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Mitigation of Satellite Tracks in LSST Data Processing

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LSST Data Release Production

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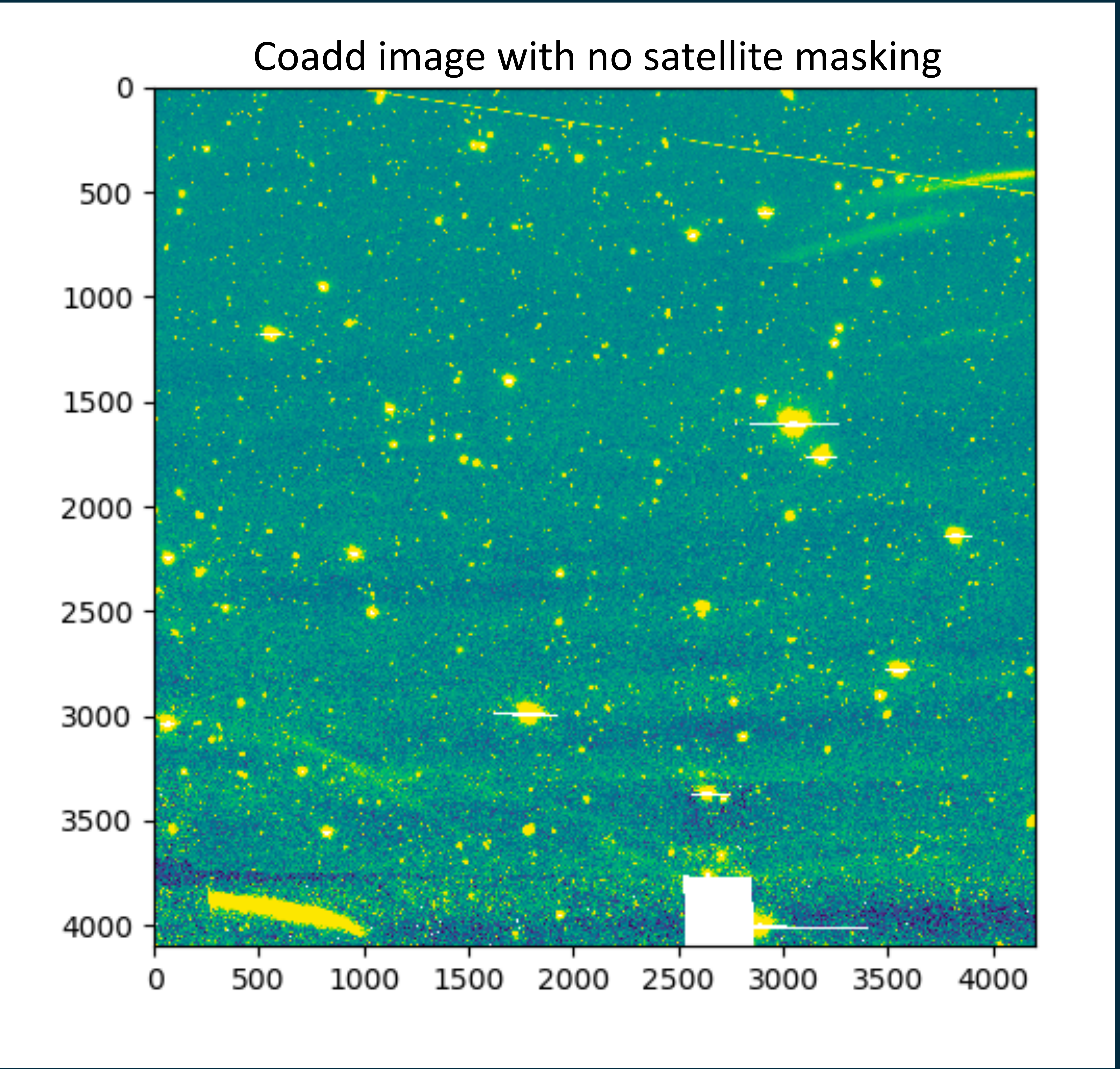
- The Data Release Production is the episodic (re)processing of all accumulated LSST images.
- LSST pipeline development is done using the precursor dataset from the Subaru Strategic Program using the Hyper Suprime-Cam (HSC) instrument.
- Satellite trails are visible in many images in this dataset
  - Satellite mitigation techniques for Rubin Observatory can be developed on this dataset

Example Stacked Image



The Plan for Satellite Mitigation:

- Satellite trails are easy to identify by eye—how do we replicate this algorithmically?
  - The Hough Transform provides an algorithm to detect lines in images automatically.
- Once we have the approximate coordinates of a line, a rough profile is fit.
  - The affected section of the image is masked out.

The Kernel-Based Hough Transform

- Finds clusters of non-zero points and splits them into line-like groups
- Only groups that meet requirements for length and straightness are kept
- Faster, more precise, and fewer false positives than with a traditional Hough Transform.

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Real-time line detection through an improved Hough transform voting scheme

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Abstract

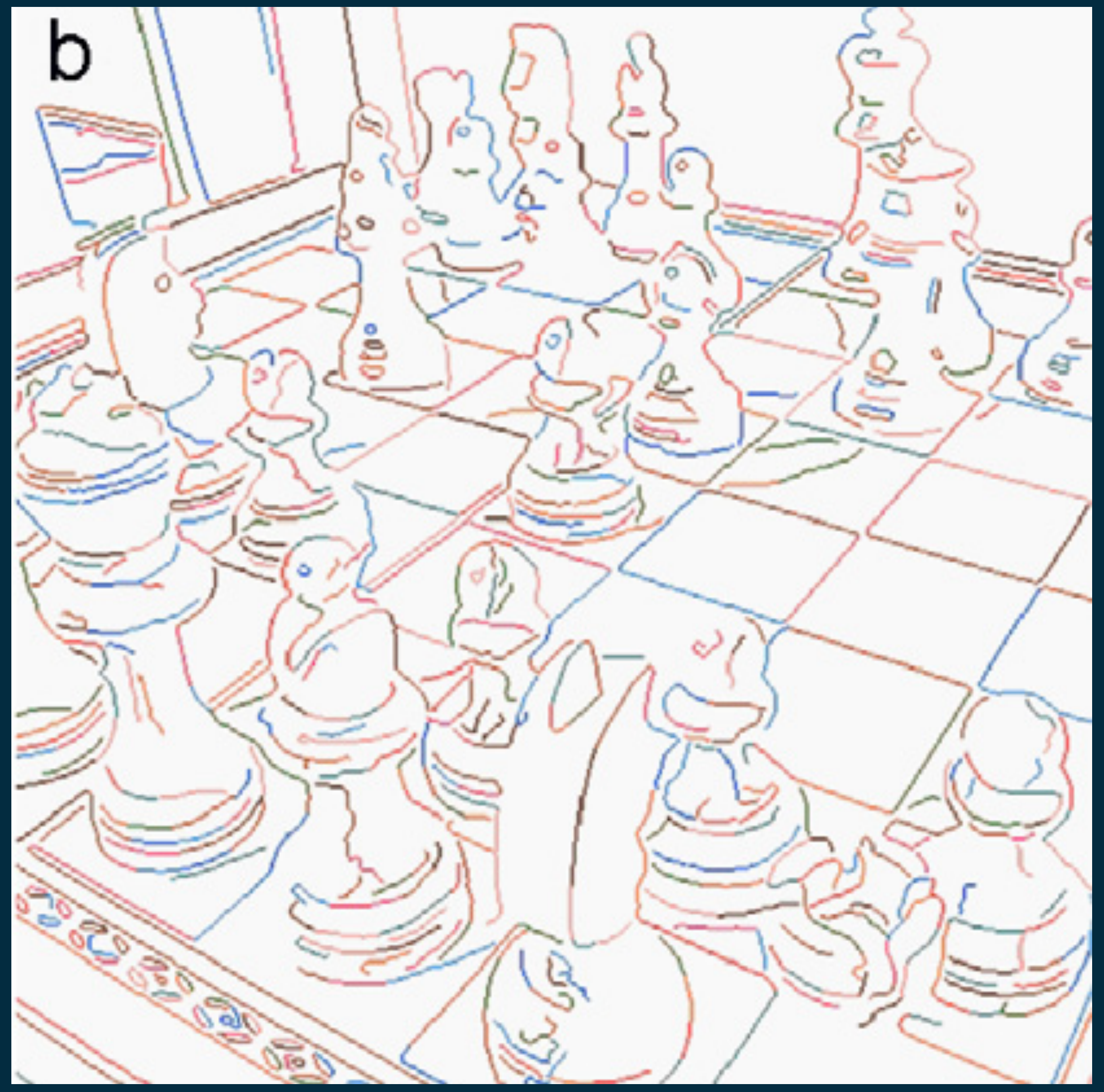
The Hough transform (HT) is a popular tool for line detection due to its robustness to noise and missing data. However, the computational cost associated to its voting scheme has prevented software implementations to achieve real-time performance, except for very small images. Many dedicated hardware designs have been proposed, but such architectures restrict the image sizes they can handle. We present an improved voting scheme for the HT that allows a software implementation to achieve real-time performance even on relatively large images. Our approach operates on clusters of approximately collinear pixels. For each cluster, votes are cast using an oriented elliptical-Gaussian kernel that models the uncertainty associated with the best-fitting line with respect to the corresponding cluster. The proposed approach not only significantly improves the performance of the voting scheme, but also produces a much cleaner voting map and makes the transform more robust to the detection of spurious lines.

