A PHOTOSPHERIC MAGNETIC FIELD STRUCTURE AND ITS EVOLUTION AT THE APPEARANCE OF AN ACTIVE REGION

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Abstract: The paper is concerned with the analysis of simultaneous observations of the longitudinal magnetic field in lines Fe I λ 5250 and 5233 A in a quiet photosphere near the developed sunspot and in the developing sunspot group. The lines used are characterized by different temperature sensitivities. Line λ 5250 is weakened in the magnetic field elements, whereas λ 5233 is not sensitive to temperature variations. Therefore, the magnetic field elements contribute to the magnetograph signal, averaged in the input aperture, with different weights in both lines. In a quiet photosphere the ratio of the mean field intensities in the indicated lines $H_{5250}/H_{5233} \approx 0.4$. It was found that at the appearance of an active region this ratio is 0.2 during the first day, 0.25 during the second day, and 0.55 during the third day. Inside the region of the developed sunspot $H_{5250}/H_{5233} \approx 0.55$. The changes in this ratio during the development inside the new active region imply the changes of the physical conditions in the photospheric structure.

Introduction

Recent investigations showed that a considerable part of the magnetic flux in quiet and active regions is concentrated within the fine-structured elements (magnetic filaments, magnetic knots) with dimensions of less than 1″. The first direct observations of magnetic knots were carried out by Sheeley [1], who observed the coincidence of regions with great field intensities and with "gaps" (considerable weakening) in some spectral lines. A more detailed study of the distribution of magnetic knots, the magnetic field direction in them, the nature of the motion of matter and their relation with the chromospheric structure in H_α and Kl Ca II can be found in [2—8].

A number of papers [5, 6, 8, 9] deals with the discussion of spectral line weakening in neutral atoms with low excitation potentials due to temperature increases upto ~ 300° in the region of line formation. During the discussion of line weakening in the region of a strong field and the effect of this weakening on the results of magnetic field measurements in two spectral lines, one of which is very temperature sensitive and the other is not, a method was proposed to study the properties of fine-structured formations [10, 11] using a magnetograph aperture, well exceeding the typical dimensions of a fine magnetic field structure. Lines Fe I λ λ 5250 and 5233 are often used for this purpose.

The analysis is performed under the assumption of a simple magnetic field structure [11]. If a fraction of the solar surface A_f inside the given aperture is occupied by magnetic knots or filaments with a field intensity h_f, while the remaining part of the surface, $A_i = 1 - A_f$, contains the interfilamentary fields of an average intensity H_i, the true net field is recorded in line λ 5233, which is not temperature sensitive,

$$H_{5233} = A_f H_f + A_i H_i .$$

The contribution to the magnetic signal in line λ 5250 is diminished in the magnetic knots by the factor δ, because of the line weakening and, hence,

$$H_{5250} = \delta A_f H_f + A_i H_i .$$

Based on [11, 13, 14], one may assume H_i to be less than 2—3 g. For fields greater than 10 g the effect of the interfilamentary field on the mean magnetograph signal may then be neglected. If the observed value H_{5250} is to be plotted as a function of H_{5233}, the slope of the curve will equal to δ, which defines the line weakening and, consequently, the change of physical conditions in the atmosphere.

By means of this method, Howard and Stenflo [11] showed that more than 90% of the solar magnetic flux is associated with a fine magnetic field structure, the value δ is equal to 1.45 and that it decreases towards the limb. Similar results were obtained by Stenflo and Frazier [12] when analysing the magnetic field of the active region.

Of considerable interest is the problem of the behaviour of H_{5233}/H_{5250} during the appearance of a new active region in so far it yields additional information on the changes of the physical conditions in the fine photosphere structure when its evolution from the quiet to active region takes place.

The present paper deals particularly with this problem.

Observations and Data Processing

Using the Sayan Observatory magnetograph, a longitudinal magnetic field in lines Fe I λ 5250 ($g_{eff}=3$), Fe I λ 5233 ($g_{eff}=1.3$), as well as the continuum brightness were recorded simultaneously. The following observations were taken for the analysis:

(a) A quiet region in the centre of the solar disk $190'' \times 80''$ was observed on August 19, 1972 with a resolution of $4'' \times 2''$.

