PROPERTIES OF PHOTOSPHERIC FLUXTUBES DERIVED FROM MAGNETOGRAPH OBSERVATIONS

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ABSTRACT. Data from magnetograph observations, obtained in six Fe I and Mg I lines with the Crimean magnetograph with a spatial resolution of 1×1 and 1×2 arcsec have been interpreted using the line-ratio method and a two-component model with spatially unresolved fluxtubes and a background field. Magnetograph data obtained by other authors have also been taken into account. The magnetic field strength, its variation with distance from the fluxtube axis, the characteristics of the spectral line profiles, as well as other properties of the fluxtubes have been determined.

1. Introduction

The first important results in the study of the fine structure of solar magnetic fields were obtained by Severny (1957). Further investigations led to the picture of 'subtelescopic fluxtubes with kilogauss field strength', which are present over practically the whole surface of the Sun (e.g. Stenflo, 1973; Solanki and Stenflo, 1984; Rachkovskij and Tsap, 1985; Lozitskij and Tsap, 1989). Though these structures have been studied by many authors, the obtained results are still tentative. The main reason for this is the complexity of the indirect methods that have to be used because of the subtelescopic dimensions of the fluxtubes.

In the present paper we are making an analysis of our own magnetograph data, including the most important data of other authors, which are informative from the point of view of predicting the properties of small-scale fields.

2. Observations

The observations were made with the double-channel Crimean magnetograph at the center of the solar disk. The longitudinal component $H_{\parallel}$ of the magnetic field was recorded simultaneously in two of the following lines: Fe I 4808, 5233, 5250, 5253, 6302 Å, and Mg I 5184 Å. As a rule we used the Fe I 5253 line in one of the channels, and one of the other above-mentioned lines in the other. The exit slits were approximately the same, sampling a window of about 40–100 mÅ from the line centre (Lozitskij and Tsap, 1989). Besides,

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simultaneous observations of $H_{\|}$ were made in the Fe I 5250 line with different exit slits, at 10–34 and 68–94 mÅ from the line centre.

For the photospheric lines the measured strength H appeared to be increasing with equivalent width D (see Fig.1), which is in good agreement with the measurements of Gopasyuk (1985). With the Mg I line we have measured two ratios in two different regions near the central portion of the disk: $H_{\|}(5184)/H_{\|}(5253) = 1.50$ and 1.15. In the 5250 line we have found $H_{\|}(10-37)/H_{\|}(68-94) = 0.86$. We have analysed these data together with the results of Stenflo (1973) and Rachkovskij and Tsap (1985), obtained in the Fe I 5247 and 5250 lines with three different exit slits.

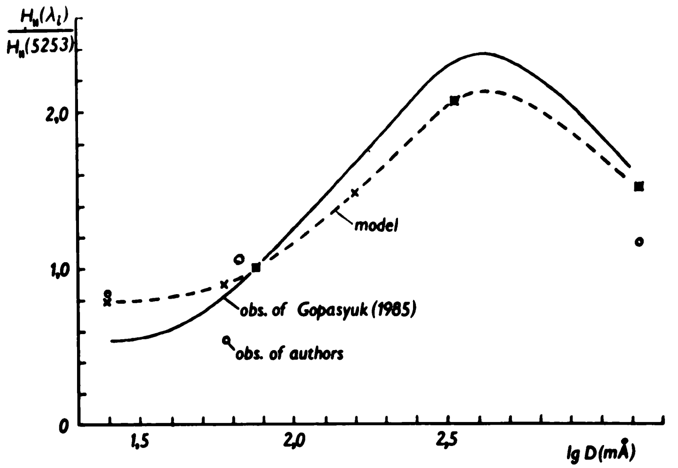

Figure 1. The field strength ratio $H_{\|}(\lambda_i)/H_{\|}(5253)$ vs. equivalent width D according to observations and model calculations.

3. Model

We have assumed that the magnetic field has two components: the fluxtubes, each of which having the same characteristics, and the background field. We also assume that the spectral line profiles of the background field are equal to those of the undisturbed atmosphere, while the line profiles in the fluxtubes might differ, both by width and shape. The Doppler shifts inside and outside the fluxtubes have been assumed to be the same. This last assumption has been well confirmed for the spatially resolved concentrations of magnetic flux (Fig.2), as well as for the subtelescopic fluxtubes (Stenflo et al., 1987).

