SUBBAND IMAGE RECONSTRUCTION
USING DIFFERENTIAL CHROMATIC REFRACTION

6/13/2018

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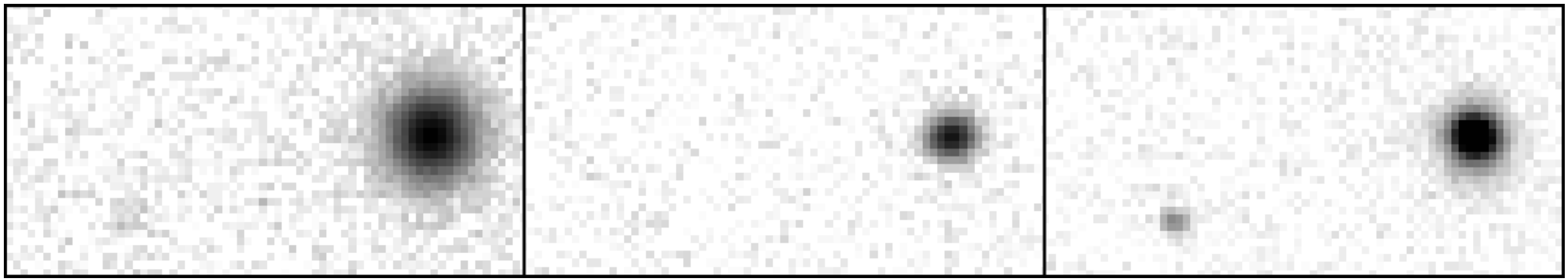
Multiple Exposures

- Each observation
  - Low signal-to-noise
  - Blurry
  - Variable quality

SDSS FRAMES



Current Methods

- Brute-force summing of images is incorrect
- Lucky imaging uses only the best images
- Convolve to worst acceptable PSF & coadd

Throwing away a lot of information!

Image Deconvolution

- Richardson-Lucy deconvolution
- Correction of Hubble optics
  - *White (1994), Starck+ (1994), Lauer (1994, 2002), …*

Fuhgeddaboudit!

- Mathematicians know it’s a solved problem
  - So why bother…
- Astronomers know it’s impossible to solve
  - So why bother…

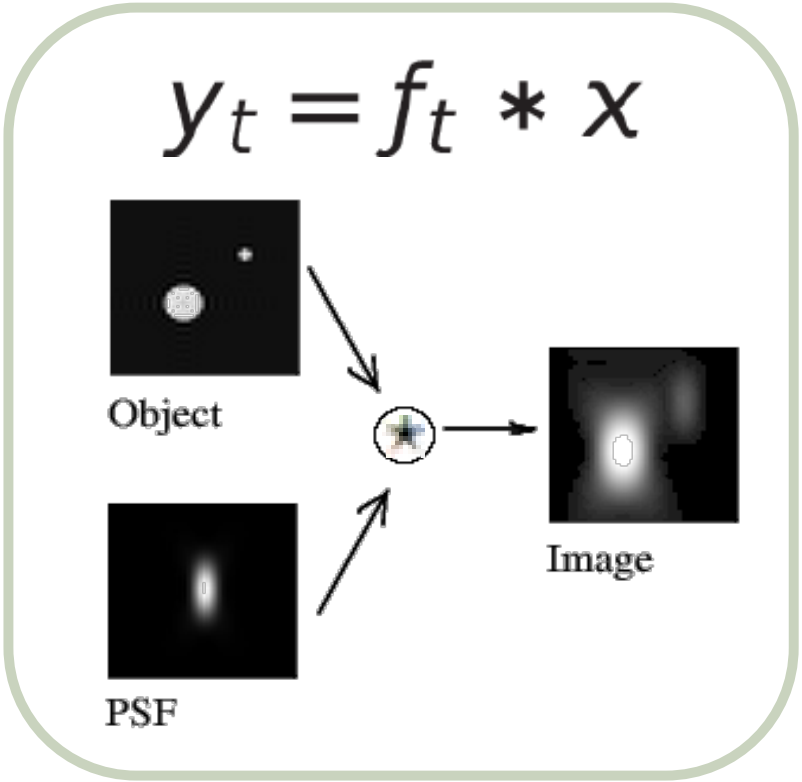
Image Reconstruction

- Model image behind the atmosphere
  - Bayesian Inference
    - Too expensive… (?!)
  - Maximum Likelihood Estimation
    - Faster, simpler… (good)
    - Wait! R-L is MLE with Poisson

Simple Model

- Background image
- Convolved with PSF
- Plus the noise

- Solve for x
- Solve for x and f_t ?!



