Explore Point Spread Function Combing Star and Galaxy Images

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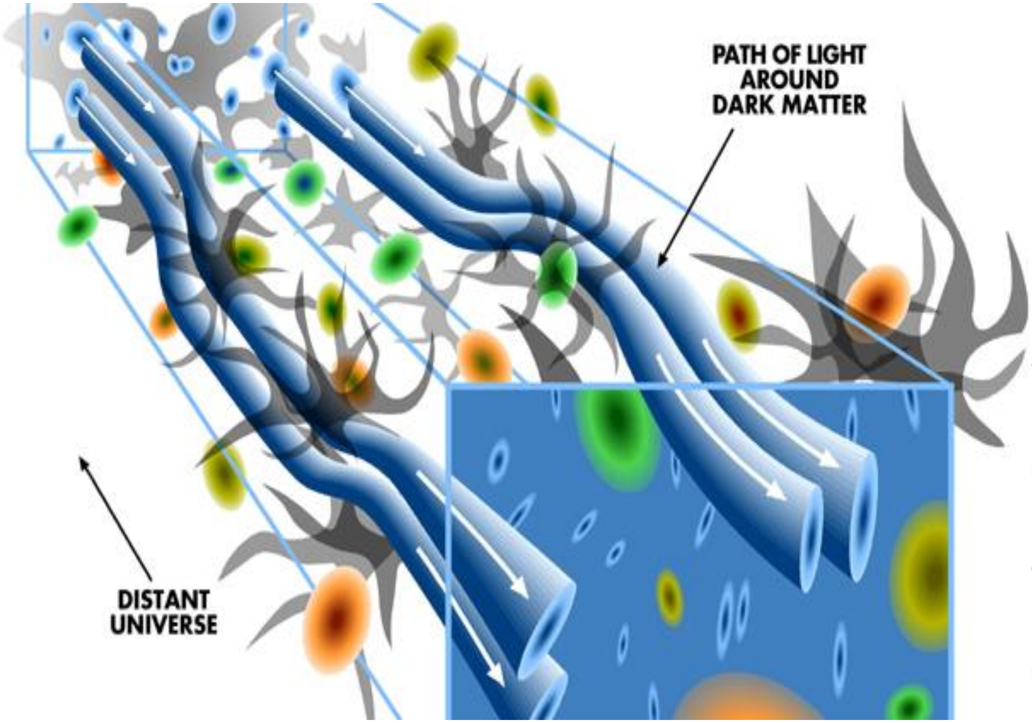
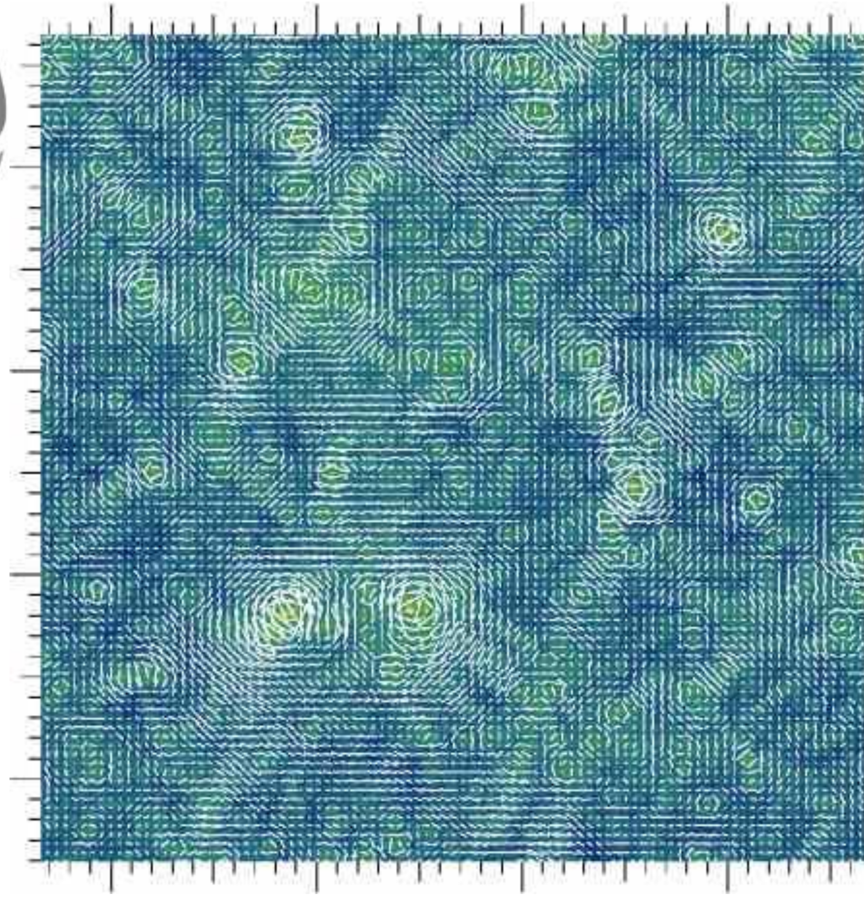
2015.08.09