Keywords: Hough transformation; Real-time line detection; Pattern recognition; Collinear points; Image processing

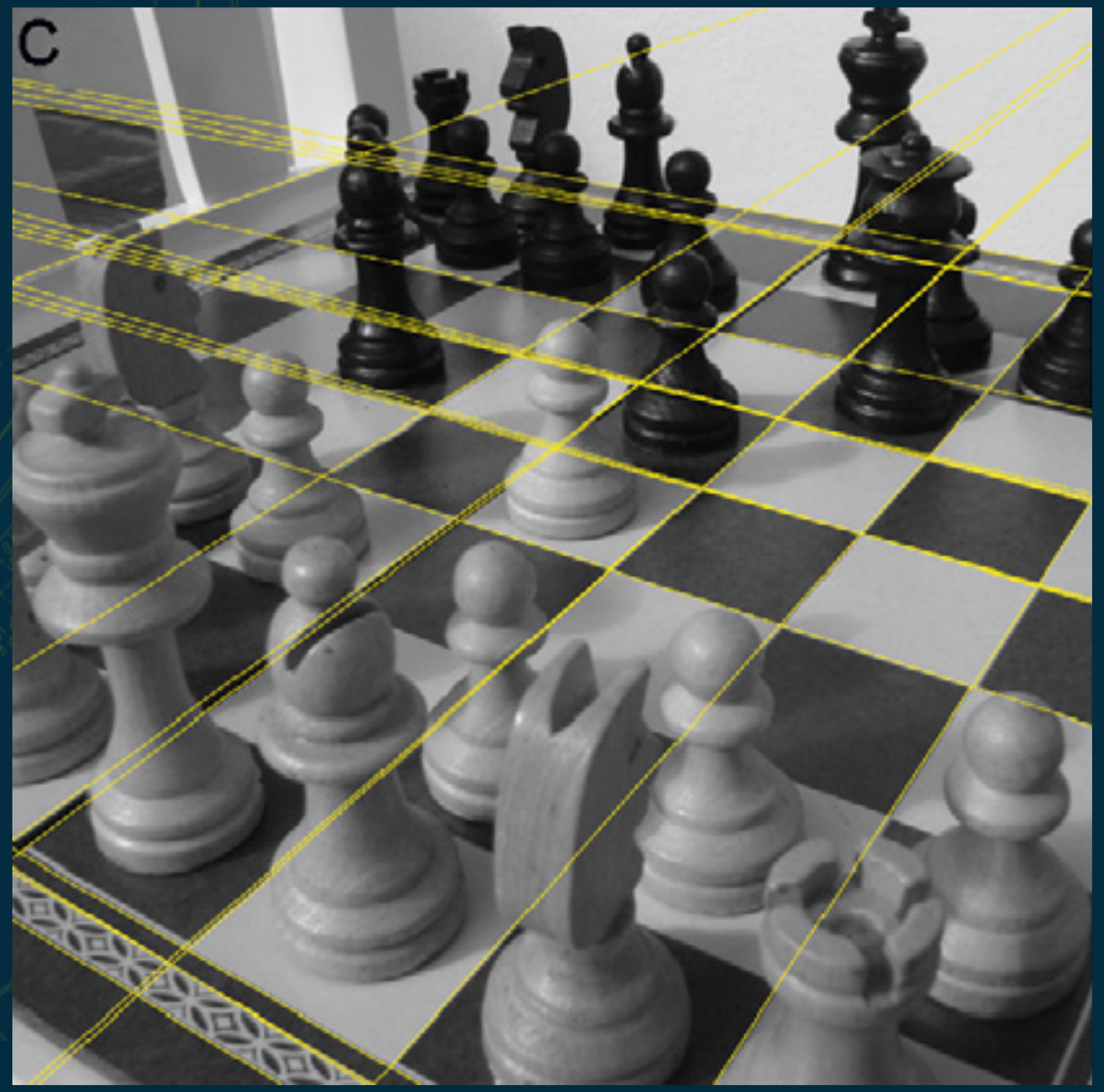
The Kernel Hough Transform

Original Image

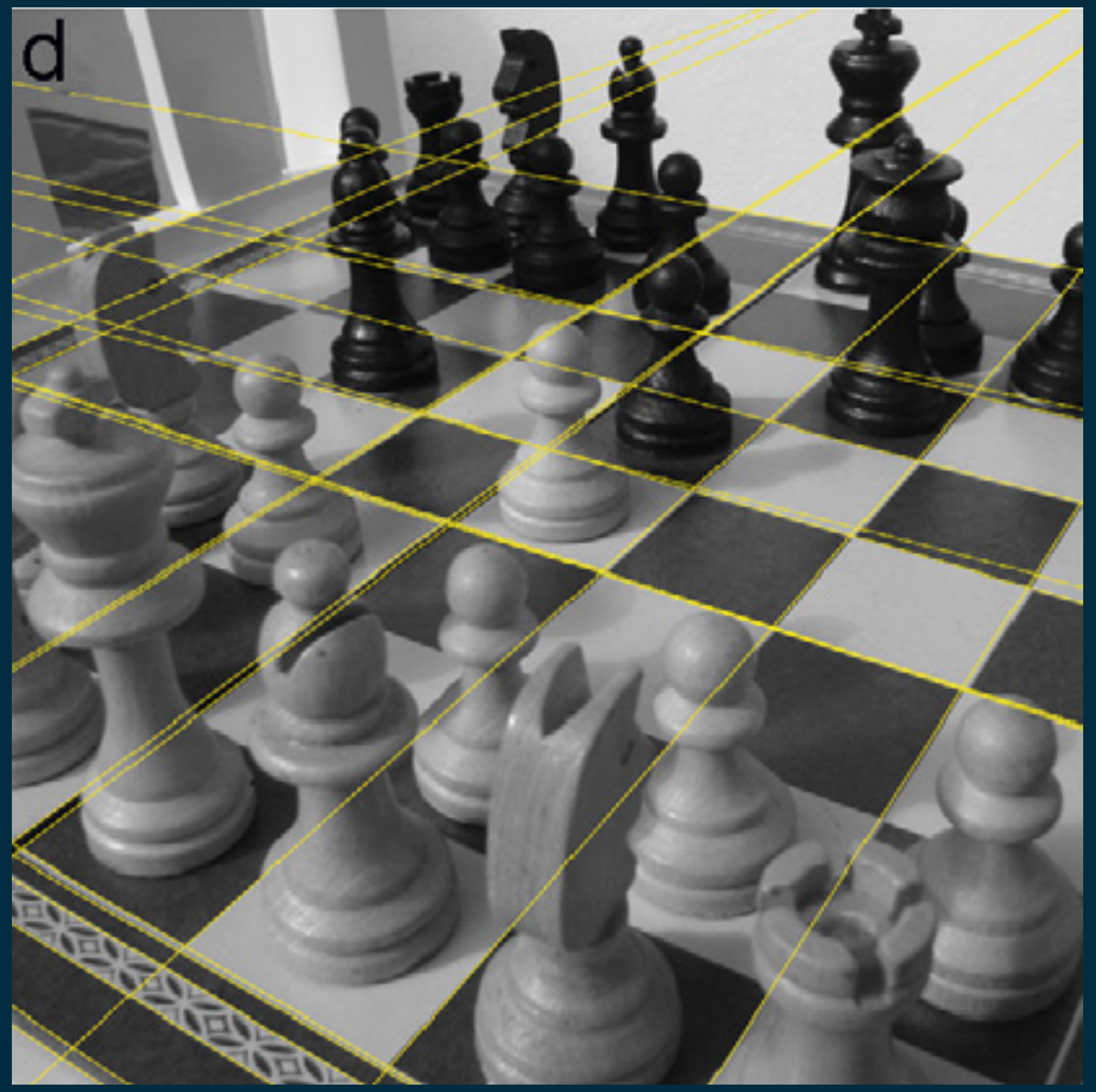
After Canny Filter



Standard Hough Transform



Kernel Hough Transform



Fernandes and Oliveira, 2006

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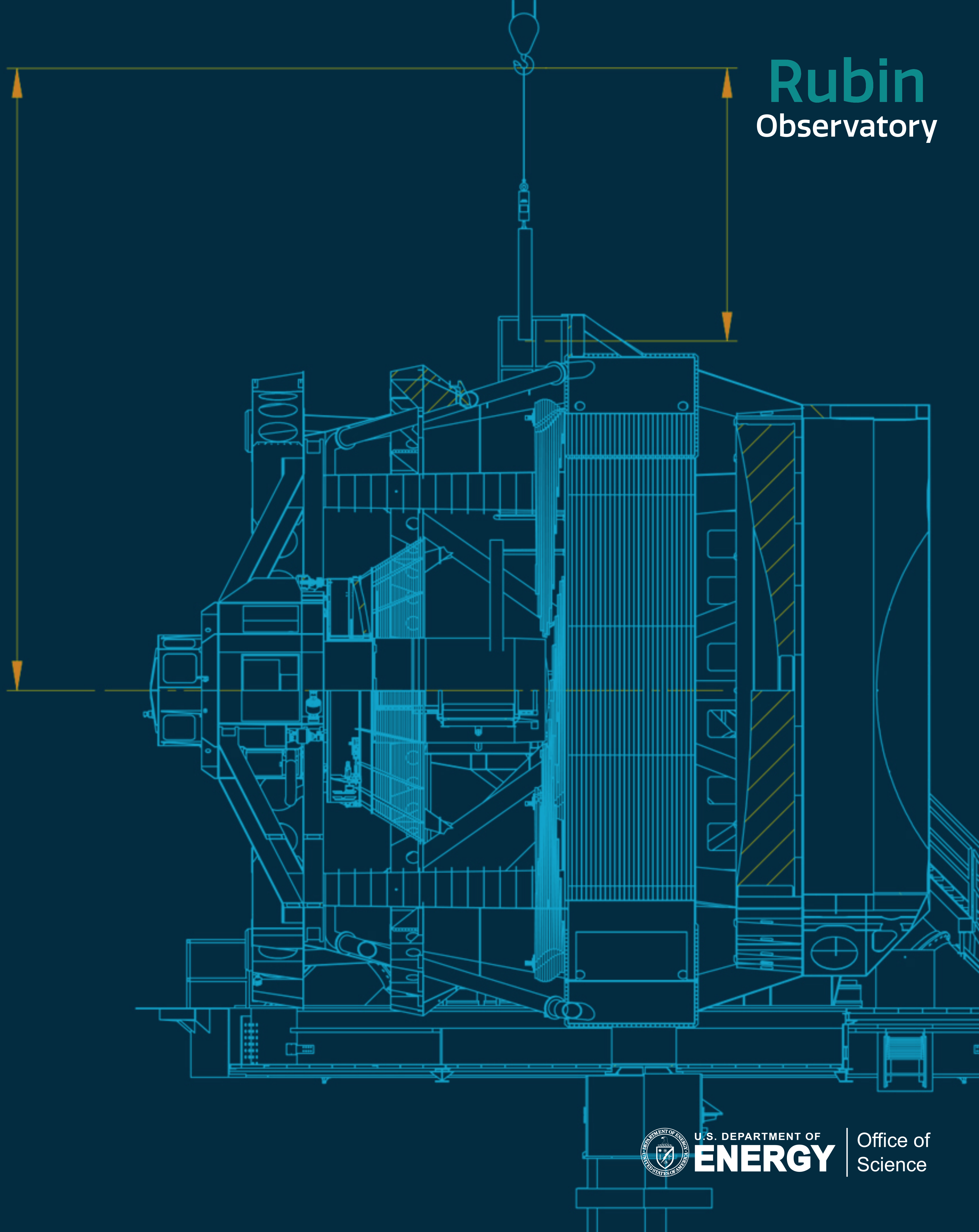
Using the Kernel Hough Transform in the LSST pipeline



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A note on the image processing

