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A SYNTHESIZED METHOD FOR SOLVING THE 180° AMBIGUITY OF SOLAR TRANSVERSE MAGNETIC FIELD

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INTRODUCTION

The 180^o ambiguity of the transverse magnetic field measured by a heliomagnetograph is an intrinsic problem due to the linear polarization in Zeeman effect(Harvey, 1969). Thus we have to make use of some criteria for calibrating the transverse magnetic fields in vector magnetograms. Up to now, a few criteria have been suggested by some solar physicists(Harvey, 1969; Krall *et al.*, 1982; Sakurai *et al.*, 1985; Aly, 1989; Wu and Ai, 1990; Canfield *et al.*, 1991). The existing criteria could be classified as observational criteria and mathematical criteria. The former is based on the observation facts, such as the fibrils and the filaments in solar filtergrams, and the latter is derived from the mathematical model of solar magnetic field, such as divergence equation($\nabla \cdot \mathbf{B} = \mathbf{0}$), potential field model and force-free field model. These criteria, however, are not applicable to all solar active regions, especially to those with complicated magnetic fields. For this reason, we suggest a synthesized method for calibrating the transverse magnetic fields in solar vector magnetograms.

A SYNTHESIZED METHOD

According to our experience in processing observed vector magnetograms, we have found that the potential criterion (Sakurai *et al.*, 1985) and Krall's criterion, $\mathbf{B}_\perp \cdot \nabla B_{//} < 0$(Krall *et al.*, 1982), always lead to the same results in some areas of an active region when the transverse magnetic fields in vector magnetograms are calibrated, respectively, by them. Since the Krall's criterion can be derived from force-free field model (see J. Wang's invited report in this volume), the magnetic fields in those areas might be potential. For convenience, we call them the areas with certain transverse magnetic fields (CA), and similarly we can also name the areas where the two criteria lead to contradictory results as the areas with uncertain transverse fields (UA).

In order to determine the transverse magnetic fields in UA, we introduce an assumption that the force-free factors (α) at neighbouring points are close in value. Comparing the assumption with the potential field model ($\alpha = 0$) and the constant α force-free field model, we can call the assumption 'smooth α force-free field model'. According to this model, the α distributions in UA could be calculated by extrapolating from CA, and hence the transverse magnetic fields in UA could be determined as well.

Special computer softwares have been developed for execution of the method. These softwares can process the vector magnetograms quickly and reliably.

APPLICATION OF THE METHOD

We have obtained some examples which demonstrate the availability of the method, but we can not show them one by one due to the restriction on the length of the paper. Therefore we have to show one of them.

The observational data used here are the high resolution photospheric vector magnetograms (in FeI5324) obtained by the solar vector telescope magnetograph of Beijing Astronomical Observatory for the active region AR5988 on March 25, 1990 (S7, E10). The solar magnetograph has been described by Ai & Hu (1986) and Ming *et al.* (1988), and the calibration for the photospheric vector magnetograms was well established by Ai *et al.*(1982) and Zhang (1986). The measured vector magnetograms are shown in Figures 1-3.

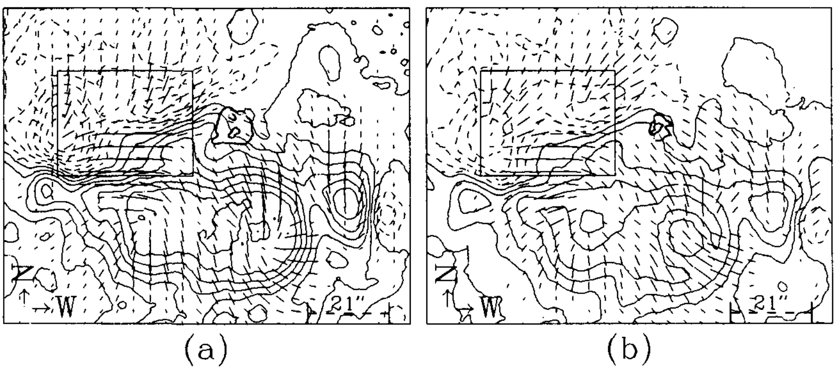

Fig. 1. The general information about the active region AR5988 on March 25, 1990. The field-of-view of the active region is about 105″×75″, and the size of the small window shown in this figure is 35″×25″. The solid and dotted contours indicate the areas of positive and negative polarities, respectively, for longitudinal field $B_{//}$. The contour levels are $\pm 50, \pm 250, \pm 450, \pm 650, \pm 850, \pm 1050$ and ± 1250 G. The bold contours indicate the H_β flare kernels. the bars represent the transverse field with 180° ambiguity. (a) The small flare was observed at 06:23UT, the longitudinal field was measured at 05:57UT on March 25, and the transverse field at 06:03UT (before the small flare). (b) The small flare was observed at 06:31UT, the longitudinal field was measured at 07:20UT on March 25, and the transverse field at 07:10UT (after the small flare).

