Polarimeter to Unify the Corona and Heliosphere

~286 days to launch

Science Operations Center Development

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PUNCH Science Meeting 5 Pre-meeting
June 18 2024 ☀ Boulder, Colorado

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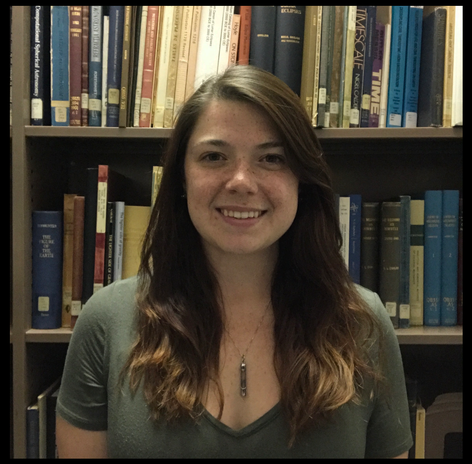


Sarah Kovac

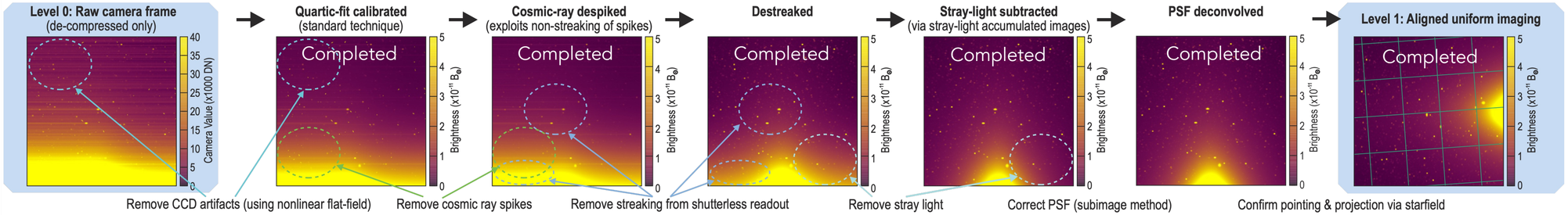
PUNCH Science Data Pipeline and Products

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.

L3 Products Levels 2 & 3 Level 1

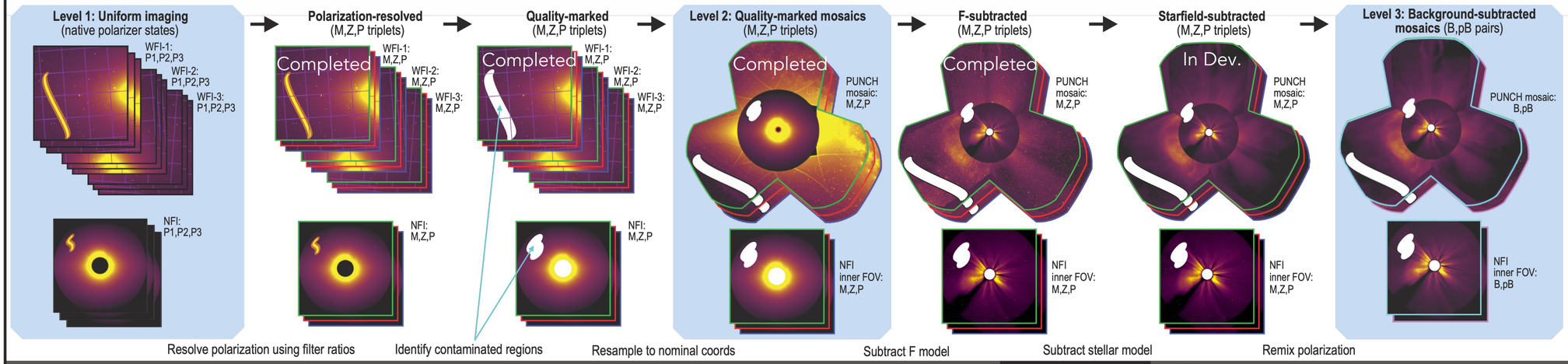
A. Level 0 → Level 1 Pipeline

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.