Robust Statistics

- M-estimation

$$\min_{\boldsymbol{\theta}} \sum_i \rho\left(\frac{y_i - \tilde{y}_i(\boldsymbol{\theta})}{\sigma_i}\right)$$

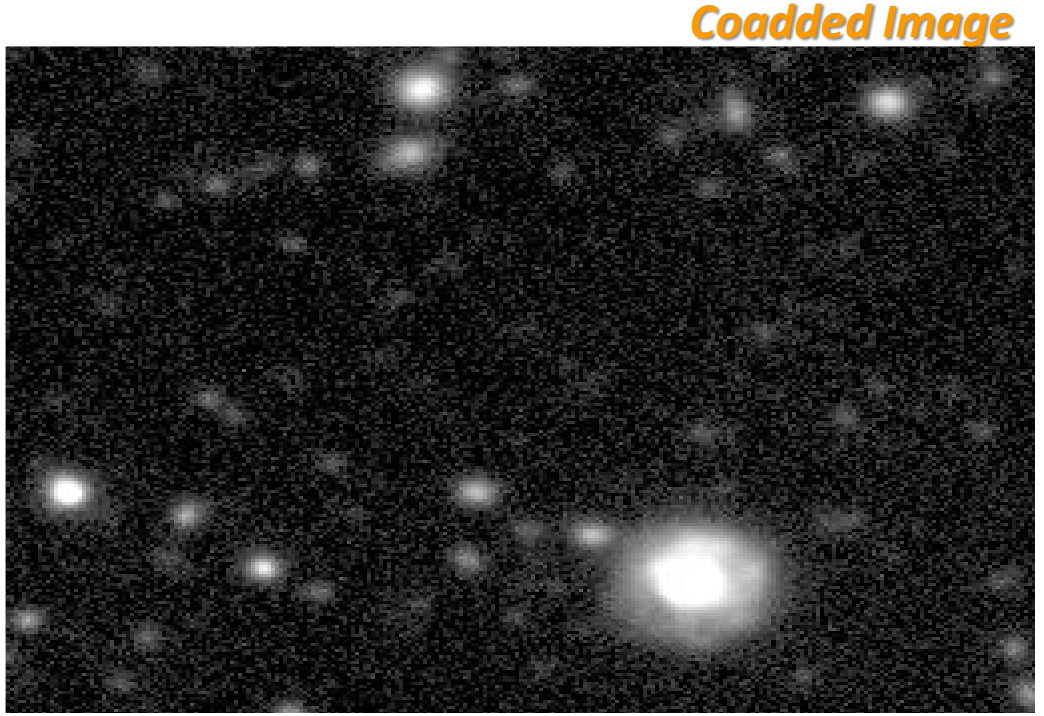
  - Deep connection with Bayesian Statistics
  - Automatic masking where model doesn't work

And some more…

- … math stuff
  - E.g., priors, likelihoods
- … algorithm stuff
  - E.g., streaming on GPUs

Image behind the Atmosphere

- Coadding
  - Brings out faint sources
  - But blurs the images
- We solve for it
  - For high-res details



Lee+ (2014, 2017)

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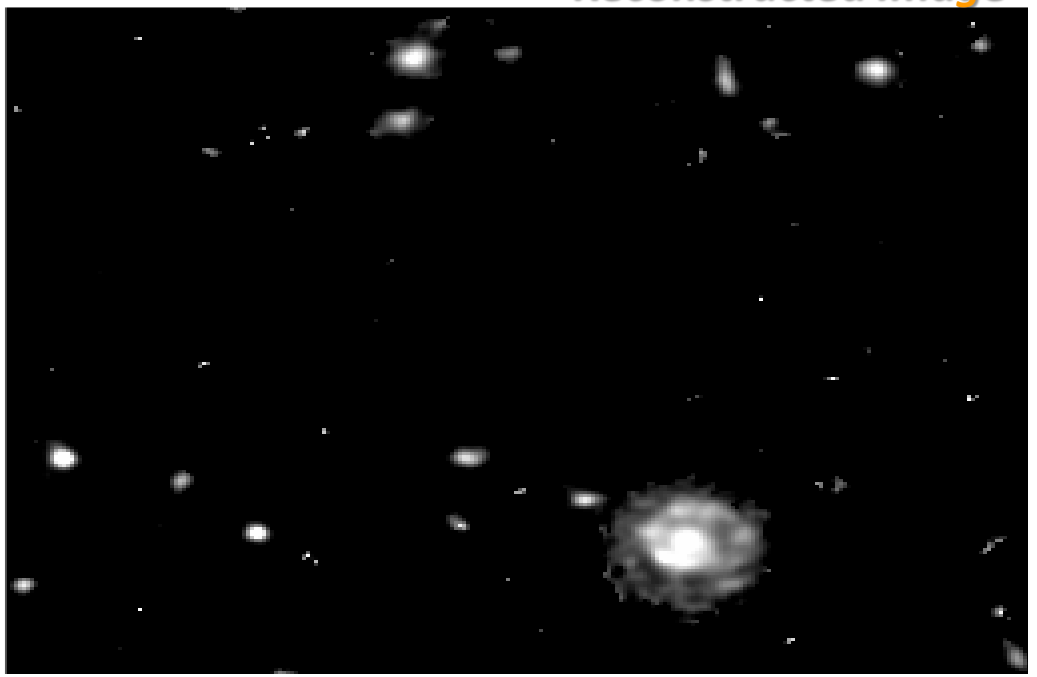

