ON THE TIME FLUCTUATIONS OF MAGNETIC FIELDS

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Abstract. The simultaneous measurements of longitudinal magnetic fields in lines $\lambda 5250$ and $\lambda 6103$, the line of sight velocities and intensities in these lines at some fixed point (area $2''.3 \times 4''.5$) within the moderately strong (~ 100 G) areas of solar magnetic fields were examined to find the possible fluctuations of m.f. with time. No fluctuations were found which cannot be correlated with the simultaneously measured seeing conditions such as contrast, image excursions and scintillations for characteristic periods less than 5^m. The possibility of $\sim 5^m$ oscillations of magnetic fields correlated with the well known sight-line velocity oscillations is pointed out.

Simultaneous strip-chart records of longitudinal magnetic field, sight-line velocity and intensity in the lines $\lambda 5250$ and $\lambda 6103$ at some fixed point on the Sun within an area with a moderately strong (~ 100 G) magnetic field were made in the summer of 1968 to investigate the possible fluctuations of magnetic field with time. The image of the Sun was held fixed on the slit with the aid of two sensors positioned at the western and southern borders of the Sun (with an accuracy of $\pm 0''.2$.). This system of pointing did not permit us to follow fluctuations for periods longer than 5–10 min, because of the rapid change in the vertical diameter of the Sun ($\simeq 1''/10^m$) due to refraction early in the morning when the seeing is usually the best. The resolution was $2''.3 \times 4''.5$ and the velocity of the records, 1 cm = 8 s at a time constant = 1 s (cf. Severny, 1967, 1968).

Simultaneously image excursions (dancing) were also recorded, along with the contrast of the granulation to exclude the possible influence of seeing on the behavior of magnetic field records. The image excursions were measured by photoresistors (Si) in two modes: (1) behind a slit $2''$ – wide and $10''$ in length put radially at the E – border of the image, (2) behind a hole with size $1''$ receiving light (by reflection from a transparent plate) from the same point on the disk which is being recorded. The photocurrent alternating, during the image excursions, passed through an RC-filter to an amplifier with a pass-band 0–20 Hz, and the signal was registered on the strip chart. For measurement of the contrast we scanned the granulation on the image very near to the point on the disk under investigation. A very small rod with a photoresistor behind a hole with a size of $1''$ performed oscillations with amplitude $\pm 90''$ and frequency 25 Hz. The amplifier with a wide pass-band 500 Hz–3500 Hz produced a signal which was a measure of contrast. These devices are, except for excursions at the border of the Sun, essentially of the same kind as described by Deubner (1968). From more than 30 of the best early morning records we have considered only 5 showing more or less clearly the fluctuations of magnetic field which at a direct inspection did not show close correspondence between magnetic field fluctuations and fluctuations of seeing.

Figure 1 is one of these 5 selected records showing directly good correlation between fluctuations of $\delta_{\parallel}$ (5250) and those of contrast (second from the top). It also plots sight-line velocity $v_{\parallel}$ (5250) and image-excursions $\partial I/\partial t$ showing the appearance

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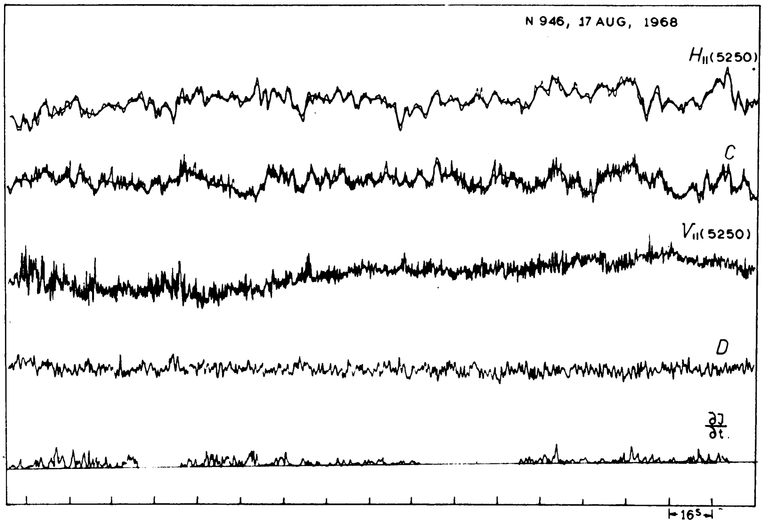

Fig. 1. The example of original records of magnetic field $H_{\parallel}$, contrast C, sight-line velocity $V_{\parallel}$, dancing of images D, measured at the limb of the solar image, and of the rate of change of intensity of granules due to image excursions $\partial I/\partial t$.

