SHORT PERIOD OSCILLATIONS*

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Abstract. Short period oscillations (with periods less than 150 s) are shown to be non-uniformly distributed on the solar surface, and in time. Rather, they appear concentrated in short bursts which preferentially occur in regions with strong instantaneous downflow motion throughout the observed extent of the solar atmosphere.

From a spatio-temporal analysis of extended series of spatial high resolution spectra, obtained with the Sacramento Peak Vacuum Tower, Deubner (1976), henceforth called Paper I, has inferred the presence of short period waves in the upper solar photosphere which contribute observable power to the velocity fluctuations at periods as short as 20 s. In the high frequency tail of these power spectra, power descends to the noise level in a conspicuous series of cascading maxima and minima (particularly in the Na D_1 line data) which in Paper I were interpreted as being due to a filtering effect of the spectral line contribution function. In a forthcoming paper (Deubner and Durrant, 1982) an alternative interpretation of the characteristic shape of the power spectra in terms of non-linear processes in the transfer of the Doppler signal will be discussed.

The present investigation is an attempt to localize *spatially* bursts of short period waves on the solar surface, i.e. with respect to other well recognizable phenomena such as granules and/or photospheric and chromospheric long period oscillations. The aim is to gain further insight into the physical processes responsible for generation of this short period power.

The observational material is the same as in Paper I and Deubner (1974) to which we refer for detailed description. In the series of spectra of September 6 (disk center) short period bursts were defined by the following procedure: The velocity fluctuations measured with the Lambdameter in the Na D_1 line were passed through a Fourier filter with a frequency passband $0.1 < \omega < 0.3\ \mathrm{s}^{-1}$. The rms fluctuations transmitted through this passband were determined as function of position x (along the slit) and time t within a 3-min-times-1-arc-sec-window run across the filtered data. 132 positions with outstanding power in the frequency range just given were selected for further analysis. Chromospheric network areas were explicitly excluded from the sample.

Centered on the selected positions, windows 6 arc sec wide and 7.5 min long were defined in the original unfiltered data arrays and, by superposition, the average variations of intensity and velocity within these windows were determined for each spectral line. Of these distributions the ones for C I 5380 and Na D_1 are displayed in Figure 1.

Most obviously these average distributions are spatially symmetric with respect to the center of the selected window areas. This we would not expect, of course, from a

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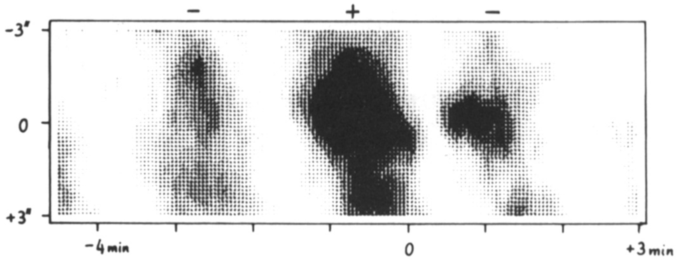
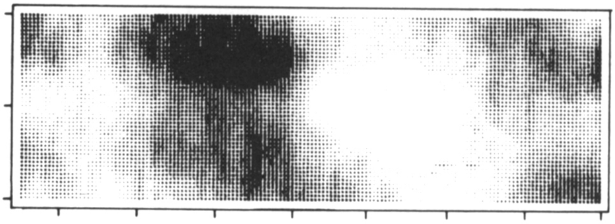
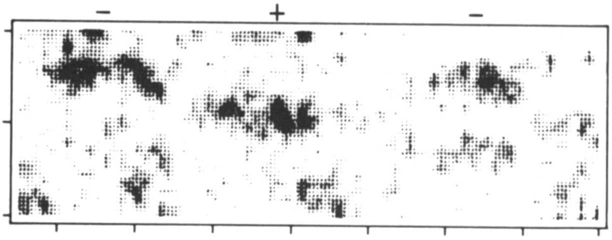


