THE BALANCE OF MAGNETIC FLUXES IN ACTIVE REGIONS

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According to modern theories of the solar cycle, active regions on the Sun are caused by a magnetic disturbance penetrating the solar surface from below. Sunspots, filaments, flares and other conspicuous events in an active region seem to be only secondary phenomena, the basic feature being the magnetic field itself.

One important property of an active region as a whole is that it is generally asymmetric in the East–West direction. From white-light photographs of sunspot groups we know that the preceding spots generally dominate over the following spots, although there are many exceptions. The same fact is known from the measurements of sunspot magnetic fields. Grotrian and Künzel (1950) found that the magnetic flux through the preceding spots is in the mean 3–4 times greater than the flux through the following spots. Hence, if only the magnetic field of sunspots is taken into account, there is a very strong disbalance between the preceding and following fluxes in active regions.

Sunspots develop when the magnetic field is strong enough to inhibit convection. By measuring the field of sunspot pores at the best available seeing, Steshenko (1967) concluded that sunspots can develop only when the field strength exceeds approximately 1100 gauss. Accordingly, the result of Grotrian and Künzel means that if only fields stronger than about 1100 gauss are considered, there is a strong disbalance between the fluxes in the region. It is therefore of great interest to study how the balance of fluxes varies with the field strength.

Isogauss maps of sunspot groups recorded in 1963 and 1965 with the magnetograph at the Crimean Astrophysical Observatory were used for the study of the flux balance. Only maps which appeared to contain nearly all the magnetic fields belonging to the spot group were studied. 17 maps of 10 spot groups were thus selected for examination. The magnetograph was equipped with a brightness compensator when the records were made, eliminating the influence of the brightness variations within the spot group. Visual determinations of the maximal field strengths in the spots were also available.

When interpreting the isogauss maps and measuring the fluxes we must know the calibration curve of the magnetograph, i.e. the relation between the magnetographic signal and the magnetic-field strength in the line of sight. Severny (1967) has determined the calibration curve of the Crimean magnetograph by observations. The

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observationally determined curve deviates very much from the curve based on the theory for the Zeeman effect in a homogeneous solar atmosphere. It has been considered to be more appropriate to use the observational curve in the study of the flux balance, but we should be aware of systematic errors introduced by errors in the calibration curve.

The magnetic fluxes in different intervals of the longitudinal field strength (i.e. between different isogauss lines on the maps) were measured on the isogauss maps using a planimeter. The measured fluxes in a spot group were then represented in the form of histograms, giving the flux Φ_i per unit interval of the longitudinal field strength H, i.e. $\Phi_i/\Delta_i H$, as a function of the field strength H. Some of the common properties of the histograms may best be studied by determining a distribution, which is the

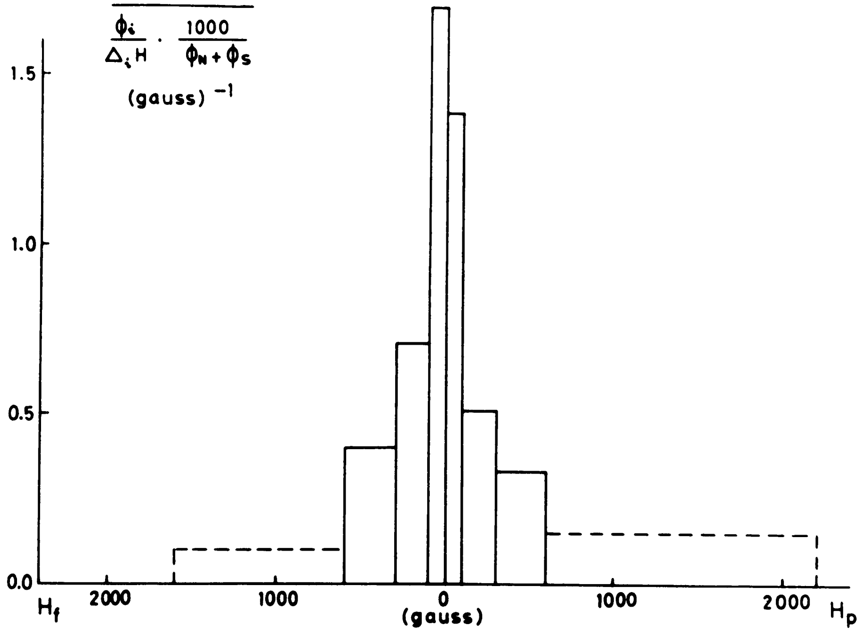

FIG. 1. *Distribution of magnetic fluxes. H_p (H_f) means longitudinal field strength of preceding (following) polarity.*

mean of all the individual histograms. The result is shown in Figure 1. As a kind of normalization, the fluxes Φ_i are divided by the sum of the total fluxes of N- and S-polarity in the region, $\Phi_N + \Phi_S$, before the mean is taken. The histogram is dashed in the strong field intervals, because the upper interval limit is somewhat uncertain. It is seen that the weaker fields are responsible for a considerable part of the total flux. We also notice the asymmetry of the distribution, which is very pronounced for the stronger fields (sunspot fields). Taking the difference between the p- and f-fluxes in the same H-intervals, Figure 2 is obtained, which describes the flux balance. We find that the following part of the region contains more flux, if only longitudinal fields H weaker than about 600 gauss are considered. For stronger fields the situation is reversed. Hence we obtain very nearly a total balance of fluxes in the region.

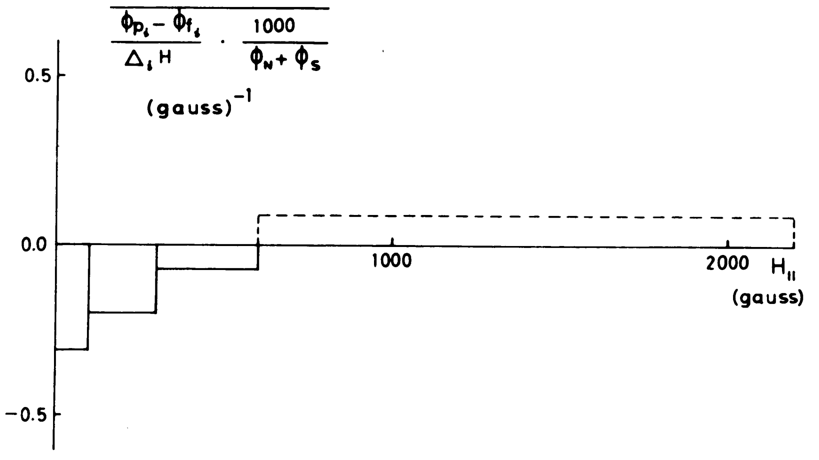

FIG. 2. *Flux-balance diagram.*

We can now better understand the result obtained by Grotrian and Künzel. Let us study the ratio between the p- and f-fluxes, Φ_p/Φ_f, for different H-intervals. In the interval 0–600 gauss we find this ratio to be about 0·8. For $H > 600$ gauss it is 2·5. Hence the result of Grotrian and Künzel that $\Phi_p/\Phi_f \approx 3{\cdot}5$ for sunspots, i.e. for $H \gtrsim 1100$ gauss, agrees very well with the present results, although our statistical material (the number of isogauss maps) is rather limited.

On the basis of what has been said, the general magnetic character of an active region as a whole could very briefly be described as follows: The magnetic field is bipolar, and the preceding and following fluxes balance each other. There is an East–West asymmetry. The magnetic lines of force are more concentrated in the preceding part of the region than in the following part, where they are spread out over a larger area.

References

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