MODELING THE HSC PSF AND THE BRIGHTER-FATTER EFFECT

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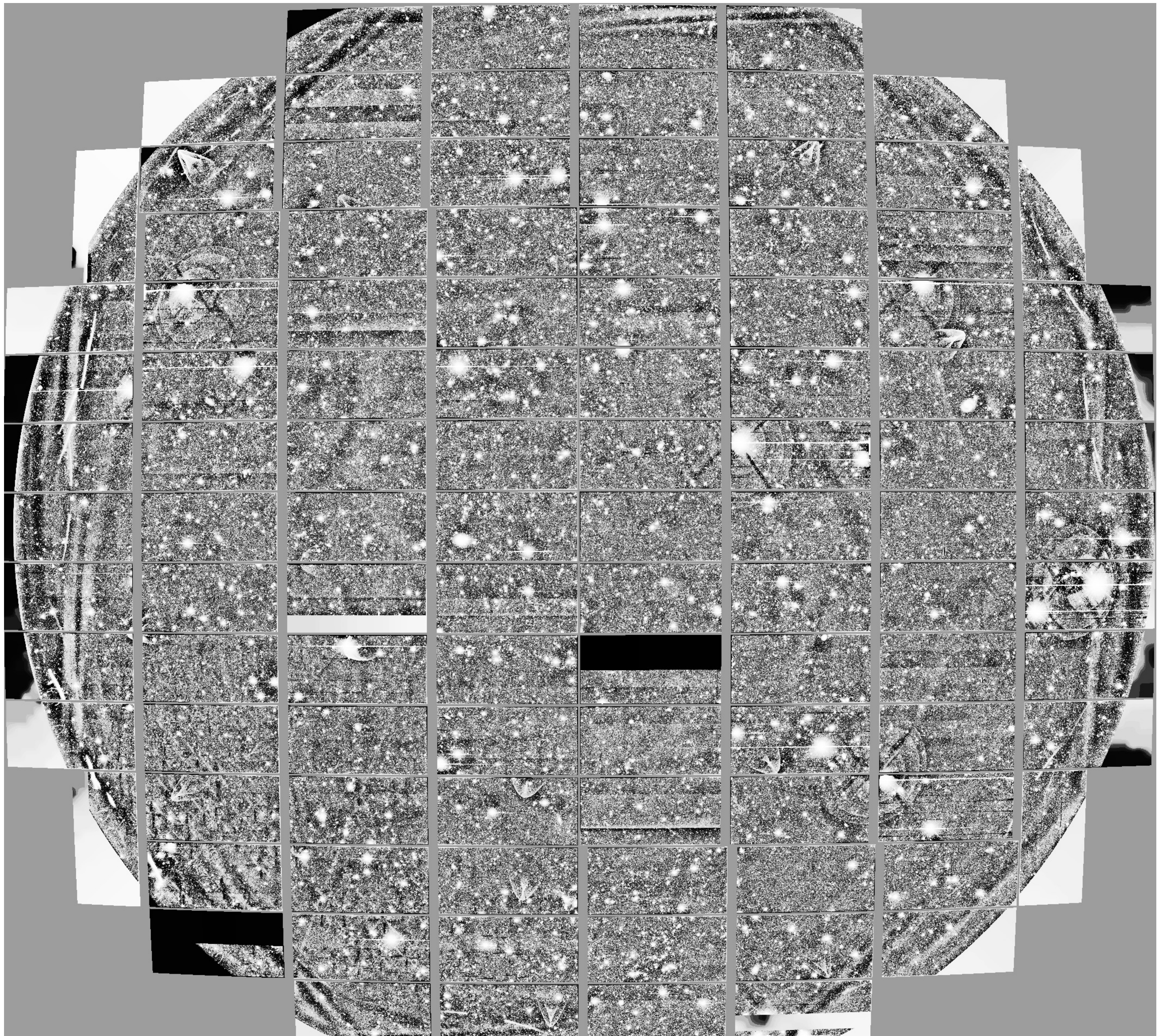
BACKGROUND

- The Subaru Strategic Program is performing a survey using Hyper Suprime-Cam on the 8.2m Subaru Telescope.
- Supernova science is possible in the COSMOS and SXDS Deep and UltraDeep fields.
- Using data taken in *grizy* bands
- LPNHE has developed an independent pipeline for identifying supernovae and processing the data.
    - ➡ The following results are all based on data from the LPNHE pipeline.

SUBARU HSC DATA



BASELINE PSF-FITTING STRATEGY

- Based on DAOPHOT, by way of the SNLS pipeline.
- Identify isolated, unsaturated stars with S/N above a given level.
- Use stars to fit PSF as a spatially varying function of the CCD position.
- PSF is mostly described by analytic function, pixel basis makes small adjustments.

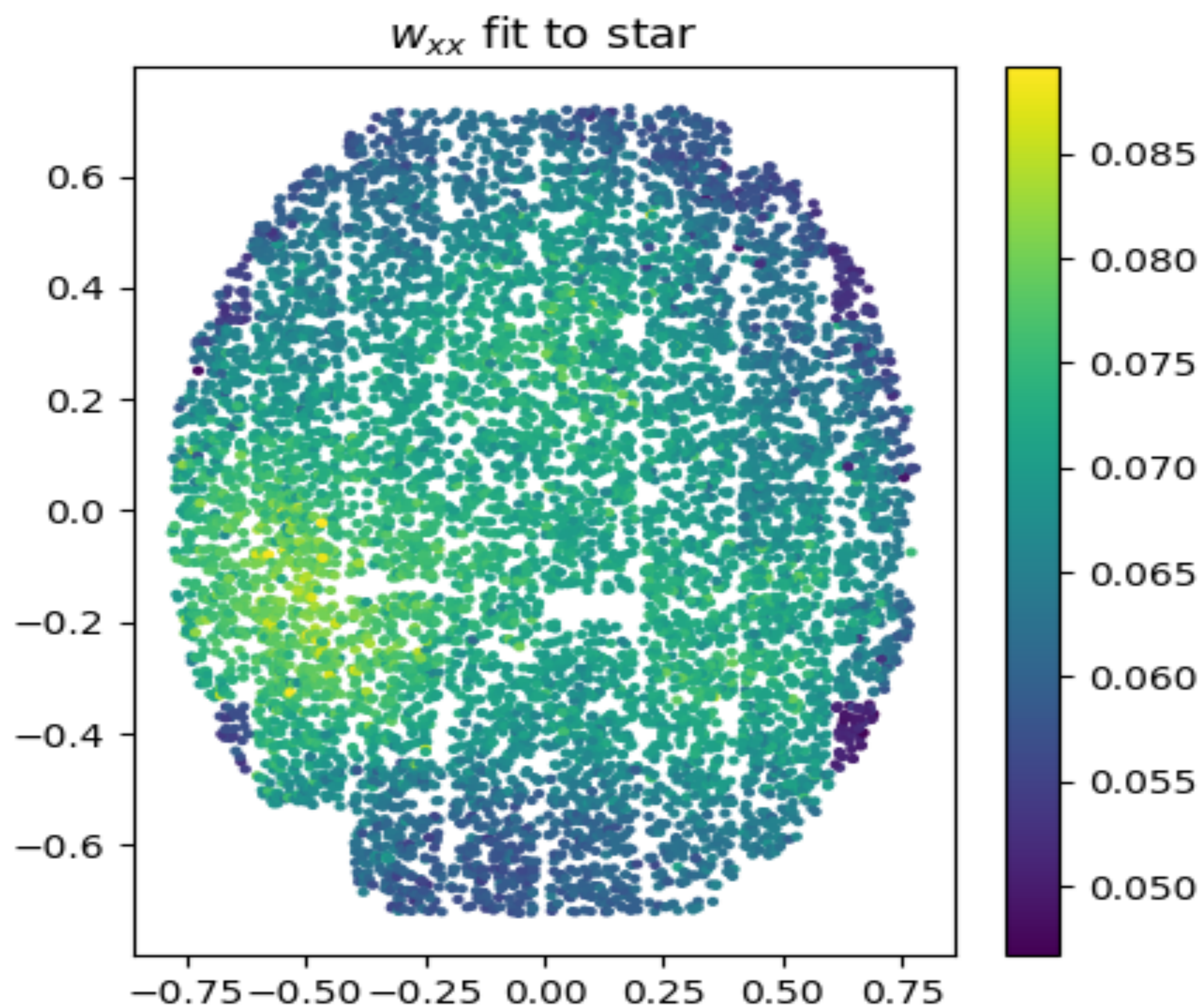
The PSF: $$\Psi_{i,j}(x,y) = (1 - \Sigma_{i,j} R_{i,j}(x,y))\phi_{i,j}(x,y) + R_{i,j}(x,y)$$

where $$\phi(x,y) = N(1 + w_{xx}x^2 + w_{yy}y^2 + w_{xy}xy)^{-2.5}$$

and $$w_{xx}(x,y) = w_{xx,0} + w_{xx,x}x + w_{xx,y}y + \ldots$$
$$R_{i,j}(x,y) = R_{i,j,0} + R_{i,j,x}x + R_{i,j,y}y + \ldots$$
etc.