(b) A quiet region with the leading sunspot of the developed group N 72 (according to Bull. Solnechnye Dannye) was observed on June 20 and 23, 1972 with a resolution of $2'' \times 2''$.

(c) A region in which the sunspot group N 174 was developed. The latter appeared on the disk in the form of a group of pores with coordinates $\varphi = -11°.5$, $\lambda = -25°$ on June 21, 1972. To the evening of the same day the leading pore of the northern polarity started to develop into a small sunspot with a penumbra. Our first records of the magnetic field refer just to this moment.

On June 22 the penumbra of the leading sunspot increased, the number of pores increased and the group extended in longitude. In subsequent days the form of the group changed but little. Observations of the magnetic fields were carried out on June 21 (3 magnetograms), 22, and 23, 1972 (1 magnetogram) with a resolution of $4'' \times 2''$.

To compare the results of the fields observed in the two lines we have drawn the diagram H_{5250}—H_{5233}. The slope of the curve in the diagram defines the value δ. In order to avoid having to plot all the points (about 1000 points per 2 magnetograms) we have divided the group of points with the interval 5 g (for the quiet region 2.5 g) in H_{5250} and determined the mean value of H_{5233} and its mean square deviation for the points in each interval.

Results

(a) The ratio $\delta = H_{5250}/H_{5233}$ in the quiet and active regions. Figure 1 represents the diagram H_{5250}—H_{5233} for the quiet photosphere in the centre of the solar disk (Fig. 2) for the plage region around the leading sunspot of group N 172, and Figure 3 for the penumbra of the leading sunspot of the same sunspot group. The quantity δ for the indicated regions is equal to 0.4, 0.55, and 0.7, respec-

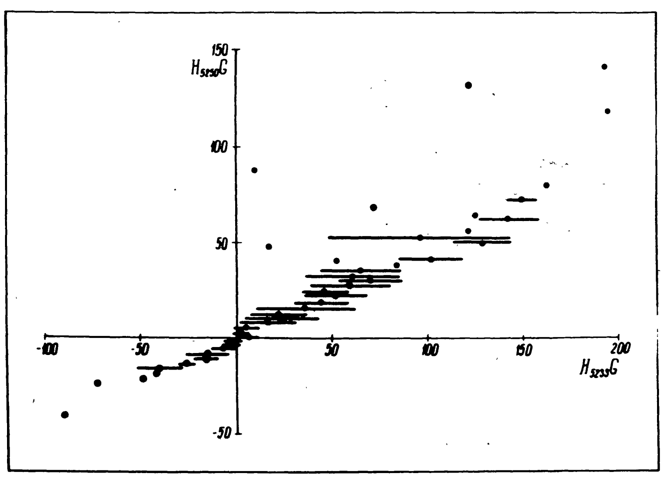


Fig. 1. H_{5250}—H_{5233} diagram for the quiet photosphere in the centre of the solar disk.

