PUNCH Polarization Resolver and the IMAX Effect

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Overview

The Polarimeter to Unify Corona and Heliosphere (PUNCH) will take white-light polarimetric observations of the outer solar corona and the heliosphere with a wide field of view (FOV) of ~90°. This is the widest polarimetric imager built to date. PUNCH science is based on the physics of Thomson scattering, which is used to derive 3D information about the corona and associated transients, while relating the dynamics from the outer corona to the heliosphere. An important aspect involves combining the observations taken at polarizer angles of -60°, 0° and +60°. Due to PUNCH's orbit, the polarization has to be resolved based on a continuously varying reference frame, and hence conventional measurements such as the Stokes parameters need to be modified accordingly. Moreover, the background star-field are polarized with respect to (w.r.t.) the celestial north pole. Hence, an efficient method/tool is required to separate the different polarization signals.

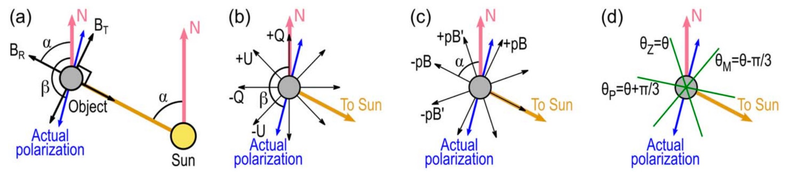


Figure 1: Linear polarization represented for solar corona (DeForest et al. 2022).

What is solpolpy?

The polarization resolver being developed for PUNCH is known as the *solar polarization resolver in python* (solpolpy). solpolpy is based on the mathematics described in DeForest et al. (2022) and describes the polarization in any arbitrary oriented frame of reference. solpolpy can resolve *between* many polarization bases: tangential (B_T) and radial (B_R); Stokes I, Q and U; total brightness (B) and polarized brightness (pB); degree of polarization; and polarization triplet (Minus, Zero, Plus: MZP) measurements (Figure 1).

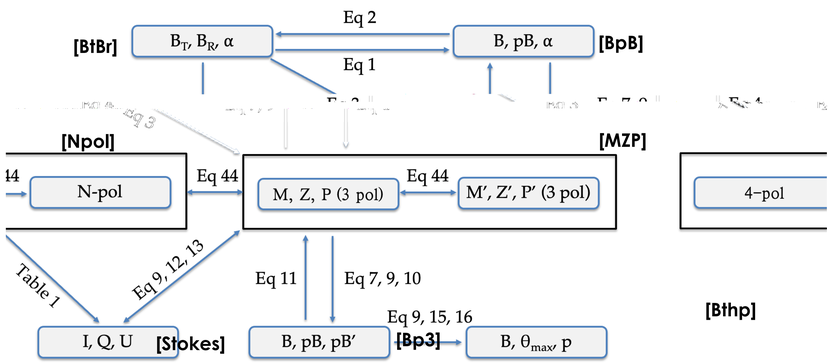


Figure 2: A flowchart of inter-convertible polarization states supported by solpolpy based on DeForest et al. (2022).

How does it work?

solpolpy is developed in python and the calling procedure of solpolpy is structured as:

```
import solpolpy
output = solpolpy.load(input FITS)
final_output = solpolpy.resolve(output, transform)
```

where the input parameter:'transform'is a polarization basis in string format supported by solpolpy, e.g., 'MZP'. All available bases are listed in square brackets adjacent to each box in Figure 2.

solpolpy features:

- Open-source python package
- Supports NDcube with WCS information
- Currently supports LASCO, and SECCHI data (e.g., Figure 3)
- Extendable to 4-pol system of KCor and SolO/Metis or any N-pol system
- Provide polarization w.r.t. any defined reference
- It will support upcoming missions: PUNCH, PROBA-3/ASPIICS

