Part III

OPTICAL STRUCTURE OF AN ACTIVE REGION

ON THE STATE OF THE PHOTOSPHERE BEFORE THE APPEARANCE OF SUNSPOTS

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1. Observations

The object of our investigation was to clarify the behavior of the fluctuations in the brightness in photosphere on the scale of the supergranulation 1–2 days before the appearance of sunspots.

A detailed photometrical treatment and statistical analysis of areas with sizes $100'' \times 200''$ and $100'' \times 100''$ have been made.

Three groups near the center of the disk have carefully been studied at 8 moments of their development, using Tashkent daily white-light plates obtained by means of Macksutov's system photoheliograph ($D = 100$ mm, $F = 8200$ mm).

Printon plates with effective wavelength 4100 Å have been used.

2. Analysis

In order to reduce the influence of the measuring errors and errors of the observations, the control areas have also been measured on the same plates, on the same distance as the areas under study.

The fluctuations in the brightness have been recorded at about 3000 points on every area under study and at about 1500 points on every control area.

The next values were obtained at every area: $\bar{J}$ = the average meaning of the brightness for the area on the whole in terms of the brightness at the center of the disk; $\Delta J/\bar{J}$ = the contrast at every point; two-dimension autocorrelation function

$$B(l, m) = \frac{1}{(L-l)(M-m)} \sum_{\lambda=1}^{L-l} \sum_{\varphi=1}^{M-m} \frac{\Delta J}{\bar{J}}\,\lambda, \varphi \; \frac{\Delta J}{\bar{J}}\,\lambda + l, \varphi + m$$

where $l = 0, 1, 2 \ldots 20$; $L = 80$. $m = 0, 1, 2 \ldots 20$; $M = 40$.

Kiepenheuer (ed.), Structure and Development of Solar Active Regions, 151–160. © *I.A.U.*

Table 1

	The areas under study (size ~ 200″ × 100″)				The control areas (size ~ 100″ × 100″)								
N	Date U T	φ	λ	ρ	N	φ	λ	ρ	J_S (%)	J_c (%)	ΔJ (%)	$\sqrt{\left(\frac{\Delta J}{J}\right)^2_s}$	$\sqrt{\left(\frac{\Delta J}{J}\right)^2_c}$
I													
1	22/IX/61 $5^h 11^m$	+ 7	—17	0·29	2	—10	0	0·29	101	98	3	2·1	2·7
15	8 22	+ 7	—15	0·27	16	—10	0	0·29	103	98	5	1·3	1·1
5	23/IX/61 5 08	+ 7	+ 1	0·07	6	—10	+13	0·39		Spots			
II													
3	22/IV/59 $3^h 35^m$	+16	+14	0·42	4	—30	0	0·42	98	92	6	3·2	2·2
7	23/IV/59 6 19	+16	+27	0·53	8	—30	+13	0·47		Spots			
III													
11	2/VI/65 12 04^m	—10	+ 7	0·30	12	+10	+ 7	0·30	97	98	—1	7·3	3·7
9	3/VI/65 3 44	—10	+15	0·30	10	+ 9	+15	0·30	100	96	4	3·2	2·5
13	4/VI/65 4 58	—11	+28	0·50	14	+11	+28	0·50		Spots			

$\Delta l = \Delta m = 1$ corresponds to 2".6 on the disk. Table 1 shows time of observations, the coordinates, the average meanings of the brightness and root-mean-square contrasts of the areas under study in comparison with the control areas.

3. Results and Conclusions

The appearance of sunspots is accompanied by a very strong photosphere disturbance, involving an excess of the brightness, a change of the structure, unusual time-dependent macroscopic fluctuations in the brightness.

Before the appearance of sunspots the brightness increases on the whole area at an average for some cases of about $3{\cdot}5 \pm 2{\cdot}4\%$. The additional radiation is observed on the place with size $200'' \times 100''$ for 1 day, the total extra energy being of the order of 10^{34} erg.