Outlines

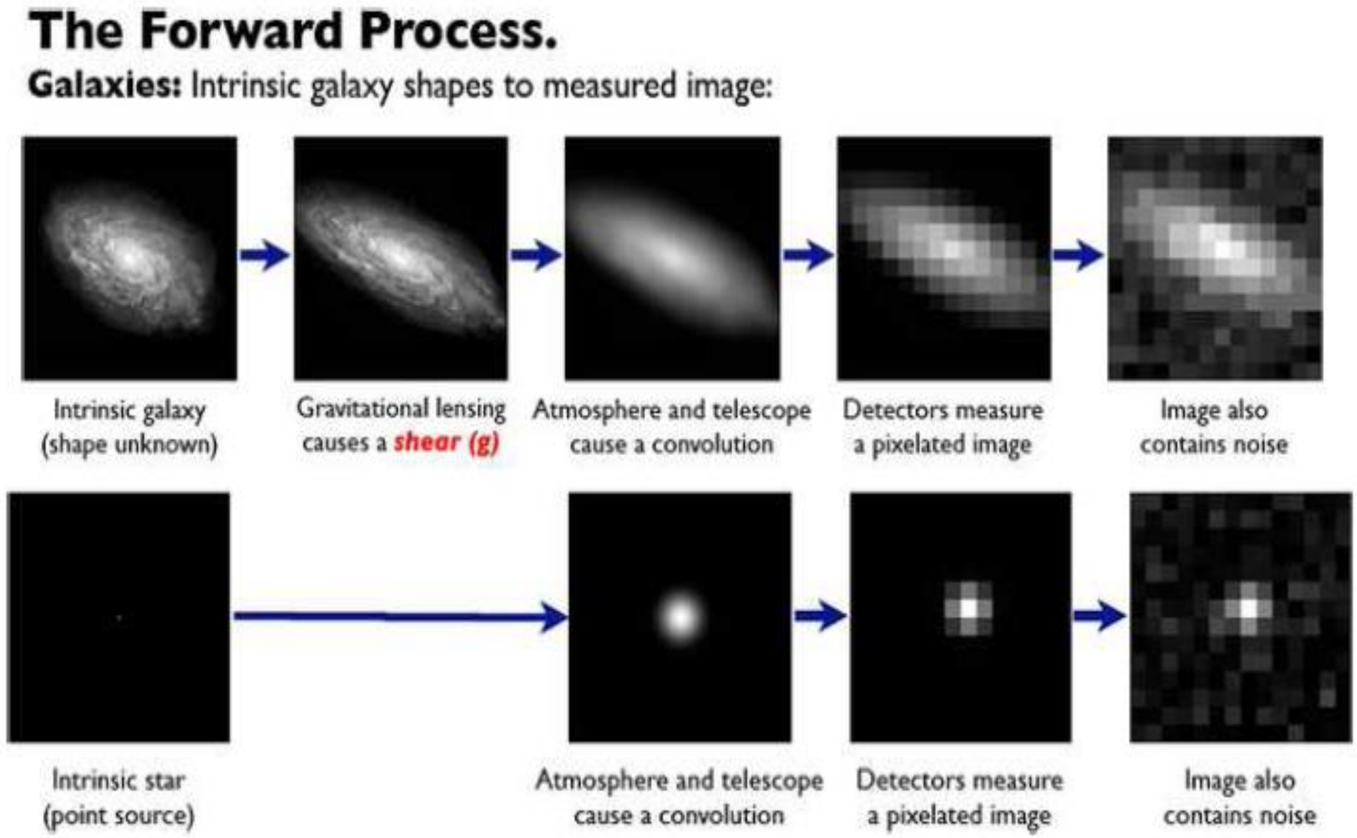
- Weak lensing background
- Basis function and PSF reconstruction
- Our new algorithm
- Testing
- Summary

Weak lensing background





Point Spread Function



Usually, the distortion introduced by PSF is larger than that caused by cosmic shear!

