

Polarimeter to Unify the Corona and Heliosphere



Science Operations Center Development

Marcus Hughes, Craig DeForest, Sarah Kovac,
Derek Lamb, Chris Lowder, Ritesh Patel,
Jillian Redfern, Dan Seaton, Matthew West

Southwest Research Institute

PUNCH Science Meeting 5
June 20 2024 ✧ Boulder, Colorado





SOC Members



Derek Lamb



Dan Seaton



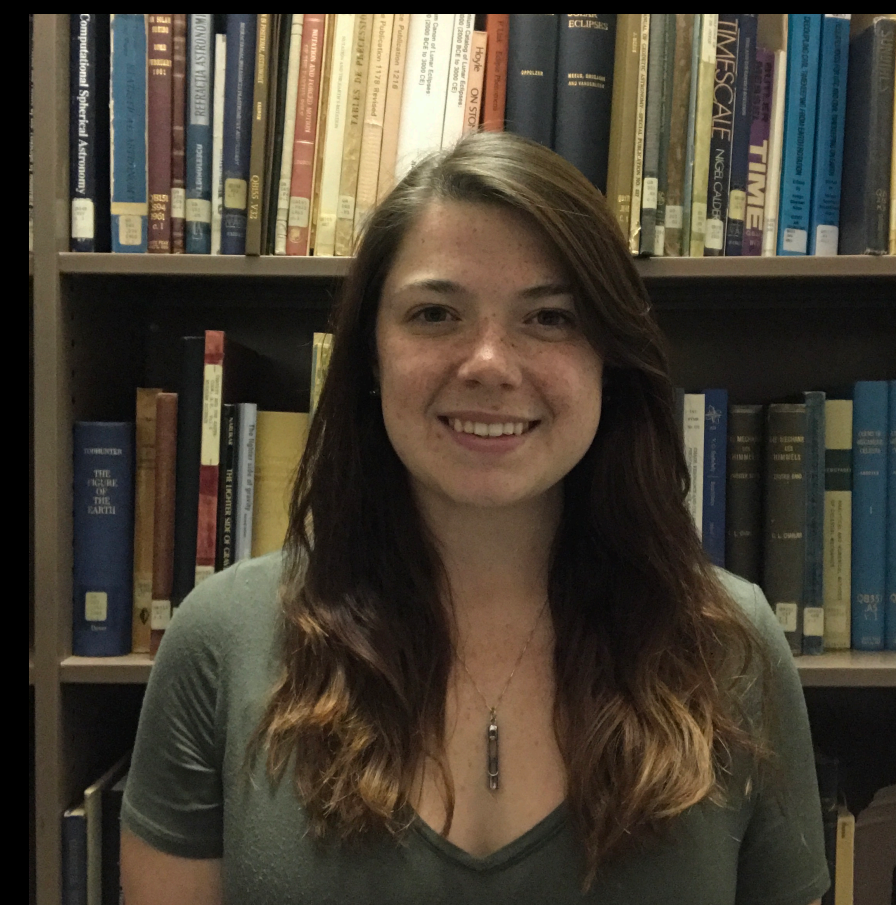
Ritesh Patel



Matt West



Chris Lowder



Sarah Kovac

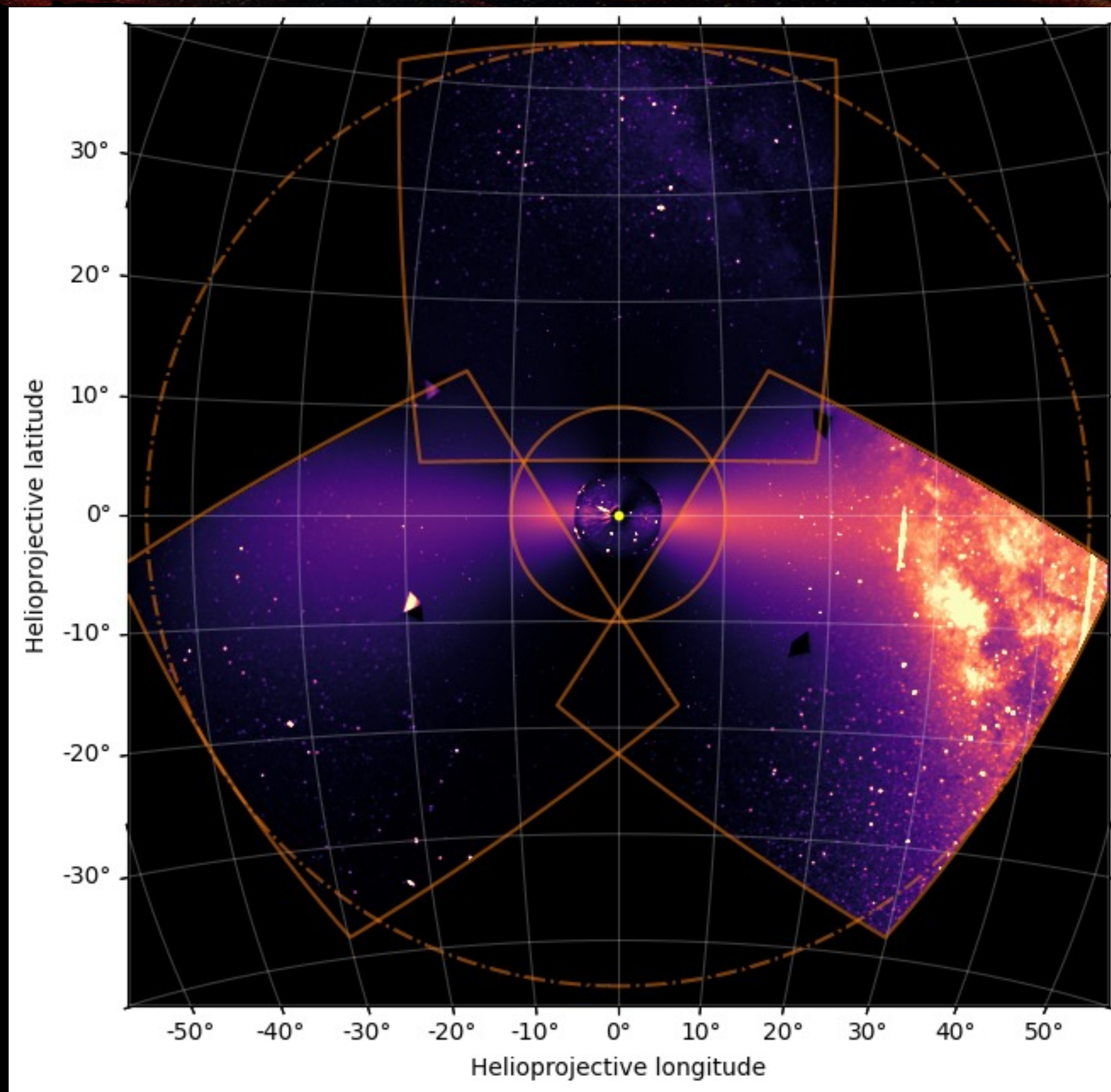


Marcus Hughes



Many Observations to Make Combined Data Product

- PUNCH observes continuously at 4-min. cadence
- NFI covers $5.4\text{--}32 R_{\odot}$
- WFI covers $20\text{--}180 R_{\odot}$, 3 separate segments
- PUNCH produces 3 full mosaics per orbit, from $6\text{--}180 R_{\odot}$





Level 1

Levels 2 & 3

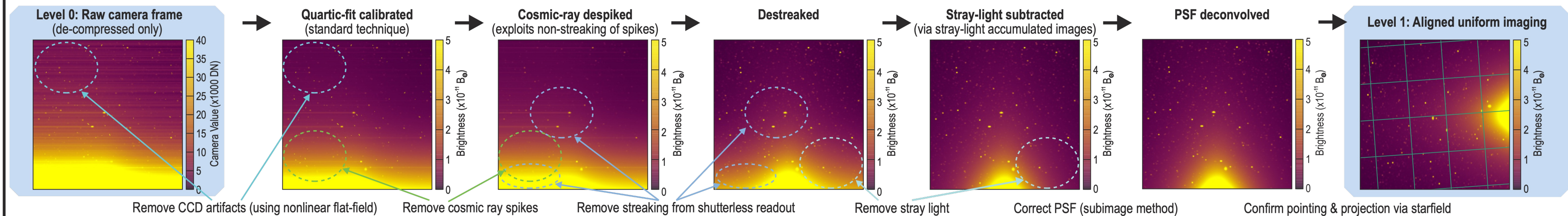
L3 Products

PUNCH Science Data Pipeline and Products

For effective data analysis by the PUNCH team and the broader community, PUNCH produces (A-C) and disseminates (D) calibrated, simple-to-use data products and analysis tools.

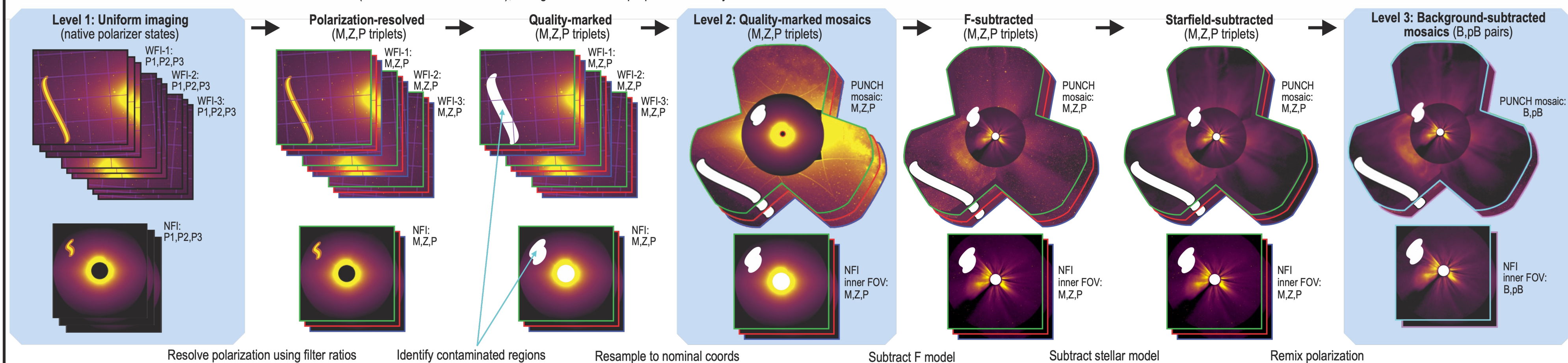
A. Level 0 → Level 1 Pipeline

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.