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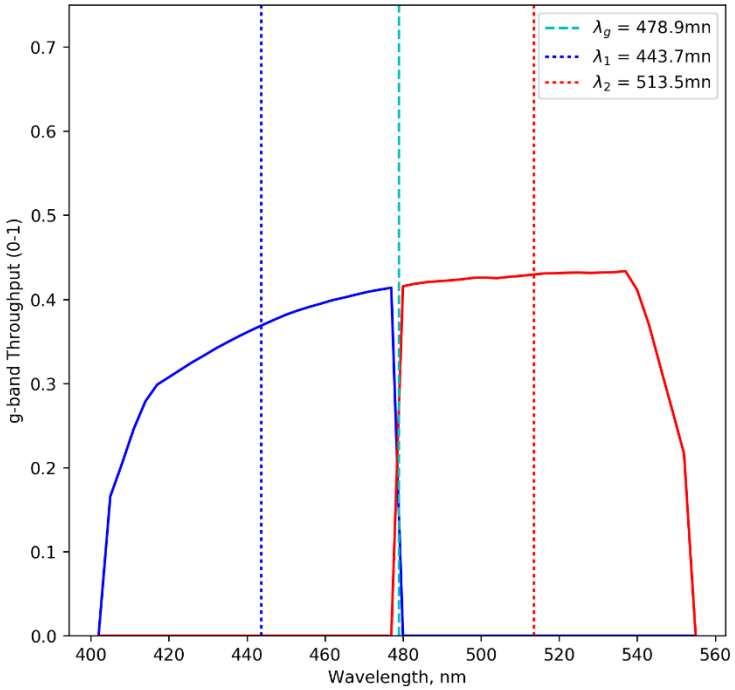
Hubble Image

Lee+ (2014, 2017)

Subband Colors?

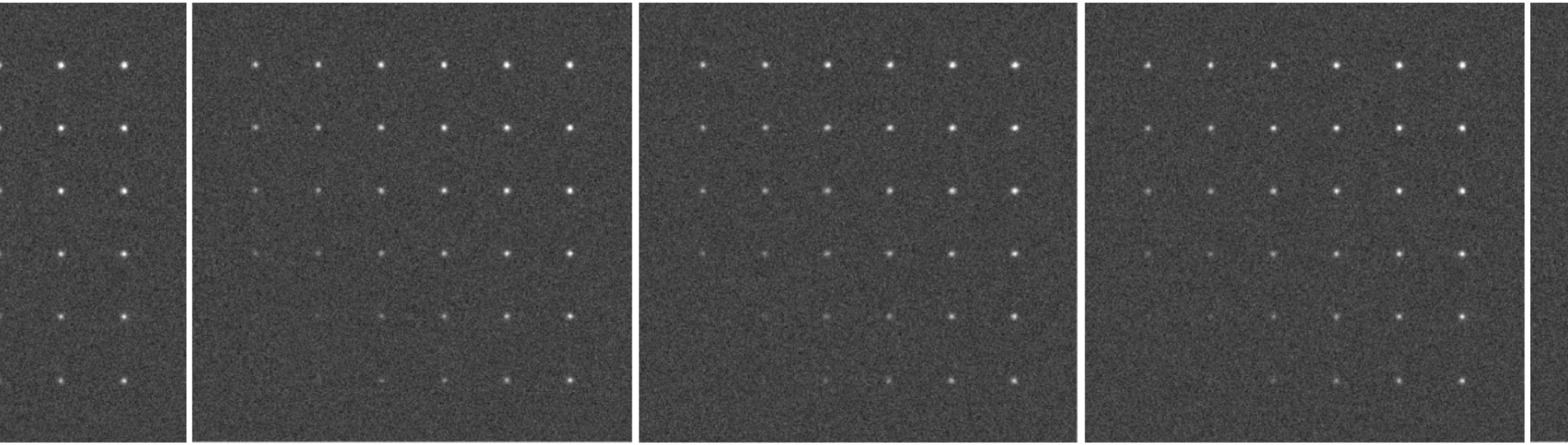
- Differential Chromatic Refraction
  - Known nonlinear physics
- New model
  - Subband filters
  - Subband images



Work with Matthias Lee (JHU), Andy Connolly, and Ian Sullivan (UW)