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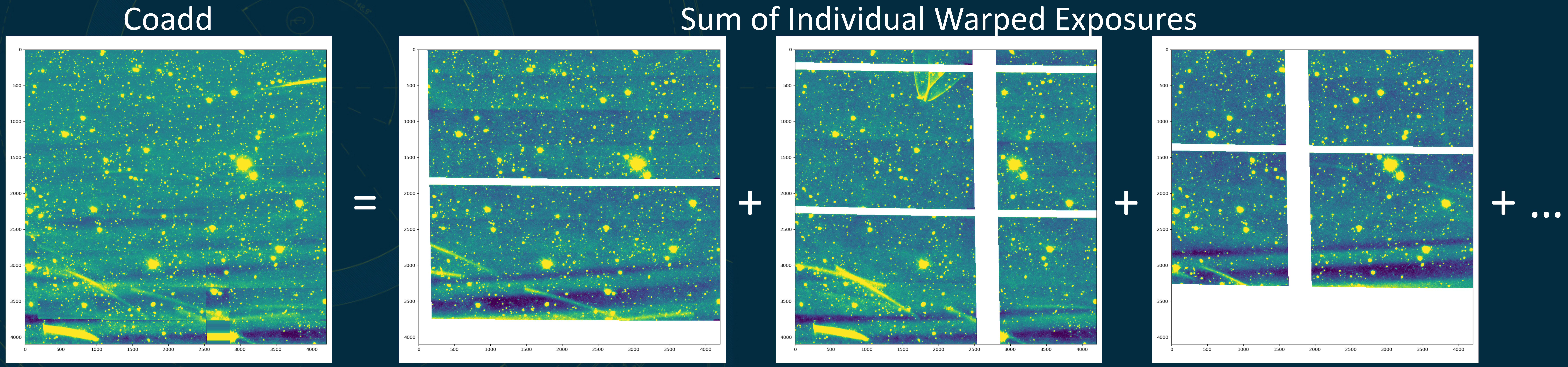
- For the data release production, we split field into “patches” — quadrilateral sub-regions of about 1.5 degrees on a side.
- Coadds are constructed out of all exposures that overlap with a given patch, warped onto the tangent plane.



- For the data release production, we detect artifacts by looking at the difference between individual exposures and the conservatively clipped coadded image.

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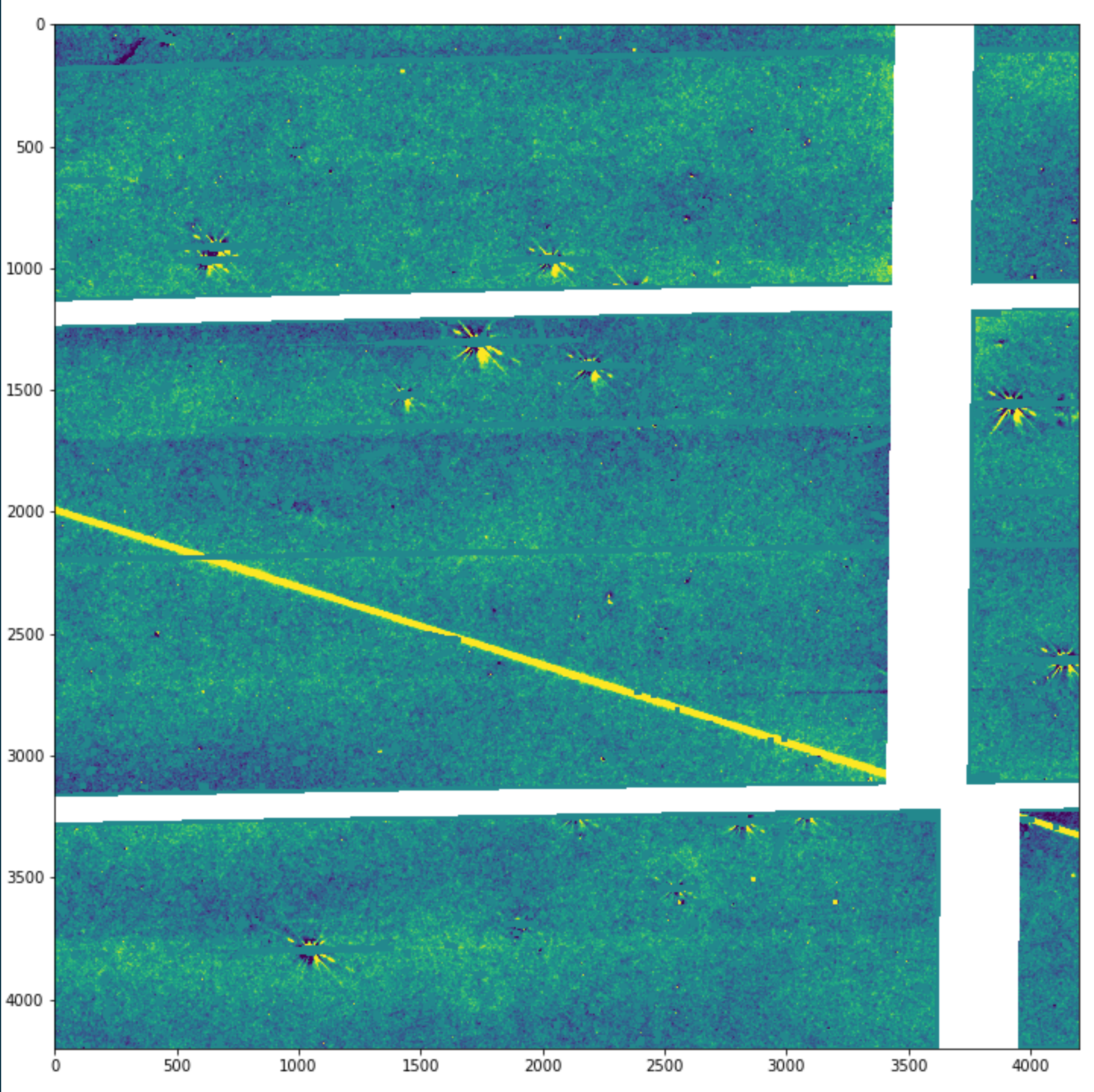
Image Preprocessing