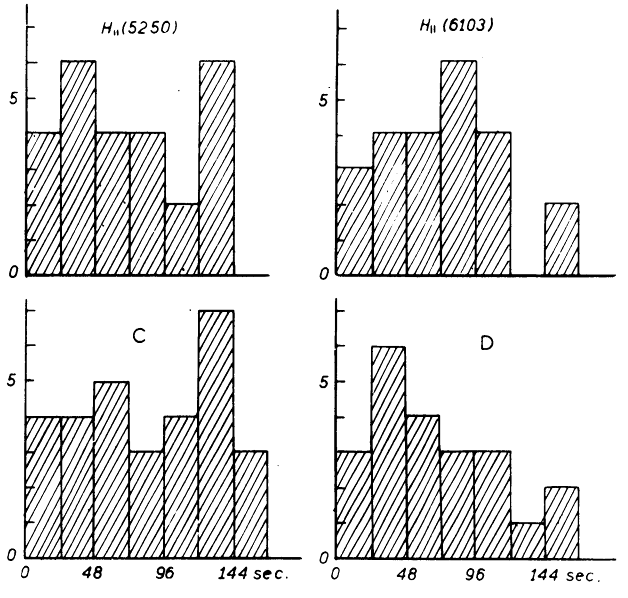

Fig. 2. The distribution of the periods of oscillations found from autocorrelation curves for simultaneous records of magnetic fields in two lines $\lambda 5250$ and $\lambda 6103$, of contrast C and image dancing D.

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of SPO (Howard, 1967) at $v_{\|}$ – records simultaneously with the appearance of peaks on image dancing records. There is nothing new here, and this agrees with conclusions obtained earlier by Deubner (1968) that most of magnetic field and sight-line velocity SPO fluctuations correspond to fluctuations of contrast and image-motions.

However, we should be cautious with such 'at first sight' conclusions and to try to evaluate quantitatively the correlations in question. For this purpose the auto-correlation curves for all such fluctuations as well as cross-correlations between different fluctuations were computed with a lag $\Delta m = 1$ which corresponds to 2 mm on the records or to 1.6 s of time.

In all cases the autocorrelation curves show some periodicity of fluctuations and the graph on Figure 2 shows that the distribution of periods in 7 cases considered is more or less 'grey', although there is, possibly a tendency for fluctuations in $H_{\|}$ (5250) to show a similarity in distribution with that of the contrast. The most suggestive are, however, the cross-correlation curves (see Table I). This table shows that in most cases the magnetic field fluctuations are well correlated with image dancing and fluctuations of contrast, (some time lag in cross correlation with D and C can be due to the

TABLE I

Cross correlations between fluctuations of different records

C.C.	938 (I) 8 Aug. 58	938 (II) 8 Aug. 68	939 9 Aug. 68	943 13 Aug. 68	946 (*A*) 17 Aug. 68	946 (*B*) 25 Aug. 68
AB	$+0.15(0)$	$-0.25(3^s.2)$	$0.34(0)$	$+0.01(0)$ $-0.63(-43^s)$	–	$+0.40(-6^s.0)$
AC	$0.00(0)$	$+0.23(0)$	$-0.06(0)$	$-0.10(0)$	$+0.45(0)$	$-0.27(+5^s.0)$
AD	$+0.59(0)$	$+0.50(0)$	$+0.28(0)$	$-0.02(0)$	$0.23(0)$*	$-0.40(-5^s.0)$
AI	–	–	–	$+0.56(-2^s.5)$	–	–
BC	$+0.02(0)$	$+0.13(0)$	$-0.11(0)$	$+0.14(0)$	–	$+0.42(0)$
BD	$+0.30(0)$	$-0.26(-3^s.2)$	$-0.28(0)$	$-0.28(0)$	–	$-0.10(0)$
AV	–	–	–	$-0.09(0)$ $+0.32(11^s.0)$	–	–
Source	*D*	*D*	*D*	*I*	*C*	*C, D*

