Abstract. The deduction of magnetic fields from chromospheric structure is extended to active regions and transverse fields. Fields independently predicted by these rules from a high resolution Hα filtergram are compared with a high resolution magnetogram. The Hα method has the advantage over conventional magnetograms that it shows transverse fields and relates the fields to the real Sun. It has the disadvantage that higher spatial resolution is required and that it is difficult and time consuming in very complicated regions.

The response of the chromosphere to magnetic fields is most consistent. Vertical field is invariably marked by bright plage, with brightness roughly proportional to the field strength (except for sunspots). All dark fibrils mark transverse fields and are parallel to field lines. All polarity changes are marked by dark fibrils, which may be transverse fibrils perpendicular to the field boundary, or filaments (prominences) which connect more distant points, and in which the field lines run nearly parallel to the boundary. The asymmetry between preceding and following polarity found by Veeder and Zirin (1970) does not exist; it was due to the low resolution of the Mount Wilson magnetograms.

The complexity of active region field structure depends on the history of the region; all flux erupts in simple bipolar form, and lines of force remain connected to sibling spots until reconnection takes place. Thus the complex structure only occurs after eruption of several dipoles which reconnect. The phenomenon of ‘inverted polarity’ turns out to be due to the emergence of satellite bipolar fields, where the p spot merges with the rest of the p field and the f spot appears as an included f field. Flares usually occur when the field lines from f spot reconnect from its sibling to the main spot.

1. Introduction

It was shown by Veeder and Zirin (1970) that chromospheric morphology could be used to deduce the distribution of weak magnetic fields on the surface of the Sun. This work was limited by the resolution of the pictures with the five inch Caltech photoheliograph (2") and the Mt. Wilson daily magnetograms (17"). With improved 2" magnetograms from Aerospace Corporation and Kitt Peak the relations are more clear (Zirin, 1970a, b). For each improvement, a few pairs of filtergrams and magnetograms become a ‘Rosetta Stone’ to determine the relationships involved, which then can be applied to the millions of individual filtergrams to deduce the fields when no magnetograms were available.

In this paper we summarize relationships deduced from new high resolution Hα pictures and then test them by comparing the predicted magnetic field with a high resolution magnetogram. We then apply the method to understanding the structure and history of several active regions.

The value of comparison of Hα and magnetic fields lies beyond the simple production of magnetograms; it lies in the evaluation of the chromospheric morphology, in the understanding of the development of solar magnetic fields and in the possibility of the assessment of the physical structure of the different magnetic regions.
We find that the history of any field line plays an important role in its shape; until reconnection takes place, bipolar fields (and there are no monopolar fields on the Sun) remain connected by field lines, often over great distances. Because the Hα pictures enable us to evaluate the direction and strength of transverse fields, they enable us to trace some of these lines of force and infer others.

Our basic data are filtergrams from the Big Bear Solar Observatory, made with twin ten inch f/14 lenses, with secondary magnification to produce a solar image between three and six inches in diameter. With SO 392 film the modulation appears to be about 25% at 1 arc sec and 10% at one 1/2 arc sec (these are guesses). A new Halle filter using a contrast element of 0.7 Å (this change was proposed to Bernhard Halle Nachfl. by the author as a result of calculations of the optimum sideband suppression for a 1/2 Å filter; I am greatly indebted to them for carrying out this improvement) made possible greatly improved contrast in Hα; because the resolution depends on the contrast, the limiting resolution is improved. Thus two systems operate simultaneously in various pairs of wavelengths. The pictures are compared with longitudinal magnetograms; by added assumptions the vector field may be deduced.

The higher spatial resolution of the Big Bear pictures makes it possible to recognize the response of chromospheric fine structure to the governing magnetic fields. Since the identification of a chromospheric structure requires an association of several picture elements, the resolution possible is somewhat reduced by comparison with the magnetograph, which measures the Zeeman effect in a single point. We assume the magnetograms are always right and disagreements are due to poor deduction or incorrect rules.

2. Rules for Deduction of the Magnetic Field

To illustrate the rules which are a synthesis of previous and present work, we have used pictures taken October 11, 1970 of a fairly simple region, Mt. Wilson 18157 + 18161, marking numbers on Figure 1 (Hα) and 2 (Hα +0.5 Å) to indicate different features of interest.

A. Dominant preceding sunspots (lp, 2p) are identified by large size and well-developed penumbras. Of course, they normally precede, but there are occasional exceptions. Dominant following spots (lf) usually follow p spots, do not have well-developed penumbral structure, and are of course separated from the p spots by field transitions.

B. All regions of vertical field (3p and 3f) except sunspots are bright in Hα and have fine granular structure at ±1/2 Å. The brighter the plage, the greater the field strength.

C. Emerging flux regions (Weart and Zirin, 1969) or EFR are always marked by bright plage, crossed by dark arches (Bruzek, 1967) 5p and 5f mark an EFR arising in an existing f plage. The EFR’s are invariably symmetric and bipolar.

D. All regions of predominantly transverse field are dark. All dark fibrils are parallel to the magnetic lines of force. Older neutral lines (4) inside the active region are marked by what Prata (1971) calls field transition arches (FTA) parallel to field lines.