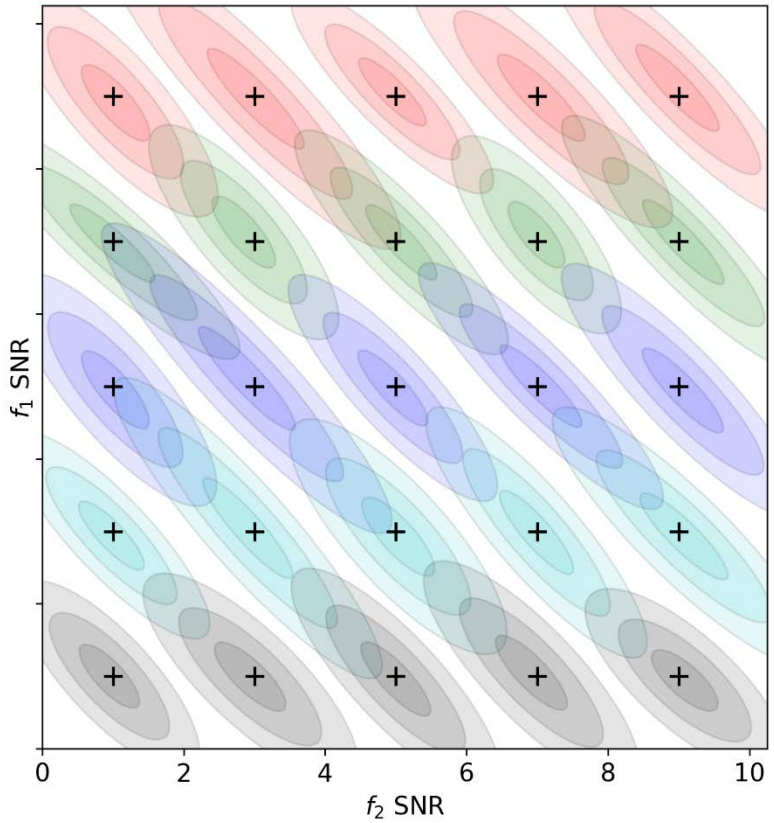
Simulated Stars

- Subband fluxes vary as fn of sky coordinates



Inferred Fluxes

- Signal-to-noise ratio – varying errors



