

Packing a PUNCH: Wide-Field Polarimetry of the Heliosphere

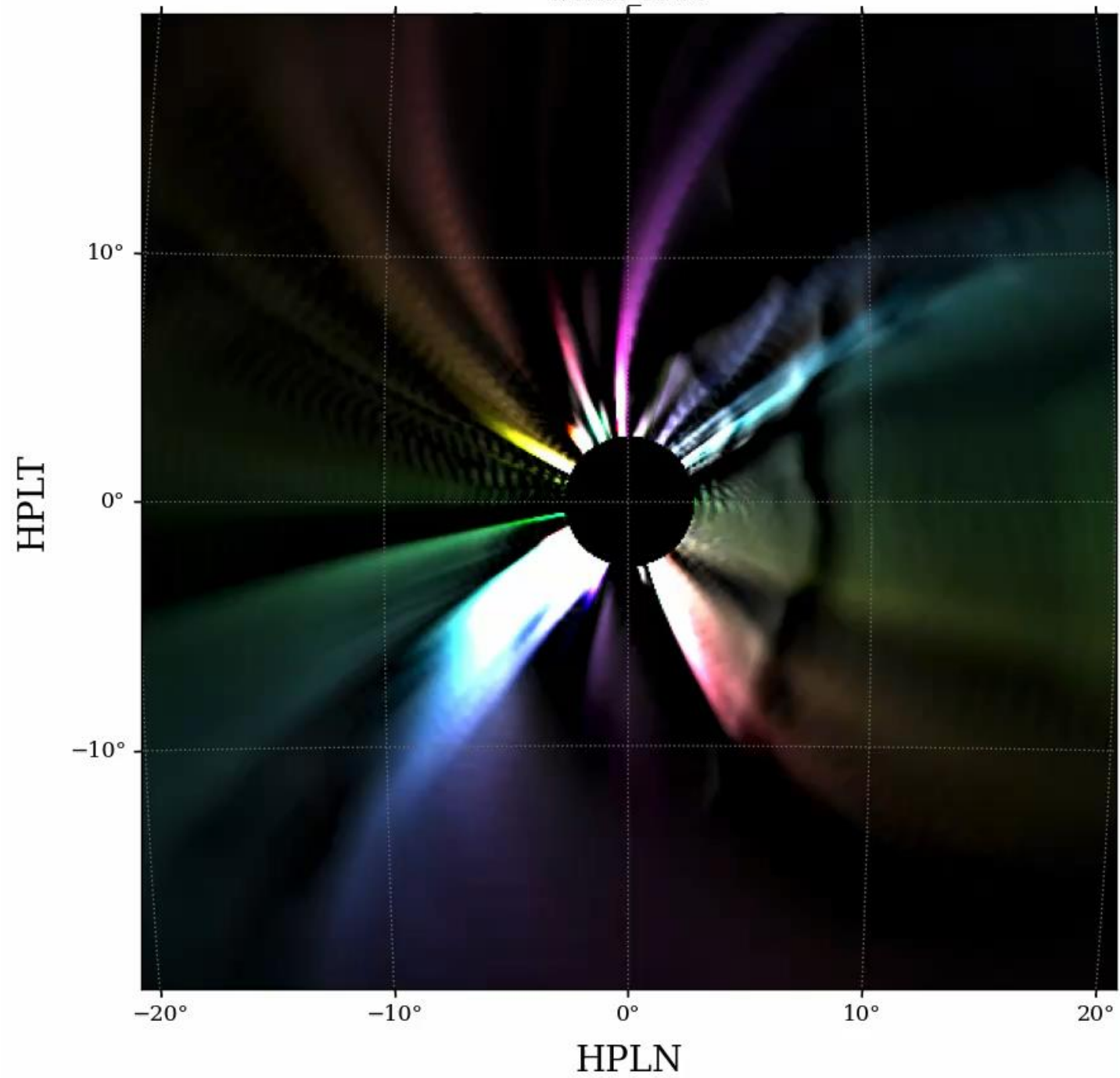


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Marcus Hughes, Chris Lowder, Craig DeForest, Derek Lamb, Jillian Redfern, Dan Seaton, Sam Van Kooten, Matthew West



frame_0000



PUNCH DATA: routine images of the entire inner heliosphere

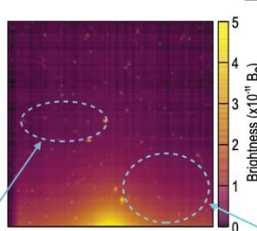
A. Level 0 → Level 1 Pipeline

Level 1 images are photometrically calibrated, precisely aligned images with instrumental artifacts corrected. To demonstrate PUNCH data reduction, we degraded and then processed data from STEREO/HI1 to show the PUNCH L1 processing. For clarity, all visual effects are 10-40x stronger here than in actual PUNCH images. These processing steps are the same for both WFI and NFI.

Level 0: Raw camera frame (de-compressed only)

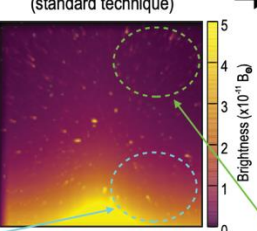


Destreaked



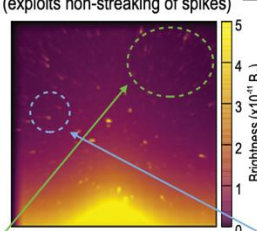
Remove CCD artifacts (using nonlinear flat-field)

Quartic-fit calibrated (standard technique)



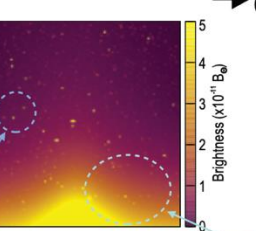
Remove cosmic ray spikes

Cosmic-ray despiked (exploits non-streaking of spikes)



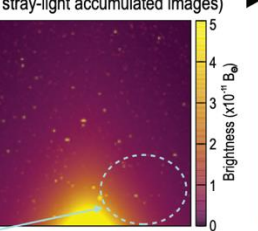
Correct PSF (subimage method)

PSF deconvolved



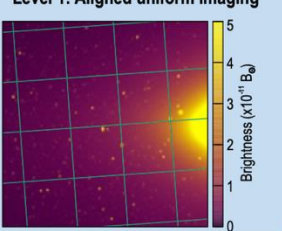
Remove stray light

Stray-light subtracted (via stray-light accumulated images)



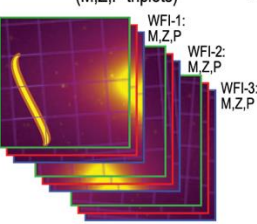
Confirm pointing & projection via starfield

Level 1: Aligned uniform imaging

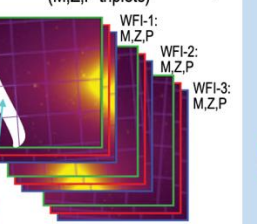


The L1 to L2 stage maps polarization to M,Z,P triplet polarizer brightnesses, then generates full PUNCH mosaics. Clear exposures (not shown) skip the (M,Z,P) step. The L2 to L3 stage removes background F corona (fixed in heliospheric coordinates) and starfield (fixed in celestial coordinates), then generates B and pB products. Nearly all frames have no contamination.

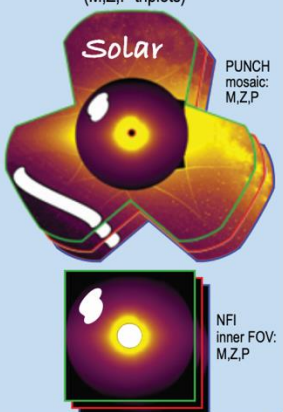
Polarization-resolved (M,Z,P triplets)



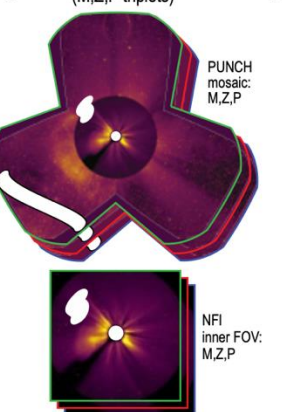
Quality-marked (M,Z,P triplets)



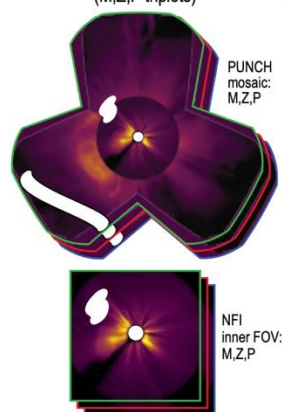
Level 2: Quality-marked mosaics (M,Z,P triplets)



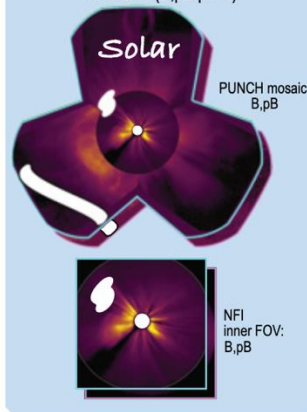
F-subtracted (M,Z,P triplets)



Starfield-subtracted (M,Z,P triplets)



Level 3: Background-subtracted mosaics (B,pB pairs)



Identify contaminated regions

Resample to nominal coords

Subtract F model

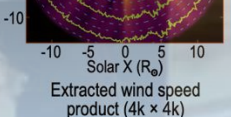
Subtract stellar model

Remix polarization

PUNCH Data Products are produced and clear photometric images are available for download using common existing software environments and with PUNCH-specific tools distributed by the project. Primary science products are shown.