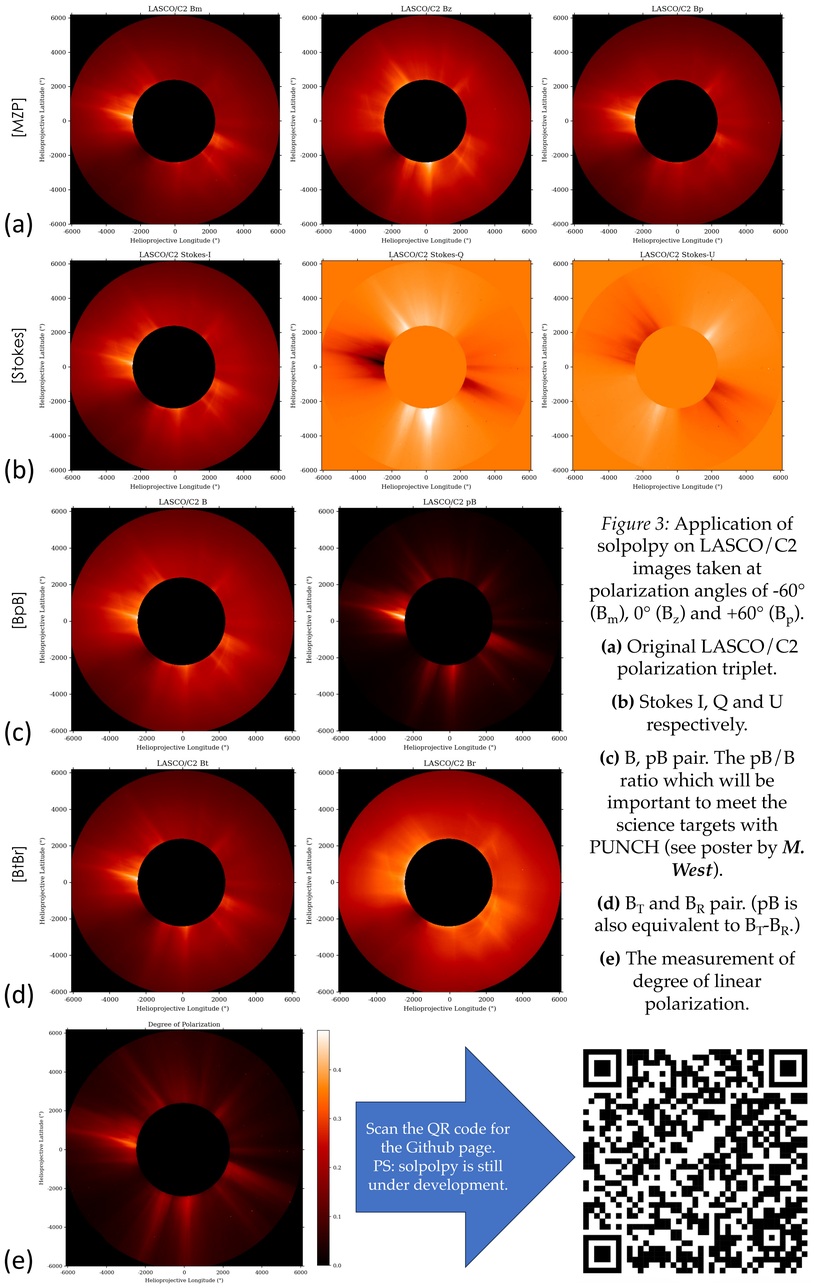


Figure 3: Application of solpolpy on LASCO/C2 images taken at polarization angles of -60° (B_m), 0° (B_z) and +60° (B_p).

(a) Original LASCO/C2 polarization triplet.

(b) Stokes I, Q and U respectively.

(c) B, pB pair. The pB/B ratio which will be important to meet the science targets with PUNCH (see poster by ***M. West***).

(d) B_T and B_R pair. (pB is also equivalent to B_T-B_R.)

(e) The measurement of degree of linear polarization.

Scan the QR code for the Github page.
PS: solpolpy is still under development.

