THE SUPERGRANULAR PATTERN AND THE STABLE STAGES OF SUNSPOT GROUPS*

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Assuming the sunspot area to evolve smoothly and the sunspot-group lifetime distribution to be a monotonous decreasing function one can easily conclude that the function $N(S)$, determining the number of sunspot groups having the area S at this moment, must increase monotonously and smoothly with decreasing area S.

The real behaviour of the function $N(S)$ in the individual 11-year cycles no. 15–18 (according to the Zürich numbering), obtained by Kopecký (1964) using the Greenwich catalogue and analysed in more detail by Dmitrieva *et al.* (1967), is not in accordance with this theoretical conclusion. All principal peculiarities of the $N(S)$ behaviour can be illustrated by the $N(S)$-curve of cycle no. 17.

Firstly all $N(S)$-curves show a clear maximum at $S_0 = 2\text{–}5 \times 10^{-6}$ hemisphere. Secondly all $N(S)$-curves do not decrease smoothly and uniformly with the increase of S at $S > S_0$. At several intervals of S values the $N(S)$ decreasing rate is appreciably reduced or even becomes zero, i.e. $N(S)$ is then practically a constant within the range of these values (Figure 1). Therefore one may speak of two 'steps' in the $N(S)$-curve, the first one is within the area range from $8\text{–}13 \times 10^{-6}$ hemisphere and the second one within the area range from $60\text{–}200 \times 10^{-6}$ hemisphere. The reality of these steps may be confirmed by two other ways at least.

We can explain these peculiarities of the $N(S)$-curves in the following way. It is quite probable that a sunspot originates only when the magnetic field reaches some critical value. As the magnetic field occupies the solar surface for a *part* of definite size at this moment, so the originating sunspot cannot have infinitely small size and must have a definite minimal area. In that case the area S_0 corresponding to the maximum of $N(S)$ must be accepted to be the mean value of the minimal sunspot-group area in statu nascendi.

The presence of steps on the $N(S)$-curves indicates that a number of the sunspot groups with areas corresponding to these parts of the curves is more than it must be in accordance with the natural sunspot-group area distribution and consequently such sunspot groups occur more often. As at the $N(S)$ determination the sunspot groups of various evolution stages were used, so the mentioned steps on the $N(S)$-curves

* Presented by G. V. Kuklin.

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Kiepenheuer (ed.), Structure and Development of Solar Active Regions, 174–177. © *I.A.U.*

correspond to the stable stages of the sunspot group evolution in the sense that in the evolution process with the continuous area change, the sunspot groups stay within the range of corresponding values of S sufficiently longer than at other values of S.

It should be noted that the supergranule area is approximately equal to $160–230 \times 10^{-6}$ hemisphere, that is in quite good accordance with S values of the second step on the $N(S)$-curve. Assuming the supergranules to fill the solar surface uniformly and closely one may easily calculate the area of the solar surface part between the adjoining supergranules to be of the order of $6–8 \times 10^{-6}$ hemisphere.

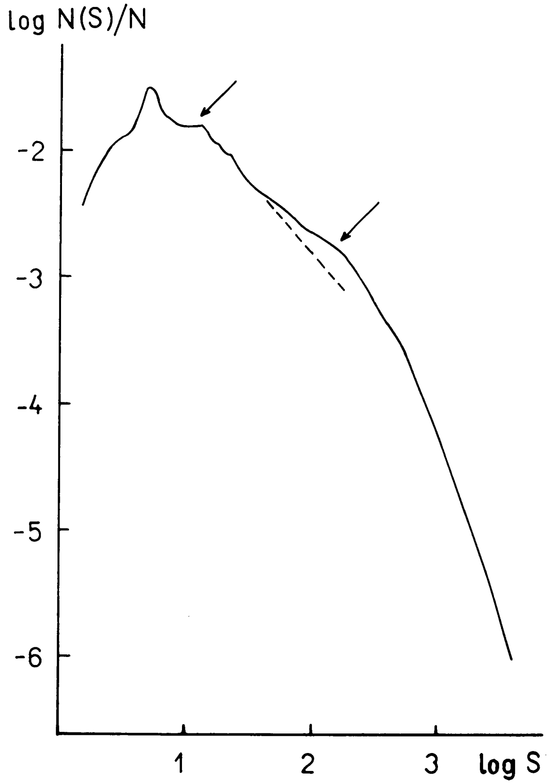

FIG. 1.