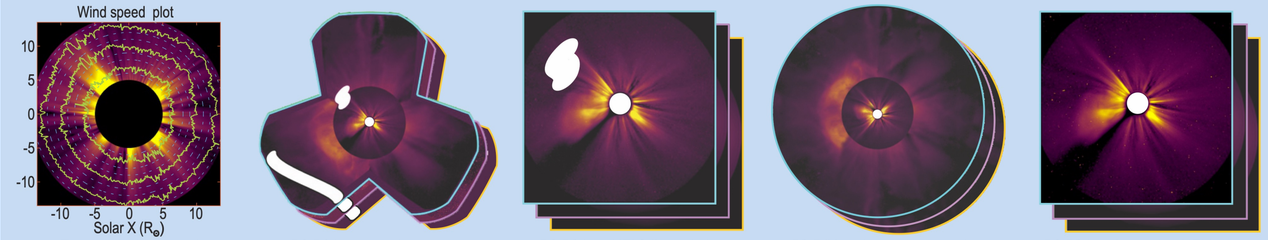
B. Level 1 → Level 3 Pipeline

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

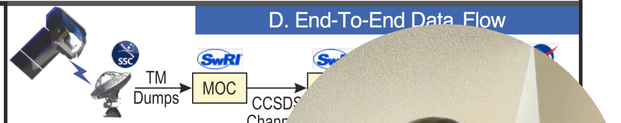
PUNCH Data Products are polarized and clear photometric images suitable for analysis in common existing scientific environments and with PUNCH-specific tools distributed by the project. Primary science products are shown.



Legend

- Data Product
- Polarized Images:
  - M (–60°)
  - Z (0°)
  - P (+60°)
- B
- pB
- Clear

D. End-To-End Data Flow



PUNCH data are downlinked and transferred to the MOC, reduced (Panels A-C) at the SOC, then mirrored to SDAC for archiving & dissemination. SOC software written in Python and publicly accessible via SunPy/Github.

SOC pipeline workflow orchestrated by Pre
Data & metadata flow managed with NDCube

Original figures and layout from PUNCH CSR

Data Products

- Data is retrieved from the SDAC using VSO queries

Table 5-1: PUNCH Science Data Products

NASA Data Level	Product Description	First Delivery After Start of Science Ops	Maximum Data Latency After First Release
Level 0	Individual decommutated, raw uncalibrated camera frames; science images, darks, flats	1 day	1 day
Level 1	Individual camera frames, flat fielded, with preliminary calibration applied and co-aligned meta data tags derived from the star field	30 days	3 days
Level 2	Re-sampled mosaics, 4 minute cadence 6k x 6k, rectified and polarization resolved in heliocentric equal-radius azimuthal projection. Types: C, RP, TP	60 days	7days
Level 3	Processed/background subtracted B & pB images. Types: NFI: C, B, pB 4 minute; PUNCH WFI/NFI mosaic: C, B, pB 4 & 32 minute; Corresponding background models. Quantitative solar wind speed maps: speed at 6 radii, 1440 azimuths, 12 hr.	90 days	14 days
Quick Look Products	One best image, 3 x per orbit for NFI & WFI. R-log-theta combined WFI & NFI best image montage per orbit. Wind speed display plot at the lowest height 1x per orbit, obtained from real time motion filtering of NFI clear L1 data, plotted on NFI image for context	30 days	4 days
Cal. Products	Weekly background models for NFI and for the full field 6k x 6k. Flat fields and nonlinear calibrations per pixel.	60 days	30 days

Data Products

Most people will want L3 products with stars and F-corona removed and polarization resolved into B/pB

