



PUNCH's Plumbing: Background Subtraction and Calibration in the PUNCH Pipeline



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Background subtraction 101

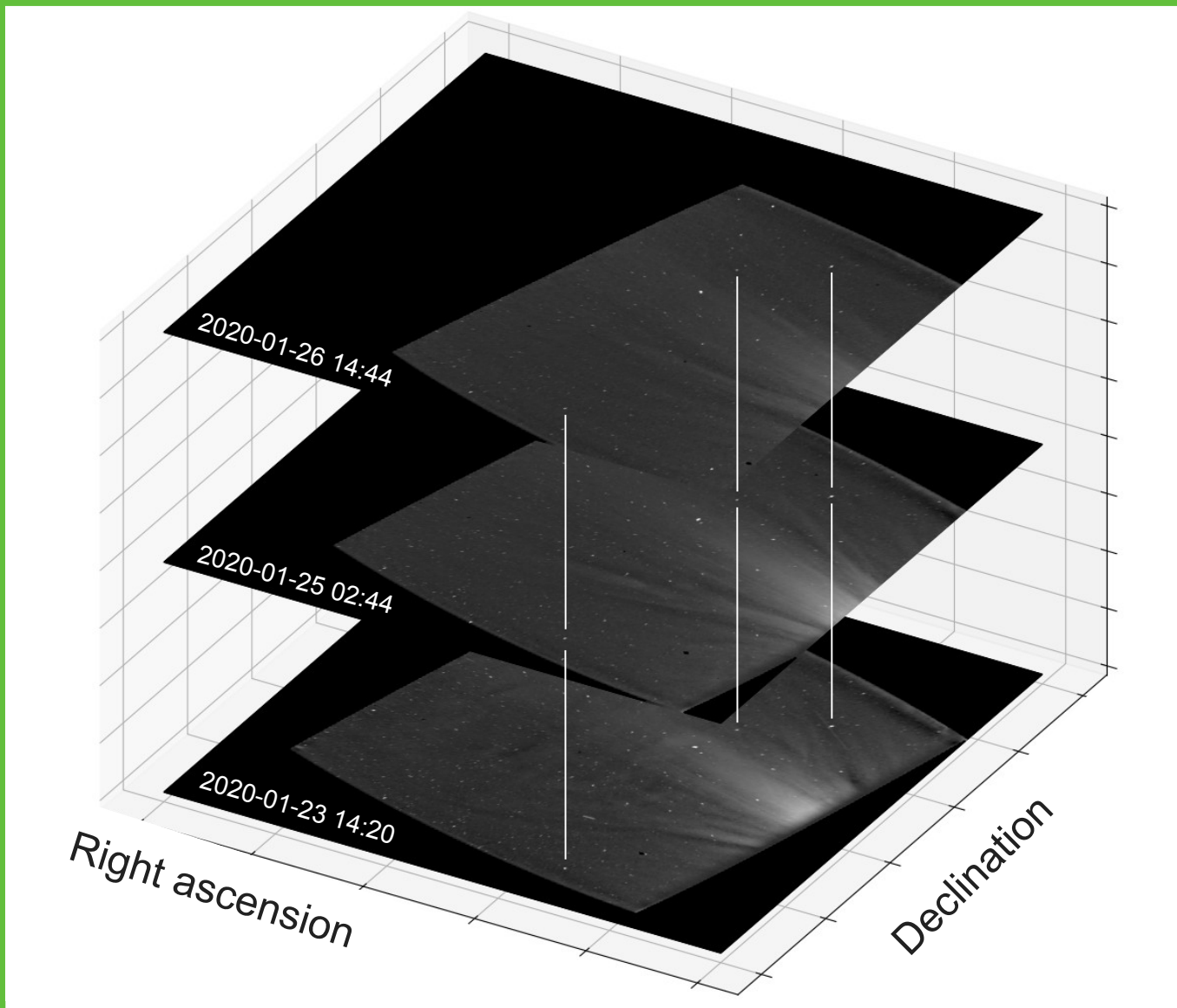
To estimate and remove a background:

Frame: Put a time-series of images in a frame where the background is fixed. E.g.:

- For stray light, the instrument frame
- For stars, the celestial frame

Reduce the stack with a low percentile or similar to capture "pure" background.

