CHROMOSPHERIC OSCILLATIONS IN PLAGES

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Abstract. The 5-min oscillations in Hα plages as reported by Bhatnagar and Tanaka (1971, *Solar Phys.* **24**, 87) are discussed with respect to spatial – both horizontal and vertical – phase relation. Data for analyses include (a) Hα filtergrams at -0.5 Å (1050 min in total) (b) Hα filtergrams simultaneously taken at ± 0.5 Å (60 min) (c) Simultaneous Hα -0.5 Å and Fe I 5233 Å videomagnetograms (Doppler mode) (100 min in total). Projection (16 and 35 mm) -photocell method (Bhatnagar and Tanaka, 1971) was used for tracing the data with special attention to the guiding and reproducibility. Also photographic prints were used for comparison. The results are as follows:

(1) those showing oscillatory brightness changes are dark dot-like features (size $\lesssim 1''$) in brighter regions of plage and slightly elongated features (1×1.5–$2''$) in less bright regions. The mean number density of these features is one per 2200 ± 500 km square.

(2) There are always a few regions with a size 8″ or more in one plage which show very regular oscillations with a period of about 5 min for a long time (at least 6.5 h, Figure 1). The distribution of the intervals between successive intensity peaks is much narrower than the Gaussian distribution and has a skewness towards longer period.

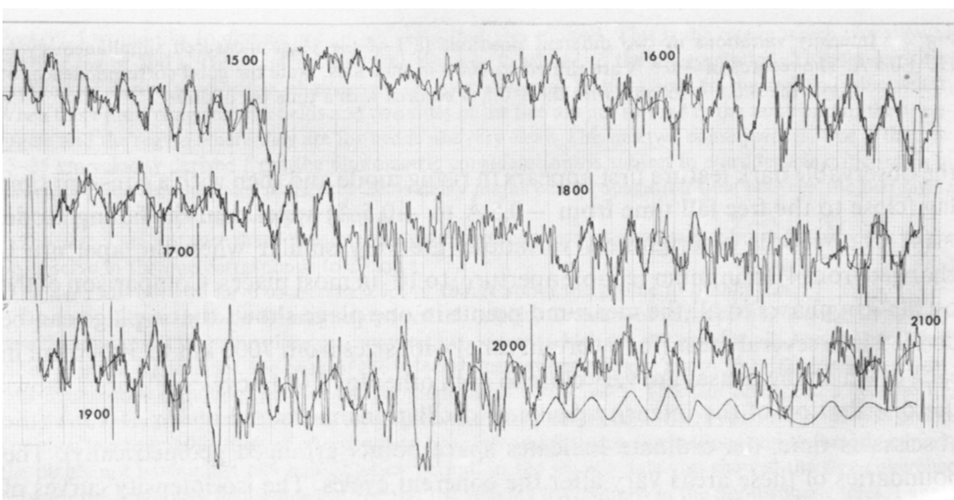

Fig. 1. Intensity variation in plage measured at Hα -0.5 Å with the 8″ aperture. Rather steady oscillations are seen for the observed duration (6.5 h) except the periods of bad seeing. The smoothed-out curve between 20:00 UT and 21:00 UT shows the record of the velocity oscillations measured in Fe I λ5233 Å at the same position.

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The other places in the plage show relatively irregular patterns, but with the mean interval of the fluctuations still being 5 min.

(3) In regular 5-min brightness oscillations the phase of oscillations in one wing is complementary to that in the opposite wing, indicating velocity oscillations. When the intensity records are relatively irregular there are many cases (76%) in which the blue wing patterns can be matched well for the whole time sequence with the red wing records by advancing the red wing records by 196 ± 18 s, (see Figure 2) indicating that