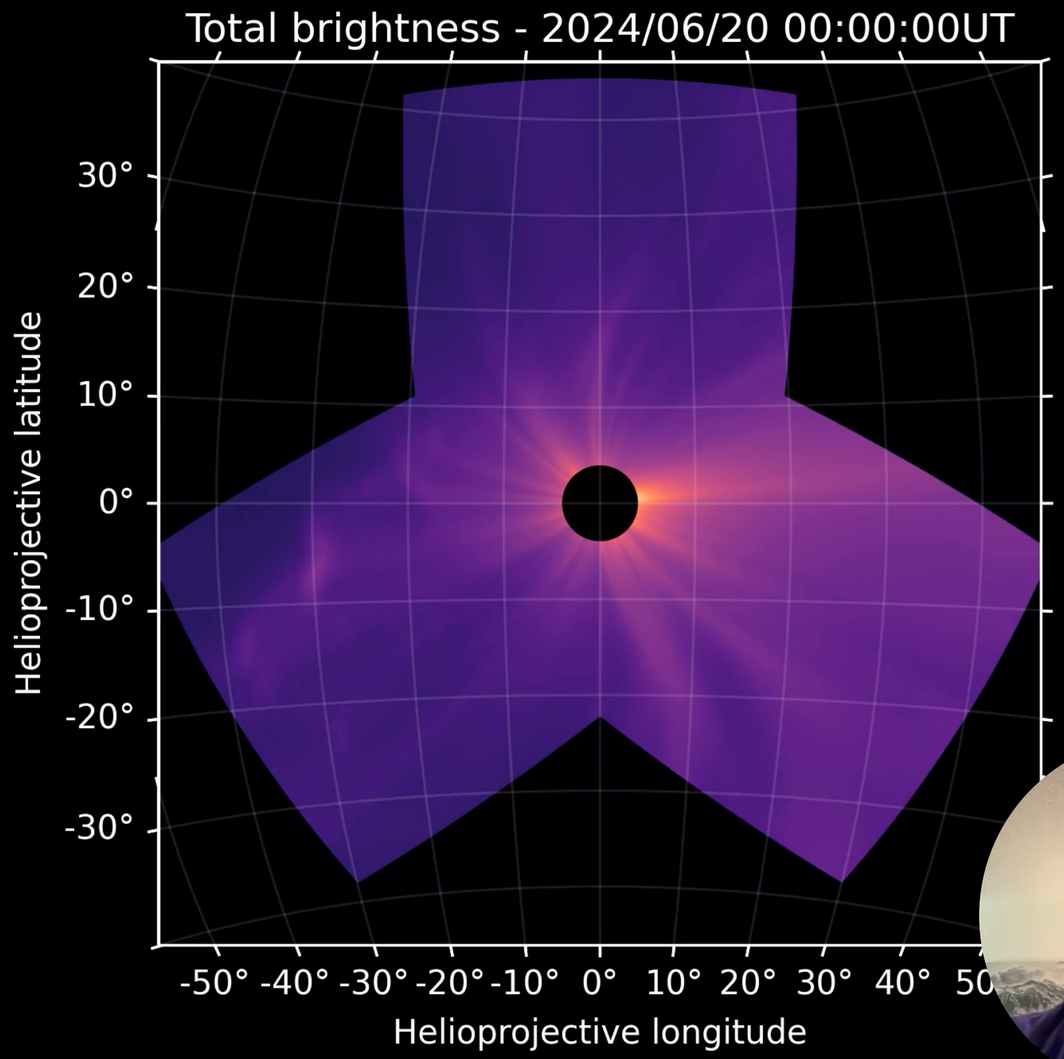
Lev	Code	Primary HDU	Secondary HDU	Description
0	PM1-4, PZ1-4, PP1-4, CR1-4	2k×2k	-	Science images in the standard polarization (PM, PZ, PP) and clear (CR) states, in DN (direct from instrument)
0	PX1-4	2k×2k	-	Science images in a nonstandard polarization state, in DN (direct from instrument)
0	DK1-4, DY1-4	2k×2k	-	Cal. Images: polarizer im dark pos.; stim lamp off (DK) or on (DY)
0	OV1-4	?×2k	-	Cal. Image: CCD overscan
0	XI1-4	?×?	-	Experimental image (no set parameters; variable crop)
0	ST	-	-	STEAM data packet (CSV format)
1	BD1-4	2k×2k	-	Calibration: Deficient Pixel Map (1bit Kernel)
1	PM1-4, PZ1-4, PP1-4, CR1-4	2k×2k	-	Science images in the standard polarization (PM, PZ, PP) and clear (CR) states, in $B_\odot$ (photometric calibrated)
1	FQ1-4	5×2k×2k	-	Calibration: Flat-field parameters (quartic polynomial coefficients), by pixel
1	GM1-4, GZ1-4, GP1-4, GR1-4	2k×2k	-	Calibration: Vignetting functions for the standard polarization (GM, GZ, GP) and clear (GR) states
1	SM1-4, SZ1-4, SP1-4, SR1-4	2k×2k	-	Calibration: Instrumental additive stray light model for the standard polarization (SM, SZ, SP) and clear (SR) states
1	RG1-4	?k×?k	-	Calibration: Point Spread Function model for the standard polarization and clear states
2	PTM	3×4k×4k	3×4k×4k	Pol. science mosaics (Trefoil) in output coordinates, resolved into MZP pol. triplets, and pixel-weight
2	CTM	4k×4k	4k×4k	Clear science mosaics (Trefoil) in output coordinates, resolved into image and pixel-weight
2	PNN	3×2k×2k	3×2k×2k	Pol. NFI images in output coordinates, resolved into MZP pol. triplets, and pixel-weight
2	CNN	2k×2k	2k×2k	Clear NFI images in output coordinates, resolved into image, and pixel-weight
QP	CNN	1k×1k	-	QuickPUNCH NFI images
QP	CTM	1k×1k	-	QuickPUNCH Mosaic images (5.4–80 $R_\odot$)
