Stokes Profile Inversion and Comparison to Full-Resolution Data

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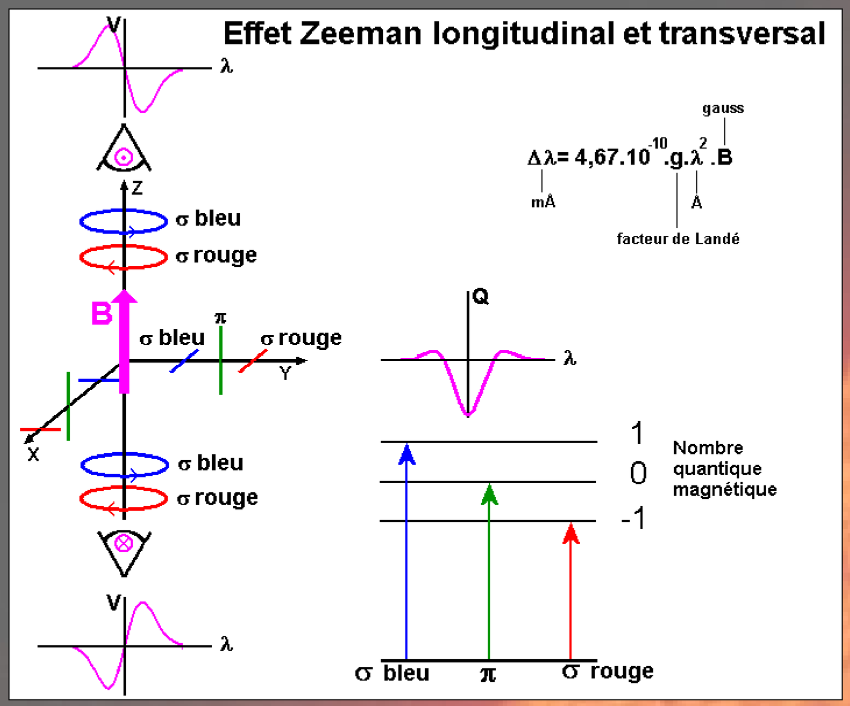
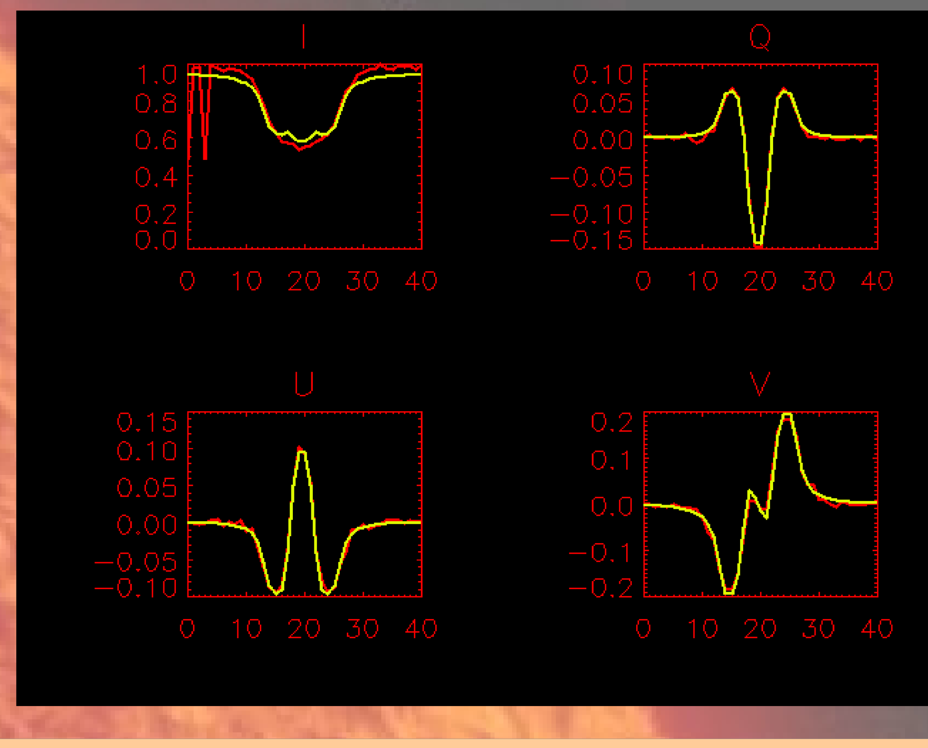


ChroMag is an imaging spectro-polarimeter that is being prepared for observation of the solar atmosphere at different heights. We simulated data from ChroMag by degrading data from Hinode's scanning spectro-polarimeter and then inverting it. Then, we compared the degraded, inverted parameters to those already calculated by Hinode. We found that the two inversion schemes and data resolutions yielded a linear relationship between Milne-Eddington parameters and that the best fit to Stokes profiles accurate to intensities <.01 the intensity of the I profile.