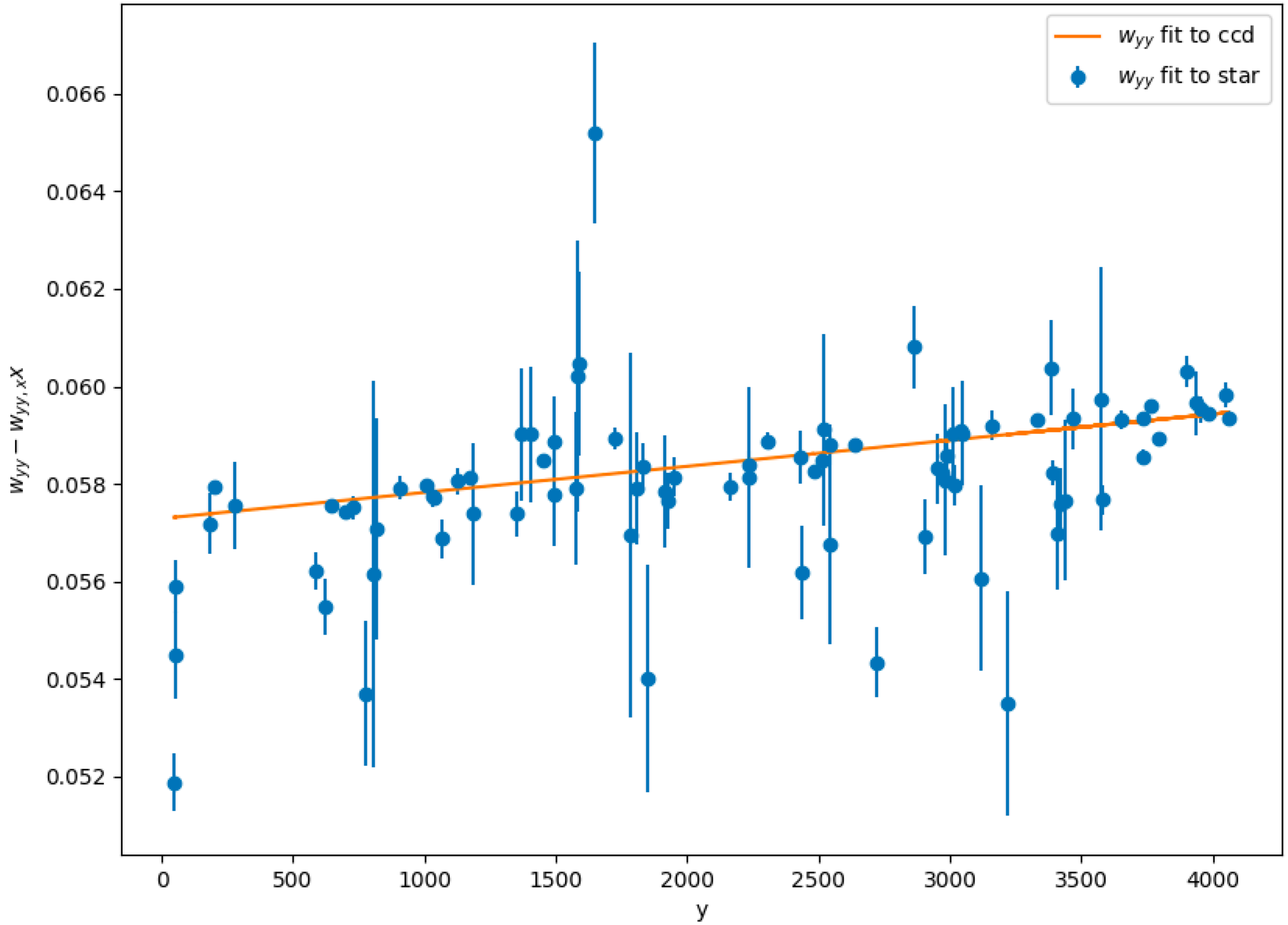
BASELINE ALGORITHM

- Step 1: Fit Moffat PSF parameters to each star individually.



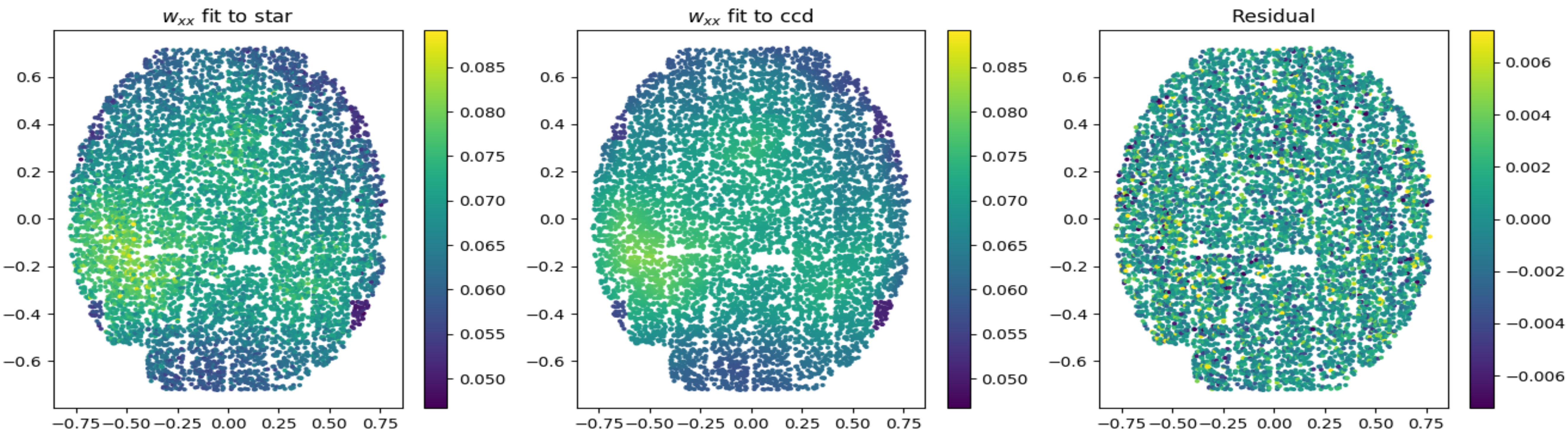
BASELINE ALGORITHM

- Step 2: Fit Moffat parameters as a function of the CCD position:



BASELINE ALGORITHM

- Moffat parameters over the full FOV:

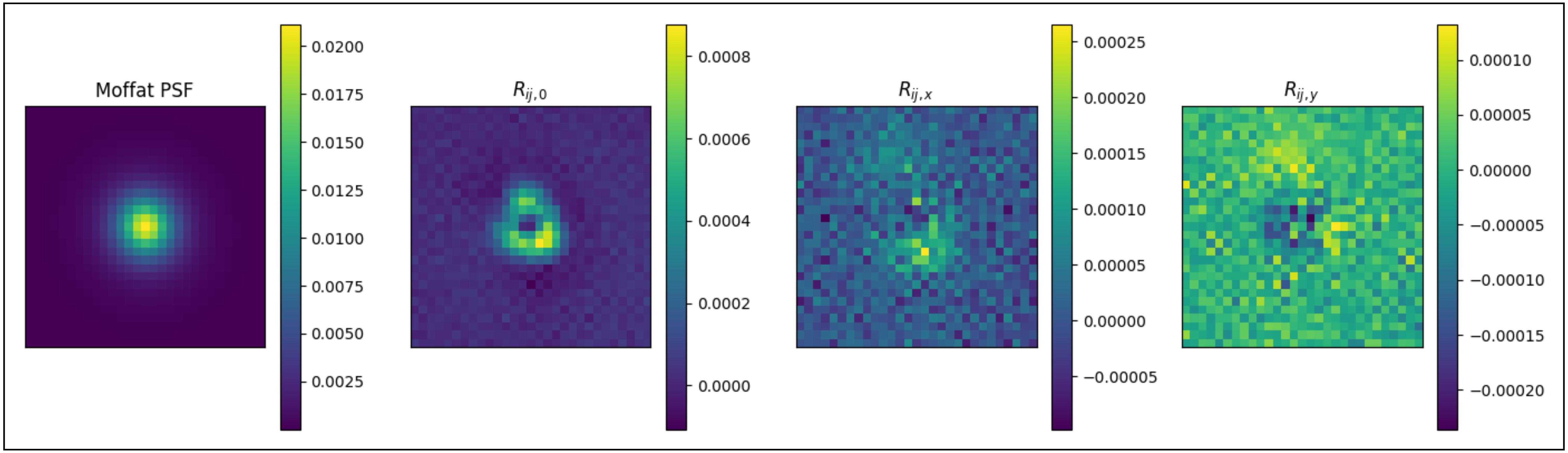


BASELINE ALGORITHM

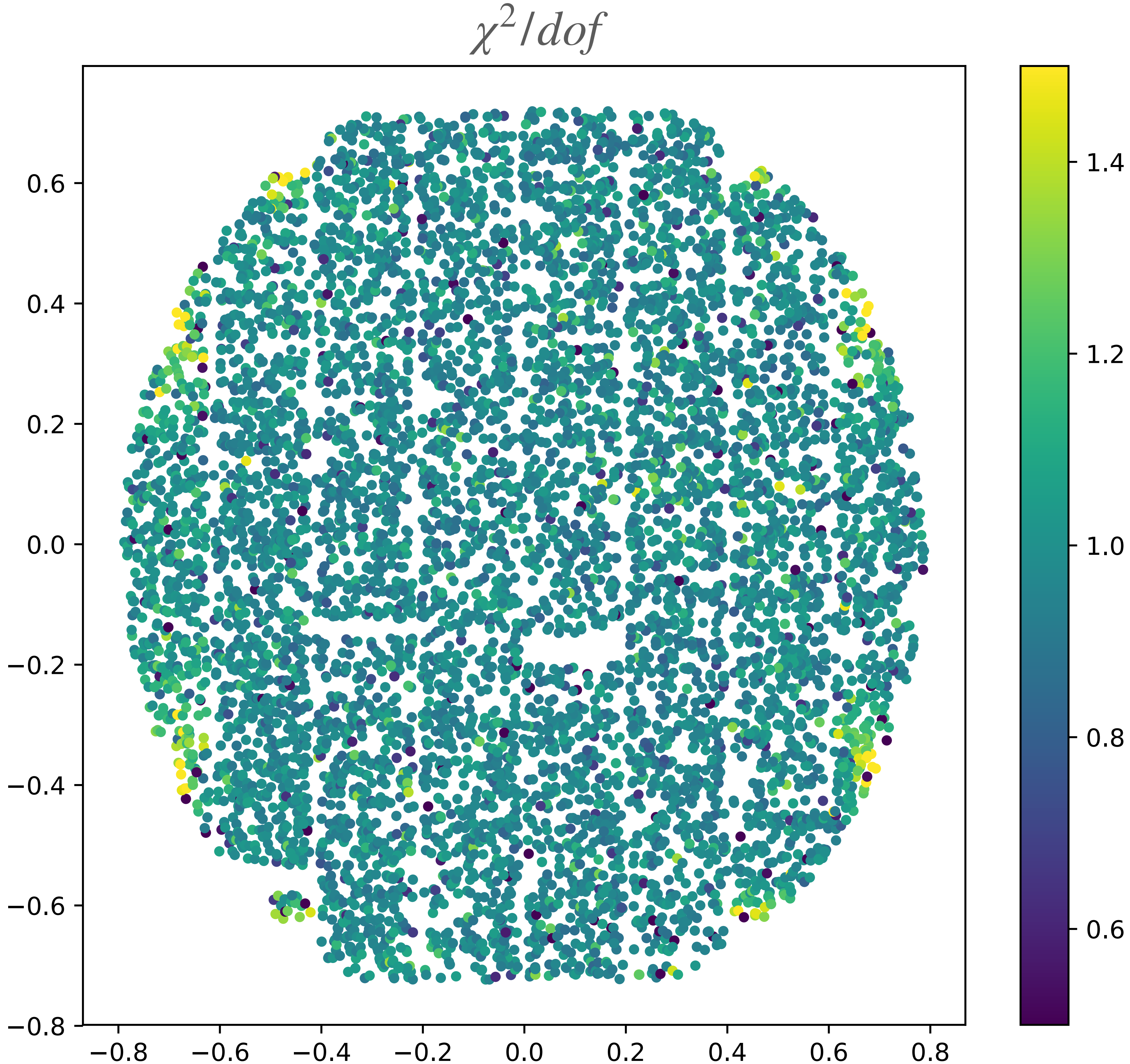
- Step 3: With analytic part of PSF fixed, fit remaining variation with pixel basis.

$$\Psi_{i,j}(x,y) = (1 - \Sigma_{i,j} R_{i,j}(x,y))\phi_{i,j}(x,y) + R_{i,j}(x,y)$$

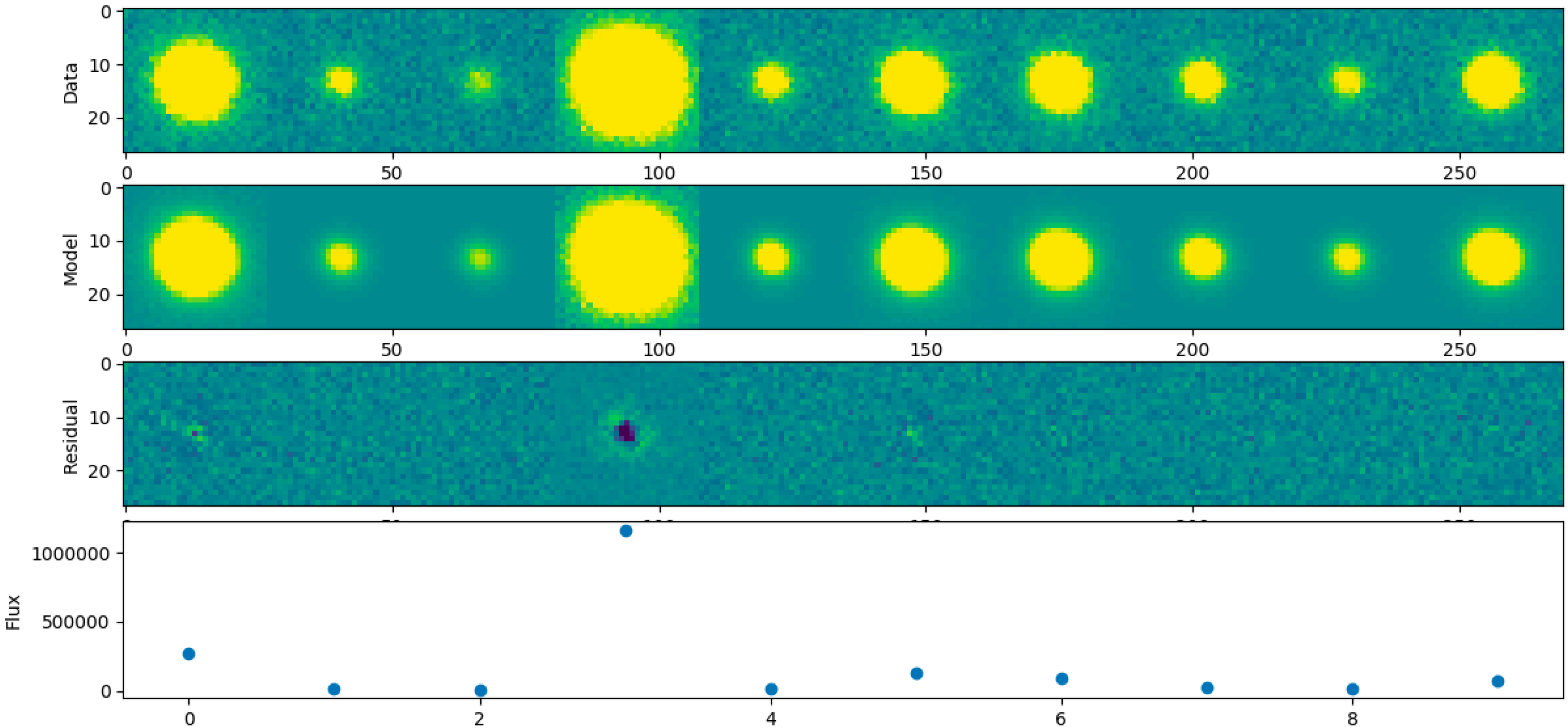
$$R_{i,j}(x,y) = R_{i,j,0} + R_{i,j,x}x + R_{i,j,y}y + \ldots$$



