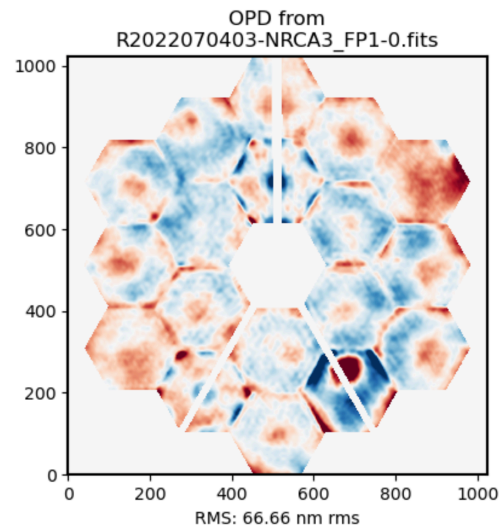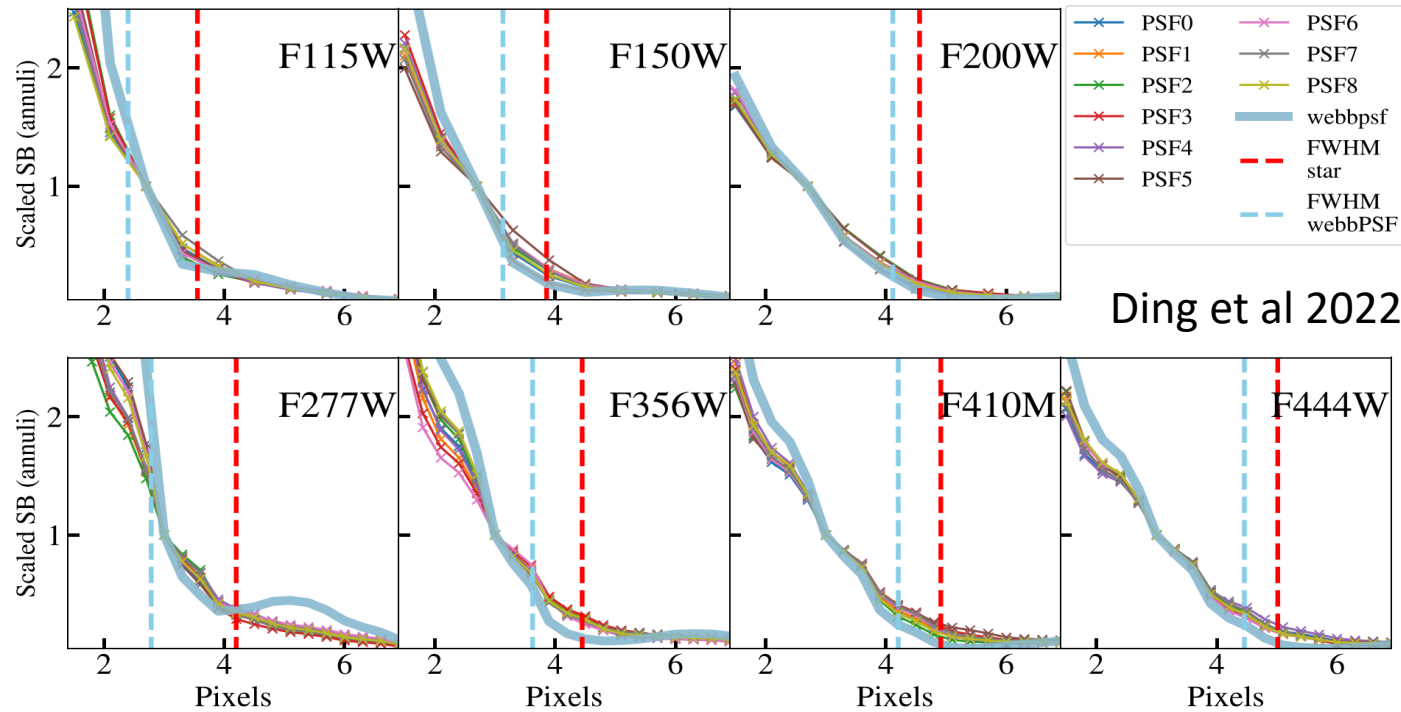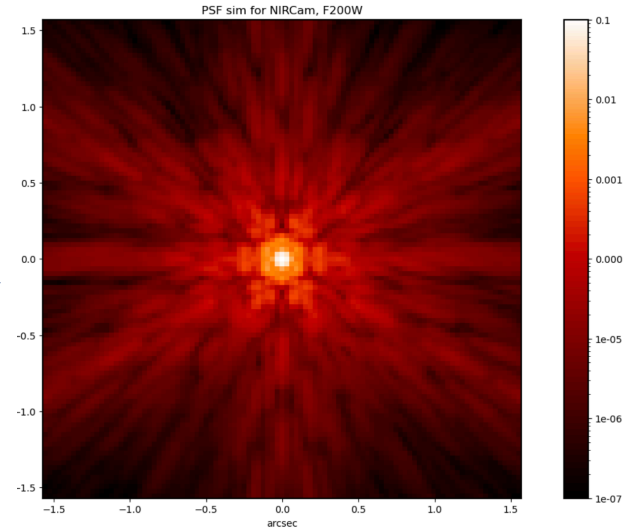# HybPSF: Hybrid PSF reconstruction for the observed JWST NIRCam image

2023 12 21

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OPD from
R2022070403-NRCA3_FP1-0.fits

