ON THE IMPORTANCE OF POLARIZATION IN HELIOSPHERIC IMAGERS

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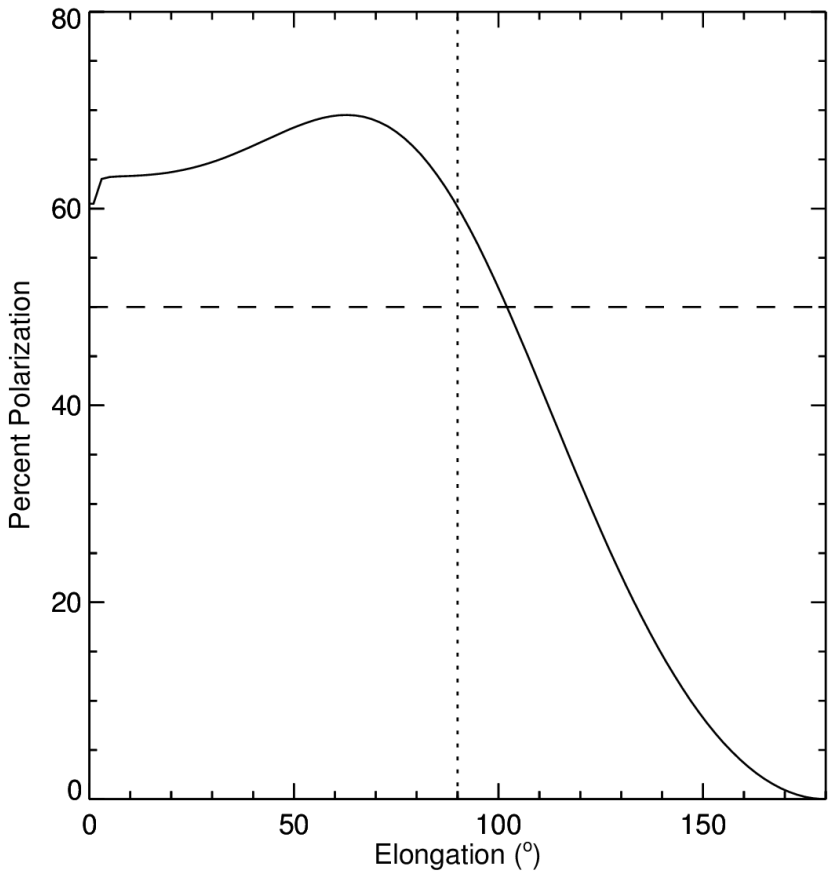
Introduction

- Heliospheric imagers, have been shown to be a powerful tool for tracking CMEs (and other solar wind structures) through the heliosphere.
- Hitherto they have only detected total intensity.
- Coronagraphs have had polarizers since the days of C/P on SMM and SOLWIND on P78-1.
  - This capability has tended to be underused. Mainly because of low cadence.

Polarization at Large Elongations.



- High degree of polarization of Thomson-scattered light to well past 90°.
- Current imagers are not noise-limited. Has been shown that exposures ≤10min would still give adequate signal to noise (c.f. HI-2 at 80 min).

What does polarization provide?

- Depth perception, since the scattering function for polarized brightness is much more peaked towards the Thomson sphere than for total brightness.
  - For coronagraphs there is still a fore-and-aft ambiguity.
  - For wide-angle imagers this can be resolved if the CME can be tracked.
- Also can be used to reduce background, but less useful.