Original Difference Image



*Difference Image = individual exposure - (aggressively clipped coadd of many exposures)

Image Preprocessing

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Binary Image (above or below limit for 'detected' pixels)

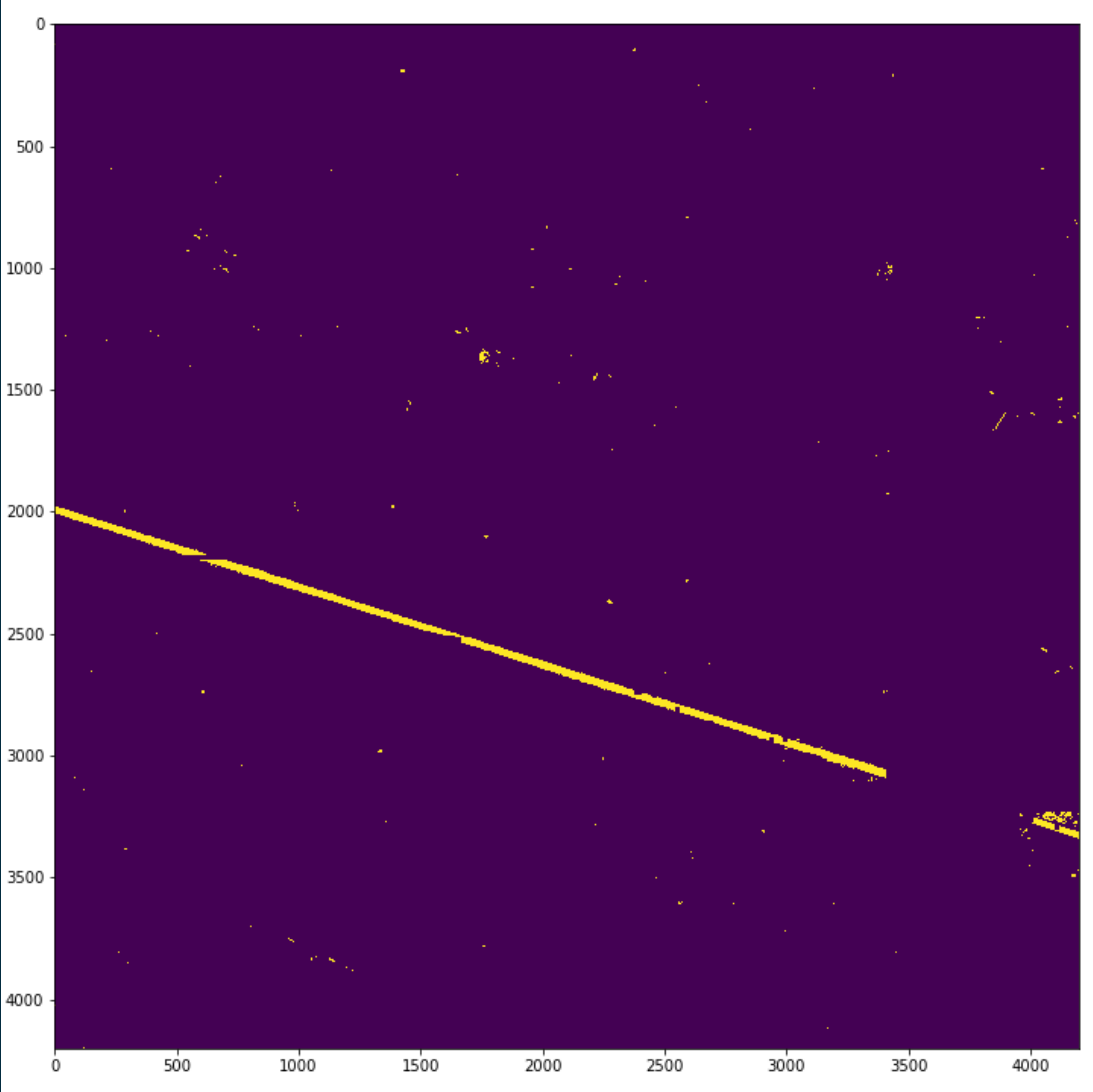

Image Preprocessing

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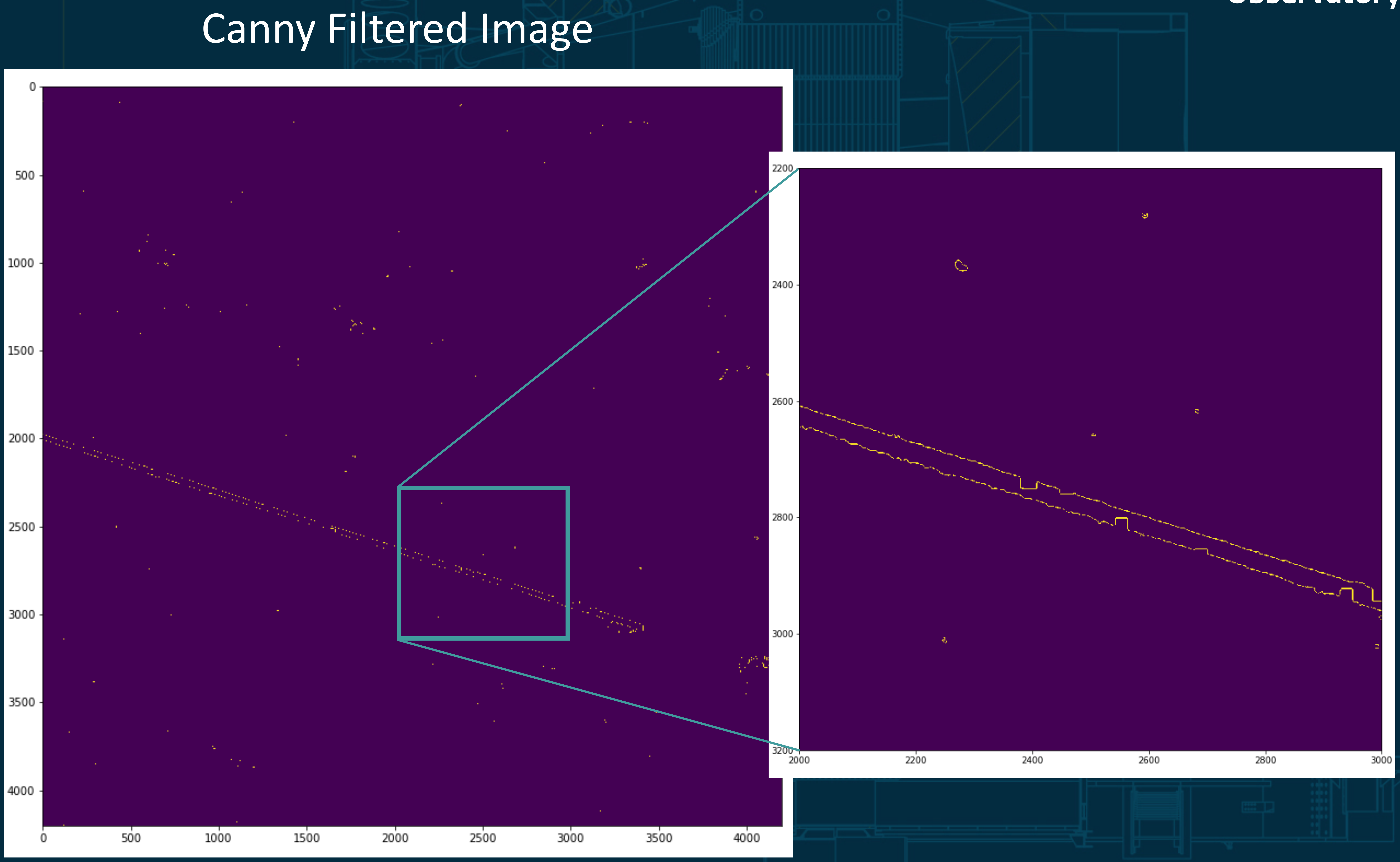

