Reclaiming Blurry Data

Assessing Pointing Stability Guided Image Deconvolution

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Overview

- HiC 2.1
  - Mission background
  - Results Overview
  - Pointing Jitter
  - Syncing pointing with images
  - Generated motion blur PSFs
  - Deconvolution results
  - Conclusions

https://www.nasa.gov/centers/marshall/news/hi-c-launches-to-study-suns-corona/index.html

Hi-C Background

- High Resolution Coronal Imager
  - 1.0 launched 11 July 2012 - 19.3 nm
    - Success
  - 2.0 Modified Reflight -17.2 nm
    - No science data
    - Shutter Failure
  - 2.1 launched 29th May 2018 - 17.2 nm
    - Active Region 12712
    - Success
    - Some issues with jitter observed

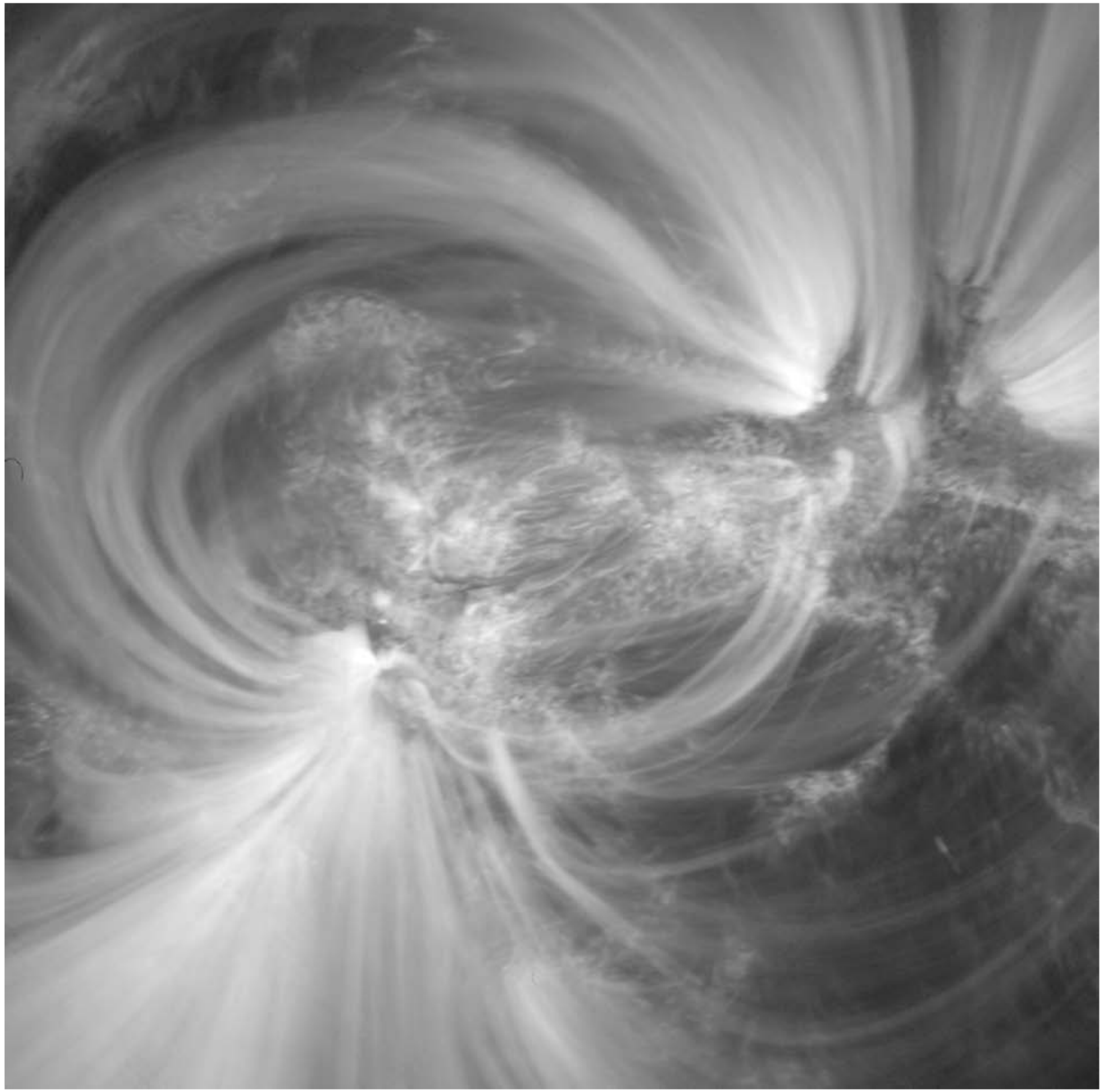
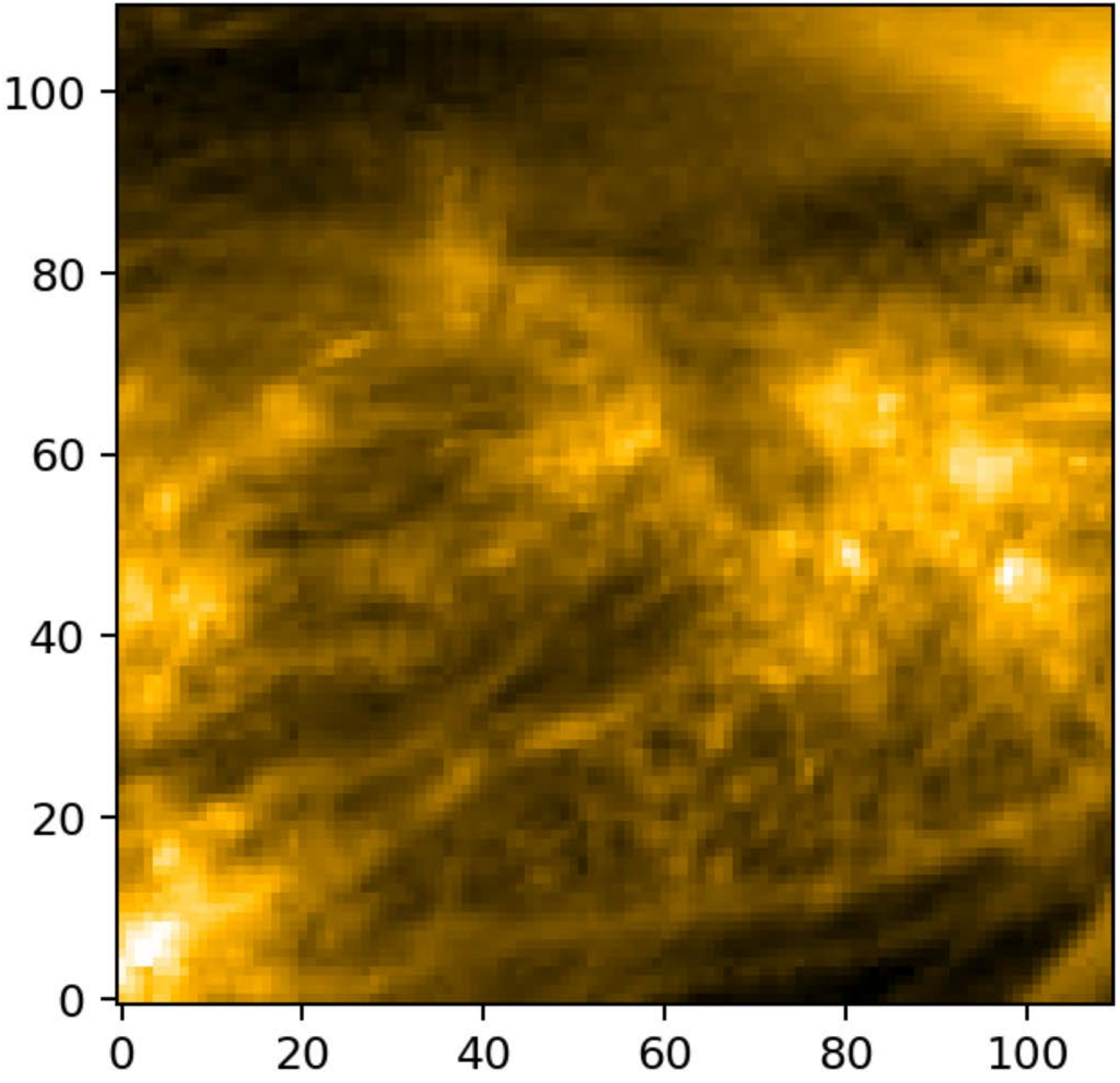