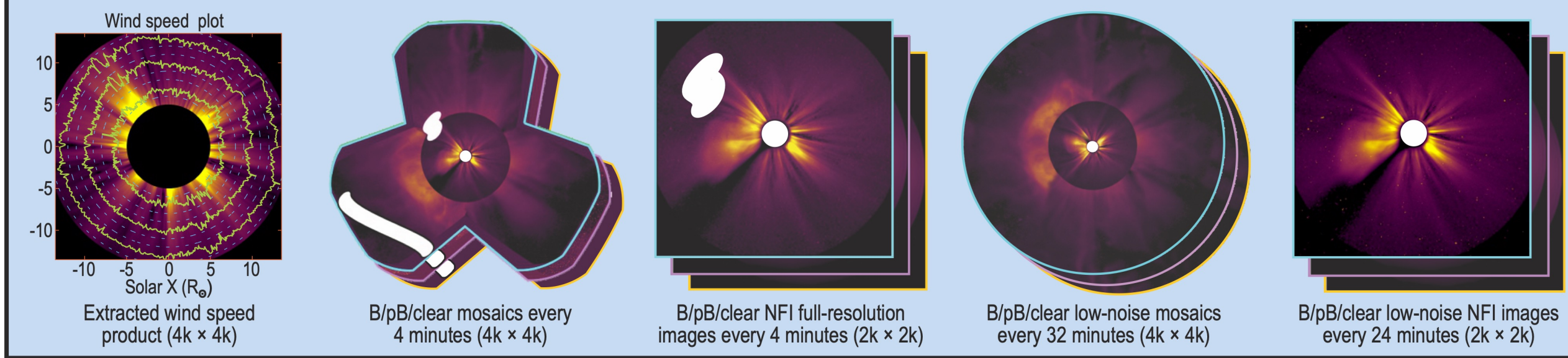
B. Level 1 → Level 3 Pipeline

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.

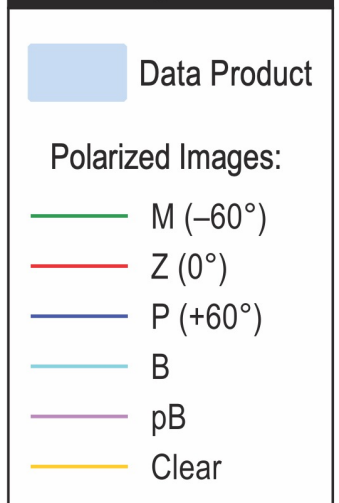


C. Level 3 Data Products

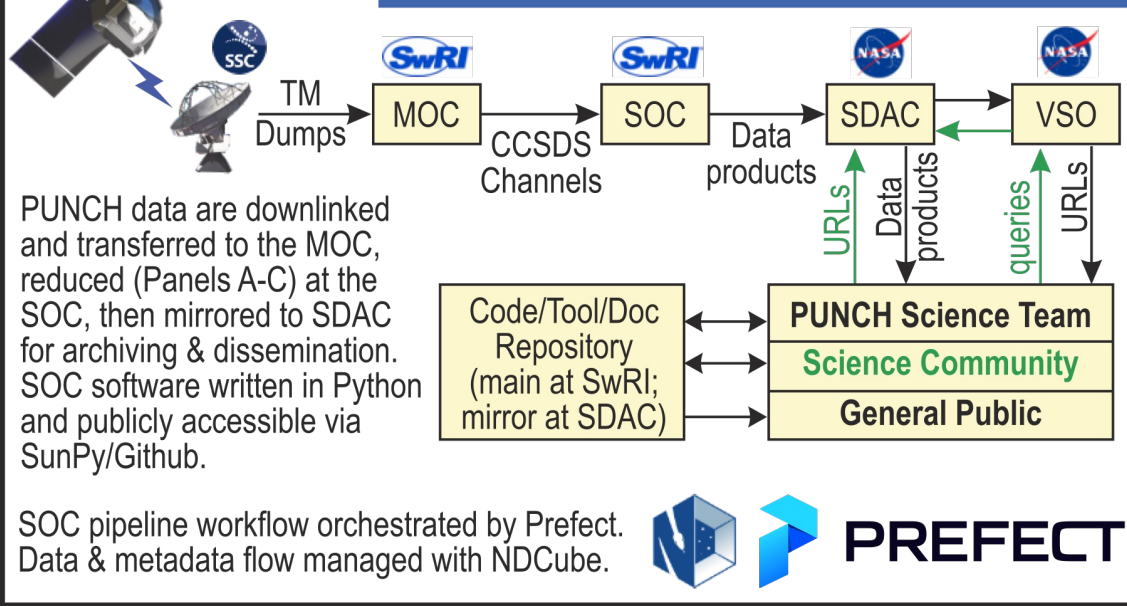
PUNCH Data Products are polarized and clear photometric images suitable for analysis in common existing scientific environments and with PUNCH-specific tools distributed by the project. Primary science products are shown.



Legend



D. End-To-End Data Flow





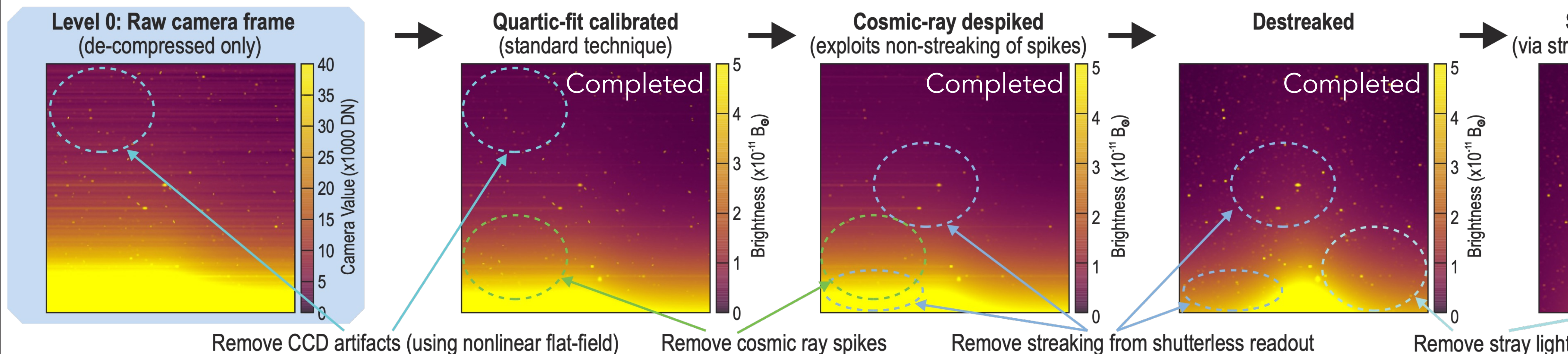
PUNCH

Science Data Pipeline and

For effective data analysis by the PUNCH team and the broader community, PUNCH produces (A-C) and dis

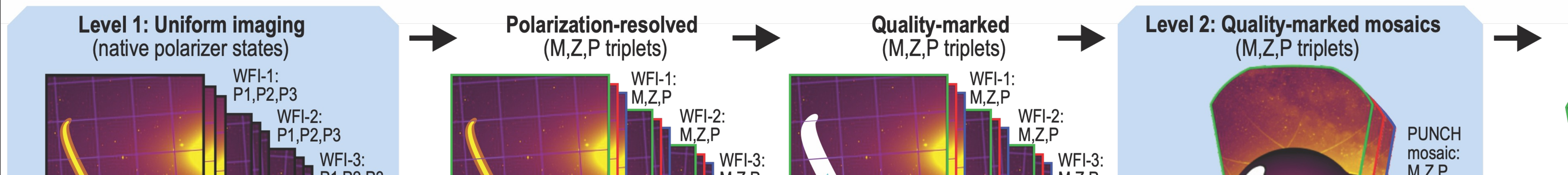
A. Level 0 → Level 1 Pipeline

Level 1 images are photometrically calibrated, precisely aligned images with instrumental artifacts corrected. To demonstrate L1
For clarity, all visual effects are 10-40x stronger here than in actual PUNCH images. These processing steps are the same for



B. Level 1 → Level 3 Pipeline

The L1 to L2 stage maps polarization to M,Z,P triplet polarizer brightnesses, then generates full PUNCH mosaics. Clear exposures
starfield (fixed in celestial coordinates), then generates B and pB products. Nearly all frames have no contamination.