Key to notations: *A*-$H_{\|}$ (5250); *B*-$H_{\|}$ (6103); *C*-contrast; *D*-image dancing, $V_{\|}$-sight-line velocity λ5250; * measured in the second made.

difference in the position of seeing sensors and the entrance slit hole). The absence of cross correlation between magnetic field *A* and *B* fluctuations can frequently be due to atmospheric dispersion which is usually most pronounced early in the morning at good seeing.

However, sometimes the cross-correlation between the magnetic field fluctuations and those of *C* and *D* is not pronounced, or absent altogether while the magnetic field fluctuations clearly show the periodicity. In this respect the case of record 943 of August 13, 1968 deserves special attention. Figure 3 shows part of the original records with curves drawn to smooth out noise. We see clearly pronounced a 30^s

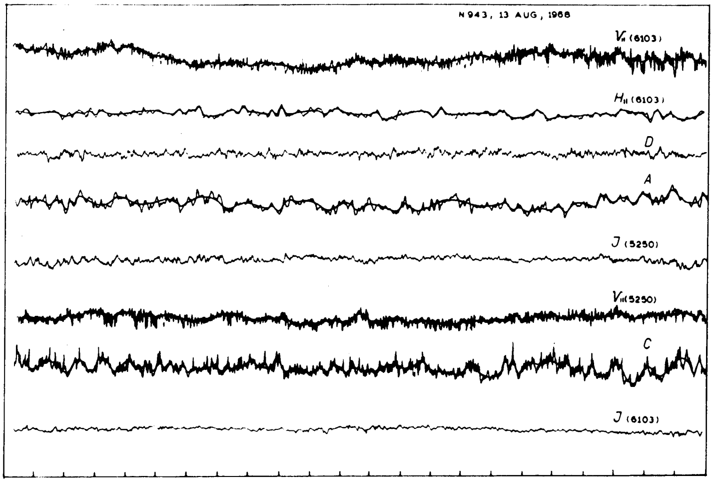

Fig. 3. The part of original simultaneous records of magnetic field in $\lambda 5250$ (A) and in $\lambda 6103$ (B) of sight line velocities $V_{\parallel}$ in these lines, contrast C, image dancing D and of intensities in the cores of both lines I.

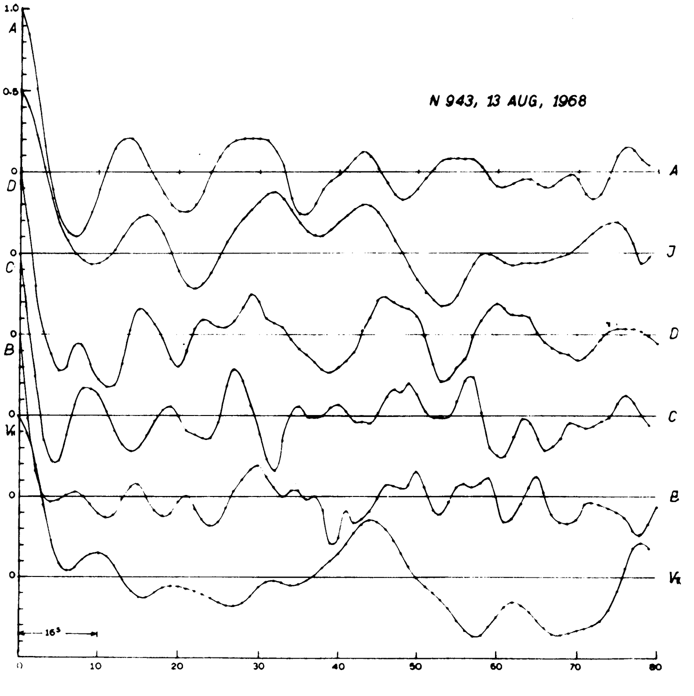

Fig. 4. Autocorrelation curves for the records presented on Figure 3.