RMS: 66.66 nm rms

WebbPSF

PSF sim for NIRCam, F200W

Webb PSF models are **shaper** than the observed data

Ding et al 2022

jw02736001001_02105_00009_nrcblong_cal.fits

detected object
PSF star
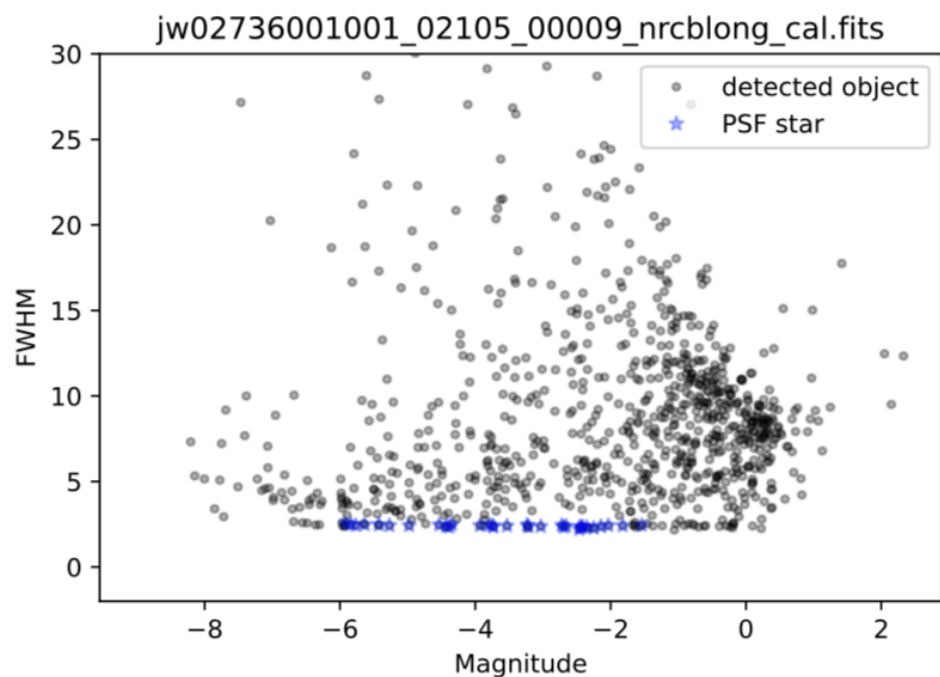
Table 2. Mean number of selected stars in each SCA and corresponding FWHM.

|	SCA	F090W	F150W	F200W	F277W	F356W	F444W
				Number / FWHM[pixel]^a			
Module A	NRCA1^b	11/1.98	14/1.86	13/2.31			
	NRCA2	10/1.97	14/1.88	13/2.35			
	NRCA3	10/2.06	10/1.92	9/2.35			
	NRCA4	7/2.06	11/1.98	12/2.43			
	NRCA5				29/1.72	23/2.06	31/2.44
Module B	NRCB1	8/2.23	10/1.99	9/2.39			
	NRCB2	11/2.16	14/2.05	14/2.45			
	NRCB3	11/2.43	14/2.20	12/2.58			
	NRCB4	11/2.42	17/2.25	13/2.64			
	NRCB5				26/1.81	20/2.09	29/2.44
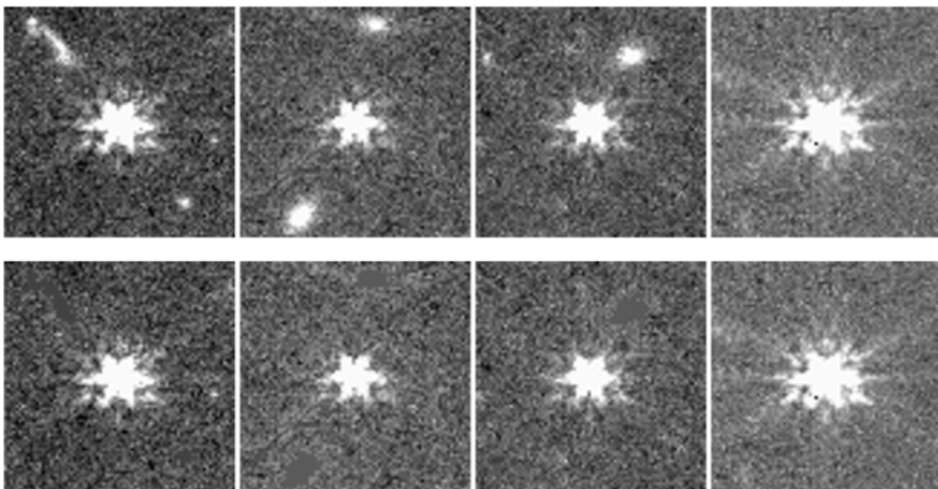
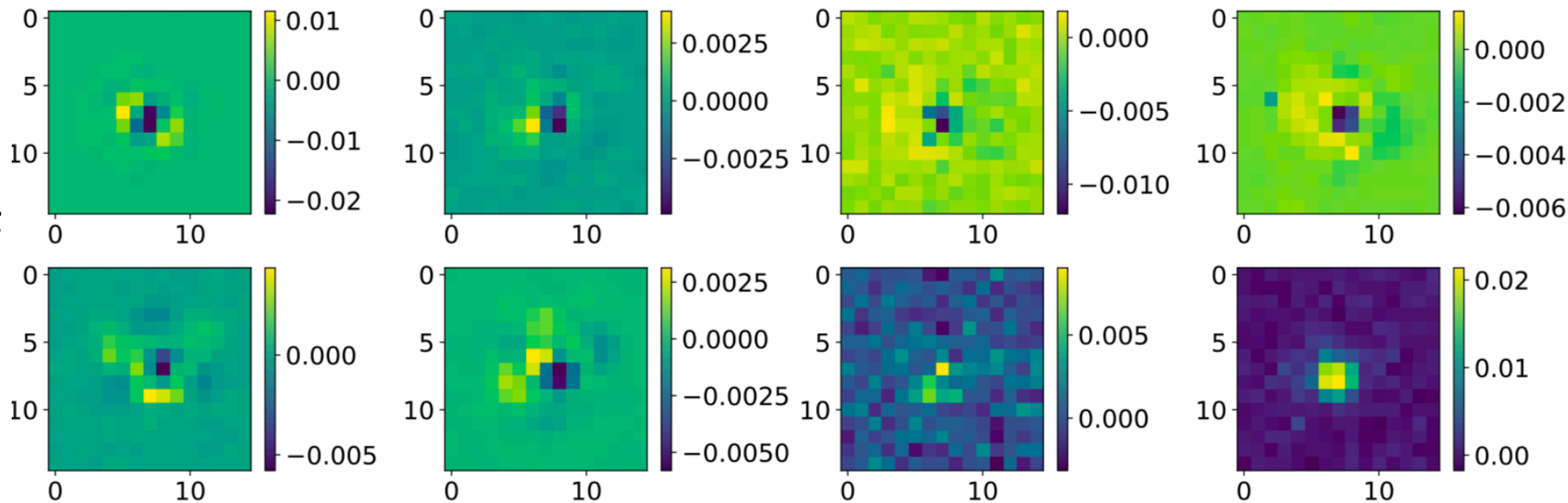Chips with star number >7 are used in PSF reconstruction
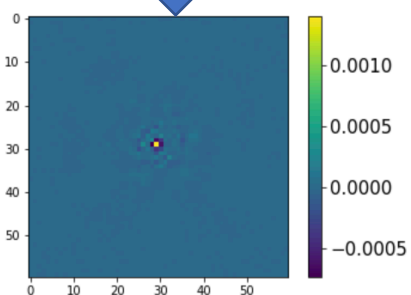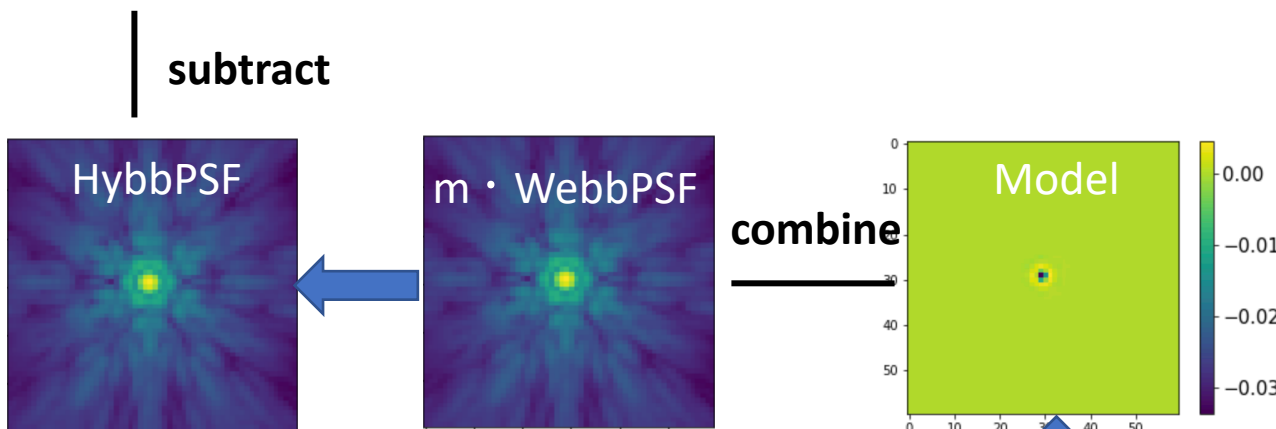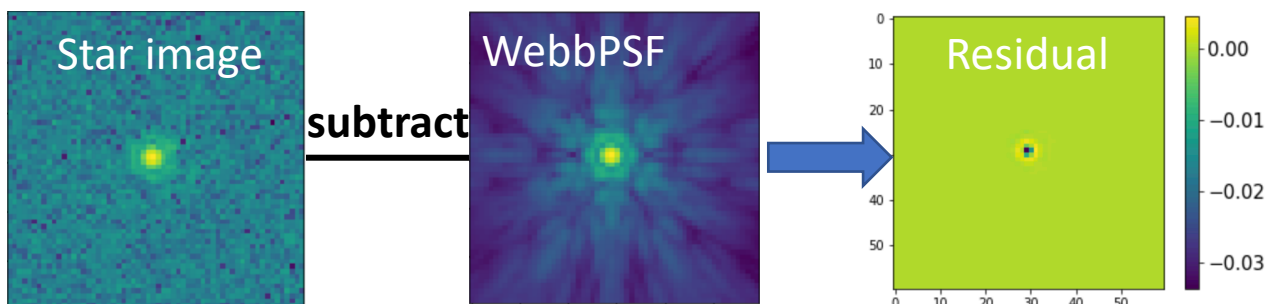
Star
candidates

