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A Survey of the Size-flux Relation for Pores and Spots

W. Li, G. Ai, H. Wang

Beijing Astronomical Observatory, NAOCAS, A20 Datun Road, Chaoyang District, Beijing, 100012 China

Abstract. Using the vector magnetic field data from the Huairou Solar Observing Station of Beijing Astronomical Observatory, we study their size-flux relations for various magnetic elements identified as pores and spots. More than 725 pores and spots which located near the central meridian are selected. The power-law relationships for the mature sunspots are derived, and, there are different power-law relationships for the different magnetic elements. We also find that there are not evident relations between size and flux of the pores and protosunspots. Such the results may be useful for understanding the physical conditions and dynamical processes of magnetic flux tubes in the solar plasma during the sunspot's formation. In addition, their characteristic size is also given.

1. Introduction

As we know some time ago in a general way (Broxon J.W., 1942; Alfven H.,1950;) that the magnetic flux of solar magnetic elements increases with their size or lifetime. These studies cover large volumes of observational data, but assume a linear dependence between the quantities under consideration. A recent study (Semel & Skumanich, 1998) found that the total flux associated with a pore or sunspot is given by $\varphi =< fBz > \times A$, where A is the magnetic area of the feature and the vertical flux density ¡fBz¿ is itself an average over the sampled resolution volume.

A statistics study of the size-flux relation for photospheric magnetic features without any assumption is now possible given. We use observations with the Huairou Solar Observing Station (HSOS) of Beijing Astronomical Observatory, a high spatial and spectral resolution vector magnetic field data. We selected data here not only include mature sunspots, but also include protosunspot and pore. We studied not only their size-flux relations of pore, protosunspot and mature sunspot, but also studied that of the relations of umbra and penumbra of the mature sunspots. Such study may be useful for understanding the physical conditions and dynamical processes of magnetic flux tubes in the solar plasma during the sunspot's formation.

2. Observation and results

The observations presented here were obtained with the HSOS During poried of 1989 to 1996. Solar Magnetic Field Telescope (SMFT) in HSOS is a vector videomagnetogrph system (Ai and Hu, 1982). The photospheric line FeI5324$\AA$ is adopted in this system. The radiative transfer of the FeI 5324$\AA$ line in the magnetic field and its theoretical calibration were made by Ai, Li and Zhang (1986). We can get vector magnetograms and fieltergrams in the photosphere. The field of view is 5.2'×3.6'. Each CCD pixel corresponds to is about 0.7"× 0.5" on the solar surface.

The selected data in this paper were usually observed under rather good seeing conditions and they should be provided with a regular shape. Our study concentrated on data obtained between heliocentric longitude E25 -W25, so as to avoid the projection effect. More than 1000 pairs of sunspot's and pore's photospheric magnetograms and relevant white light images were analyzed. To match the real spatial resolution determined by atmospheric seeing, a 3×3 pixels smooth average was made before the flux measurments were made. The noise level after smoothing is around 10 gauss for the magnetograms with a spatial resolution of 2 arcsec. The area (in pixels) of various magnetic elements were defined using the observing white light image. An automatic identification algorithm was applied to the boundary of the element (pore, sunspot, umbra and penumbra). Then, from this we calculated their area and the relevant magnetic flux of them. Befor flux measurments, all pixels with flux density lower than 10 Gause were set to 0 Gause. The calculations were made with an interactive data language (IDL) procedure. Therefore, the measured flux in an element is unaffected by seeing, except for threshold effects.

Relationship between magnetic flux and area of various magnetic elements were shown in Figure 1. The solid line represents a linear fit. From Figure 1, we can see that: 1) The flux of pore ranges from 1.03×10^{19} to 9.85×10^{19} Mx. The area of pore ranges from 5.60×10^6 to $4.03{\times}10^7 km^2$. 2) The flux of mature sunspot magnetic element ranges from 1.01×10^{20} to 7.46×10^{22} Mx. The area of mature sunspot magnetic element ranges from 8.31×10^6 to $8.92{\times}10^9 km^2$. As we can see, in the mature sunspots the large the area, the large the flux, so that there is a dependence of flux on area. There exist some power-law relationships between the magnetic flux and area of sunspots (include penumbra and umbra). And, there are difference power-law relations for difference magnetic elements (shown in Table 1).