Before the analyses for all of the vector magnetograms, a smoothed average of 3 × 4 square pixels which equals the practical resolution of 2″.1×2″ was made for improving the ratio of signal to noise and the position match between the longitudinal magnetograms and the transverse magnetograms was checked carefully.

The general information about the AR5988 on March 25, 1990 is shown in Figure 1. During the observation period on March 25, a small flare began at 06:11UT and ended at 06:31UT. Before and after the small flare, the vector magnetograms in Figure 1(a) and Figure 1(b) were measured.

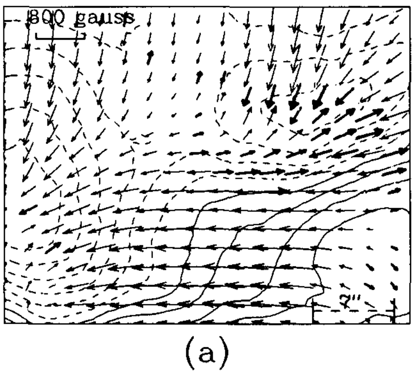

Fig. 2. Vector-magnetogram in the small window shown in Figure 1(a). The length and direction of arrows represent the strength and orientation of transverse field $B_{\perp}$. The areas with bold arrows are the UA and the others are the CA. (a) The directions of the bold arrows were determined by Krall's criterion, and hence they must be opposite to the directions determined by potential criterion. (b) The directions of the bold arrows were determined by 'smooth α force-free field model'.

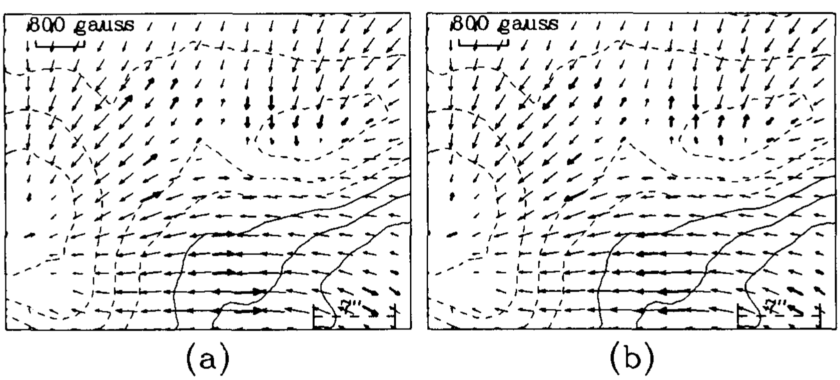

Fig. 3. Vector-magnetogram in the small window shown in Figure 1(b). The legends of this figure are the same as those in Figure 2.

From Figure 2 and Figure 3, we find the following facts: Some bold arrows in Figure 2(b) are consistent with those in Figure 2(a). It indicates that the 'smooth α force-free field model' supports Krall's criterion to a certain degree. On the other hand, most of bold arrows in Figure 3(b) are opposite to those in Figure 3(a). It means that the 'smooth α force-free field model' supports the potential criterion . In addition, the bold arrows in Figure 3 are not as numerous as those in Figure 2. It shows the UA in Figure 3 is smaller than that in Figure 2. The facts demonstrate the magnetic fields in Figure 2 are nonpotential and those in Figure 3 potential. Considering the vector magnetograms in Figure 2 and Figure 3 were measured, respectively, before and after the small flare, this result seems reasonable.

SUMMARY

This method contains two main steps:

(i)The transverse magnetic fields in observed magnetograms are calibrated respectively by means of potential criterion and Krall's criterion so as to find out CA and UA.

(ii)Assuming that the force-free factors (α) at neighbouring points are close in values, the distributions of α in the UA are obtained by extrapolating from the CA, and then the directions of the transverse fields in the UA are determined according to the right α.

The first step makes use of the advantages of the potential criterion and Krall's criterion ,and the second step can test whether the magnetic fields in the UA are potential or not.

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