Kernel Hough Transform Line Detection

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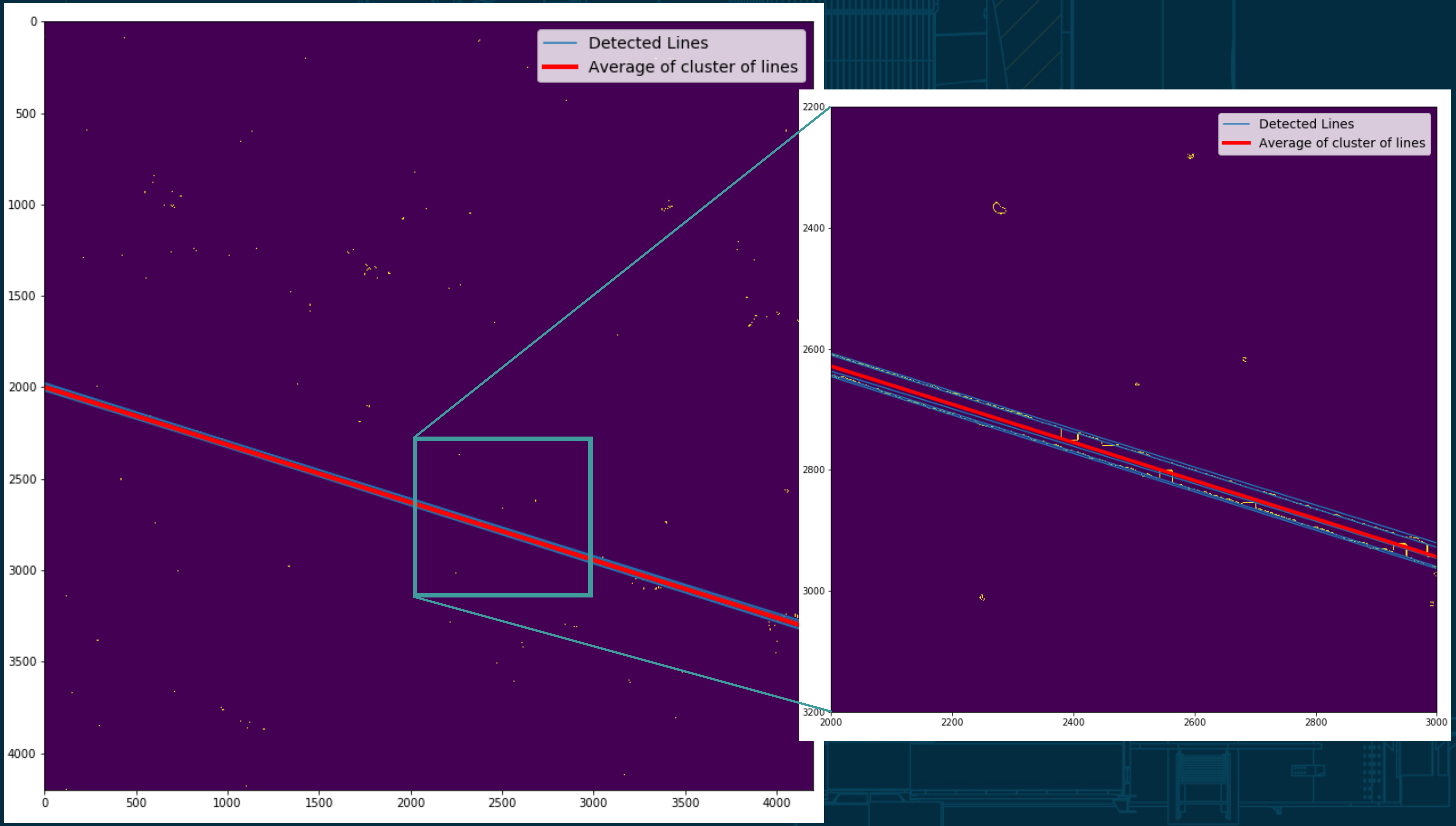
Line Detections



Fitting the Line Profile

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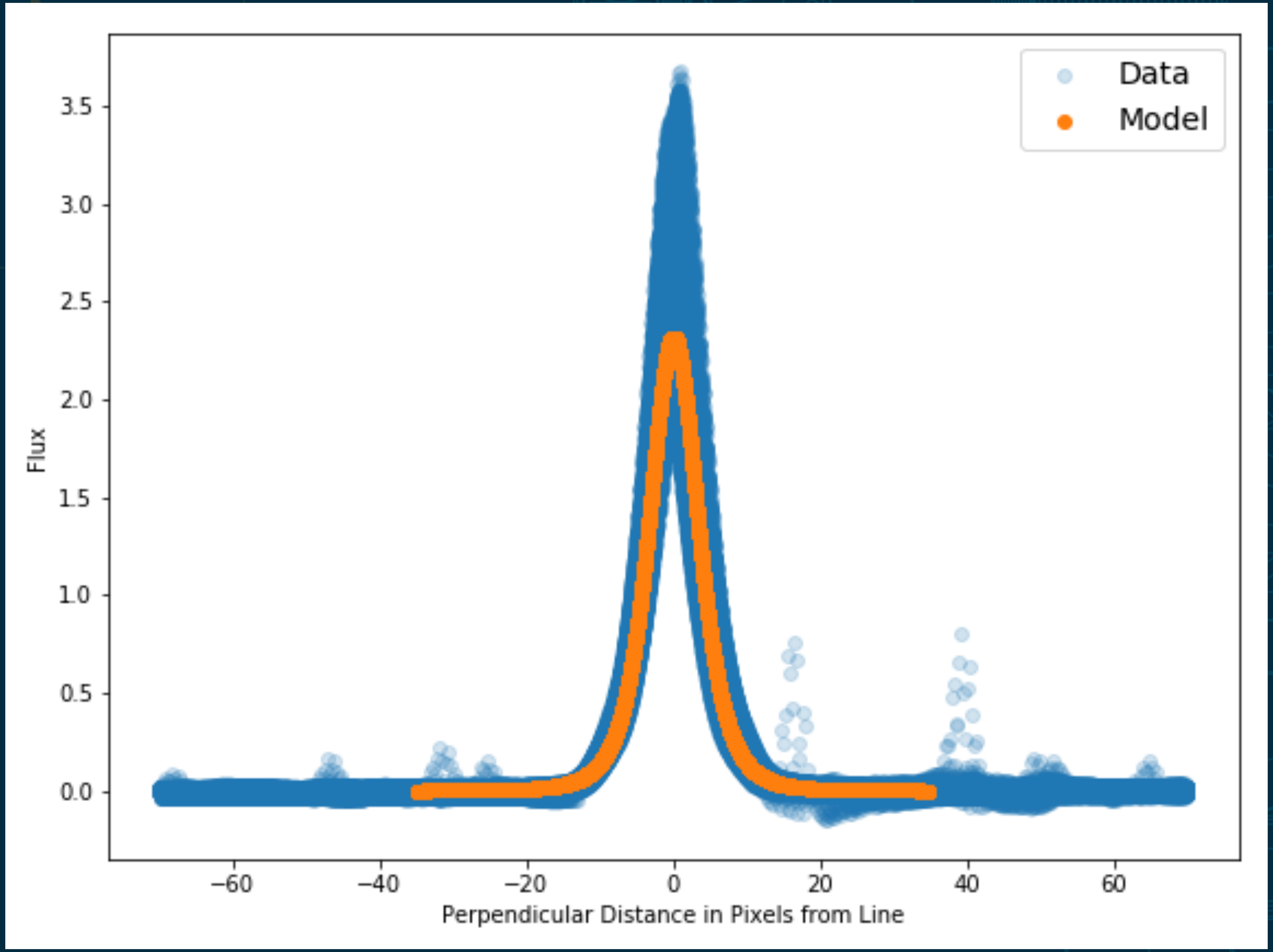
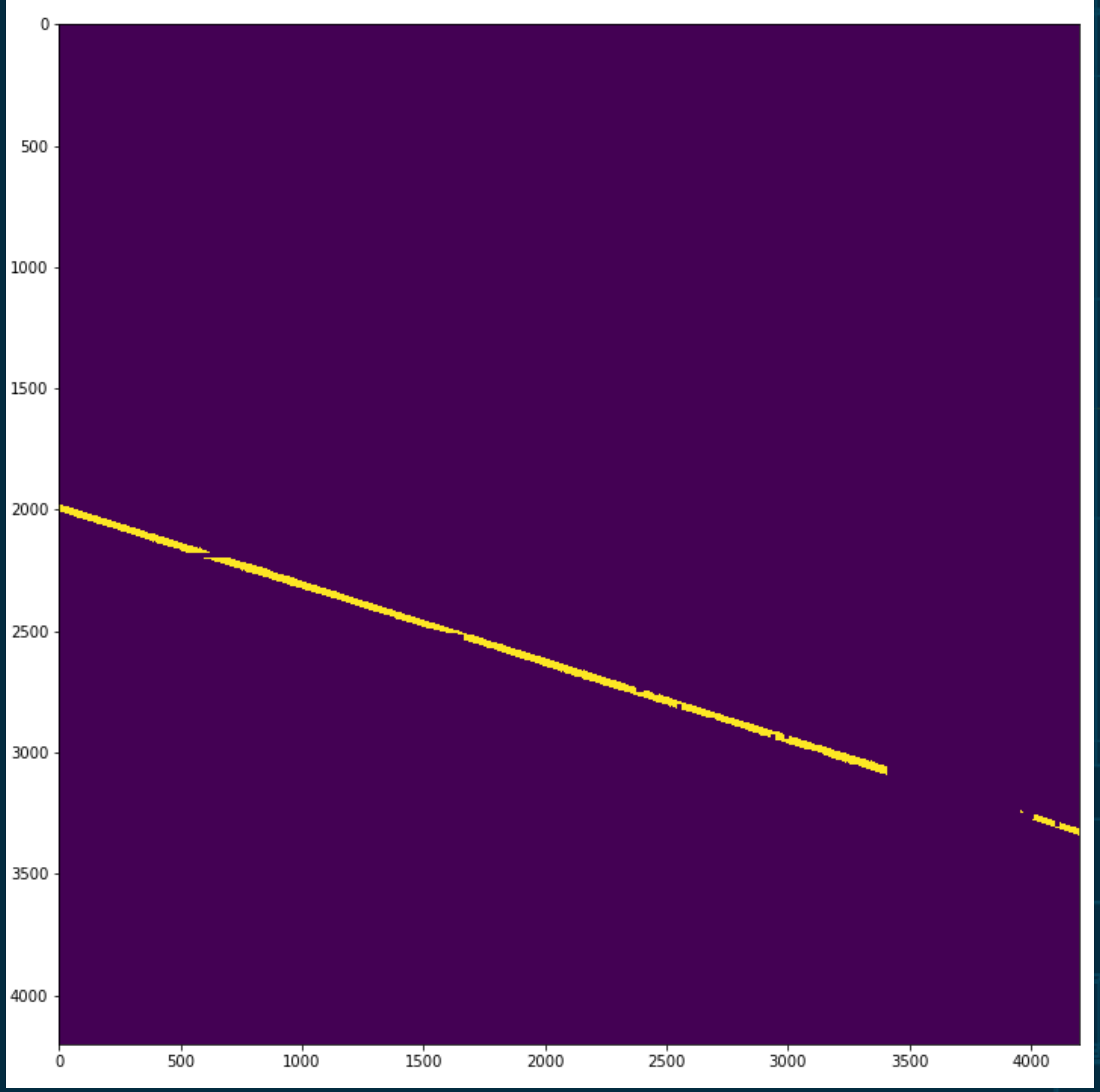