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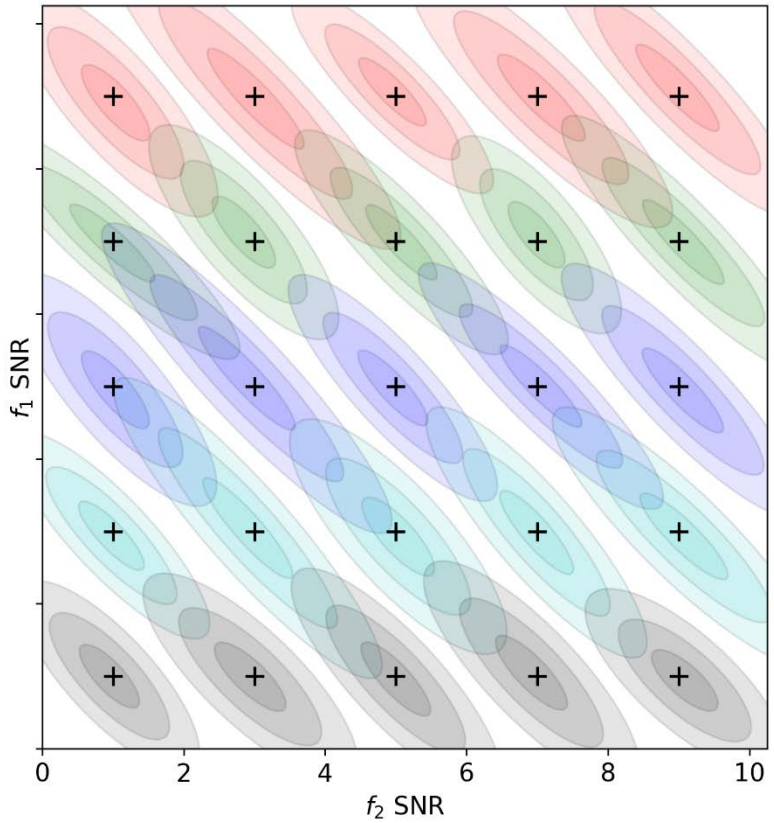
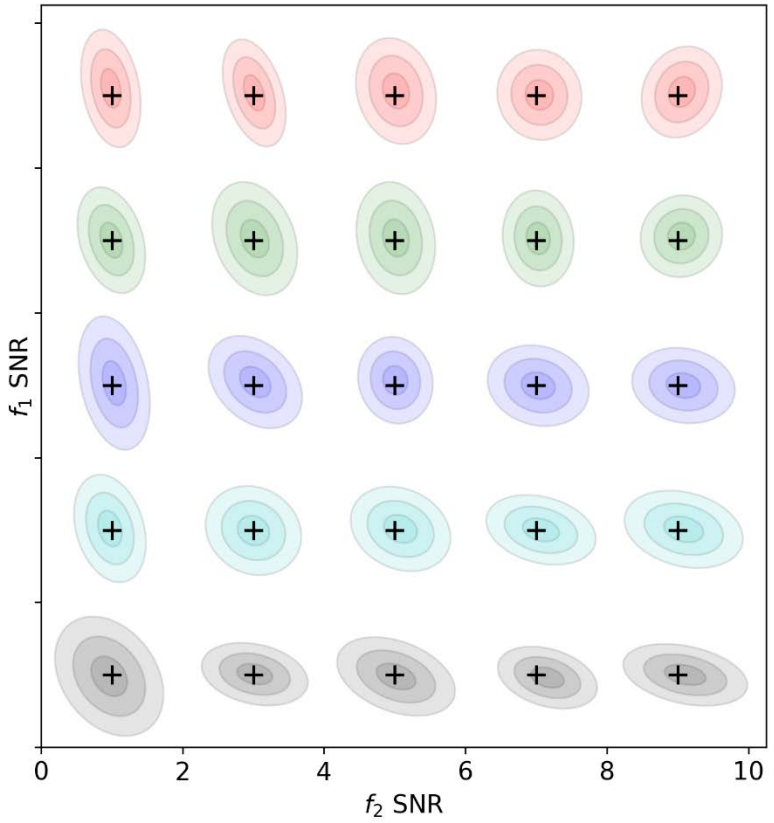
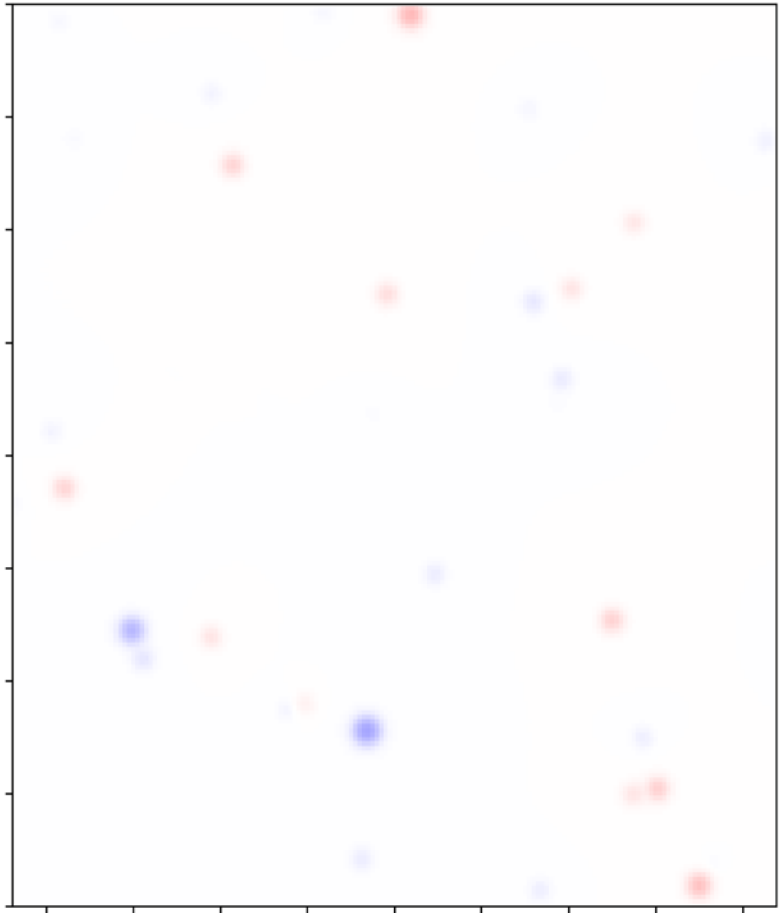
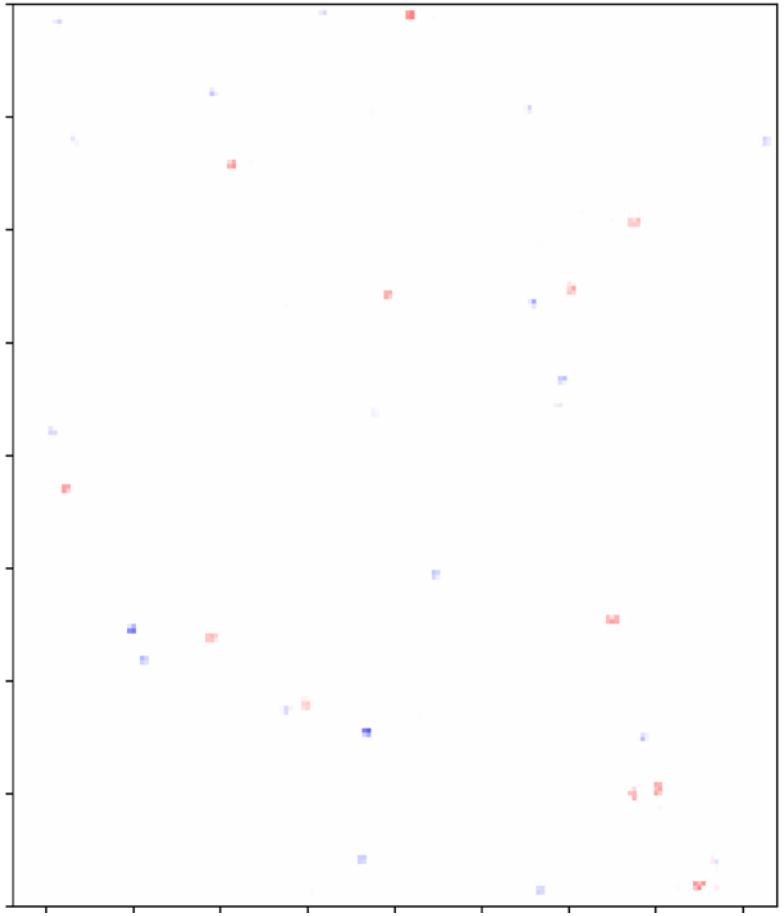