L3 data products:

Merged, background-subtracted, polarimetric images of the outer corona and inner solar wind



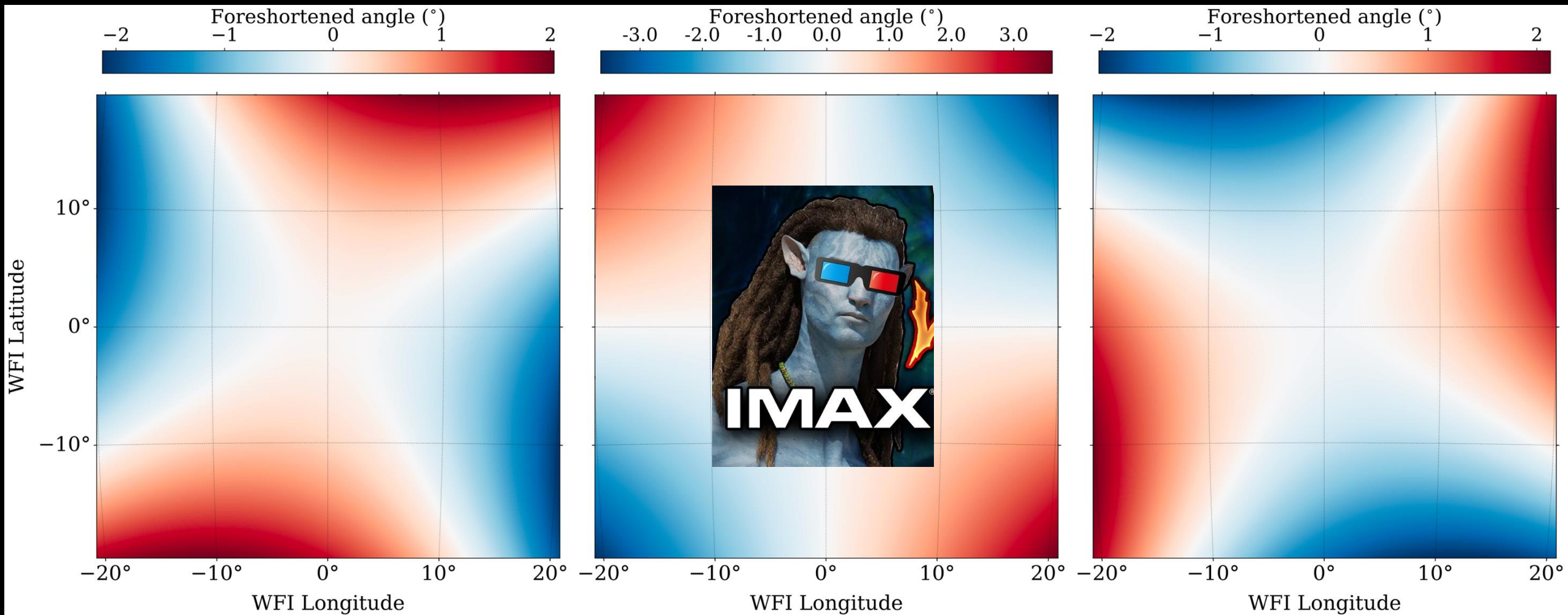
B & pB / clear mosaics every 4 / 8 minutes (4k x 4k)

B & pB / clear NFI full-resolution images every 4 / 8 minutes (2k x 2k)

B & pB / clear low-noise mosaics every 32 minutes (4k x 4k)

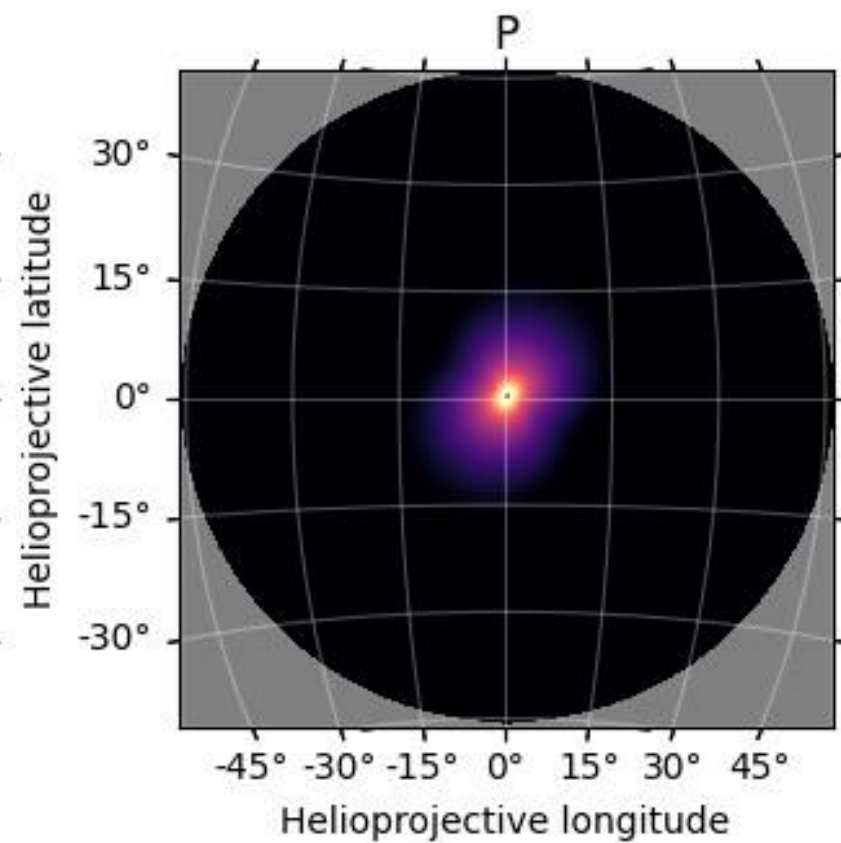
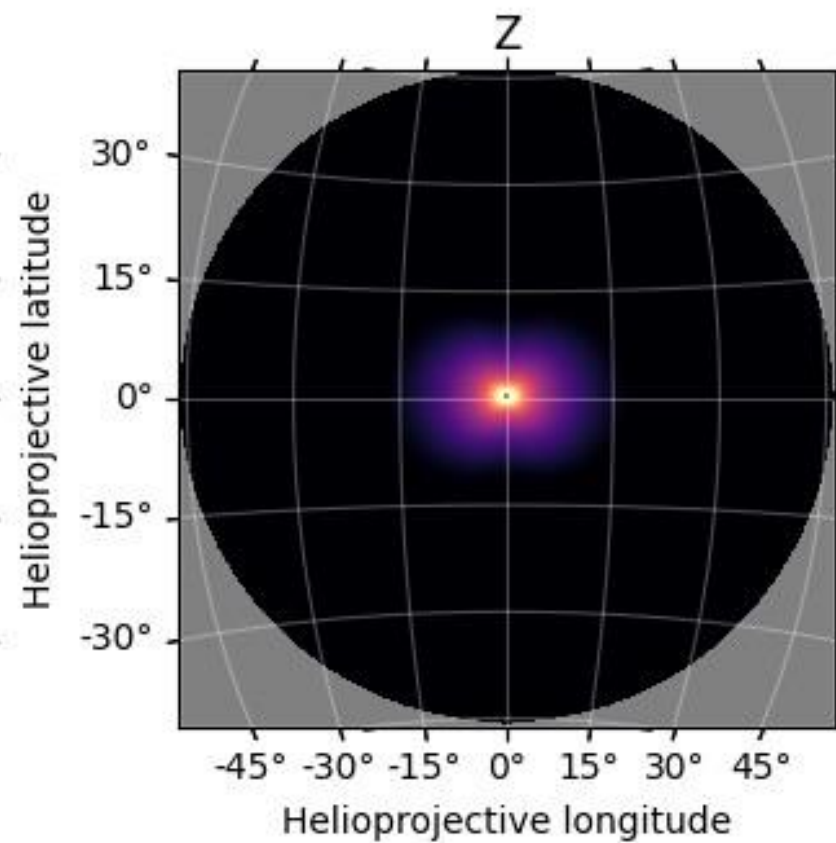
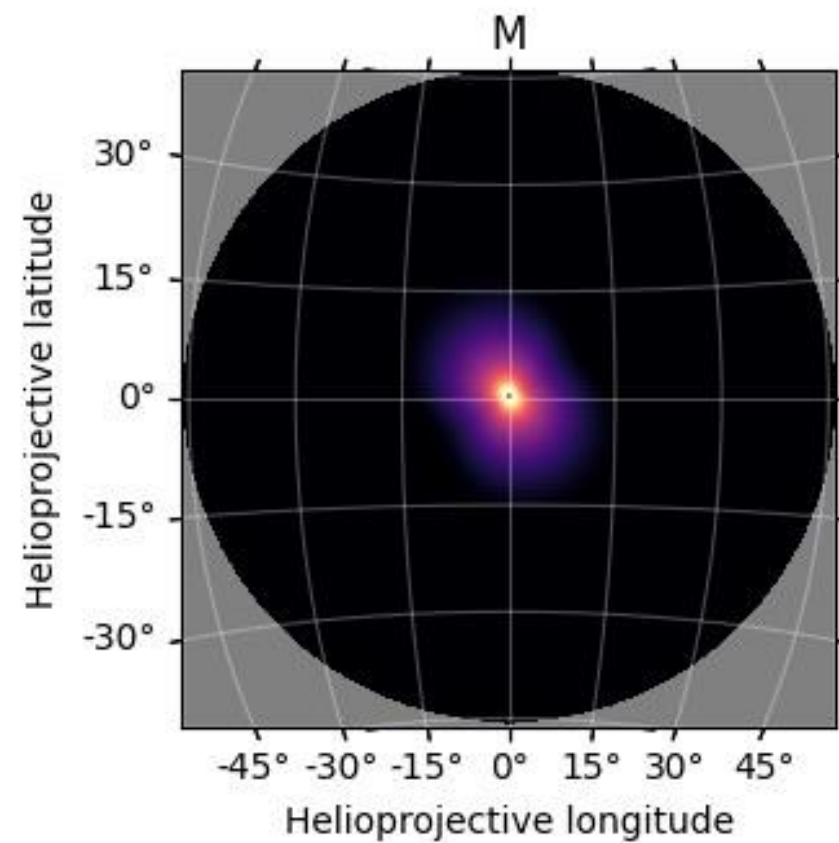
B & pB / clear low-noise NFI images every 24 minutes (2k x 2k)