FIT OF PSF OVER THE FIELD OF VIEW



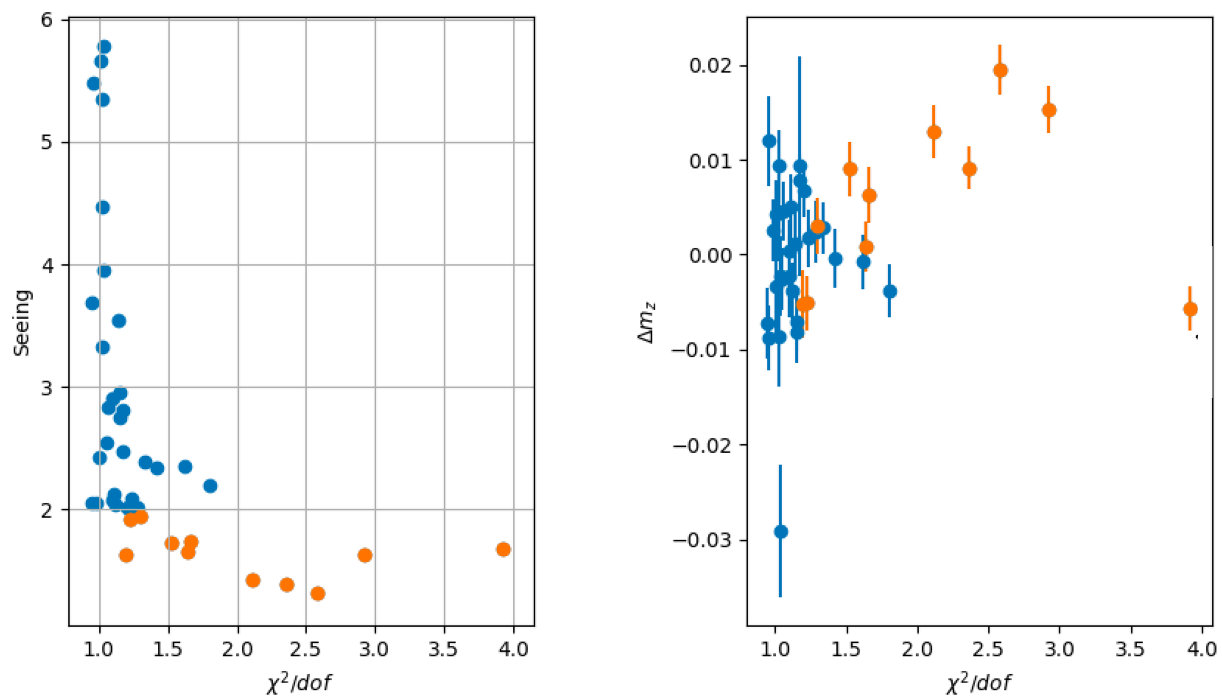
SAMPLE RESIDUALS



A REMINDER OF WHY WE CARE ABOUT GETTING THE PSF RIGHT

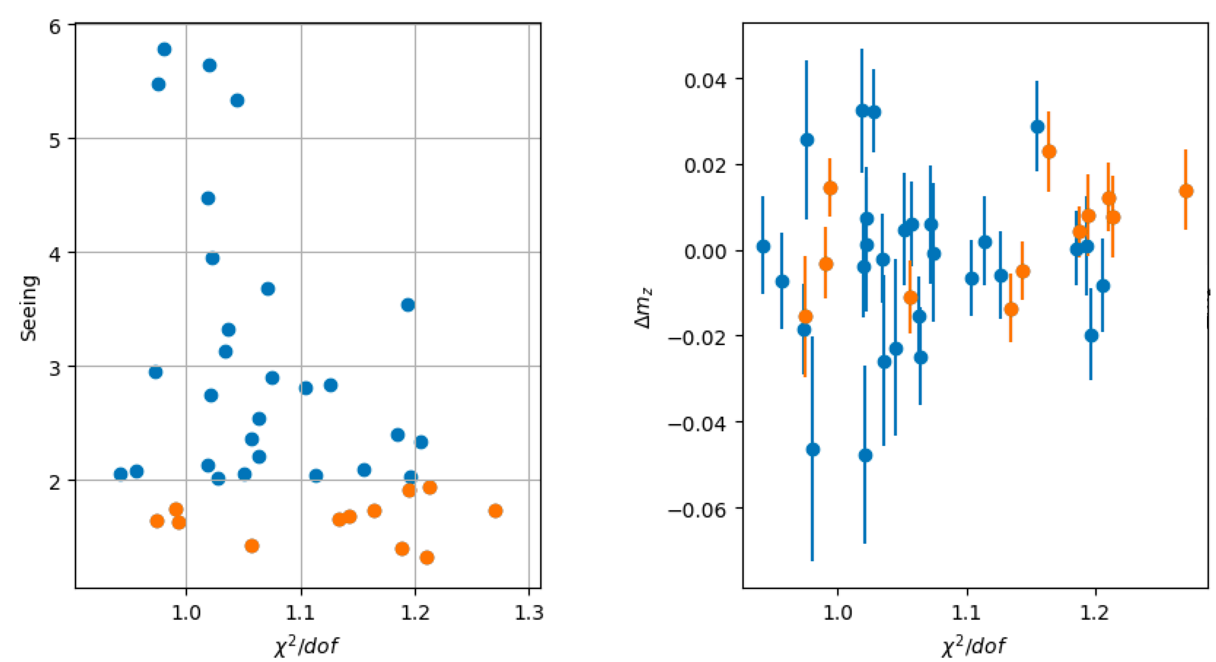
Bright star:

(flux~10^6)



Dim star:

(flux~10^5)



ADDING THE BRIGHTER-FATTER EFFECT

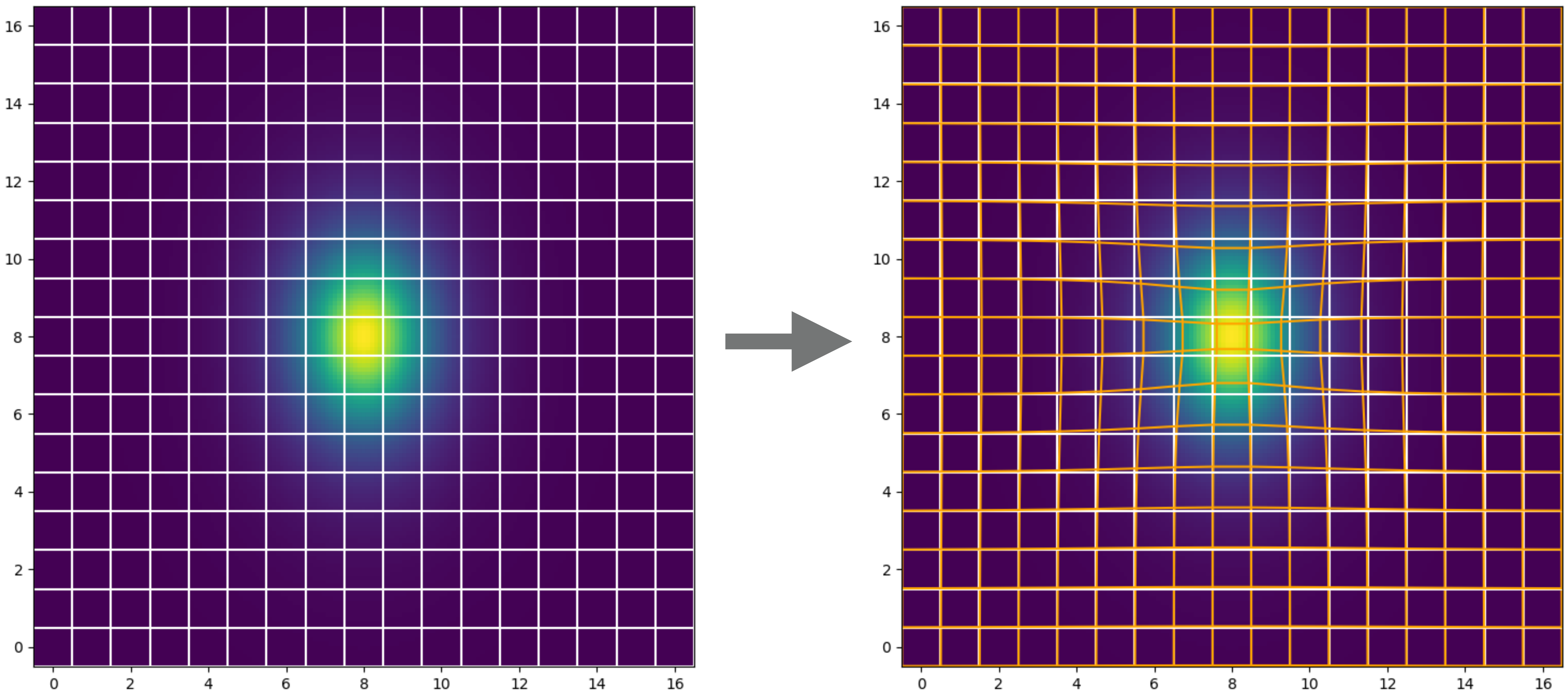
- Follow simple model suggested in Guyonnet et al. 2015:

$$\delta^X = \sum_{i,j} a^X Q_{i,j}$$

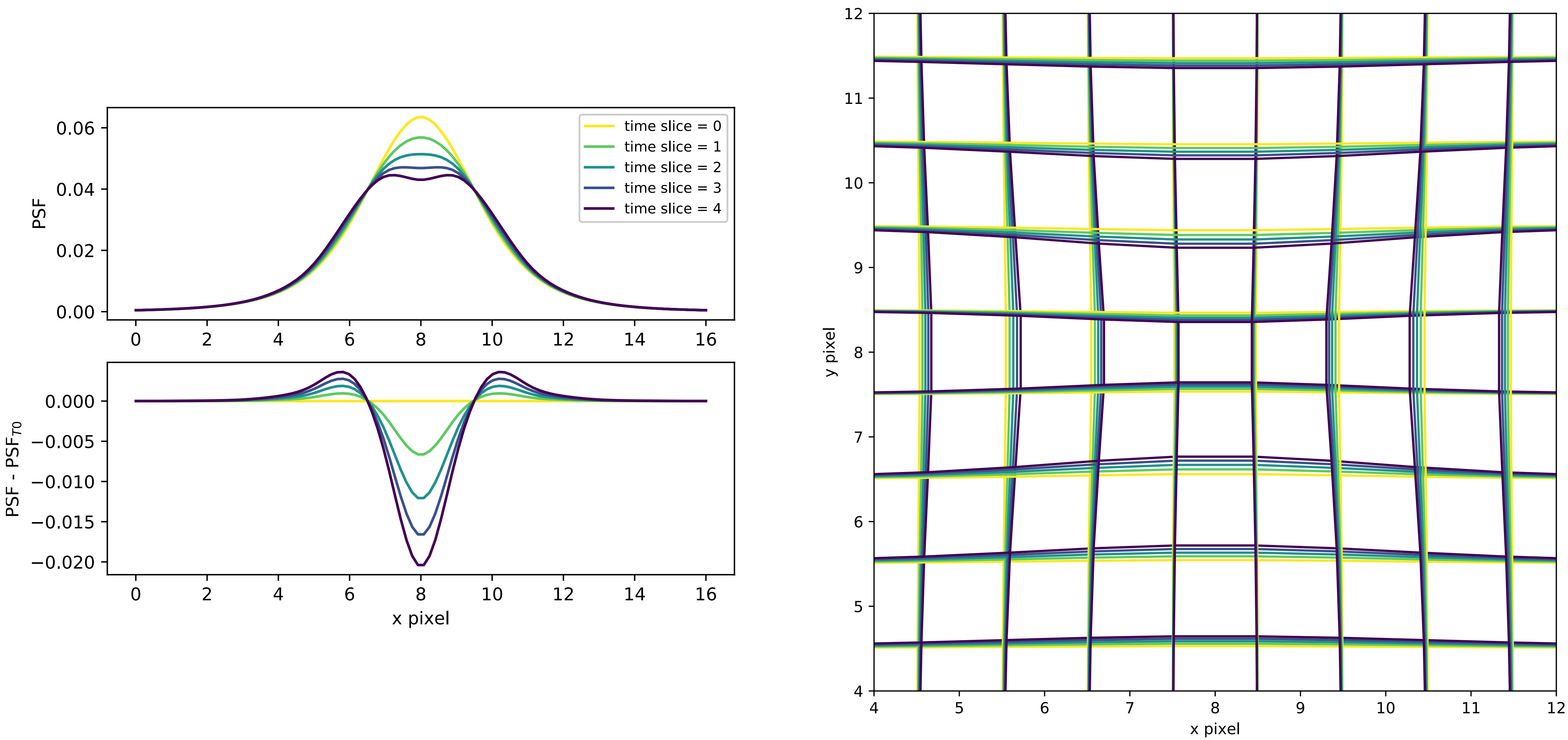
where Q is the charge in pixel (i, j), δ^X is the pixel corner at position X with respect to Q, and a^X is the coefficient defining the brighter-fatter effect at position X.

- Use algorithm suggested by Pierre Astier:
    - Split integration into T steps,
    - Iterate between increasing Q in each pixel based on current pixel corners and calculating the distortion in the pixel corners based on the current charge distribution Q.
    - Use Gaussian Quadrature to calculate integral over the distorted pixels.

PIXEL DISTORTIONS



PSF SHAPE AND PIXEL CORNERS OVER TIME-STEPS



APPROACH TO FITTING THE BRIGHTER-FATTER MODEL

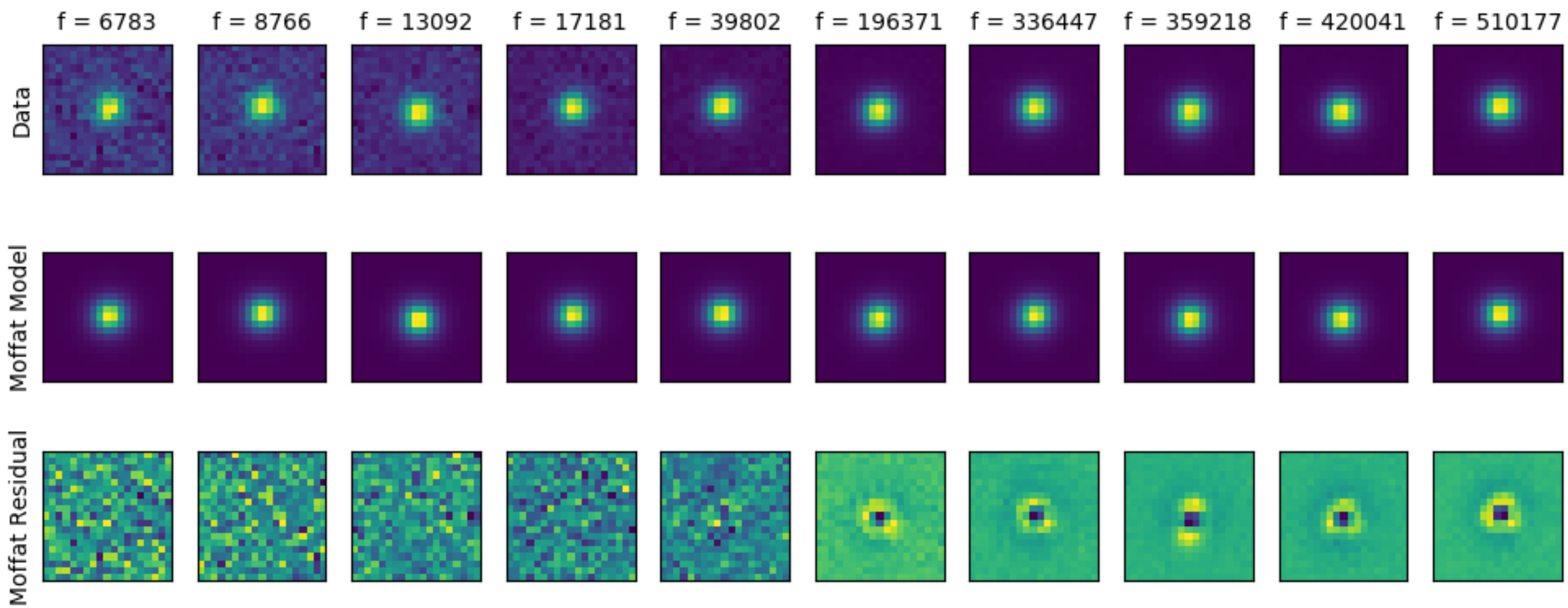
- First, test fitting the model + star fluxes on simulated data.
  - ➡ Successful test: model parameters and fluxes are not degenerate
- Preliminary test on HSC data:
  - Fit PSF to stars with low maximum flux
  - Use only Moffat part of the PSF (smooth spatial derivative helps with fit)
  - Fit Brighter-Fatter model and fluxes for all stars.