Masking

Mask = (Line Profile > Threshold) ∩ (Detection Map)



Masking

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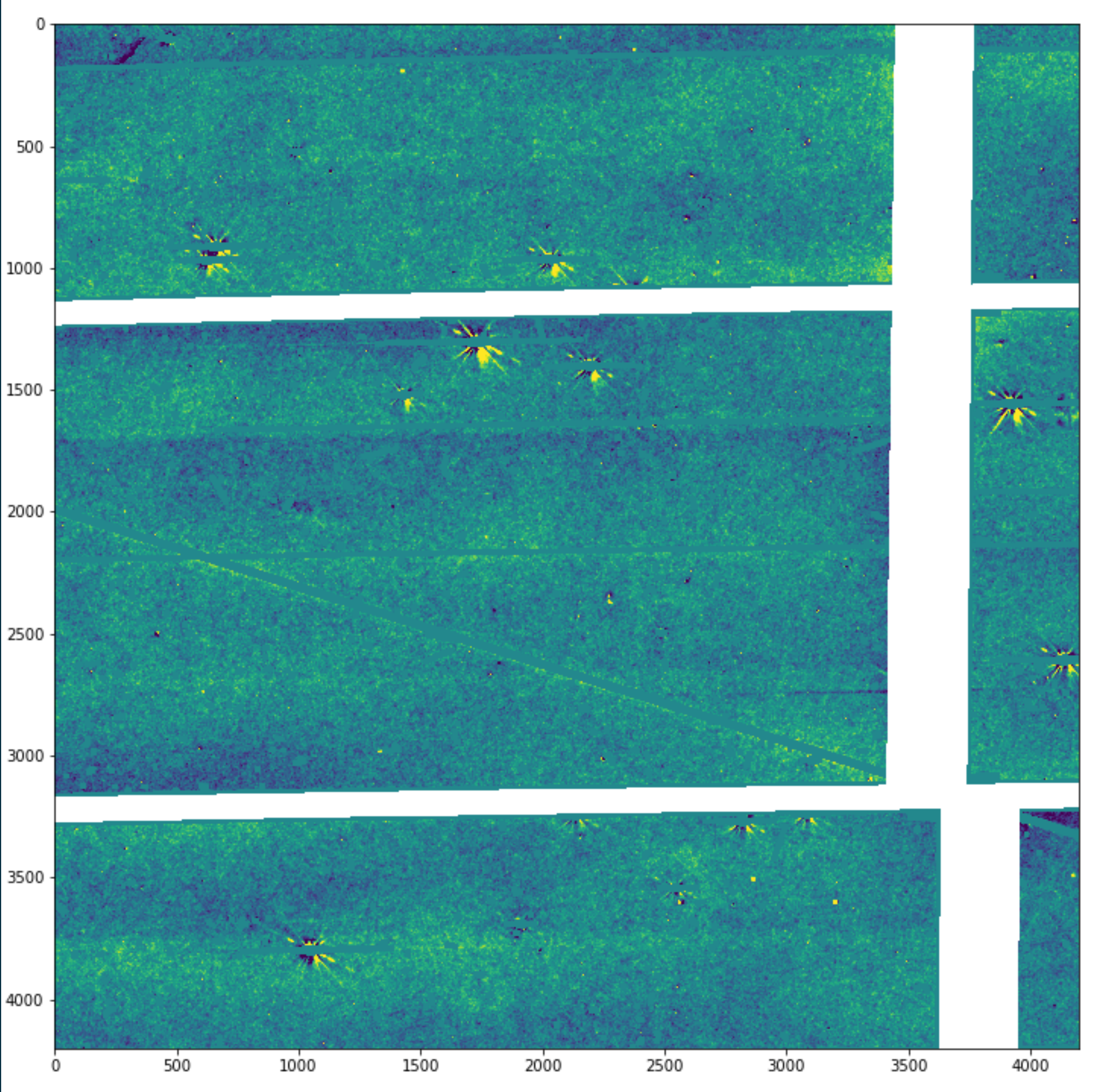
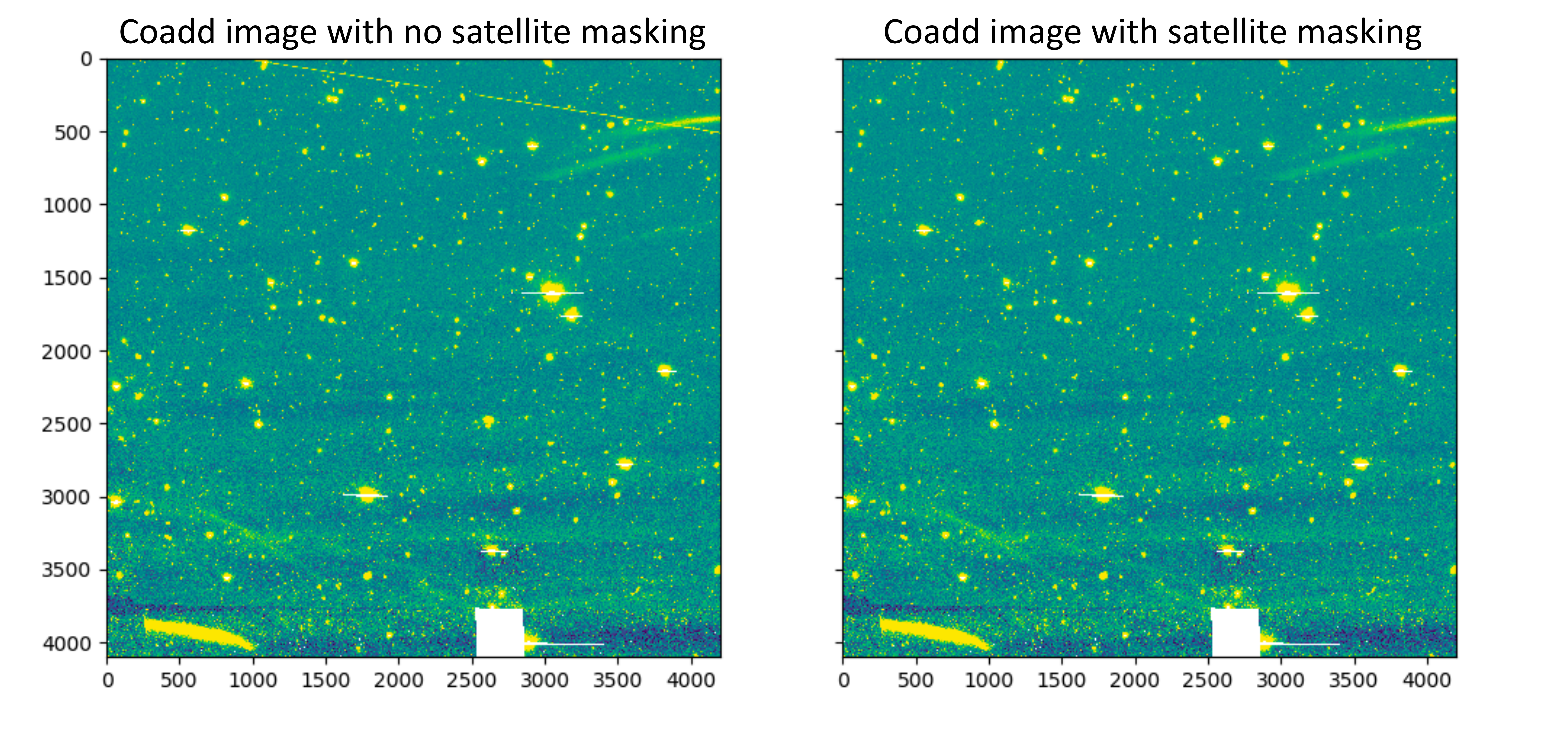
Mask = (Line Profile > Threshold) ∩ (Detection Map)