Resolving Polarization

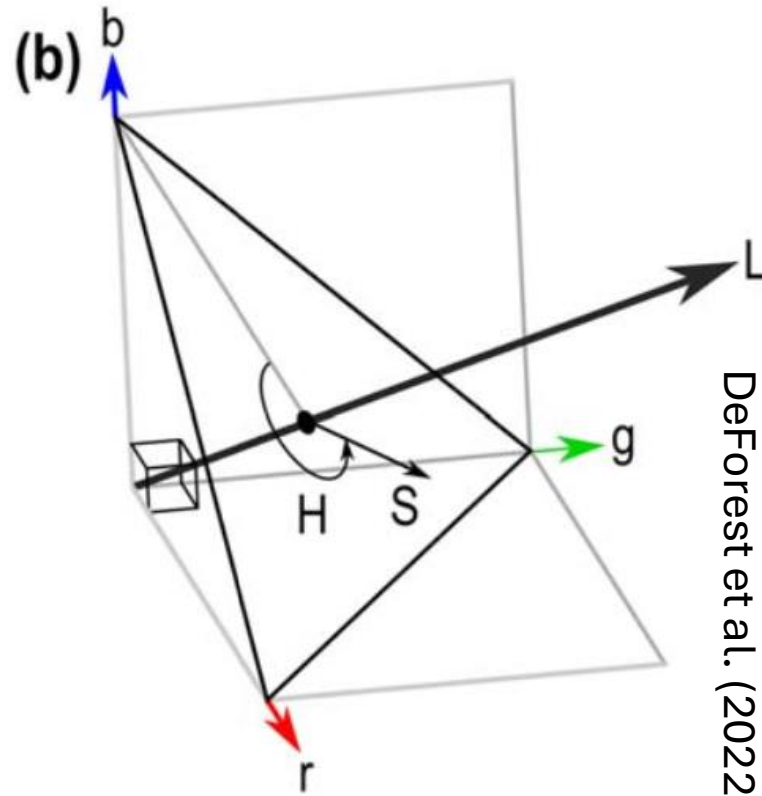
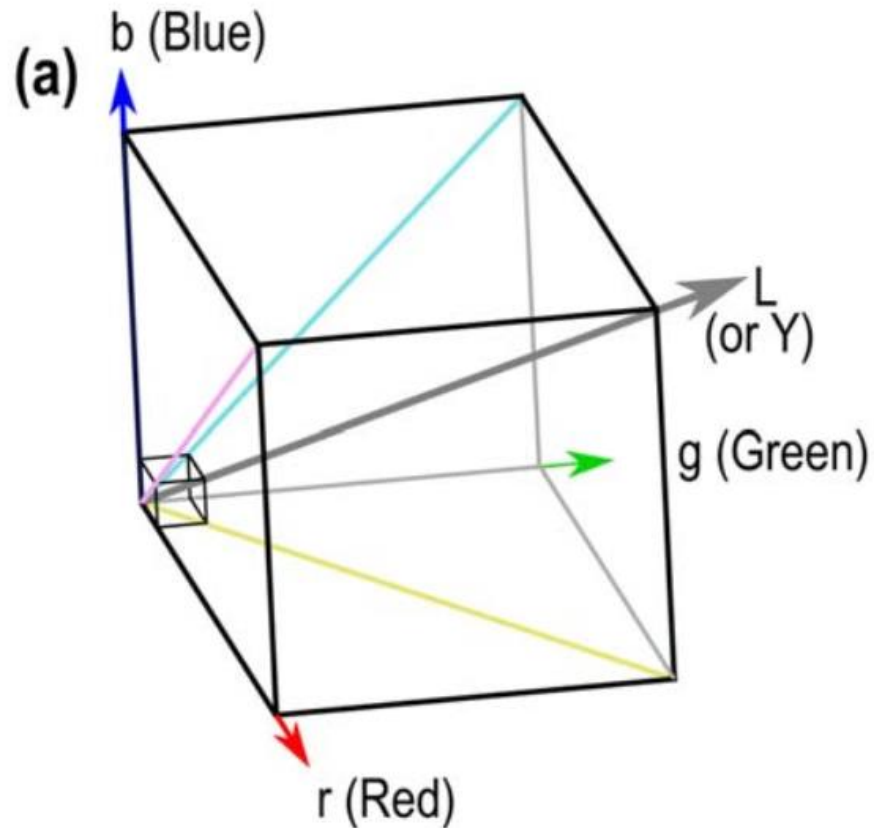




