Validation of the weak-lensing power spectrum and point-spread function residuals for Euclid

Jingwei Wang

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Laboratory: CosmoStat, Irfu, CEA

Projet: Euclid

Tutors: Martin Kilbinger
David Ryckelynck
Elie Hachem

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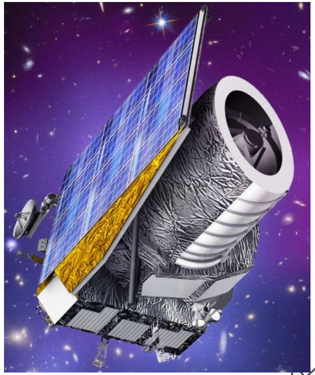
INTRODUCTION

Euclid?

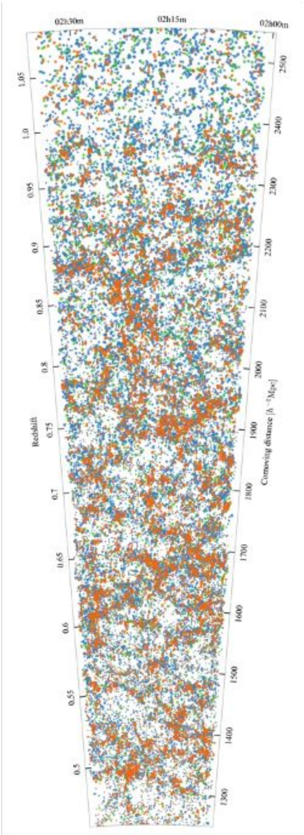


Dark matter?

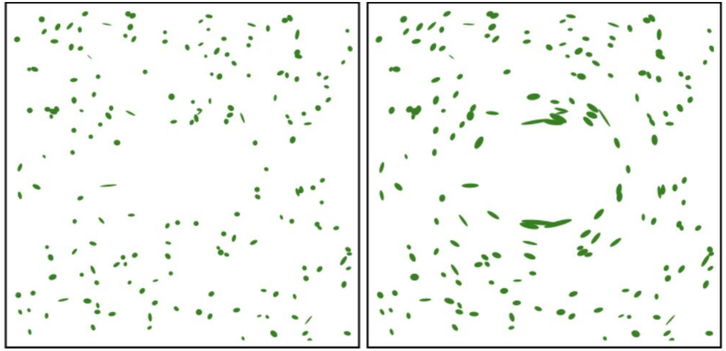
Dark energy?

?HOW?

II. Galaxy clustering

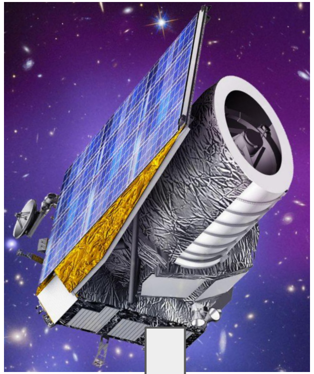


I. Weak gravitational lensing



Source: wikipedia

Euclid?



Explore the “dark” ingredients:

Dark energy

Dark matter

Probes	**Weak gravitational lensing**; Galaxy clustering
Resolution	0.1 arcsecond; 0.3 arcsecond
Wavelength range	(550-900 nm) - Visible imager (VIS) (900-2000 nm) - Near Infrared Spectrometer and Photometer (NISP)
Field of view	15 000 deg^2 (more than ⅓ of the sky)
Number of objects	1.5 billion shapes, 35 million 3D galaxy positions

Euclid

Euclid consortium

cea irfu

CosmoStat

https://www.cosmostat.org

"The CosmoStat lab bridges the gap between the realms of astrophysics and signal processing."

- ESA
- €500-600 million
- 15+ countries
- 2600+ members
- 200+ laboratories

What did I do?

- participates in several projects, as **Euclid**, UNIONS, SKA, LSST DESC, etc.
  - **Management**
  - **Data Analysis**: to provide the highest-quality science-ready products (LE3)
  - **Cosmological Interpretation**
- Dr Martin Kilbinger
  - Leader of the development of validation tools for **External Data** in the science-level data processing group
  - Co-leader in charge of **validating** Shear data and processing tools
  - Co-leader of the French **Shear data processing** activities
  - Co-leader of the **Weak Lensing science working group**

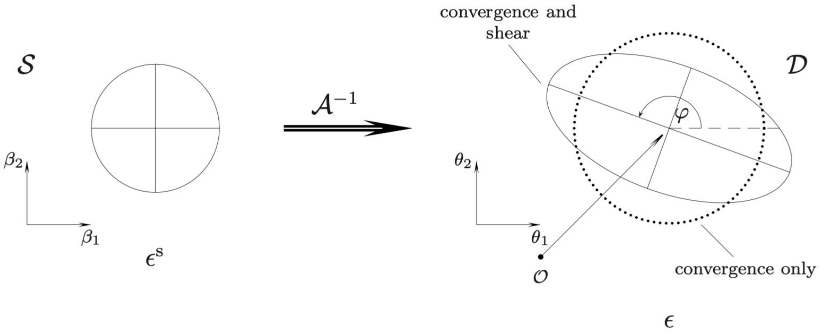
METHODOLOGY AND RESULTS

I. Validation of weak-lensing power spectrum

II. Analysis of correlated point-spread function residuals

I. Validating of weak-lensing power spectrum

- Shear?