- Since everything is optically-thin and additive, this is the cleanest sample of the BG, with the fewest additional photons.



For a stellar background, put the data in a celestial frame, where a given star always appears in the same pixel.

(Example data is WISPR L3, encounter 4 —someday I'll remake this figure with PUNCH!)

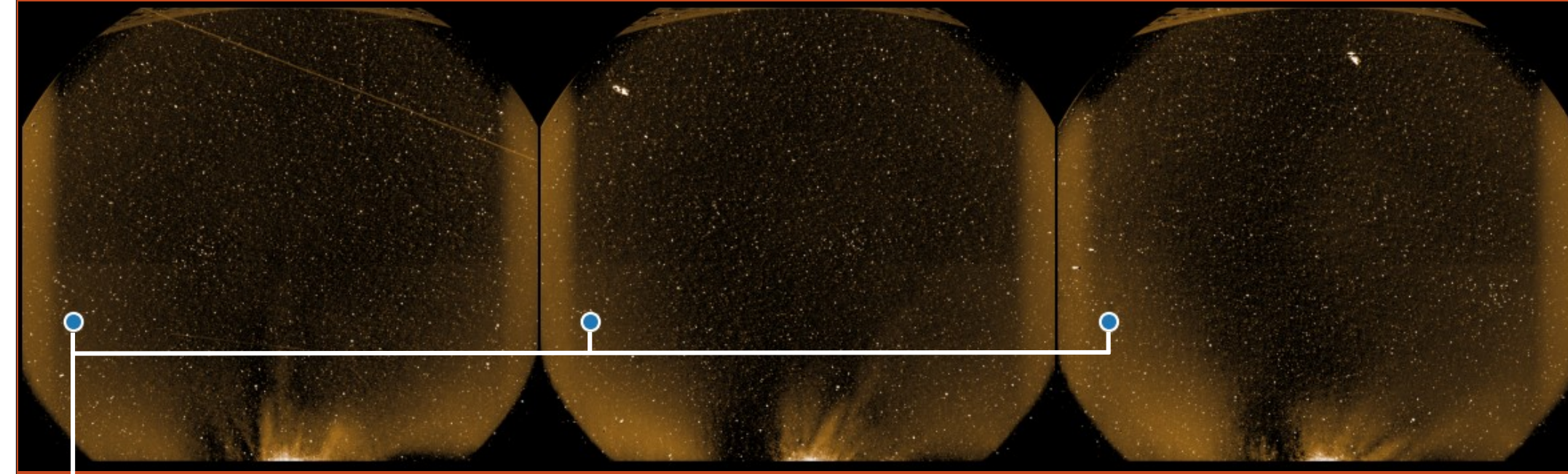
Stray light

Step 1: Frame Stray light is fixed in the instrument frame.