QL	CNN	?k×?k	-	Quicklook NFI images
QL	CTM	?k×?k	-	Quicklook Mosaic images
3	PFM	3×4k×4k	3×4k×4k	Polarized mosaic F corona model, resolved into MZP pol. triplets, and pixel-weight (from MP's)
3	CFM	4k×4k	4k×4k	Clear mosaic F corona model, resolved into image and pixel-weight (from MC's)
3	PSM	3×4k×4k	3×4k×4k	Polarized mosaic stellar model, resolved into MZP pol. triplets, and pixel-weight (from MP's)
3	CSM	4k×4k	4k×4k	Clear mosaic stellar model, resolved into image and pixel-weight (from MC's)
3	PFN	3×2k×2k	3×2k×2k	Polarized NFI F-corona model, resolved into MZP pol. triplets, and pixel-weight (from NP's)
3	CFN	2k×2k	2k×2k	Clear NFI F-corona model, resolved into image and pixel-weight (from NC's)
3	PTM	2×4k×4k	2×4k×4k	Polarized K PUNCH science mosaics (Trefoil), bkg-sub & resolved into B, pB, & pixel-weight
3	CTM	4k×4k	4k×4k	Clear K science mosaics (Trefoil), bkg-sub & resolved into B & pixel-weight
3	PNN	2×2k×2k	2×2k×2k	Polarized K NFI science image, bkg-sub & resolved into B, pB, & pixel-weight
3	CNN	2k×2k	2k×2k	Clear K NFI science image, bkg-sub & resolved into B & pixel-weight
3	VAM	?×1440	?×1440	Mosaic derived wind velocity maps extracted from MP's: 1440 pos. angles at various altitudes
3	VAN	?×1440	?×1440	NFI derived wind velocity maps extracted from MP's: 1440 pos. angles at various altitudes
3	PAM	2×4k×4k	2×4k×4k	Polarized low-noise science mosaic, bkg-sub & resolved into B, pB, & pixel-weight
3	CAM	4k×4k	4k×4k	Clear low-noise science mosaic, bkg-sub & resolved into B & pixel-weight
3	PAN	2×2k×2k	2×2k×2k	Polarized low-noise NFI science image, bkg-sub & resolved into B, pB, & pixel-weight
3	CAN	2k×2k	2k×2k	Clear low-noise NFI science image, bkg-sub & resolved into B & pixel-weight
3	PLM	TBD	TBD	All-PUNCH (r,log-theta) combined montage
3	VOM	TBD	TBD	Speed display plot, once per orbit