$$\mathcal{A} = \begin{pmatrix} 1-\kappa-\gamma_1 & -\gamma_2 \\ -\gamma_2 & 1-\kappa+\gamma_1 \end{pmatrix}$$

$$\boldsymbol{e}^{\mathbf{obs}} \approx \boldsymbol{e}^{\mathbf{S}} + \boldsymbol{\gamma}$$

$$\langle \boldsymbol{e}^{\mathbf{obs}} \rangle = \boldsymbol{\gamma}$$

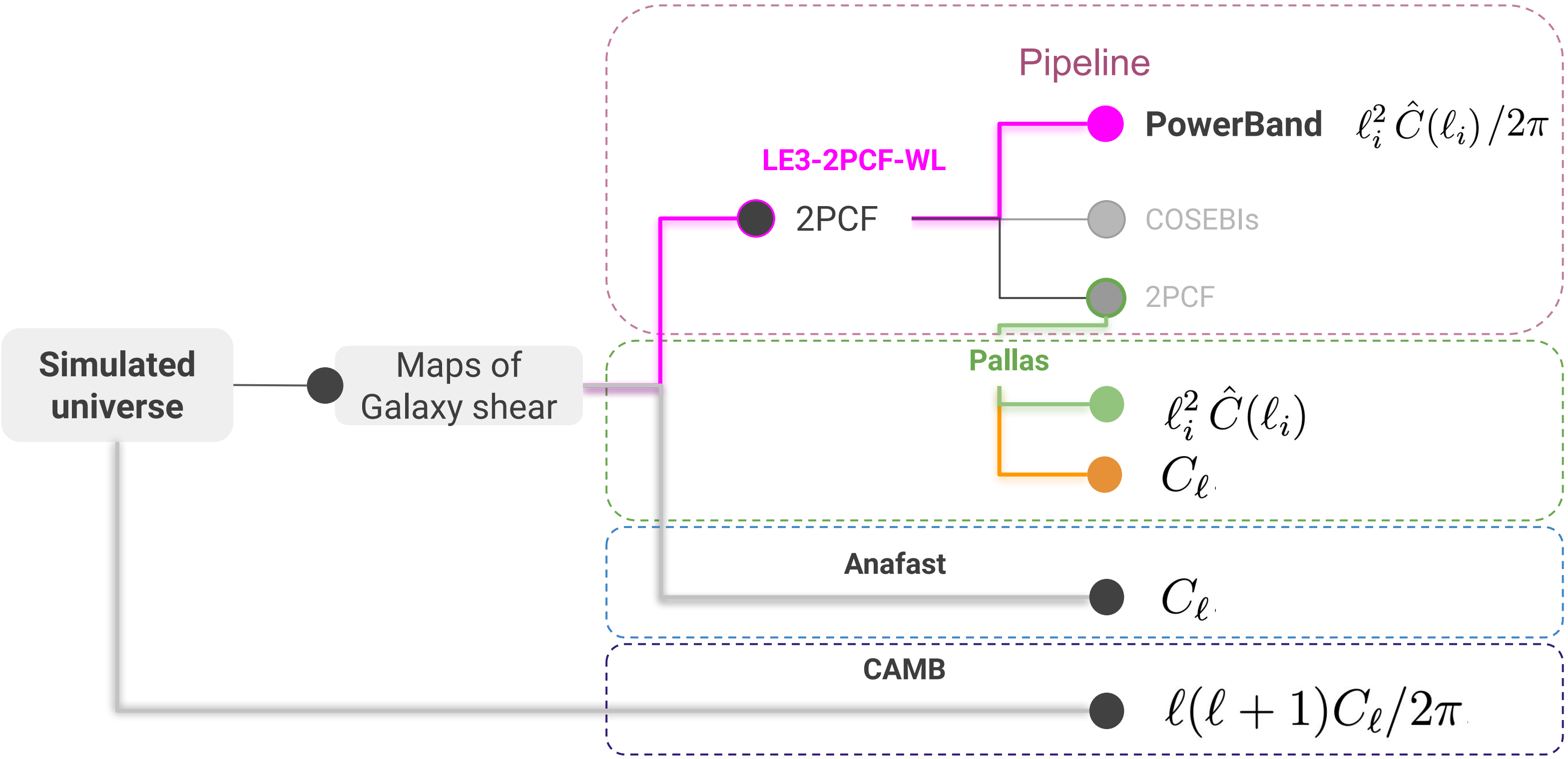
- Shear 2-point correlation function:

$$\xi_+(\theta) = \langle \boldsymbol{\gamma}\boldsymbol{\gamma}^* \rangle(\theta)$$
$$\xi_-(\theta) = \Re[\langle \boldsymbol{\gamma}\boldsymbol{\gamma} \rangle(\theta) e^{-4i\phi}]$$

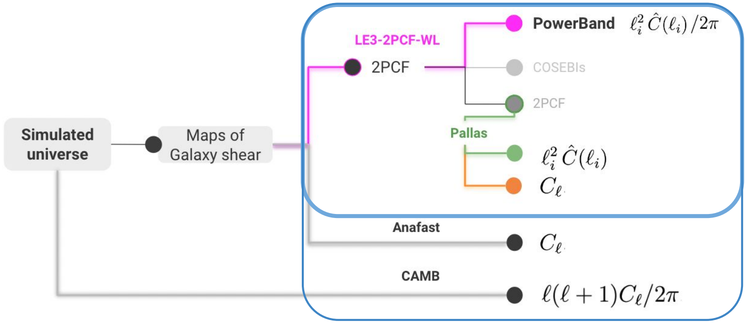
- Angular power spectrum?