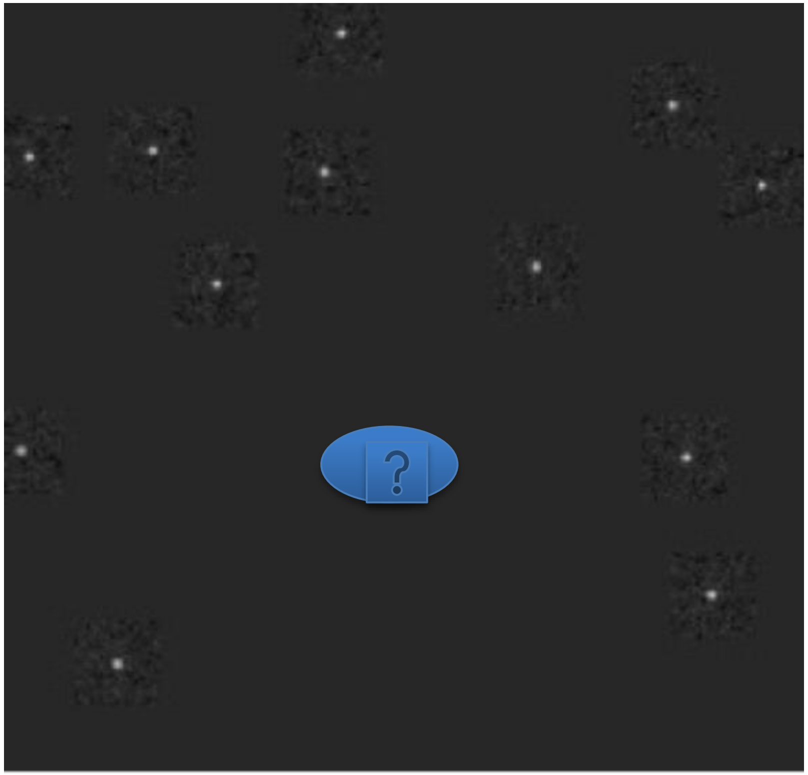
How do we do the reconstruction?

A) Star identification.

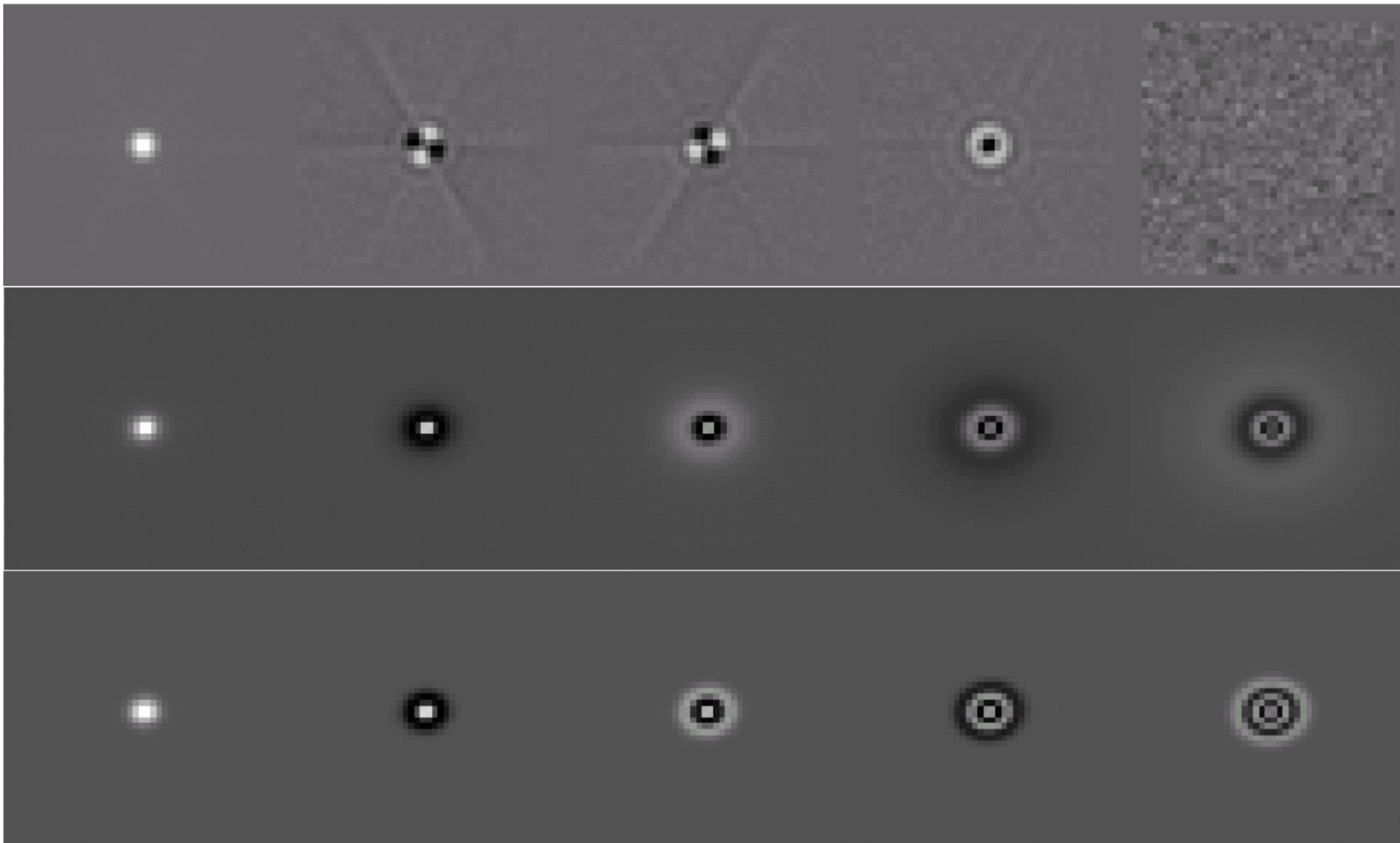
B) Parameterized image of stars.