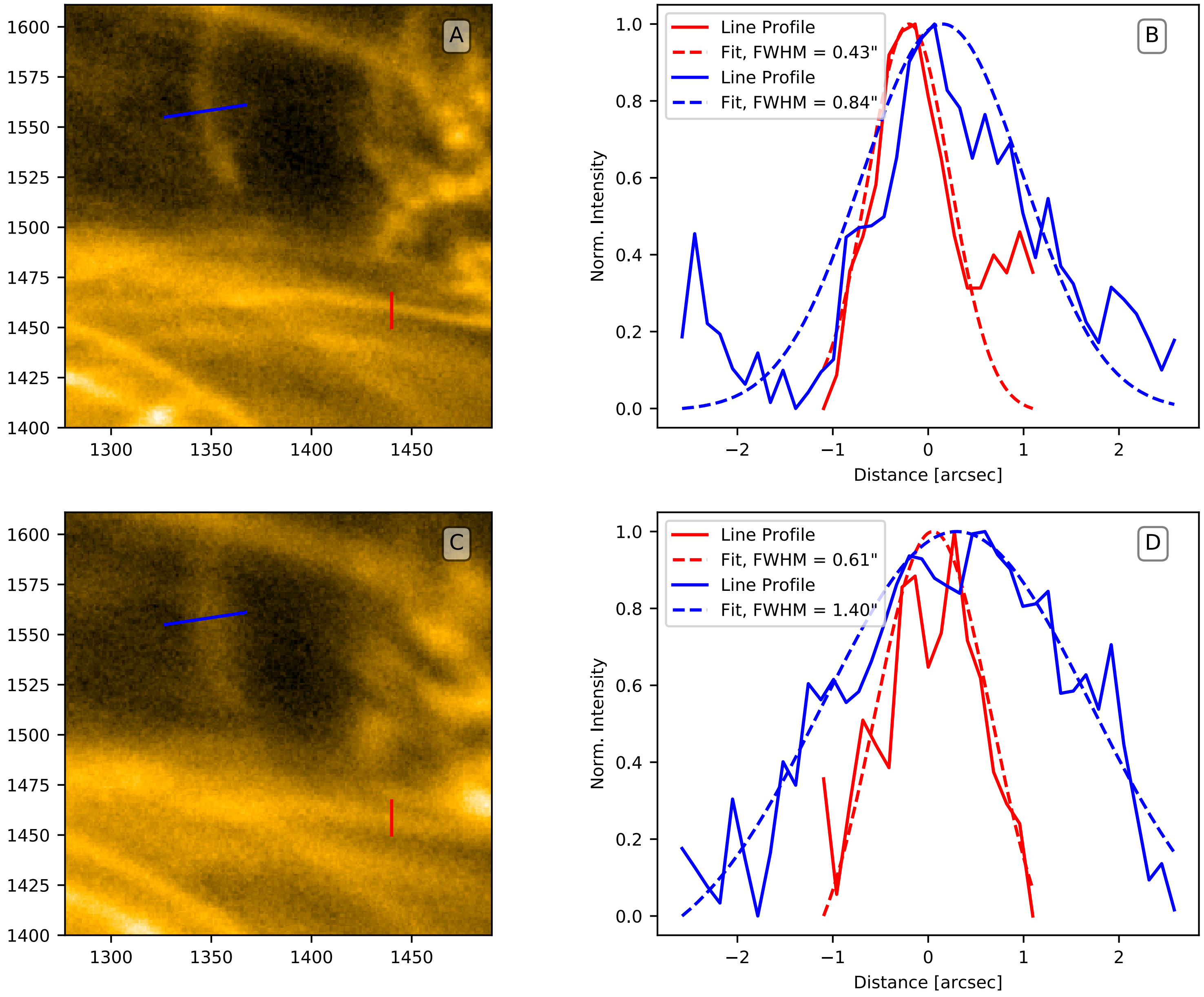
Image Results

- Every 7-8 images or so are blurry.