Applying this technique in the original stacked image



Masking Other Linear Image Artifacts

- Optical ghosts (multiple reflections off of surfaces in the primary optical path)
- Diffraction spikes from bright stars

Masking Optical Ghosts

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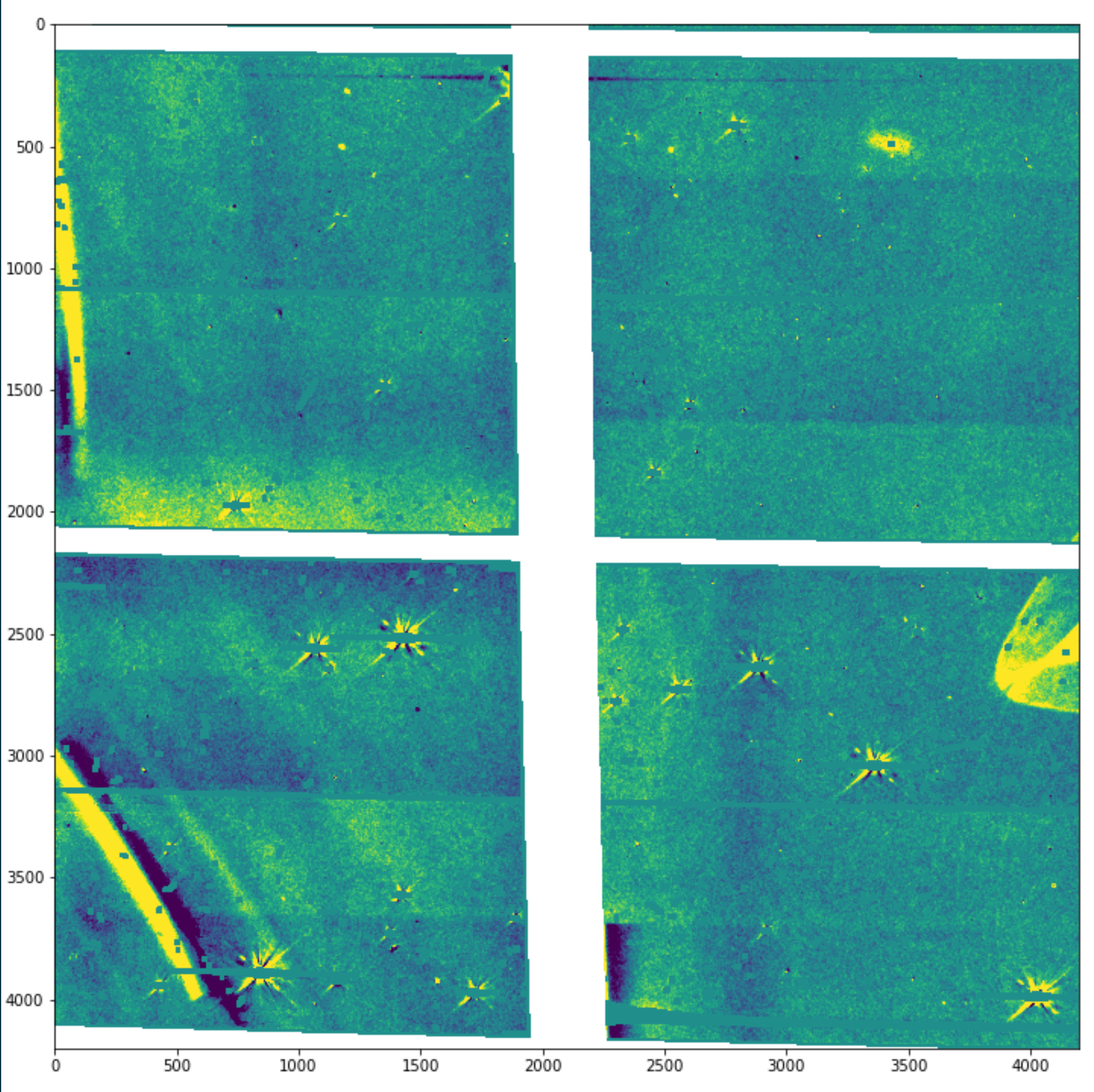
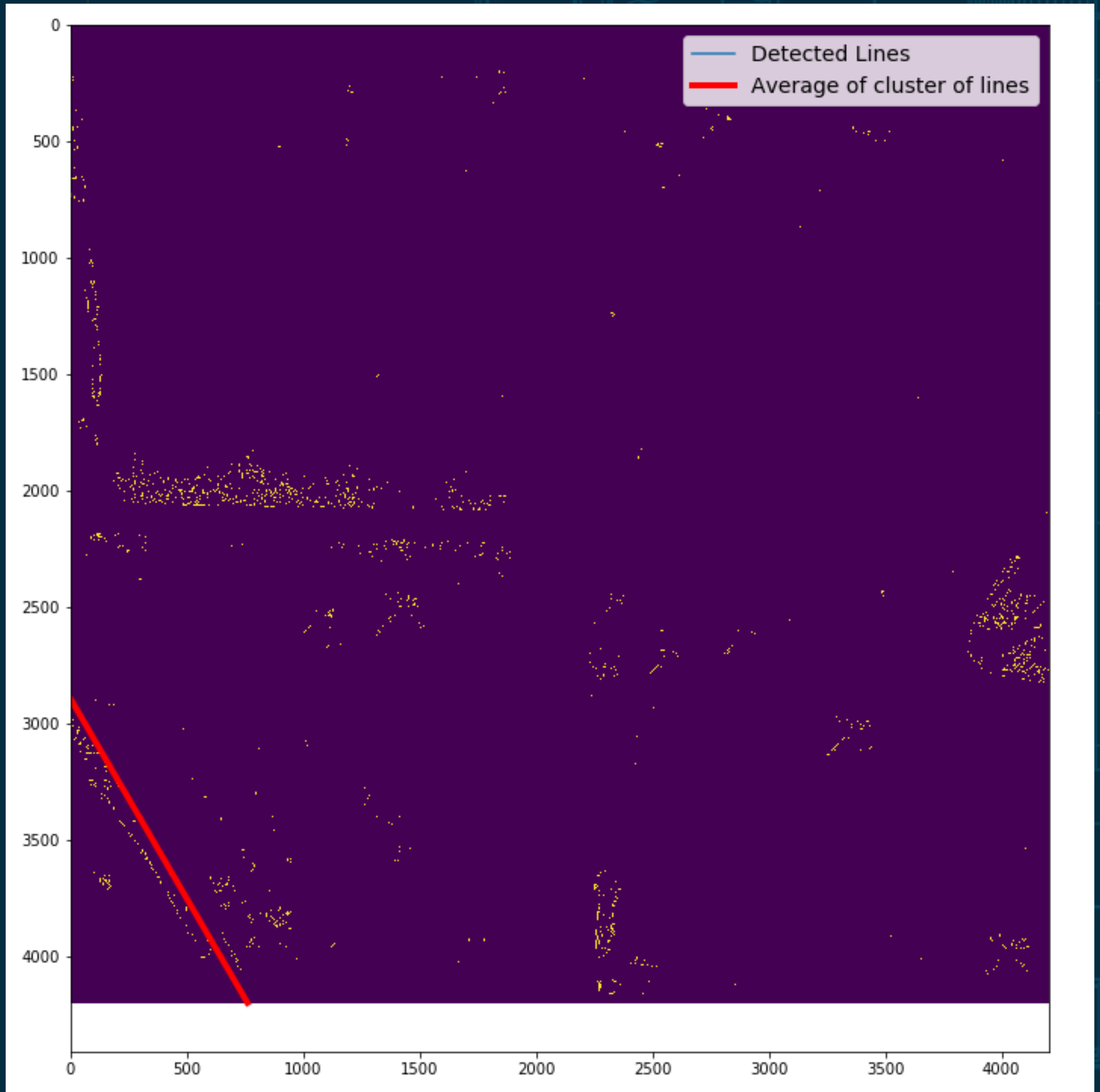
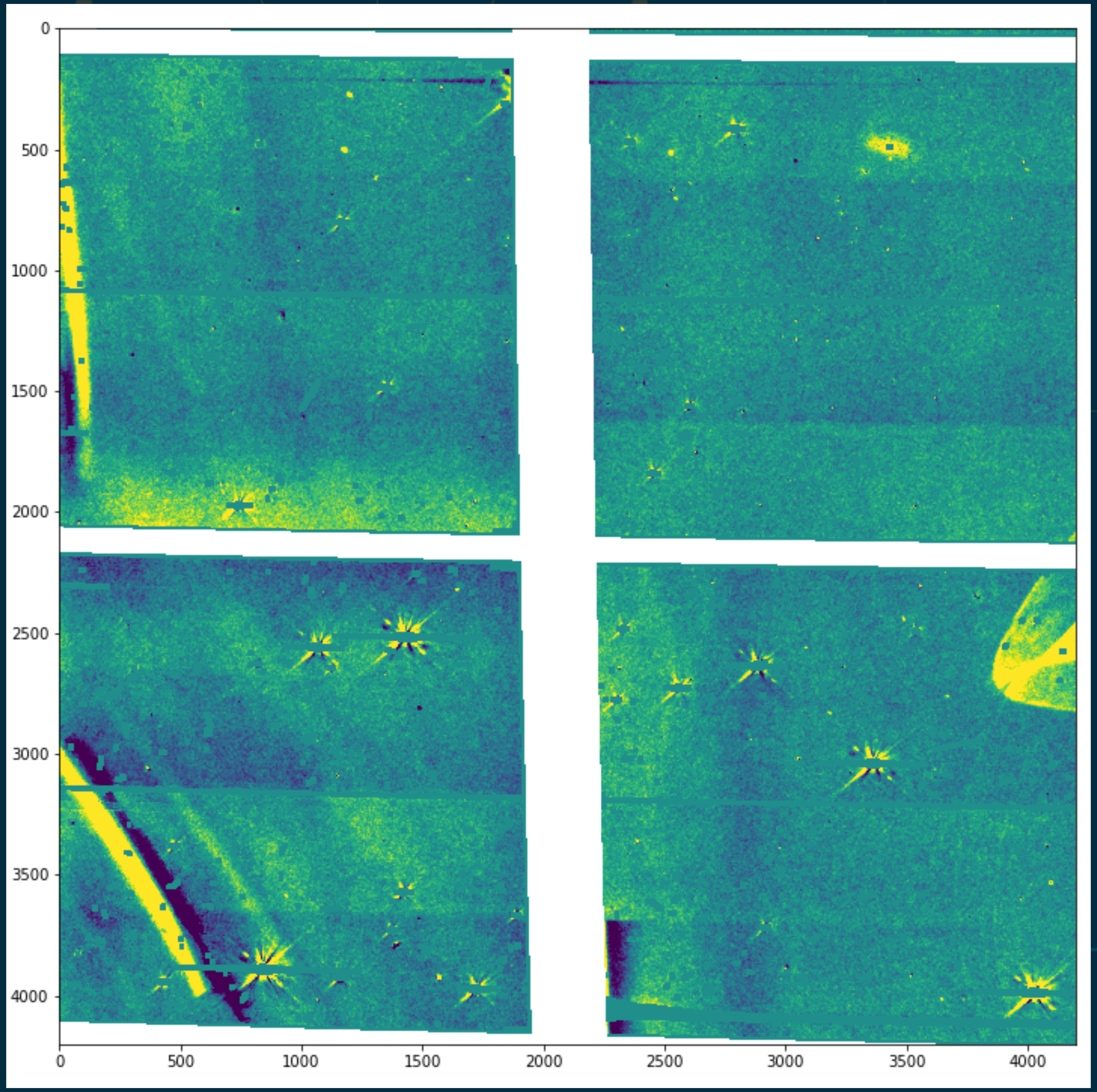
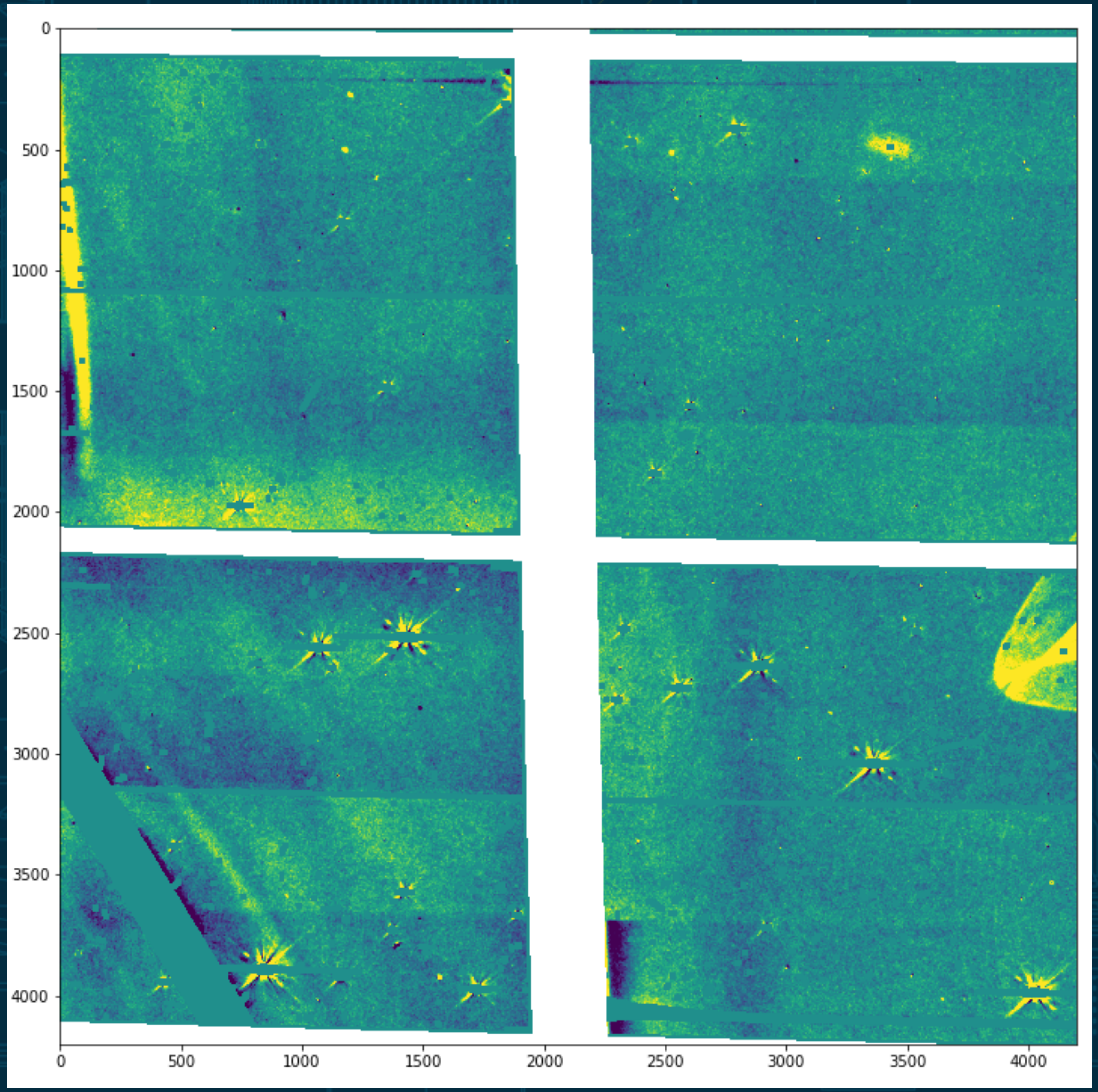


Masking Optical Ghosts



Masking Optical Ghosts





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Conclusions

- Even in current conditions, we can expect data to be frequently affected by satellite trails
- Nevertheless, satellite trails and other artifacts can be reliably detected and masked out
  - Some data is lost, but contamination is greatly reduced.
- The work shown here is tuned to artifact rejection in coadded data release production images.
  - Variations on the same technique will need to be tuned to meet the detection limit for transients and other science cases, though it may remain difficult to mask all low-surface-brightness effects.