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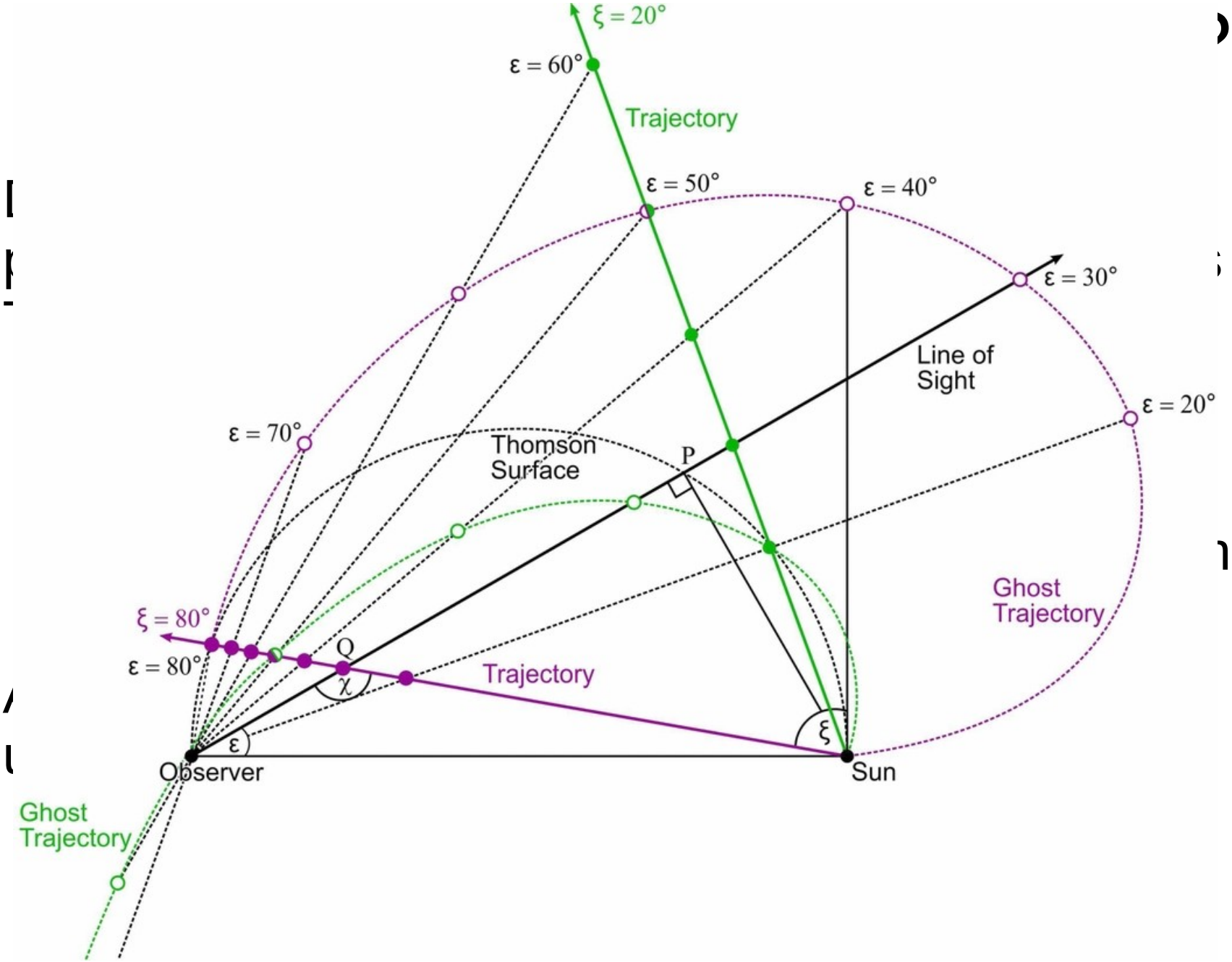
ξ = 20°
ε = 60°
Trajectory
ε = 50°
ε = 40°
ε = 30°
Line of
Sight
ε = 20°
ε = 70°
Thomson
Surface
P
ξ = 80°
ε = 80°
Q
χ
Trajectory
Ghost
Trajectory
ε
ξ
Observer
Sun
Ghost
Trajectory