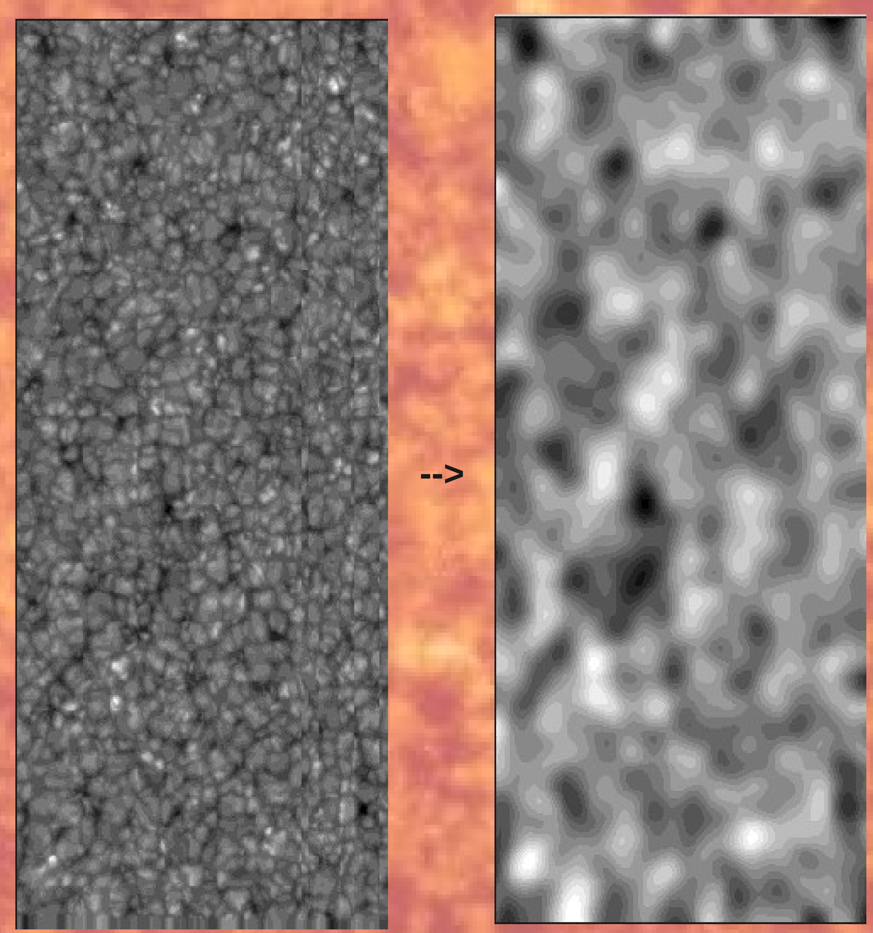
Stokes Profiles



Introduction

The desire to understand the magnetic field strength and orientation in the atmosphere of the sun originates in its being an indicator of present and future space weather and solar activity. The magnetic field allows more energy levels for electrons to occupy via the accessibility of nonzero magnetic quantum numbers (the Zeeman Effect) and polarizes light into four Stokes profiles: the intensity I, two linear polarizations Q and U, and one circular polarization V. These profiles also contain information about the solar atmosphere outside of the magnetic field vector, like line-of-sight velocity and stray light. Spectro-polarimeters are able to observe the spectrum of solar light as well as the Stokes profiles, which can then be inverted using inversion codes, such as the HEXIC program used here, to reveal the atmospheric parameters for a specific area, including the magnetic field vector. The Chromosphere and Prominence Magnetometer, ChroMag, is one of these spectro-polarimeters (2.2” resolution), which focuses on imaging.