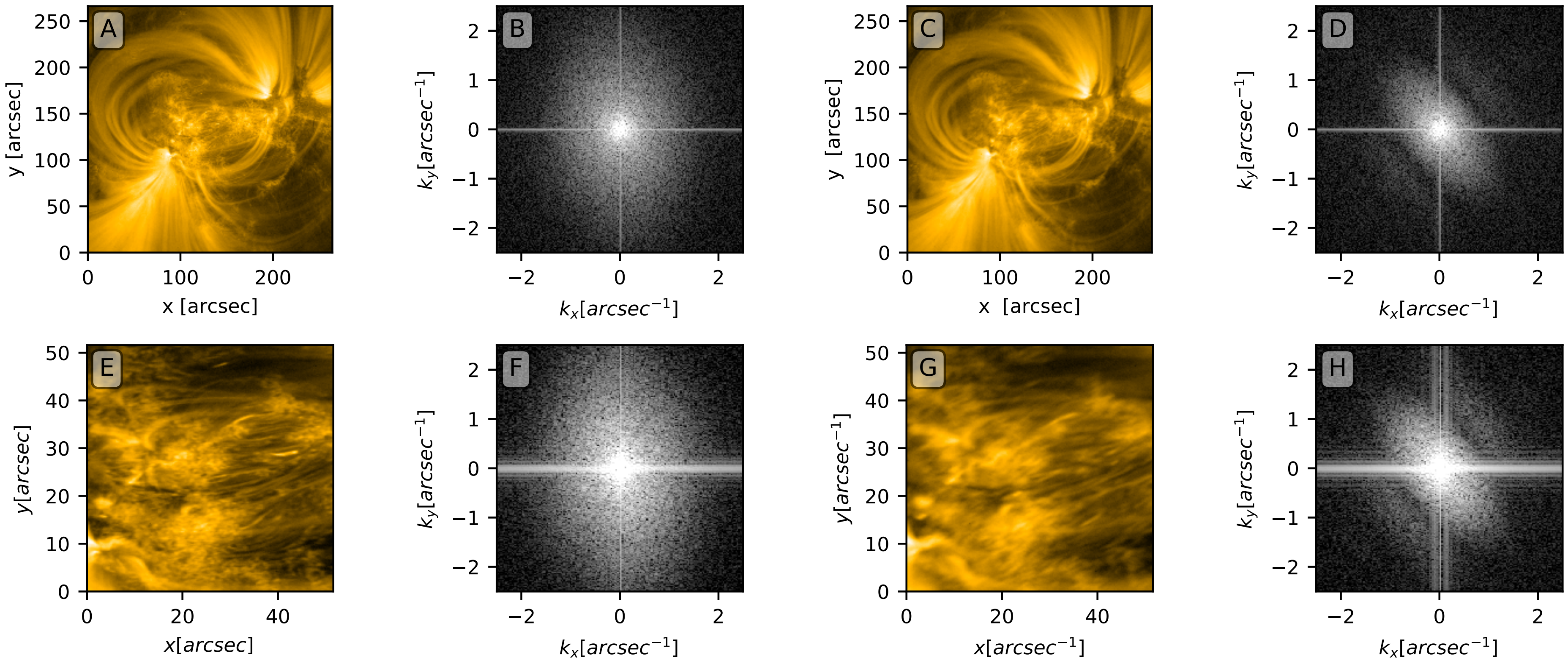
Estimate resolution from line profile

- Find small feature
- Fit gaussian to the line profile to determine FWHM
- This method is good first approximation of image resolution, but ultimately inadequate
    - Feature not constant over flight
    - Asymmetry not well understood since depends entirely on features picked
    - Hard to find the 'best' feature to use