As to a structure, its changes are manifested in the enlargement of the macroscopic inhomogeneities and visible separation of the area under study on two parts (Figure 1a, b).

The new spots tend to be placed along the boundary, dividing lighter-than-average and darker-than-average regions (Figure 1c).

Such a location of new spots seems to be similar to the formation of the spots on the boundaries of the adjacent supergranules according to Bumba and Howard (1965). Besides the enlargement, changes of the structure are indicated by the forming of the dark lanes and the bright features, stretched along the equator. Spatial autocorrelation functions in Figure 2 convincingly show this phenomenon. The same photosphere phenomena with the appearance of the characteristic structure have been observed at the active regions before pores' birth by Loughhead and Bray (1961) and in photosphere between spots by Miller (1960).

The filamentary structure of the inhomogeneities in the longitude direction before the appearance of sunspots seems to be a distinctive trait in the development of the active regions. We found such a structure at nine more cases without special treatment. The typical character of the straightened elements in the photosphere is to be emphasized by the appearance of the elongated filaments in Hα at the first stage of development of active regions.

The comparison of two pairs of areas under study at two different moments reveals definite time-dependent fluctuations in the brightness on a large scale. The lighter-than-average region turns into the darker-than-average one and on the contrary. For all that, the location of the dividing line is roughly kept.

Figure 3 shows this phenomenon at the area for 3 days of the development of active region. But another studied case reveals the same character of changes in the brightness for 3 hours, and we do not yet know the low limit of such fluctuations.

Possible rapid changes of the macroscopic fluctuations in the brightness ($\sim$20 min) on the scale of the supergranules in the photosphere have been discussed by Beckers

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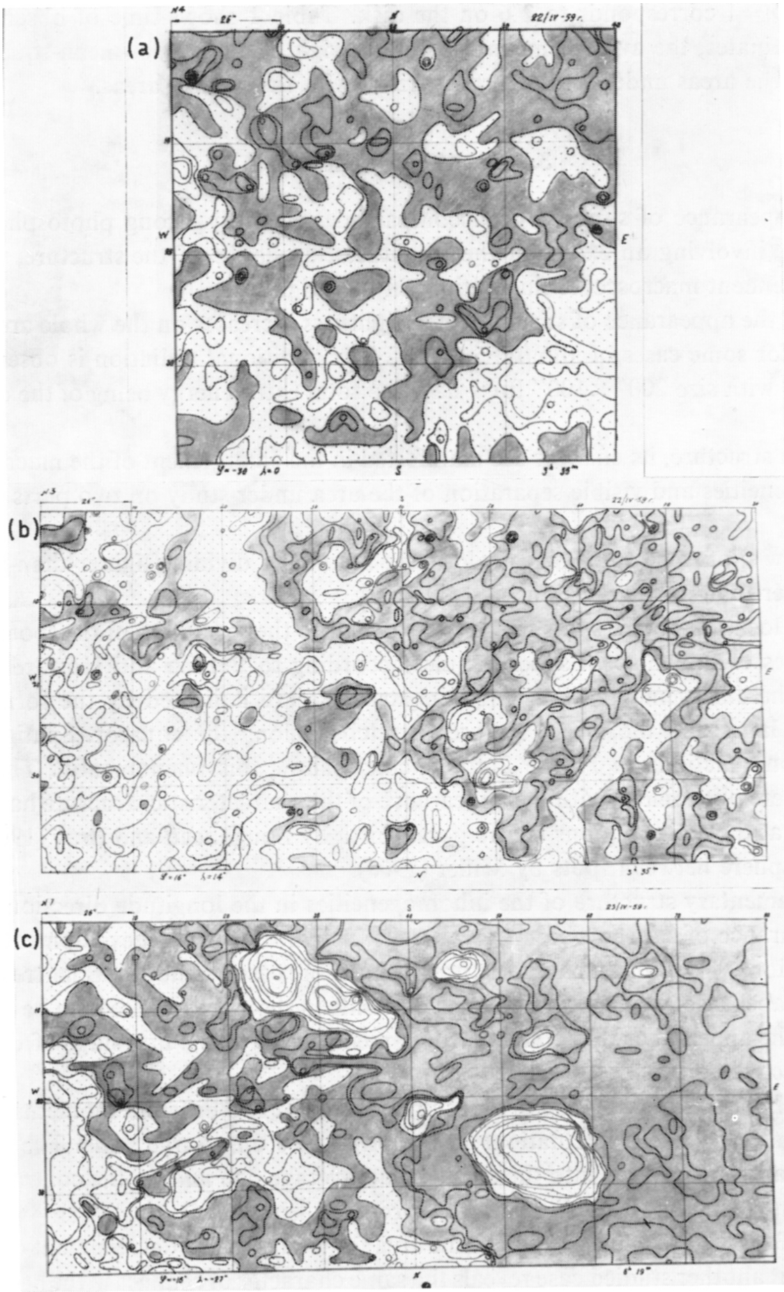

