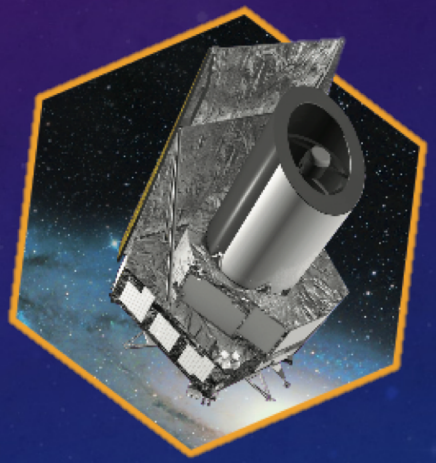
EUCLID: WEAK LENSING MASS MAPS



SANDRINE PIRES, CEA SACLAY

On behalf of the Euclid Consortium

SANDRINE.PIRES@CEA.FR

cea

CosmoStat

france for euclid

Euclid consortium

OUTLINE

- Introduction
- Weak lensing data analysis
- Weak lensing mass maps systematics
- Ongoing projects

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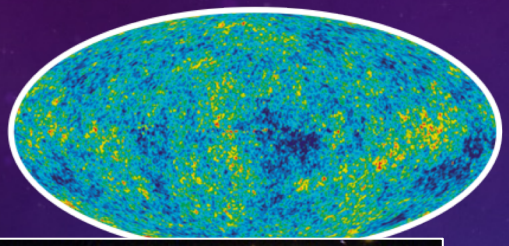
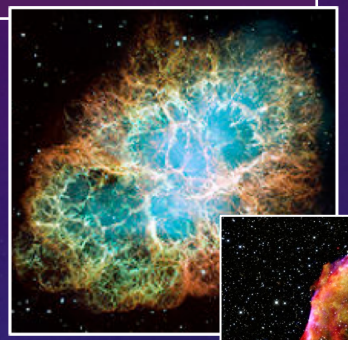
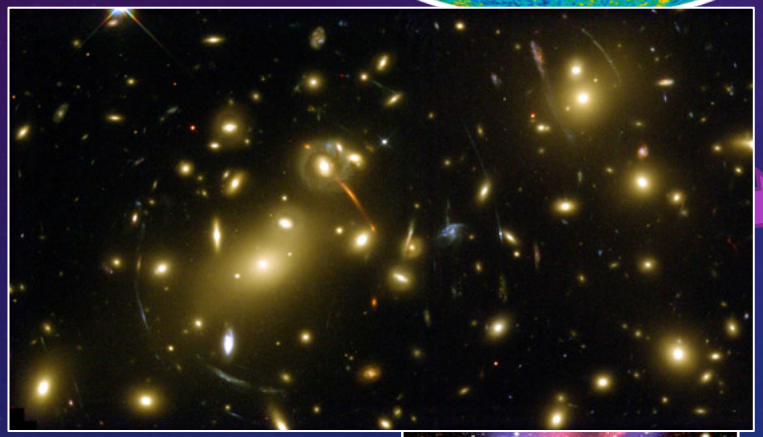
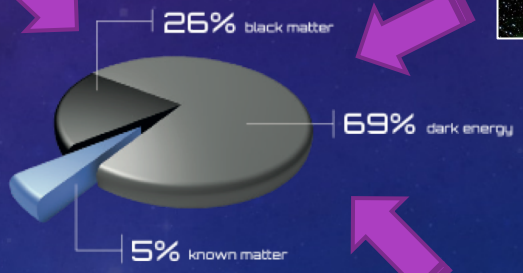
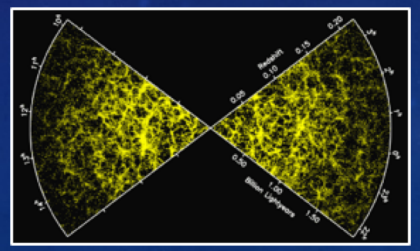
COSMOLOGY



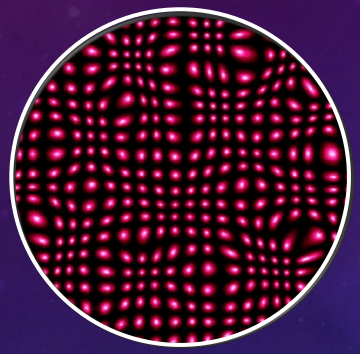




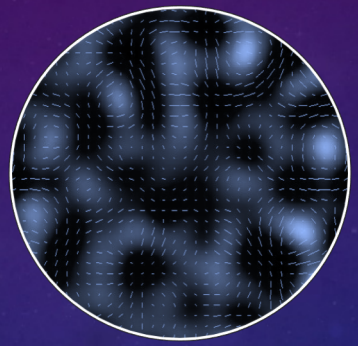




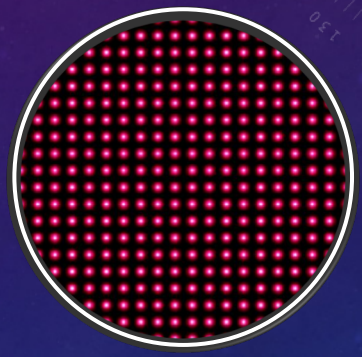
THE WEAK LENSING EFFECT



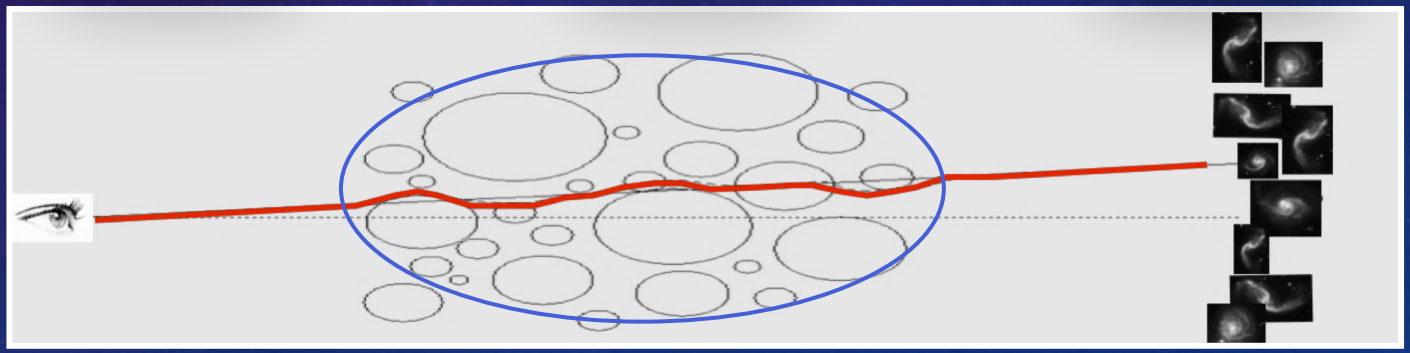
Observer



Gravitational lens

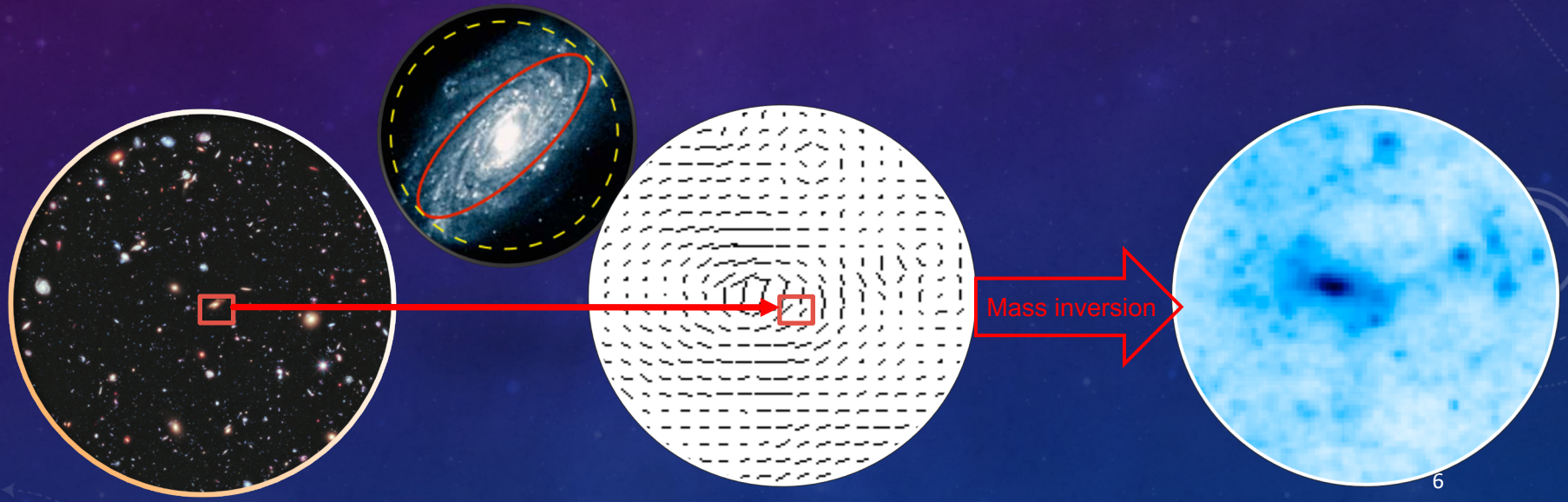


Background galaxies



FROM SHEAR TO CONVERGENCE MAPS

$$\begin{pmatrix}\epsilon_1\\ \epsilon_2\end{pmatrix} = \frac{1-\beta}{1+\beta}\begin{pmatrix}\cos 2\phi\\ \sin 2\phi\end{pmatrix}$$