**Before We Start, We Got To Have
Some Ground Rules.**



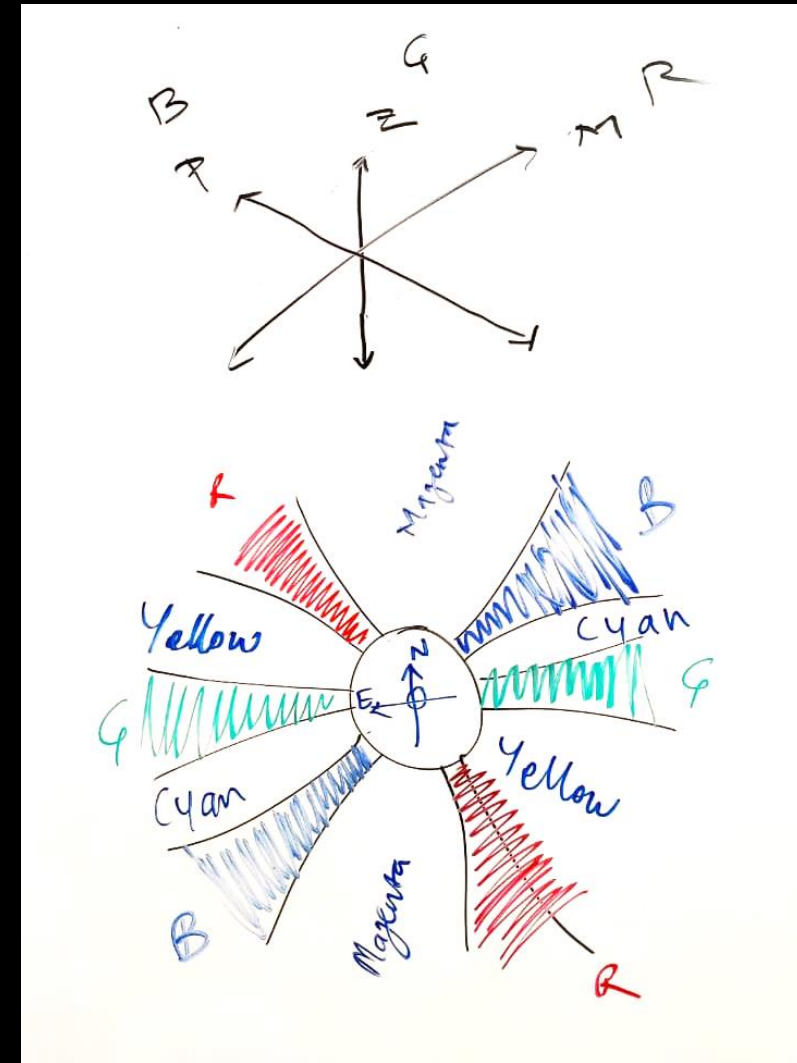
Polarimetry \leftrightarrow Colorimetry

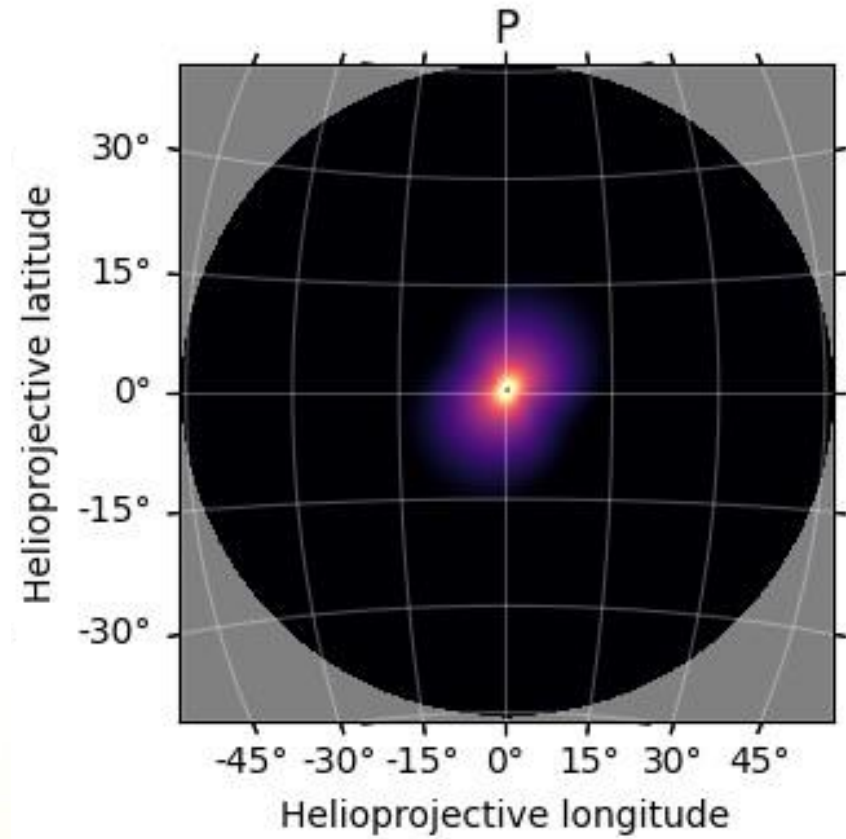
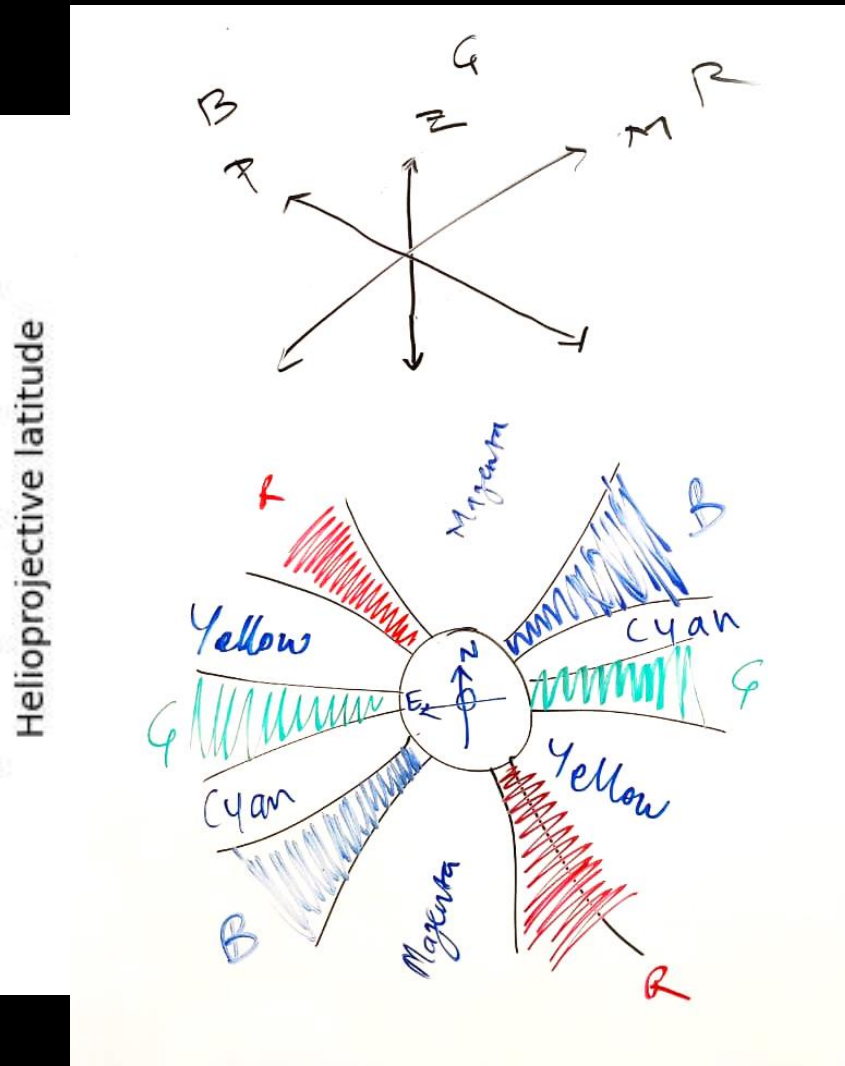
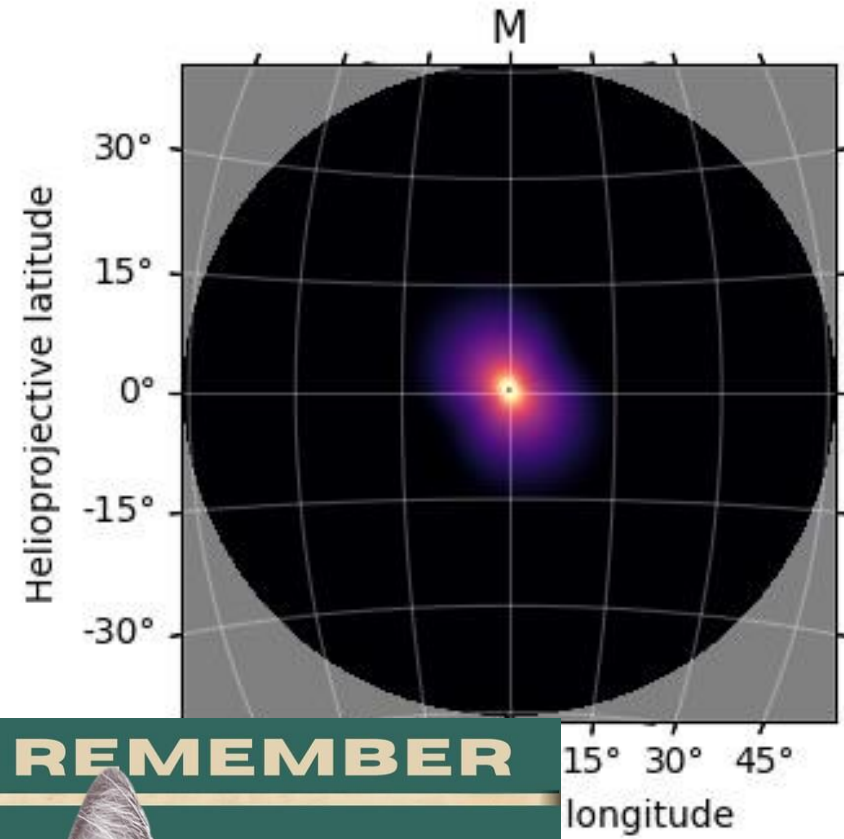


DeForest et al. (2022)