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Where

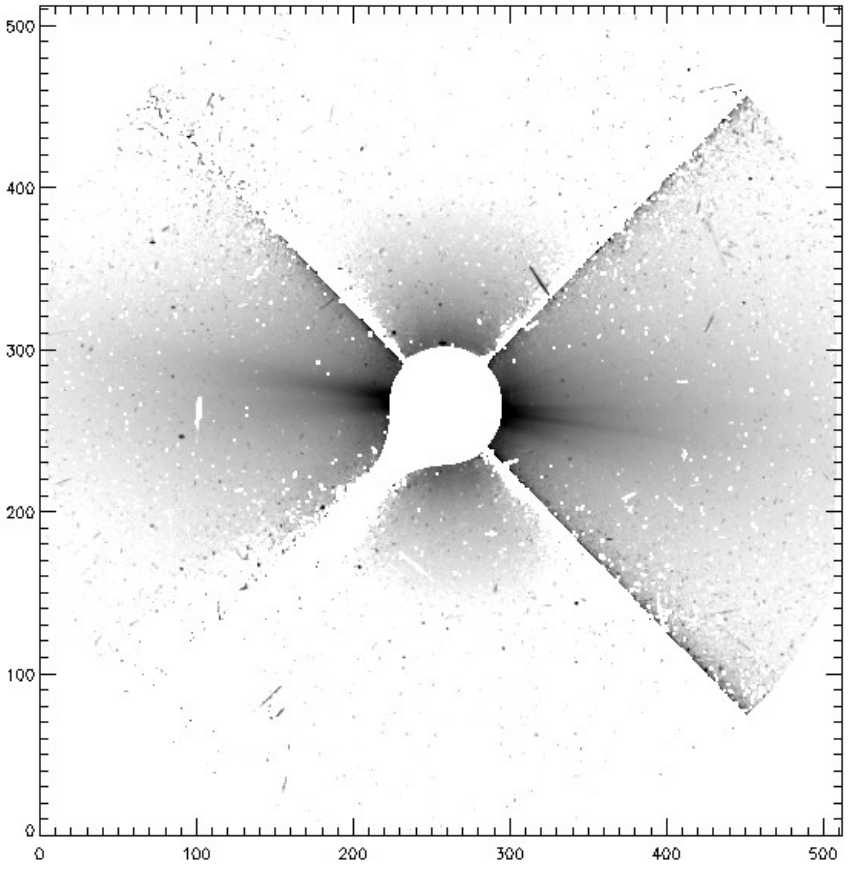
- Need to get polarized images where the difference between the real and “ghost” trajectories is largest.
  - This means at large elongations. So for a system comparable to the STEREO HI instruments, it is the HI-2 instrument that needs the capability.
  - **Advantage**: The HI-2 location means that any potential stray-light compromise will be much less important.
  - **Disadvantage**: There isn't much room in the current HI-2 design, and any other design will still have small-aperture fast optics, thus the optical assembly will be small.
  - **Disadvantage**: There are fewer photons at large elongations.

How to measure it.

- We would like to measure the radial and tangential components of the intensity.
  - Since we have a large field of view, this cannot be done directly.
- We therefore measure a number of linearly polarized components and combine them.
- 3 independent values are needed for an absolute determination.
- 2 can in principle be used if we assume that the polarization is always tangential.