C) Interpolate the parameters in the filed of view.

D) Create the expected PSF at the position of galaxies.



Parameterization of PSF PCA,Gaussianlets and Moffatlets



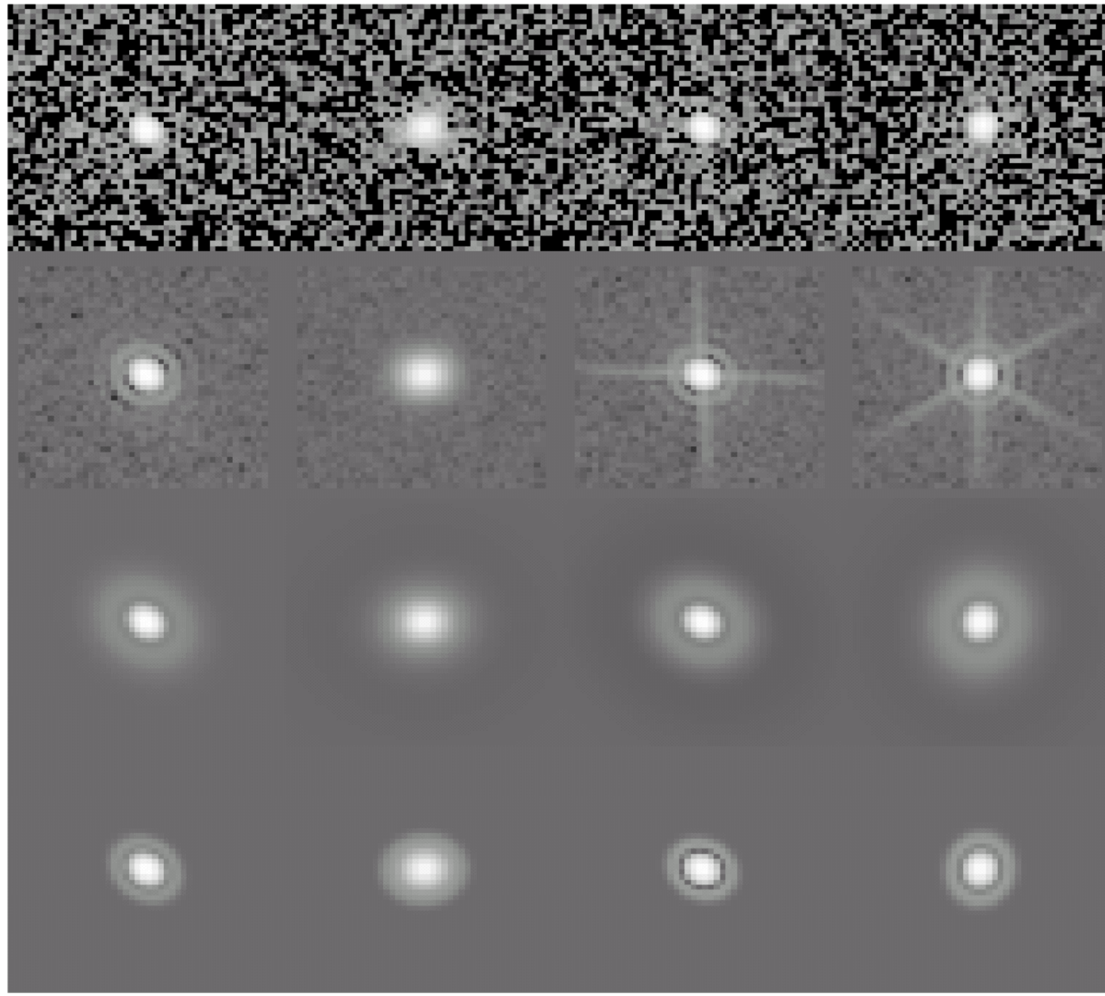
Test with GREAT10 data

One star in different data set

Principal Component Analysis (PCA)