Star-WebbPSF

F200W
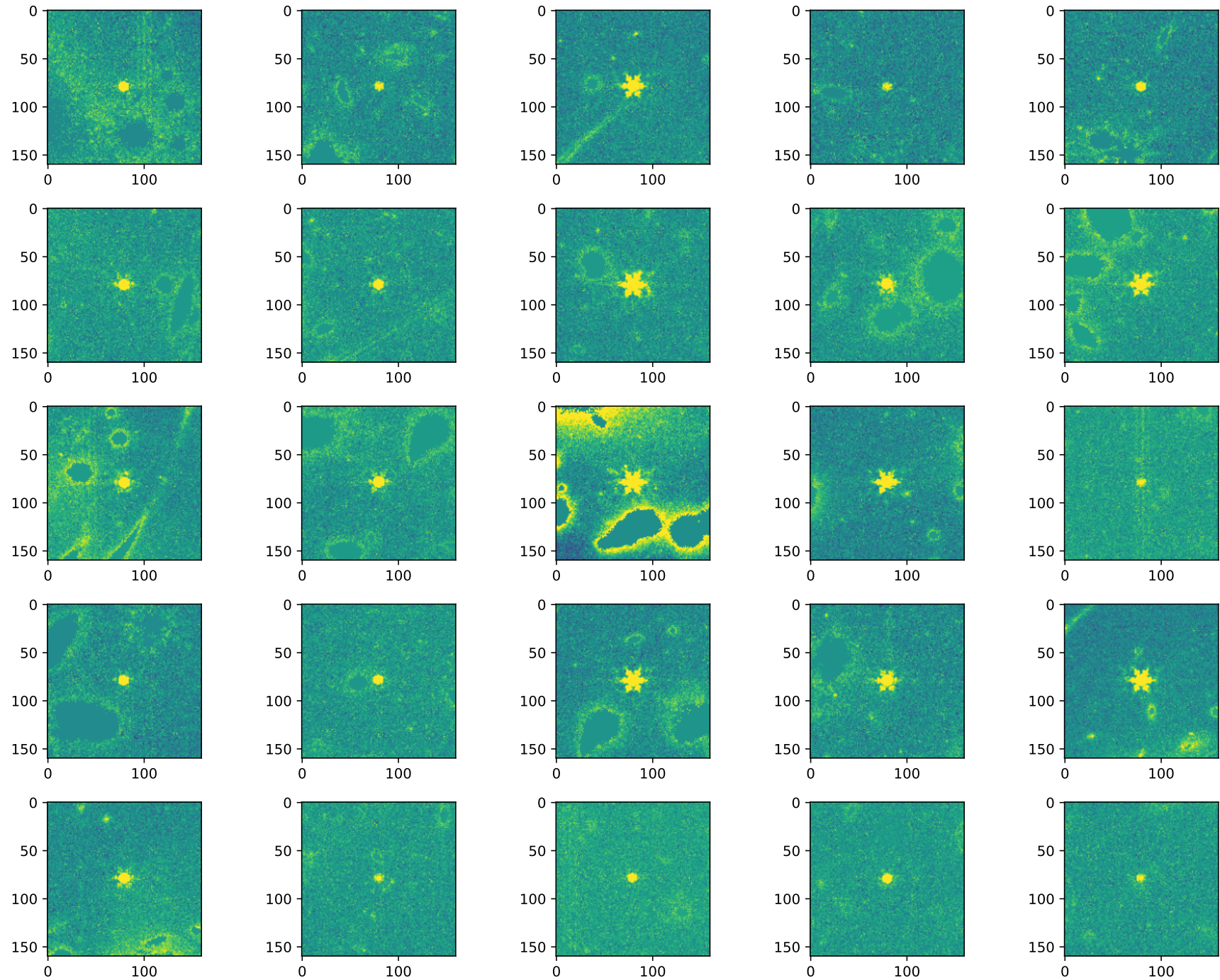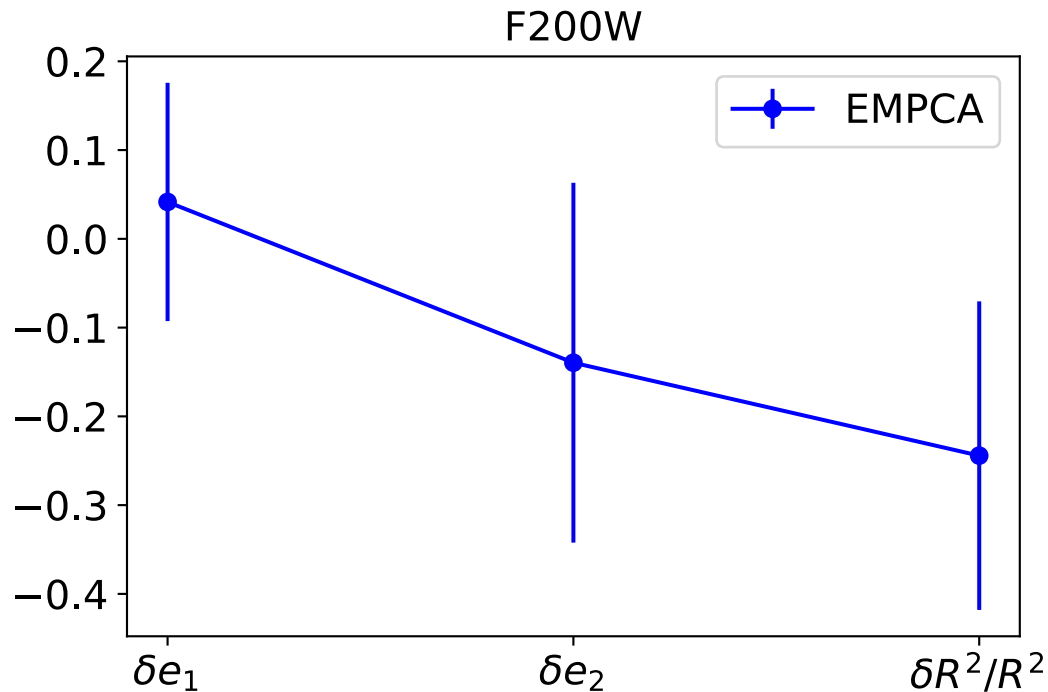
The discrepancy between data and WebbPSF is mainly at central region