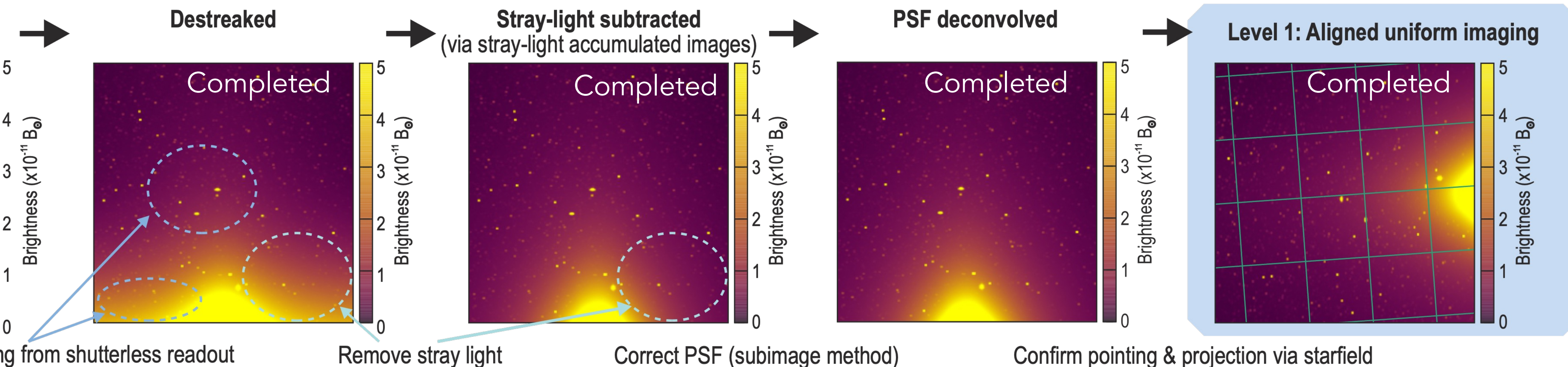




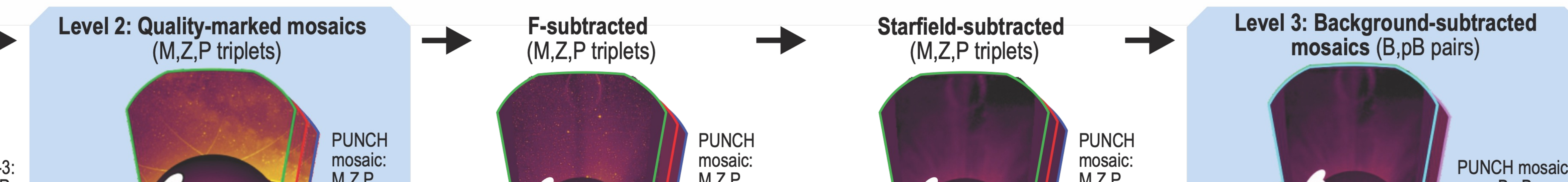
a Pipeline and Products

ty, **PUNCH produces (A-C) and disseminates (D) calibrated, simple-to-use data products and analysis tools.**

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. PUNCH images. These processing steps are the same for both WFI and NFI.



nesses, 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 products. Nearly all frames have no contamination.





PSF correction via *regularizepsf*

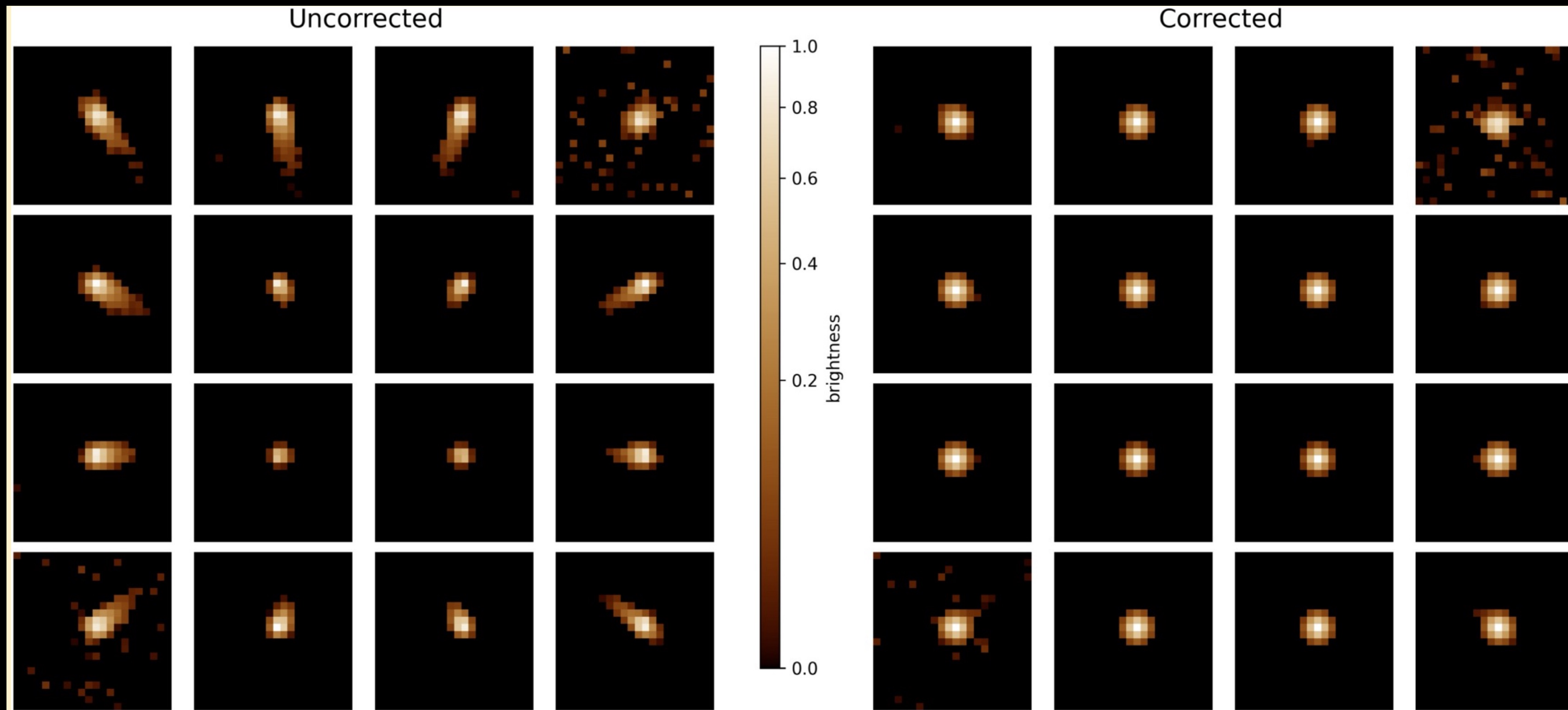
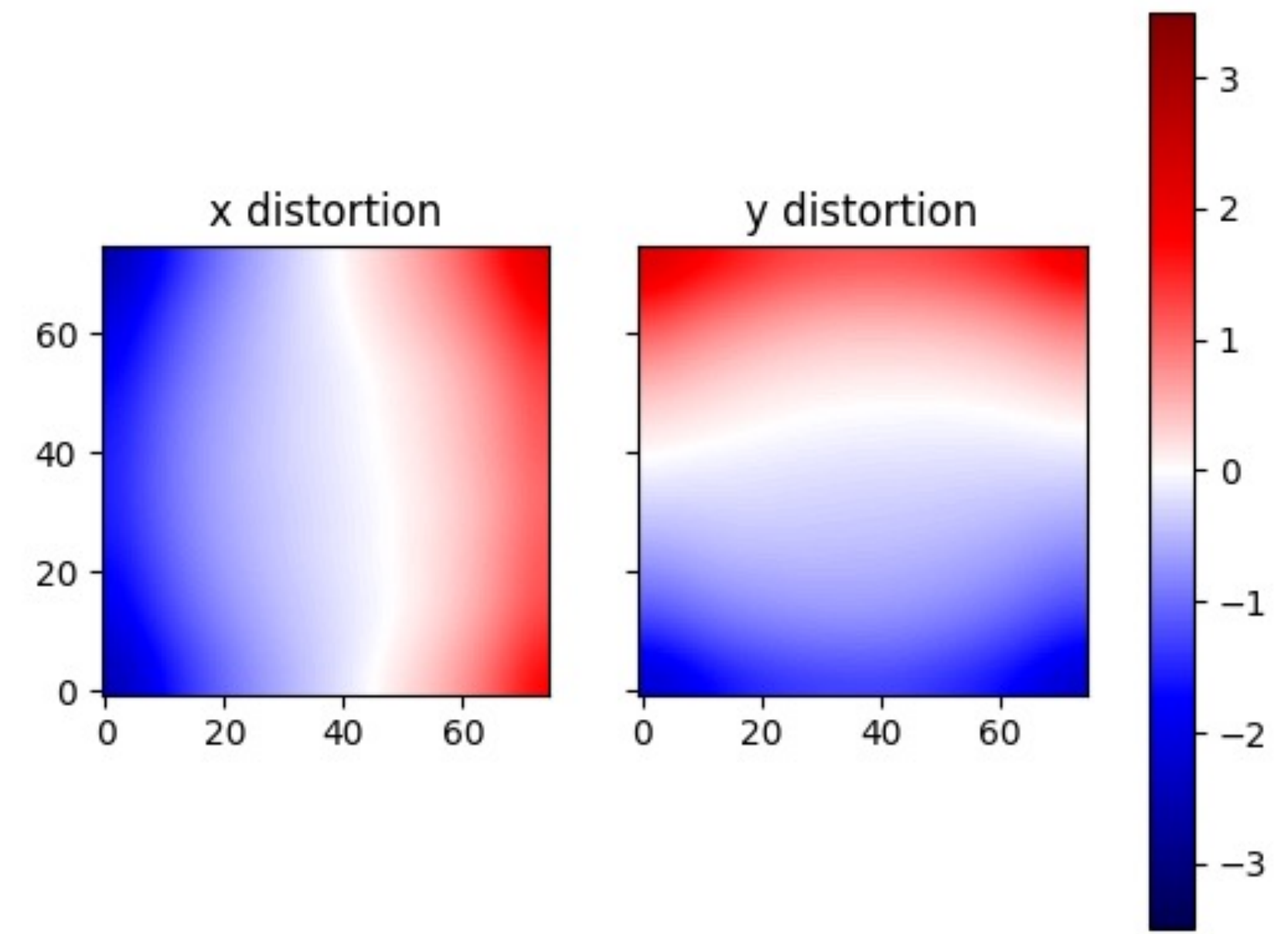
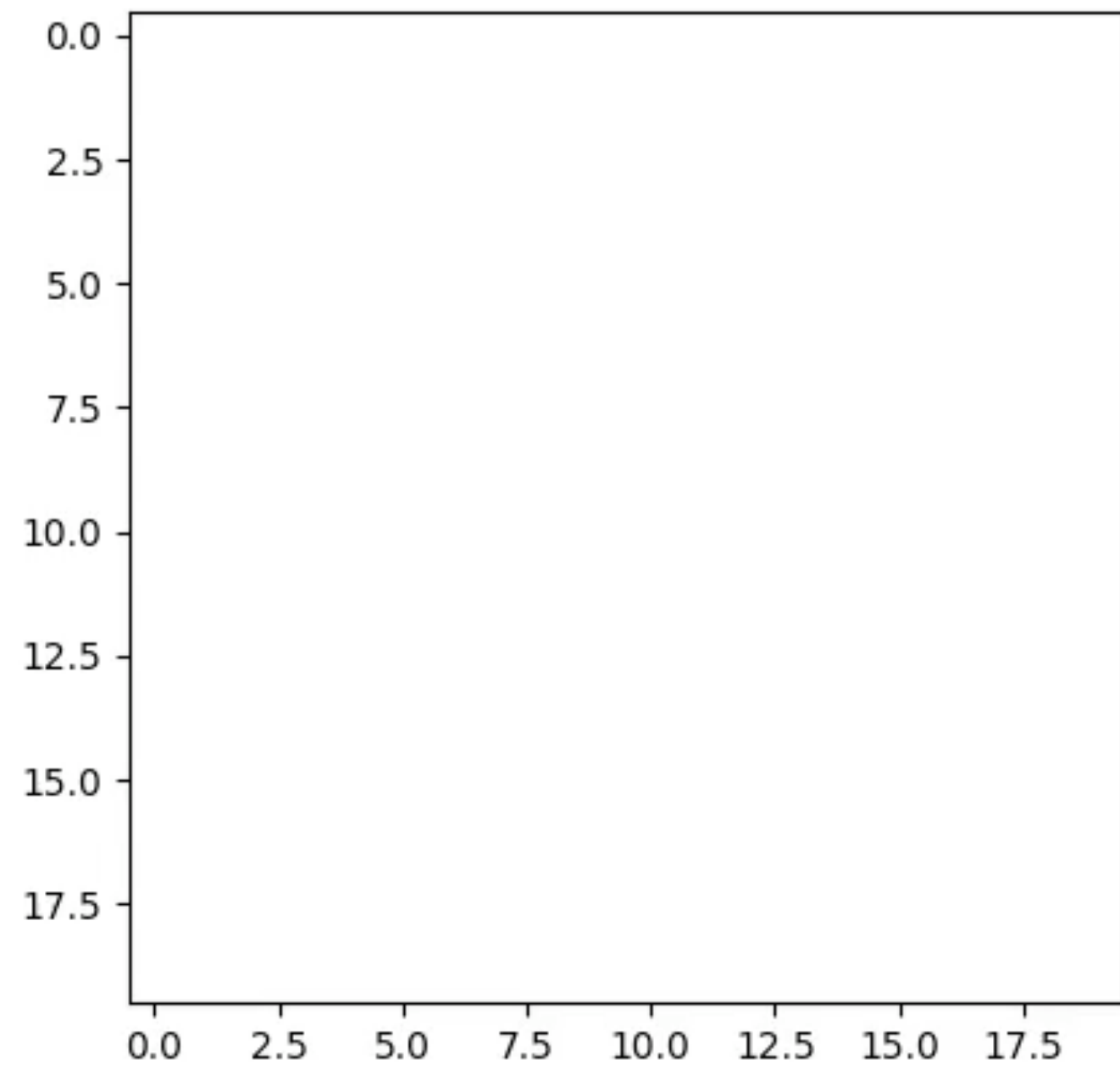
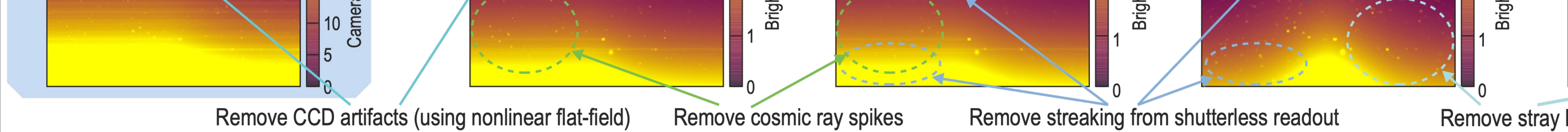