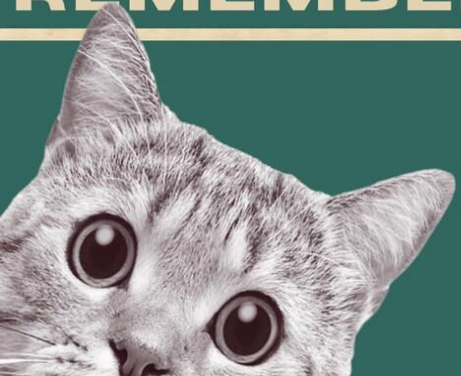
$I_M = g, I_Z = b, I_P = r:$
 M, Z, P

$I = L, \beta = H/2, p = S:$
 I, β, p

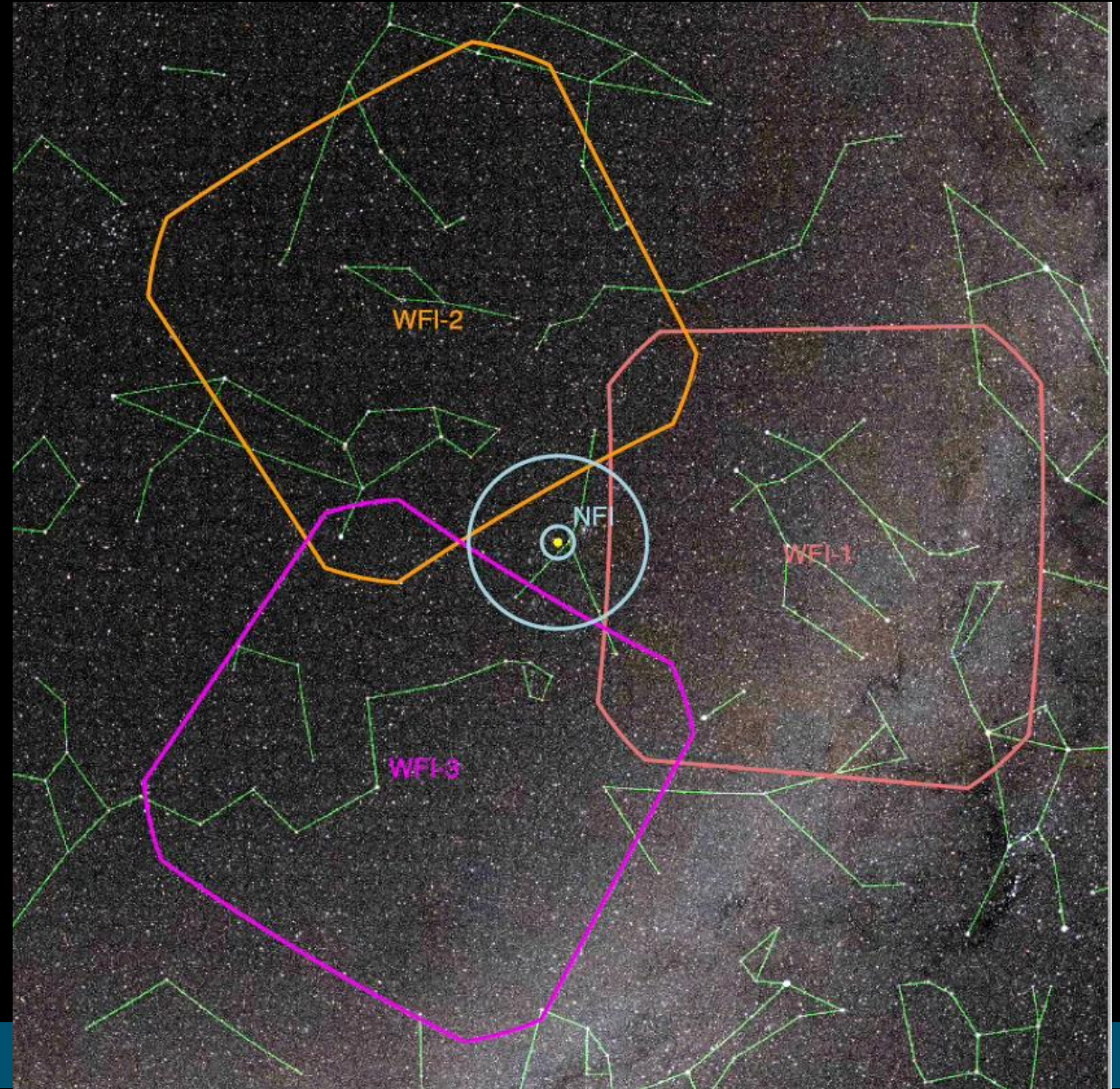
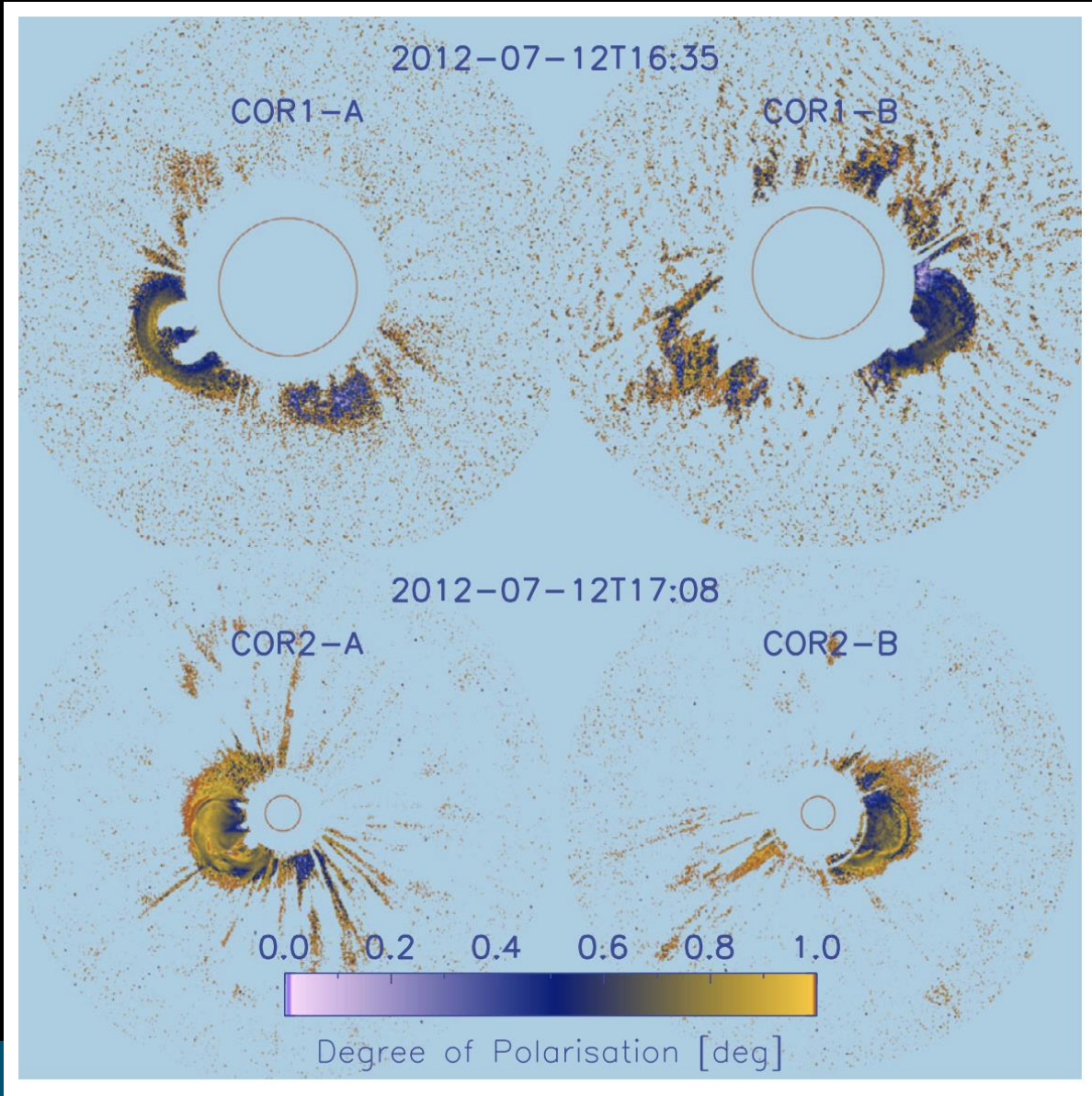




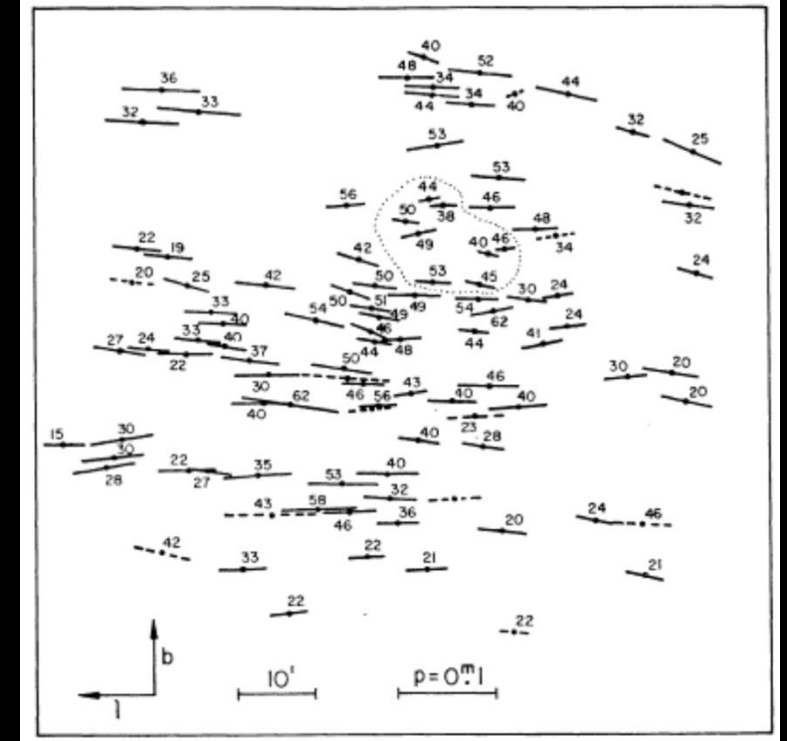
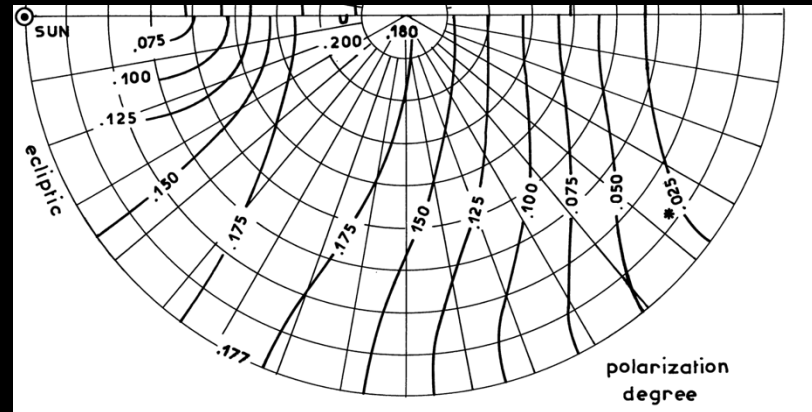
REMEMBER



Resolving Polarization



POLARIZED BACKGROUNDS: VECTORS, NOT SCALARS



Instrumental scattering is likely polarized

The F corona is up to 20% polarized.
(Figure: Dumont & Sánchez 1976)

The starfield itself is up to 5% polarized.
(Figure: Serkowski 1973)

Fixed in Instrument frame

Fixed in solar frame

Fixed in celestial frame



PUNCH Polarimetry

1

Generate
Polarized Stray
Light Model in
Instrument
Frame



2

Transform
Polarization to
Solar Frame and
Generate
Polarized F-
corona
background



3

Remove F-
corona.
Transform
Polarization to
Celestial Frame
and Remove
Starfield
background

