. (1969), Musman and Rust (1970) and Bhattacharyya (1972). Considerable data have accumulated throughout the years by many investigators using one technique or the other, most of them oriented towards studies of the temporal properties of the velocity oscillations, with observations on 2 or 3 spectral lines at one time. It would be desirable to know the depth dependent properties of these oscillations combined with the time parameter. The present investigation is an analysis with time sequence spectra covering a number of lines to study their depth-wise properties.

2. The Observations

The observations were made with the horizontal solar tower telescope and the 18-m spectrograph at the Kodaikanal Observatory. A two-mirror fused quartz coelostat
of 61 cm aperture feeds a 38 cm two-element achromat of 36 m focal length. The image scale of the telescope is 5.5" per mm. The Littrow spectrograph has a 20 cm two-element achromat of 18.3 m focal length and a Babcock grating of ruled area 135 x 200 mm with 600 grooves mm⁻¹ and blazed in the fifth order green. A number of time sequences of spectra were obtained around chosen spectral regions with the spectrograph slit located on quiet regions near the centre of the solar disc. The effective length of the slit was 19 mm and a width of 100 μ was maintained in all the sequences. A hair stretched across the spectrograph slit during the observations served as a fiducial line along the direction of dispersion. The overlapping orders of the grating were eliminated with wide-band glass colour filters. The solar rotation was compensated in proper amounts so that the same part of the Sun lay over the slit throughout the period of observation. The spectra were obtained within two hours after sun-rise, when the visibility at Kodaikanal is usually at its best. The exposure time was continually decreased to compensate for the increase in brightness of the solar image due to the rapid change in the value of s z. 35 mm film in spools of 100 ft were used in a camera with mechanical film transport. The films were calibrated with a six-step wedge and an out of focus image of the centre of the solar disc.

Of the many sequences, three sequences obtained under exceedingly good visibility conditions were chosen for the present study. The details of the spectra are given in Table I.

<table>
<thead>
<tr>
<th>Sequence designation</th>
<th>Date</th>
<th>Spectral region</th>
<th>Grating order</th>
<th>Dispersion</th>
<th>Emulsion</th>
<th>Time between exposures</th>
<th>Duration of sequence</th>
</tr>
</thead>
<tbody>
<tr>
<td>A 1082</td>
<td>Apr. 16, 69</td>
<td>6340 Å</td>
<td>IV</td>
<td>6.677 mm Å⁻¹</td>
<td>Kodak IV-E</td>
<td>20'</td>
<td>40'</td>
</tr>
<tr>
<td>A 1100</td>
<td>Jan. 11, 70</td>
<td>6587 Å</td>
<td>IV</td>
<td>7.096 mm Å⁻¹</td>
<td>Kodak IV-E</td>
<td>20'</td>
<td>22'</td>
</tr>
<tr>
<td>A 1133</td>
<td>Mar. 12, 71</td>
<td>4280 Å</td>
<td>VI</td>
<td>10.306 mm Å⁻¹</td>
<td>Ansco Hypan-X</td>
<td>15'</td>
<td>40'</td>
</tr>
</tbody>
</table>

The high image quality shown by the high contrast in the continuum streaks and the line wiggles are maintained throughout the lengths of the sequences without significant change. The full-width at half maximum (FWHM) of the auto-correlation curve of the granulation intensity field was 1100 km which may be considered as an average value, while the best isolated frames have a FWHM of 800 km. The average value of our sequence is identical with that of the time sequence obtained under excellent visibility conditions by Evans at Sacramento Peak and studied by Edmonds et al. (1965). The guiding excursions could not have exceeded ±0.5"; this accuracy being ensured by the photoelectric guiding employed in the observations. This is also confirmed by the correlation coefficient of the continuum fluctuations of successive frames which has a value of 0.99 from the beginning to the end of the sequences.