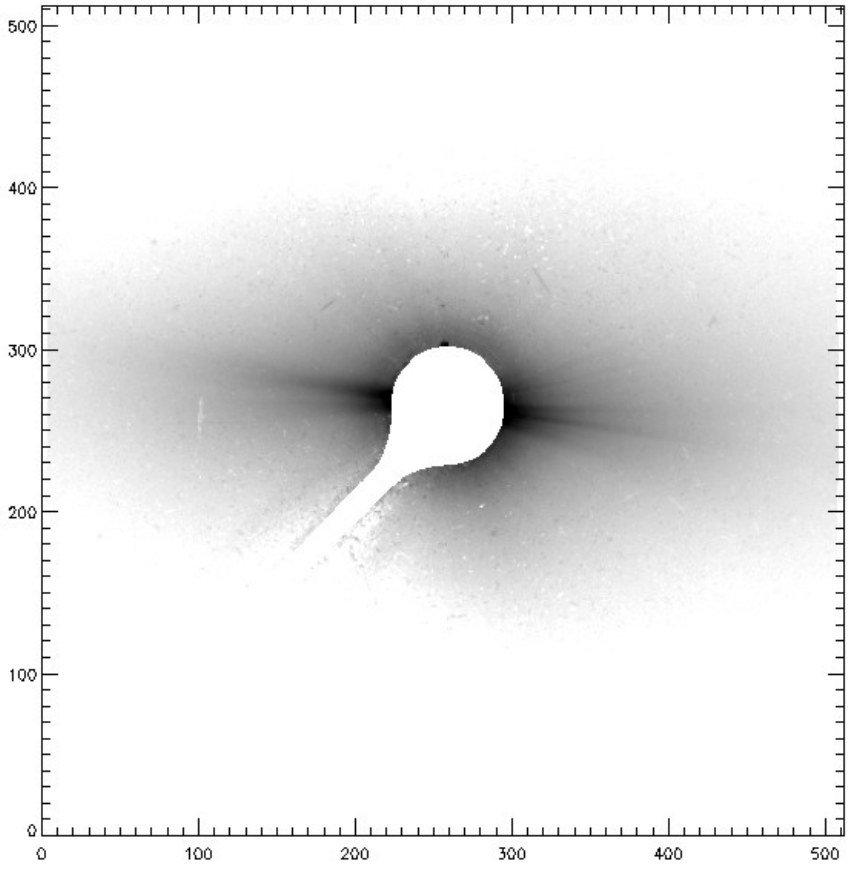
2 components

- Relies on assumption that polarization direction is strictly tangential.
- Singularity where direction is along a bisector of the angles between the polarizer axes.



3 Components

- Can use 3 different directions (0°, ±60°).
- Or: 2 directions and an unpolarized image (but 0°, 90° and clear does not work).
  - This is what LASCO C3 has done since the “vacation” as the 0° polarizer was damaged.