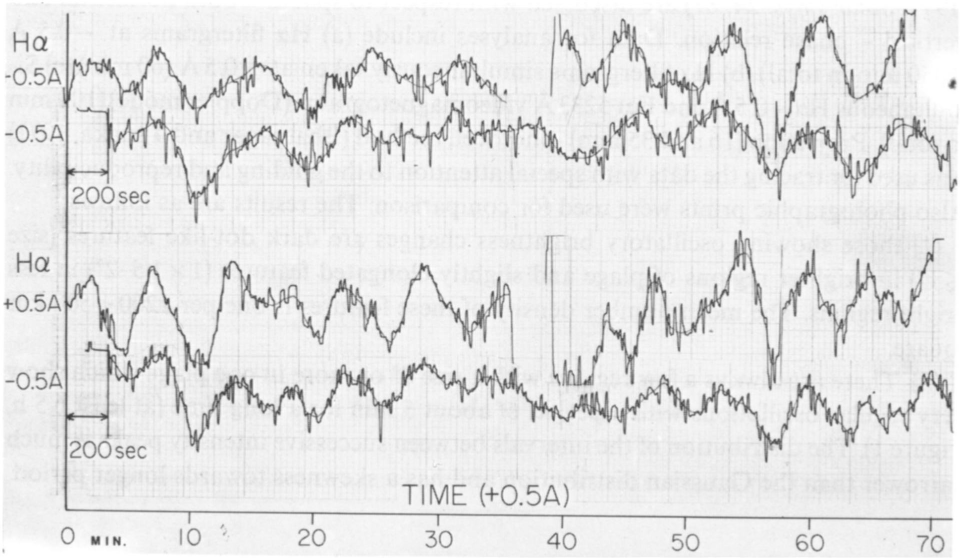

Fig. 2. Intensity variations in two different positions (8″) of the plage measured simultaneously at Hα ±0.5 Å. The records of −0.5 Å are shifted by 200 s in time axis. Note the good correspondences of the +0.5 Å records with the −0.5 Å records with a time lag of 200 s.

the observable dark feature first appears in rising mode and then with a constant time lag (close to the free fall time from −0.5 Å to +0.5 Å) appears in the falling mode.

(4) The records of brightness variations are very similar when the aperture is changed from 4″ (minimum reliable aperture) to 10″ in most places. Comparison of the oscillation phases in all the measured points in one plage shows that a plage can be divided into several areas (for a certain time) with sizes from 7000 km to 30000 km in each of which the phases are very close to each other for 2 to 10 cycles. Figure 3 shows the distribution of the intensity peaks of oscillations measured at Hα −0.5 Å (the abscissa is time, the ordinate indicates space points arranged geometrically). The boundaries of these areas vary after the coherent cycles. The iso-intensity curves of the intensity-time records (see Figure 3) have slopes corresponding to horizontal phase velocity 100 km–600 km s^{-1}.

(5) The phase relation between Hα regular 5 min and Fe I 5233 Å 5-min velocity oscillations at the same place is almost constant for more than 5 cycles although the

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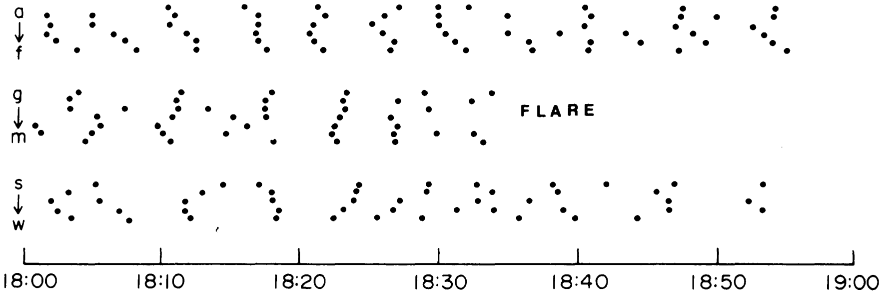

Fig. 3. Distribution showing only peaks of the intensity oscillations (dots) with respect to the various places (ordinate). All the measured places are divided into three groups ($a \rightarrow f$, $g \rightarrow m$, $s \rightarrow w$) in which phases of oscillations are correlated each other.

phase lag is different from place to place. (See, for example, the period from 20:00 UT to 21:00 UT in Figure 1. The smoothed-out curve denotes the record of the velocity oscillations in λ5233 Å taken simultaneously.) The distributin of the phase lags is peaked at about 1 min. Assuming 1000 km for height difference of two lines the vertical phase velocity is equal to 17 km s^{-1}.