FIG. 1. *The brightness maps of some areas in the photosphere with the meanings of the contrast $\Delta J/J$ equal to 0·03; 0·05; 0·07; 0·1 in regions far from spots. (a) The undisturbed control area; (b) The area under study before the appearance of sunspot group 22/IV/59; (c) The location of spots on the same area next day, 23/IV/59.*

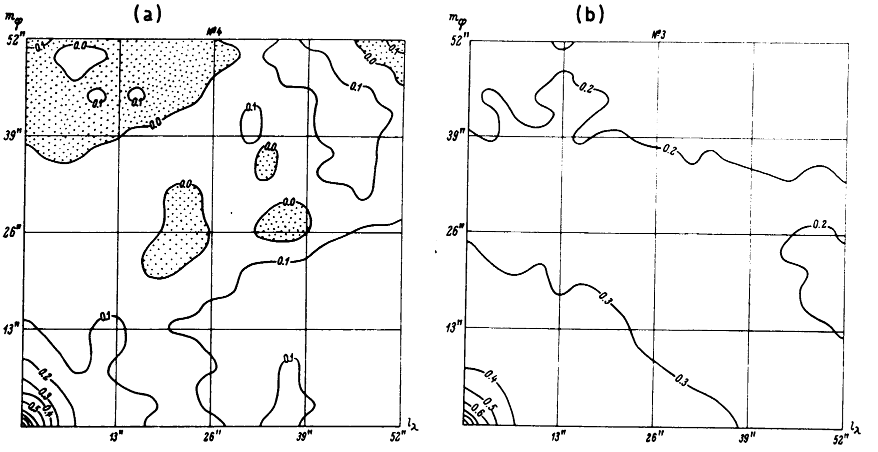

FIG. 2. *Samples of the two-dimensional autocorrelation functions; (a) for the undisturbed control area (Figure 1a); (b) for the area under study 22/IV/59 (Figure 1b). l and m are longitude lag and latitude one accordingly.*

(1966) and Harvey (1965). As a result of our treatment, we obtained time-dependent changes of the areas under study which have no common features with those of the control undisturbed areas.

In conclusion we can say that the observed structure at disturbed photosphere seems to be caused by the rising of the magnetic loop with filamentary structure. This explanation as to pores was offered by Loughhead and Bray.

Time of the disturbance of the photosphere before the pores' and spots' birth is equal to 3^h and $20–30^h$ respectively.

If we accept the speed of the magnetic-field rising equal to 10^4 cm/sec, according to Iksanov and Vitinsky (1966), we shall obtain the size of the cross-section magnetic loops of the order of 10^8 cm and 10^9 cm, which is in agreement with the size of pores and spots. Then it is to be noted that our results appear to be affected by the definite selection of the observations. We treated the areas with the brightest features, and the future groups turned out to be very unstable with the great flares.

So, our test sunspot groups make us conclude that the character of the inhomogeneities in the brightness before the appearance of spots reflects the conditions of sunspot genesis and reveals the possibilities of predicting their future history on the base of the investigation of the brightness in the photosphere.