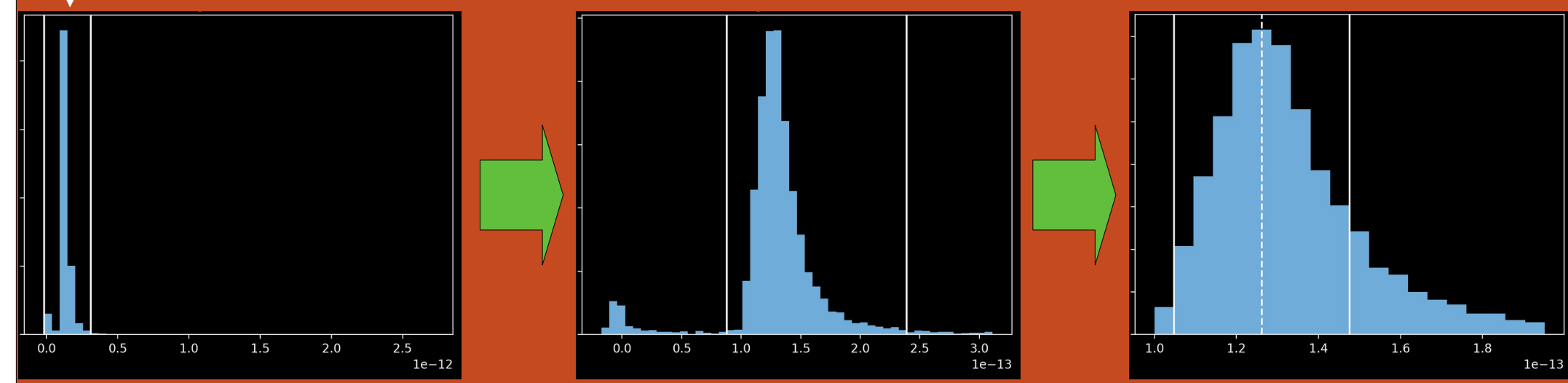
Step 2: Reduce

- Tricky: stray light is much fainter than the F corona.
- We "pre-subtract" the F and K corona just for the step.

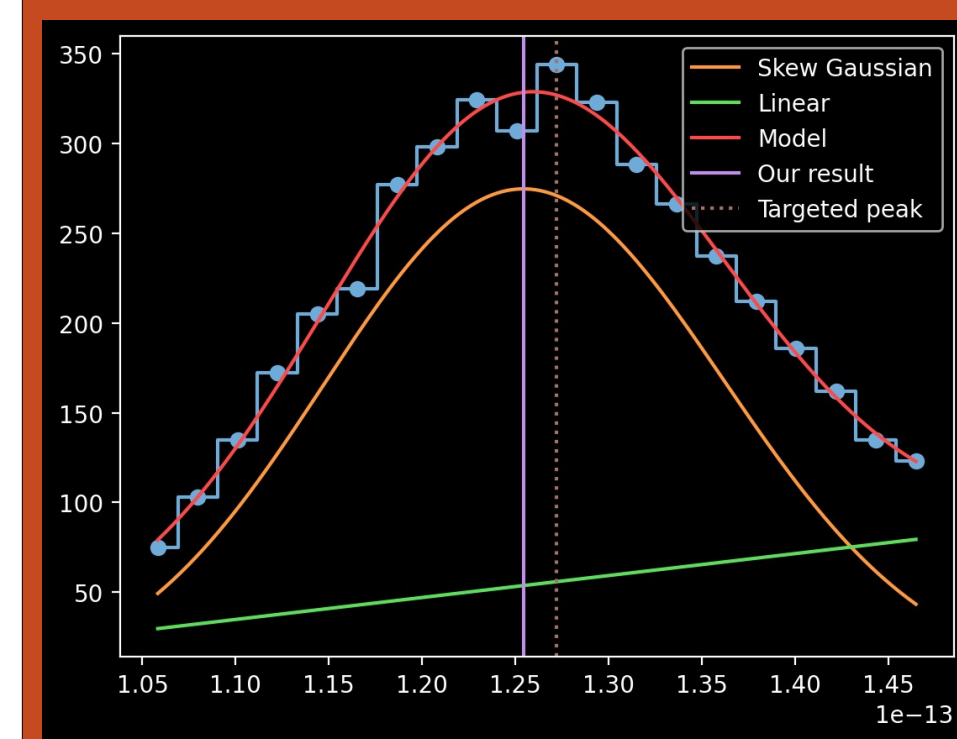
Three "pre-subtracted" images:



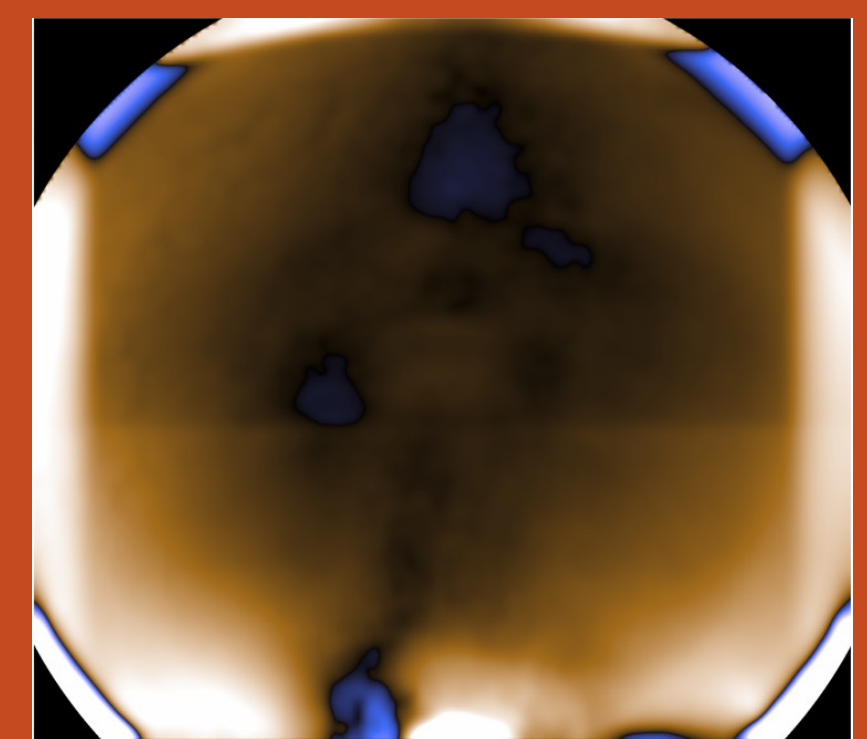
- We make a histogram for each pixel and iteratively zoom in to the Gaussian noise centered on our SL value.



- Then we fit with a skew-Gaussian @ each pixel



This makes models that look like this: (that's with a really exaggerated color bar)



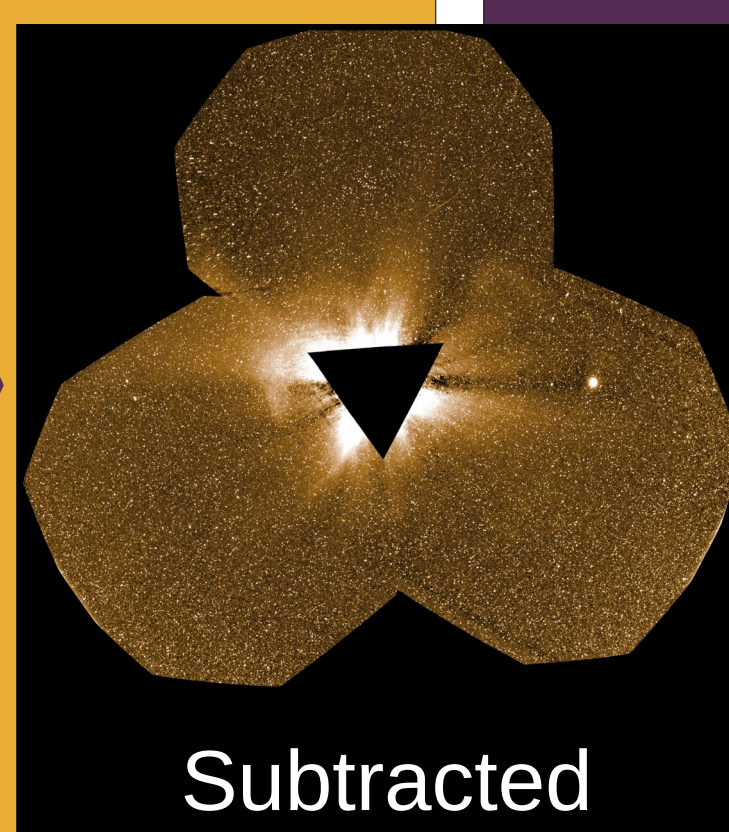
See an animation of our key pipeline stages!