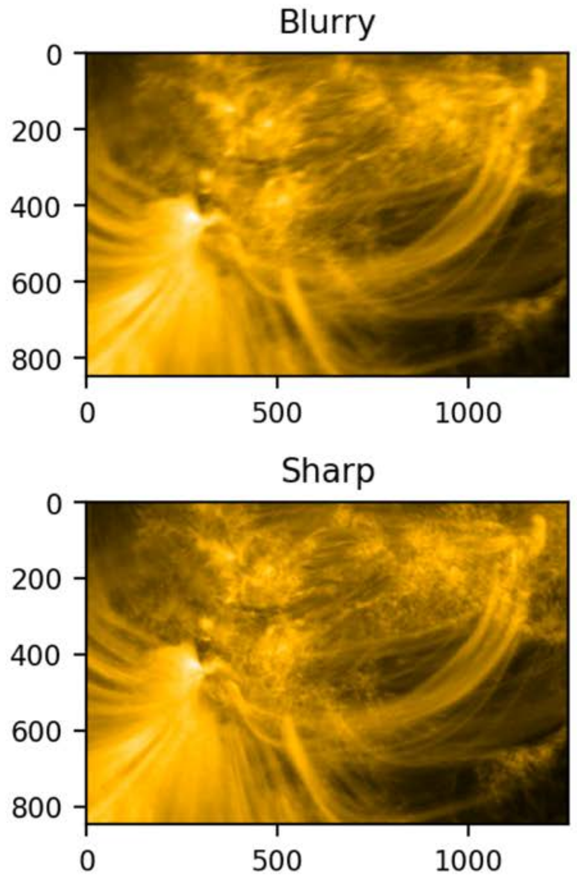
Estimate resolution from 2D FFT

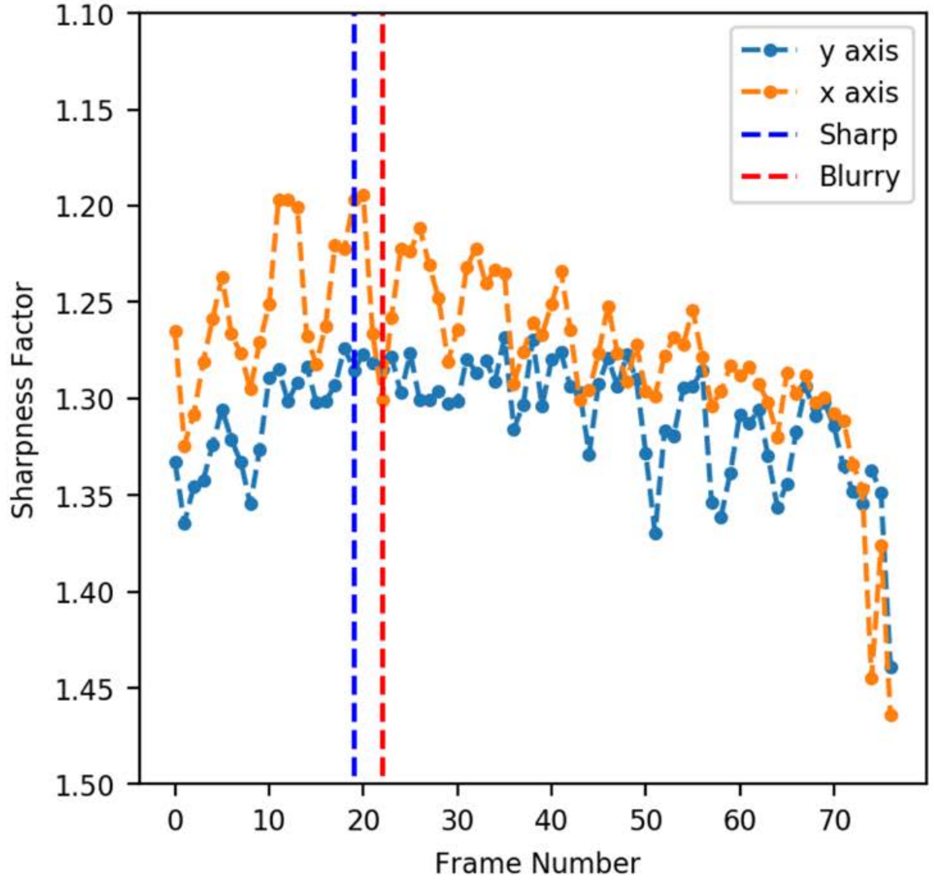
- Can assess sharpness in Fourier domain for a more generalized resolution estimate
- width of spatial bandpass directly related to image sharpness



Sharpness Factor

- Azimuthal or Altitude average of 2D FFT
  - $G(k_y) = \int G(k_x, k_y)\,dk_x$
  - $G(k_x, k_y) = FFT\{I(x,y)\}$
- Cut off spatial frequency
  - Below which features can not be distinguished from the noise
- Define a sharpness factor
  - Describes power of spatial frequency content that can be resolved distinguishable from the noise floor
  - $SF = \frac{\int_0^{k_{cut}} G(k_i)\,dk_i}{\int_0^{\infty} G(k_i)\,dk_i}$
- SF should increase with lower jitter variation