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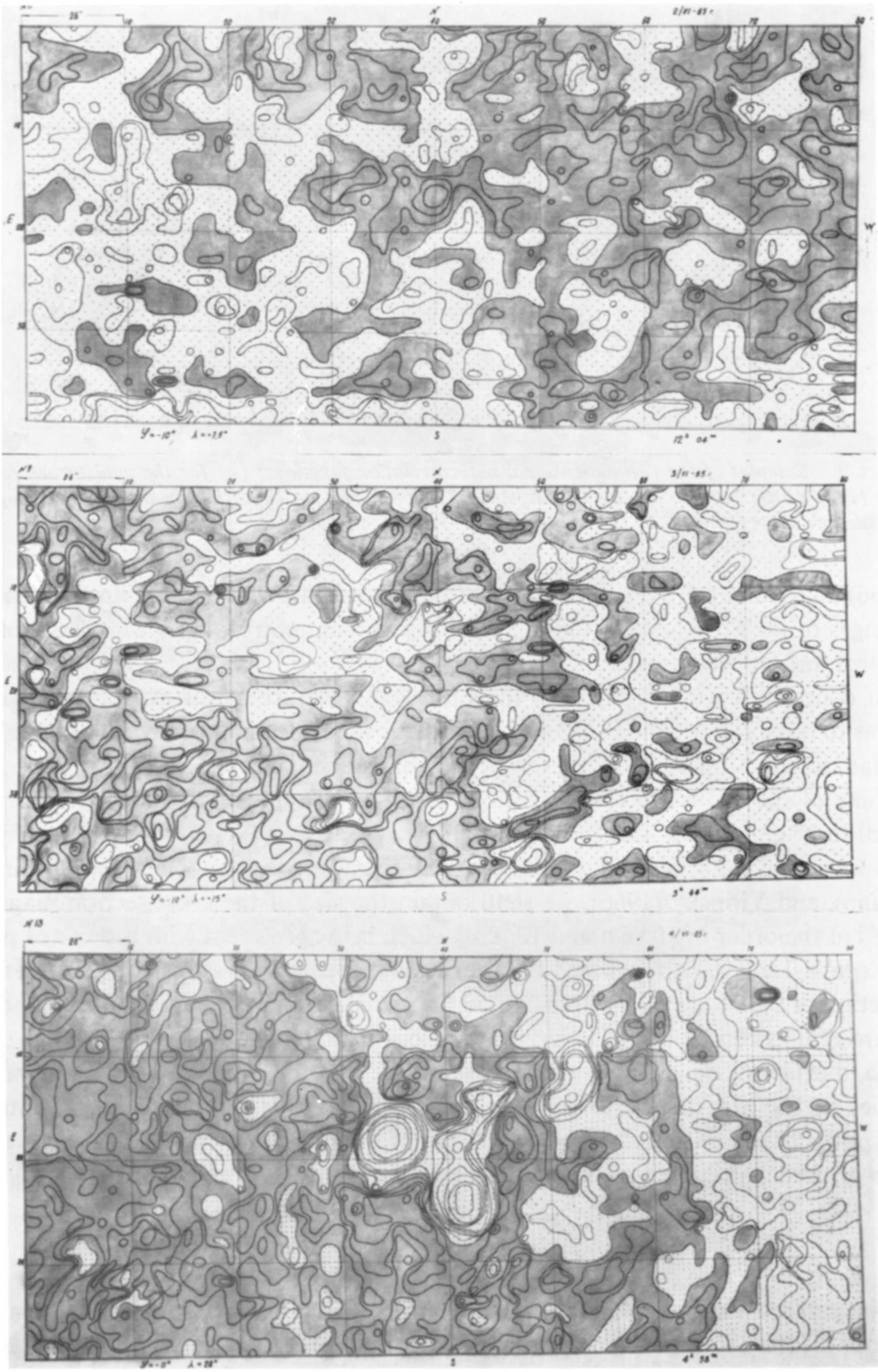

FIG. 3. *The brightness maps of one area under study for 3 days: 2, 3, and 4/VI/65.*

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DISCUSSION

De Jager: Since you find that the brightness contrast in the granular field increases prior to the birth of sunspots, I wonder whether this effect is not simply due to the birth of the photospheric facular field. In its first stage this would signify an increased brightness of the supergranulation pattern.