4. Results of the computations

Good agreement between theory and observations was obtained when the magnetic field strength H_0 at the axis of the fluxtubes is assumed to be 2.2 kG at the level of formation of the Fe I 5250 line. The line profiles in the fluxtubes need to be 30–40 % narrower

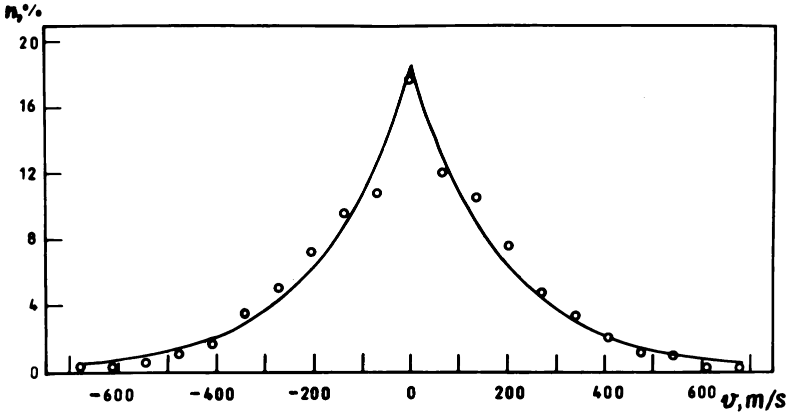

Figure 2. The line-of-sight velocity distribution in magnetic field concentrations, providing evidence that the convective motions in the magnetic elements are very small ($\lesssim 20$ m s^{-1}). The open circles represent the observations with a resolution of 1×1 arcsec, the solid line is an exponential curve fitting the observations (Tsap, 1989).

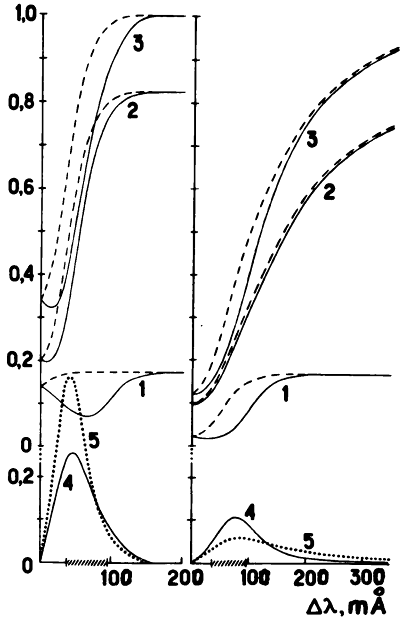

Figure 3. Variation with $\Delta\lambda$, the distance from line centre, of the model Stokes $I \pm V$ and V profiles for the line Fe I 5250 (left) and Fe I 5233 (right), assuming a filling factor of 17.5 % . 1: $I \pm V$ profiles from the fluxtubes; 2: analogous profiles from the background field; 3: total $I \pm V$ profiles (sum of components 1 and 2), which are directly accessible to observations; 4: Corresponding V profiles of the model; 5: V profiles in the case of a homogeneous field of 422 G, when the magnetic flux through the aperture is the same as in the two-component model. The shaded parts on the $\Delta\lambda$ axis show the positions of the exit slits of the magnetograph.

as compared with the undisturbed profiles and have weakened wings (Fig.3), which might indicate a decrease of the gas pressure. The magnetic profile of the fluxtubes, $H(x)$, has been represented by the expression $H(x) = H_0(1 - x^4)$, where x is the distance from the axis, in units of the fluxtube radius. This profile has practically the same shape as that found in pores (Steshenko, 1967). The total magnetic flux of the fluxtubes is 1.6 times larger than the flux of the background field.

The two empirical values $H_{\|}(5184)/H_{\|}(5253) = 1.50$ and 1.15 refer to two different situations at the level of the temperature minimum. The first value is expected for fluxtubes with small height divergence, whereas the second value (1.15) is very close to what would be expected for a homogeneous magnetic field (1.17). This may mean that in some cases the height divergence of the field lines is so rapid that the field becomes nearly homogeneous already at the level of the temperature minimum.

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