Image alignment via *thuban*

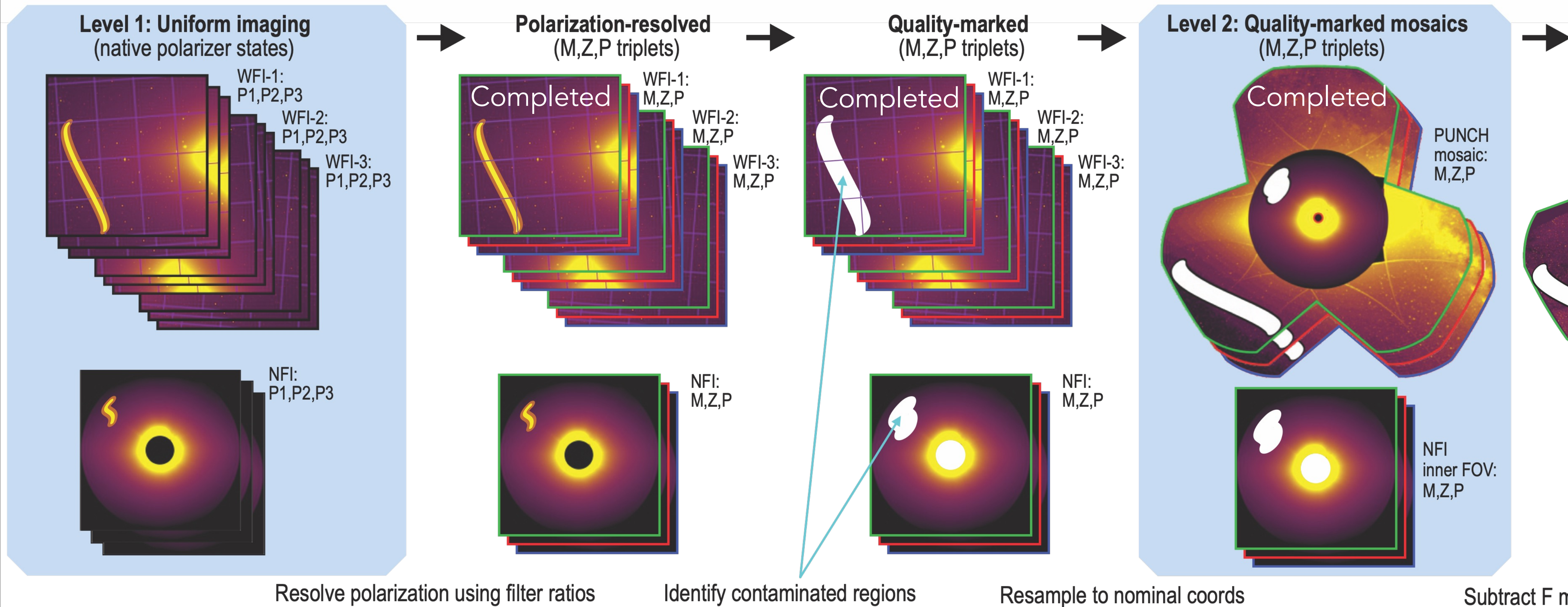
- Requirement of 0.1 pixel pointing
- RMS error on synthetic data: 0.0167 pixels





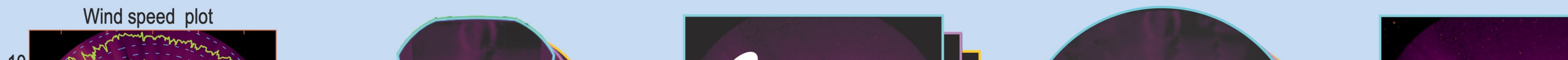
B. Level 1 → Level 3 Pipeline

The L1 to L2 stage maps polarization to M,Z,P triplet polarizer brightnesses, then generates full PUNCH mosaics. Clear exoplanet starfield (fixed in celestial coordinates), then generates B and pB products. Nearly all frames have no contamination.