Vassilyeva: We studied the properties of the brightness field in active regions before sunspot appearance and compared the results with what we obtained for the undisturbed photosphere. The cause of the difference in the brightness field was not investigated.

McIntosh: My white-light observations also show bright, distorted photospheric granules near positions where sunspots will soon form. I have not made quantitative studies of these but it appears that these brightenings are short-lived and not necessarily related to supergranules.

G. W. Simon: How do you determine the supergranular pattern from the photoelectric observations?

Vassilyeva: Autocorrelation functions of the photoelectrical records sometimes show not-accidental periodic component with a period coincident with sizes of the supergranules. Ordinary photometry of the photospheric region also shows existence of macroscopic inhomogeneities with noticeable fluctuations in brightness.

G. W. Simon: Do the autocorrelation functions show secondary maxima? If so, do these maxima occur at distances corresponding to supergranule sizes?

Vassilyeva: Two-dimension autocorrelation functions reflect non-isotropic character of the fields of the fluctuations in the brightness in disturbed and in undisturbed areas. The second maximum is observed with a lag of about 20″–30″.

Rösch: Je voudrais signaler, a l'occasion de cette communication, que nous avons récemment obtenu, a l'Observatoire du Pic-du-Midi (A. Carlier, F. Chauveau, M. Hugon, J. Rösch) une série d'images montrant la naissance d'un *pore*, dont certaines sont reproduites dans la Figure 4; l'intervalle entre les images 1 et 16 est de 26 min. Le Nord est en haut, l'Est à gauche. Objectif de 38 cm, coupole 'tourelle', film Kodak Microfile Ortho et filtre orange, pose 1/250 sec. Le cercle mesure 2″.

On remarquera, dans la région au Sud-Ouest du futur pore, des granules allongés, ressemblant plutôt a des éléments de filaments de pénombre, et suggérant l'existence d'un champ magnétique horizontal. Noter aussi le gros granule brillant, sur l'image 1, un peu au Süd-Ouest du futur pore, qui devient un fer-à-cheval sur l'image 4, puis un anneau de 5 à 8, et disparait par fragmentation à partir des images 9–10.

Beckers: Does Dr. Rösch believe that it is a common behaviour for a granule to explode or are the exploding granules exceptional cases?

Rösch: It may not be common to *all* granules, but we saw it quite often on the first movie-film we produced in 1959, and it appears more frequently on this new one, which is better in quality. Maybe one-third of the granules end in that way.

Schröter: I followed during the movie one granule. I saw that this granule dissolved by a very rapid change (decrease) of the central brightness, the boundaries remaining unchanged. Suddenly near the end of the film in the central part of this granule the brightness increased again. A new bright granule was the result. Is this observation an exceptional case or did you observe this behaviour on other granules too?

Rösch: I have noticed this case, indeed, but only the one you mention.