Other steps not illustrated

- PSF regularization
- Flat-fielding
- De-spiking
- De-streaking
- Alignment
- Dynamic stray light removal
- Adaptive resampling

F corona



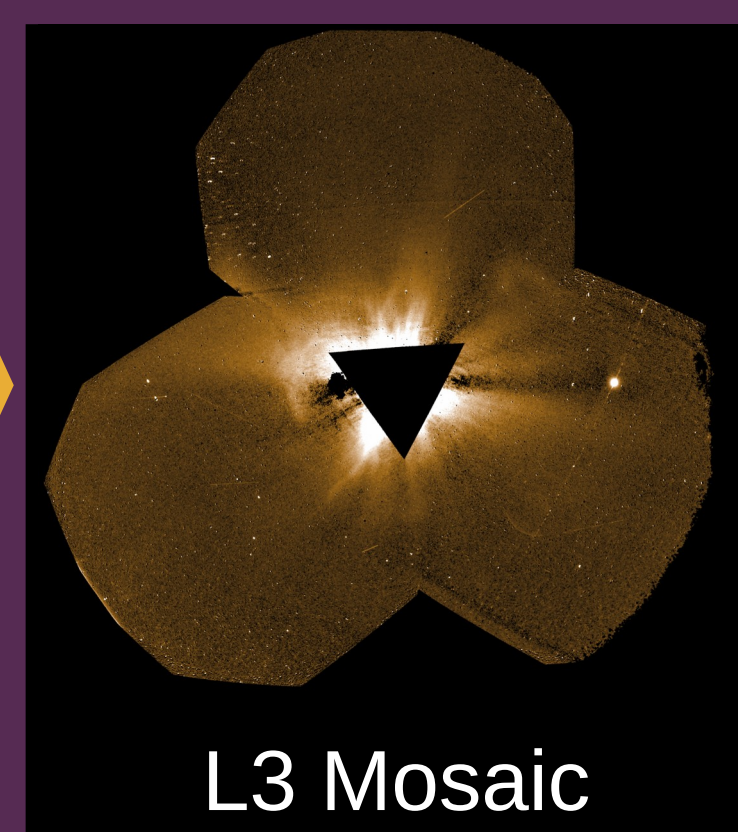
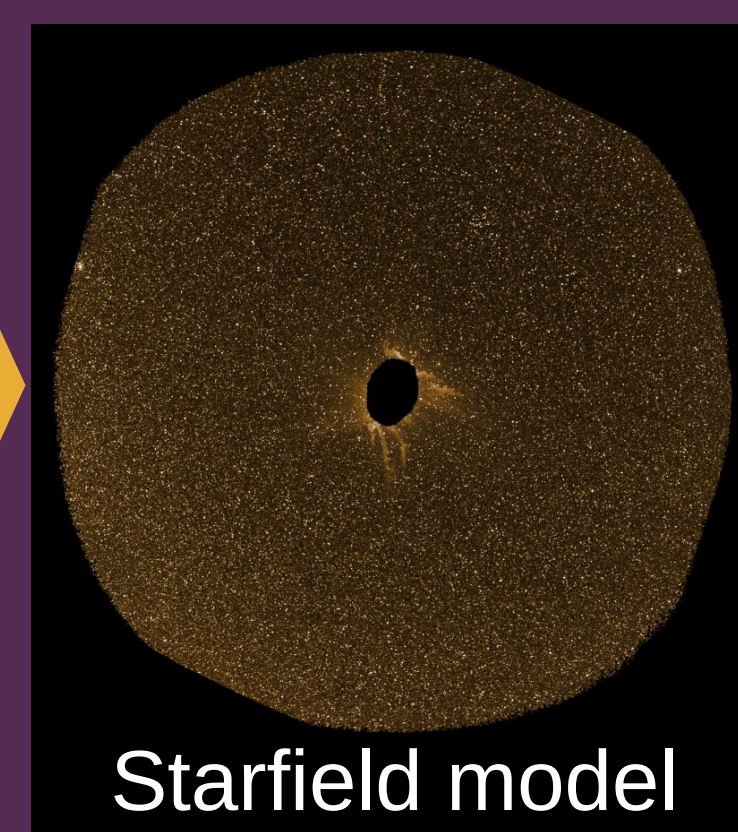
Step 1: Frame

- We put the data in the helioprojective frame when we assemble mosaics.

Step 2: Reduce

- A straight percentile works well here.