Test PSF:

$$\Psi_{i,j}(x, y) = (1 - \cancel{\Sigma_{i,j} R_{i,j}(x, y)})\phi_{i,j}(x, y) + \cancel{R_{i,j}(x, y)}$$

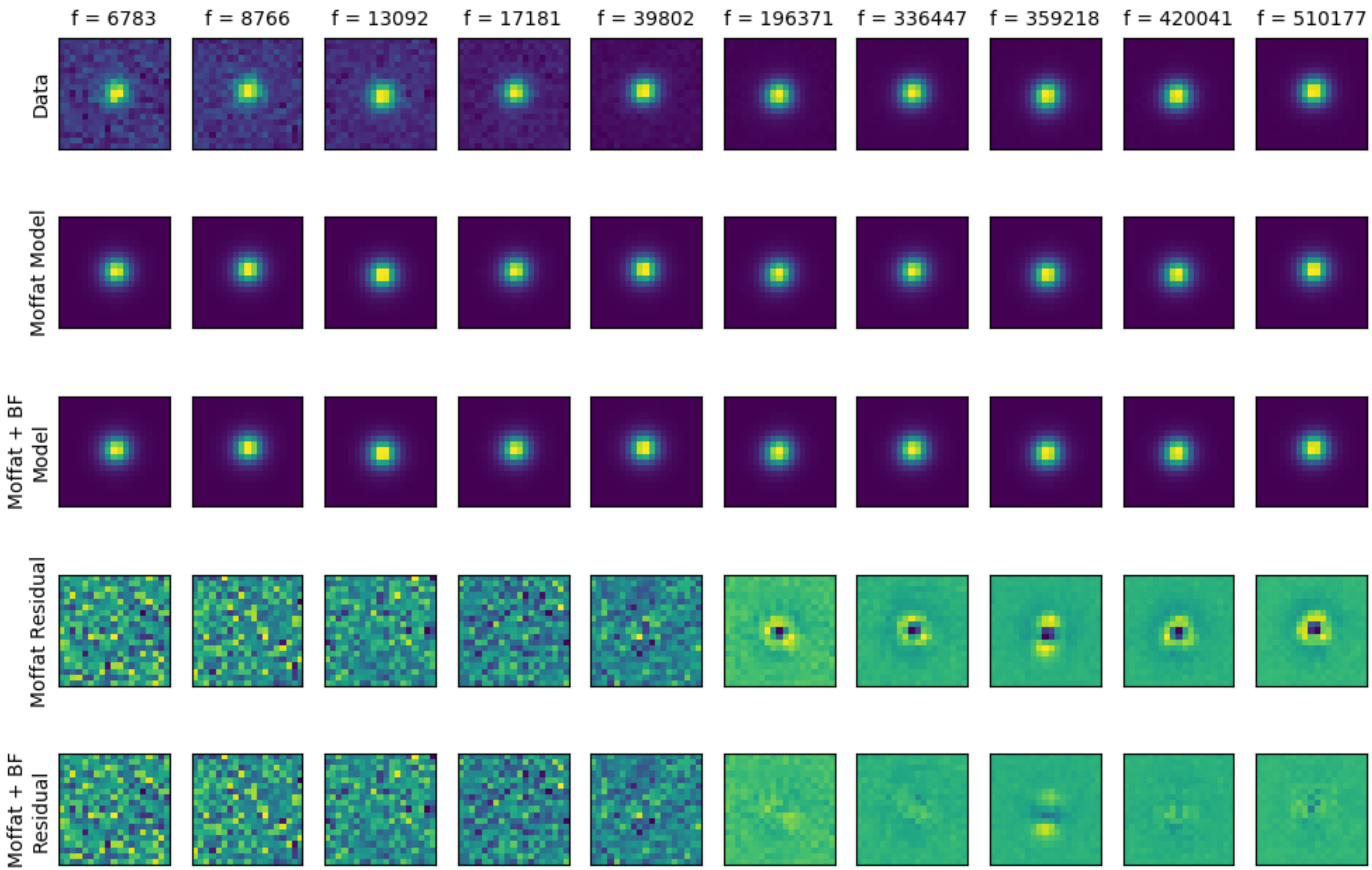
PRELIMINARY RESULTS ON EXPOSURE 103794, CCD 79