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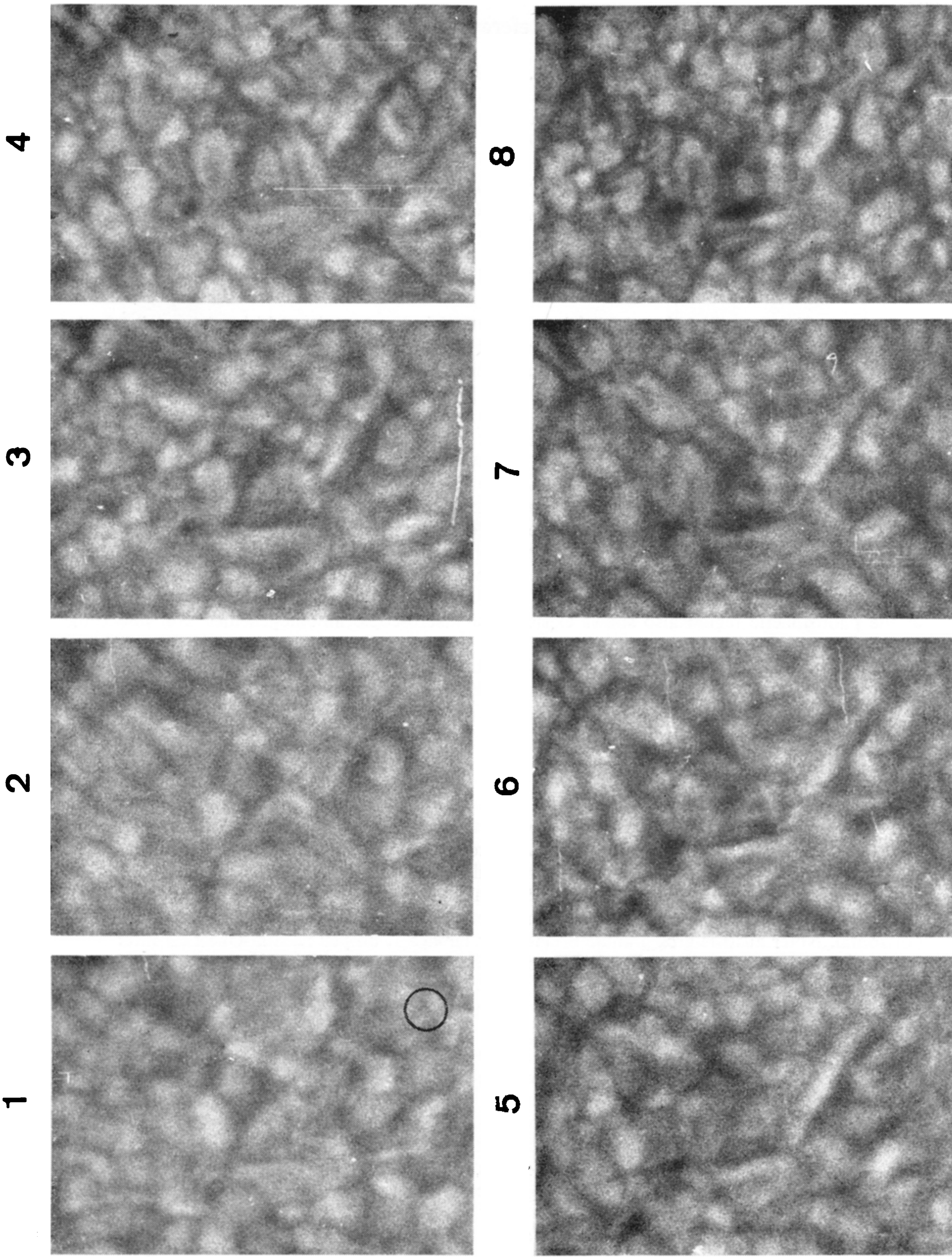