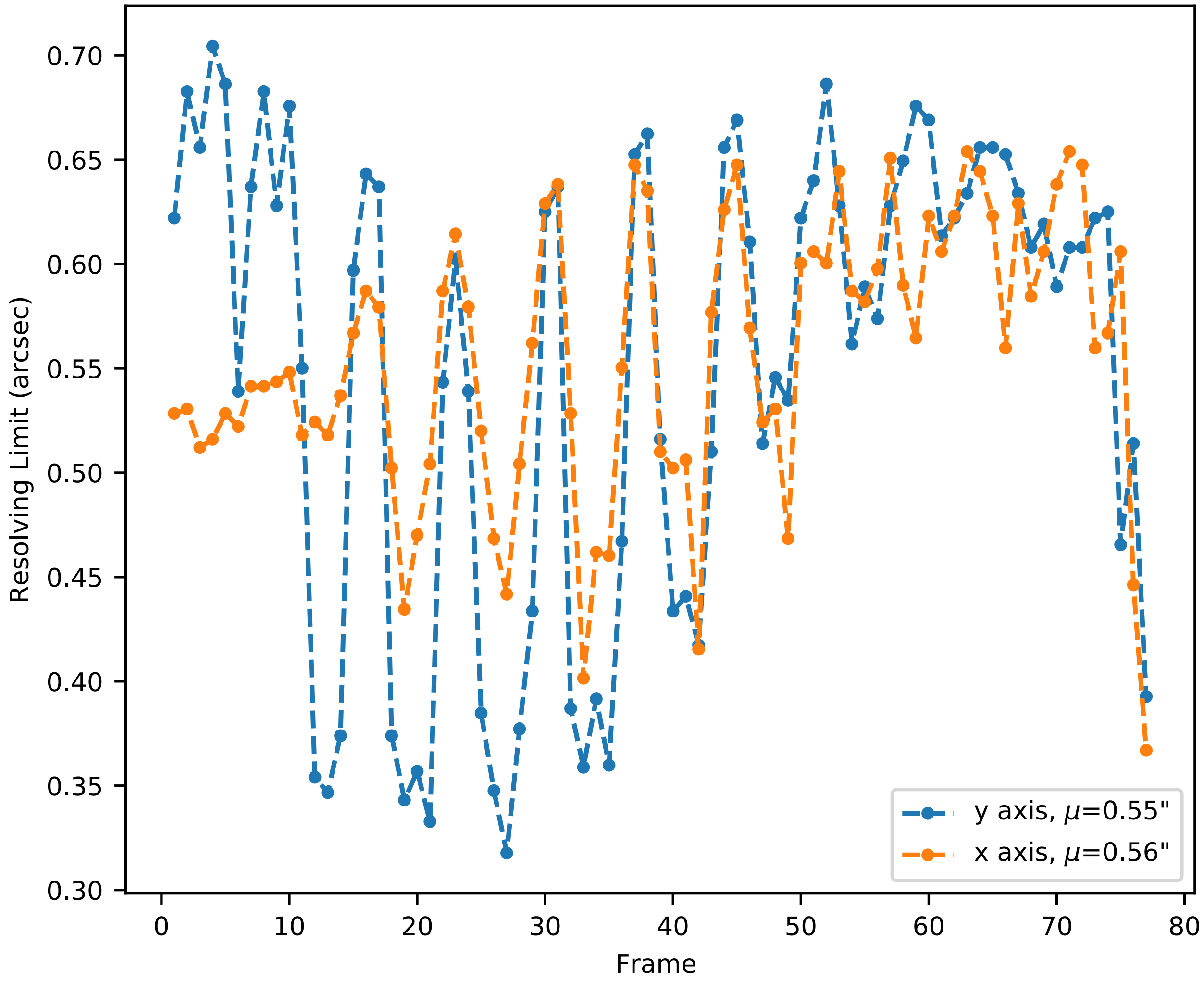




Kobayashi, K., Cirtain, J., Winebarger, A. R., Korreck, K., Golub, L., Walsh, R. W., … Windt, D. (2014). TheHigh-resolution coronal imager(Hi-C). *Solar Physics*, *289*(11), 4393–4412. https://doi.org/10.1007/s11207-014-0544-4

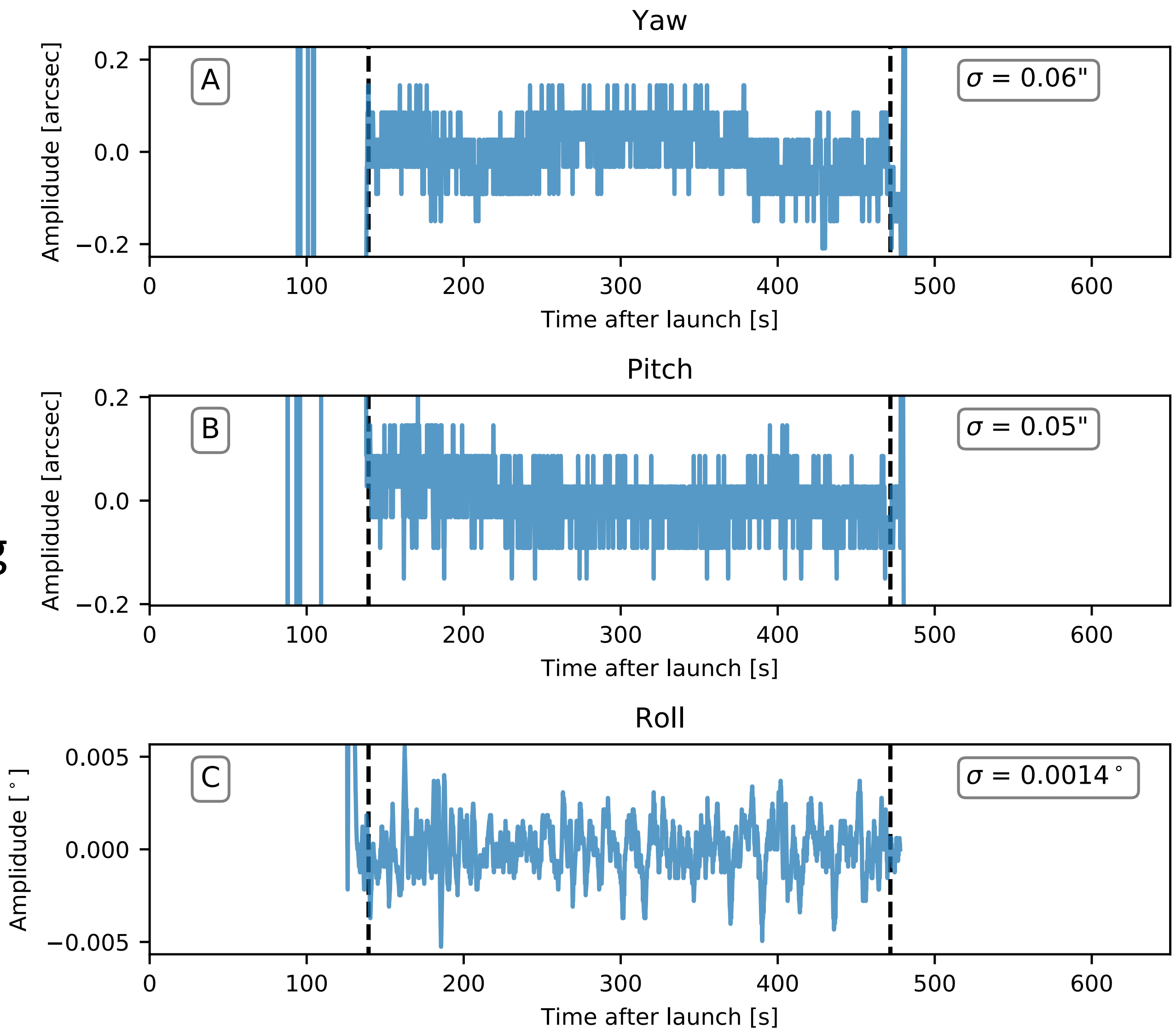
Average Resolution

- Average Resolution can then be inferred from the cutoff frequency
  - Average ~0.5”
  - Minimum ~.3”
  - Maximum ~.7”