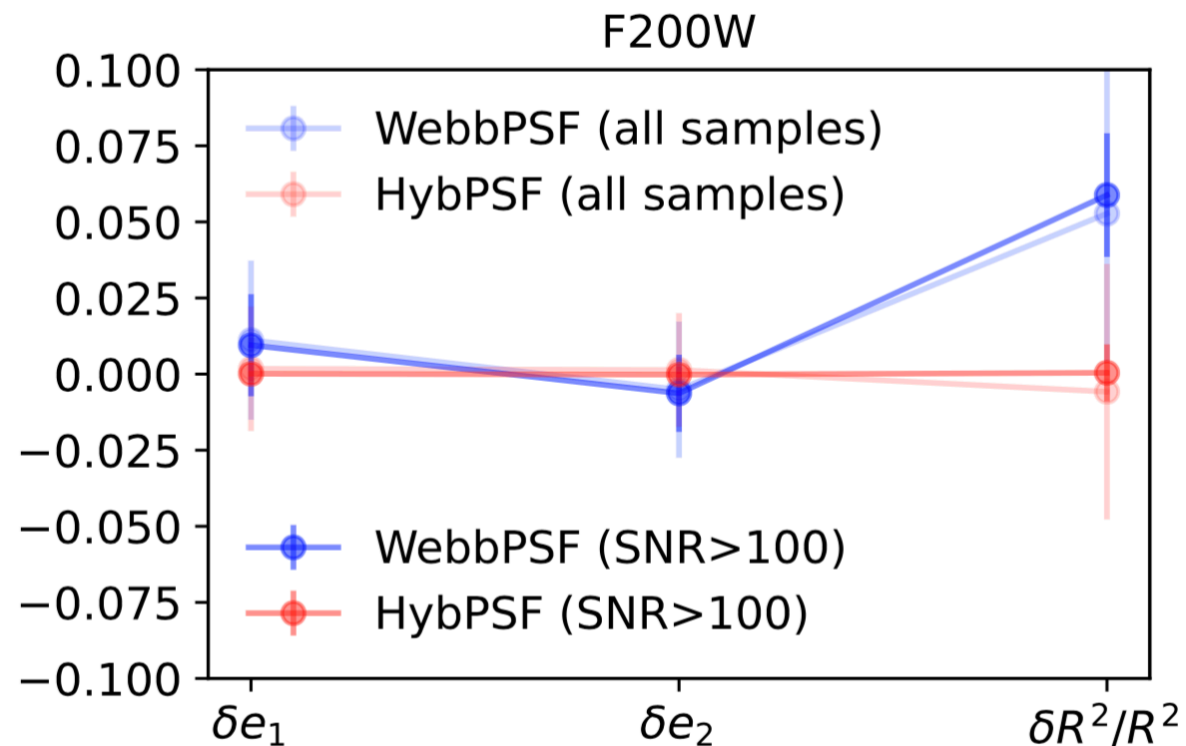Low efficiency of EMPCA due to low SNR and numbers (~ 40% of the star images have SNR < 40)

Star image

WebbPSF

Residual

HybbPSF

m · WebbPSF

Model

subtract

subtract

combine

Princial Componet Composed

F200W

WebbPSF (all samples)

HybPSF (all samples)

WebbPSF (SNR>100)

HybPSF (SNR>100)