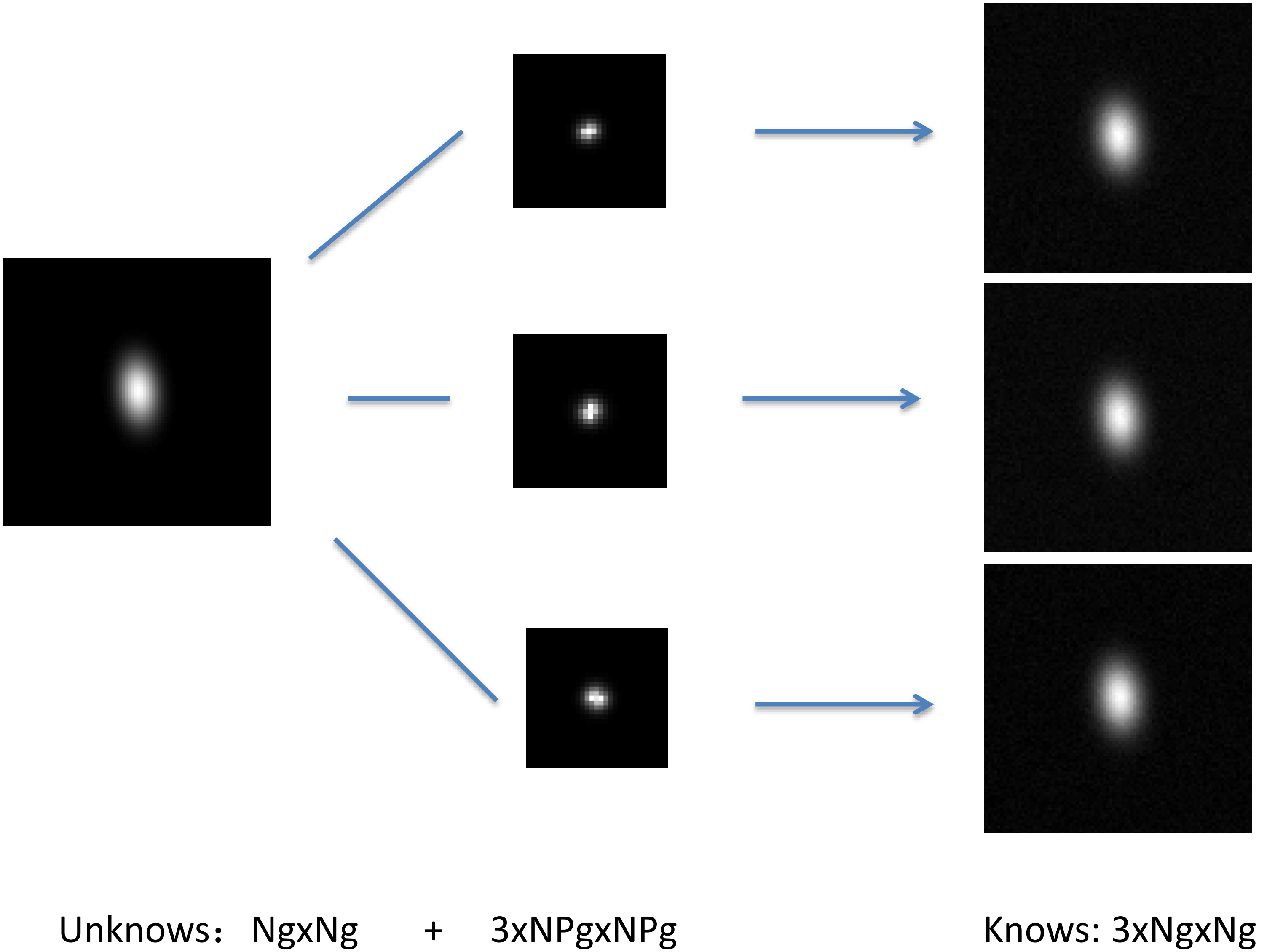
Moffatlets

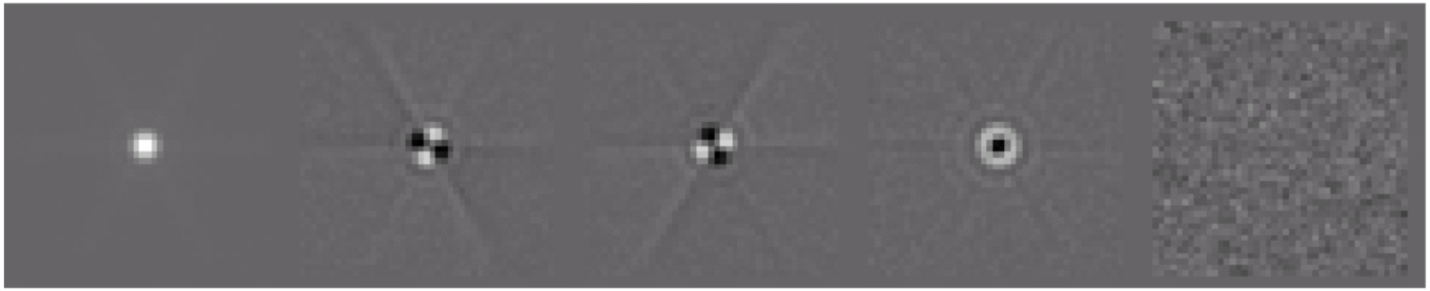
Gaussianlets



Motivation

- Interpolation doesn’t always work when the number of star is too few or the PSF changes too fast in the field.
- Galaxy images themselves contain the local information of the PSF


Unknows： NgxNg + 3xNPgxNPg
Knows: 3xNgxNg



The number of unknowns of PSF can decrease to several by using basis functions.