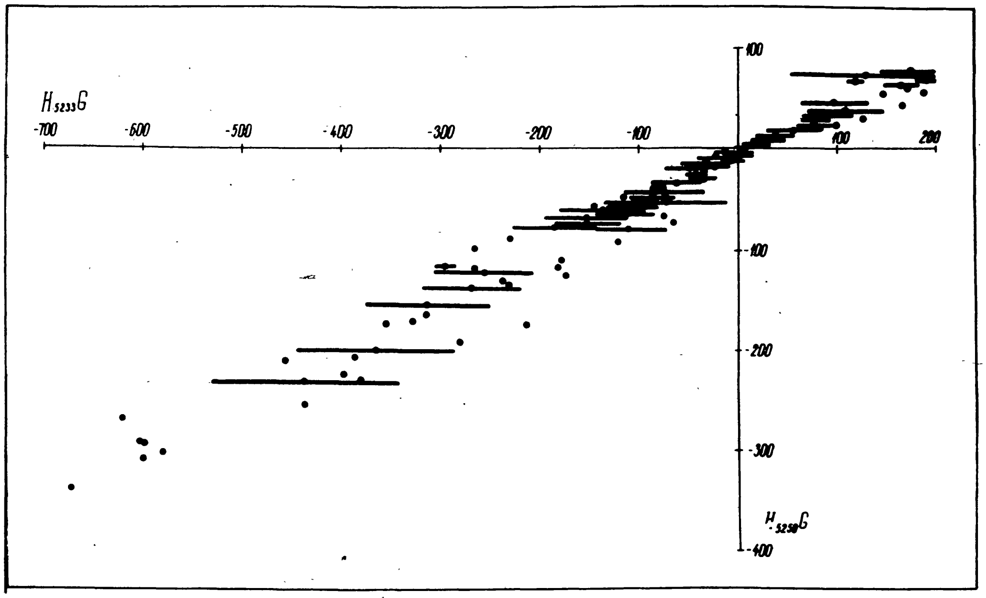


Fig. 2. The same diagram for the leading sunspot of group N 172 of the plage facular region on June 20, 1972.

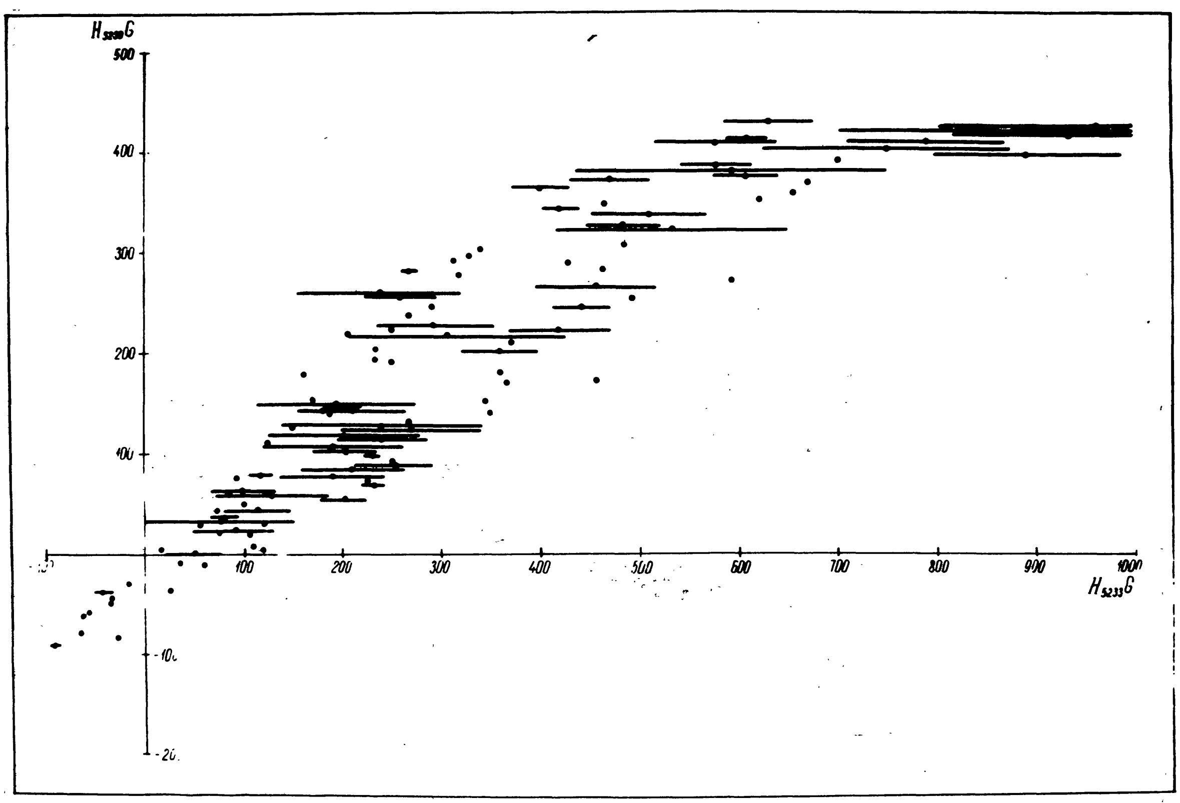
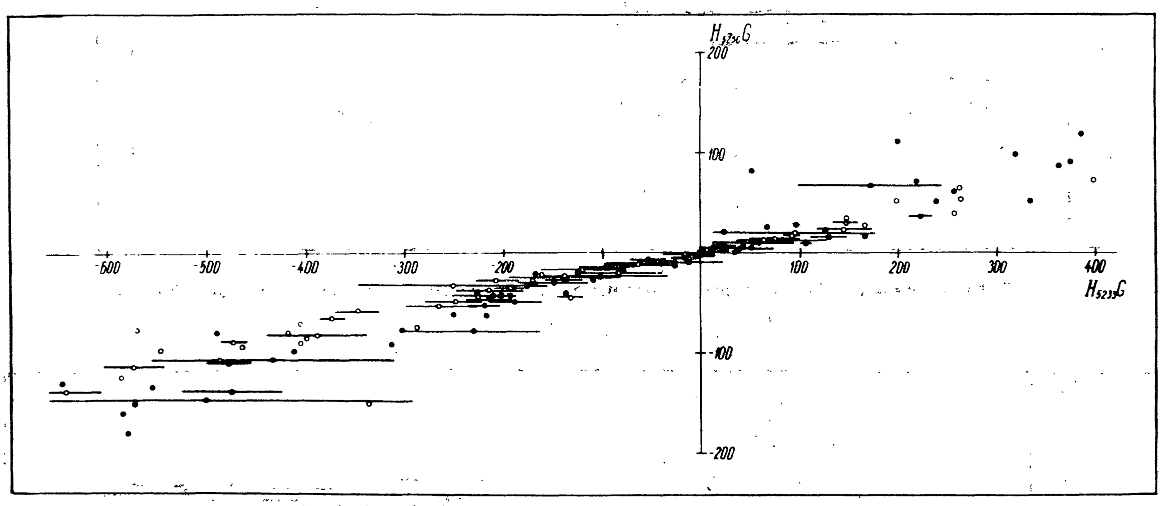