Using this fact and taking into consideration the results of papers by Bumba (1965), Bumba and Howard (1965), Kasinsky (1966), Bumba *et al.* (1966) we can suppose the following working hypothesis.

The sunspots as dark formations appear only at places where the magnetic field has reached a definite critical strength and a definite size. The originating sunspot has, on the average, a minimal area corresponding to the maximum of the $N(S)$-curve at $S = S_0$ close to the intersupergranular space area. The sunspots are born just in these spaces at the supergranular periphery. The leading and the following sunspots filling these spaces are more stable; that corresponds to the first step on the $N(S)$-curve. At the subsequent development the sunspot may fill the whole supergranule; that corresponds to another stage of higher stability of the sunspot groups, hence to the second step on the $N(S)$-curve.

Therefore we come to the conclusion that the supergranular pattern takes a determining part not only in the active-region structure but also in its evolution.

The linear and slow time variation of the sunspot area S corresponds to stable stages of the sunspot evolution (Vitinsky and Ikhsanov, 1966; Ivushkina and Kuklin, 1967) $S=S^0-\beta t$. Then we can write down an approximate correlation between the sunspot magnetic-field strength H and the sunspot lifetime T

$$H \sim T\left|\frac{\mathrm{d}H}{\mathrm{d}t}\right| = T\left|\frac{\mathrm{d}H}{\mathrm{d}S}\,\frac{\mathrm{d}S}{\mathrm{d}t}\right| = \beta T\left|\frac{\mathrm{d}H}{\mathrm{d}S}\right|.$$

Using the empirical formula for the relation between S and H (Ikhsanov, 1966)

$$\lg H = c\cdot\lg S + d$$

we obtain

$$\frac{\mathrm{d}H}{\mathrm{d}S} = C\frac{H}{S} \quad \text{and} \quad T \approx \frac{S}{c\beta}.$$

The last formula looks like the theoretical estimate of the magnetic-field Joule dissipation time $T \approx L^2/v_m$.

Therefore we are allowed to suppose the Joule dissipation as a principal mechanism of a magnetic-field disintegration which corresponds to the sunspot-evolution stages with the linear-area decrease. But it is right only at the linear parts of the S-variation curve, because the increase of β needs the electroconductivity σ decrease. Using the numerical estimations of c and β (Vitinsky and Ikhsanov, 1966; Bumba, 1963; Ikhsanov, 1966) we obtain $\sigma \sim 10^8$–10^9 CGSE corresponding to the lower limit of estimations for the sunspots and the photosphere by Kopecký and Kuklin (1966) and Kuklin (1966). The steeper parts of the S-curve may not be caused by Joule dissipation as the necessary values of σ are small too. It is evident that the rapid decrease of the sunspot area is connected with some process of unstability which apparently occupies the whole active region and leads to an activity rise (non-stationary processes). But the sunspot is absolutely stable against macroscopic magnetohydrodynamic perturbations.

Hence the supergranular pattern in the active region is a stabilizing factor in the sense that the magnetic fields being inside the supergranular borders (inner and outer) have a more stable configuration, and their changes are caused only by Joule dissipation leading to a slow linear decrease of the sunspot-group area at this evolution stage. The magnetic fields not joined to this pattern are less stable and are being destroyed by the same pattern.

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DISCUSSION

H. U. Schmidt: As I said yesterday, I find it hard to understand a decay of the whole sunspot field with the local timescale computed from the local low conductivity in the umbra because in such a decay the flux has to contract into the photospheric currents surrounding the umbra and that should take a time consistent with the high conductivity in the layers which the flux has to trespass. I think it might be possible to have the same decay behaviour which you describe caused by a flux diffusion due to the local structure of the convection surrounding the umbra.

Kuklin: We have not aimed to explain why the linear part of the sunspot-area variation curve is existing but only wanted to show the Joule dissipation may be one of possible mechanisms causing this fact.