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periodicity in the magnetic field – A fluctuations ($H_{\|}$ (5250)) which is not reflected in magnetic field B – records ($H_{\|}$ (6103)). There is also no good correspondence between the green and red line magnetic field records and the records of image dancing and contrast. On the other hand we observe very good correspondence in records of magnetic-field fluctuations in $\lambda 5250$ and the records of intensity in the same line. We wish to emphasize that this correspondence is one of the most typical and remarkable features of all our records – even the smallest peaks of the magnetic field records are usually reproduced in the records of intensity, as we can see from the example in (Figure 3), as well as in other cases. (This is why we do not even

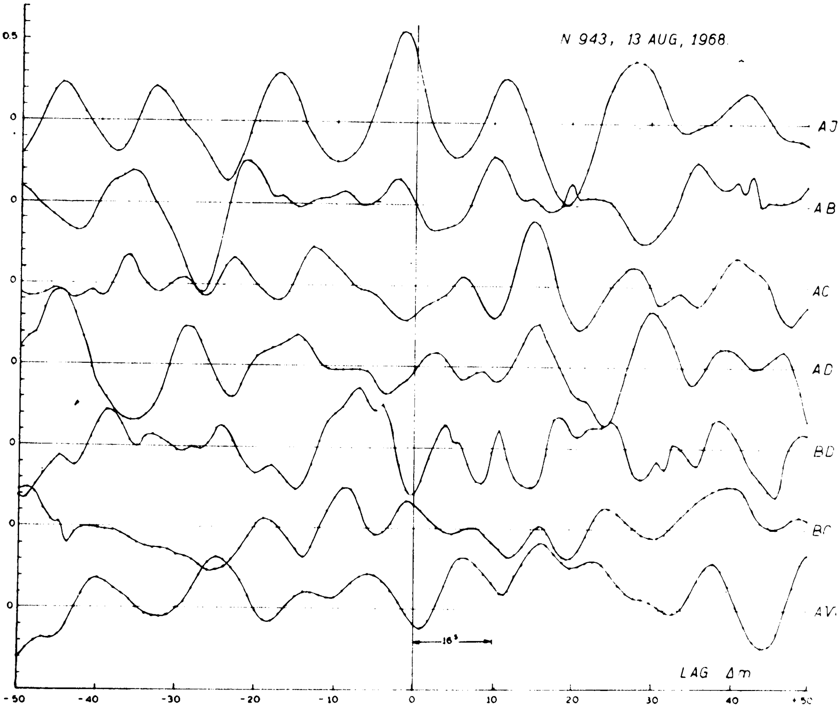

Fig. 5. Cross correlation curves between the different fluctuations presented on Figure 3.

calculate the cross correlation in this case.) The autocorrelation curves shown in Figure 4 confirm all said above: while almost all the maxima of B – magnetic-field fluctuations correspond to those of D and C, in the case of A magnetic-field fluctuations ($\lambda 5250$) there is no such agreement, and all secondary maxima are in the best correspondence with those of intensity fluctuations I. I wish to draw your attention to the fact that the characteristic periods form a sequence of successive modes, m, 15^s, 30^s, 45^s, 60^s as if we had a standing wave oscillation. The consideration of the cross-correlations brings also additional evidence of very good correlation between the magnetic field and intensity in $\lambda 5250$ as can be seen in Figure 5 (according to the data in Table I, the cross-correlation coefficient is $+0.56$ at a lag $\Delta m = -2^s.5$).