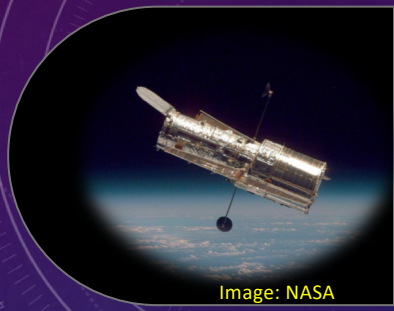
Observed region

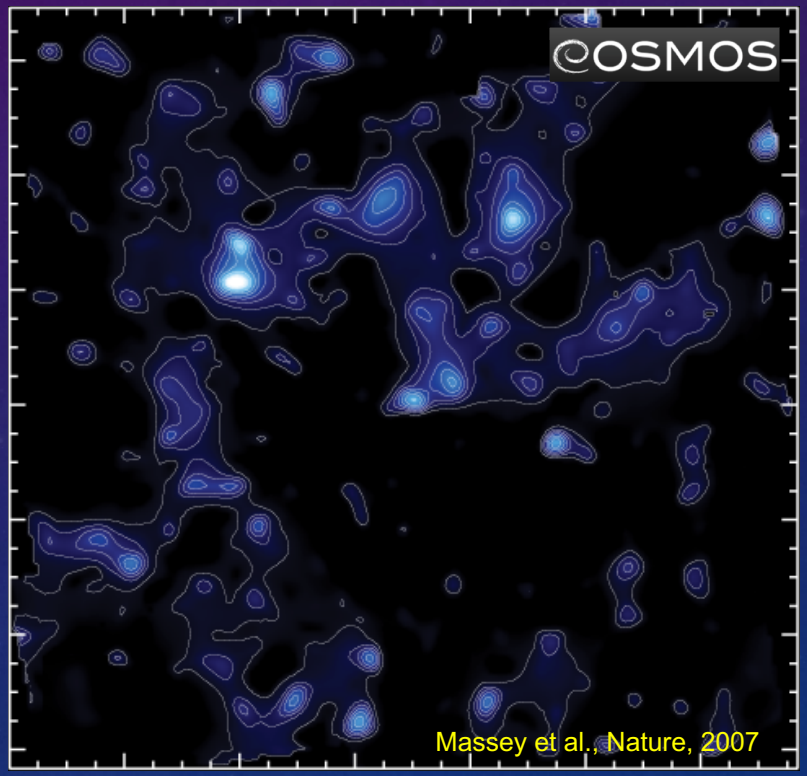
Image distortions called **shear**

$$\gamma_i = < \epsilon_i >$$

Projected dark matter distribution called **convergence**

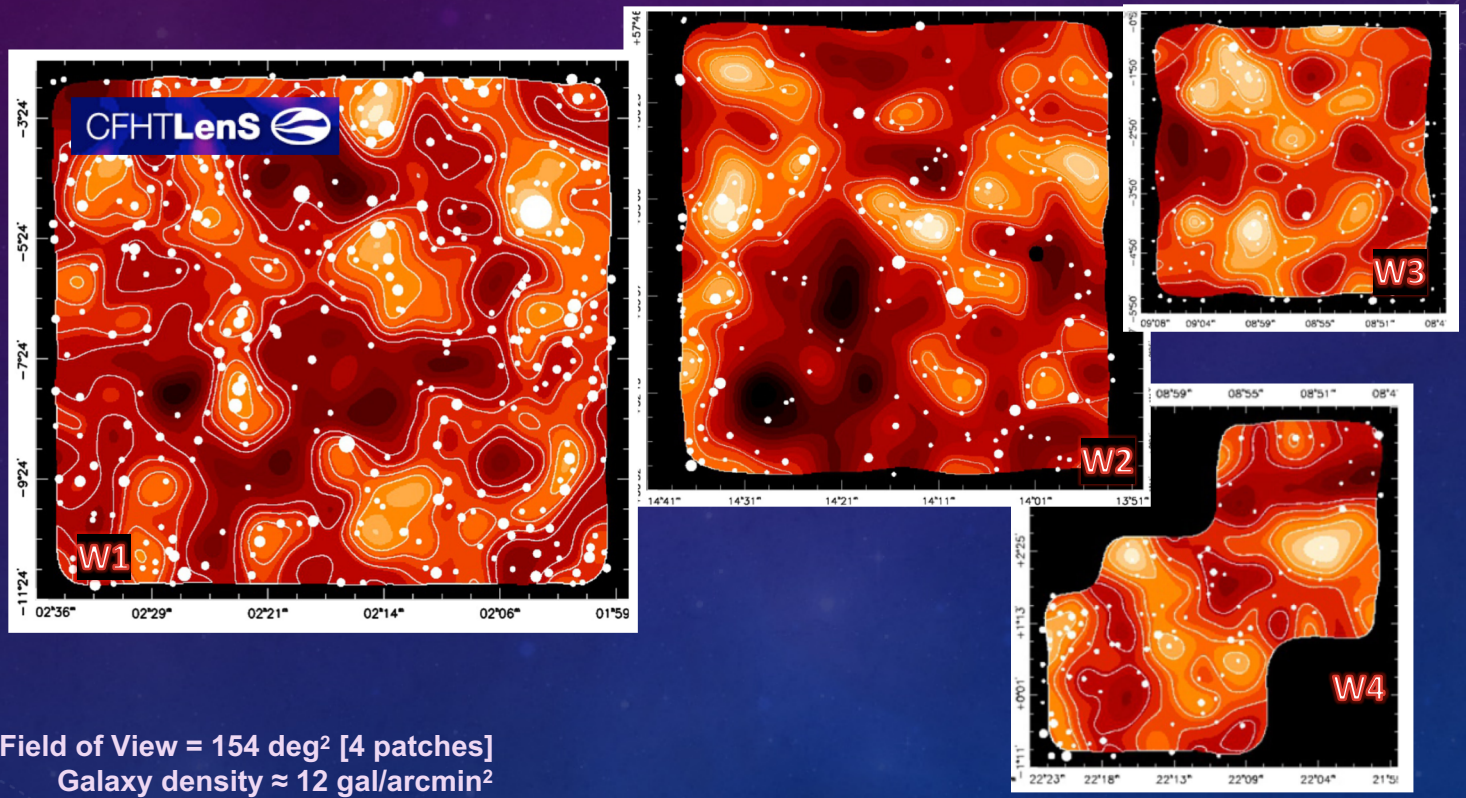
THE COSMOS SURVEY (HST)

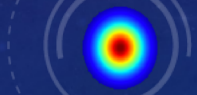




Field of View = 1.64 deg² [1 patch]
Galaxy density ≈ 67 gal/arcmin²
Telescope: Hubble Space Telescope

THE CFHTLENS SURVEY



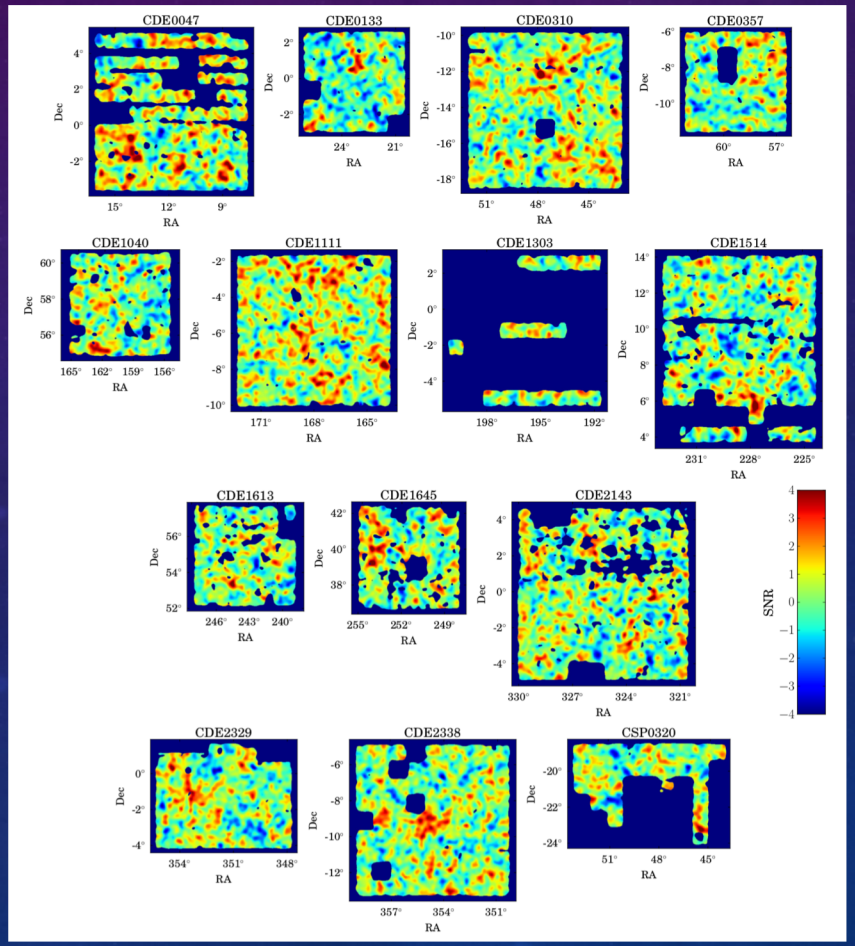


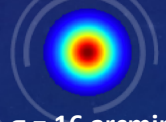
σ = 8.9 arcmin

Field of View = 154 deg² [4 patches]
Galaxy density ≈ 12 gal/arcmin²
Telscope : CFHT

Van Waerbeke et al., MNRAS, 2013

RED-SEQUENCE CLUSTER LENSING SURVEY



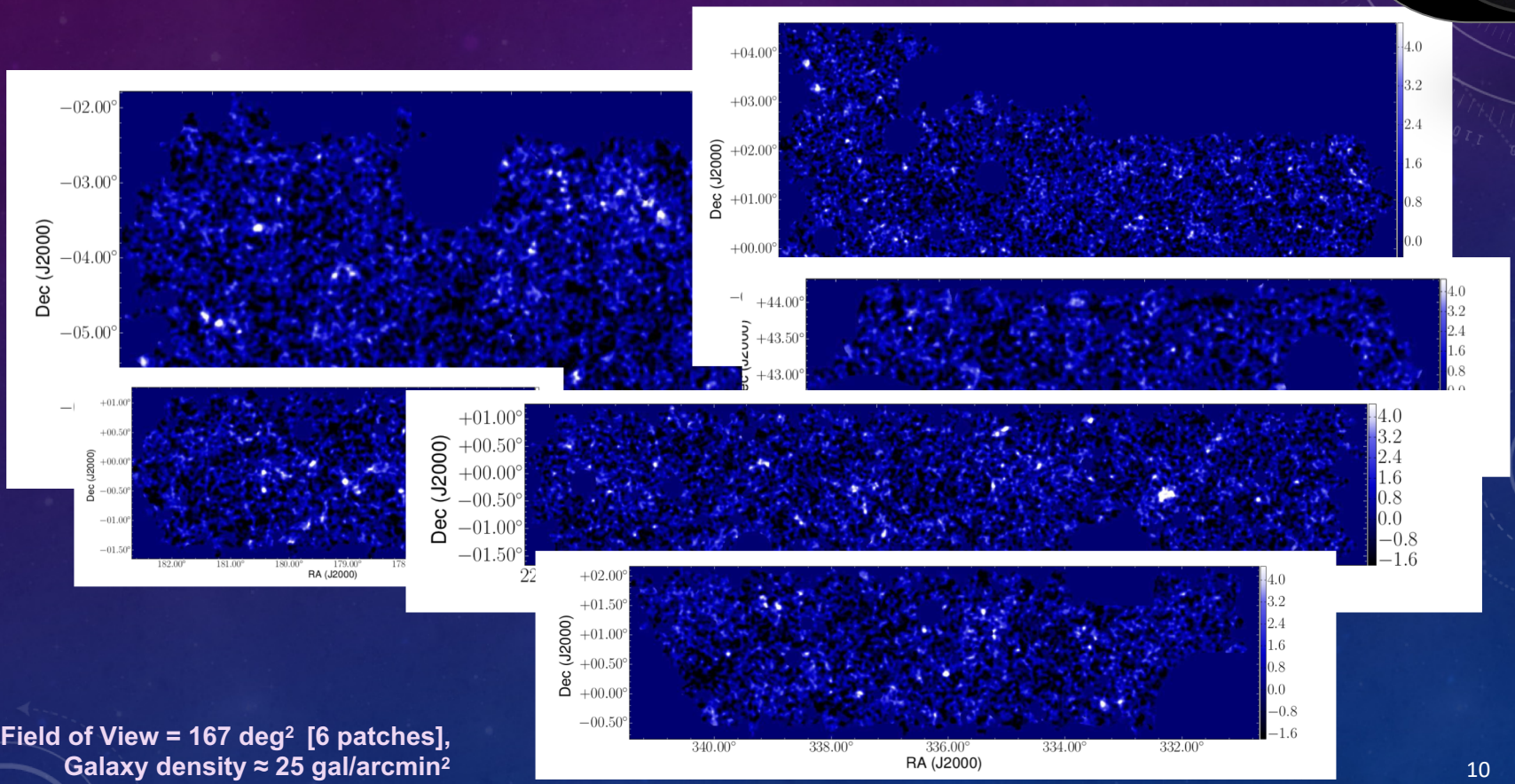


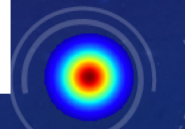
σ = 16 arcmin

Field of View = 785 deg², [14 patches]
Galaxy density ≈ 5 gal/arcmin²
Telescope: CFHT

H. Hildebrandt et al, MNRAS, 2016

THE HYPER SUPRIME-CAM SURVEY (HSC)



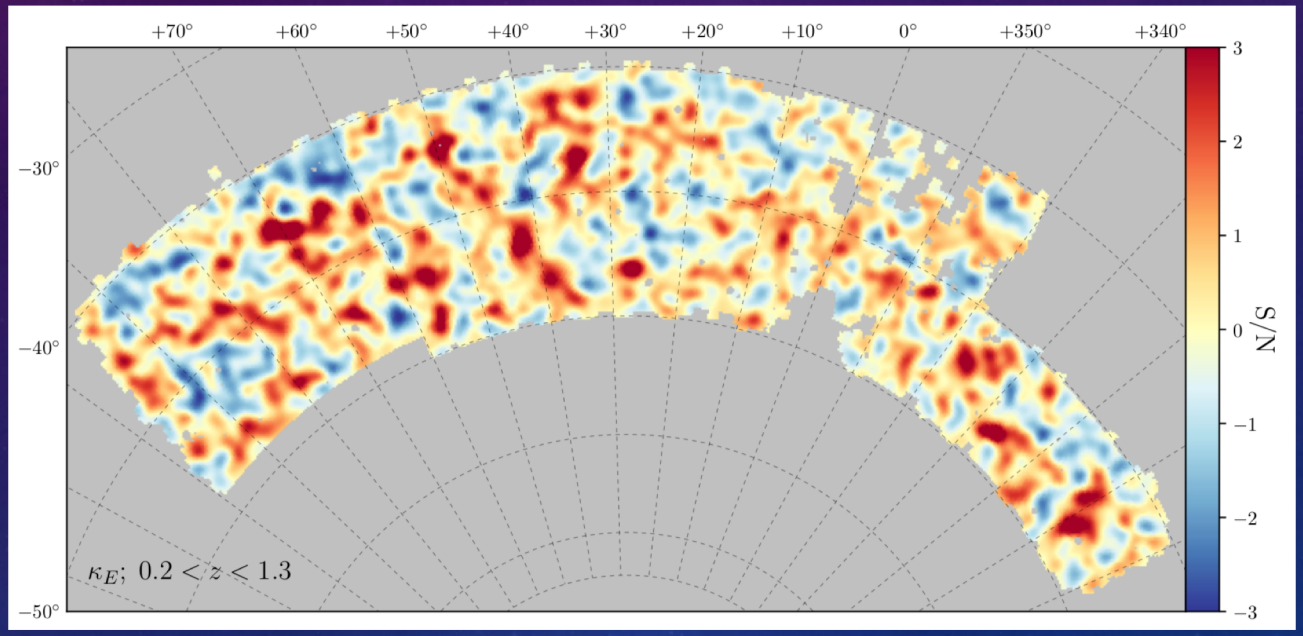


σ = 2 arcmin

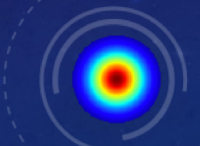
Field of View = 167 deg² [6 patches],
Galaxy density ≈ 25 gal/arcmin²
Telescope: Subaru

M.Oguri et al, PASJ, 2018

THE DARK ENERGY SURVEY (DES)