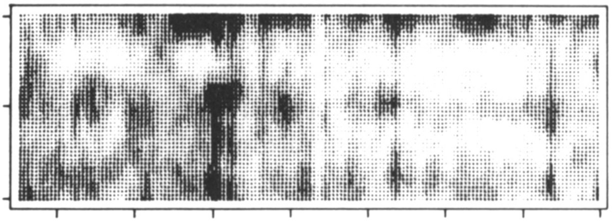
Na D_1 Velocity



Na D_1 Intensity



CI 5380 Velocity



CI 5380 Intensity

Fig. 1. Composite representation of simultaneous dynamical events in two layers of the solar atmosphere, as measured in the Na D_1 and C I 5380 lines. At time $t = 0$ a short burst of high frequency oscillations (not visible in this figure because of its low amplitude) is observed in Na D_1. 132 'burst events' ocurring in the x, t-area covered by the observation are superimposed in each frame to reveal the average brightness and velocity distribution in the vicinity of these events. + and – signs down- and up-flow. In the C I line, superposition of the oscillatory velocity field (similar to that in the Na D_1 line) and persistent flow patterns (downflow in the middle of the frame) create a velocity distribution which renders the spatial scale of the oscillations much smaller than their actual scale. Note the chromospheric and photospheric oscillations having large amplitudes and being closely in phase at $t = 0$.

randomly chosen sample. However, we would not have easily predicted it for the present sample, either.

In particular, close to the short period event, we observe in the chromosphere (Na D_1) a strong coherent oscillation with a period of ~ 220 s. Downward velocity precedes brightness by about $\pi/2$, as we expect from an evanescent wave. At the photospheric level a persistent downflow with reduced brightness (i.e. an intergranular region) is

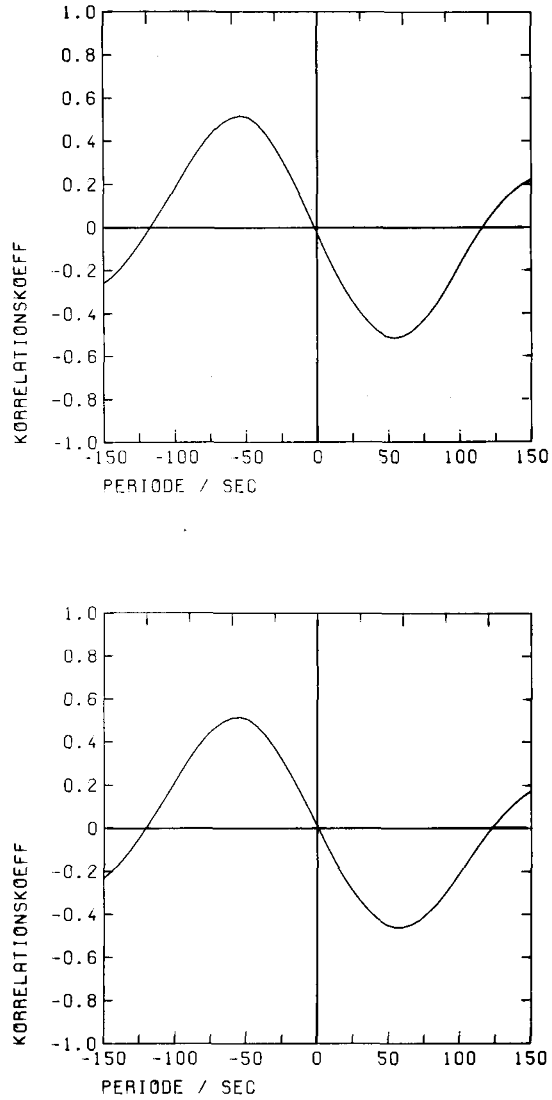


Fig. 2a. Meam cross-covariance functions of velocity and intensity fluctuations observed in Na D_1, brightness leading upward motion by approximately 90°. The upper curve is derived from the temporal variations in the selected 132 areas. The lower curve with a slightly longer period of 240 s represents a similar number of randomly selected areas.

found near the spatial center of the window, and a gradual increase of brightness (emerging granules?) is observed on either side of the central region. Superimposed on these comparatively slow changes a 300 s oscillation is also centered on the same area.