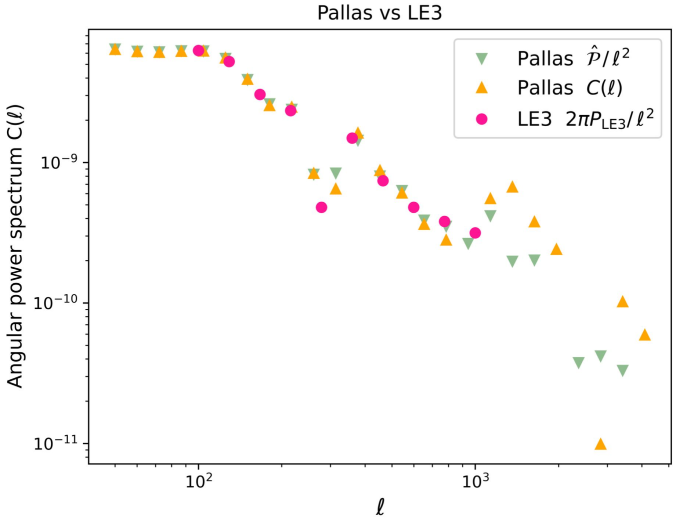
$$C(\ell) = \int \mathrm{d}^2\theta \boldsymbol{\xi}(\theta) e^{-i\ell\boldsymbol{\theta}}$$

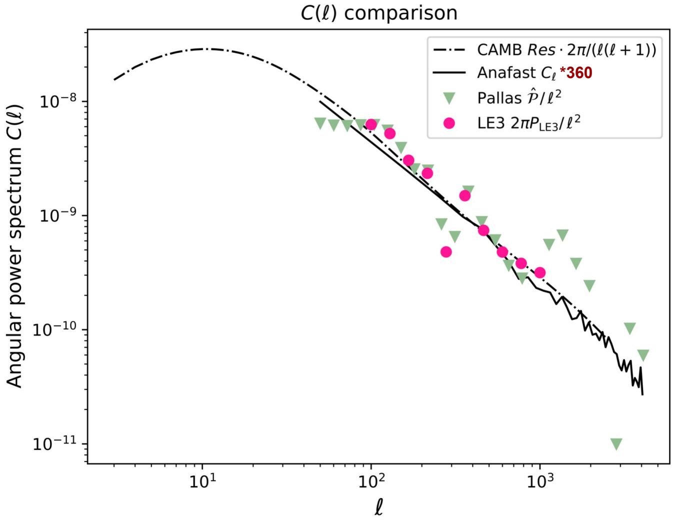
I. Validating of weak-lensing power spectrum



I. Validating of weak-lensing power spectrum







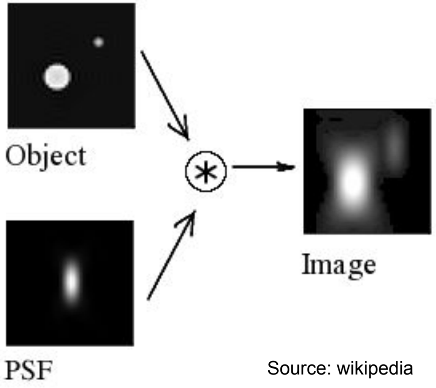
METHODOLOGY AND RESULTS

I. Validation of weak-lensing power spectrum

II. Analysis of correlated point-spread function residuals

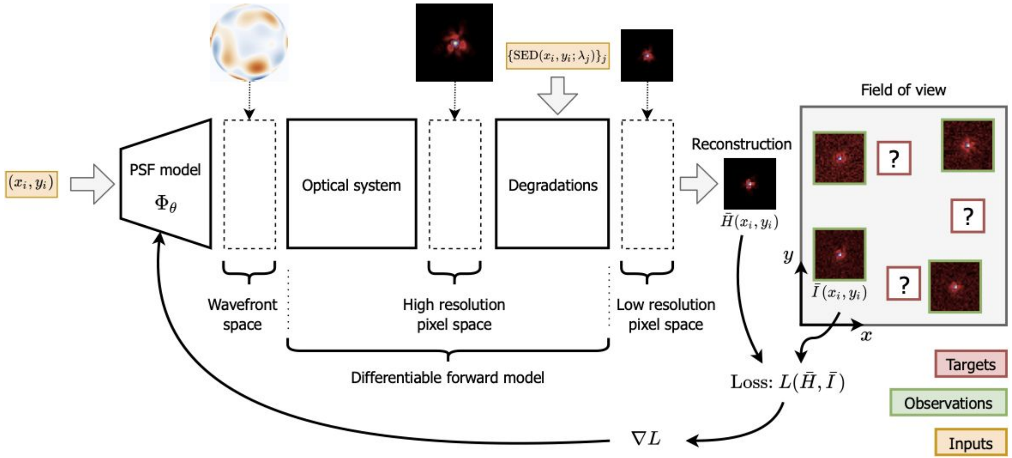
II. Analysis of correlated point-spread function residuals