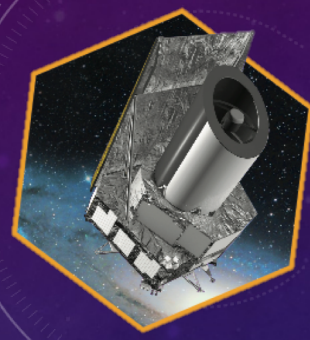
C.Chang et al, MNRAS, 2018

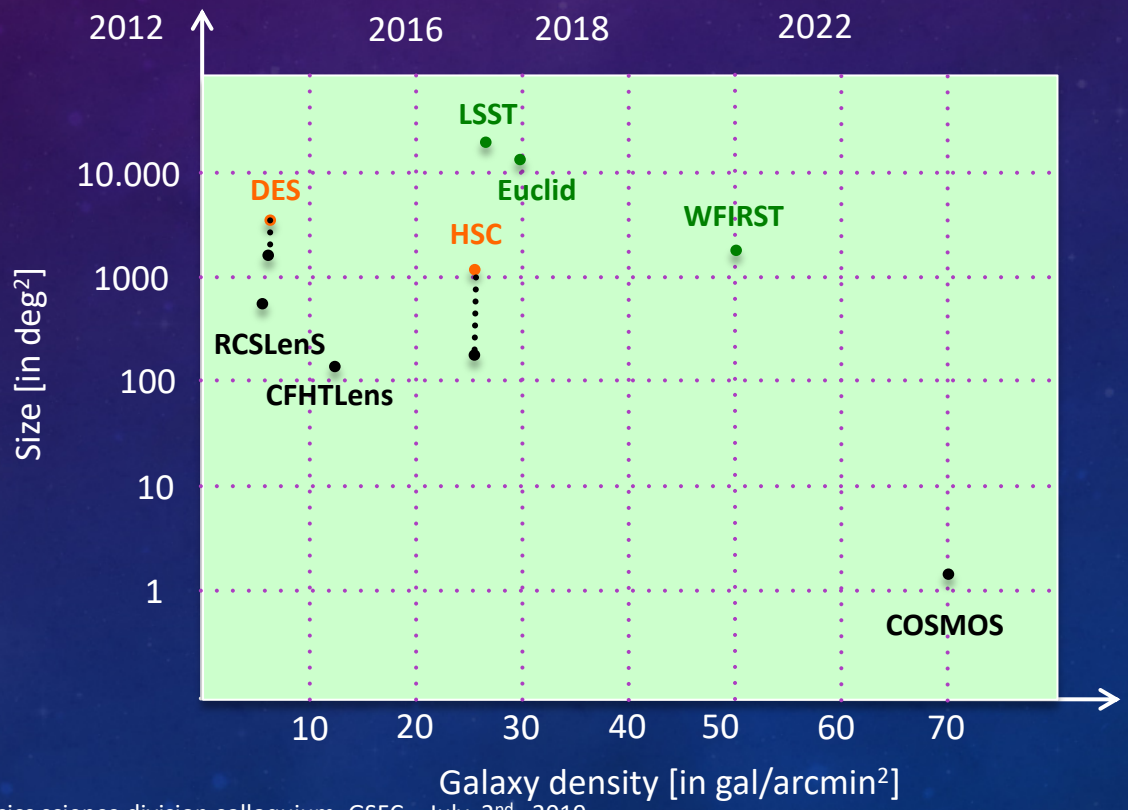


σ = 30 arcmin

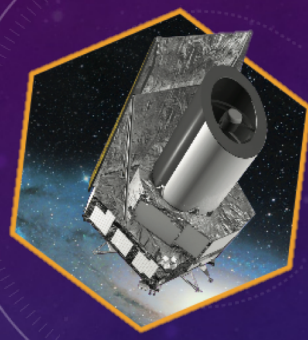
Field of View = 1500 deg² [1 patch]
Galaxy density ≈ 5 gal/arcmin²
Telescope: Victor M. Blanco (Chile)

WEAK LENSING SURVEYS





THE EUCLID MISSION



Launch foreseen in 2022 from Kourou space base, by a Soyouz rocket

6-year mission around the Sun / Earth L2 Lagrange point,
A sky survey covering 15 000 deg²

- Telescope
  Primary mirror diameter 1,20 m
  Field of view : 0,5 deg2 (twice the apparent size of the full Moon)
  Silica carbide structure (for its ultra stability).
- Instruments
  VIS, the visible photometer
  NISP, the infra red spectro photometer
  [0,9 µm ; 2,0 µm].

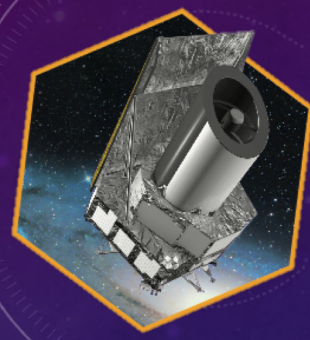
Euclid
is an ESA mission
European Space Agency

It is the second mission of the Cosmic Vision program

France has the scientific leadership of the experience.

Slide courtesy of Rodolphe Clédassou

THE EUCLID MISSION



Weak lensing

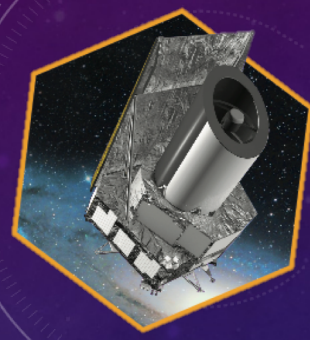
- **Visible: Galaxy shape measurements in R+I+Z<24.5 (AB,10σ), 40 resolved galaxies/amin^2, median resdshift of 0.9**
- **NIR photometry: Y,J,H<24 (AB, 5σ PS), photometric redshifts rms 003-0.05(1+z) with ground based complement**

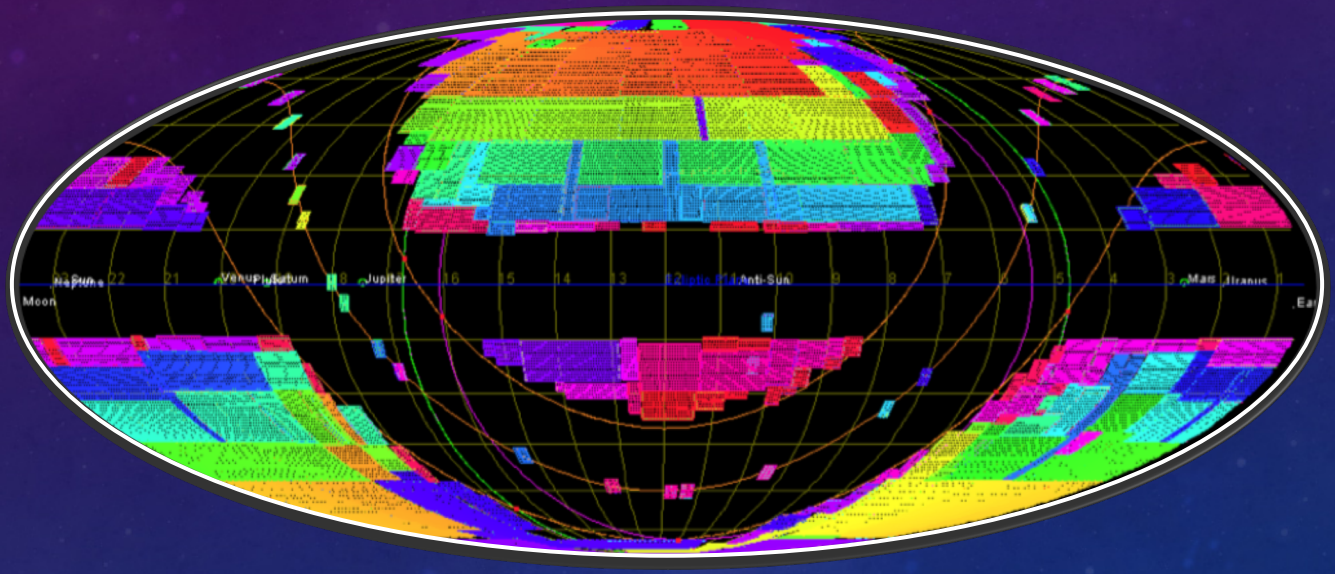
BAO

- **Spectroscopic redshifts for 33% of all galaxies with H(AB)<22 mag, σ_z<0.001**

Euclid Consortium
more than 2000 members in 280 institutes in 18 countries.

THE EUCLID SURVEY





R. Scaramella, in prep

σ ≤ 1 arcmin

Field of View = 15000 deg^2,
Galaxy density ≈ 30 gal/arcmin^2

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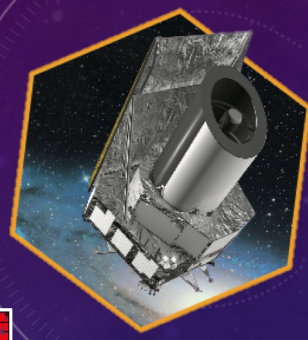
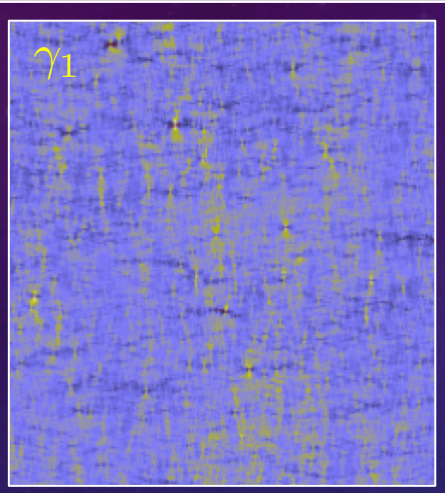
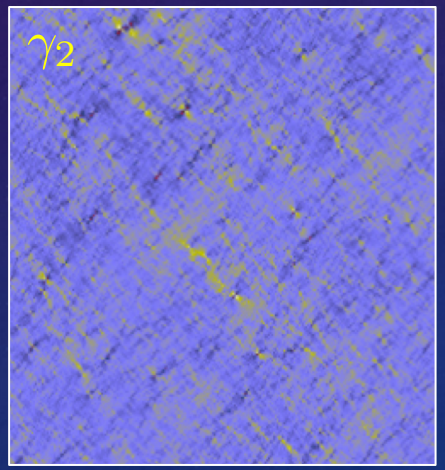
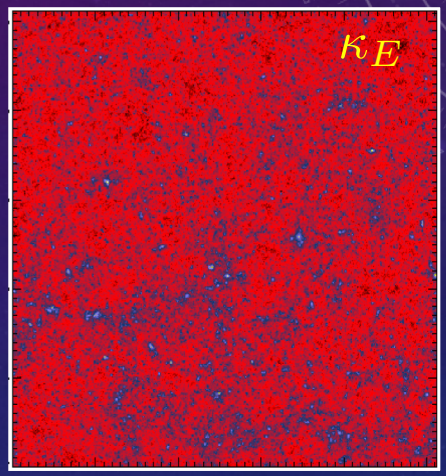
WEAK LENSING DATA ANALYSIS

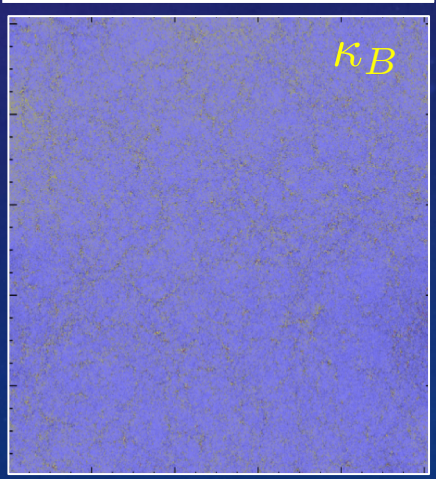






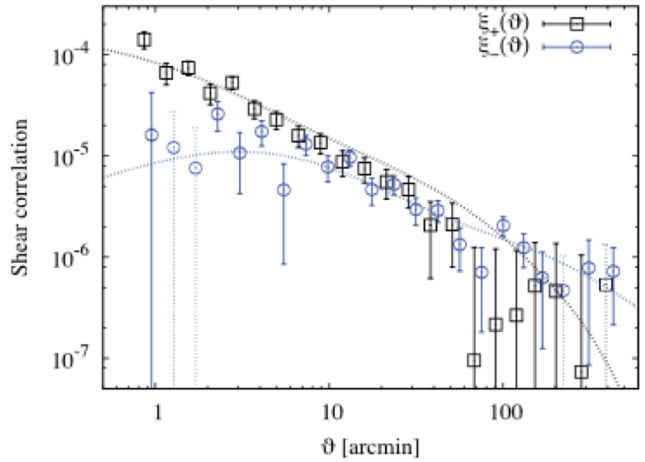
$\gamma = \gamma_1 + \mathrm{i}\gamma_2$