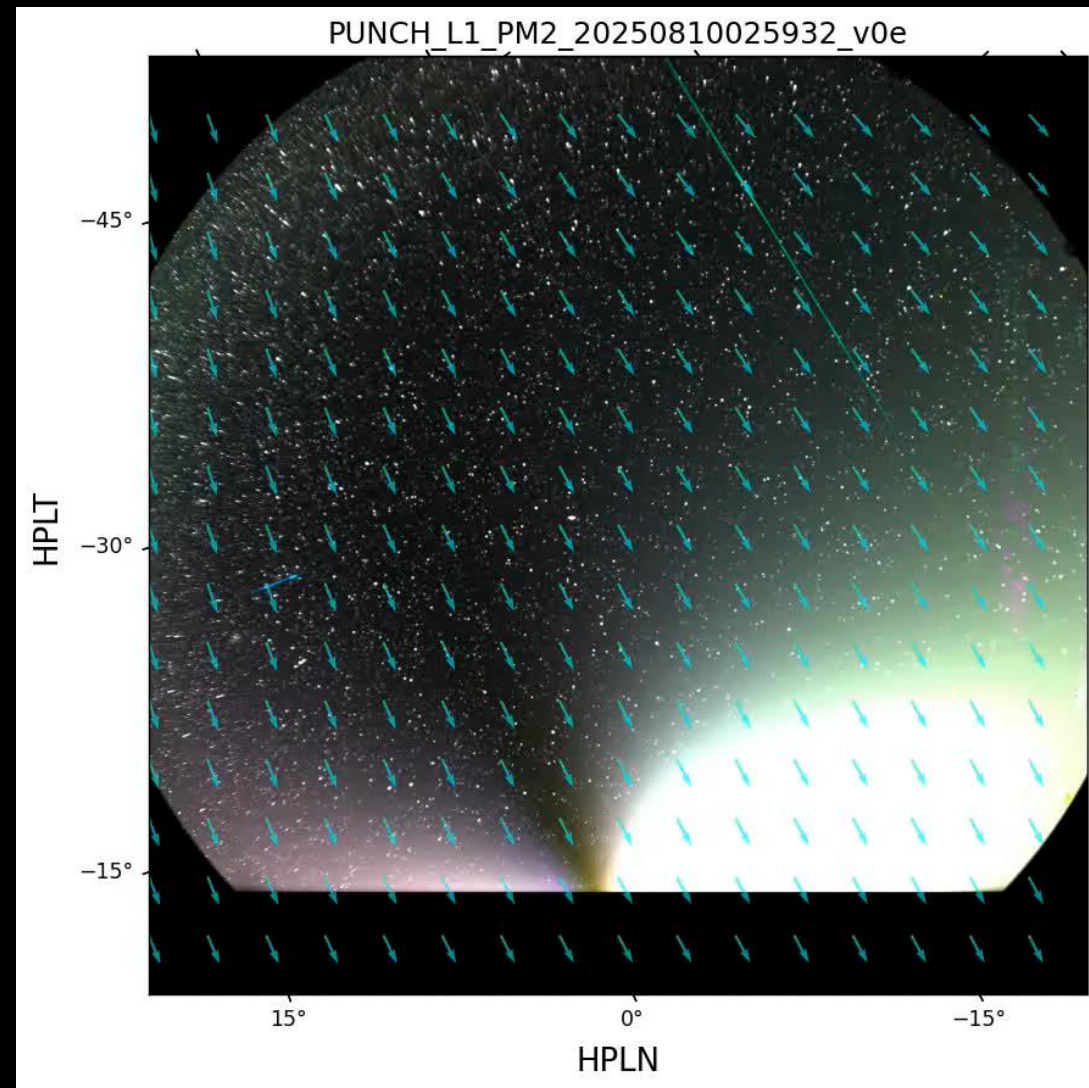
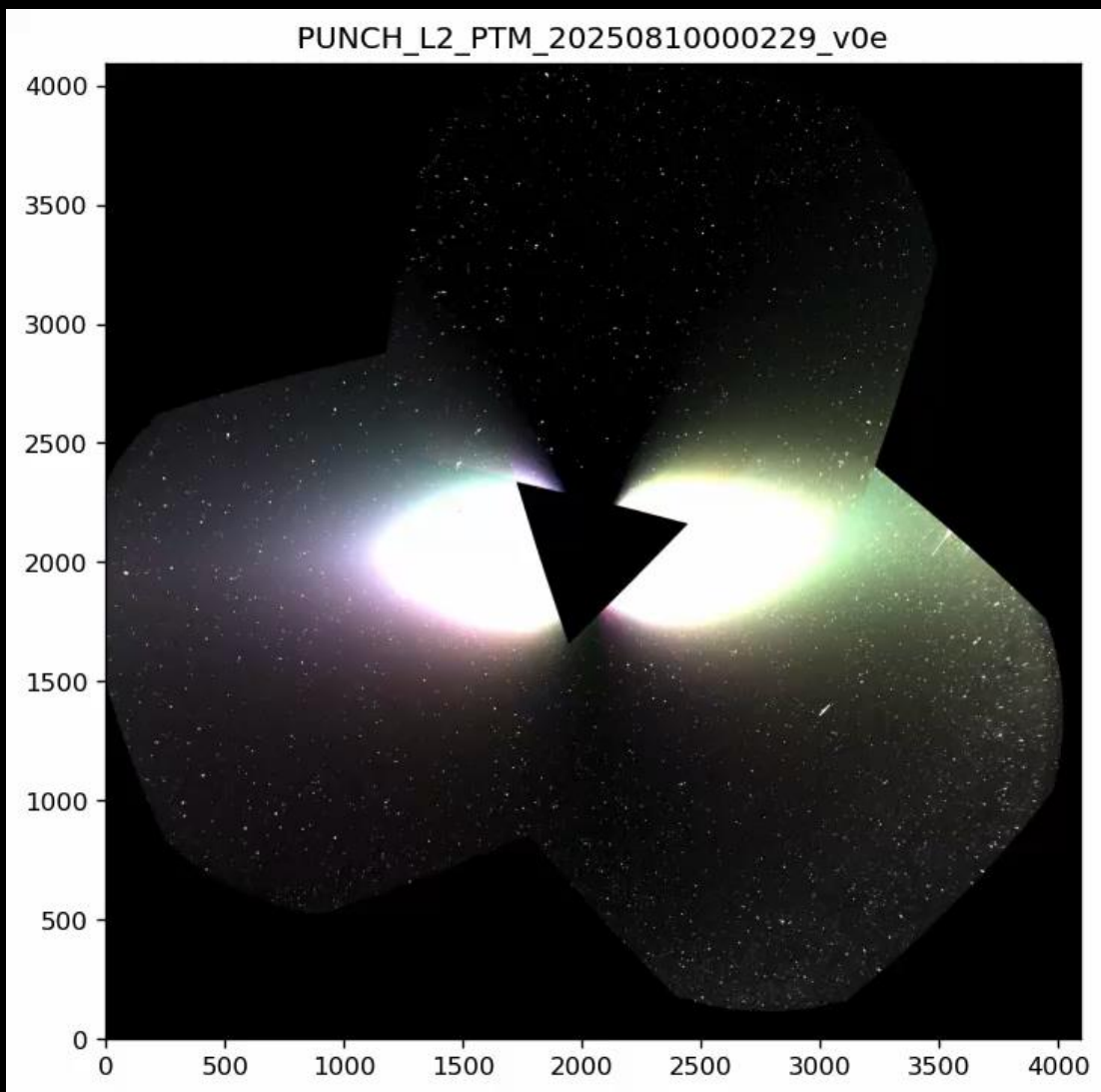


4

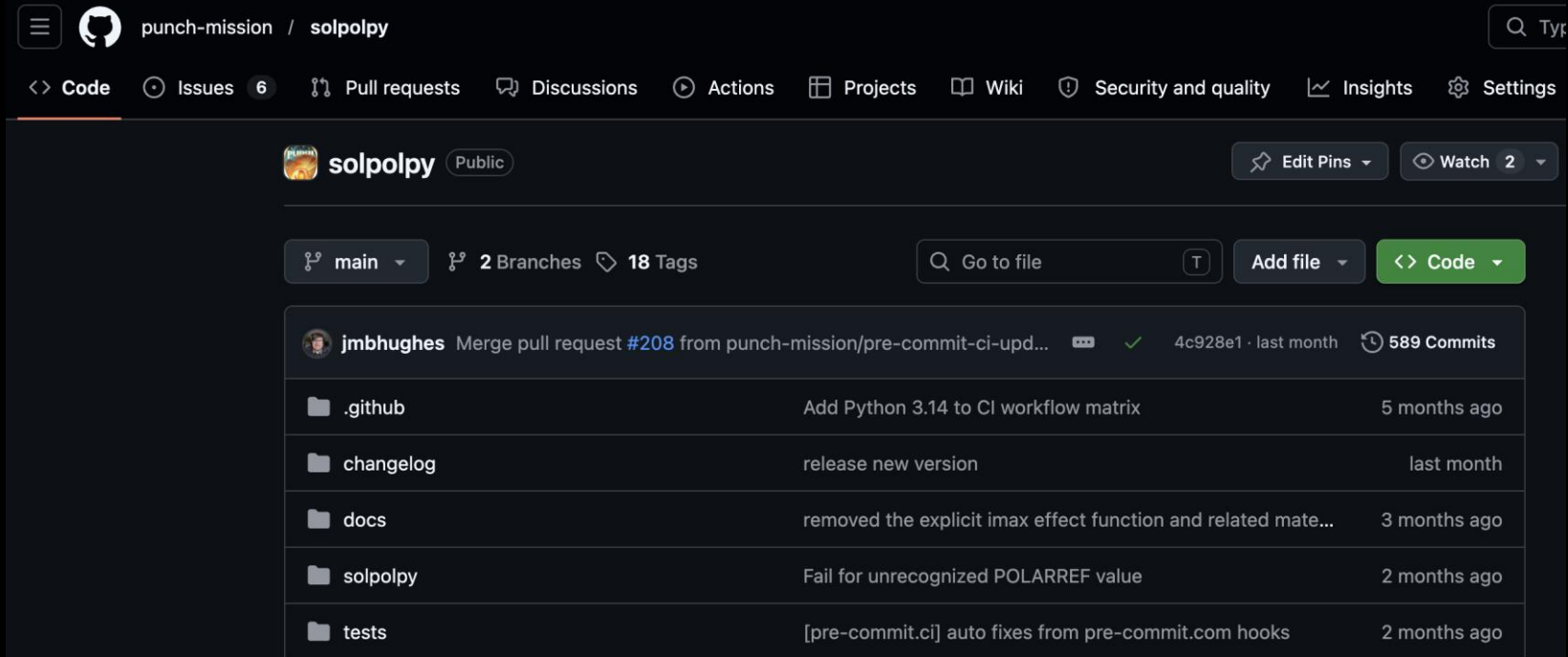
Transform
Polarization Back
to Solar Frame
and Disseminate
L3 Polarized data