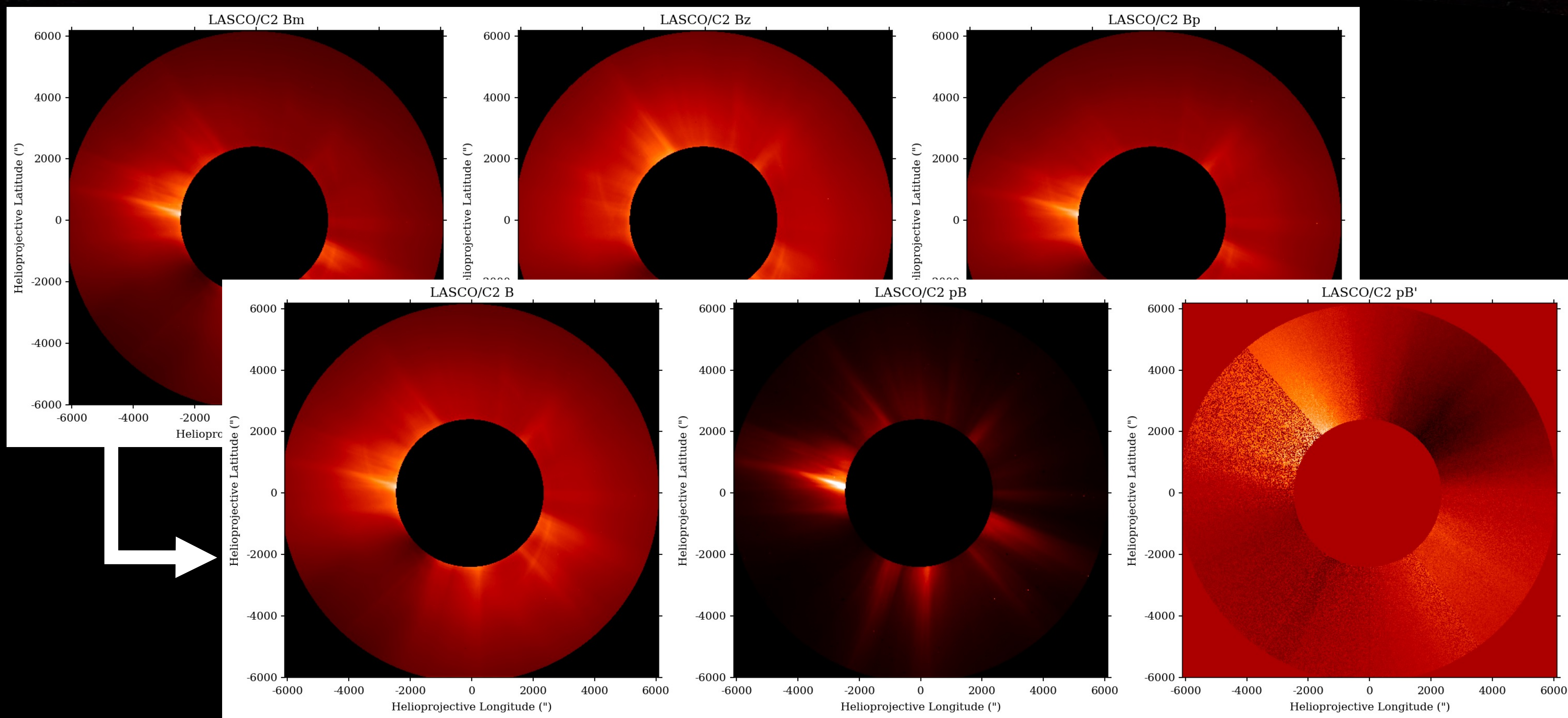
C. Level 3 Data Products

PUNCH Data Products are polarized and clear photometric images suitable for analysis in common existing scientific environments and with PUNCH-specific tools distributed by the project. Primary science products are shown.





Polarization resolution via *solpolpy*



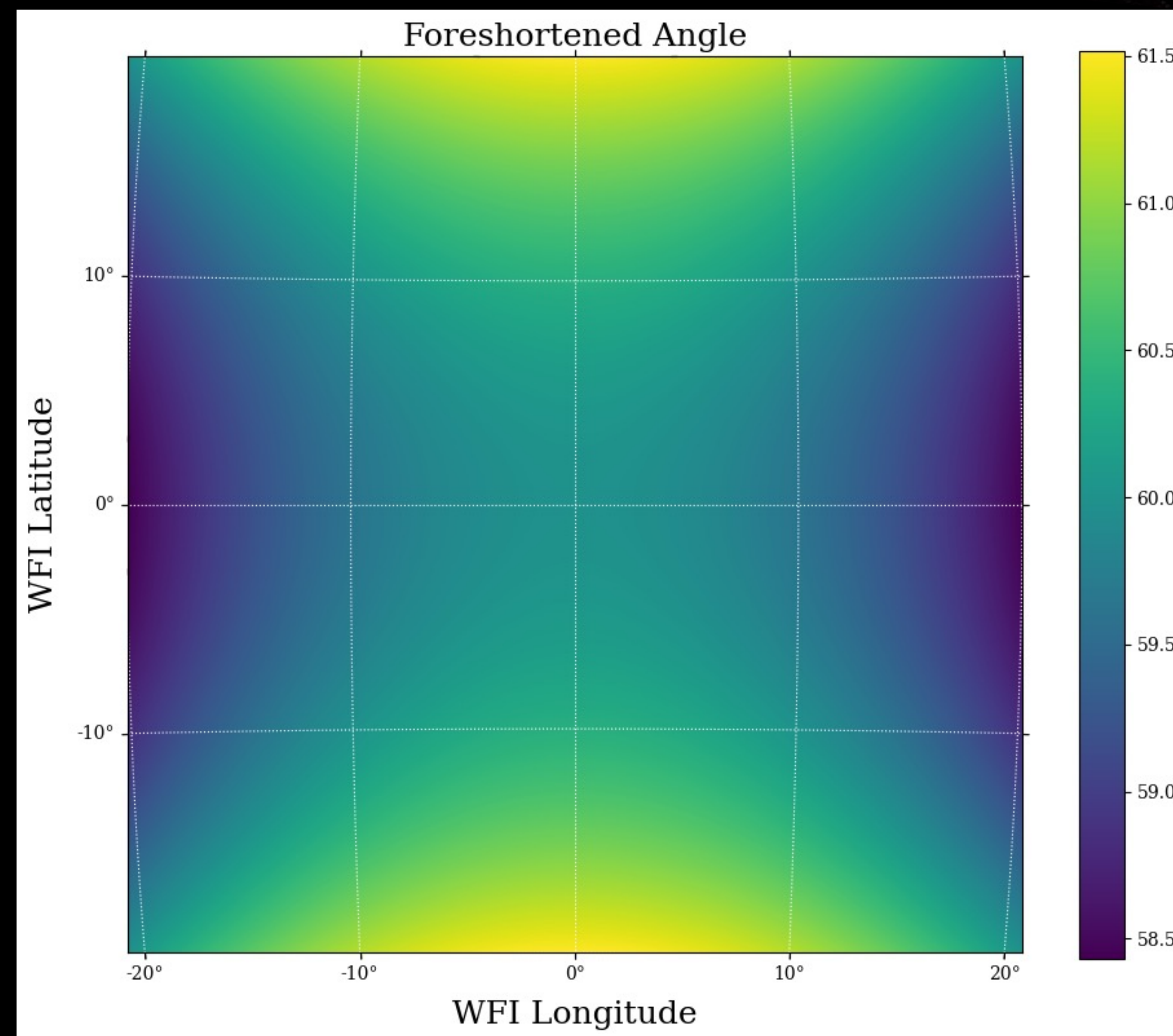
solpolpy converts from arbitrary polarization measurements to common bases.



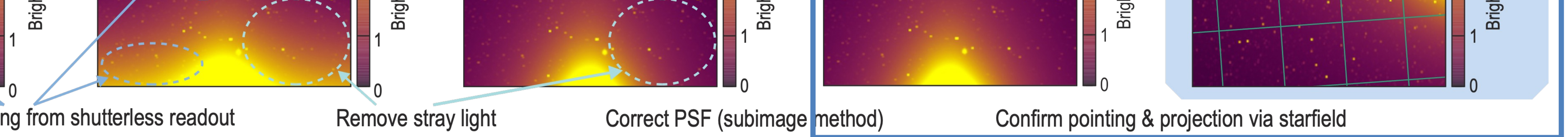
Polarization resolution via *solpolpy*

"IMAX Problem"

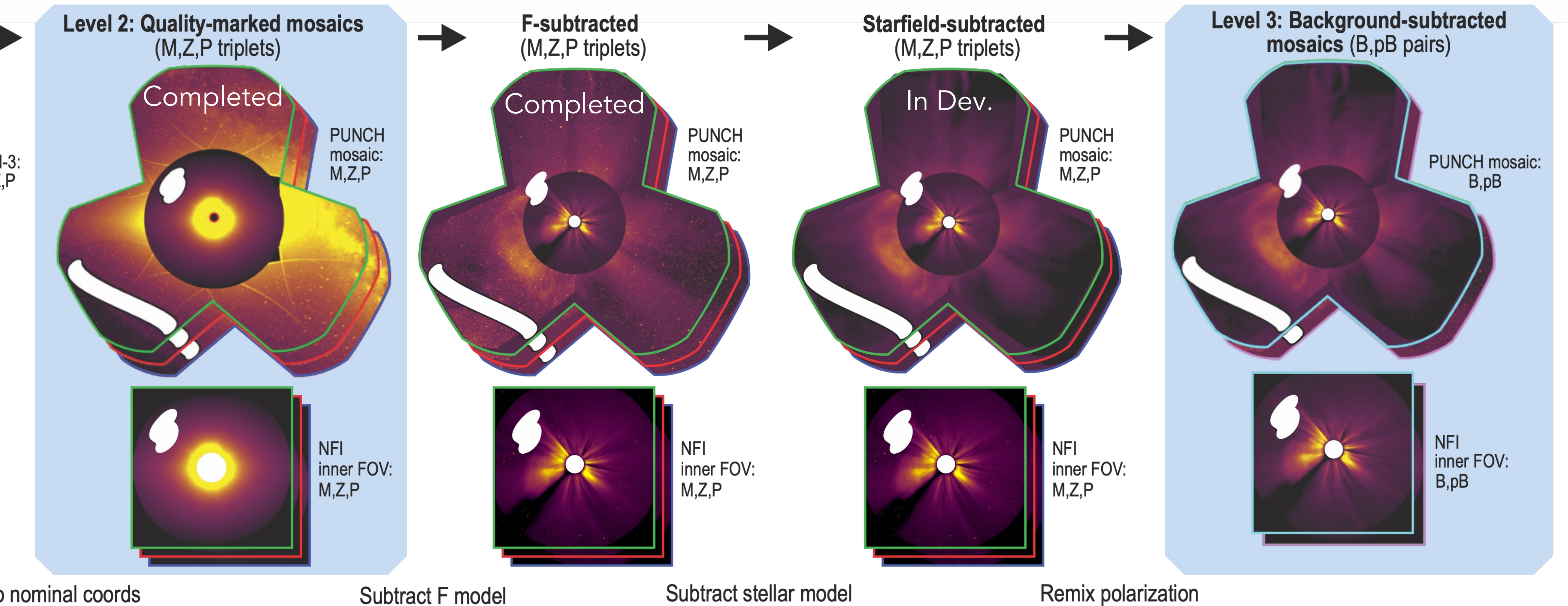
- WFI field of view is so large that sampled polarization angle varies across field of view