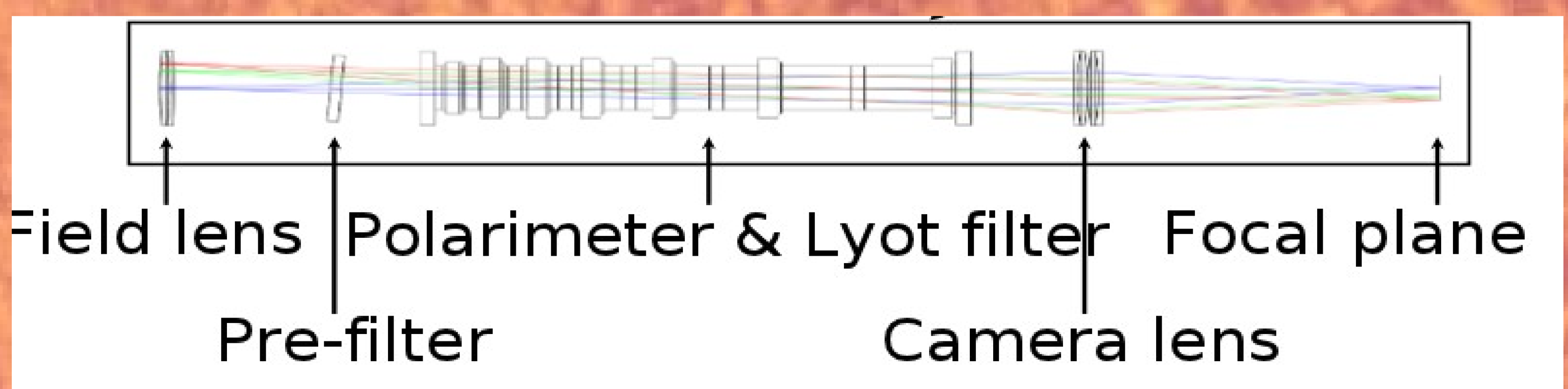
Image Degradation



Objective

ChroMag is not yet operational, but we want to know what it can detect and what it cannot in the solar atmosphere before we start collecting data. Some features that are visible in simulations and high-resolution images of the sun will be concealed by noise and the smoothing that lower resolutions cause. We also must investigate whether any Milne-Eddington parameters, variables that describe a simple solar atmosphere that are put out by the inversion process, would be distorted by the degradation process.