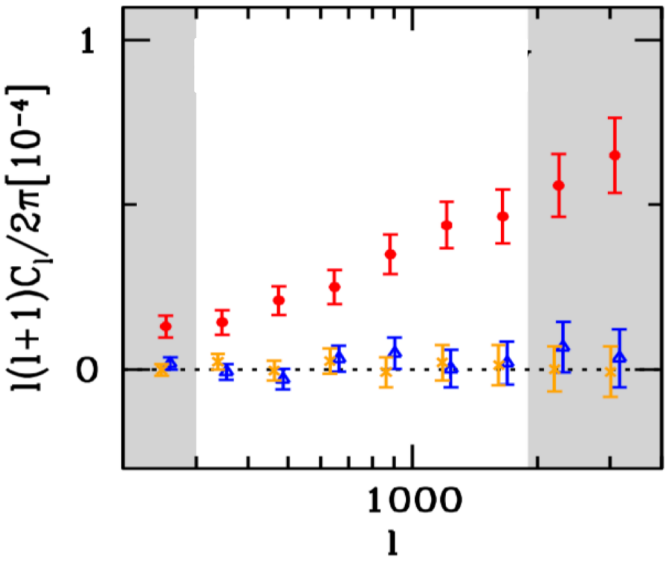


$\kappa = \kappa_E + \mathrm{i}\kappa_\mathrm{B}$

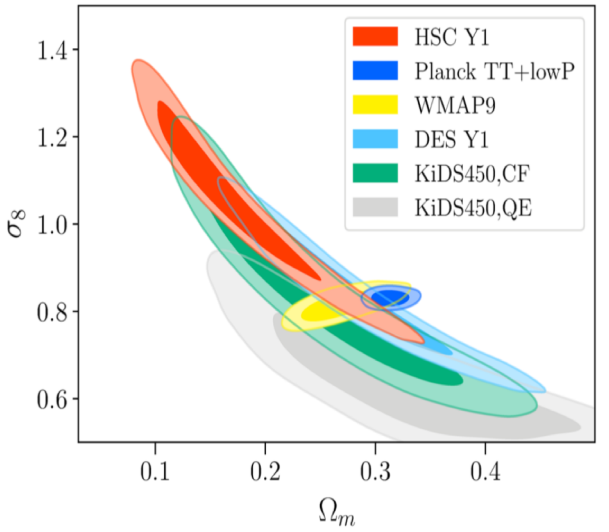
WEAK LENSING DATA ANALYSIS



Kilbinger et al., MNRAS, 2013 [CFHTLenS]

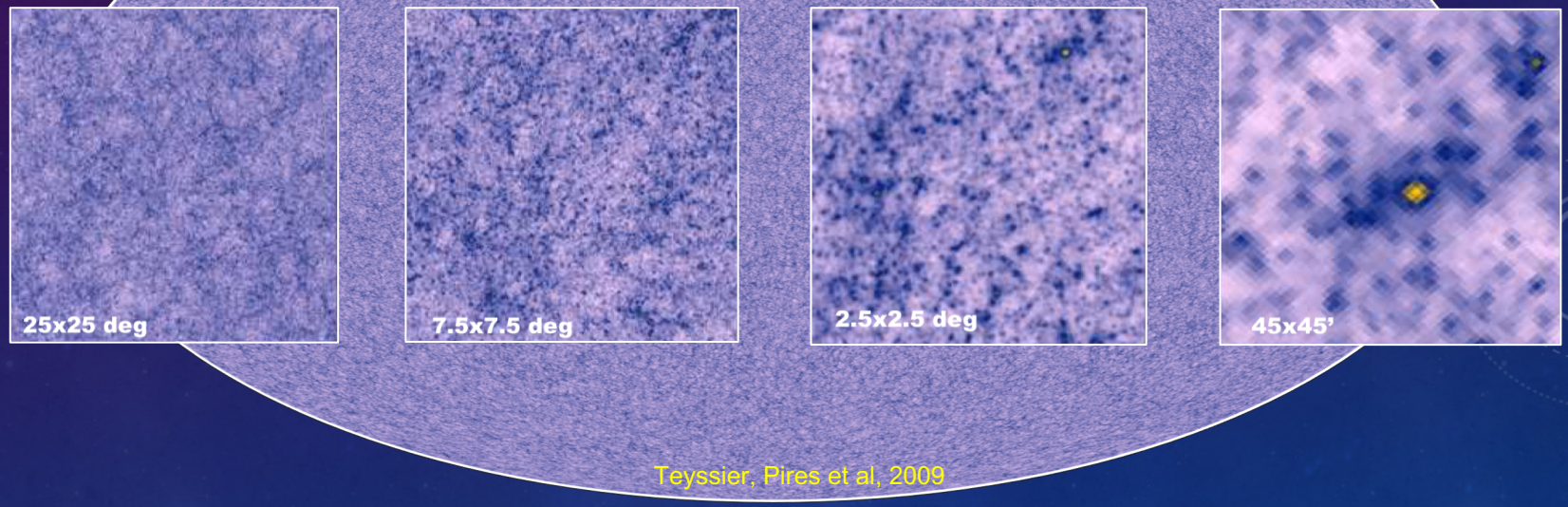


Hikage et al., PASJ, 2019 [HSC]



M.Oguri et al, PASJ, 2018

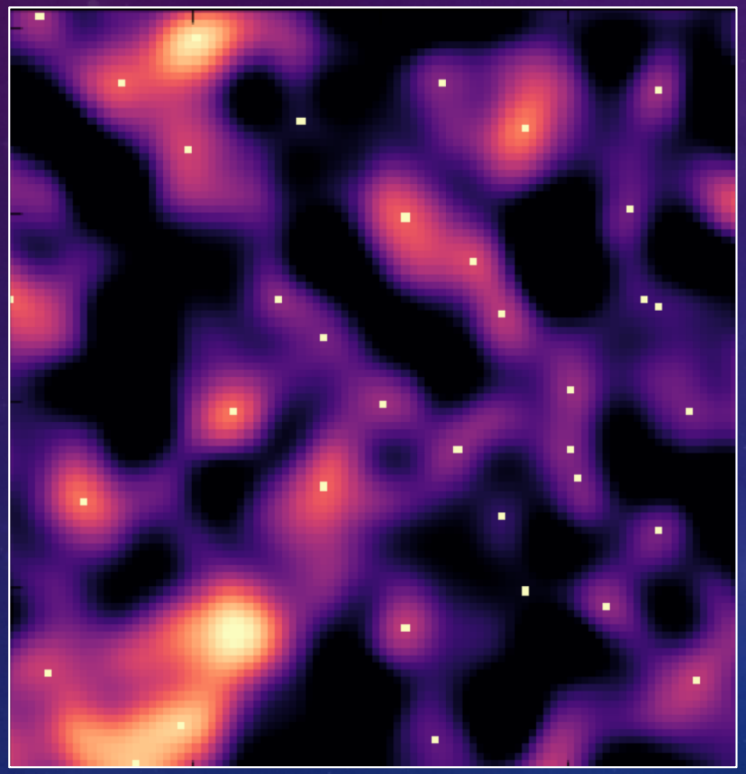
WEAK LENSING FIELD

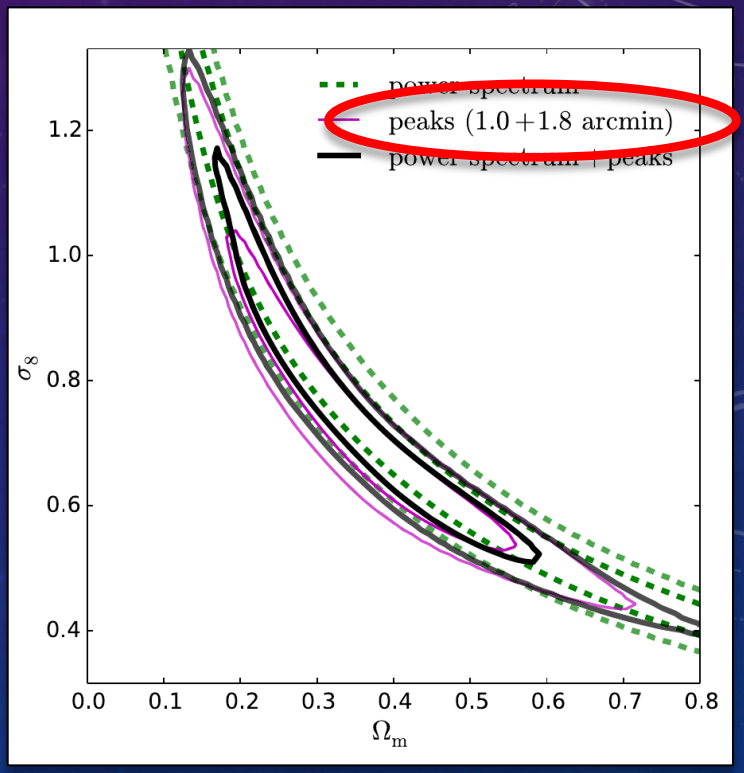


Teyssier, Pires et al, 2009

Full-sky convergence map derived from the Horizon simulation

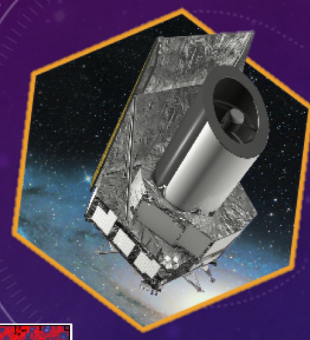
HIGHER-ORDER STATISTICS

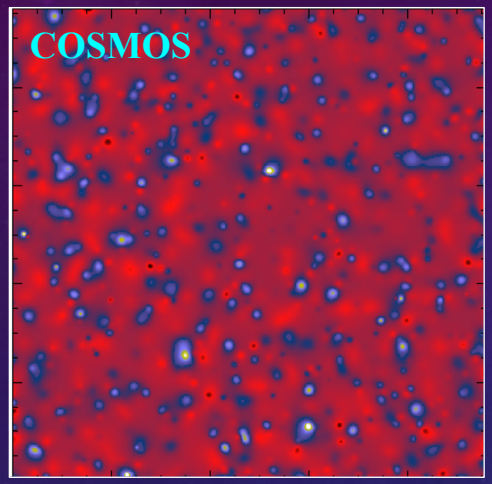


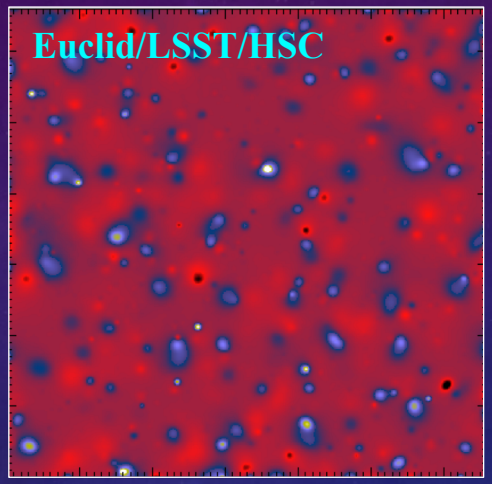


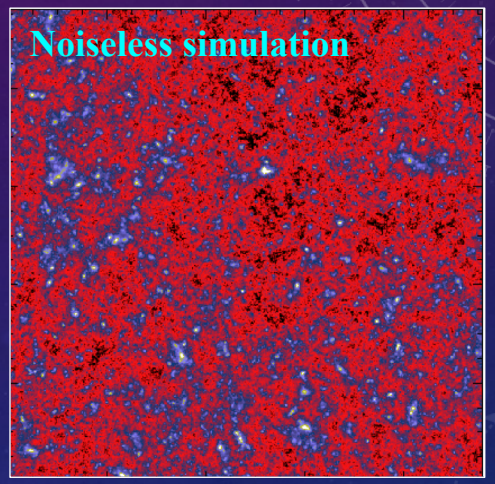
J. Liu et al., PhRvD, 2015

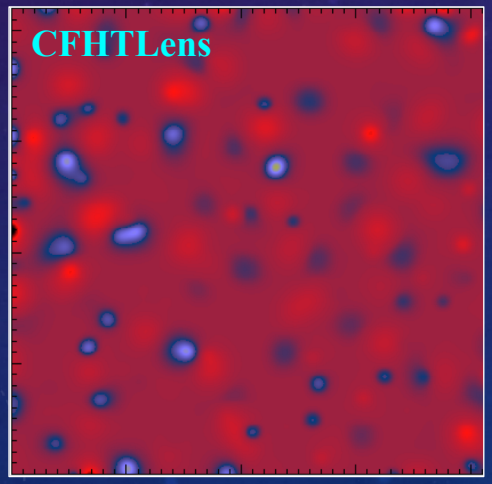
WEAK LENSING MASS MAP RESOLUTION

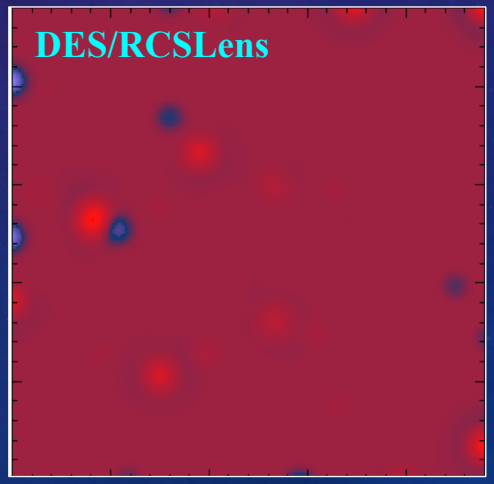












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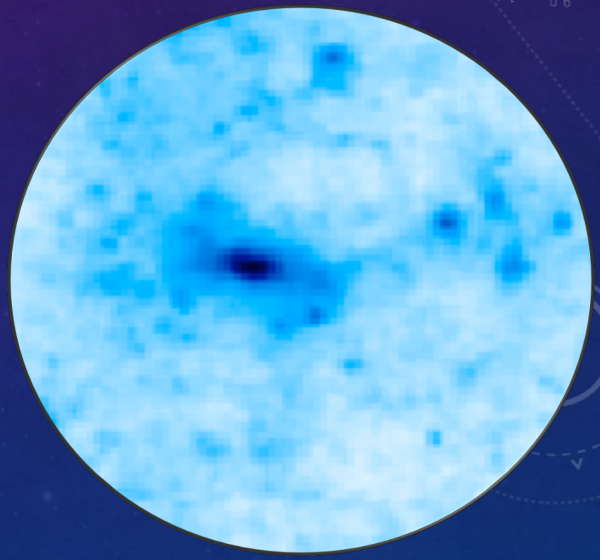
WEAK LENSING MASS MAPS SYSTEMATICS