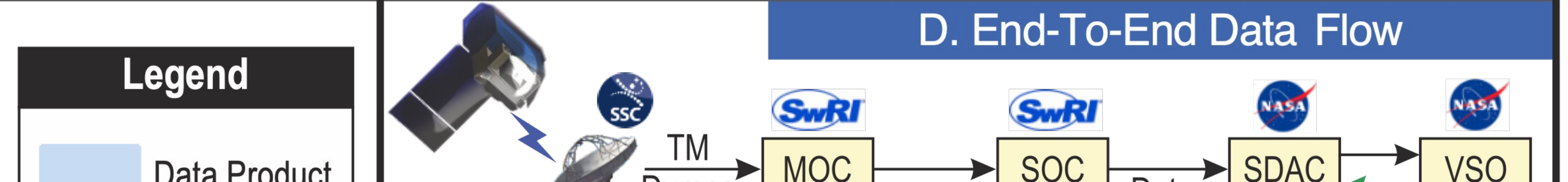
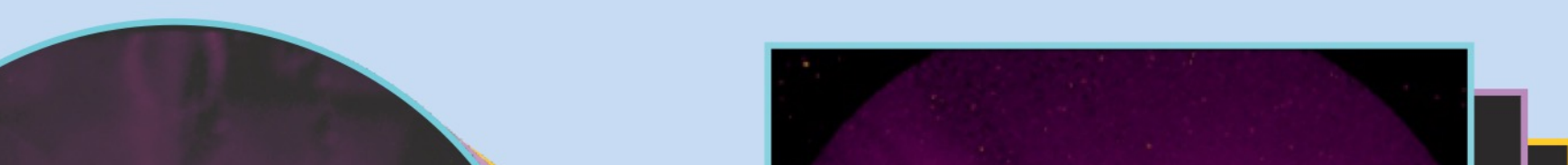
Paper in prep



tnesses, 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 products. Nearly all frames have no contamination.



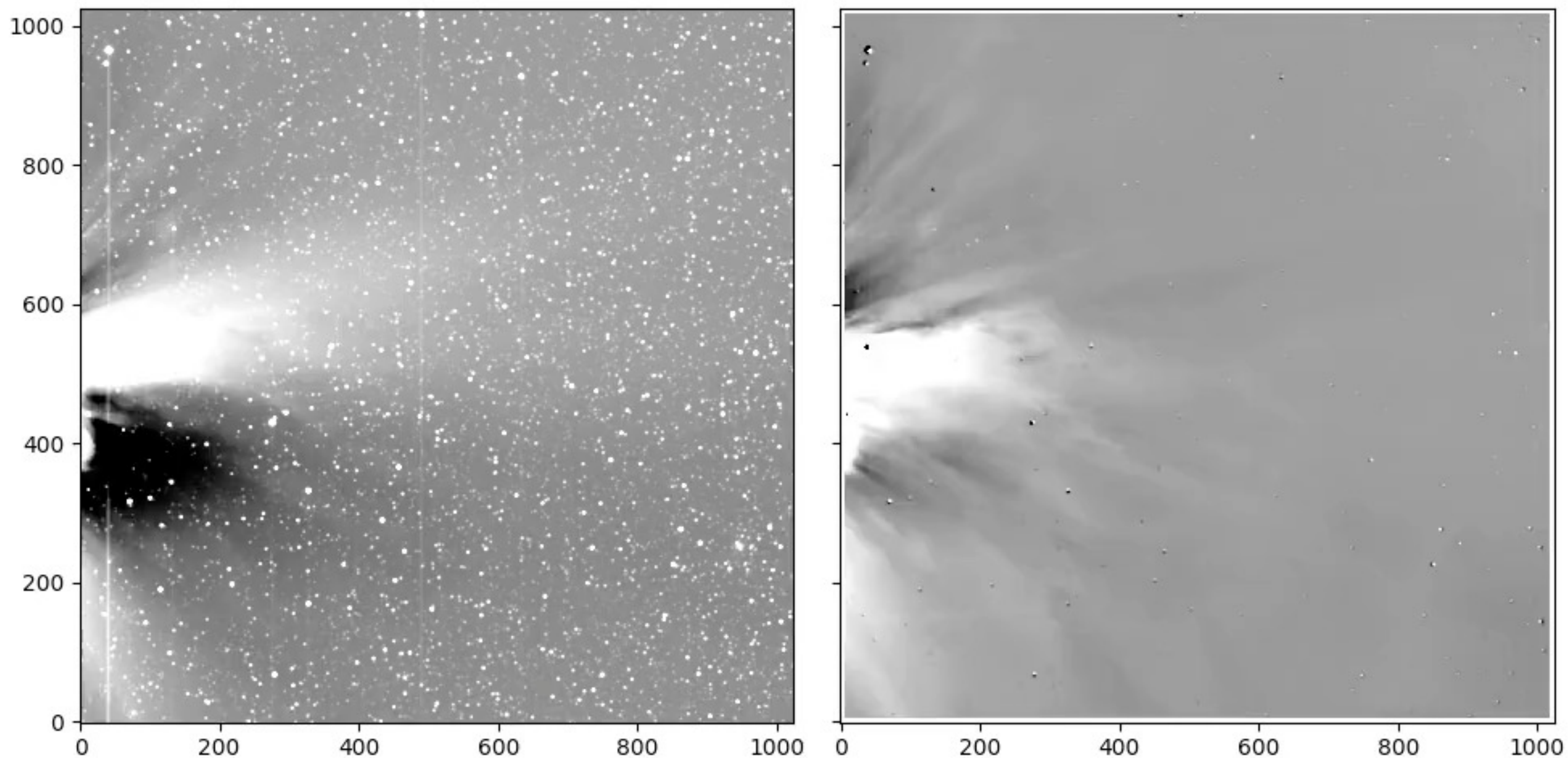
suitable for analysis in common existing scientific environments
science products are shown.





Starfield removal via *remove_starfield*

Uses Sam
Van Kooten's
star removal
package





Level 1

Levels 2 & 3

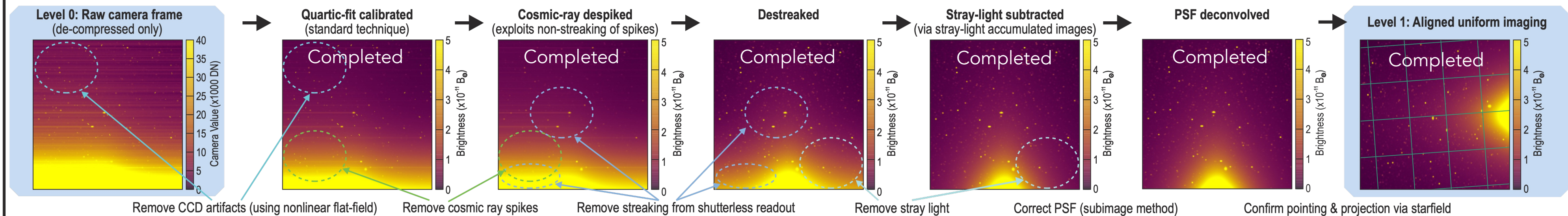
L3 Products

PUNCH Science Data Pipeline and Products

For effective data analysis by the PUNCH team and the broader community, PUNCH produces (A-C) and disseminates (D) calibrated, simple-to-use data products and analysis tools.

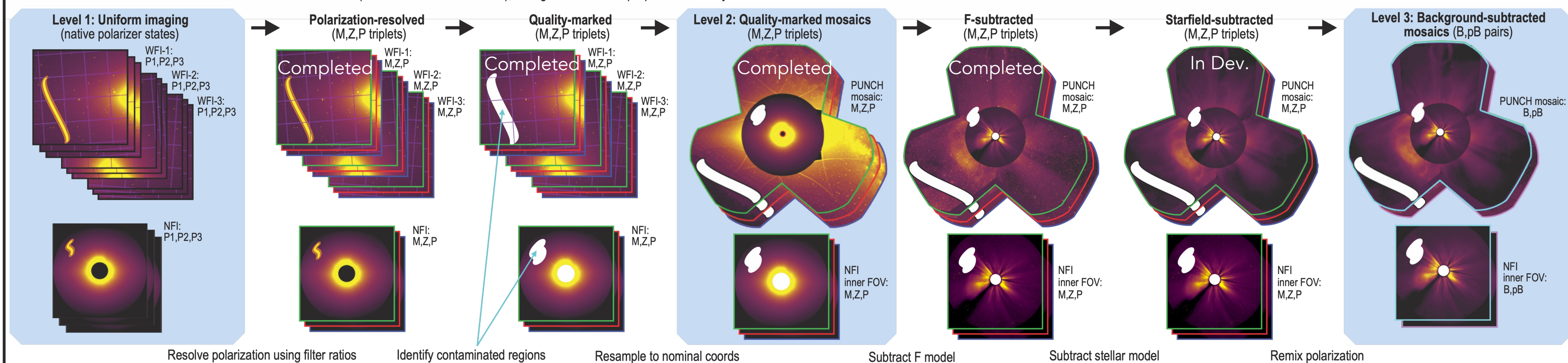
A. Level 0 → Level 1 Pipeline

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.