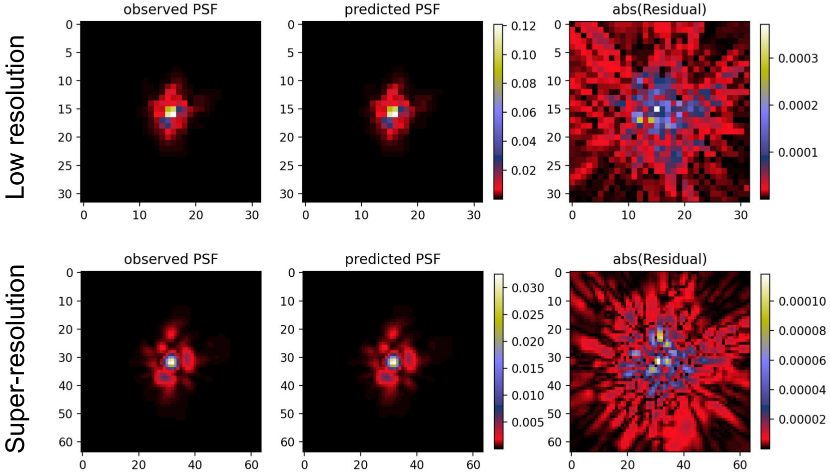
- Point-spread function?



Source: wikipedia

- Point-spread function residuals?
  PSF model:
    - Parametric models
    - Data-driven models
    - Combined





WaveDiff:
https://github.com/CosmoStat/wf-psf

II. Analysis of correlated point-spread function residuals

- ρ-statistics ?
  a diagnostic method to evaluate PSF models.
  - PSF model error on galaxy ellipticity:

$$\langle \boldsymbol{e}^{\mathrm{obs}} \rangle = \boldsymbol{\gamma} \;\Rightarrow\; \langle \boldsymbol{e}^{\mathrm{obs}} \rangle = \boldsymbol{\gamma}_{\mathrm{true}} + \alpha \boldsymbol{e}_{\mathrm{PSF}}$$

  - Bias on the measured galaxy ellipticities (Paulin-Hanriksson et al. 2008):

$$\delta e_{sys} = (e - e_{\mathrm{PSF}}) \left(\frac{T_{\mathrm{PSF}}}{T_{\mathrm{gal}}} \right) \frac{\delta T_{\mathrm{PSF}}}{T_{\mathrm{PSF}}} - \left(\frac{T_{\mathrm{PSF}}}{T_{\mathrm{gal}}} \right) \delta T_{\mathrm{PSF}}, \text{ where } T \equiv I_{xx} + I_{yy}$$

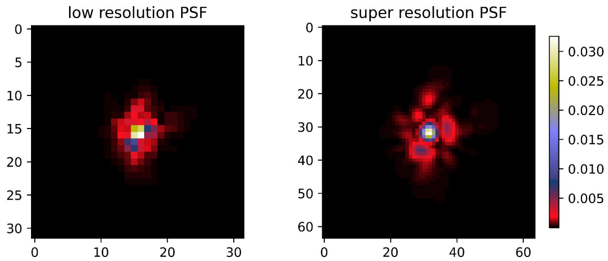
  - On two-point correlation function (Jarvis et al. 2016):

$$\delta\xi_+(\theta) = 2\left\langle \frac{T_{\mathrm{PSF}}}{T_{\mathrm{gal}}} \frac{\delta T_{\mathrm{PSF}}}{T_{\mathrm{PSF}}} \right\rangle \xi_+(\theta) + \left\langle \frac{T_{\mathrm{PSF}}}{T_{\mathrm{gal}}} \right\rangle^2 \rho_1(\theta) - \alpha \left\langle \frac{T_{\mathrm{PSF}}}{T_{\mathrm{gal}}} \right\rangle \rho_2(\theta) + \left\langle \frac{T_{\mathrm{PSF}}}{T_{\mathrm{gal}}} \right\rangle^2 \rho_3(\theta) + \left\langle \frac{T_{\mathrm{PSF}}}{T_{\mathrm{gal}}} \right\rangle^2 \rho_4(\theta) - \alpha \left\langle \frac{T_{\mathrm{PSF}}}{T_{\mathrm{gal}}} \right\rangle \rho_5(\theta)$$