Fitting Moffat PSF to faint stars only

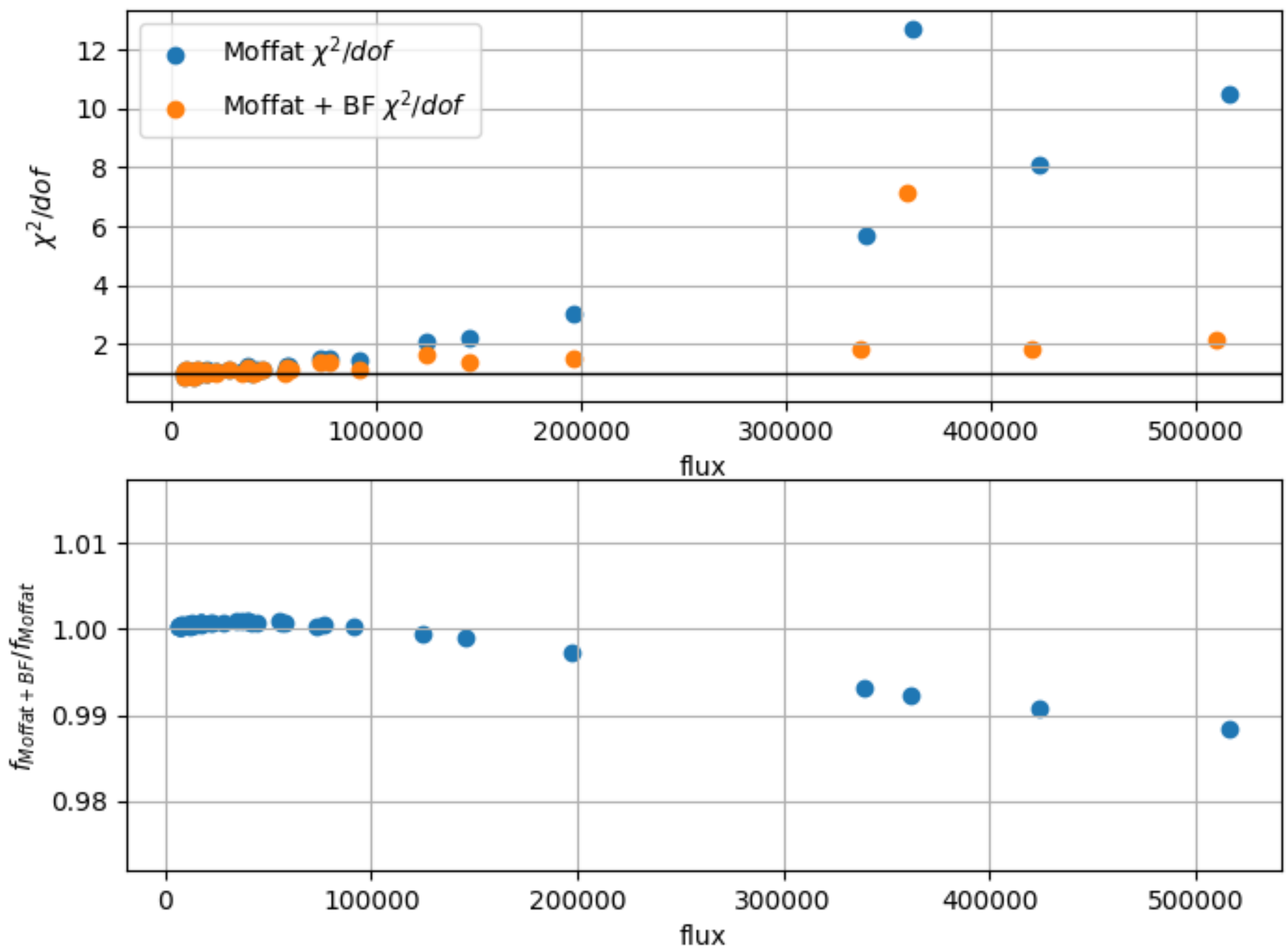


PRELIMINARY RESULTS ON EXPOSURE 103794, CCD 79

With PSF fixed, fitting the brighter-fatter effect

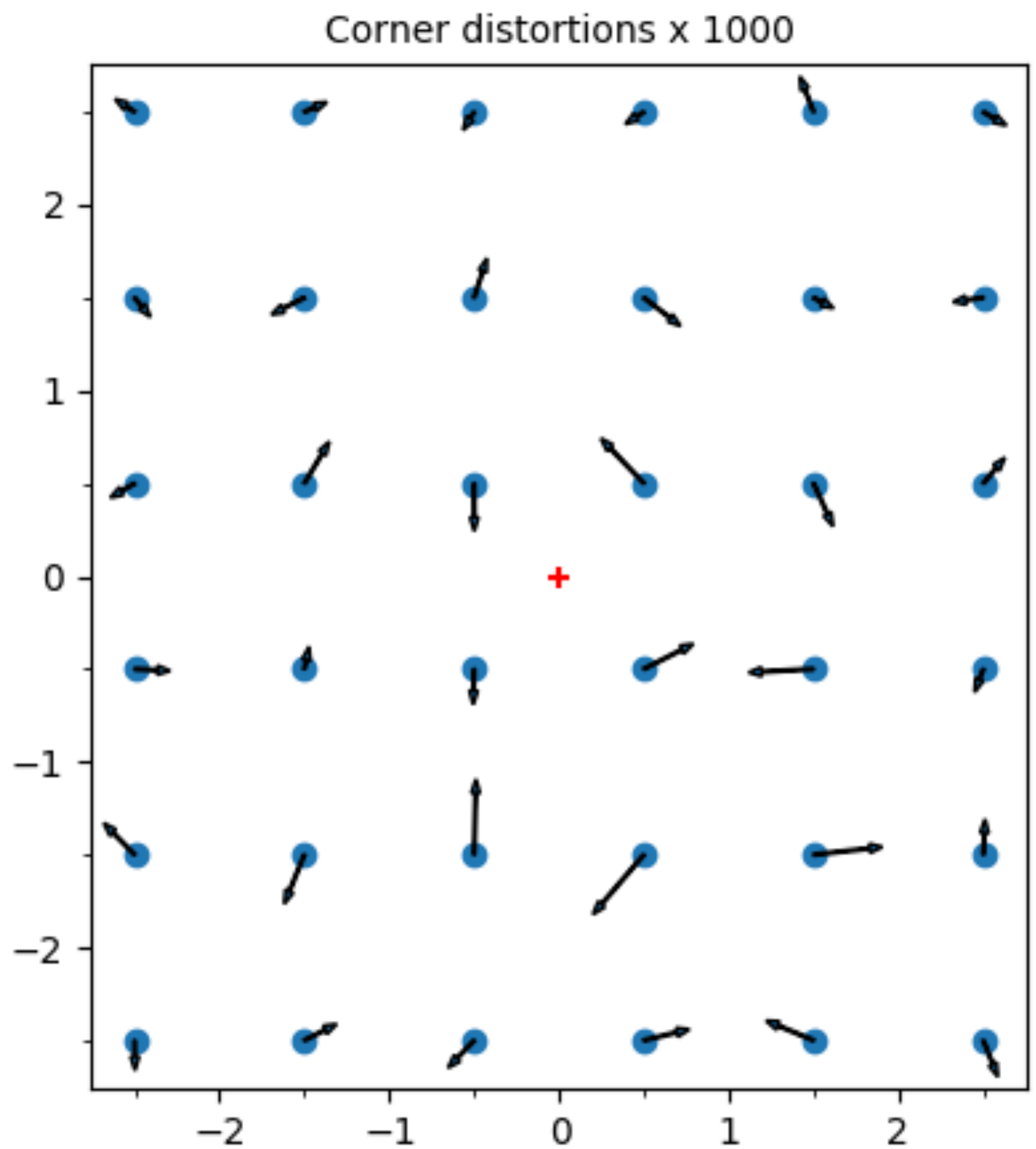


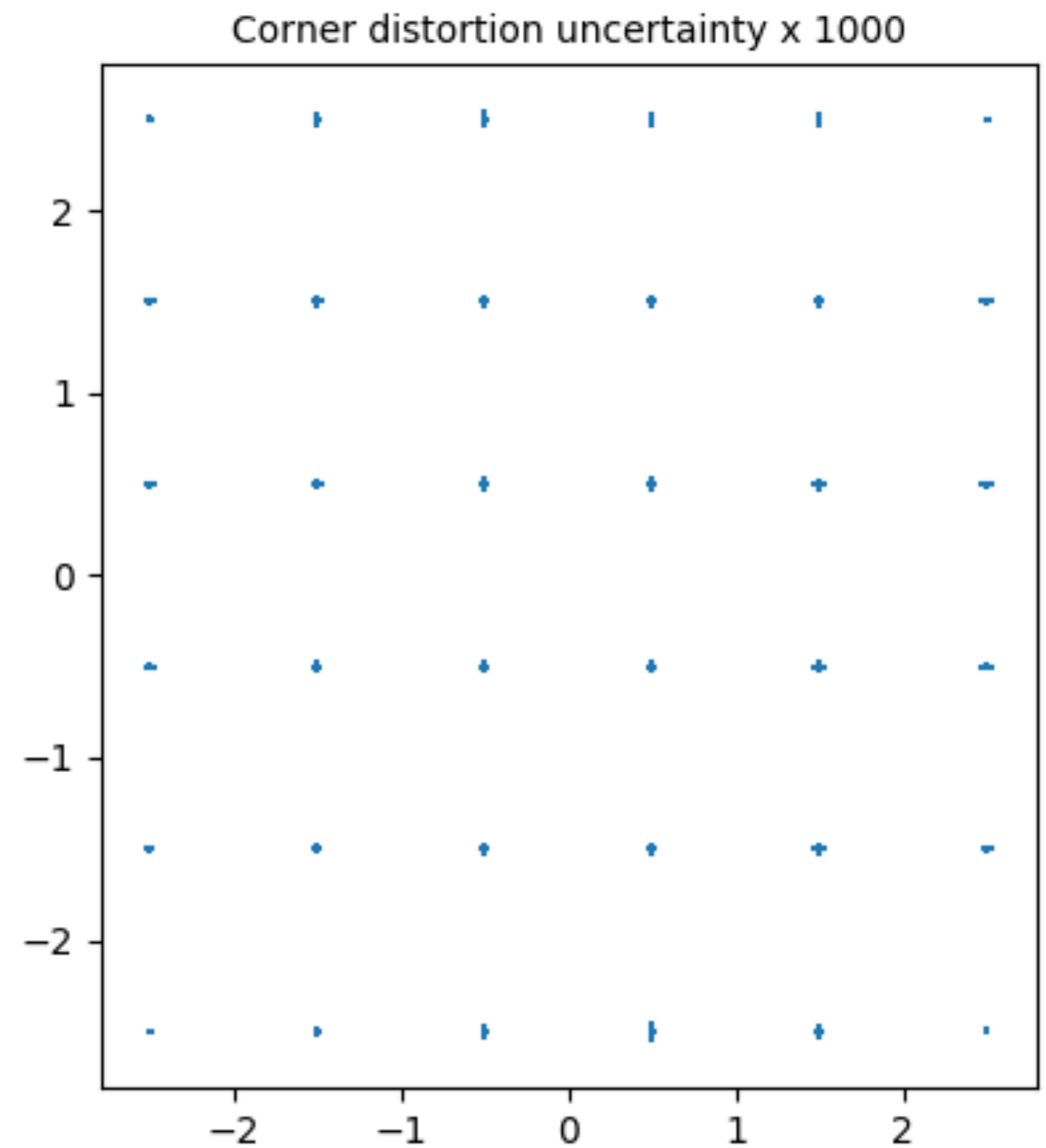
PRELIMINARY RESULTS ON EXPOSURE 103794, CCD 79