Image distortions called **shear**

- Missing data
- Border effects
- Noise effect
- Reduced shear observable

mass mapping



Projected dark matter distribution called **convergence**

EUCLID MASS MAPPING PIPELINE

- Standard kaiser and squires [Kaiser and squires 1993, KS]

$$\hat{\kappa} = \hat{P}^* \hat{\gamma} \qquad \hat{P}_1(\boldsymbol{\ell}) = \frac{\ell_1^2 - \ell_2^2}{\ell^2}, \qquad \hat{P}_2(\boldsymbol{\ell}) = \frac{2\ell_1\ell_2}{\ell^2},$$

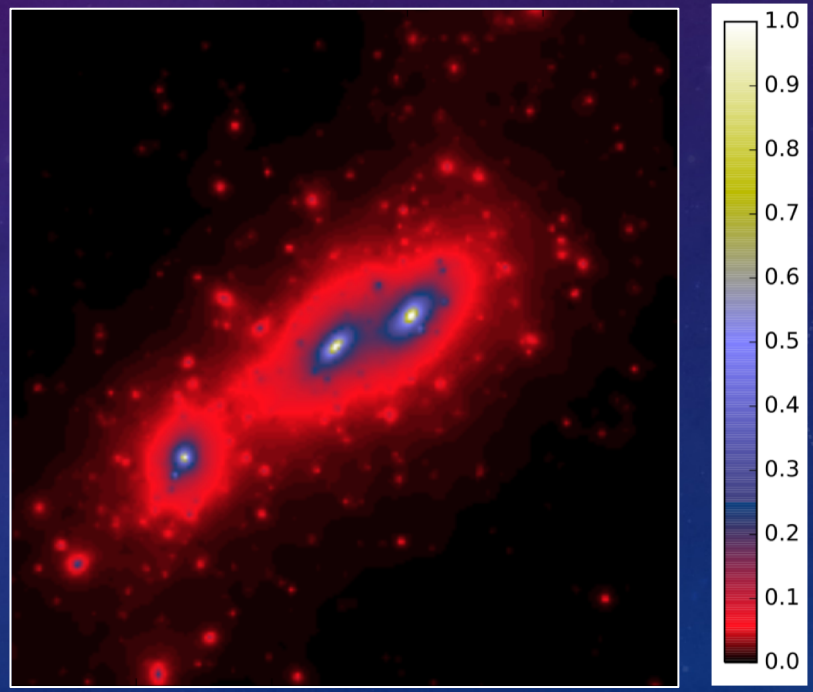
- Improved Kaiser and squires [Pires et al., to be submitted, KS+]

$$\min_{\boldsymbol{\kappa}^{\mathbf{n}}} \|\boldsymbol{\Phi}^{\mathrm{T}}\boldsymbol{\kappa}^{\mathbf{n}}\|_0 \text{ s.t. } \| \tilde{\boldsymbol{\gamma}} - \mathbf{MPW}^{\mathrm{T}}\mathbf{QW}\boldsymbol{\kappa}^{\mathbf{n}} \|^2 \leq \sigma^2$$

DEALING WITH REDUCED SHEAR

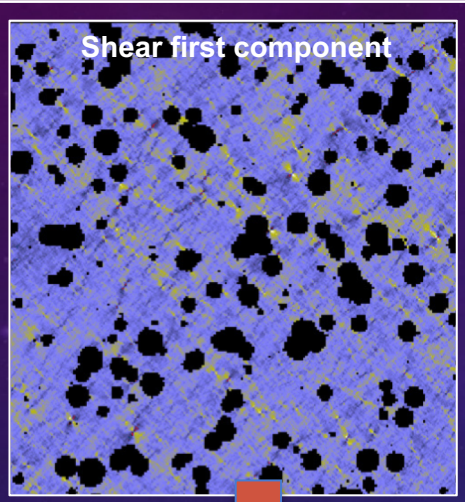
SECOND-ORDER STATISTICS

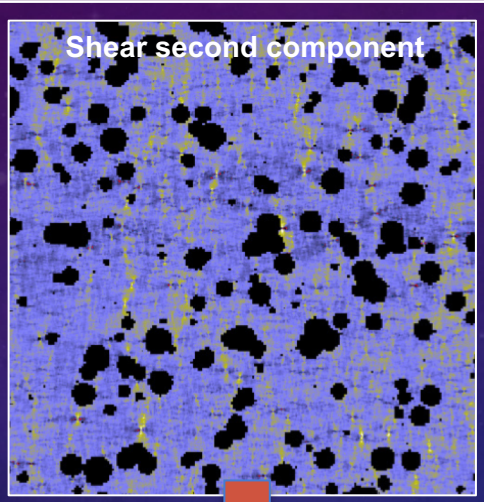
$$g \equiv \frac{\gamma}{1-\kappa}.$$

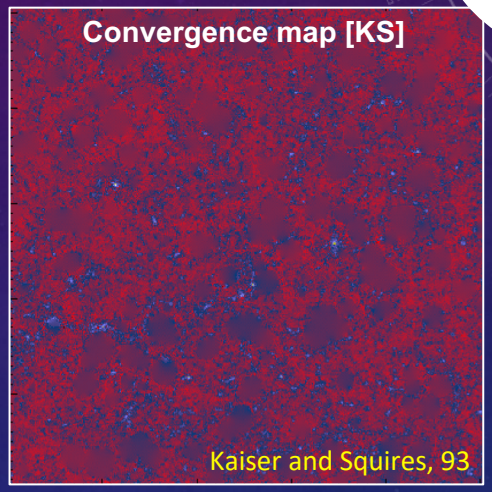


Cluster of galaxies

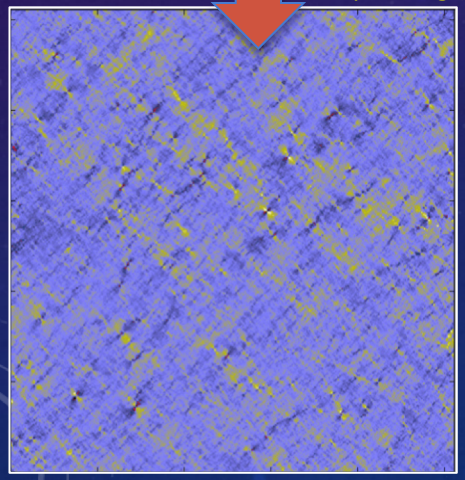
DEALING WITH MISSING DATA

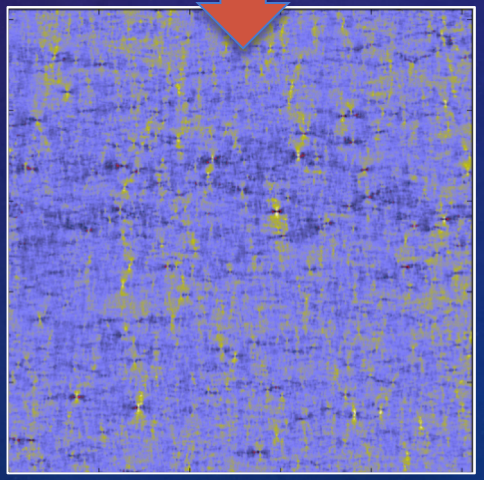


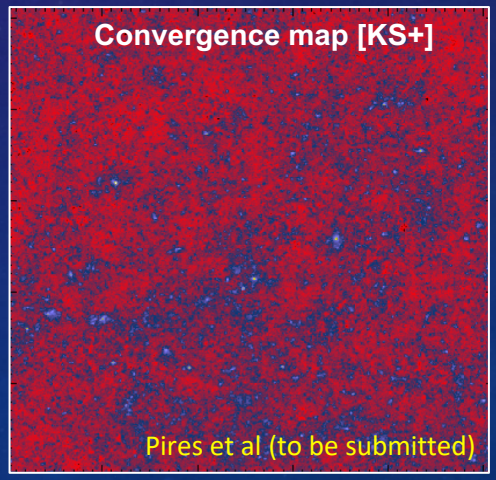




Inpainting (Pires et al. 2009)