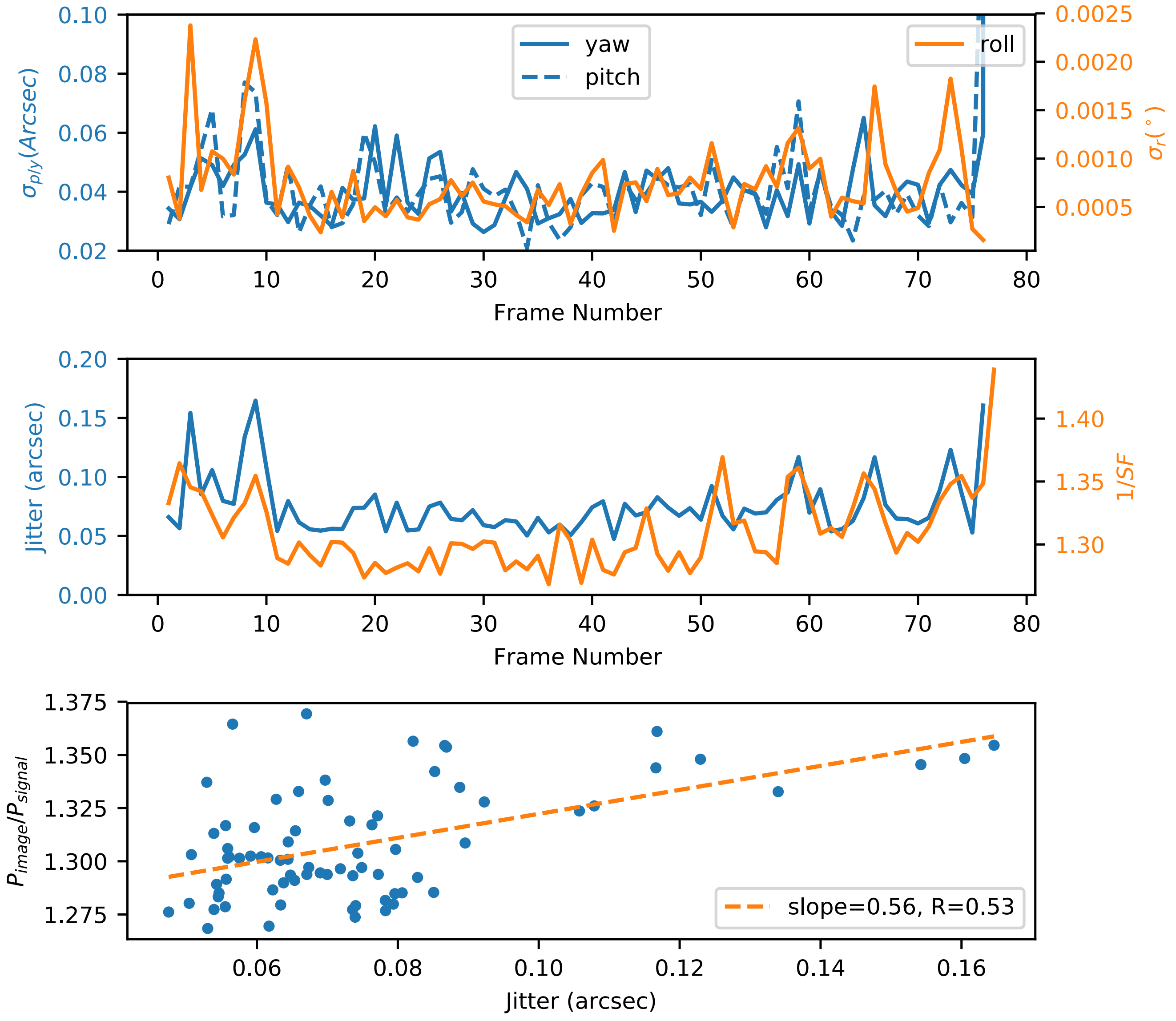
Jitter During Flight

- Well within critical science requirements
  - Roll of rms ≤ 0.01°
  - Pitch and yaw of rms ≤ 0.3
- Achieved according to data
  - Rms < 0.001
  - Pitch = 0.05”
  - Yaw = 0.06”
- There are periods of time where the swing does not meet requirement
  - If coincident with time image exposure, blur can be significant
- “…90% of the time between RLG enable and 150 km downleg…”
  - With sich high resolution imaging, the state-of-the-art pointing system may not be sufficient and requirements need to be reassessed