δe_1 δe_2 $\delta R^2/R^2$

HybPSF=m·WebbPSF+Residual

multiplicative factor   **additive factor**

WebbPSF
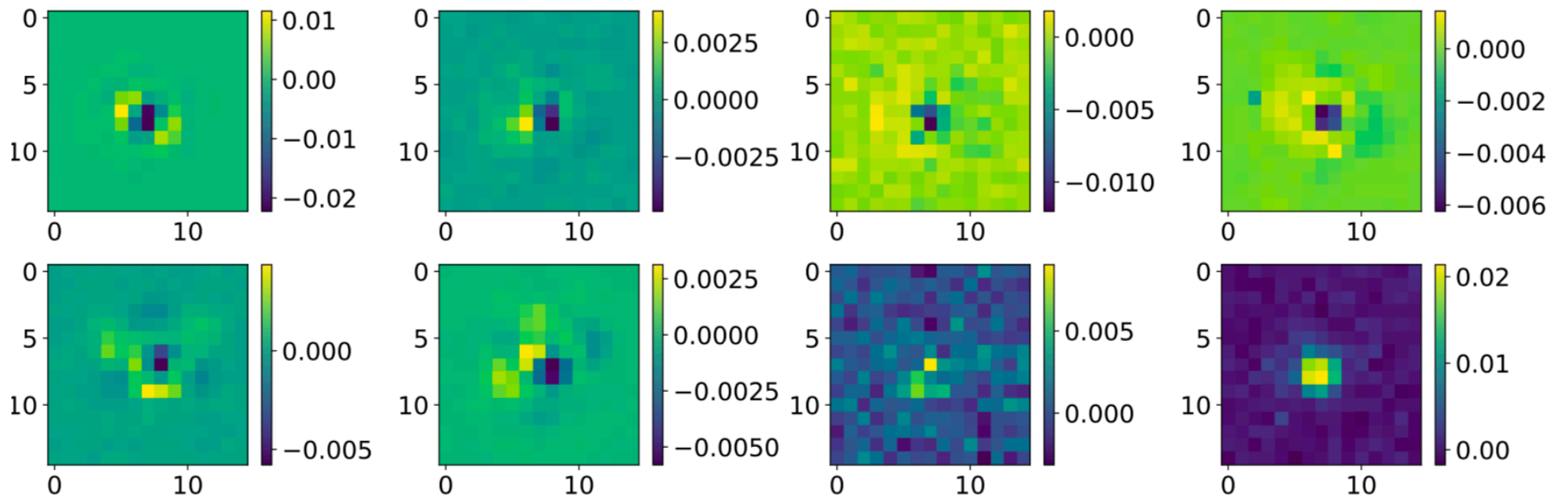
HybPSF
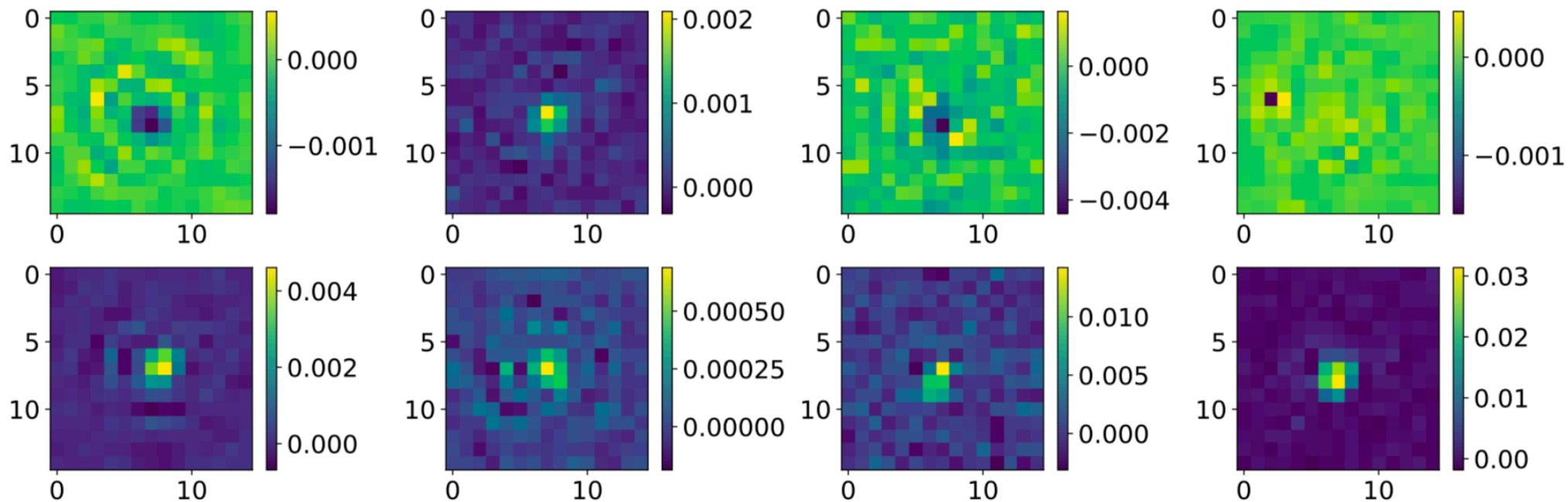