$$PSF_i = \sum_{l}^{N_{PC}} c_{il} PC_{il},$$

$$NPg \times NPg \rightarrow N_{PC}$$

$$G_0 \otimes PSF_i \otimes PSF_j = \boxed{G_i \otimes PSF_j = G_j \otimes PSF_i} = G_0 \otimes PSF_j \otimes PSF_i$$

$$\chi_{ij}^2 = \sum_{k}^{N_{pixel}} \frac{(G_i \otimes PSF_j - G_j \otimes PSF_i)_k^2}{\sigma_{ijk}^2}$$

Define $G_{ijl} = G_i \otimes PC_{jl}$

$$\chi^2 = \sum_{\substack{i,j \\ i \neq j}}^{N_{image}} \sum_{k}^{N_{pixel}} \frac{\left(\sum_{l} c_{jl} G_{ijlk} - \sum_{l} c_{il} G_{jilk}\right)^2}{\sigma_{ijk}^2}$$

The minimization $\dfrac{\partial \chi^2}{\partial c_{mn}} = 0$ leads

$$\sum_{l}^{N_{PC}} c_{ml} \sum_{\substack{i \\ i \neq m}}^{N_{image}} \sum_{k}^{N_{pixel}} \frac{G_{imnk} G_{imlk}}{\sigma_{imk}^2} - \sum_{l}^{N_{PC}} \sum_{\substack{i \\ i \neq m}}^{N_{image}} c_{il} \sum_{k}^{N_{pixel}} \frac{G_{imnk} G_{milk}}{\sigma_{imk}^2} = 0$$

