A New Universal Polarization Resolving Software Package for Solar Coronal and Heliospheric Observations

Bryce M. Walbridge1,2, Matthew J. West2, J. Marcus Hughes2, Dan Seaton2, Chris Lowder2
1. Calvin University, 2. Southwest Research Institute
bmw39@students.calvin.edu

Background

A variety of different systems are used to characterize the degree of polarization of the visible solar corona, most prominently total brightness (B) and polarized brightness (pB). Such polarization observations allow us to analyze the background solar wind, the structure of coronal mass ejections, and their kinematics as they propagate through the heliosphere. In particular, the polarization properties of Thomson scattering yield information about the 3D location of dense features in the heliosphere. Many polarimetric instruments, such as the Solar Terrestrial Relations Observatory (STEREO) COR coronagraphs, use a symmetric three-polarizer measurement and representation system to derive the (B, pB) pair or Stokes parameters via polarization resolving software. However, only instrument-specific resolvers are available: no universal resolver exists in the commonly used Python environment. The upcoming Polarimeter to Unify the Corona and Heliosphere (PUNCH) NASA mission is one such set of instruments that will rely on a polarization resolver.

Overview

Here we present a universal, open-source polarization resolver developed in Python with the PUNCH mission in mind. This resolver can convert three-polarizer measurements to B and pB and vice versa. We show the potential of the package using existing data from the STEREO mission. We test the robustness of the resolver using synthetic, forward-modeled data with the dimensions and characteristics of the PUNCH datasets. The synthetic data is produced with different noise contributions to test the ability of the resolver to construct pB and B datasets under increasingly noisy conditions and assess when data is unusable. This polarization resolver shows promise to advance our understanding of the Sun and solar wind.

Figure 1: The four panels describe linear polarization analysis in a coronal context [2], see Overview for details.

Figure 1 shows, "(a) an object near the Sun has position angle α and polarization angle β. (b) Stokes Q and U describe polarization in the "+y" and "-y" directions relative to the instrument (or solar north). (c) pB and B are Stokes parameter analogs in the solar observing reference frame. (d) Observing polarization through three polarizers mutually separated by π/3 radians (M, Z, P) is sufficient to capture the polarization state (I, Q, U) or, equivalently, (B, pB, pB'). Although Thomson-scattered light is polarized in the B, direction, we show the polarization vector slightly misaligned, to emphasize the general case." [2].

How the Polarization Resolver Works

The polarization resolver has the potential to take in polarized data sets at different polarized angles. Then the resolver produces B and pB image pairs. These images are then combined producing the ratio pB/B. The resolver can also perform the inverse process, taking in pB and B data and producing polarized triplets. The ratio pB/B is used to calculate the 3-D location of coronal structures, see [1].

Figure 2: shows the resolver transforming a STEREO M, Z, P triplet into a B and pB pair before calculating pB/B.

Simulation of PUNCH Data

Using the FORWARD package [3] we generated realistic synthetic data (simulated coronal structure and eruption) in order to test the robustness of the resolver. Specifically, PUNCH-like Poisson noise was added to the synthetic data. Figure 3 shows clean and noisy synthetic data side by side.

Figure 3: shows pB clean and with noise; B clean and with noise, and the ratio pB/B, respectively. Each clean and noisy pair has the same color scale. "The pB image clearly emphasizes different aspects of the CME from the B image; but the ratio highlights the 3D structure." [1].

Conclusions

• The package works as expected, and converts polarized data triplets (M, Z, P) into B and pB pairs and vice versa.
• We tested the polarization resolver with real (STEREO coronagraph data), and synthetic data generated with the HAO FORWARD code [3].
• We have conducted initial tests of the resolver to see how it handles noisy data, specifically with added PUNCH-like, Poisson noise.

Future Work

• The polarization resolver will be used on PUNCH data post-launch.
• We will use the polarization to reproduce the results in [1], and use the elongation angle to determine the 3-D location of solar wind structures.
• We will explore the impact of noise on 3-D location measurements.

References & Acknowledgments

Work based on literature:
3. Gibson, S.E., et al., 2016 FrASS 3 8

Acknowledgements:
• Boulder Solar Alliance REU
• Southwest Research Institution
• National Science Foundation REU Award# 1950911
• PUNCH NASA Small Explorer mission, via NASA Contract No. 80GSFC18C0014
• FORWARD package [3]

LinkedIn | Literature 1 | Literature 2