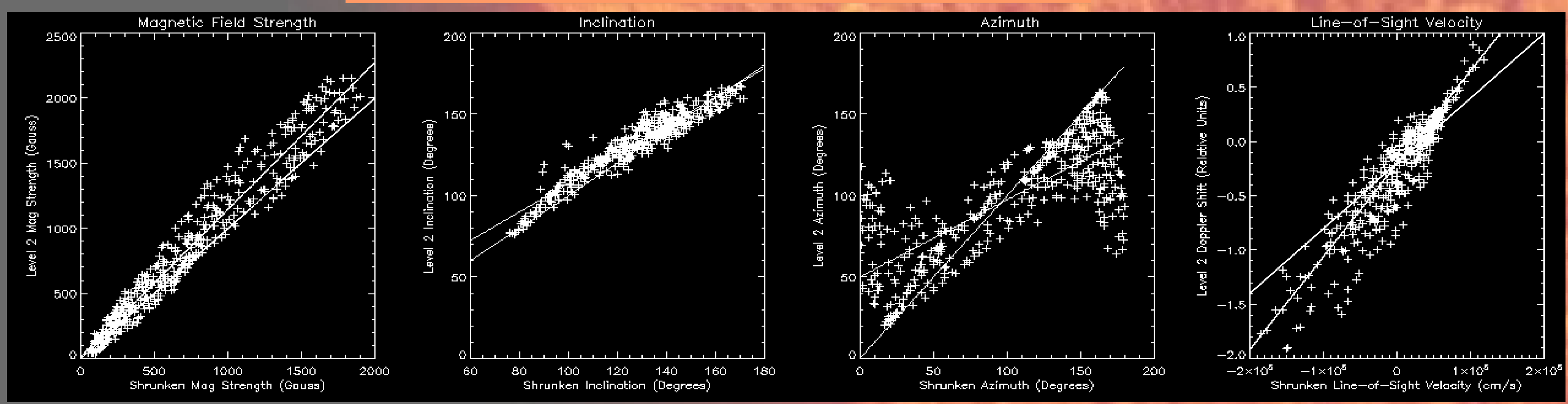
Optical ChroMag Apparatus



Methodology

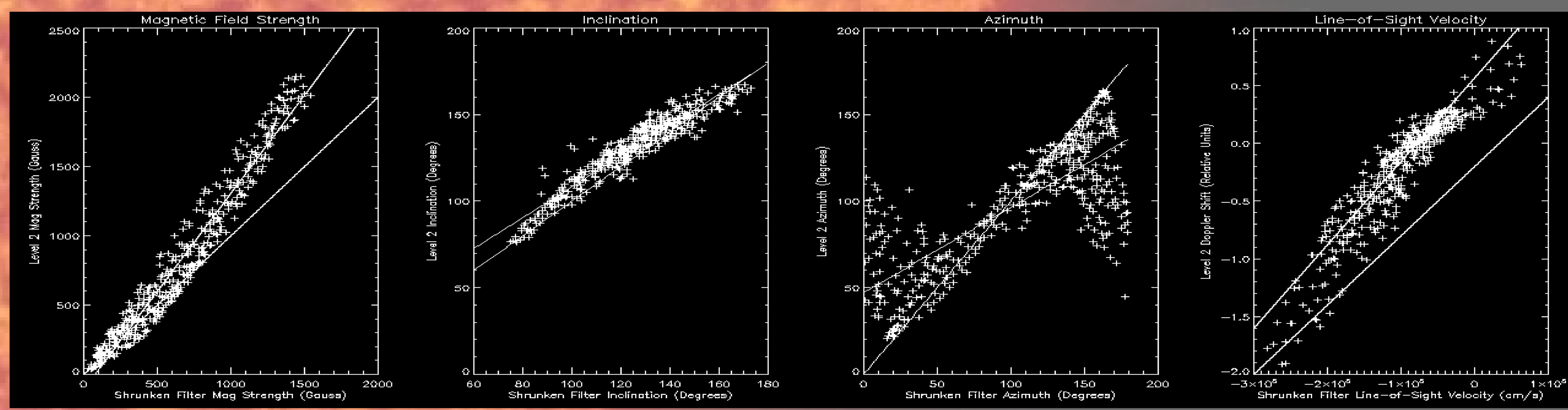
Therefore, we degraded full-resolution (.32”) sunspot data from the scanning spectro-polarimeter on Hinode, a joint JAXA/NASA mission, to the lower resolution of ChroMag. This raw, “Level 1” data from Hinode only had instrumental biases removed, and our HEXIC inversion code calculated the atmospheric parameters behind the shrunken and smoothed data. We compared this inverted data to the pre-analyzed Level 2 data of the same image. We were also able to simulate ChroMag’s set of filters so that a more complete filtergraph inversion could be performed.

Spectrograph Inversion Results Compared to Level 2 Data



Pearson Coefficients
.9772 .9496 .7584 .9057

Filtergraph Inversion Results Compared to Level 2 Data



Pearson Coefficients
.9759 .9465 .7742 .9297

Results

We have good linear correlation between the higher resolution, fully inverted Hinode data and our simulated, smoothed ChroMag data in terms of field strength, inclination, and line-of-sight velocity. There are, unfortunately, slight scaling factors in most of the Milne-Eddington parameters. The method of smoothing to create low-res data mixes the line profiles in areas larger than the pixel. In areas of low magnetic field strength, the Q and U profiles are difficult to resolve, resulting in a lack of correspondence between the shrunken data and the smoothed Level 2 data. Of course, granular features cannot be recognized with ChroMag's 2.2” resolution, but trends of magnetic field and Stokes profiles on a ~3 grain scale can be seen. The separate filtergraph and spectrograph inversions give similar correlation coefficients. An offset needs to be optimized to make sure that the line-of-sight velocities match up. They are relatively close at this point, but the accuracy can be improved.

Conclusion

ChroMag will not be able to detect much on the scale of granulation, but magnetic field strength vectors are well reproduced on a 1.1” pixel scale. HEXIC works well as an accurate inversion code, even if some small scaling factors need to be considered. In the future, stray light components need to be added into the calculation of the magnetic field strength. Overall, though, Milne-Eddington parameters are distorted only in the azimuth. The azimuthal ambiguity cannot be resolved at this point because of the nature of our averaging, but the scattershot nature of the correspondence might be improved by averaging the magnetic field vector at once rather than the parameters individually.

As for the Stokes profiles, they are accurate when they appear in a strong, coherent population, but low values for Q and U contribute to the noisy azimuth values.