Table 1, Relationship Beetween Flux and Area

Magnetic element	Function
sunspots	$\log\Phi = 12.1660 + 1.09349 \log S$
Penumbra	$\log\Phi = 11.7934 + 1.13152 \log S$
umbra	$\log\Phi = 10.2041 + 1.38172 \log S$

where S is the area of the element in Km^2 and ϕ is the magnetic flux in Maxwell. When we calculated the flux and area of the elements, we found that there is a threshold of 1×10^{20} MX for the transition from a pore to a protospot (with a partial penumbra). And, there are not evident relations between size and flux of the pores and protosunspots. In the process, the distributions show three things; the decrease in continuum intensity of the 'dark' points, increase slight in area and slight intensification of the magnetic field. The flux increase observed in those magnetic elements are not simply along with the increasing in area, especially, the pores. This is in agreement with the results of Leka et al. (1998).

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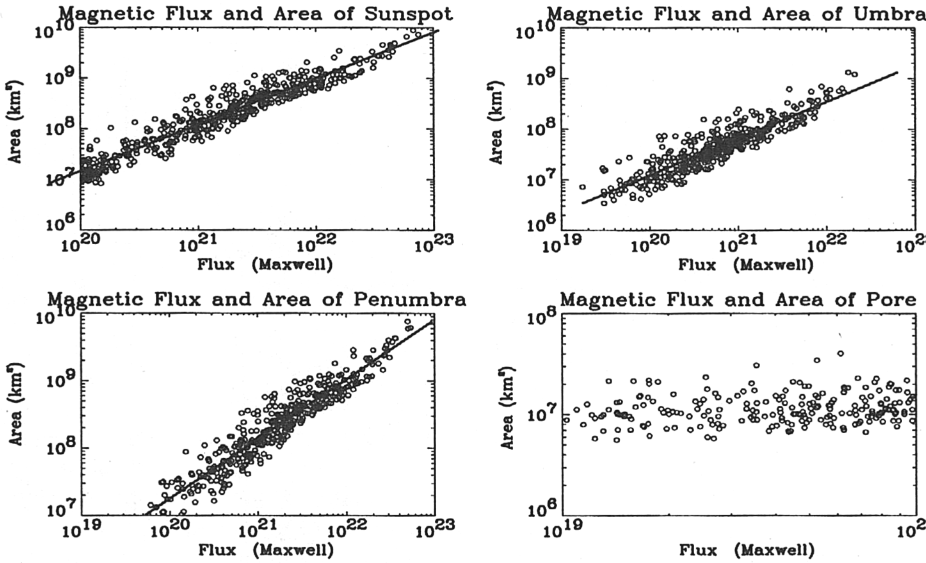

Figure 1. Relationship between magnetic flux and area of various elements.

Hence, the flux history of the pore growth and the pore-to-spot transition are not solely a function of the pore's size, but includes an intial intensification of pore itself magnetic fields and the "preumbral" magnetic feilds. We find that the umbral field strengths have been bracketed between 3676 and 400 G. Occasionaly field strengths larger than 3676 G have been measured, sometimes a few super sunspots even exceeding 4000 G. However, these high values appear to refer to only a small fraction of a sunspot umbra or penumbra. In small umbra and in pores, the field strengths between 1504 and 2507 G. The flux increase observed in those magnetic elements are not simply along with the increasing in area, especially, the pores.

The results show that the convergence level of the magnetic flux tubes in pore is larger than that of in umbra and the convergence level of the magnetic flux tubes in umbra is larger than that in penumbra. These may be explained by the buoyancy of the emerging flux tubes as well as the magnetic tension. The flux tubes not only rise but also spread during formation and evolution of the sunspot. This may also indicated that the field of pore (or umbra) is very nearly vertical, and the inclined magnetic fields appear in the penumbra.

References

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