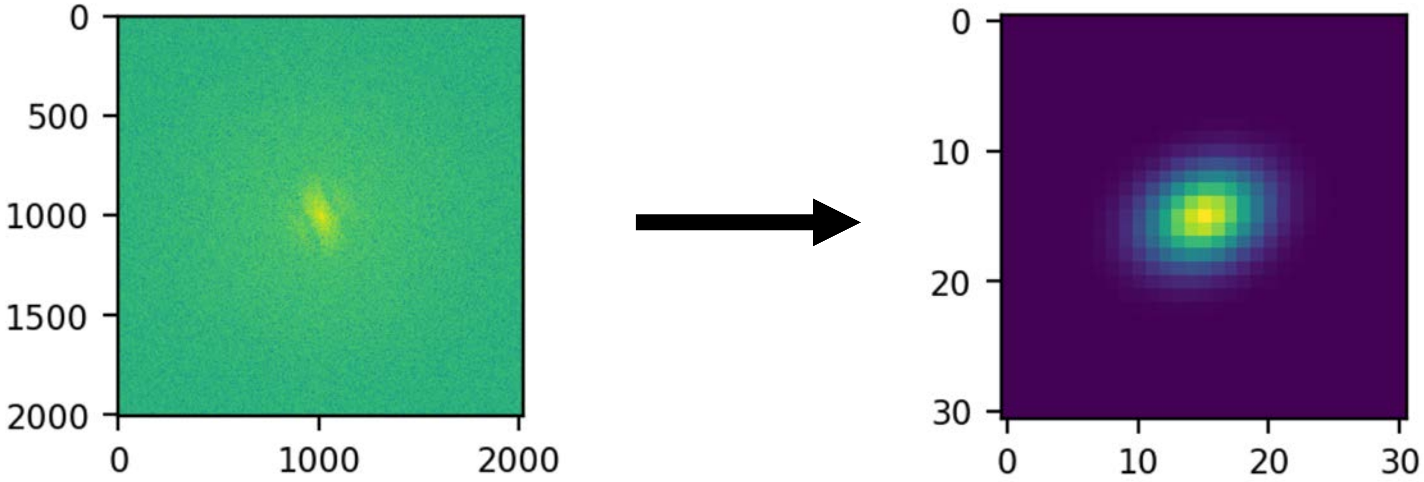
Jitter Parameter time Shift

- Importance of adequate time syncing
  - Original jitter data timestamps were completely uncorrelated to image blur
- Perform sweep of time stamp shifts for each kind of data (roll or pitch/yaw)
  - Time shift = 0.6 s for pitch/yaw
  - Time shift = 11.8 s
  - Correlation still poor



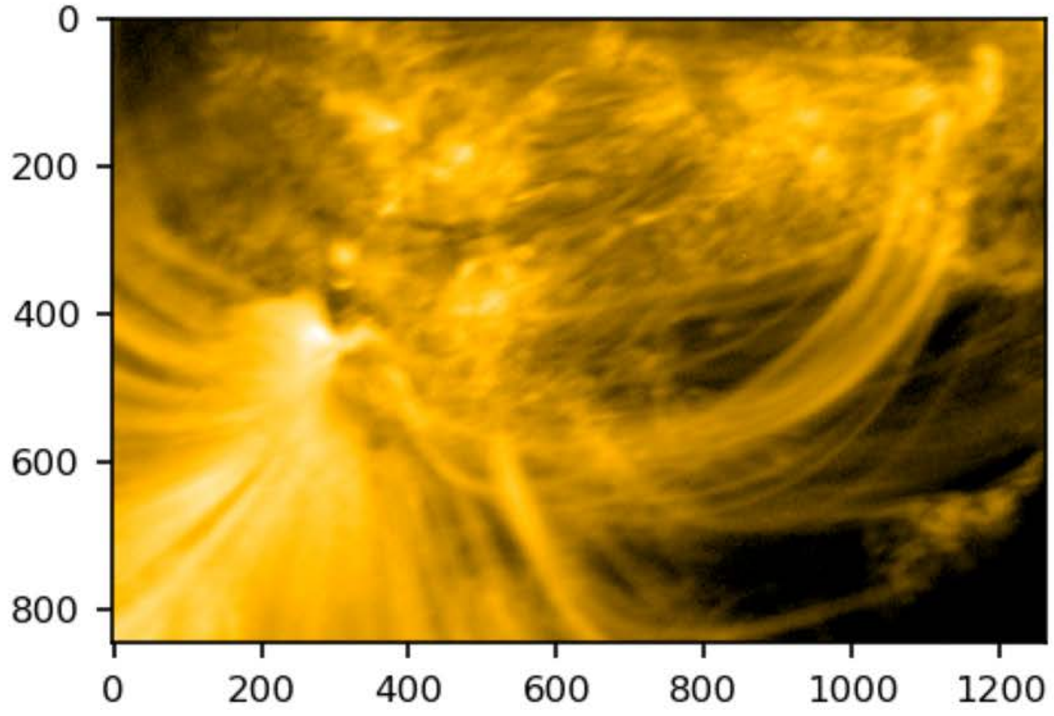
Deconvolution method comparison

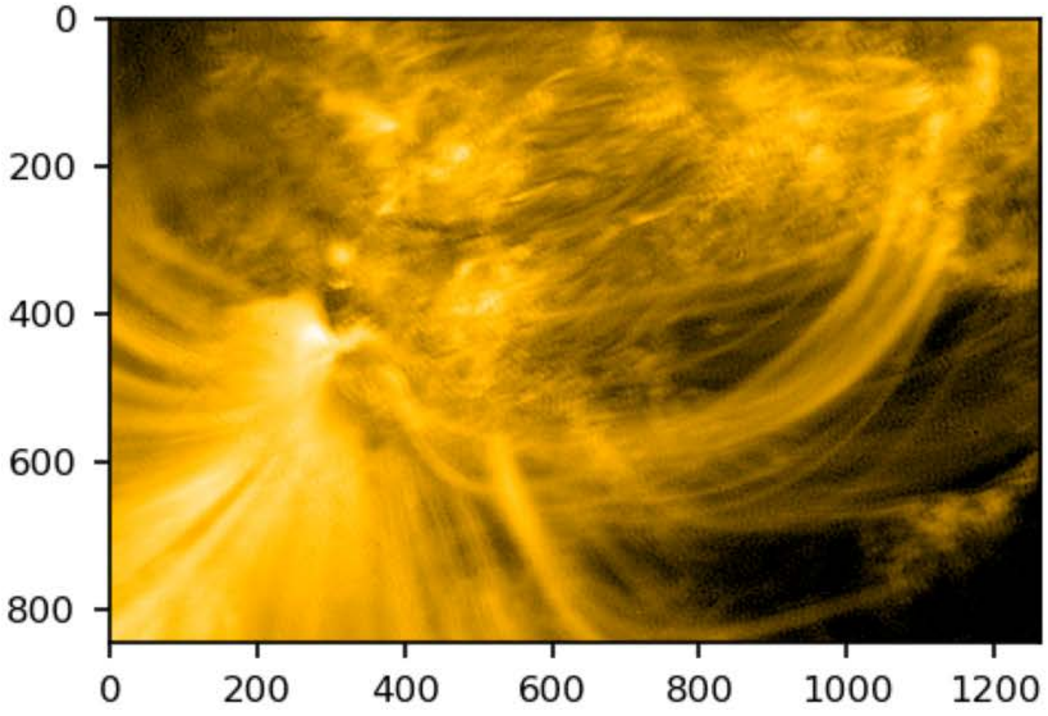
- Weiner deconvolution
- Method 1: PSF determination from FFT
- Method 2: Use of Jitter to estimate PSF not well characterized by motion blur



