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Magnetic Field Structure in Sunspots

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Abstract.
The paper deals with some structural characteristics of sunspot magnetic fields.

In this paper, we discuss some results of the study of spatial characteristics of sunspots and surrounding active regions. The analysis is based on the longitudinal magnetic field data obtained with a new spectro-magnetograph attached to the IZMIRAN Tower Telescope (FeI 6103 A) (Kozhevatov *et al.*, 2002) and the data of the MSFC vector magnetograph (FeI 5250.2 A) downloaded through Internet. The corresponding active regions are: 27.11.2000, N08 E22; 16.07.2002, N18 E00; 19.11.2003, N03 E09; 23.10.2003, N10 W06 (two spots); 24.07.2004, N08 W10; 18.08.2002, S07 W03.

We have selected the largest spot in each group, and restricted our analysis to the area with the same field polarity as the spot.

The analysis comprises two stages.

Analysis of self-similarity. It can be demonstrated that the self-similar figures are the figures that only differ by the scale factor and form a straight line of the diagram $(2\log L, \log S)$ with the angular coefficient $k = 1.0$. The shape of the figure determines the free term in the expression $2\log L = k\log S + a_0$, where a_0 is the measure of jaggedness. Thus, the free term for a circle is equal to $\log 4\pi = 2.53$ and is greater for more complicated figures.

Figure 1a illustrates the summary diagram $(2\log L, \log S)$ based on the field intensity contour lines for 7 active regions plotted at 200 G steps in the range of 2200–400 G. One can see that the relationship under discussion is well represented by two straight lines, one corresponding to the $\log S$ range from 2 to 7.2 and another, from 7.2 to 9. Both lines have the angular coefficient close to unity (accurate to the 2nd decimal place), but differ in the free term. As shown by comparison with the photospheric brightness distribution on the respective maps, the first line approximately corresponds to the sunspot umbra, the transition to the second line occurs in the vicinity of the umbra–penumbra boundary, and the second line corresponds to the penumbra and ambient photosphere. One may suggest the existence of two families of self–similar contour lines, one corresponding to the umbra and inner penumbra and another, to the outer penumbra and photosphere. The free term for the first relation equals to 2.67, which is close to the value for an ellipse with the axial ratio 0.6. For the second relation, the free term is 3.35, which indicates to jaggedness of the field lines in the outer parts of the spot.

Fractal model. We have tried also to study the peculiarities of the sunspot magnetic structure in terms of the fractal models discussed previously in (Zelenyi & Milovanov, 1991; Milovanov & Zelenyi, 1993; Mogilevskii, 1994; Mogilevskii, 2001). These models represent the sunspot as a cluster of the magnetic flux tubes described by the fractal geometry. First, we have determined for all spots the length of the field lines and the areas they enclose in the range of the magnetic field intensities from 2200 to 400 G (at 200 G steps). Then, we plotted $2\log L$ versus $\log S$ for all field lines of a given intensity, no matter which sunspot or sunspot group they belonged to. All points for each intensity

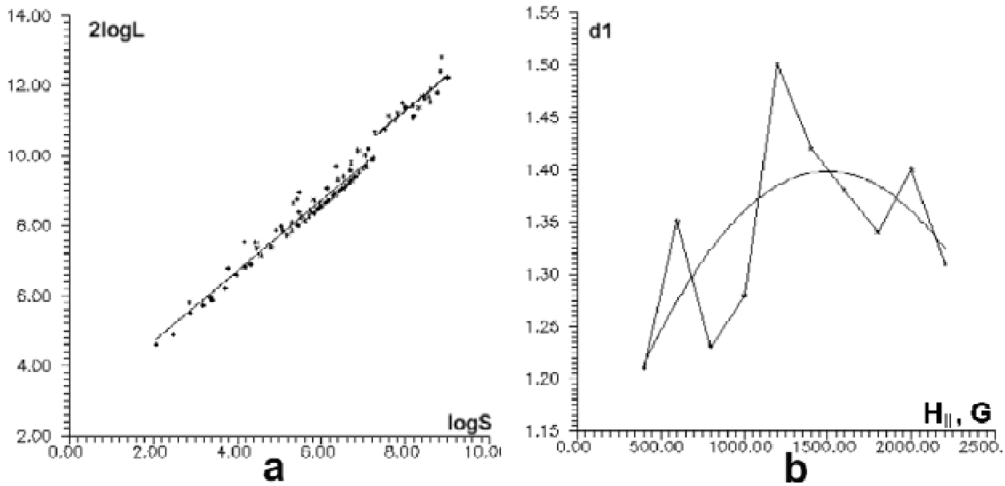

Figure 1.

value are well approximated by linear dependence. The angular coefficient d_1 of the latter is the so-called Hausdorff fractal number. A similar procedure was applied earlier to estimate the fractal dimension of clouds of different size and shape (Feder, 1988) and active regions (Meunier, 1999; Nesme–Ribes *et al.*, 1996; Balke *et al.*, 1993).

Figure 1b shows a plot of the fractal dimension versus magnetic field intensity based on calculations for all sunspots under consideration, as well as the second–order approximating polynomial. One can see that the fractal coefficient grows with the increase of intensity. The greatest value (close to 1.50) approximately corresponds to the umbra–penumbra interface. The value $d_1 = 1.50$ is close to the value obtained by Zelenyi & Milovanov, (1991) by a different method.

The particularities observed may either signify the appearance of a current system at the umbra–penumbra interface or a transition from one current system to another.

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References

Balke A.C., Schrijver C.J., Zwaan C., & Tarbell T.D. 1993 *Solar Phys.,* **143**, 215–227.

Feder J. 1988, *Fractals,* Plenum, New York.

Kozhevatov I.E., Rudenchik E.A., Cheragin N.P., Obridko V.N., & Kulikova E.H. 2002, *Instruments and Experimental Techniques,* **45,** No 1, 98–102.

Meunier N. 1999, *Ap. J.,* **515,** 801–811.

Milovanov A.V. & Zelenyi L.M. 1992 *Phys. Fluids,* **5(7),** 1406.

Mogilevskii E.I 1994, *Sov. Astron. Lett.,* **20,** N8, 607–612.

Mogilevskii E.I. 2001, *Fractals on the Sun,* Fizmatlit.

Nesme–Ribes E., Meuner N., & Collin D. 1996, *Astron. Astrophys.,* **308,** 213–218.

Zelenyi L.M. & Milovanov A.V. 1991, *Sov. Astron. Lett.,* **17,** 425.