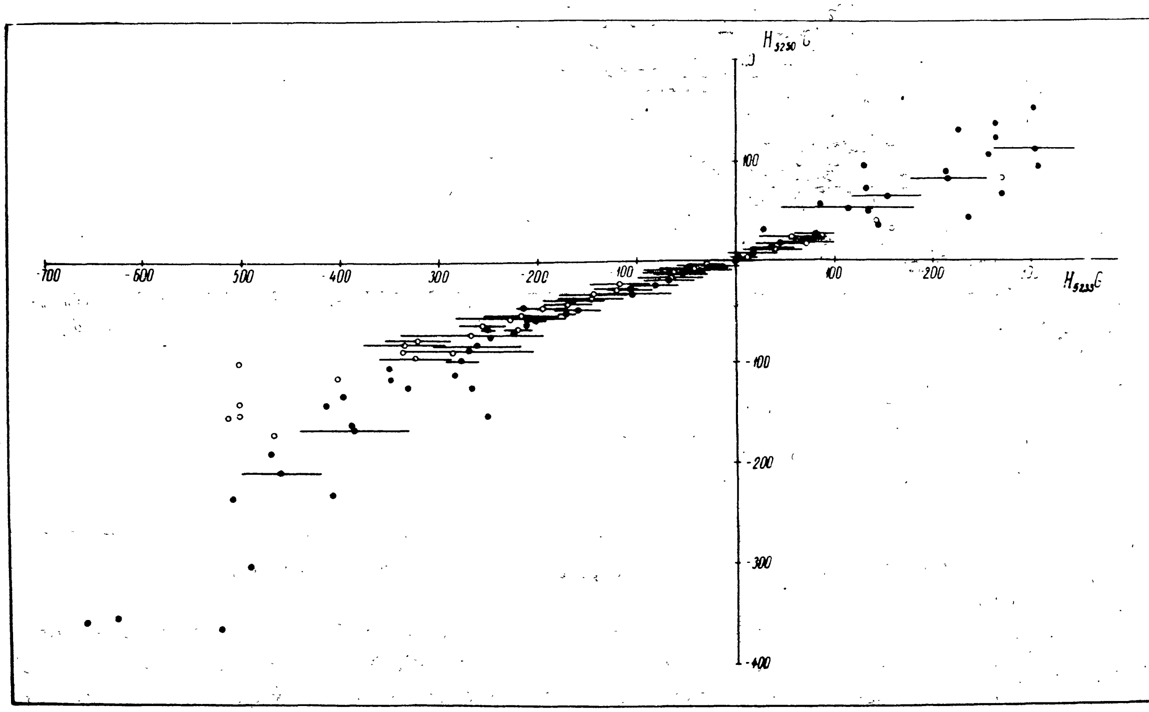
Fig. 3. The same for the leading sunspot penumbra of group N 172 on June 20, 1972.

tively. These results show that the properties of the magnetic knots or filaments, through which the solar magnetic flux passes, depend on the local physical conditions in the quiet and active regions.