Deconvolution Results

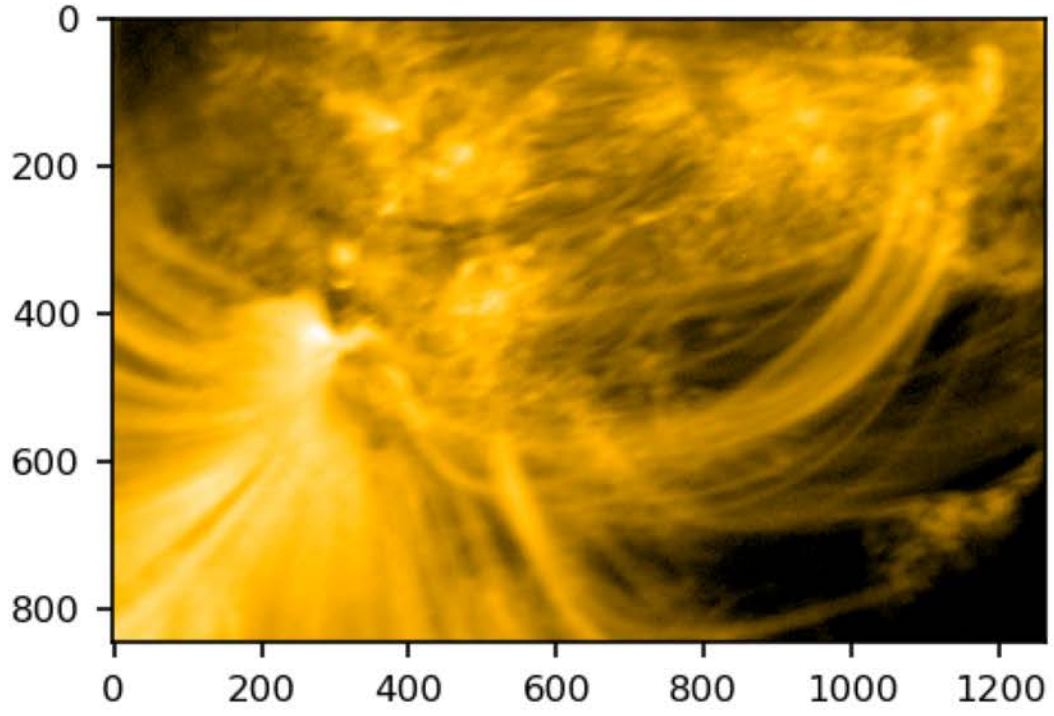
• Method 1: PSF Estimation from FFT

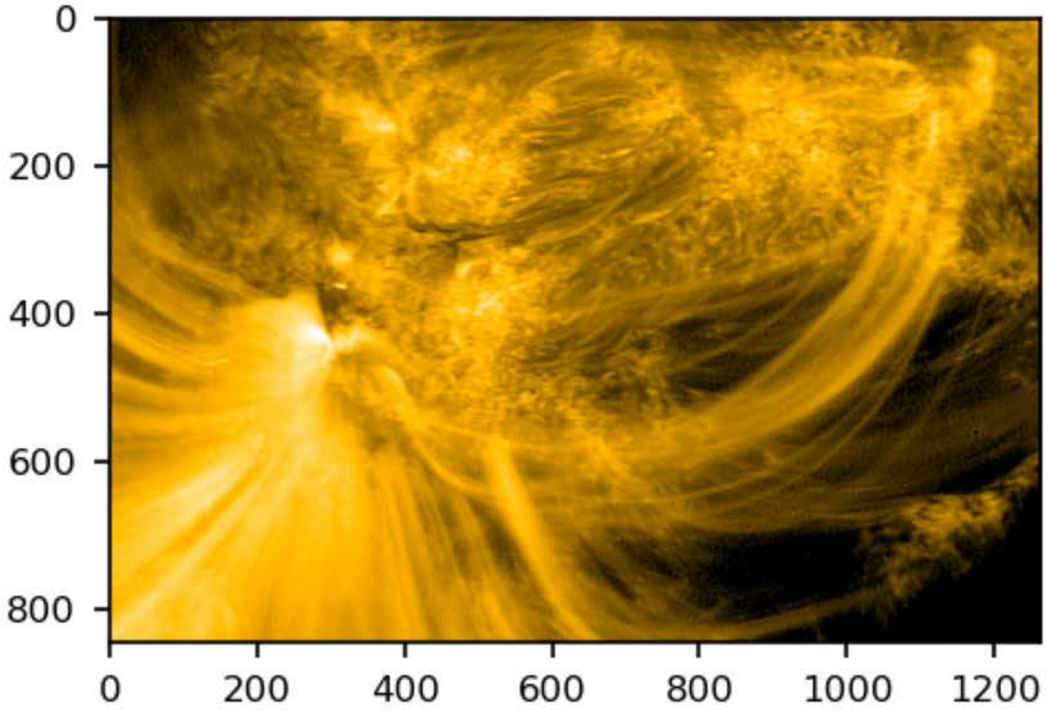




Deconvolution Results

- Method 2: Jitter guided
  - Decent results while jitter is well correlated with image blur
  - Still does not work well for images with poor correlation to measured jitter





Conclusions

- Jitter is found to be contributing factor in image degradation HiC 2.1
- Data set can partially be returned given deconvolution methods
  - Images blurred by simple motion blur can be adequately recovered by estimation of PSF from FFT of image
  - Images that suffer extreme and highly nonlinear motion blur is not well recovered and need extra input from measured jitter
  - Poor correlation between jitter and blurred images needs further investigation to accurately recapture all highly images
- A lessons learned in importance of good requirements writing and accurate time stamp measurement