jw02736001001_02101_00005_cal.fits
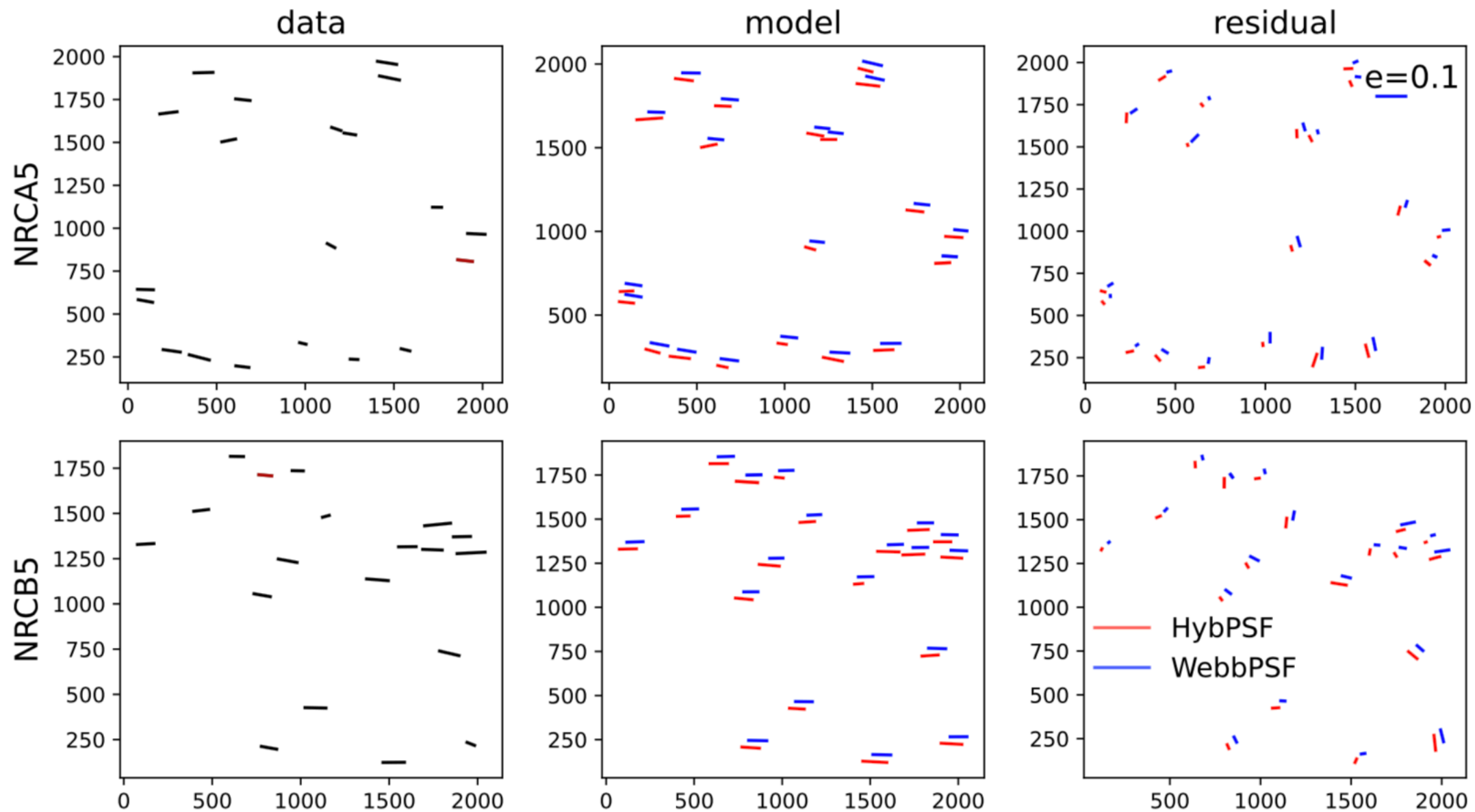
PSF shape comparison
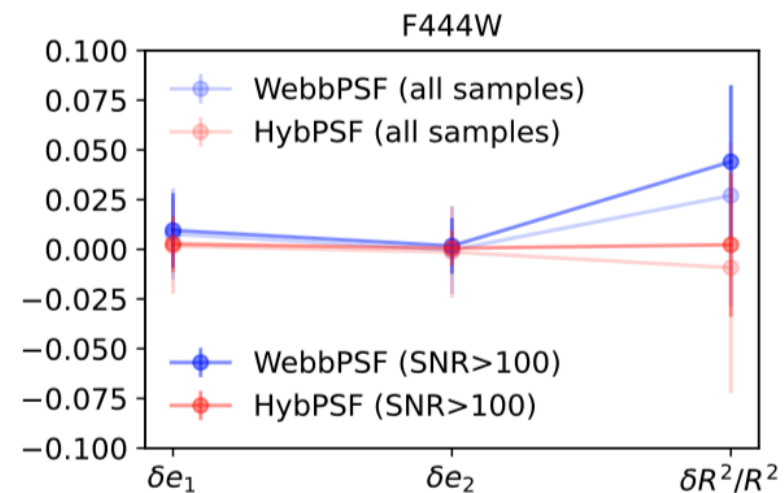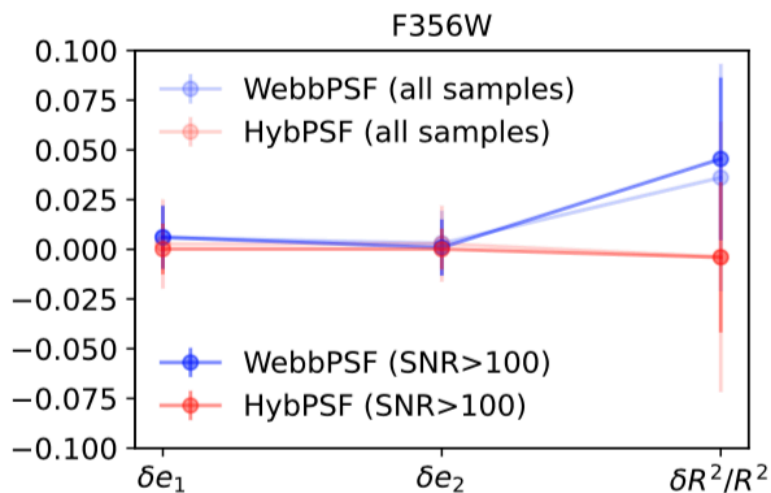
shape residuals