So far only the influence of image excursions and of the contrast on magnetic-field fluctuations have been considered. But, as is well known from stellar observations, there exists one more very important factor of seeing – scintillations or twinkling. According to measurements made by Ellison and Wilson (1951), Ellison and Seddon (1952), and by Nettelblad (1953) even in the case of planets we have appreciable scintillations. For instance in the case of Mars (4.″4) the scintillation amplitude ($Z=57°$) is $\pm 14\%$ (while for Sirius $\pm 23\%$, Ellison and Seddon (1952)), for Saturn the mean amplitude is $\Delta m = 0.^m10$ (at $D=20$ cm), or $\sim 9\%$. If we use for solar observations a small entrance aperture (4.″5 × 2.″3) we should expect the amplitude of scintillations of the same order*, because the signal of the magnetic field,

$$\delta i_{\parallel} \sim \frac{\partial I_\lambda}{\partial \lambda} \Delta\lambda_H = I_\lambda \frac{\partial r_\lambda}{\partial \lambda} \Delta\lambda_H \tag{1}$$

is proportional to the intensity in the wing of the spectral line, I_λ. The amplitude of the fluctuations of I_λ actually measured is usually 3–5% in good seeing. Being cor-

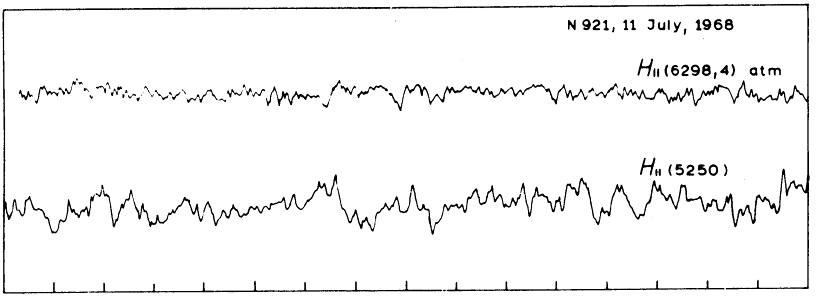

Fig. 6. Showing the absence of the influence of turbulence inside of the spectrograph on the recorded fluctuations of magnetic field $H_{\parallel}$.

rected for the change of intensity I_0 (usually measured for a large portion of the spectrum far outside the line) the signal $\delta i_{\parallel} \sim I_\lambda / I_0$ can have an amplitude twice as large because I and I_0 fluctuate non-coherently (see Zhukova, 1959) even if the distance between two spectral regions is only 500 Å. (I wish to remind you that a contrast $\sim 1\%$ corresponds to a signal ~ 10 G). The accidental excursions of the line across the exit slit uncorrected by the line-shifter can contribute still more, although a special check with a telluric line showed that the magnetic field fluctuations in this line are small, and completely independent of magnetic field fluctuations in λ 5250 (Figure 6). The effect of scintillations does not influence so strongly the magnetic field fluctuations recorded in the scanning mode, because we pass, while scanning, completely incoherent states of scintillations. We should also keep in mind that twinkling can produce immediately a signal which is equivalent to a magnetic field signal, and comparable with it if the frequency of modulation in the magnetograph is

* The image excursions and loss of contrast can reduce this amplitude due to additional incoherency brought from the parts of image outside the entrance aperture.