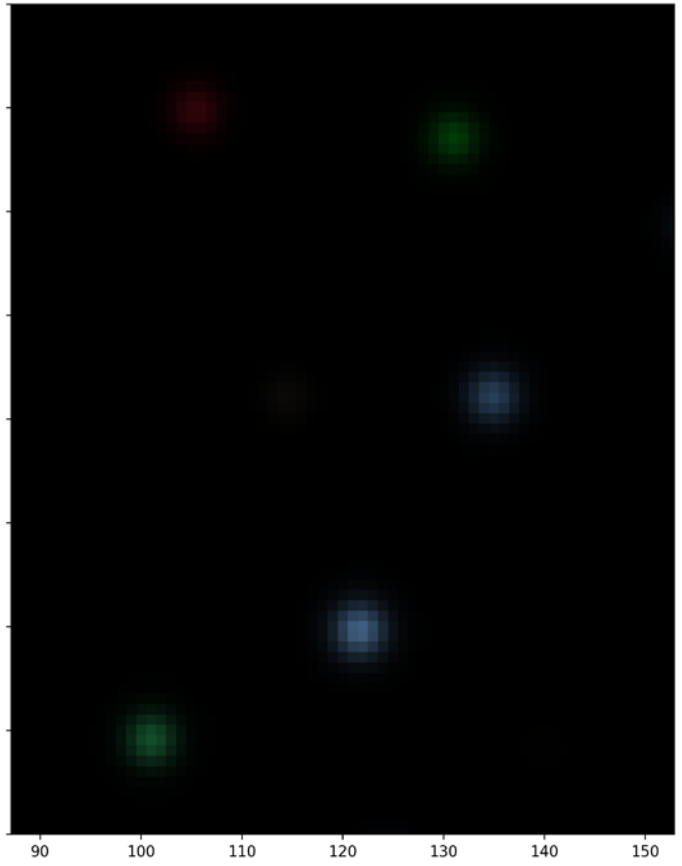


Inferred Images





Inferred


90
100
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120
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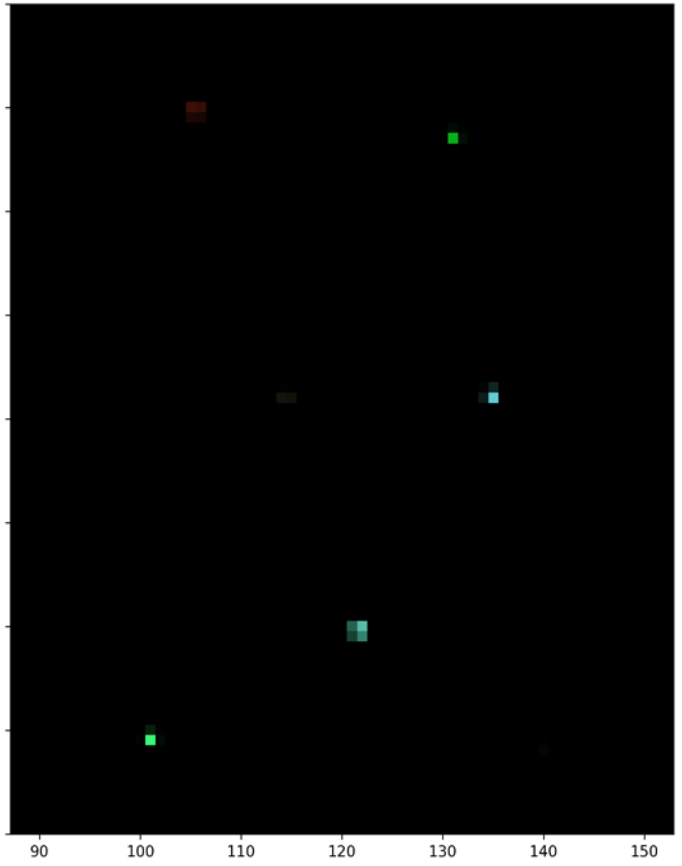