Key: "?" = variable size; "k"=1024; "Code" = 2-letter identifier code for each data product, and a satellite reference number (1-4) mosaic (M) or NFI (N); MZP=virtual polarizer triplets (M, Z, P); B=calculated unpolarized brightness; pB=excess tangential polarized brightness; F=Fraunhofer (dust) corona [or zodiacal light]; K = Kontinuierlich (Thomson-scattered) corona [or young solar wind].

Sample Products Are Ready

GAMERA Model-derived Data Products are now available

- https://github.com/punch-mission/punch-5-meeting



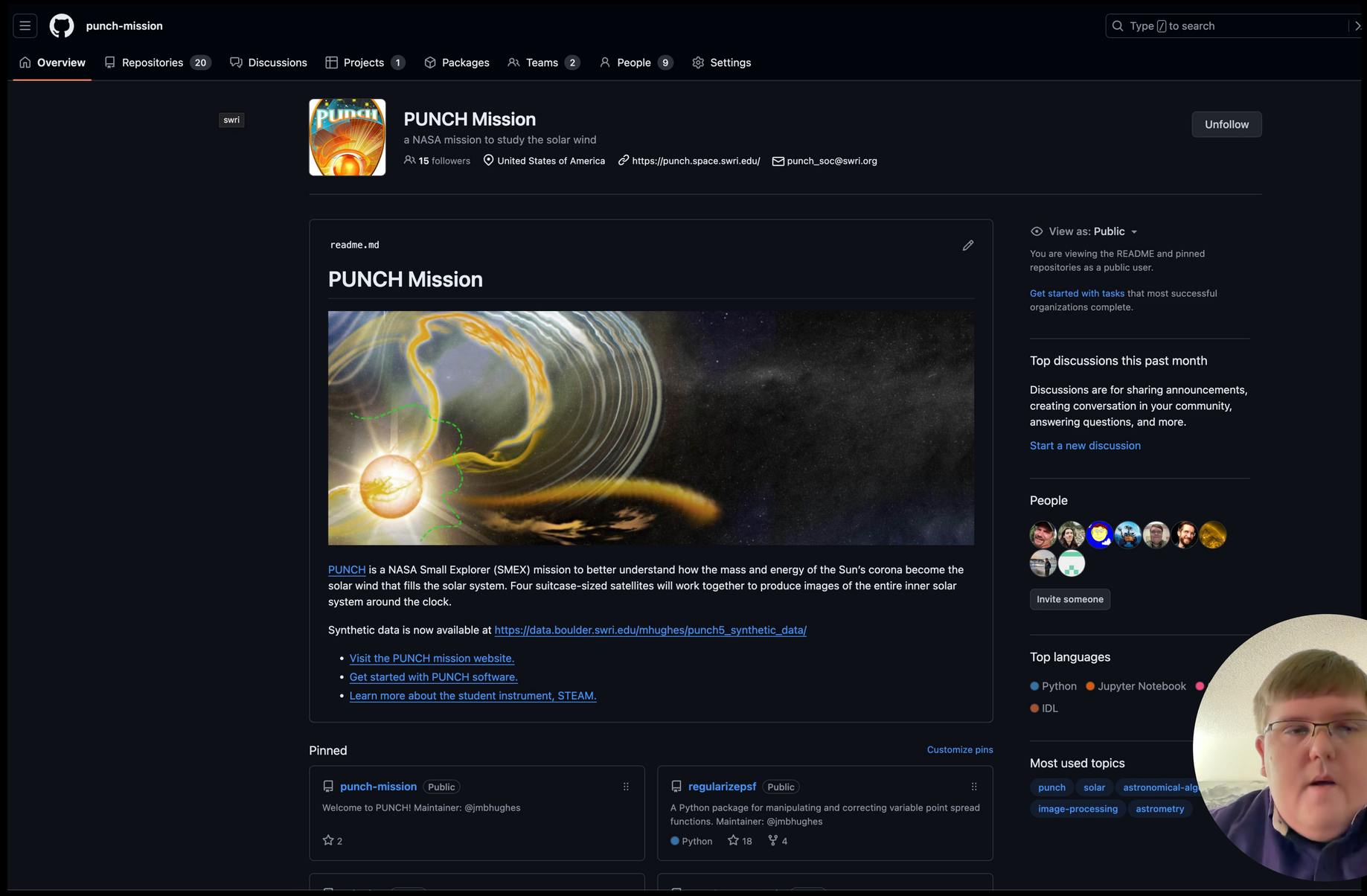
SOC Discussion Topics

- Will people prefer SunPy Maps (with a layer option) or NDCube?
- How do people browse data? JHelioviewer?
- What analysis tools are being developed? How can the SOC incorporate them and advertise through GitHub?
- What do people look for in good user guides? Examples seem key.

GitHub Organization

https://github.com/punch-mission

SCAN ME



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We want to work with you!

Get in touch!

SCAN ME

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