PUNCH Polarimetry



PUNCH Polarimetry



punch-mission / solpolpy

<> Code Issues 6 Pull requests Discussions Actions Projects Wiki Security and quality Insights Settings

solpolpy Public Edit Pins Watch 2

main 2 Branches 18 Tags Go to file Add file Code

jimbhughes Merge pull request #208 from punch-mission/pre-commit-ci-upd... 4c928e1 · last month 589 Commits

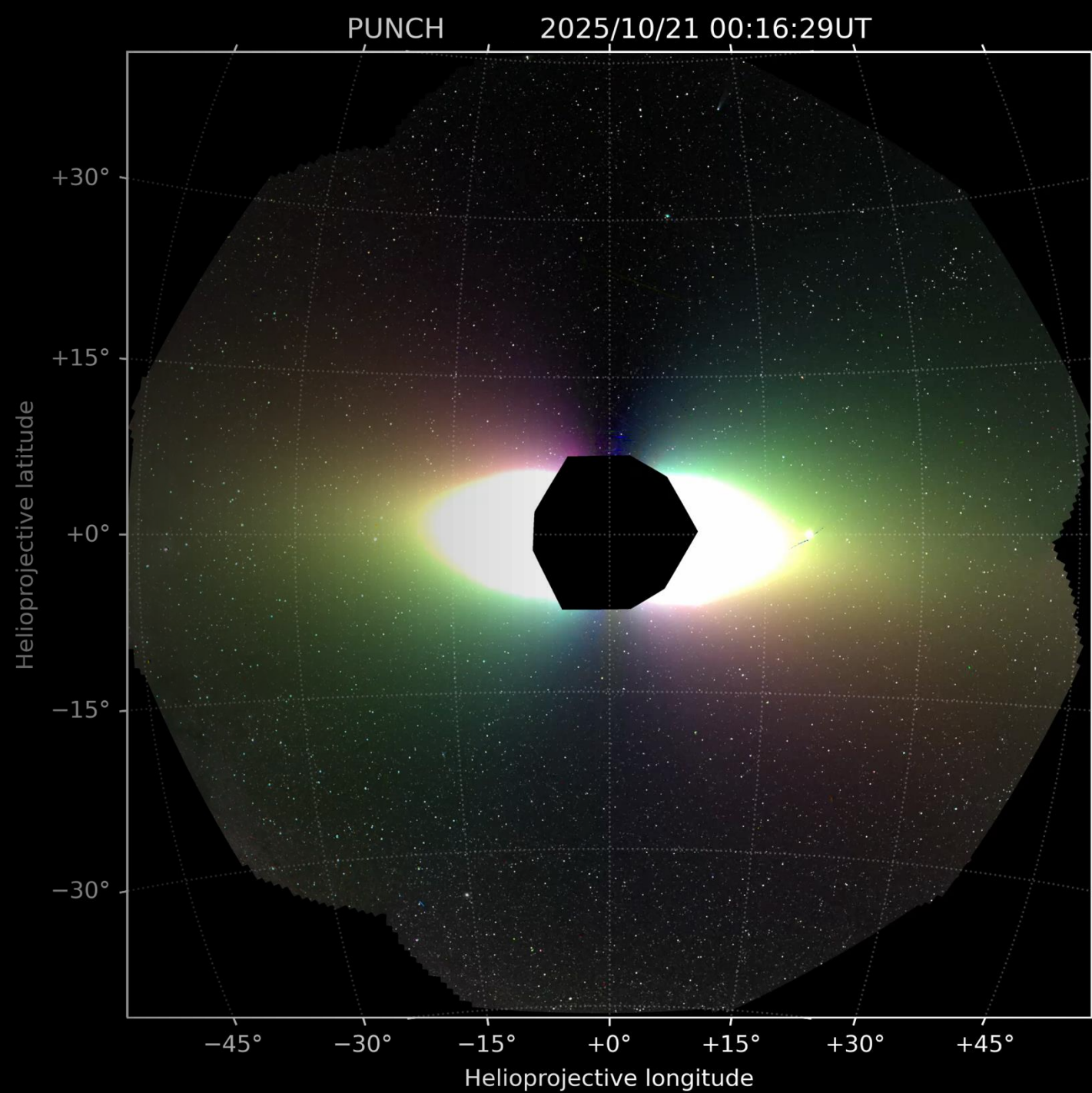
.github	Add Python 3.14 to CI workflow matrix	5 months ago
changelog	release new version	last month
docs	removed the explicit imax effect function and related mate...	3 months ago
solpolpy	Fail for unrecognized POLARREF value	2 months ago
tests	[pre-commit.ci] auto fixes from pre-commit.com hooks	2 months ago



SCAN ME

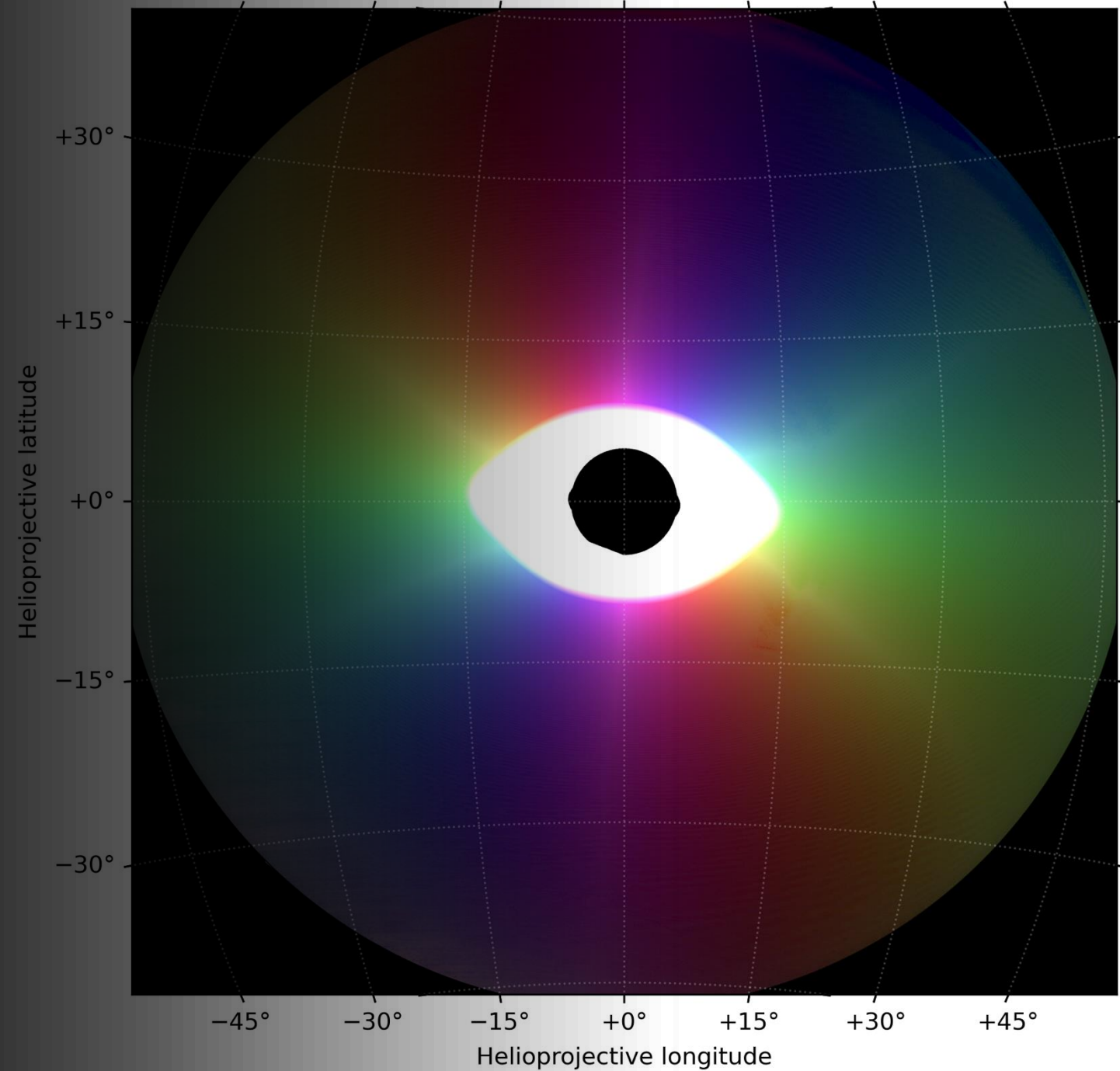
Based on DeForest et al. (2022)