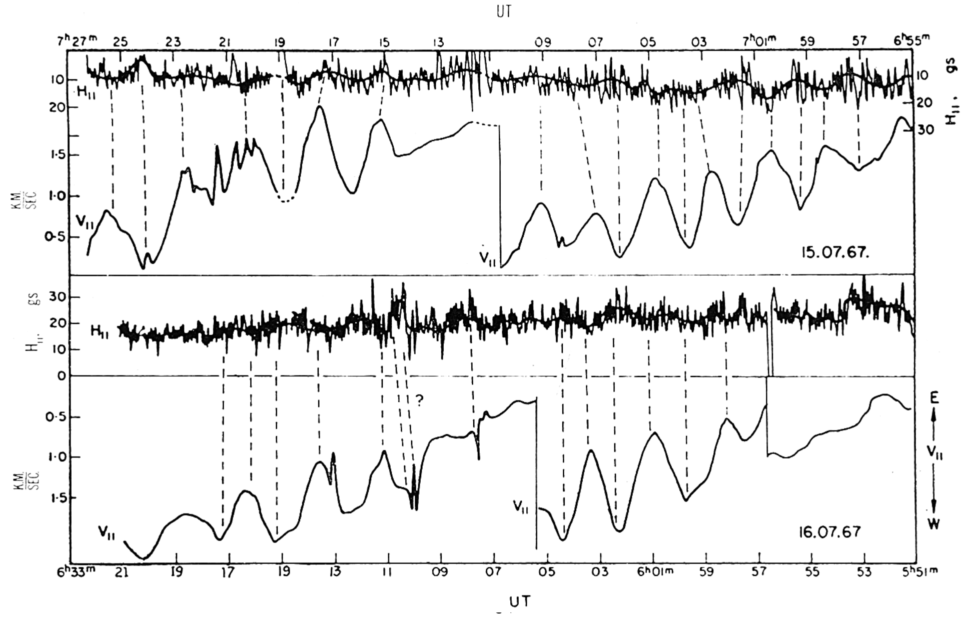

Fig. 7. Illustrating some synchronism in fluctuations of magnetic fields $H_{\parallel}$ and velocities $V_{\parallel}$ with the period $\sim 5^m$.

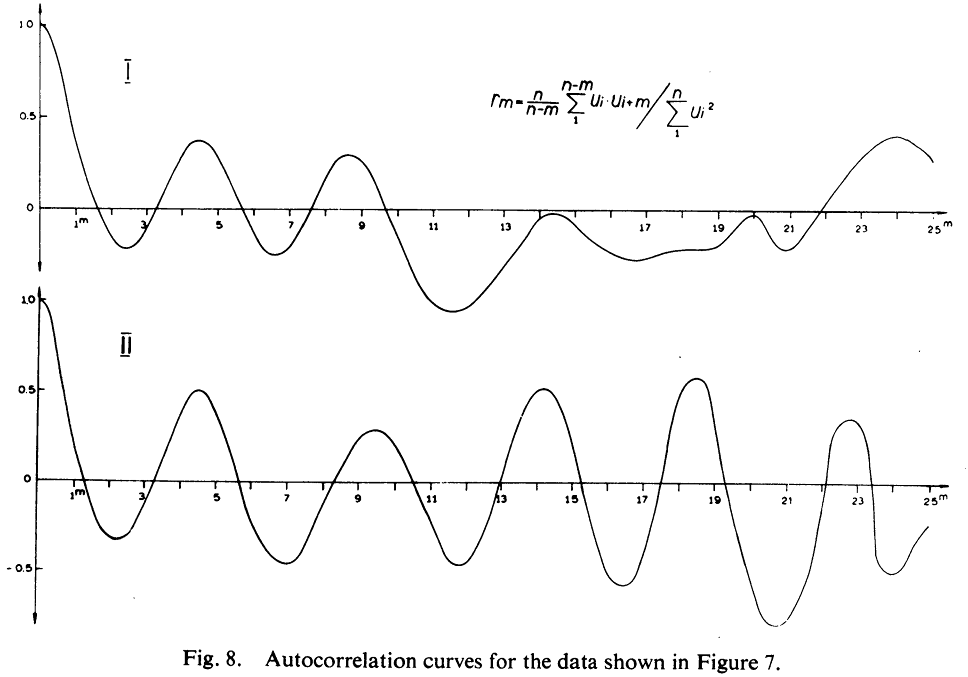

Fig. 8. Autocorrelation curves for the data shown in Figure 7.

within the range of frequencies of scintillations, which is very wide and can reach even 100 Hz and more (Vinogradova, 1959).

So we are coming to the rather pessimistic conclusion that most of the short-period time fluctuations of magnetic field signal and velocity signal observed so far are probably due to fluctuations of seeing.

At the same time we observe sometimes good coherency between the well-known 5^m – fluctuations of sight-line velocity and fluctuations in magnetic field, taking 20–30^s averages, as can be seen from Figure 7. A similar correspondence was found by Howard (1967). The autocorrelation curve for the fluctuations shown above is in Figure 8, showing clearly expressed periods which are a little less than 5^m. There are no corresponding fluctuations in intensity for these fluctuations and they are probably too slow to be ascribed to any variations in seeing.

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