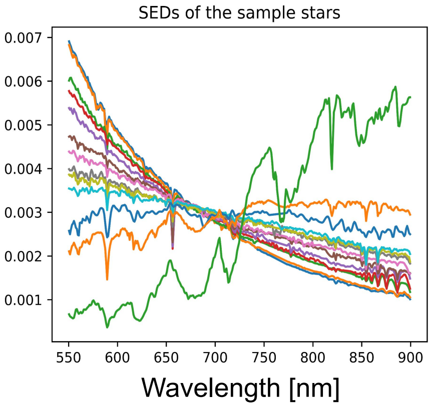
$$\begin{aligned}
\rho_1(\theta) &\equiv \langle \boxed{\delta e^*_{\mathrm{PSF}}}(\mathbf{x}) \delta e_{\mathrm{PSF}}(\mathbf{x}+\theta) \rangle \\
\rho_2(\theta) &\equiv \langle \boxed{e^*_{\mathrm{PSF}}}(\mathbf{x}) \delta e_{\mathrm{PSF}}(\mathbf{x}+\theta) \rangle \\
\rho_3(\theta) &\equiv \left\langle \left(e^*_{\mathrm{PSF}} \boxed{\frac{\delta T_{\mathrm{PSF}}}{T_{\mathrm{PSF}}}} \right)(\mathbf{x}) \left(e_{\mathrm{PSF}} \frac{\delta T_{\mathrm{PSF}}}{T_{\mathrm{PSF}}} \right)(\mathbf{x}+\theta) \right\rangle \\
\rho_4(\theta) &\equiv \left\langle \delta e^*_{\mathrm{PSF}}(\mathbf{x}) \left(e_{\mathrm{PSF}} \frac{\delta T_{\mathrm{PSF}}}{T_{\mathrm{PSF}}} \right)(\mathbf{x}+\theta) \right\rangle \\
\rho_5(\theta) &\equiv \left\langle e^*_{\mathrm{PSF}}(\mathbf{x}) \left(e_{\mathrm{PSF}} \frac{\delta T_{\mathrm{PSF}}}{T_{PSF}} \right)(\mathbf{x}+\theta) \right\rangle.
\end{aligned}$$

II. Analysis of correlated point-spread function residuals

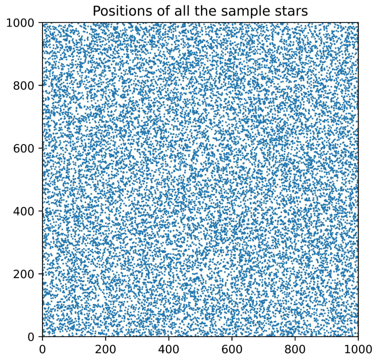
- What do we have?
  20, 000 simulated PSFs in both resolutions:



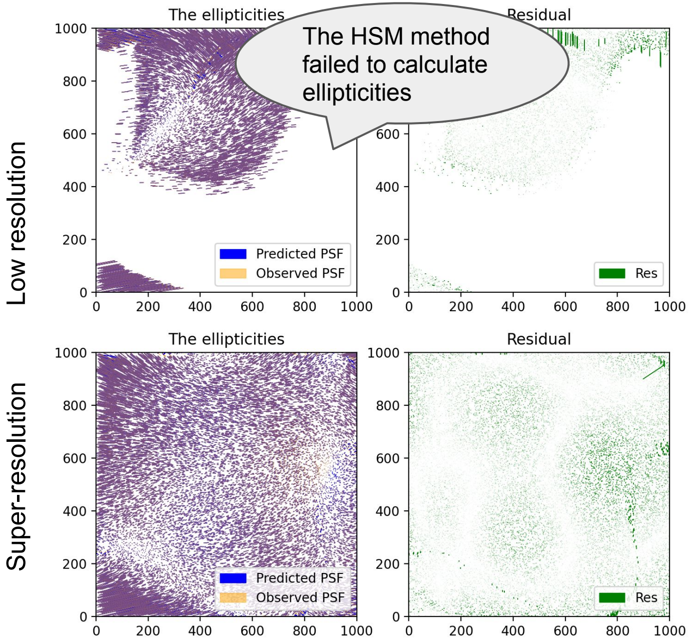
  - Spectral energy distribution:
    13 different SEDs



  - Positions:
    Randomly distributed



- After running the model:
  - Predicted PSFs in both resolutions
  - Simulated & predicted PSF ellipticities
  - T_{PSF}



II. Analysis of correlated point-spread function residuals

- Comparison with requirements:
  - Requirement:

$$\delta\sigma_8 = 0.019$$

$$\delta\xi_+^{\max}(\theta) \sim \left|\frac{\partial\xi_+(\theta)}{\partial\sigma_8}\delta\sigma_8\right|$$

$$\rho_{1,3,4}^{\max}(\theta) \sim \frac{1}{2}\left\langle\frac{T_{\rm PSF}}{T_{\rm gal}}\right\rangle^{-2}\delta\xi_+^{\max}(\theta);$$

$$\rho_{2,5}^{\max}(\theta) \sim \frac{1}{2}|\alpha|^{-1}\left\langle\frac{T_{\rm PSF}}{T_{\rm gal}}\right\rangle^{-1}\delta\xi_+^{\max}(\theta),$$

$$\left\langle\frac{T_{\rm PSF}}{T_{\rm gal}}\right\rangle \sim \frac{7\times0.1^2}{\pi(0.7)^2} \sim 0.05$$