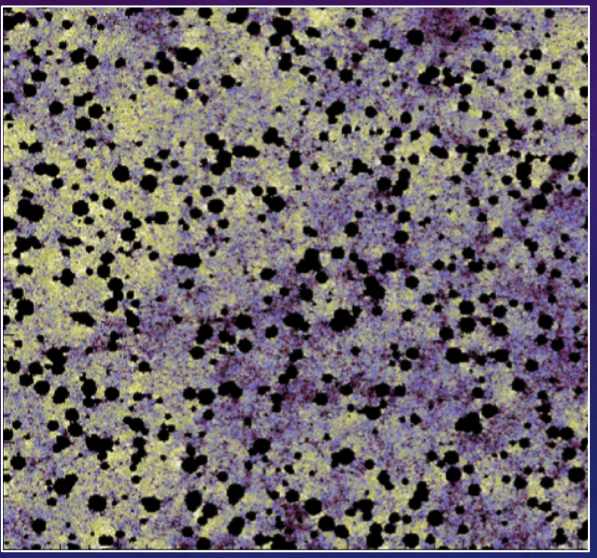




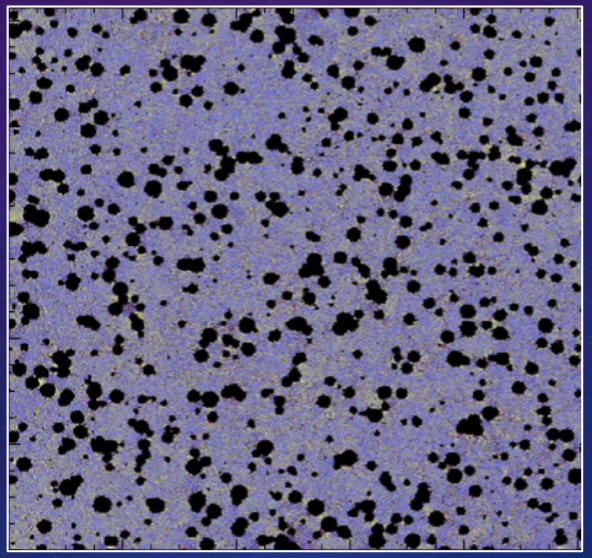


DEALING WITH MISSING DATA

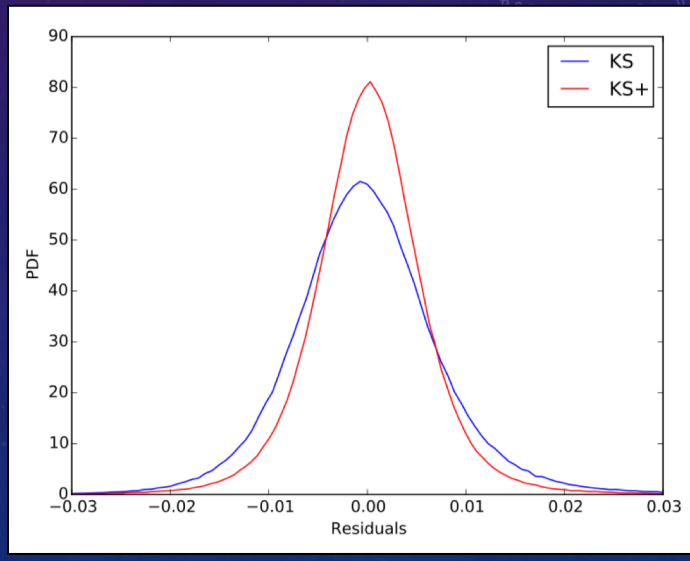
FIRST-ORDER STATISTICS



KS residual errors



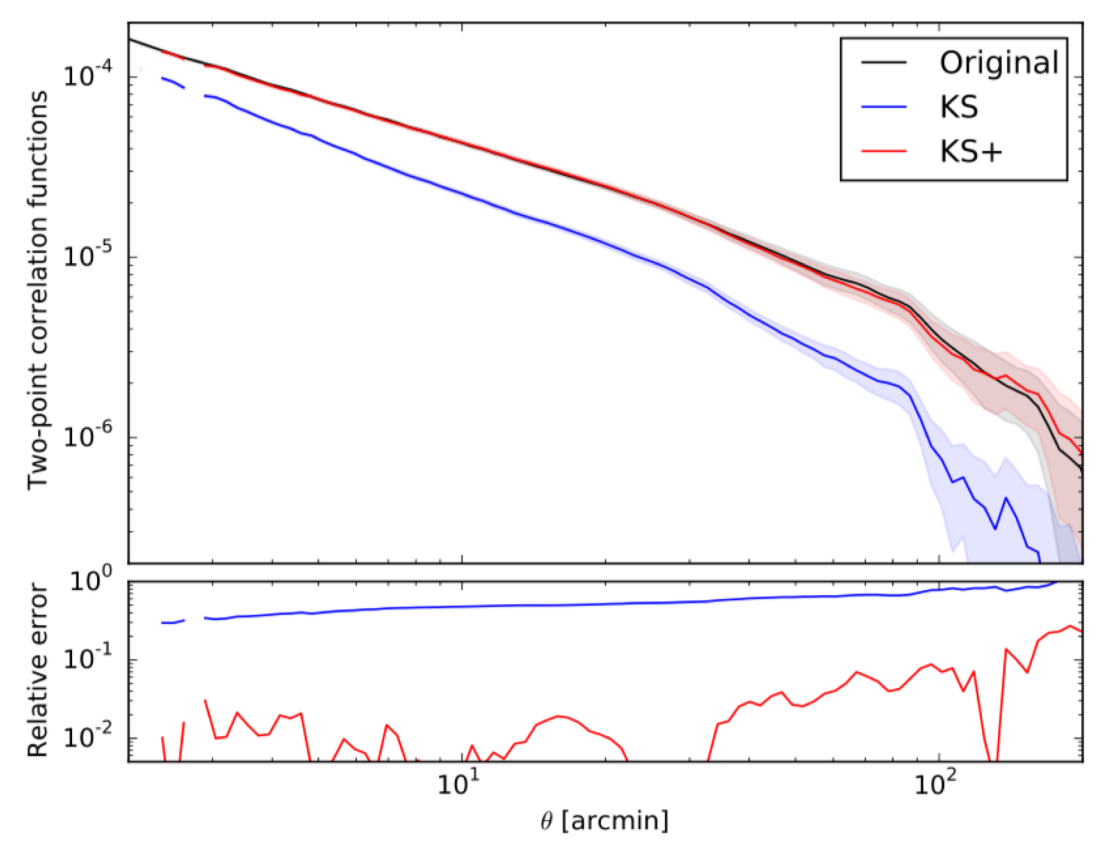
KS+ residual errors



PDF of residual errors

DEALING WITH MISSING DATA

SECOND-ORDER STATISTICS

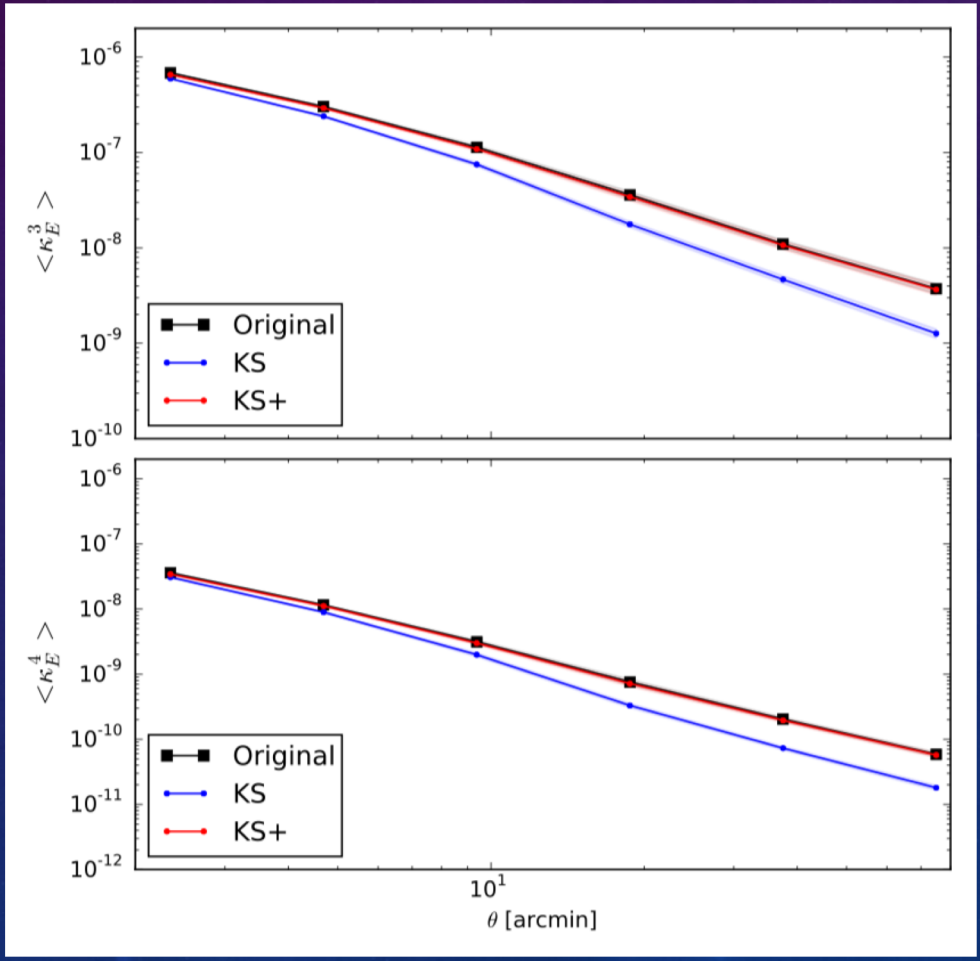


Shaded area represent the standard error on the mean estimated from 1000° sq

Pires et al (to be submitted)

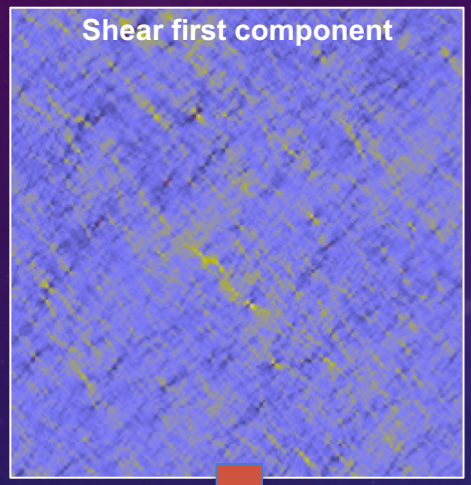
DEALING WITH MISSING DATA

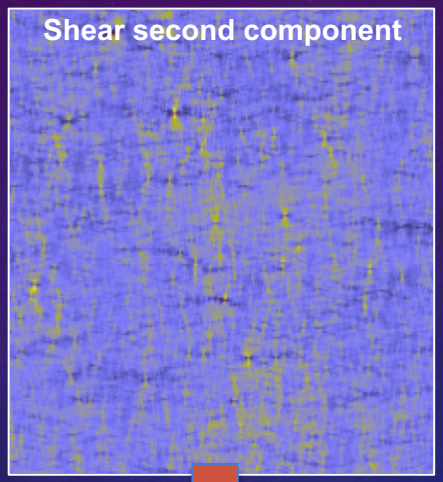
THIRD- AND FOURTH-ORDER MOMENTS

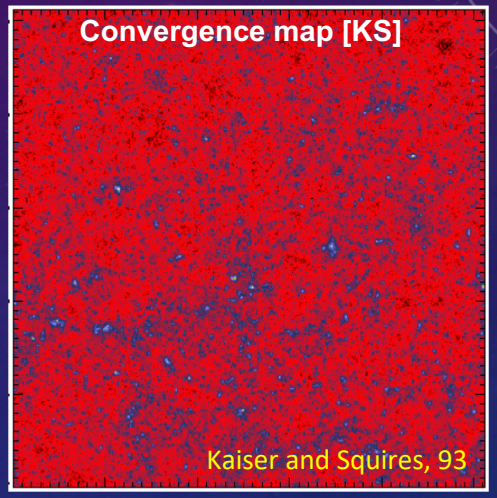


Pires et al, 2019 (submitted)

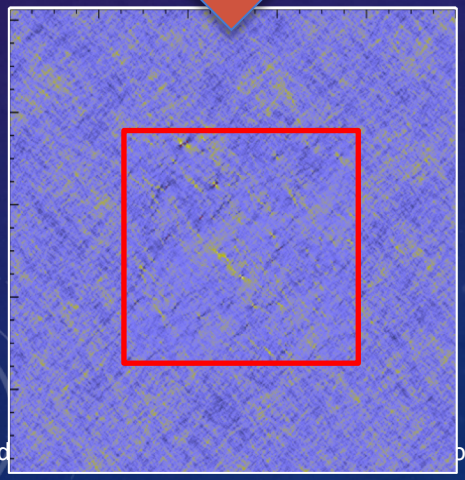
DEALING WITH BOUNDARY EFFECT DATA

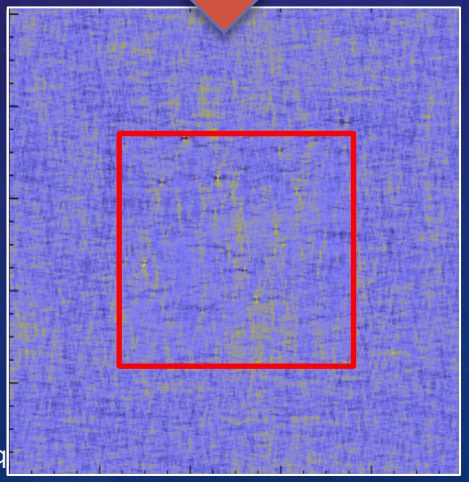


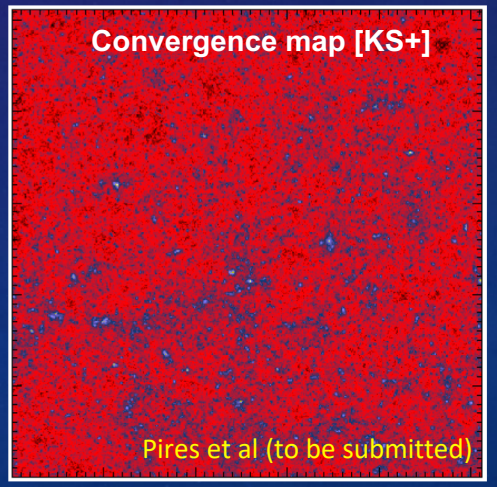




Inpainting (Pires et al. 2009)