PUNCH
Polarimetry

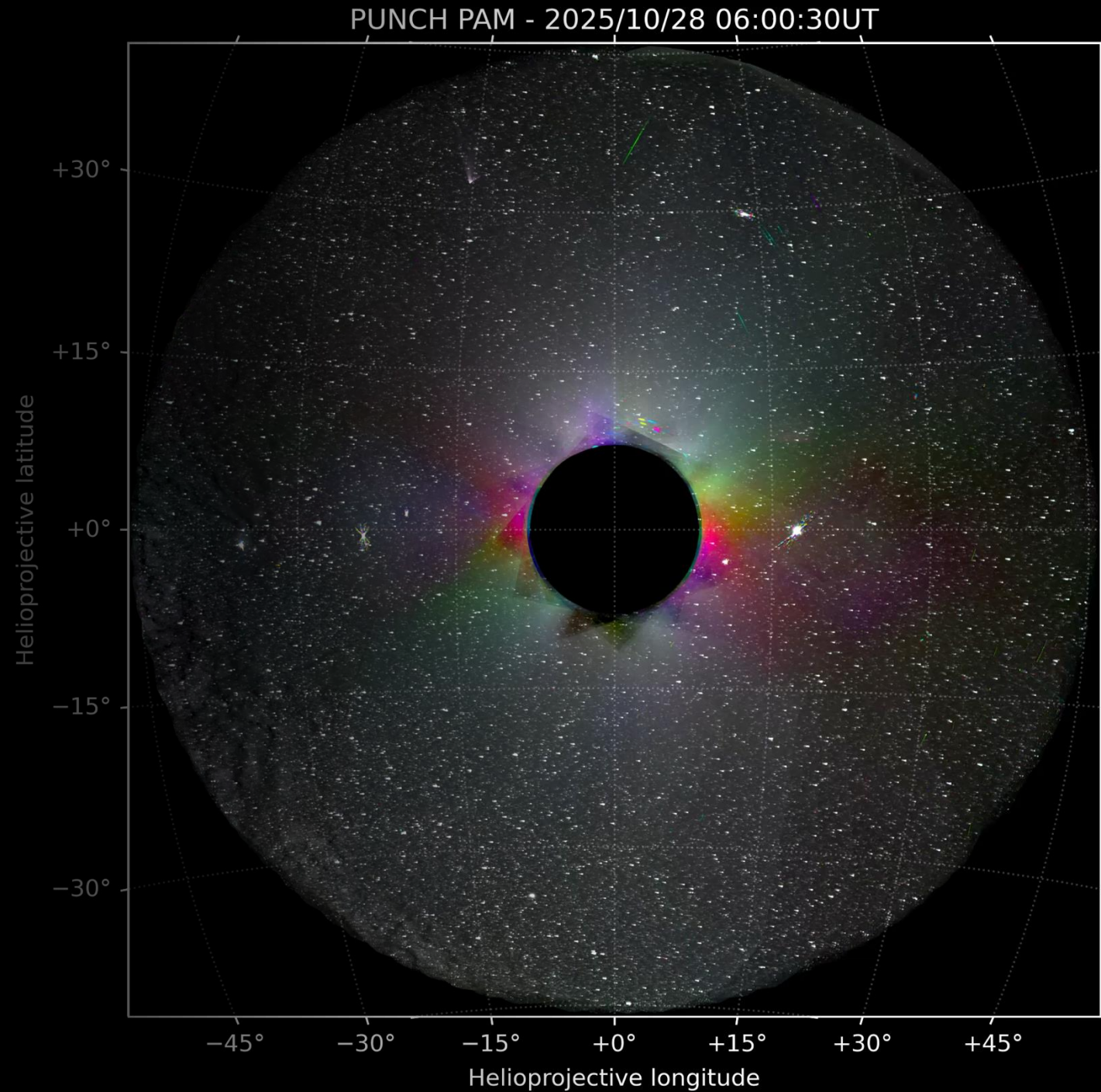




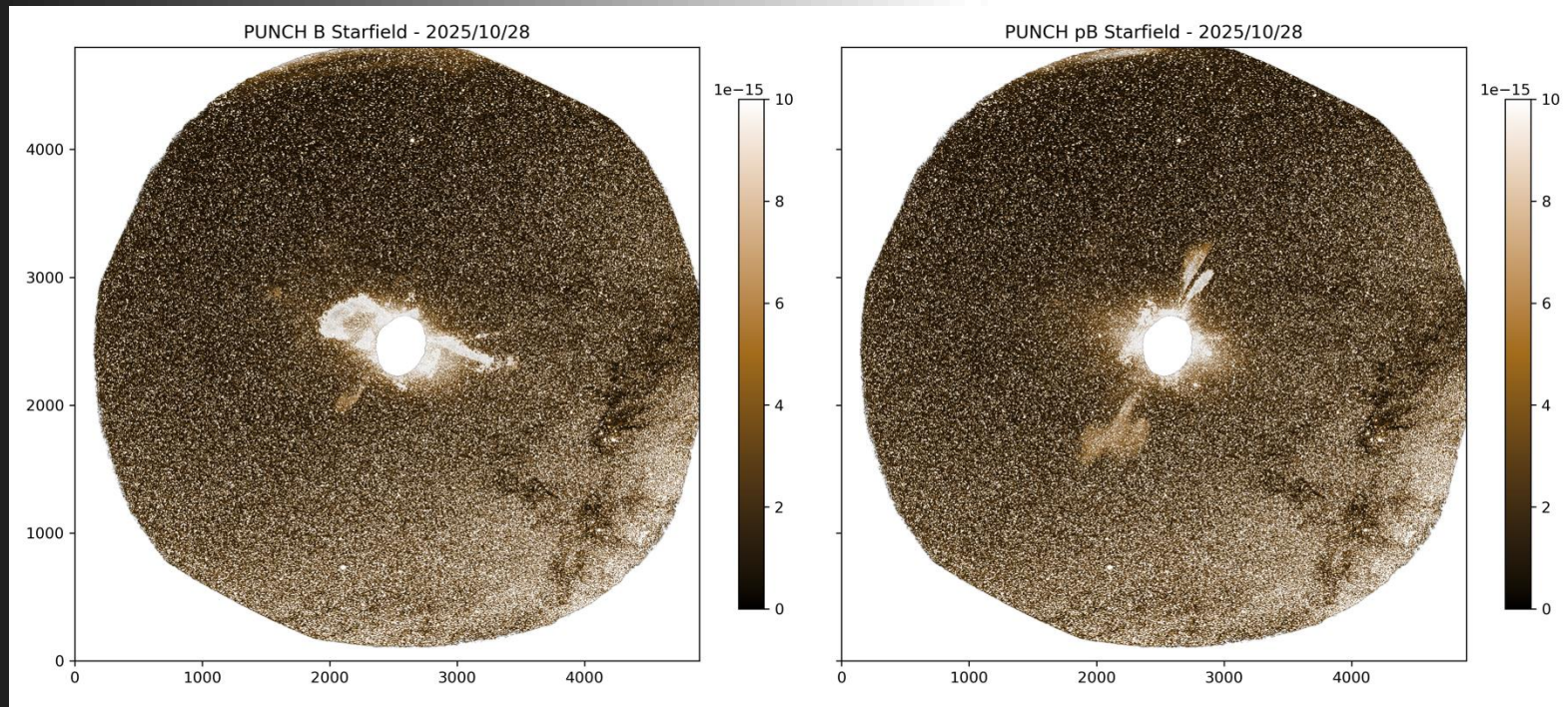
PUNCH Polarimetry



PUNCH
Polarimetry



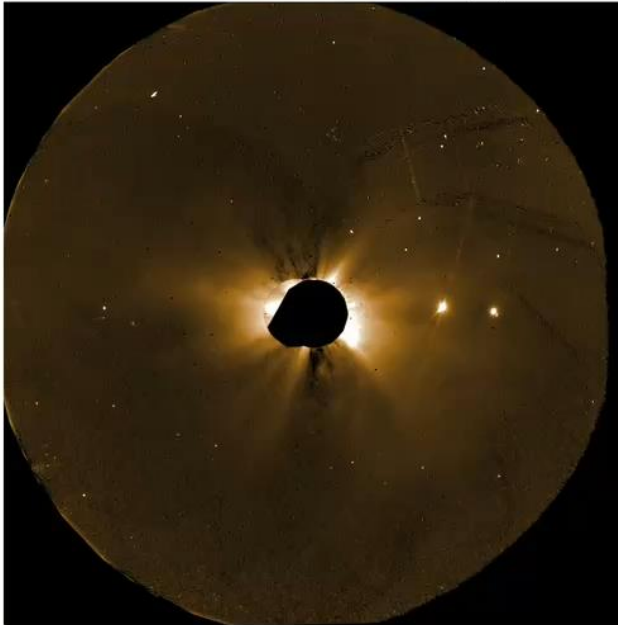
PUNCH Polarimetry



PUNCH Polarimetry

(DeForest et al.)

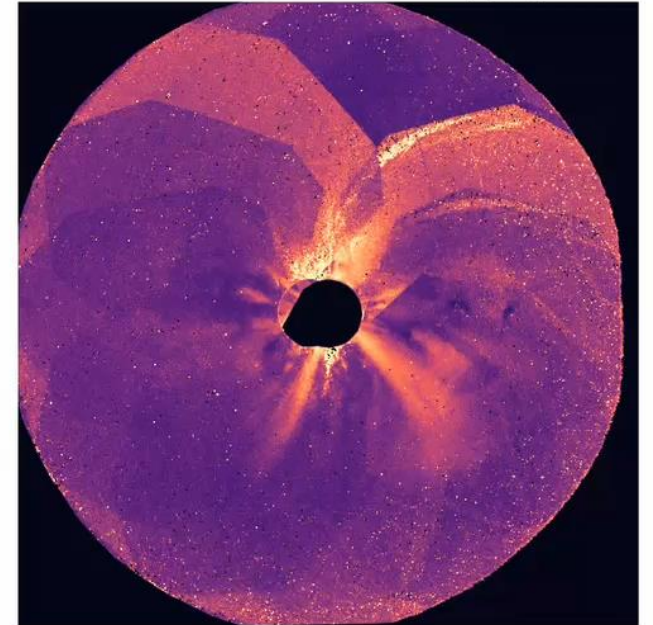
PUNCH L3 2025-09-20T01:52:30 (tB)



PUNCH L3 2025-09-20T01:52:30 ($^{\circ}\text{pB}$)



PUNCH L3 2025-09-20T01:52:30 ($^{\circ}\text{pB/B}$)



Summary

- With wide field of view comes wider challenges.
- Backgrounds at various reference frames has to be removed to reveal the heliospheric polarization.
- Level 3 polarized data products are corrected for non-relevant polarized signals.