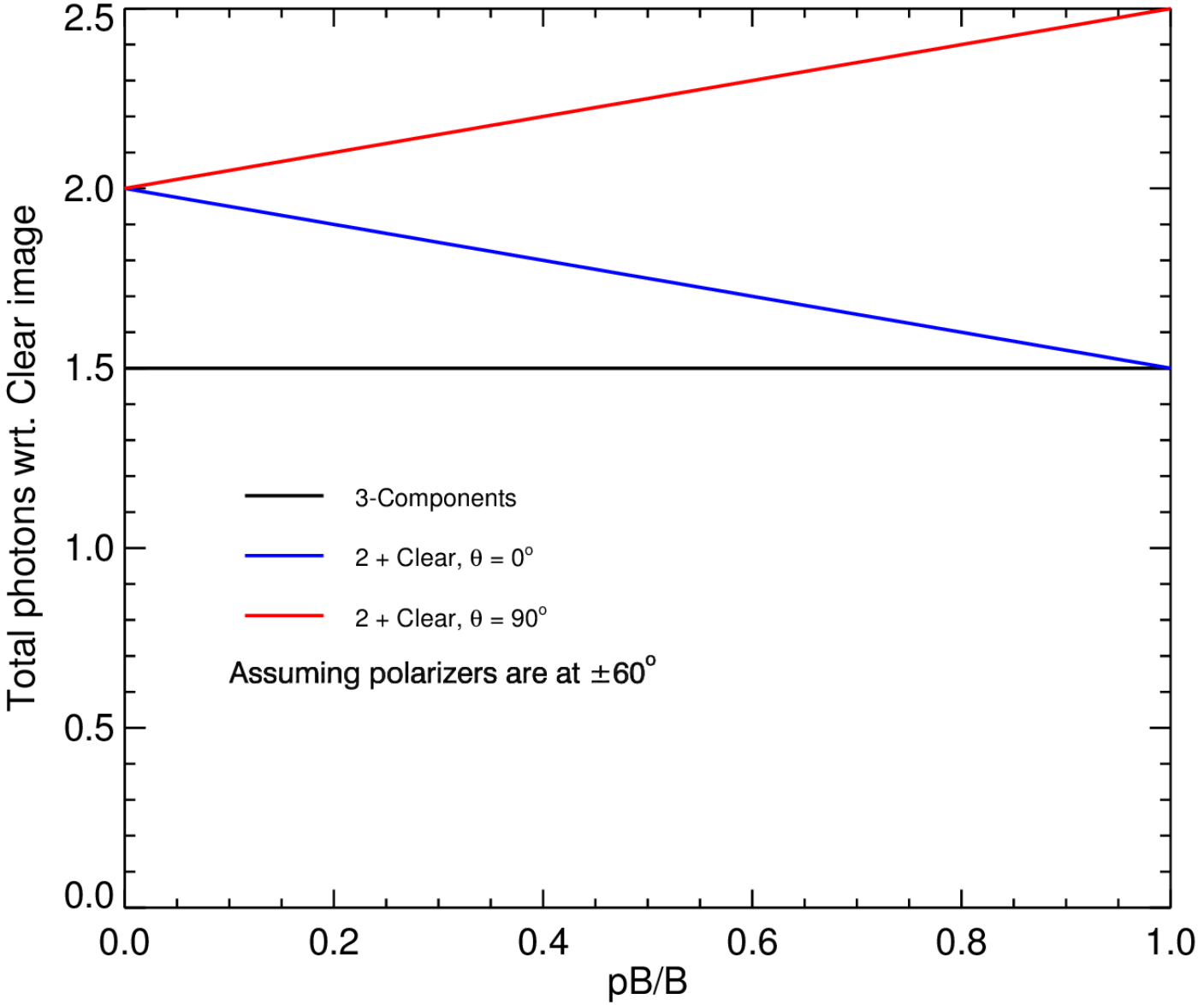


2+Clear vs. 3 Directions

- 2 + Clear
  - Requires a filter wheel assembly (as in LASCO).
    - Must calibrate the transmission of the polarizer accurately.
    - Takes up space off the optical axis.
  - More photons.
    - Not uniform wrt. polarization direction, or degree of polarization.
- 3 Directions
  - Can use a single rotating filter (as in the STEREO CORs).
    - Easier to calibrate
    - Easier to fit into the confined space of a wide-angle heliospheric imager.
  - Fewer photons
    - Uniform wrt. polarization direction, and degree of polarization.

2 + Clear vs. 2 Directions

- 2 +



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Other possibilities

- 4-directions (0°,±45°,90°) .
  - Gives redundancy, but at a cost of photons/image.
  - Might be useful in a LEO environment.
- 3-directions + clear.
  - Used on LASCO (C3 only up to “vacation”).
  - Provides redundancy, but has the engineering and calibration concerns of 2+clear.

Observing scheme

- A STEREO-HI like method of taking many short-exposure images and summing on board is needed to allow cosmic ray removal and to manage the dynamic range.
- On HI-2, motion blur is a significant issue (and I think, the major problem for the use of HI-2 data).
  - Want to maximize exposure integration, while minimizing duration, i.e. minimize the dead time.
    - A frame-store CCD should help reduce the dead-time between exposures.
    - If telemetry is a limitation, then better to have gaps than to extend the exposure.
  - Also need to interleave the polarizations, otherwise the structures will have moved significantly between polarizations.

Summary

- Polarization measurements would enhance the capability of a future heliospheric imager.
- 3 directions (0°, ±60°) provides the best quality of image.
- Most important in a large-elongation instrument where the front-back ambiguity can be resolved best.
- Need to interleave short exposures. Should be flexible to find the optimum exposure time to trade-off between signal/noise and motion blur.
- Much easier to do in an L5 “sit & stare” instrument than a LEO scanner.