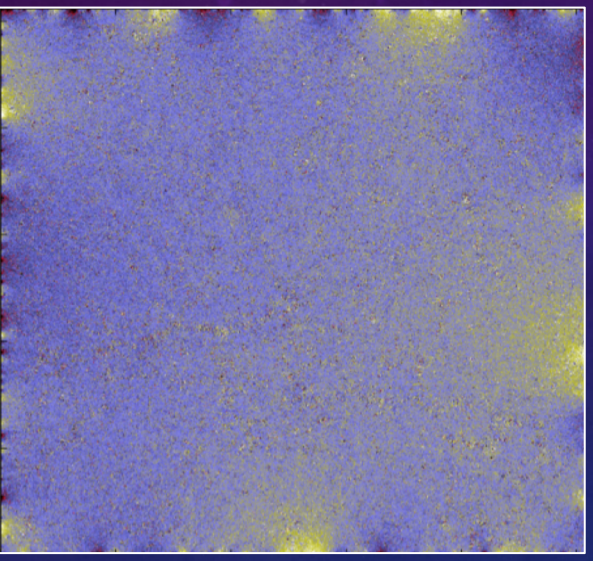




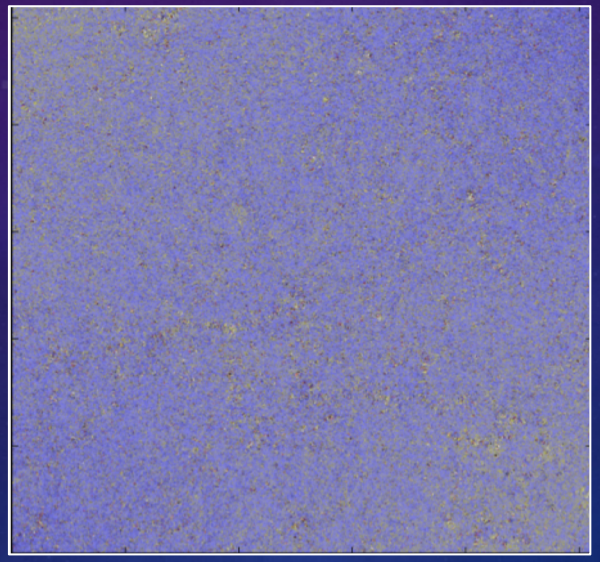


DEALING WITH BOUNDARY EFFECT

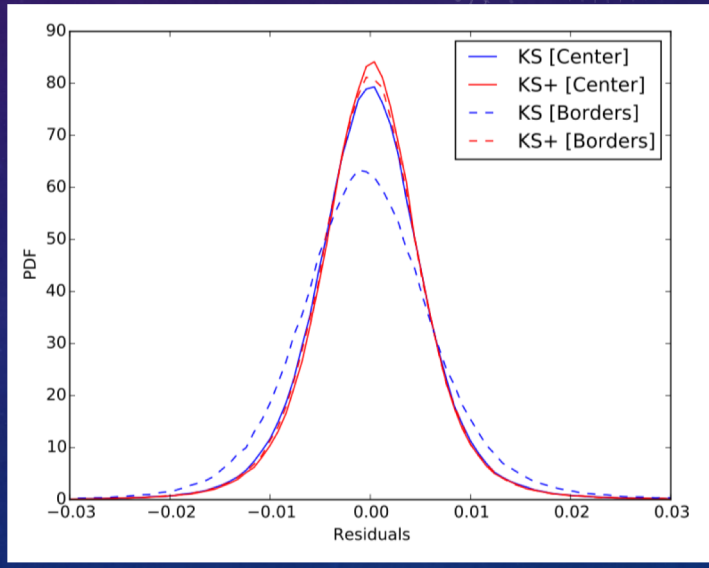
FIRST-ORDER STATISTICS



KS residual errors

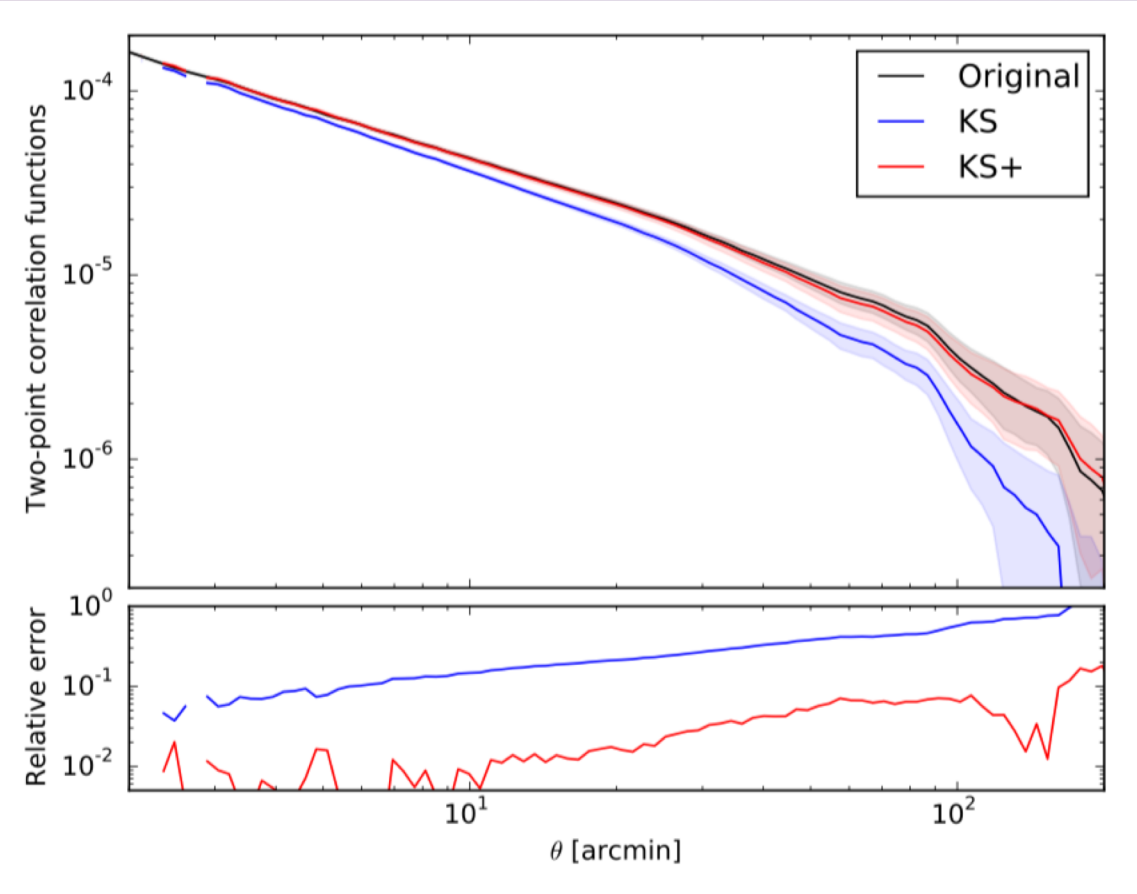


KS+ residual errors



DEALING WITH BOUNDARY EFFECT

SECOND-ORDER STATISTICS

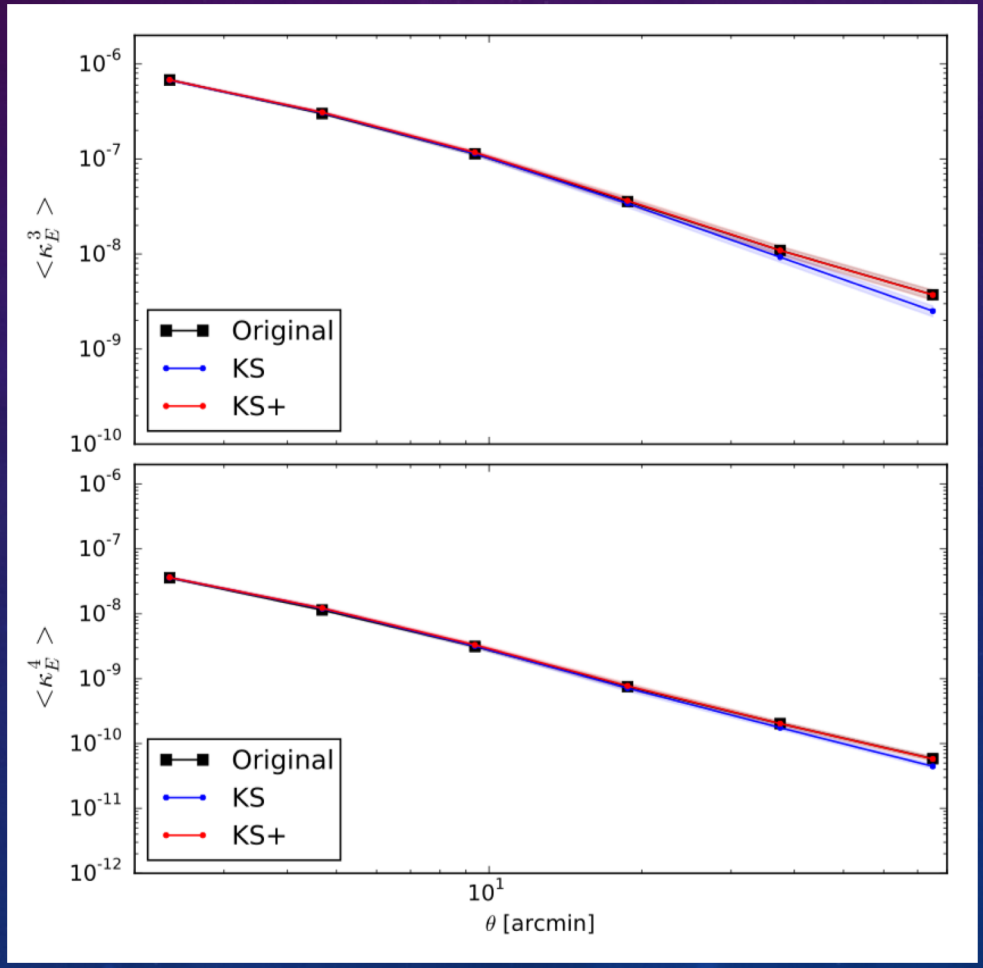


Shaded area represent the standard error on the mean estimated from 1000° sq

Pires et al (to be submitted)

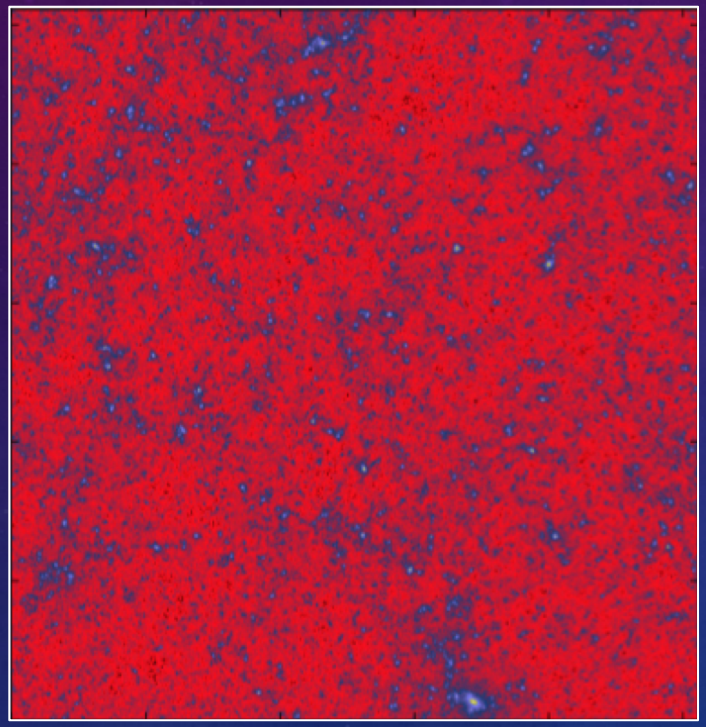
DEALING WITH BOUNDARY EFFECTS

THIRD- AND FOURTH-ORDER MOMENTS

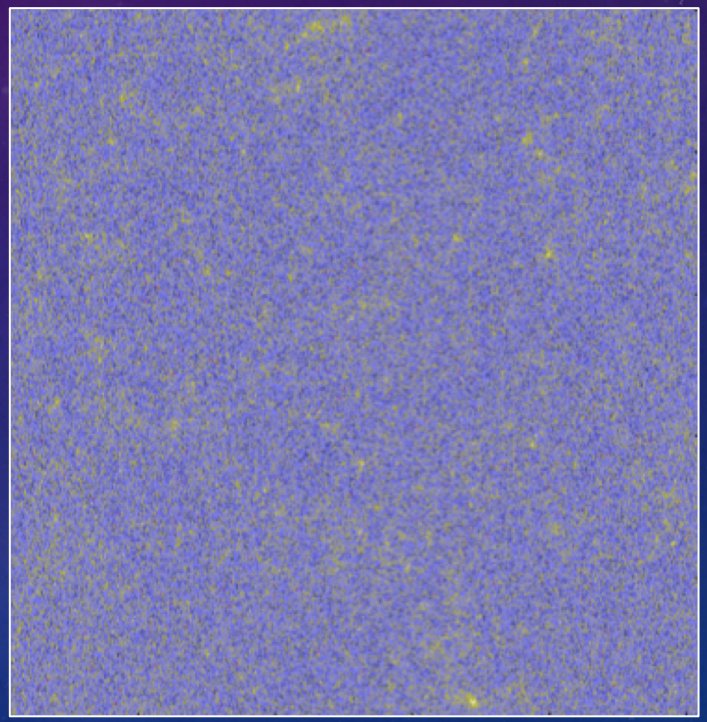


Pires et al (to be submitted)

