Quantitative Comparison between the Polarization Data Taken with the Solar Flare Telescope and with the Hinode SOT Spectro-Polarimeter

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Abstract. The aim of this study is to establish the method to derive correct vector magnetic fields from imaging polarimetry data taken with the Solar Flare Telescope of the National Astronomical Observatory of Japan. We compared our imaging polarimetry data taken during 2006 December with the spectro-polarimetry data taken with the Hinode Solar Optical Telescope. While the polarization signals obtained with the two instruments are basically consistent to each other, we found some systematic differences between them, particularly in transverse magnetic field vectors.

1. Introduction

There are two principal methods for observing solar vector magnetic fields. One is filter-based imaging polarimetry and the other is spectropolarimetry. Magnetic field data obtained with these different methods have been compared extensively in the past. For example, Lites et al. (1994) compared vector magnetograms observed with a filter-based system and those obtained with the Advanced Stokes Polarimeter. They found substantial errors in the transverse field of plage regions measured with the filter magnetograph.

In this paper, we will present quantitative comparison of various characteristics in Stokes parameters obtained with the Solar Flare Telescope and those obtained with the spectropolarimeter of Hinode, and discuss the method to derive correct magnetic field vectors from imaging polarimetry data taken with the Solar Flare Telescope.

2. Data

The Solar Flare Telescope (SFT/MTK; Sakurai et al. 1995) is in operation at the Mitaka campus of the National Astronomical Observatory of Japan. Its polarimeter consists of a Lyot filter (FeI λ6302.5Å –80mÅ), a polarization modulator with two ferroelectric liquid crystals, and a high speed CCD camera which has 128 × 128 pixels (Hanaoka 2007). Stokes parameters are derived from integrated images (400fps × 2minutes). We
compared Stokes parameters taken with SFT/MTK with those taken with the high spatial resolution SpectroPolarimeter (SP) of the Solar Optical Telescope (SOT; Tsuneta et al. 2008) aboard Hinode (Kosugi et al. 2007).

Our target of the analysis is NOAA 10930 located at [S05, W08] on 2006 December 11. SP/SOT scanned the active region from 03:10:04 UT to 04:19:25 UT when SFT/MTK took 91 magnetograms.
Figure 2. Comparisons of the strengths (left) and the azimuth angles (right) of the transverse components obtained with SFT/MTK and SP/SOT.

3. Results

Firstly, we estimated the true observation wavelength of the SFT/MTK Lyot filter. We compared the SFT/MTK polarimetry data with 'simulated' Stokes maps based on the SP/SOT data. We synthesized the 'simulated' maps at various wavelengths around $-80\text{m}\AA$ of the FeI 6302.5Å line, namely the nominal wavelength of the Lyot filter, taking the filter transmission width ($1/8\text{Å}$) into consideration. The correlation between the SFT/MTK data and the synthesized data is maximized at $-49.8\text{m}\AA$. The left and middle columns of Figure 1 show the SFT/MTK Stokes maps and the maps synthesized from the SP/SOT Stokes data at the maximum correlation wavelength, 6302.451Å. Right panels show the correlation of Stokes parameters between SFT/MTK and SP/SOT. Figure 1 also gives the estimation for the scattered ligh in both of the instruments. We found that the ratios in intensity at the center of the sunspot to the surrounding region are 43.8% for SFT/MTK and 5.6% for SP/SOT, respectively. The images taken with SFT/MTK contain significant scattered light. Furthermore, from Figure1, we can confirm that there is no systematic trends in the linear fitting analysis. This means that the cross-talk effect from the circular polarization to the linear one is negligible in both instruments.

Next, we compared linear polarization signals measured with two instruments. Figure 2 shows comparisons of the field strengths and the azimuth angles derived from linear polarization signals. By adopting an appropriate calibration constant $C_T$, the transverse magnetic field strength is given by

$$B_T = C_T \left( \frac{Q^2}{I^2} + \frac{U^2}{I^2} \right)^{1/4}. \quad (1)$$

The azimuth angle $\theta$ of the transverse field is given by

$$\tan 2\theta = \frac{U}{Q}. \quad (2)$$
In Figure 2, the field strengths Eq.(1) with $C_T=1$ and azimuth angles from the two instruments are compared.

In Figure 3, the distributions of the linear polarization signals in the active region are compared. On the Stokes $V$ map taken with SP/SOT, the transverse magnetic field vectors obtained with SP are plotted with white arrows, and those obtained with SFT/MTK are overplotted with black arrows. Although the overall distributions of the azimuth vectors obtained with SFT/MTK and with SP/SOT are similar to each other, we can find that in some areas the azimuth angles show significant differences. In such areas, the azimuth angles obtained with SP/SOT seem to be nearly parallel to the thread-like structures seen in the $V$ map.

Figure 3. A map demonstrating the relationship of the transverse field components between SFT/MTK (black arrows) and SP/SOT (white arrows). The background picture is the Stokes $V$ map of SP/SOT.

4. Summary

We presented a quantitative comparison of various characteristics in the Stokes parameters obtained with SFT/MTK and with SP/SOT. The Stokes parameters observed with the two instruments generally show good coincidence, but we can find systematic differences in some areas similar to the results by Lites et al. (1994).

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