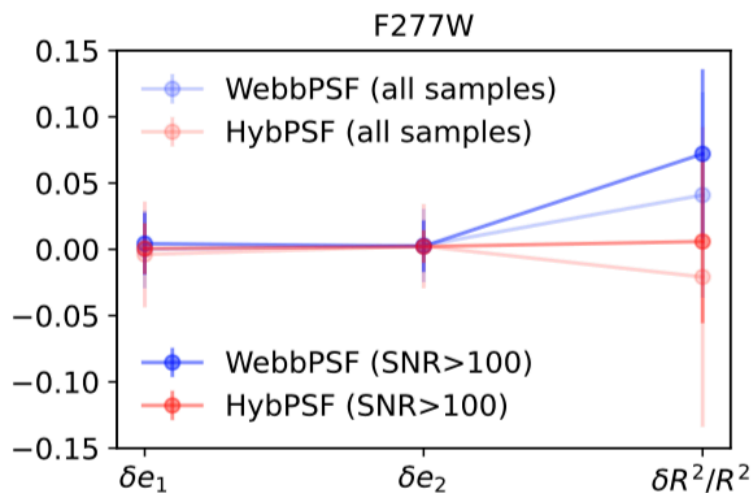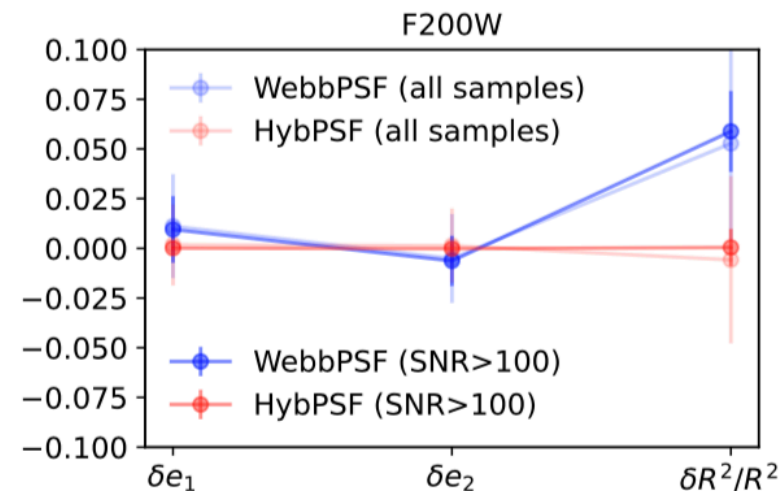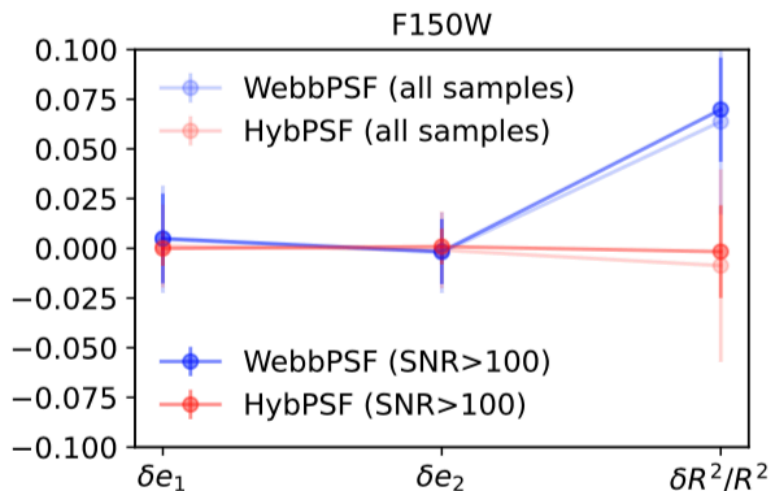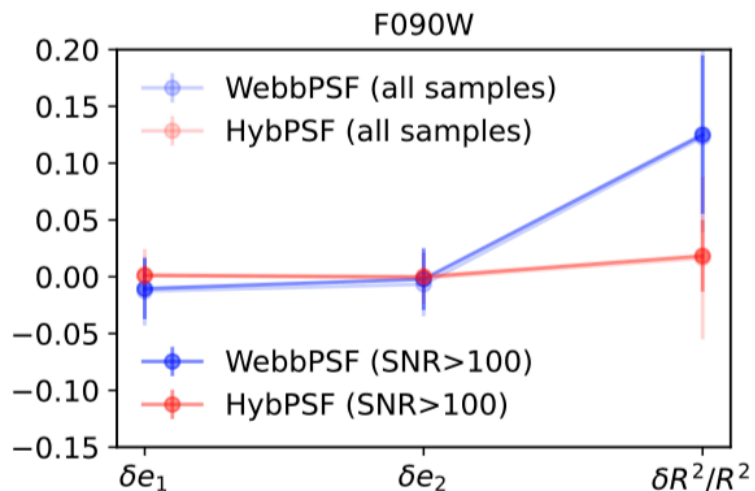| Methods	Channels	$< \delta e_1 >$	1σ width	$< \delta e_2 >$	1σ width	$< \delta R^2 / R^2 >$	1σ width	number of contrast
WebbPSF	F090W	-0.010	0.026	-0.002	0.027	0.12	0.069	241
	F150W	0.004	0.022	-0.001	0.016	0.069	0.026	431
	F200W	0.009	0.016	-0.006	0.012	0.058	0.020	340
	F277W	0.004	0.023	0.002	0.019	0.071	0.063	174
	F356W	0.006	0.015	0.0008	0.014	0.045	0.040	205
	F444W	0.009	0.018	0.001	0.013	0.044	0.038	213
HybPSF	F090W	0.0008	0.008	0.00	0.007	0.018	0.031	241
	F150W	0.00	0.008	0.0008	0.008	-0.001	0.023	431
	F200W	0.0001	0.003	-0.0001	0.002	0.0004	0.009	340
	F277W	0.0005	0.019	0.002	0.012	0.005	0.061	174
	F356W	0.0001	0.012	0.0001	0.010	-0.004	0.037	205
	F444W	0.002	0.014	0.0005	0.008	0.002	0.036	213