leakage $\alpha = 0.03$

$$|\rho_{1,3,4}(\theta)| < x\rho_{1,3,4}^{\max}(\theta);$$

$$|\rho_{2,5}(\theta)| < x\rho_{2,5}^{\max}(\theta)$$

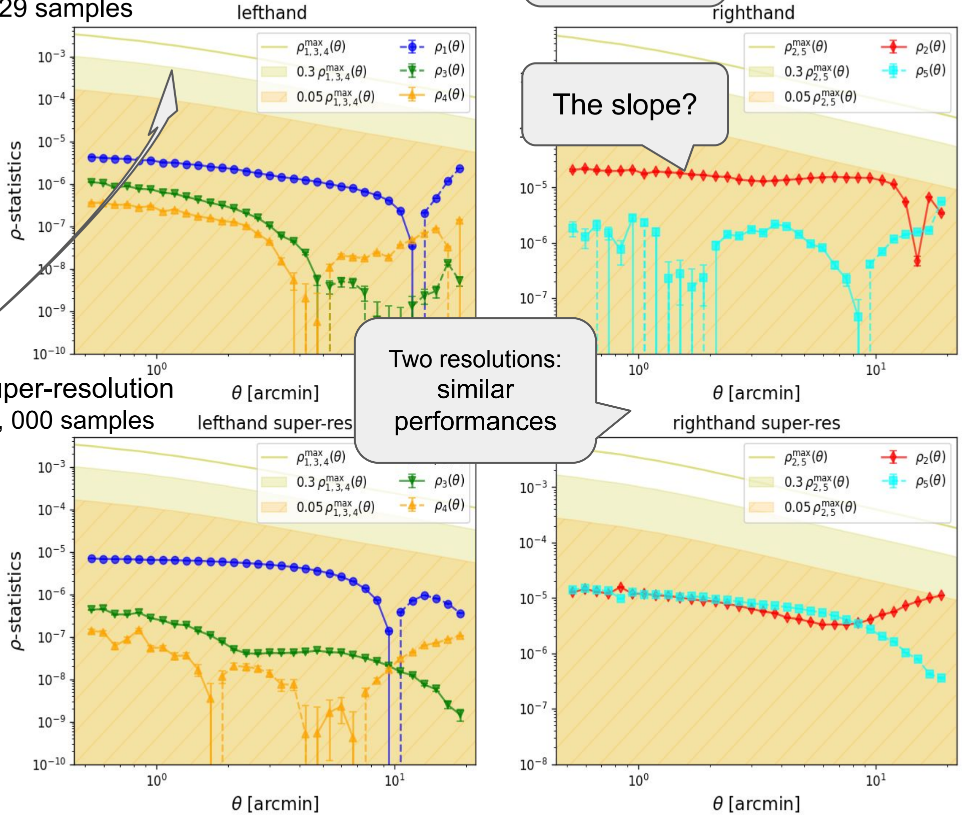
$x = 0.3$
or $x = 0.05$

  - Low resolution
7429 samples
  - Super-resolution
20, 000 samples

Combine several pictures

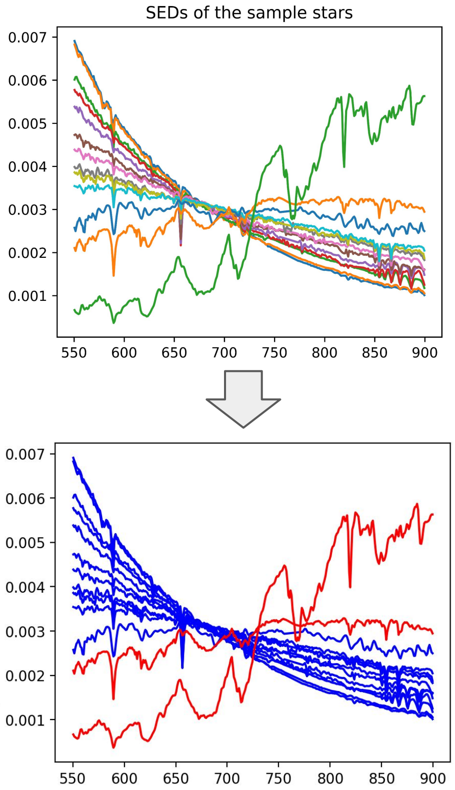
The slope?