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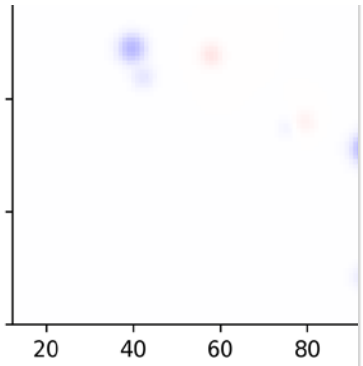
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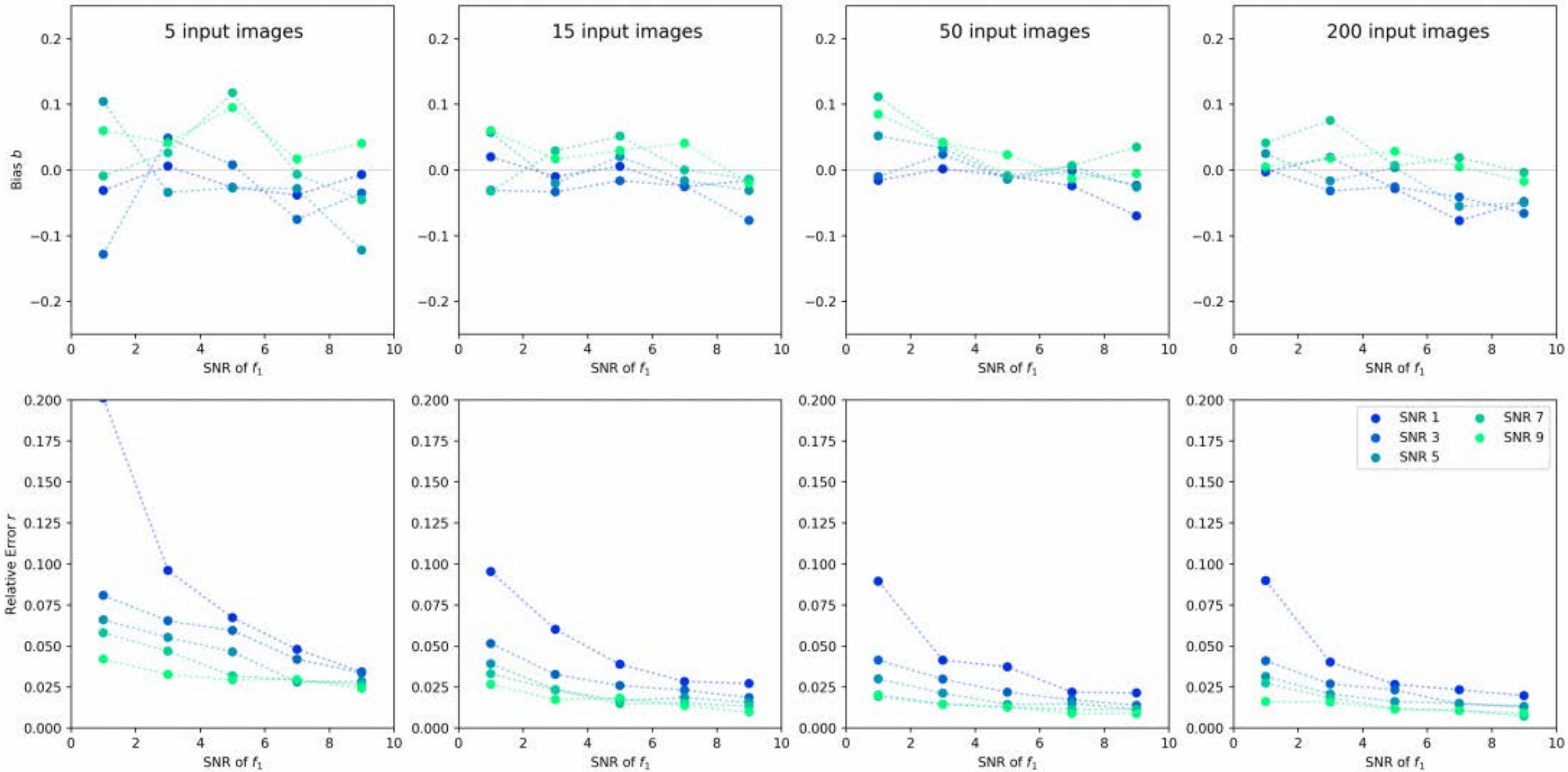
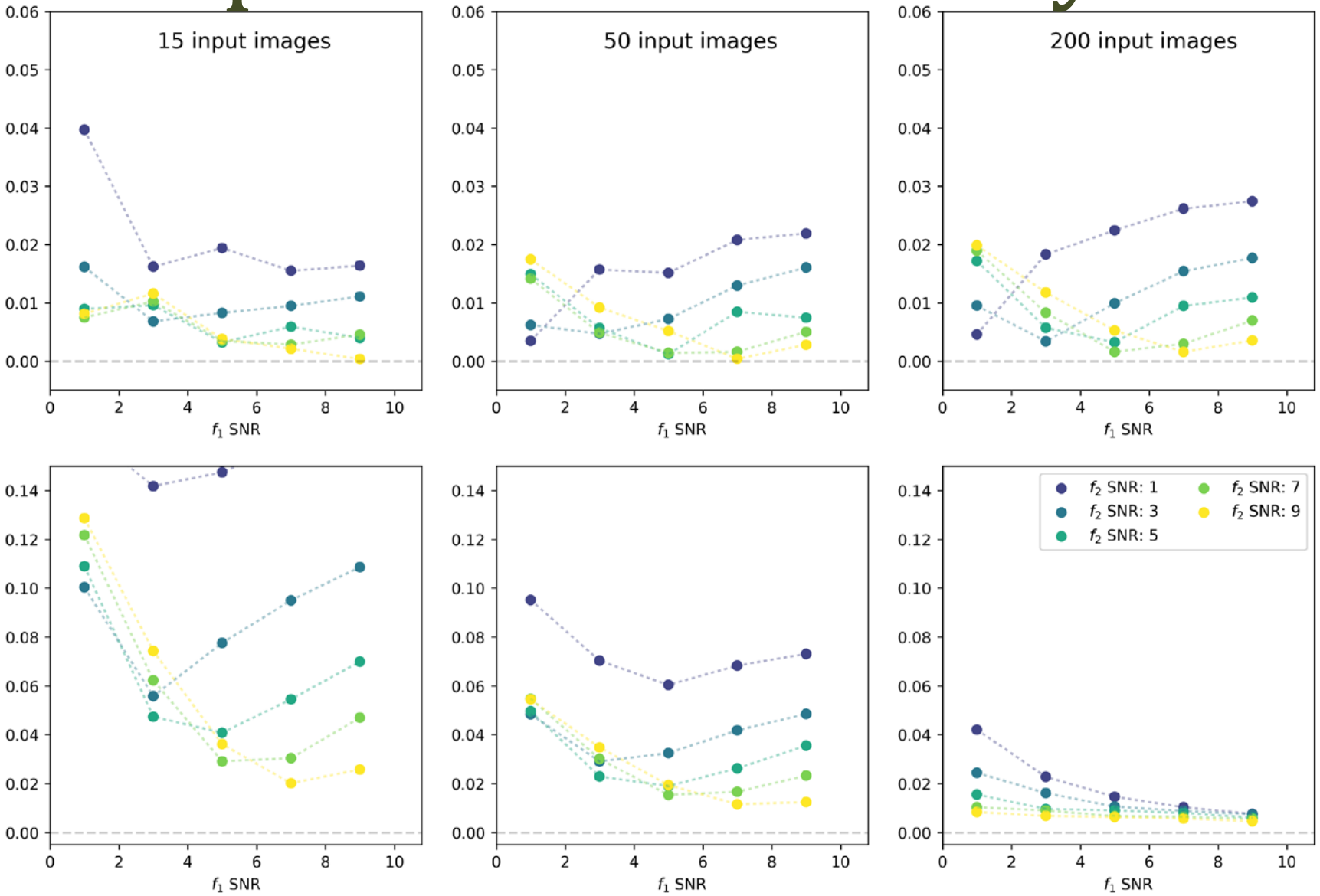