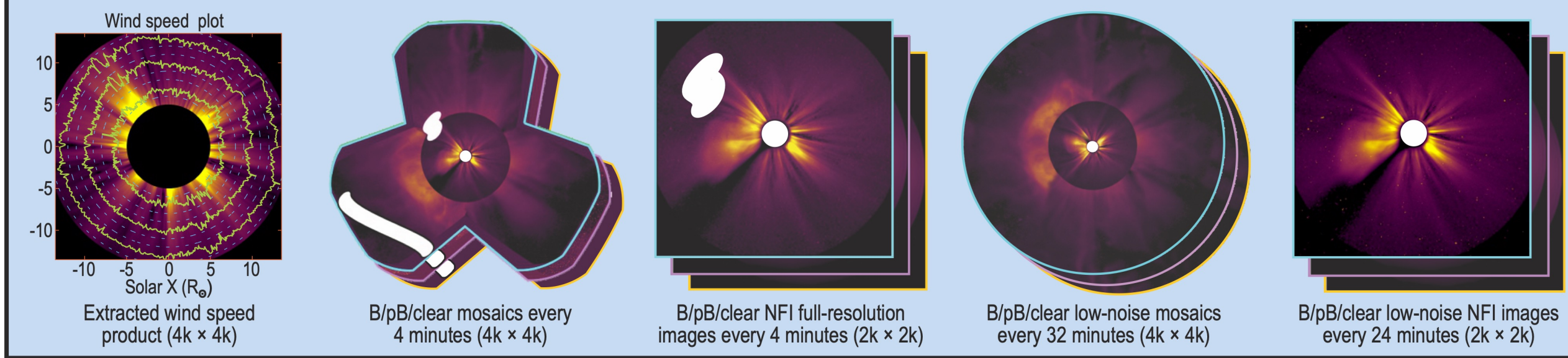
B. Level 1 → Level 3 Pipeline

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.

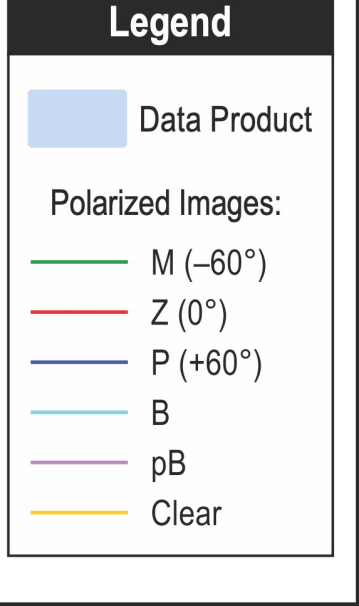


C. Level 3 Data Products

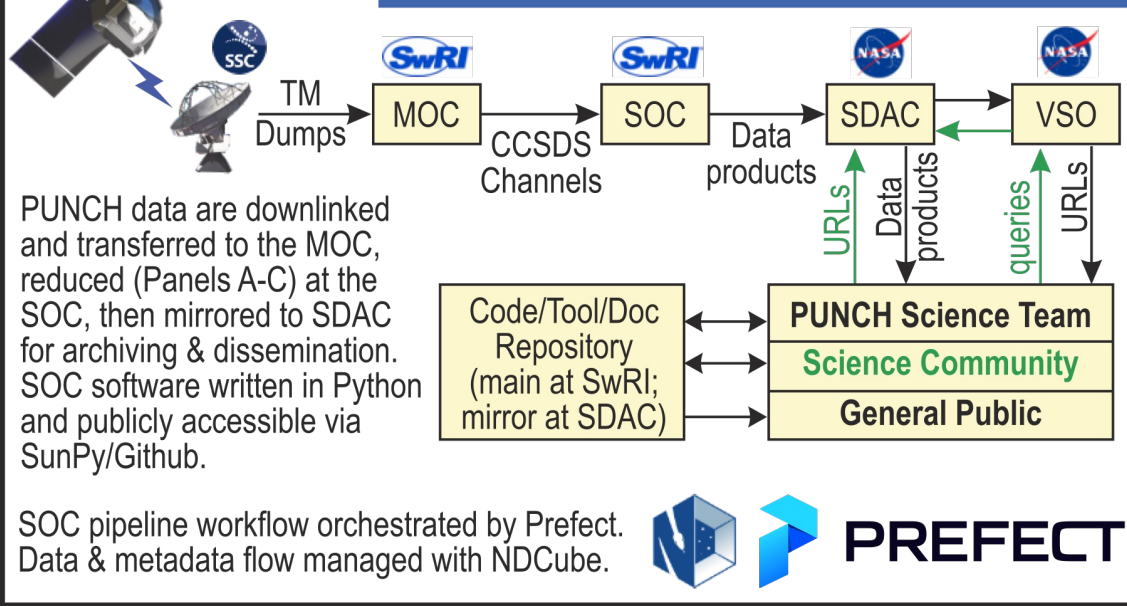
PUNCH Data Products are polarized and clear photometric images suitable for analysis in common existing scientific environments and with PUNCH-specific tools distributed by the project. Primary science products are shown.



Legend



D. End-To-End Data Flow





Pipeline automation and monitoring

Flow Runs

Flows

Deployments

Work Pools

Blocks

Variables

Notifications

Task Run Concurrency

Artifacts

FLOW RUNS

Default view

Date Range04/03/2023 → 04/11/2023

StatesAll run states

FlowsAll flows

DeploymentsAll deployments

Work PoolsAll pools

TagsAll tags

11s

8s

6s

3s

0s

Mon 03

Tue 04

Wed 05

Thu 06

Fri 07

Sat 08

Apr 09

Mon 10

Tue 11

14999 Flow runs

Search by run name

Newest to oldest

create-fake-level0 > mauve-cockatoo

auto-scheduled

Scheduled

Scheduled for 2023/04/10 09:45:46 AM

None

Deployment create_fake_level0

Work Pool default-agent-pool

Work Queue default

level2-scheduler-flow > black-trout

auto-scheduled

Scheduled

Scheduled for 2023/04/10 09:45:39 AM

None

Deployment level2_scheduler_flow

Work Pool default-agent-pool

Work Queue default

level1-scheduler-flow > amorphous-capybara

auto-scheduled

Scheduled

Scheduled for 2023/04/10 09:44:45 AM

None

Deployment level1_scheduler_flow

Work Pool default-agent-pool

Work Queue default

launcher-flow > blond-slug

auto-scheduled

OverallAlertsLevel 0Level 1Level 2Level 3

Level 2: 2023/04/08 00:41 to 2023/04/11 00:41

Average Duration [sec]3.5

Stddev Duration [sec]5.1 from 4.1

Number of files written512 from 510

Running flow count0

Queued flow count0

count

duration

1.3k rows11 columns13.8k cells

Run SQL QueryExport

	flow_id	flow_level	flow_type	flow_run_name	flow_run_id	state
1	446	2	level2_process_flow	pastel-wallaby	7df40d50-baa4-4b8c-b...	completed
2	450	2	level2_process_flow	daft-jerboa	b8ad46ee-8f89-42e3-...	completed
3	456	2	level2_process_flow	magic-dragon	7e5b47e6-3693-48a7-...	completed
4	459	2	level2_process_flow	viridian-bee	aacc4d5c-6fea-4796-9...	completed
5	462	2	level2_process_flow	pastoral-urchin	e1f978ec-5cd6-462f-9...	completed
6	465	2	level2_process_flow	khaki-raccoon	97386080-e15e-4dd0-...	completed
7	468	2	level2_process_flow	resourceful-beagle	99e0f6ca-b177-43f3-9...	completed





