ON THE CALIBRATION OF LINE-OF-SIGHT MAGNETOGRAMS

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Abstract. Inference of magnetic fields from very high spatial, spectral, and temporal resolution polarized images is critical in understanding the physical processes that form and evolve fine scale structures in the solar atmosphere. Studying high spectral resolution data also helps in understanding the limits of lower resolution spectral data. We compare three different methods for calibrating the line-of-sight component of the magnetic field. Each method is tested for varying degrees of spectral resolution on both synthetic line profiles computed for known magnetic fields and real data. The methods evaluated are: (a) the differences in the center of gravity of the right and left circular components for different spectral resolution, (b) conversion of circular polarization, at particular wavelengths, to magnetic fields using model-dependent numerical solutions to the equations of polarized radiative transfer, and (c) the derivative method using the weak field approximation. Each method is applied to very high spatial and spectral resolution circular polarization images of an active region, acquired in the Fe I 5250 Å Zeeman-sensitive spectral line. The images were obtained using the 20 mÅ pass-band tunable filter at NSO/Sacramento Peak Observatory Vacuum Tower Telescope. We find that the center-of-gravity separation offers the best way of inferring the longitudinal magnetic field.

1. Introduction

Magnetic fields in the solar atmosphere have the remarkable ability to arrange themselves spatially into features ranging in size from large active regions (several arc min) down to small flux tubes (<0.3 arc sec). The strength of the magnetic field and the magnetic flux associated with these features play a crucial role in determining their characteristics and evolutionary properties. The concentration

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of field into flux tubes and its interaction with flow fields is now recognized as
the primary ingredient in atmospheric heating, flares, mass ejections, high speed
solar wind streams, and energetic particle acceleration. Many of the processes
responsible for field evolution occur on subarcsecond scales, and distinguishing
among them requires observations at very high spatial resolution. We must measure
the field strength as well as the motions at these subarcsecond scales in order to make
progress in modeling of the processes. To this end, a very narrow spectral bandpass
filter system has been developed for use in high spectral and spatial resolution
observations of the solar atmosphere (this system is described in Bonaccini and

When used to measure magnetic field, the filter is stepped through a Zeeman-
sensitive line in both states of circularly polarized light. Accurate conversion of
the polarization images to magnetic field measurements will play a crucial role in
developing an understanding of the role magnetic field plays in the Sun. Whether
the fields dominate or whether the atmospheric dynamics do, depends on the actual
strength and orientation of the field. Errors in determining the field can result in an
incorrect assessment of the physical processes in the atmosphere.

In addition to obtaining good quality observations, which in itself is a chal-
lenging problem, we must take extreme care in calibrating the polarization signals.
Several methods for converting polarization measurements into solar magnetic
fields have been discussed in the literature. These methods vary, depending on
the type of instrument used to measure the polarization and the application of
the field measurements. Instrumentation falls into two broad categories, full line
spectromagnetographs, which have high spectral resolution, but must be spatially
scanned to obtain a two-dimensional solar image (Lites et al., 1991; Jones et al.;
1992; Mickey, 1985), and imaging, filter magnetographs with continuous spatial
coverage, but poor spectral resolution (Hagyard et al., 1982; Zirin, 1985; Ai, 1987;
Makita, Hamana, and Nishi, 1985; Rust and O'Byrne, 1991; Lundstedt et al., 1991;
Title, Tarbell, and Topka, 1987). The advent of narrow-band filter systems holds
out the promise of combining the best features of both categories.

Calibration methods for line-of-sight magnetograms include (a) wavelength
separation of the center of gravity of the sigma components proportional to the
magnetic field (Rees and Semel, 1979), (b) conversion of the observed polarization
at a given wavelength in the spectral line, using model-dependent polarized radia-
tive transfer calculations to derive the magnetic field (Hagyard, Gary, and West,
1988), and (c) conversion of the observed polarization at a particular wavelength
in the line, using the derivative of the intensity profile in the weak field approxima-
tion (Landi Degl'Innocenti and Landi Del'Innocenti, 1973; Jefferies and Mickey,

This paper examines the influence of the calibration process in the determination
of line-of-sight magnetograms, using a narrow-band imaging system. The major
advantage of using a narrow-band system stems from its ability to step through the
line and measure a complete line profile. Although the points in the line are not