Two resolutions: similar performances

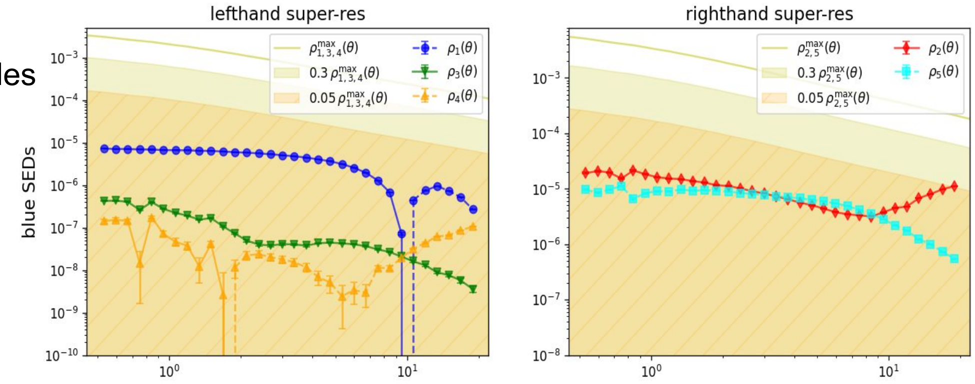


II. Analysis of correlated point-spread function residuals

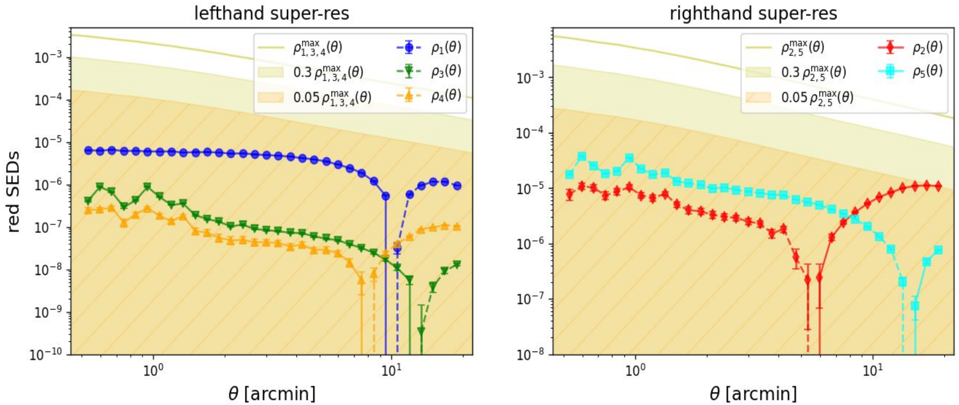
- Classify the sources into “blue” and “red”, super-resolution:



- Blue
16 889 samples

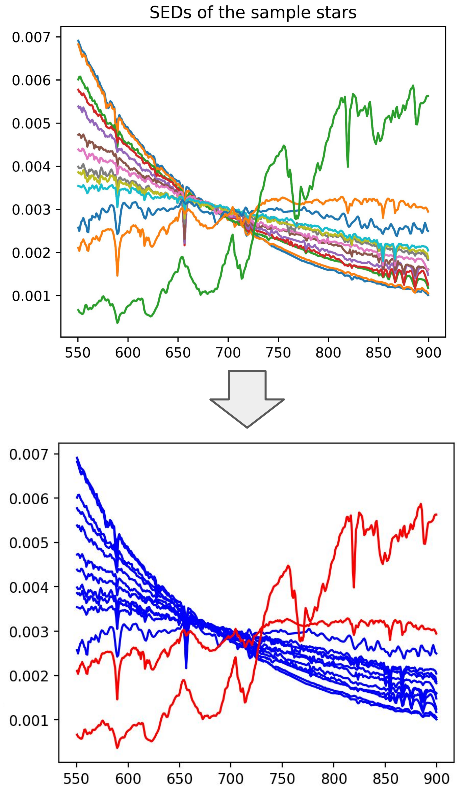


- Red
3111 samples



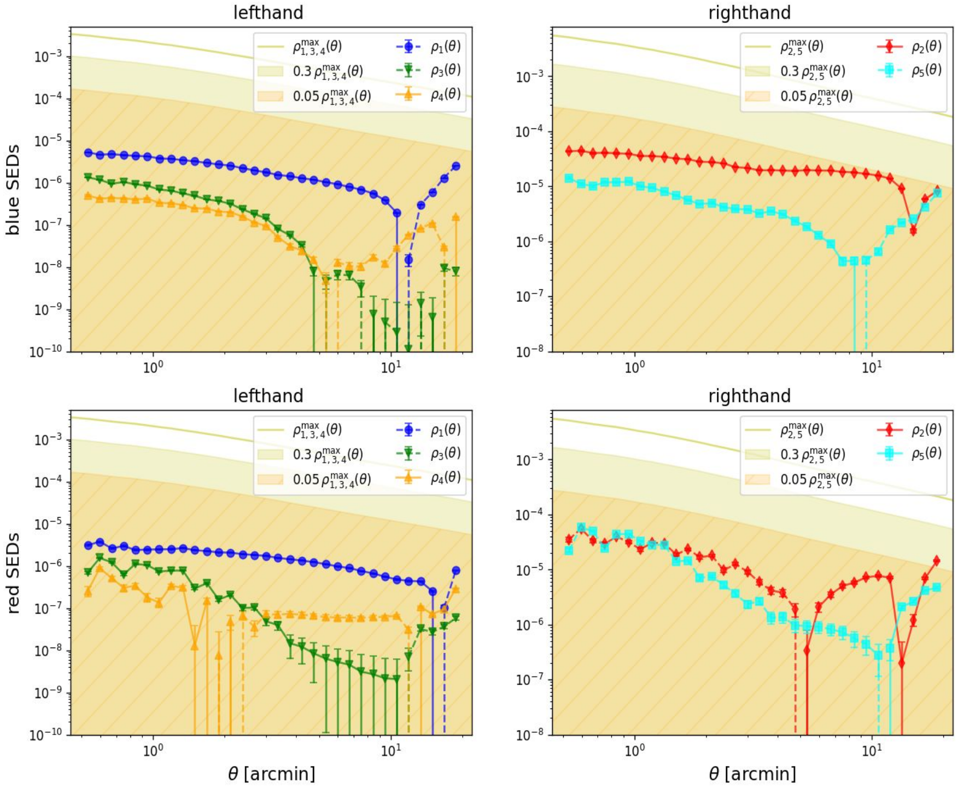
II. Analysis of correlated point-spread function residuals