(6) There is an indication that the flare originating in the plage occurs about 20 min after the oscillations start to be in phase (1-min accuracy) in very large scale ($\gtrsim$20000 km) although the samples (6 flares in three different plages) are not large enough for statistically meaningful discussions.

DISCUSSION

Pecker: I would like to discuss one of the slides that you showed. This is the one in which you showed the time lag of 200 s. The point I would like to make is related to the interpretation. This concerns the question of deriving velocities of propagation by comparing features seen in the red and blue wings. When there are strong velocity fields and two sides of the line are not formed in the same part of the atmosphere and the region where they are formed is not very clear. This has two consequences. One is that the 15–25 km velocity derived from the photometric considerations is subject to considerable criticism from this cause. The second point is that the 200-s delay might be a propagation time between the two layers in which you are looking, whatever they are.

Tanaka: I am not sure that filtergram measurements can give good velocities but 0.5 Å which is where we observe in the line corresponds to 23 km s^{-1}.

Pecker: Oh but you have to assume a lot of things about the profile to obtain this.

Deubner: If you try to do Fourier analysis of the velocity fluctuations in the core of Hα and the brightness fluctuations at the same place you arrive at two spectra which are not equal at all. They have entirely different mean frequencies, the peak of the velocity fluctuations being at about 150–180 s and the brightness fluctuations equalling those in the photosphere of about 300 s. This can be expected because the brightness in Hα pretty much reflects the brightness in the photosphere. When you look inside the profile you then have a combination of effects due to line shift and intensity fluctuations and that might explain the plages not having just one half of either period. In the second slide you showed the nice coherence between the brightness fluctuations in Hα and the velocity fluctuations in the photospheric lines. I agree that they are coherent but I would conclude from the slide that the phase differences are somewhere around 90° or 60° which again confirms that the intensity fluctuations in Hα go with the intensity fluctuations in the photosphere rather than with the local velocity fluctuations in Hα.

Athay: In that same connection I think it should be noted that when you are one half angstrom off-center in Hα about half of the observed intensity comes from chromospheric layers and half from photospheric layers. Current model chromospheres give a double peaked contribution function which at this wavelength is about equally divided between two regions. When you add the Doppler shift into the line you may see primarily chromosphere on one side and primarily photosphere on the other side of the line, so I think there are very large uncertainties in the height relationships between the two sides of the line.

Tanaka: Yes, I agree we do not know the height relationship. However in Hα I can identify dark granular features that have the characteristic appearance of chromospheric structures and we have measured the brightness fluctuations in these features so I think clearly we are talking about chromospheric features and that the brightness and velocity fluctuations are chromospheric in origin.

Athay: How can you be sure?

Tanaka: I have compared photospheric images with chromospheric images and although there is some similarity most of the features are quite different. I am convinced that the features we have looked at in the line wings correspond with those in the chromospheric images and not with those in the photospheric images.

Pecker: When looking at the 200-s delay shown on your (Tanaka) slide #2 between red and blue sides of the Hα line, and at Giovanelli's films, one cannot escape being terribly impressed by the quality of observation. But theoreticians should give a warning and some advice: the optical depth where the 'red' point and the 'blue' point are 'formed' is certainly not the same (a), and (b), it is very badly defined.

Hence I suggest (a) that the 200-s represent a propagation in the atmosphere between two levels, but that we cannot specify the two levels accurately enough. (b) that the velocities deduced by Giovanelli from photometry of his films are indeed very dubious, as they assume the profile to be displaced (from upwards going points to downwards going points) but not disturbed, perturbed, etc.