(b) The ratio $\delta = H_{5250}/H_{5233}$ at the appearance of the new active region. Figures 4a,b,c show the diagrams of H_{5250}—H_{5233} in the region of appearance and development of group N 174 on June 21 (a), 22 (b), 23 (c), 1972. A comparison of the diagrams shows that the slope of the curve changes essentially during the evolution of the new active region. The value of δ is equal to 0.2 in the course of the 1st day of the appearance of the sunspot group on the disk, during the 2nd day it increased to 0.25 and during the third day to 0.55, a typical value for a developed sunspot group.

If the weakening if line λ 5250 in the magnetic knots is to be explained by the temperature increase in the region of its formation, the increase of δ from 0.2 to 0.55 at the early development stage of the active region indicates a temperature increase of less than 10% [9] in the upper photosphere ($\tau = 10^{-2}$—10^{-1}), when the magnetic field of a new region emerges from the subphotospheric layers.





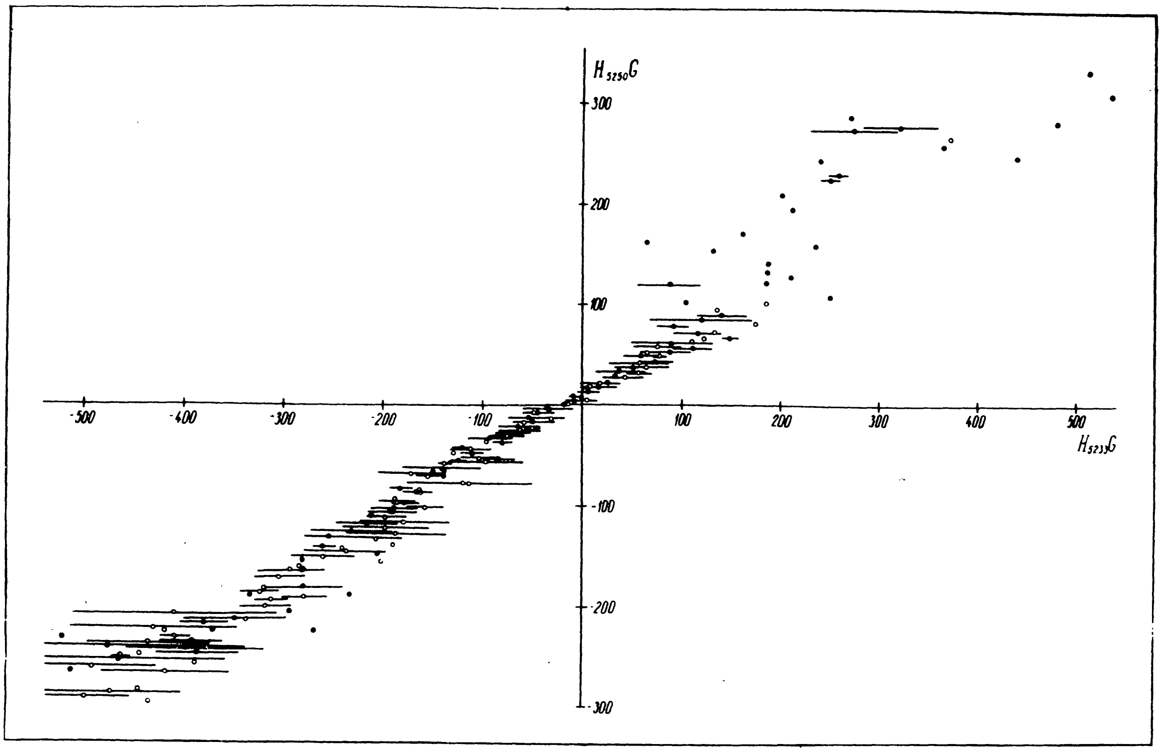


Fig. 4. H_{5250}—H_{5233} diagrams in the region of appearance and development of group N 174 on June (a) 21, (b) 22, and (c) 23, 1972.

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