- Classify the sources into “blue” and “red”, low resolution:



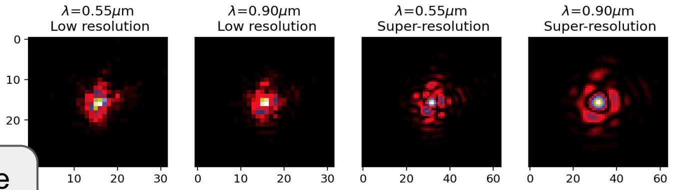
- Blue
6142 samples

- Red
1287 samples



II. Analysis of correlated point-spread function residuals

- Monochromatic? An idealistic imaginary situation
  "550 nm" vs "900 nm"; low resolution vs super-resolution:



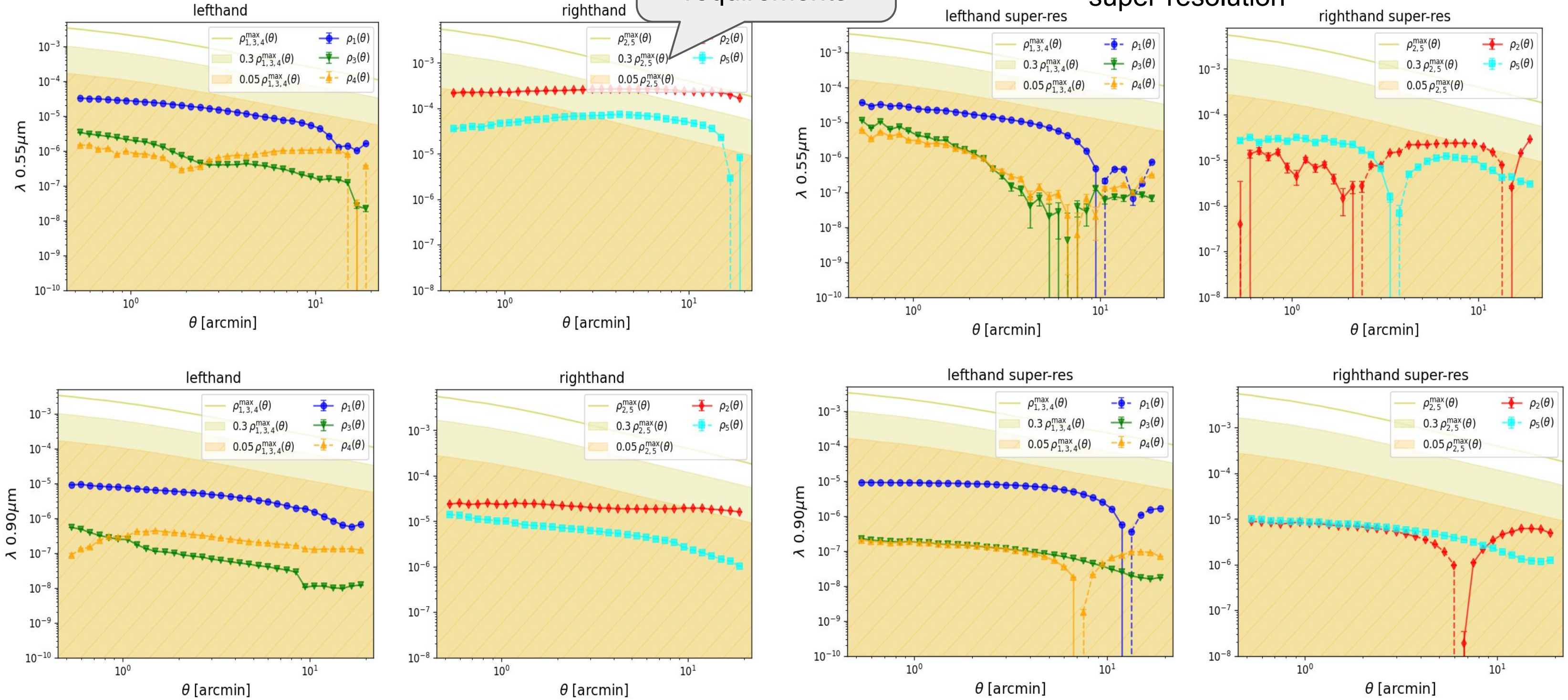
Cannot meet the requirements

Low resolution

super-resolution

550 nm

900 nm



CONCLUSION

- ➢ Internship work:
  - ✓ Validation of angular power spectrum
  - ✓ ρ-statistics on PSF model error analysis
- ➢ Personal improvement
- ➢ Acknowledgement

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