5 input images
15 input images
50 input images
200 input images
Bias b
Relative Error r
SNR of f_1
SNR 1
SNR 3
SNR 5
SNR 7
SNR 9

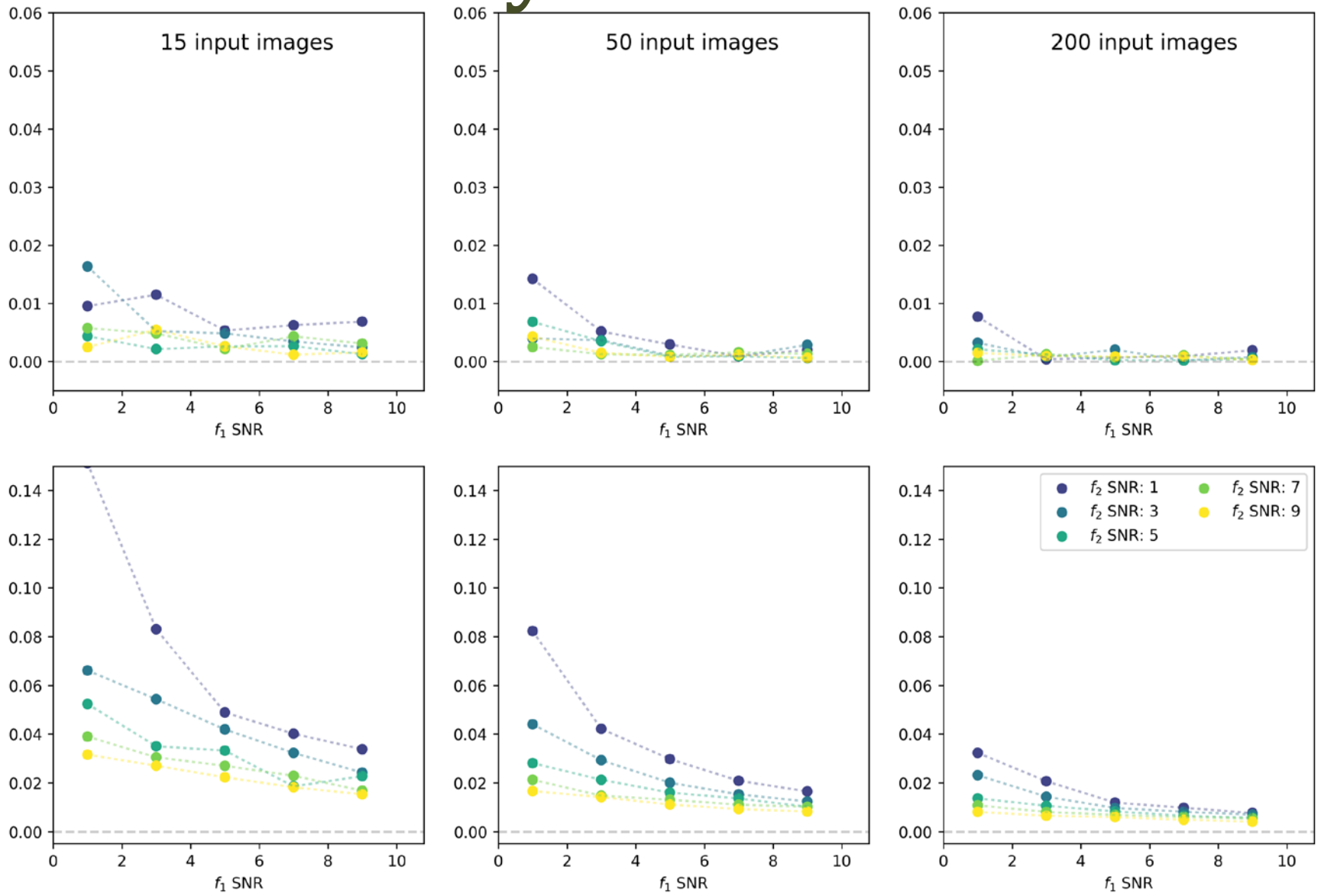
Improved Astrometry



coadd is biased

Improved Astrometry

new is unbiased



Summary

- Robust inference for hyper-resolution images
  - Time-domain observations provide breakthrough
- Subband color information accessible
  - Modeling the nonlinear optics of the atmosphere
- Improved astrometric uncertainties