GitHub Organization

<https://github.com/punch-mission>



SCAN ME

punch-mission

Overview

Repositories20

Discussions

Projects1


Packages

Teams2

People9

Settings

swri



PUNCH Mission

a NASA mission to study the solar wind

15 followers

United States of America

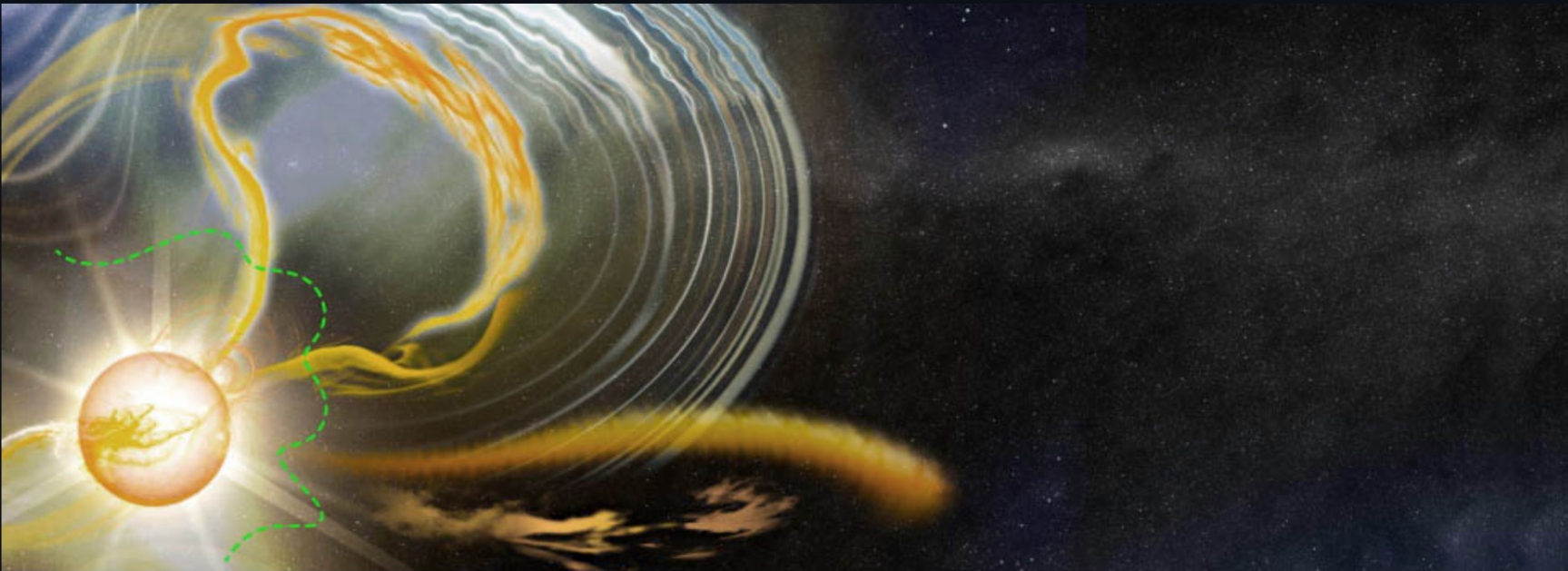
<https://punch.space.swri.edu/>

punch_soc@swri.org

Unfollow

readme.md

PUNCH Mission



PUNCH is a NASA Small Explorer (SMEX) mission to better understand how the mass and energy of the Sun's corona become the solar wind that fills the solar system. Four suitcase-sized satellites will work together to produce images of the entire inner solar system around the clock.

Synthetic data is now available at https://data.boulder.swri.edu/mhughes/punch5_synthetic_data/

- [Visit the PUNCH mission website.](#)
- [Get started with PUNCH software.](#)
- [Learn more about the student instrument, STEAM.](#)

View as: Public

You are viewing the README and pinned repositories as a public user.


[Get started with tasks](#) that most successful organizations complete.

Top discussions this past month

Discussions are for sharing announcements, creating conversation in your community, answering questions, and more.

[Start a new discussion](#)

People



Invite someone

Top languages

Python

Jupyter Notebook

C++

IDL

Most used topics

punch

solar

astronomical-algorithms

image-processing

astrometry

Manage

Pinned

punch-mission

Public

Welcome to PUNCH! Maintainer: @jmbhughes

2

regularizepsf

Public

A Python package for manipulating and correcting variable point spread functions. Maintainer: @jmbhughes

Python

18

4

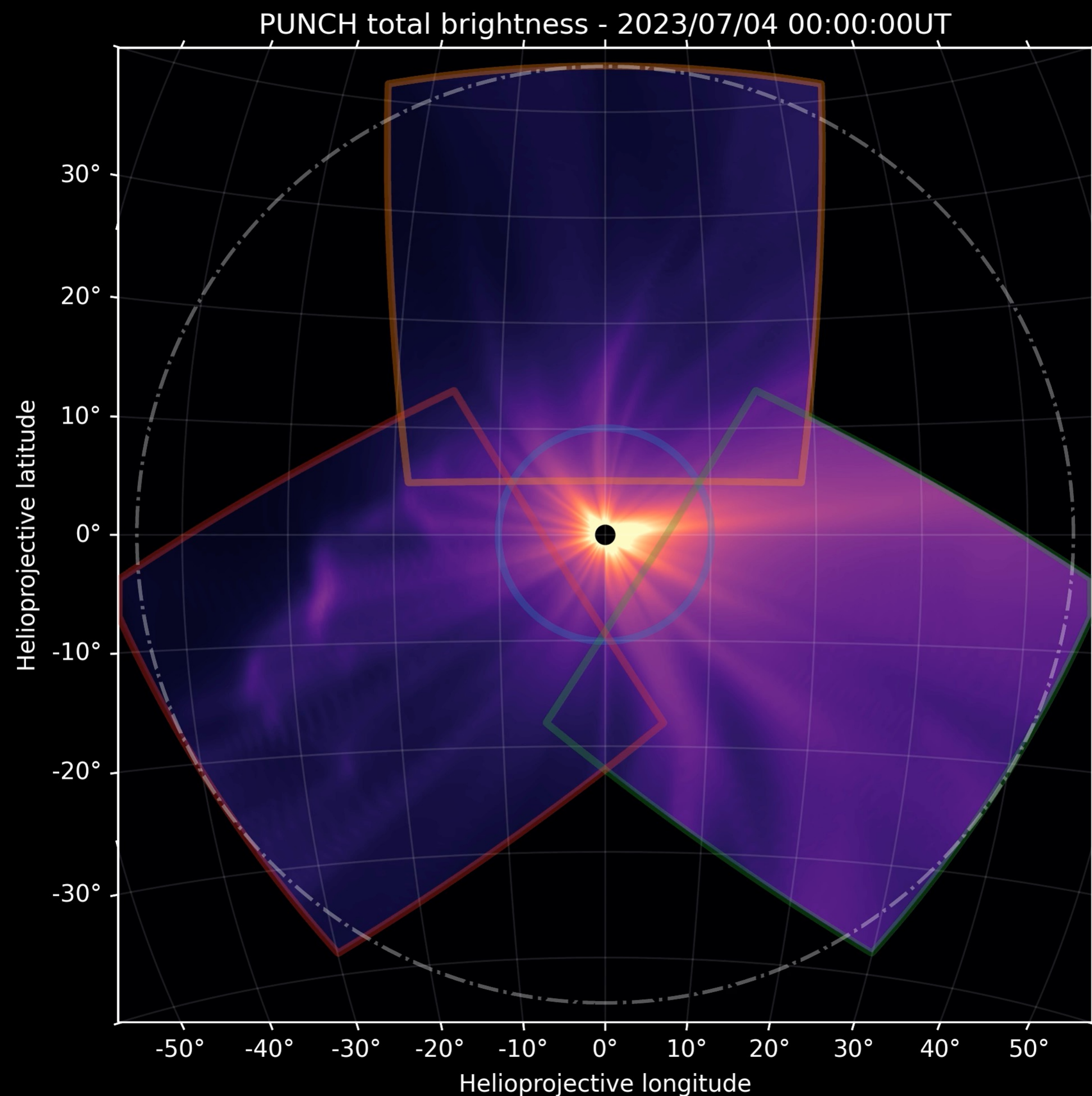
Customize pins



Sample Products Are Ready

**GAMERA Model-derived Data
Products are now available**

- Get FITS files here:
<https://tinyurl.com/punch-data>





Next up

- Develop more and better synthetic data via *simpunch*
- Deploy server and test product-archive interfaces
- Finish starfield removal
- Complete uncertainty quantification and propagation
- Incorporate flow tracking algorithm and develop flow tracking data products
- Complete development of QuickPUNCH products
- Begin SunPy affiliation process



Summary

- Data pipeline is nearly complete
- End-to-end testing planned
- **Synthetic Data Available Now: <https://tinyurl.com/punch5data>**

Other SOC-related presentations:

- **Chris Lowder:** Working with PUNCH Data: A How-To Guide
- **Dan Seaton:** QuickPUNCH Data for Space Weather Operations

Polarimeter to Unify the Corona and Heliosphere



SCAN ME

We want to work with you!

Get in touch!

github.com/punch-mission

punch_soc@swri.org

Polarimeter to Unify the Corona and Heliosphere

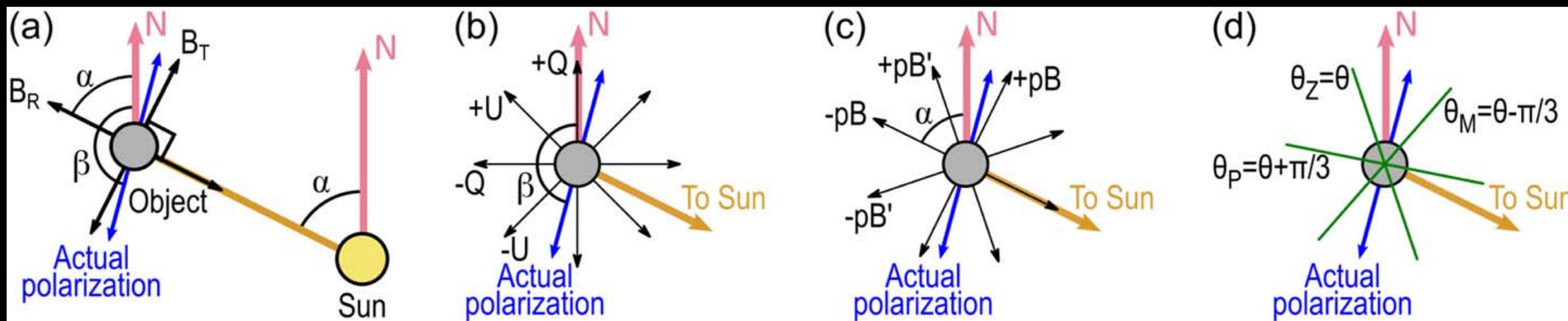


Backup Slides



Polarization resolution via solpolpy

SolPolPy converts from arbitrary polarization measurements to common bases.



Radial/Tangential

Stokes

B/pB

MZP