PRELIMINARY RESULTS ON EXPOSURE 103794, CCD 79

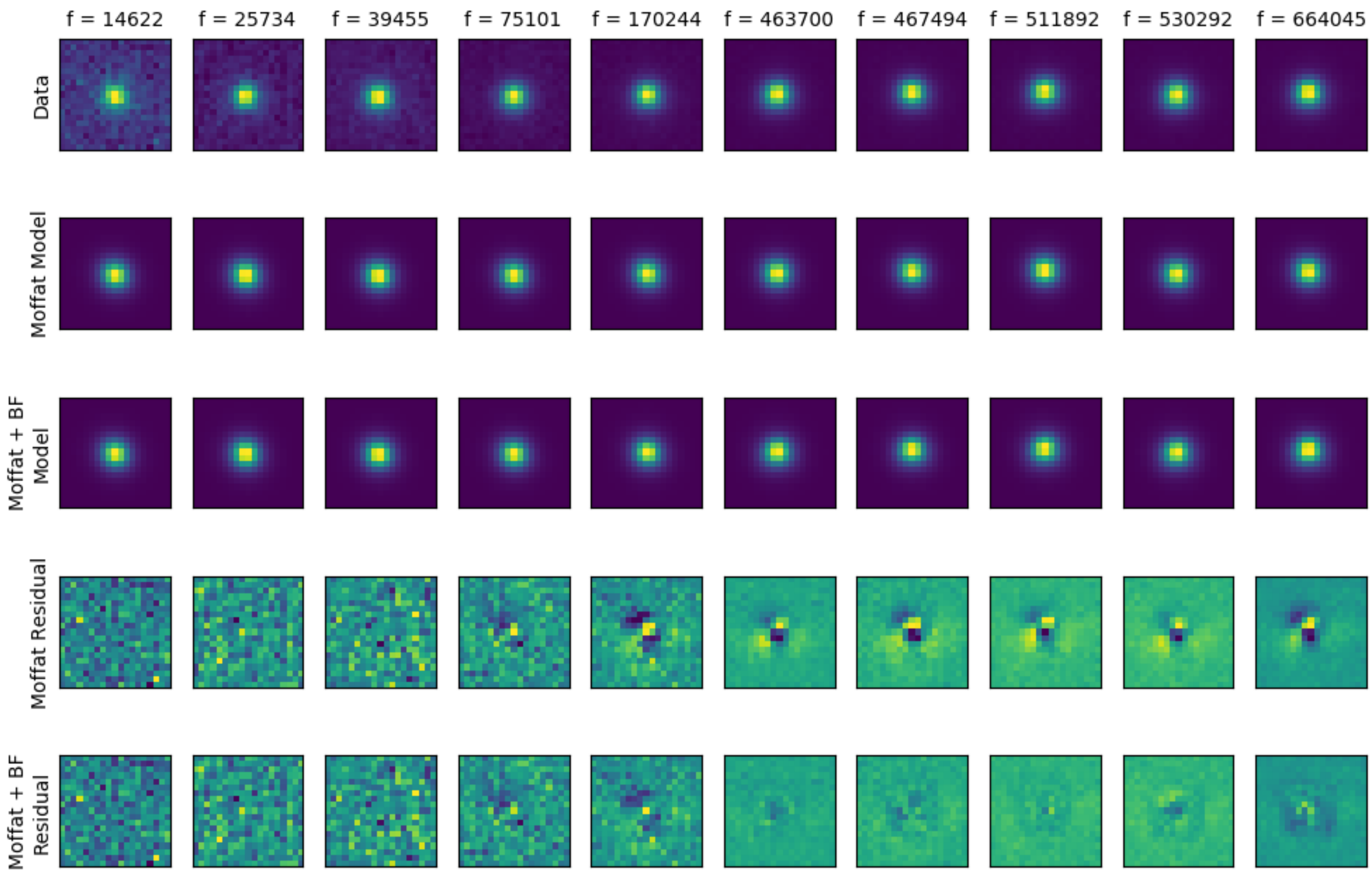
Current distortions likely capture brighter fatter effect + unmodeled pixel grid part of PSF





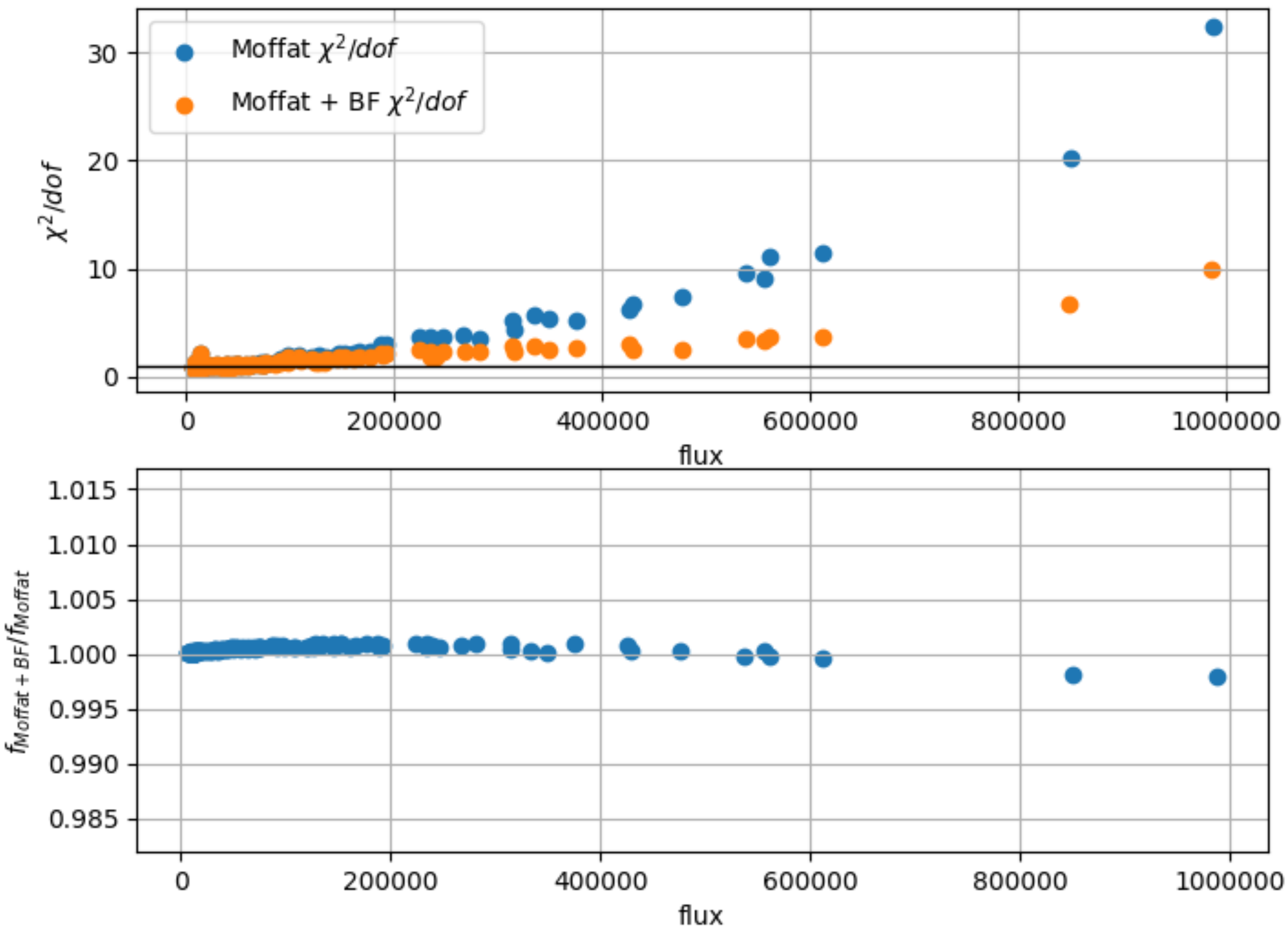
PRELIMINARY RESULTS ON EXPOSURE 11730 OF CCD 79

Full Moffat + Pixel Grid PSF Model Likely Needed Here



PRELIMINARY RESULTS ON EXPOSURE 11730 OF CCD 79

Full Moffat + Pixel Grid PSF Model Likely Needed Here



CONCLUSIONS

- Brighter-fatter model and fluxes are non-degenerate and can be constrained by data.
- Initial results fitting the brighter-fatter effect on science exposures look promising.
- Next steps:
    1. Testing whether time-integration method can be improved.
    2. Add Pixel Grid to PSF
    3. Implement iterative fitting of Moffat PSF, Pixel Grid, and Brighter-Fatter model.
    4. Fix Brighter-Fatter model for future data processing.