With noise $G_i^{'} = G_i + n_i$

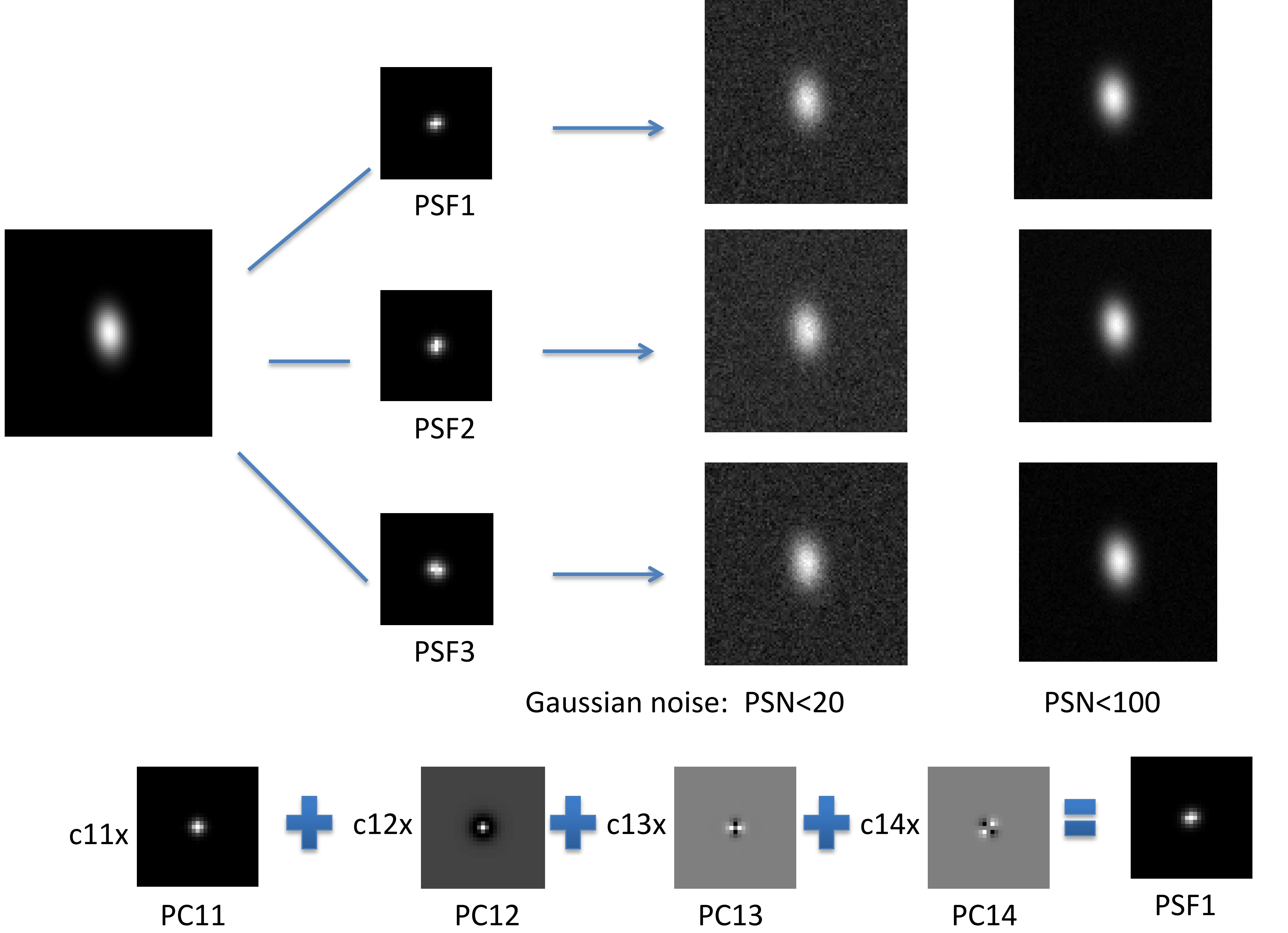
Define $n_{ij} = n_i \otimes PSF_j$

We get
$$\chi^2 \cong \sum_{\substack{i,j \\ i \neq j}}^{N_{image}} \sum_{k}^{N_{pixel}} \frac{\left(\sum_l c_{jl} G_{ijlk} - \sum_l c_{il} G_{jilk}\right)^2 + (n_{ijk} - n_{jik})^2}{\sigma_{ijk}^2}$$

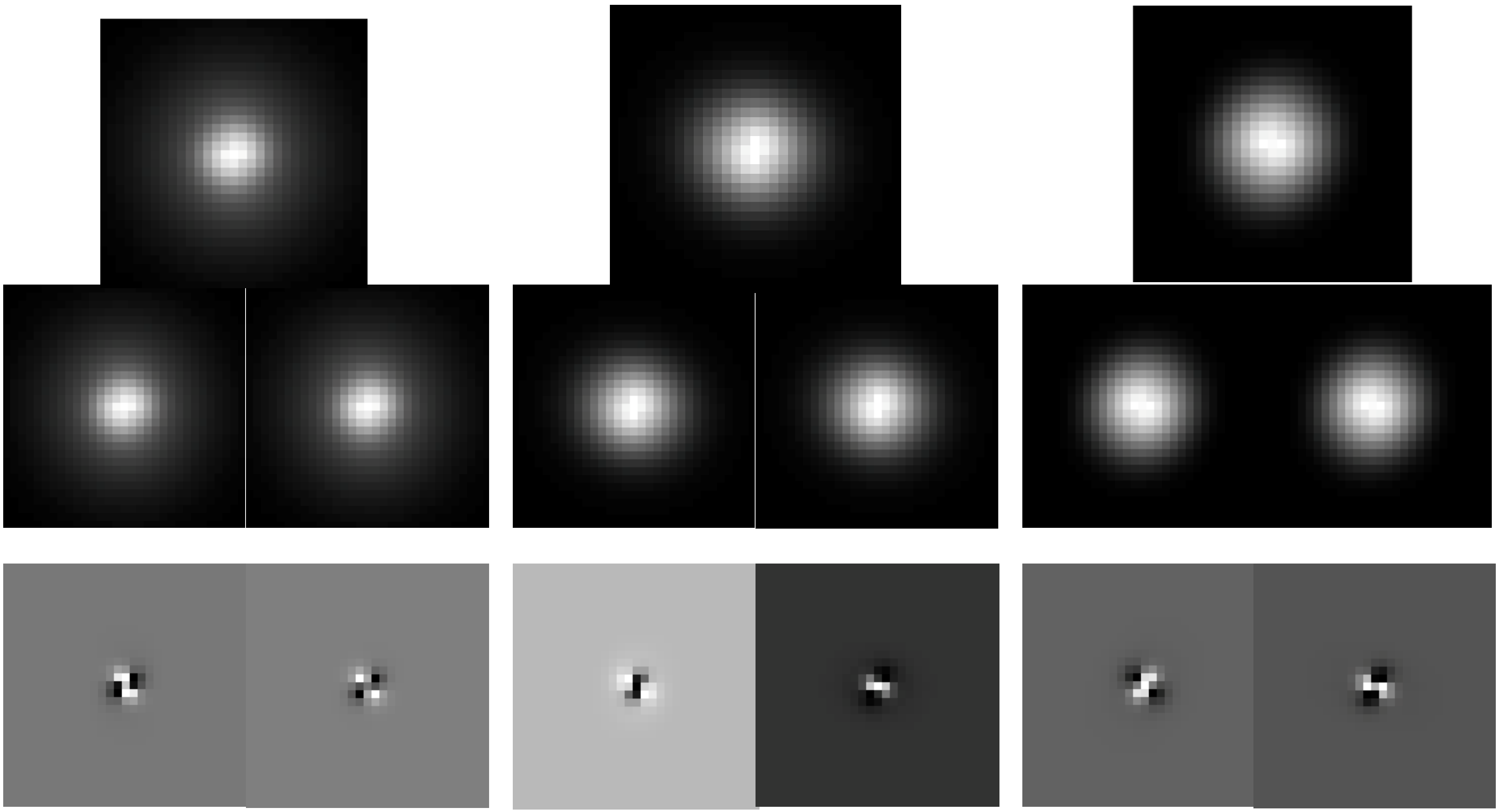
$$G_i \otimes PSF_j = G_j \otimes PSF_i \Rightarrow w \times G_i \otimes PSF_j = w \times G_j \otimes PSF_i$$

