OBSERVATIONAL EVIDENCE FOR QUANTIZATION IN PHOTOSPHERIC MAGNETIC FLUX*

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Abstract. Observations are presented which suggest that away from sunspots photospheric magnetic flux is quantized. Assuming the elemental area of a magnetic region to be 1 (arc-sec)^2 the elemental field strength is 525 G.

1. Introduction

The line profile of Fe I 5250.2 Å in the photosphere has been shown to be different in a magnetic region compared to the undisturbed disk (Chapman and Sheeley, 1968). This change of line profile is primarily a temperature effect, the magnetic region being hotter. Further, and most remarkable, this magnetic profile appears to be nearly constant and does not change appreciably over the observed range of field strength, $4 < H_z < 400$ G (Harvey and Livingston, 1969). The above facts lead to the deduction that magnetic regions must have a narrow range of temperature. Either of two physical conditions on the sun could explain these results: (1) The presence of a magnetic field causes an incremental rise in temperature, creating a temperature plateau independent of field strength, or (2) the temperature of a magnetic region depends on field strength, but all photospheric magnetic regions (outside of sunspots) possess the *same* field strength. In this note we consider observations intended to test the second hypothesis, that the field strengths are single-valued.

2. Observations

The Babcock-type magnetograph, which we use, measures not total field intensity but line-of-sight field intensity per area s of the input aperture, i.e. magnetic flux. Assume there exists some elemental flux unit having a strength h, and that these units are arrayed, say as tubes, perpendicular to the solar surface. Let n^+ and n^- be the number of such elements contained within s, the $+$ and $-$ indicating outward and inward flux, respectively. Then the magnetograph will give a signal H_z:

$$H_z = \frac{Nh}{s} \text{ G (aper. area)}^{-1} \quad \text{where} \quad N = |n^+ - n^-| = 1, 2, \ldots .$$

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For an observational test of magnetic field quantization the choice of entrance aperture size s is critical. If s is too large N will likely be $\gg 1$, a condition tending to mask any quantization. Also the extra light is a source of noise. If s is too small compared with the imaged size of h, some flux will be lost, again reducing any quantization. Some estimate of the size of h is already available. The best spectroheliograms taken by Sheeley (1969) in CN 3883 show brightness patches which are co-spatial with the photospheric magnetic fields. When distant from sunspots these patches typically break into dot-like areas 1–2 arc-sec in diameter. In addition, high resolution line-scans with the magnetograph indicate the size of magnetic elements to be 1–2 arc-sec (Livingston, 1968). Based on these considerations a $5'' \times 5''$ aperture was chosen.

Using the Fe I 5233 Å line, with the usual exit slits for this line, magnetograph recordings were made on June 5 and 6, 1969, near the center of the disk. The telescope was diaphragmed to 90 cm. The image was moved slowly across the $5'' \times 5''$ aperture until a magnetic feature was detected. This feature was then centered watching the magnetic signal (time constant = 0.1 sec) as a guide. Deflections were recorded for 30 sec – long enough to expect several moments where the seeing is $< 1''$. Then we moved along to the next encounter. Excluding certain selection effects the flux measurements were taken sequentially along a nearly spiral path. Natural selection arose because: (1) a lower limit to flux was set by the noise (5 $\text{G} \cdot \text{s}^{-1}$ peak-to-peak); (2) full scale on the recorder was set to 90 $\text{G} \cdot \text{s}^{-1}$, so that flux regions exceeding this value were ignored; and (3) if the region appeared bipolar, that is, if a small decentering caused a reversal of polarity, the region was skipped. In all 60 regions were studied on the two days.

3. Discussion of Results

Figure 1 is a histogram of the measurements. A definite clustering of the flux magnitudes is evident. A value of $h = 21$ $\text{G} \cdot \text{s}^{-1}$ and $N = 1, 2, 3$ to give $H_z = 21$, 42, and 63 $\text{G} \cdot \text{s}^{-1}$ is consistent with this data. Assuming the elemental area of h to be $(1'')^2$, the elemental field strength is $h = 5 \times 5 \times 21 = 525$ G.

Any random inclination of the fields or loss of flux beyond the $5''$ aperture caused by seeing or optical imperfections would skew the histogram toward lower flux values. Such an asymmetry is noticeable in the $N = 1$, 2, and 3 peaks (Fig. 1).

An indication of the significance of the results shown in the histogram has been obtained by comparison with a hypothetical distribution function of flux which declines linearly from $N = 5.3$ at 5 G to $N = 1$ at 100 G. A χ^2 test indicates that the probability that the observed distribution arose by random fluctuations from the hypothetical distribution is about 0.02. Therefore we might conclude that the results are significant in a statistical sense. However, more observations are needed to clearly confirm or reject quantization of photospheric magnetic flux.

We know that within newly born magnetic regions transverse fields are important and that a wide range of longitudinal field strengths have been detected (cf. Beckers and Schröter, 1968). There may be evolutionary significance that this evidence for quantization has been found far distant from such areas.

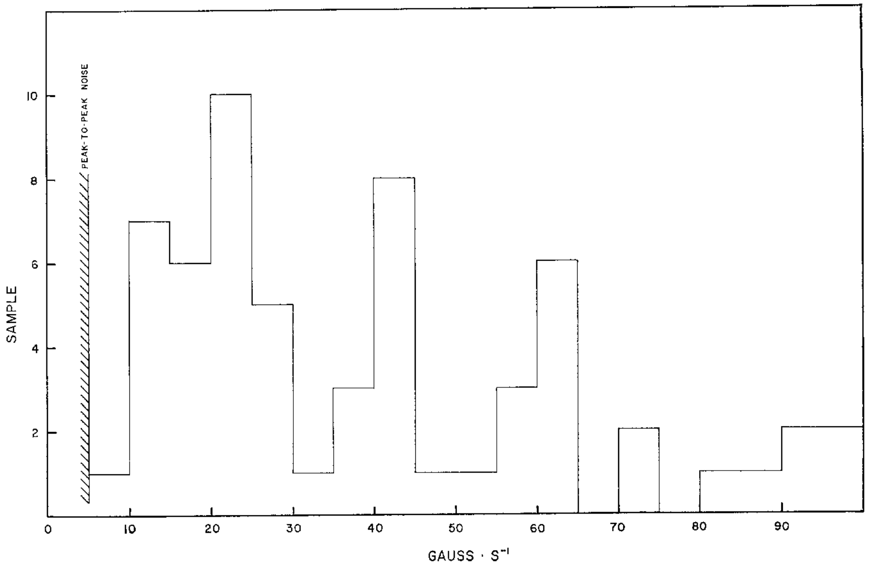

Fig. 1. Frequency distribution of flux measurements through a 5″ × 5″ aperture (*s*), at times of good seeing, and at the center of the disk, on June 5 and 6, 1969 combined.

References

Beckers, J. M. and Schröter, E. H.: 1968, *Solar Phys.* **4**, 142.
Chapman, G. A. and Sheeley, N. R., Jr.: 1968, *Solar Phys.* **5**, 442.
Harvey, J. and Livingston, W.: 1969, *Solar Phys.* **10**, 283.
Livingston, W.: 1968, *Astrophys. J.* **153**, 929.
Sheeley, N. R., Jr.: 1969, *Solar Phys.* **9**, 347, Figure 3.