Starfield



Step 1: Frame

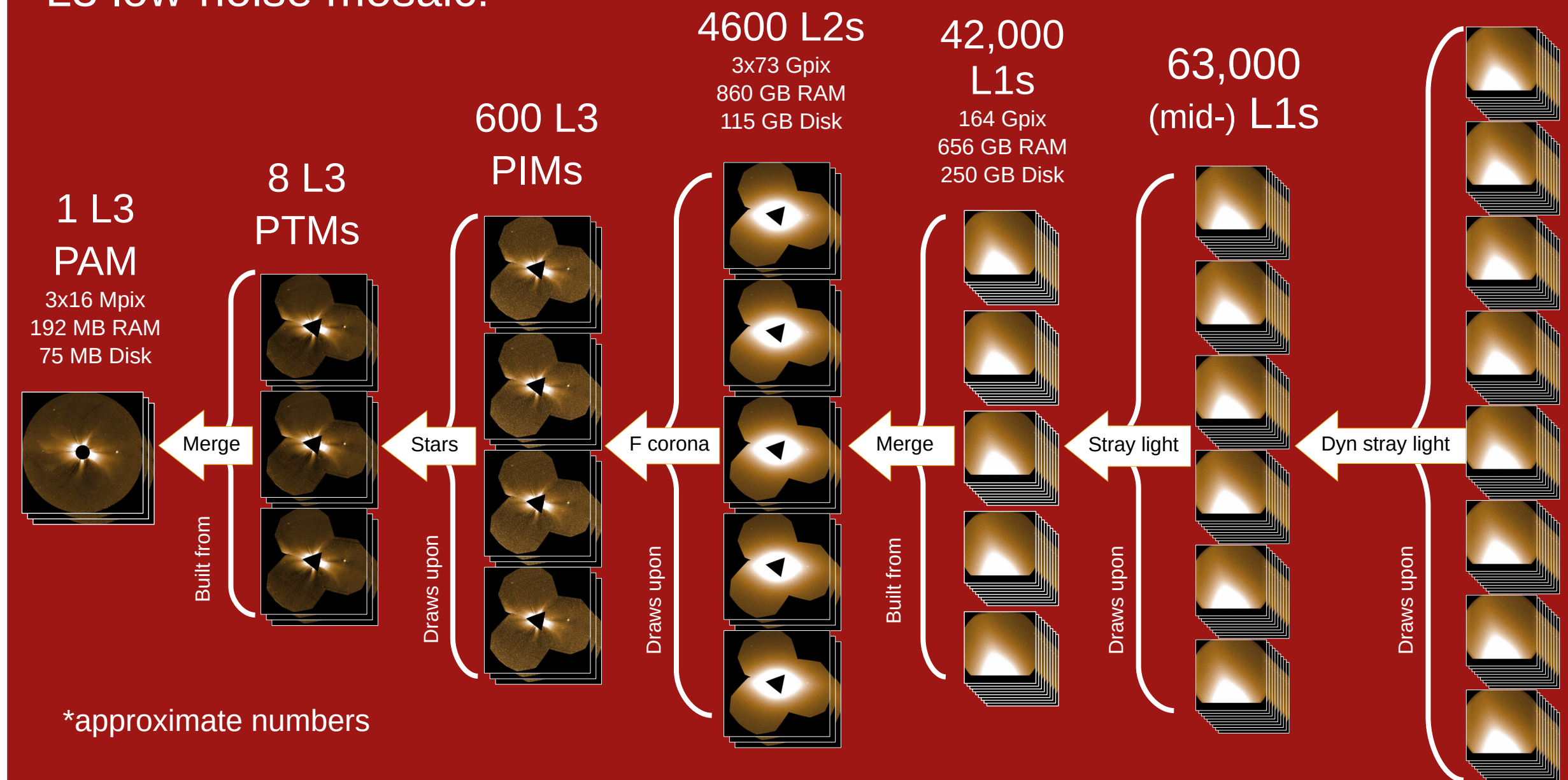
- We reproject to the celestial frame.

Step 2: Reduce

- Outlier rejection, then Gaussian fitting works well.

Data volume

The "pyramid" of background models and their inputs means we draw on ~150,000 raw frames to build one polarized L3 low-noise mosaic!



152,000 L0 frames
593 Gpix
2.3 TB RAM
904 GB Disk