data   data-WebbPSF   data-HybPSF

https://github.com/linngithub0/HybPSF
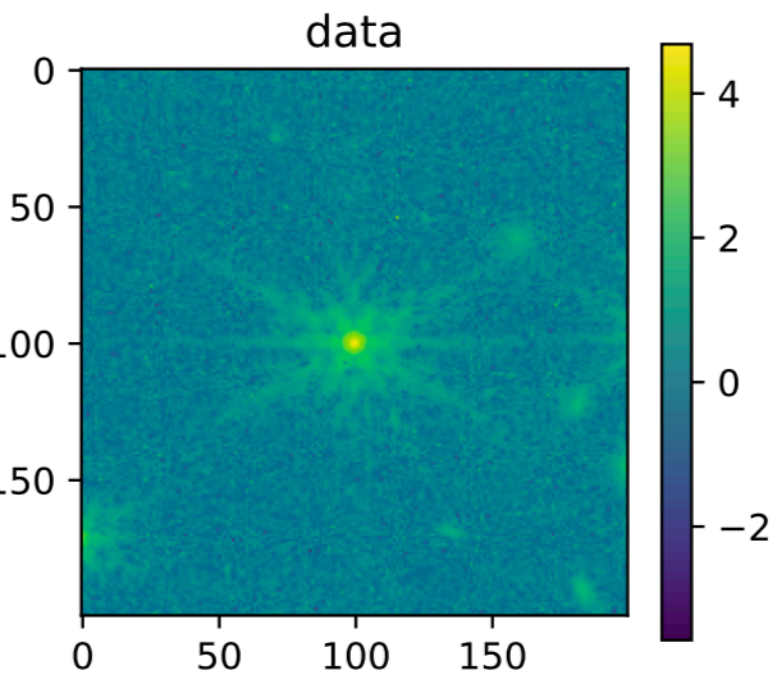
Very large stamp test
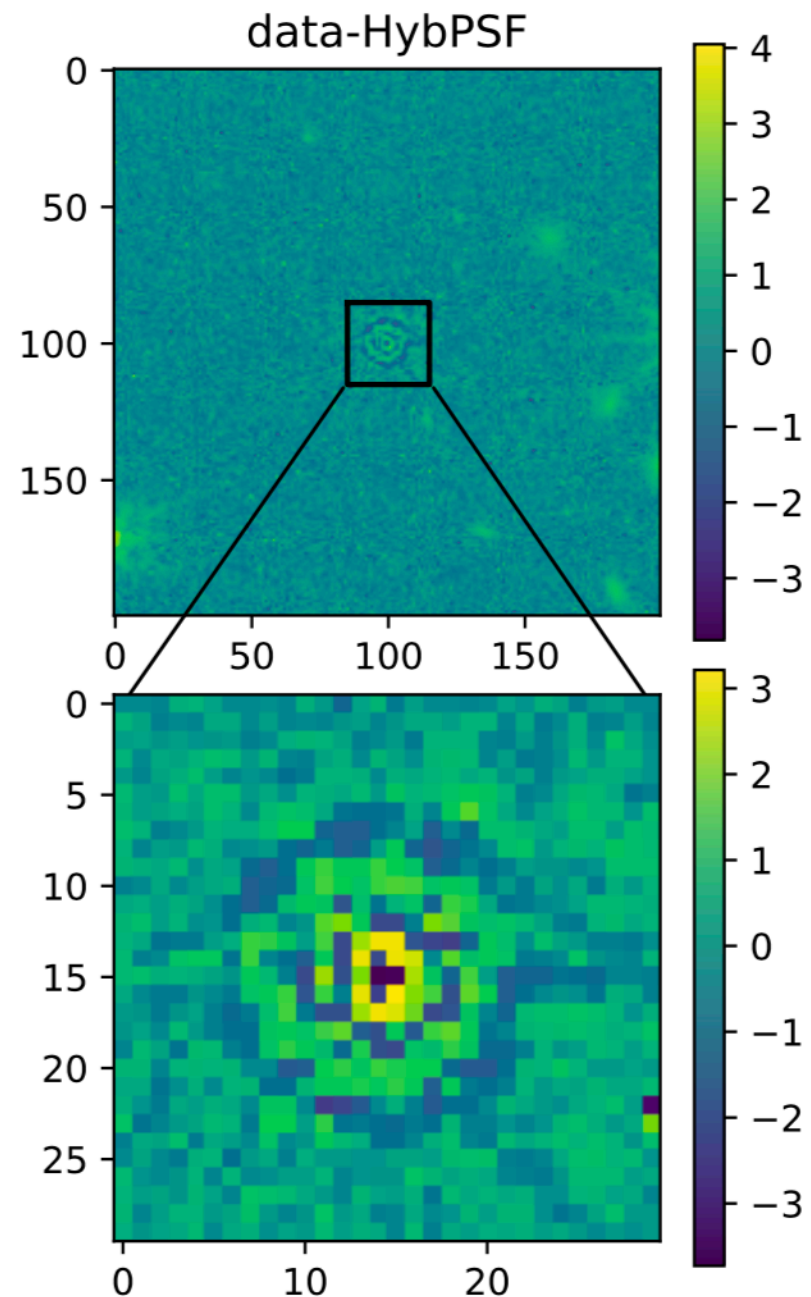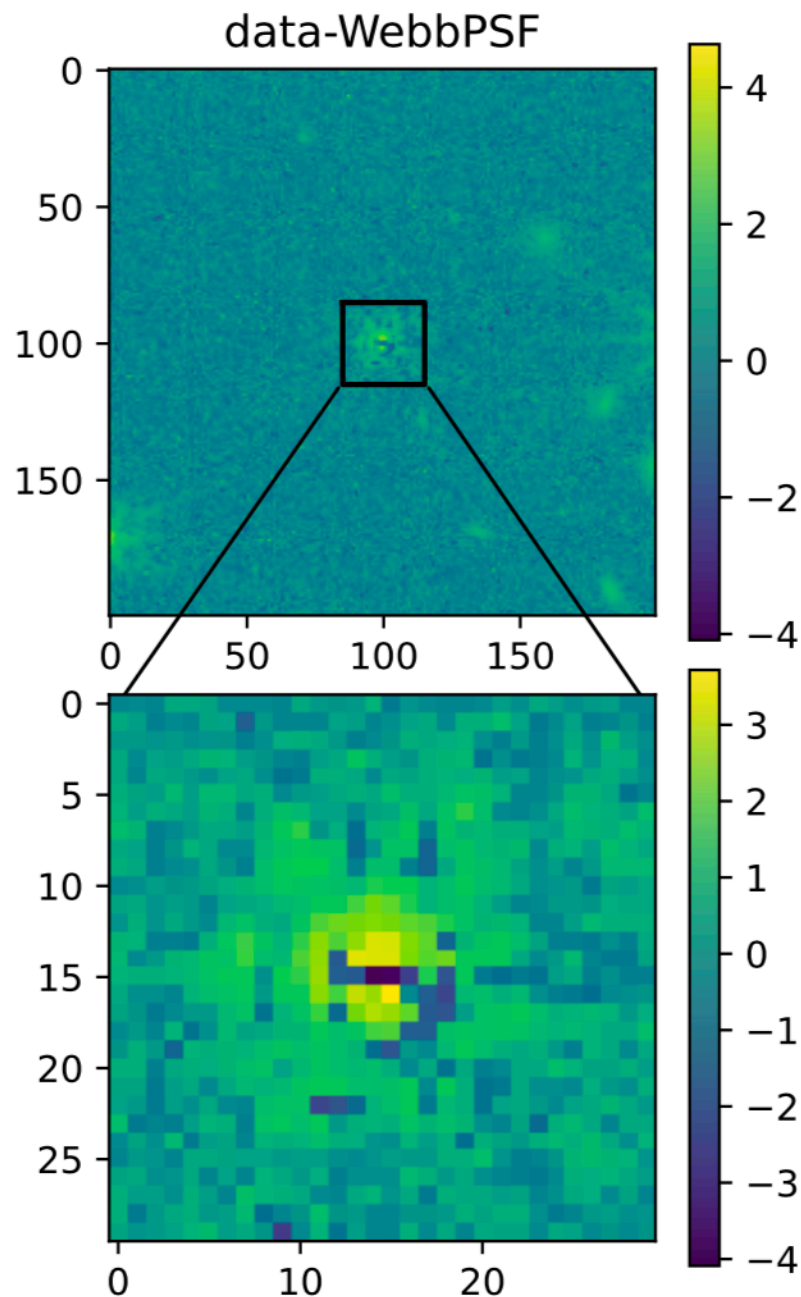
- HybPSF could improve the PSF size reconstruction roughly by a factor of ~10

- Spike structures are contained in HybPSF.

- Applicable for undersampled data.

- Star images in multiple CCDs will be considers in future

Thanks

$$\chi^2 = \sum_{i=1}^{N_{\text{star}}} \sum_{k=1}^{N_{\text{pixel}}} \left(I_{ik} - HybPSF_{ik}\right)^2 W_{ik},$$

$$= \sum_{i=1}^{N_{\text{star}}} \sum_{k=1}^{N_{\text{pixel}}} \left(I_{ik} - m_i WPSF_{ik} - \Sigma_{l=1}^{l_{\max}} P_l C_{il}\right)^2 W_{ik},$$

$$P_{nk} = \sum_{l=0}^{l_{\max}} D_l M_{lk} \longleftarrow \text{Moffatlets basis fucntions}$$

Align the centers of basis functions to the data
Basis functions are oversampled