Given the presence of long period velocity fields with high amplitudes in the selected areas, we first need to check the hypothesis that the short period power is merely a spurious consequence of image motion coupled to the long period velocities. (Such effects are certainly present (e.g. see Howard and Livingston, 1968).)

Figure 2 shows mean cross-covariance functions derived from the Na D_1 intensity and velocity data out of the selected window areas as well as in an equivalent number of randomly chosen control areas. A comparison of these curves shows that the average period of the chromospheric oscillations is markedly shortened during the high frequency events, whereas we find the familiar 240 s in the control areas. We propose that additional high frequency power generated, or concentrated, in the selected regions causes the observed change of the mean period.

In conclusion, we find that three well known solar phenomeny, previously regarded as not being directly related to each other, namely: granulation, photospheric and chromospheric *p*-modes, are coupled together spatially under certain additonal constraints with regard to temporal phase. This coupling produces a fourth phenomenon which may be a short period burst or just a rapid pulse.

The average velocity variations in the chromosphere also show indications of asymmetric wave forms and phase acceleration which we shall discuss in a forthcoming paper. The whole sequence of events in the various distributions shown is strongly reminiscent of earlier observations by Evans and Michard (1962), who suggested a

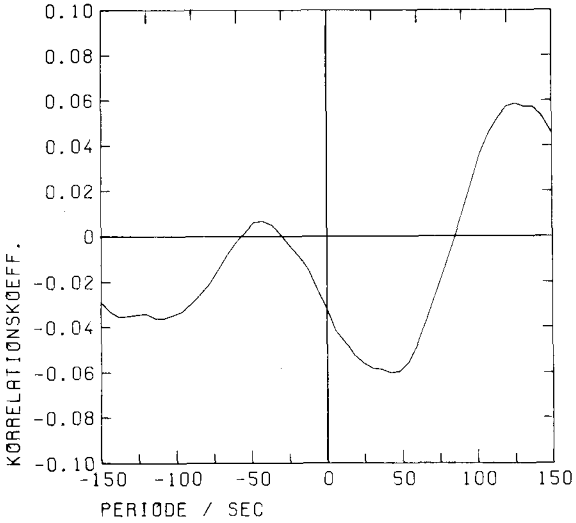


Fig. 2b. The difference of the two cross-covariance functions shown in Figure 2a brings out the presence of enhanced short period power in the selected burst events. The difference signal has a period of roughly 170 s.

causal relation between rising granules and the excitation of both photospheric and chromospheric oscillations. In the light of today's improved knowledge of nonradial resonant solar oscillations we interpret the present observations a being indeed strongly indicative of some kind of coupling between convection and the p-modes.

Since we are inclined to believe that short period bursts, or pulses, are either generated by rising (hot) granules, or are propagated more or less uniformly from lower layers in the convection zone, we may wonder how the observed short period flux gets concentrated in the intergranular lanes. Considering the geometry of the regions involved, it seems to us that wavefront retardation would be the most natural mechanism. By forming a concave wavefront on top of the intergranular lane, short period waves would most efficiently be directed to converge where enhanced short period flux is observed. Sufficient wave front retardation is easily achieved by the concomitant effects of reduced sound speed and stationary downflow in the intergranular region. Further intermittent enhancement may occur during phases of simultaneous oscillatory downflow.

Finally, we wish to draw attention to the result that the acoustic energy appears to be concentrated in the solar atmosphere at those locations which according to common belief are the footpoints of the magnetic network. It is from these places that the acoustic energy flux (in the form of magneto-acoustic and Alfvén waves) is preferentially carried higher up into the chromosphere and corona. It appears that the transfer of energy to the upper layers of the atmosphere is substantially facilitated by processes directing an enhanced flux of short period waves to these locations before the wave energy is dissipated in shocks.

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