FIG. 4. *Naissance d'un pore, le 11 juin 1967, de 7^h42 à 8^h04 TU.*

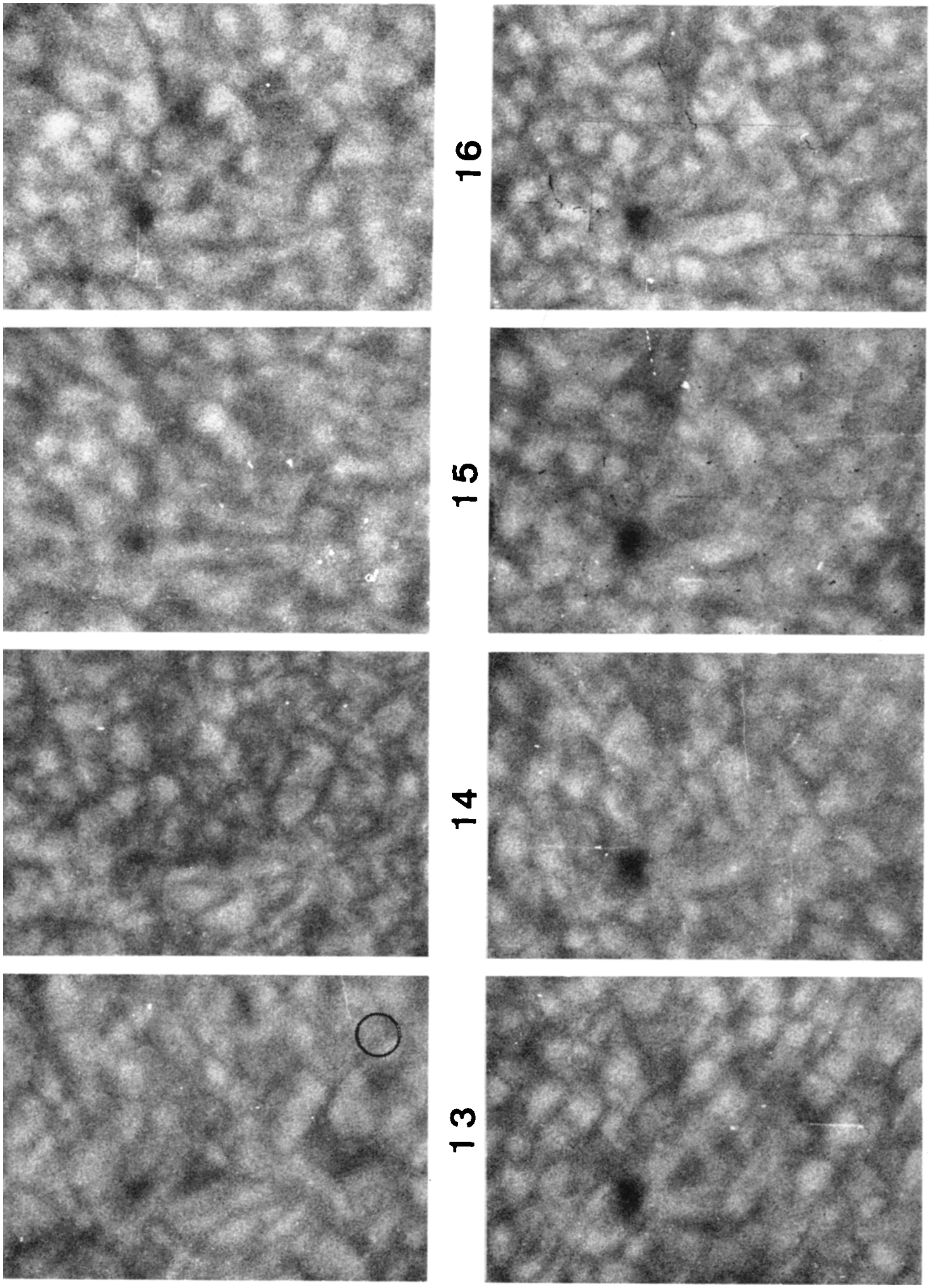

Fig. 4b

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G. W. Simon; Sometimes a granule seems to be crossed by a dark lane. Then the granule suddenly divides along this lane and becomes two granules which then move apart from each other.

Rösch: This case is rather common; the structure is what I have called a 'coffee-grain'.

Fokker: There seemed to be some kind of a regular fluctuation or oscillation affecting the whole image. Is this effect of an instrumental or atmospheric nature, or can it be considered as of real solar origin?

Rösch: Because of its regularity, and rather long period ($\sim$ 300 sec perhaps!) I do not think it may be atmospheric. Of course, we should try to confirm that it has something to do with supergranulation.

Righini: What is the resolving power on these pictures?

Rösch: We have seen some small dots not larger than one-third of a second of arc.