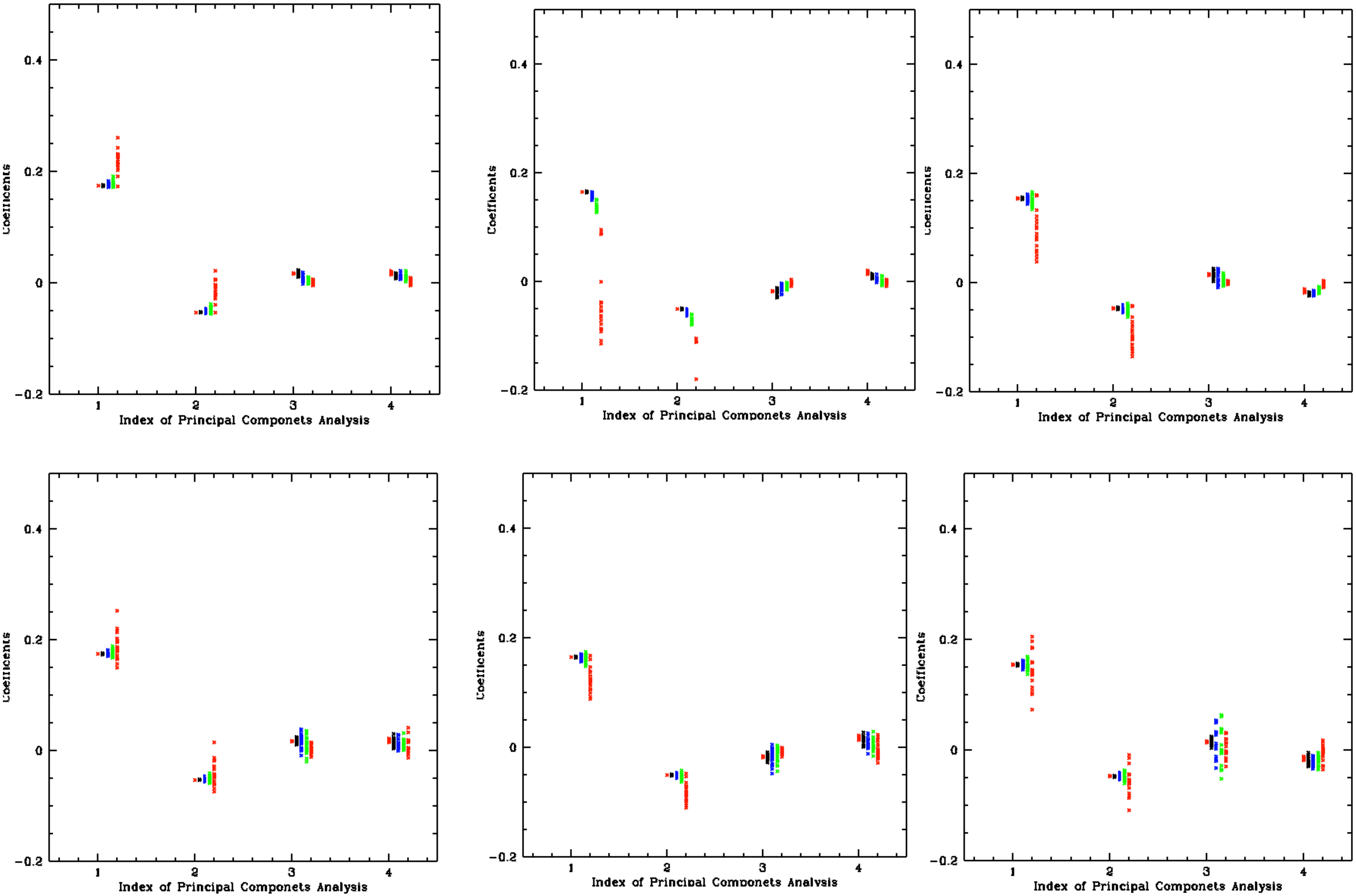
The final equation is:

$$\sum_{l}^{N_{PC}} c_{ml} \sum_{\substack{i \\ i \neq m}}^{N_{image}} \sum_{k}^{N_{pixel}} \frac{w_k G^{'}_{imnk} G^{'}_{imlk}}{\sigma_{imk}^2} - \sum_{l}^{N_{PC}} \sum_{\substack{i \\ i \neq m}}^{N_{image}} c_{il} \sum_{k}^{N_{pixel}} \frac{w_k G^{'}_{imnk} G^{'}_{milk}}{\sigma_{imk}^2} = 0$$


PSF1
PSF2
PSF3
Gaussian noise: PSN<20
PSN<100
c11x
PC11
c12x
PC12
c13x
PC13
c14x
PC14
PSF1

The Reconstructed PSFs




Coefficents
0.4
0.2
0
−0.2
1
2
3
4
Index of Principal Componets Analysis

Summary

- It works!
- It needs multi-exposured images with **different** PSF.
- Principal Components Analysis of stars provides the most compact basis function .
- More tests needed: center disalignment, noise estimation of the cross-convolved images，incomplete PCs

Thanks