IMAX Effect:

The wide FOV of PUNCH/WFI induces the challenge of resolving proper polarizing angles, which was identified in an IMAX 3D movie. The wide angular span of the FOV not only distorts the shape but also the inscribed angles viewed from different regions of the FOV. This becomes important for PUNCH due to its large FOV and the objective of measuring polarization in the heliosphere, where the anticipated signal is very faint as compared to the solar disk.

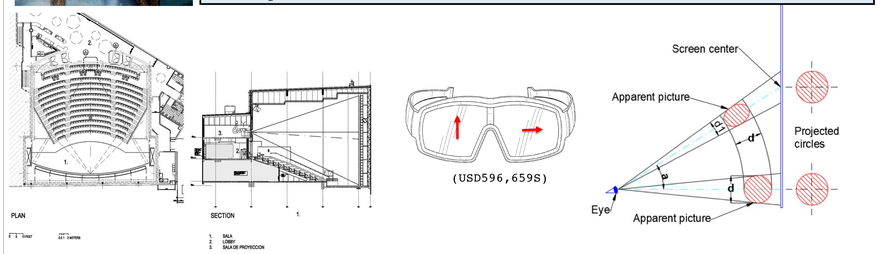
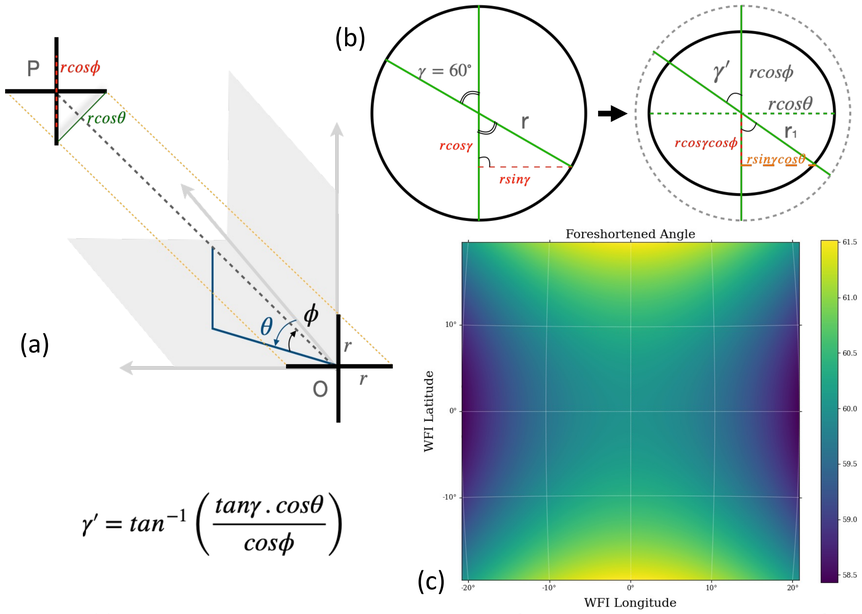


Figure 4: left: An example wide screen IMAX theatre, *middle:* Polarizer-based IMAX-3D glasses, *right:* Distortion of a circular image due to the wide viewing angle.



$$\gamma' = tan^{-1}\left(\frac{tan\gamma \,.\, cos\theta}{cos\phi}\right)$$

Figure 5: (a) Measurement of polarization angle variation within PUNCH/WFI FOV considering the orthographic projection. (b) Example circle (left) and projected ellipse (right), which affects the angle γ as a function of position (θ,φ). (c) Foreshortening of angle across the WFI FOV (originally all 60°) . The observed polarizer angle will vary by ~3°.

Summary & Future Work

The basic structure of the polarization resolver has been developed and tested for existing datasets of the LASCO and STEREO coronagraphs. Steps are being taken to implement the IMAX effect while resolving the polarization for PUNCH/WFI images. This will be integrated with the reprojection module to make composite mosaics so that the final PUNCH data products can be represented as a B, pB pair w.r.t solar north.

Reference: DeForest et al. (2022b) ApJ, 927, 1

For any queries and/or suggestions email me at ritesh.patel@swri.org