DEALING WITH NOISE



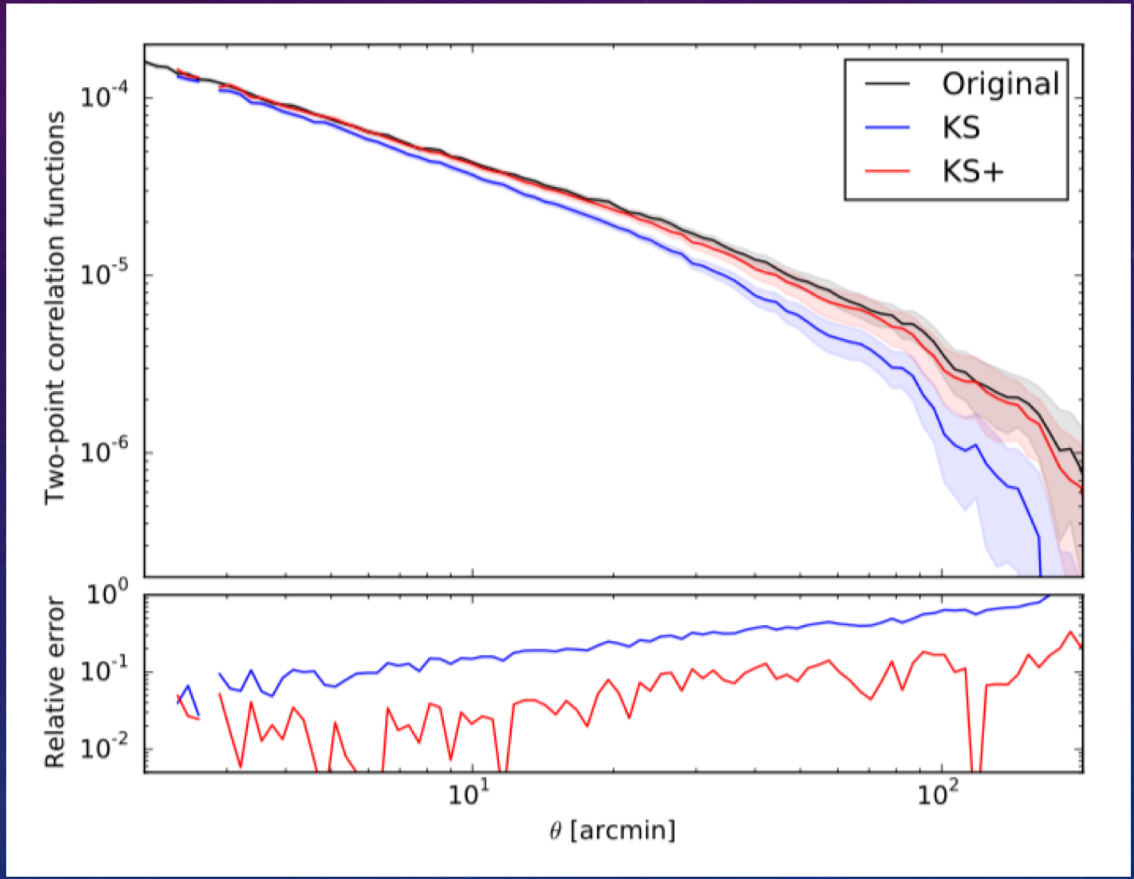
Without noise



With noise

DEALING WITH NOISE

SECOND-ORDER STATISTICS

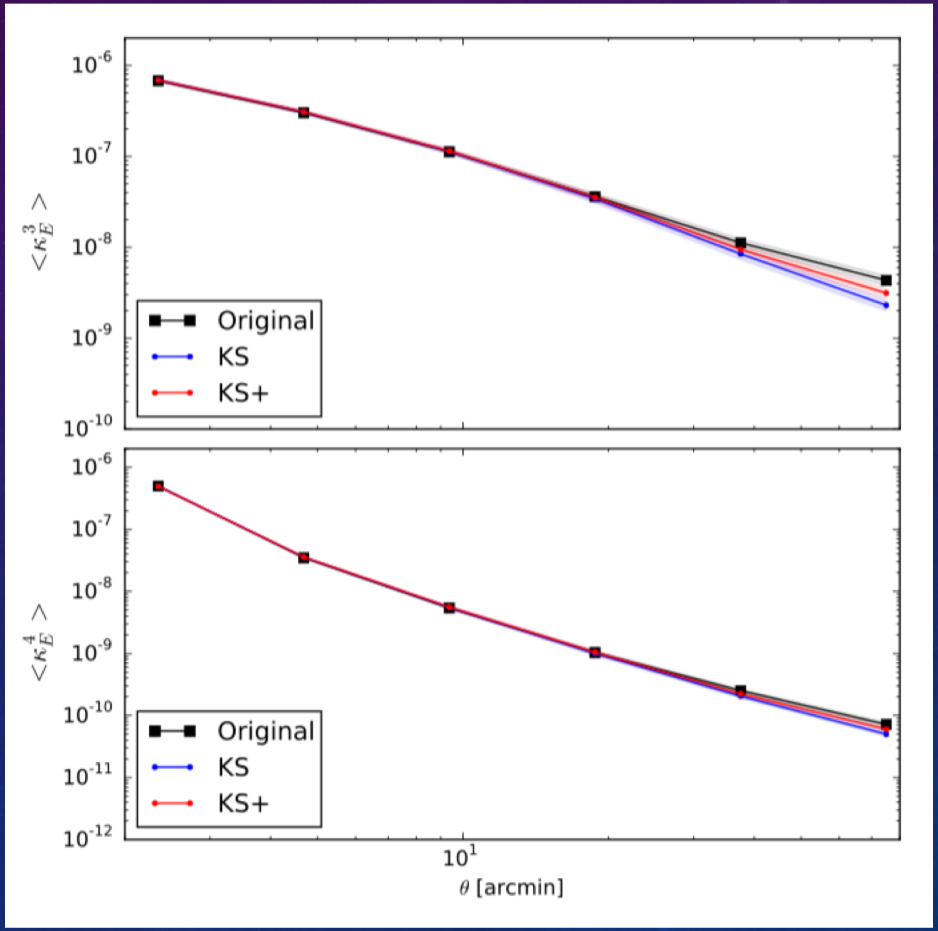


Shaded area represent the standard error on the mean estimated from 1000° sq

Pires et al (to be submitted)

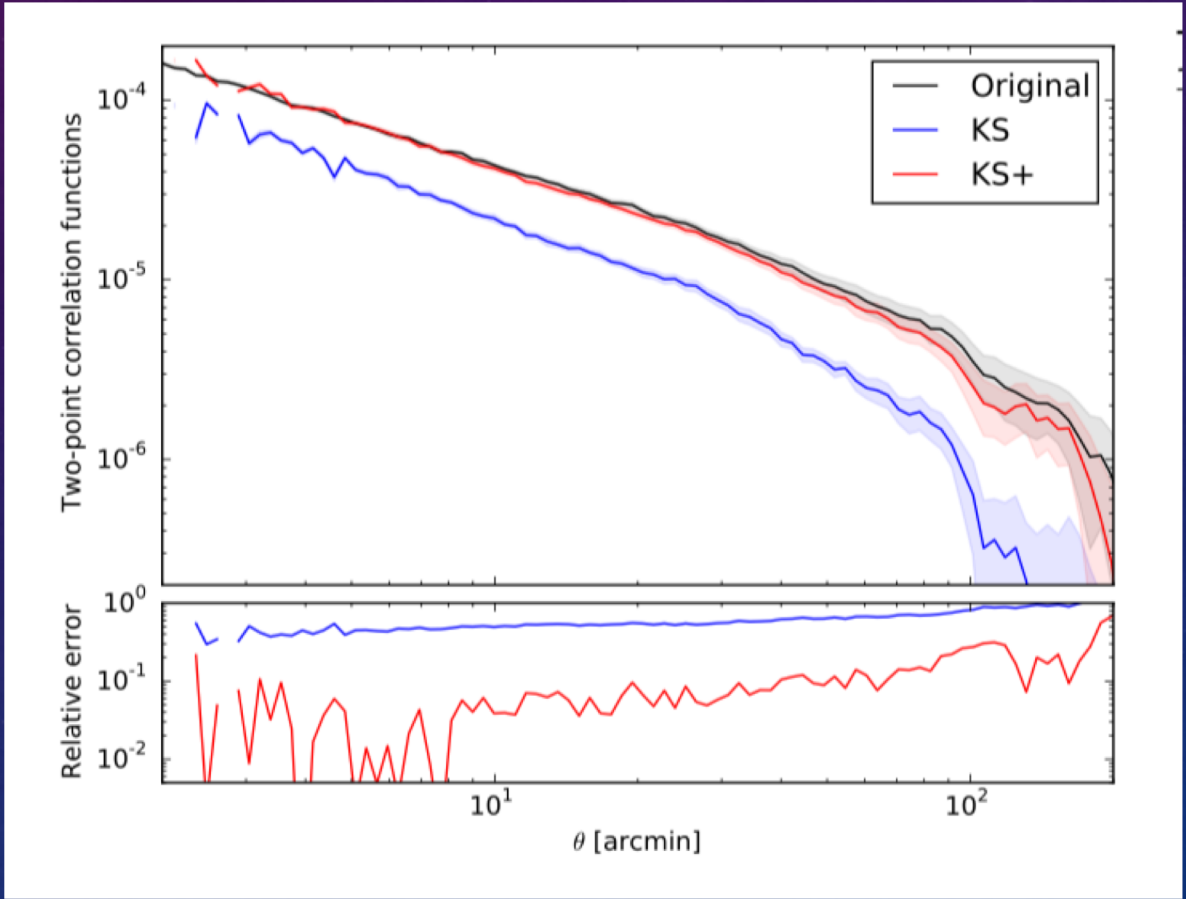
DEALING WITH NOISE

THIRD- AND FOURTH-ORDER MOMENTS



Pires et al (to be submitted)

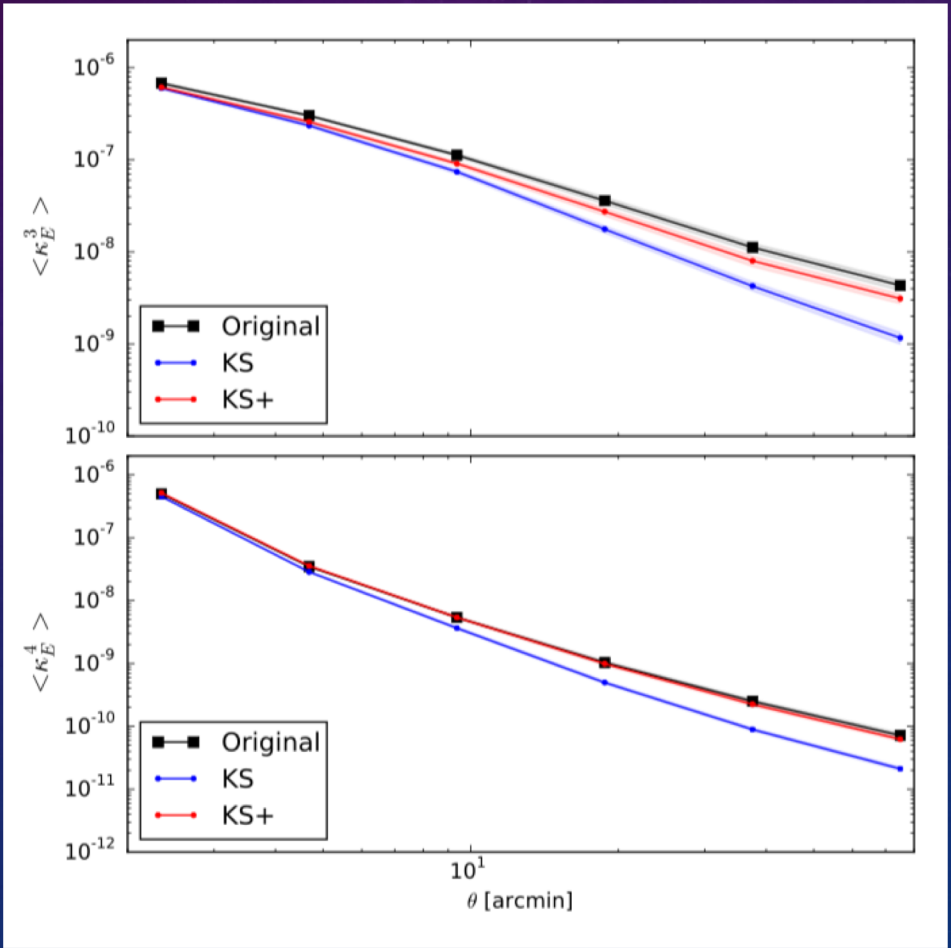
DEALING WITH ALL SYSTEMATIC EFFECTS



Shaded area represent the standard error on the mean estimated from 1000° sq

Pires et al (to be submitted)

DEALING WITH ALL SYSTEMATIC EFFECTS



Pires et al (to be submitted)

OUTLINE

- Introduction
- Weak lensing data analysis
- Weak lensing mass maps systematics
- Ongoing projects

HOWL'S PROJECT

HIGHER-ORDER WEAK LENSING STATISTICS

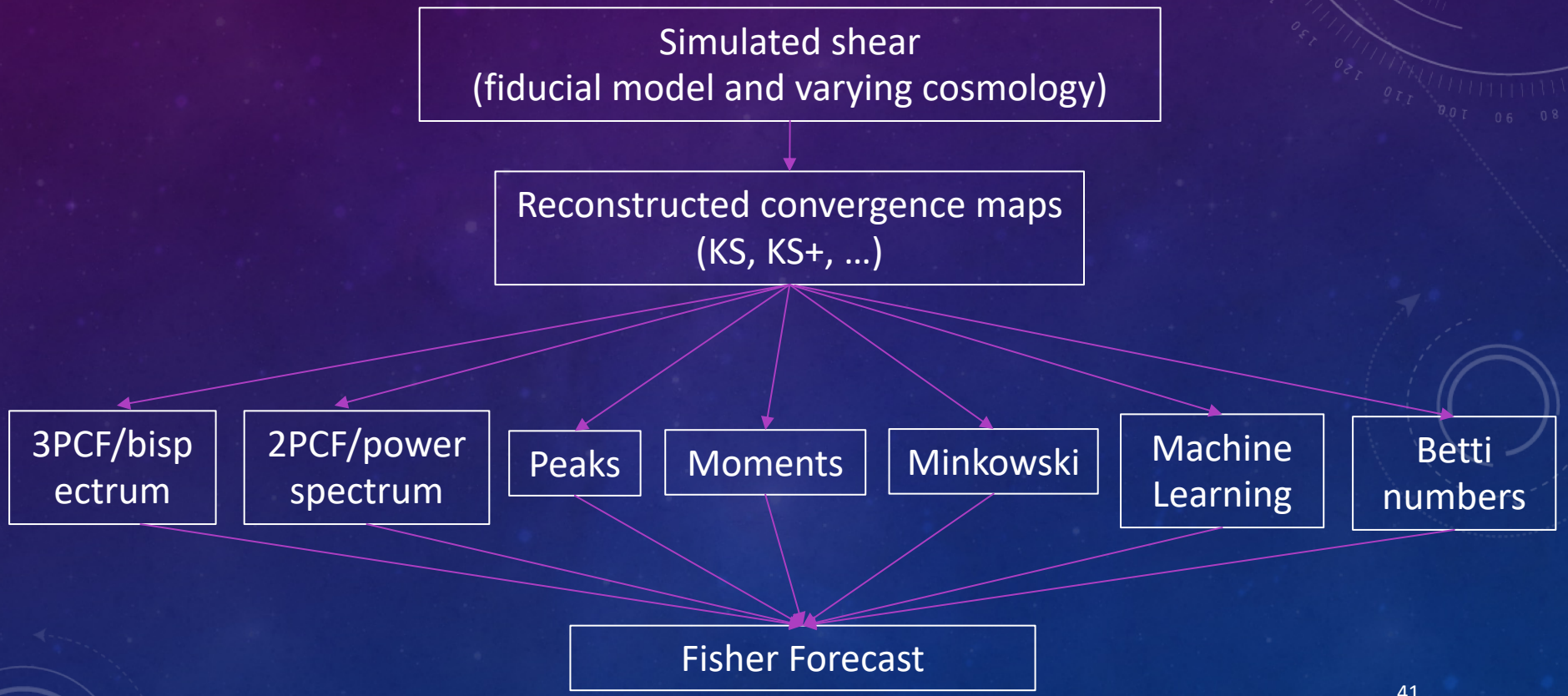
Collaborative project between different groups in Euclid to compare different higher-order estimators based on the same set of reconstructed convergence maps.

- *Going higher than 2nd order to break parameters degeneracies*
- *Compare different mass inversion methods to find the best strategy*
- *Quantify the impact of systematics in self consistent way*
- *Check for correlations among probes and with 2nd order statistic*
- *Compare different HOS to find the best strategy*

On behalf of the Howl's project members

HOWL'S PROJECT

HIGHER-ORDER WEAK LENSING STATISTICS

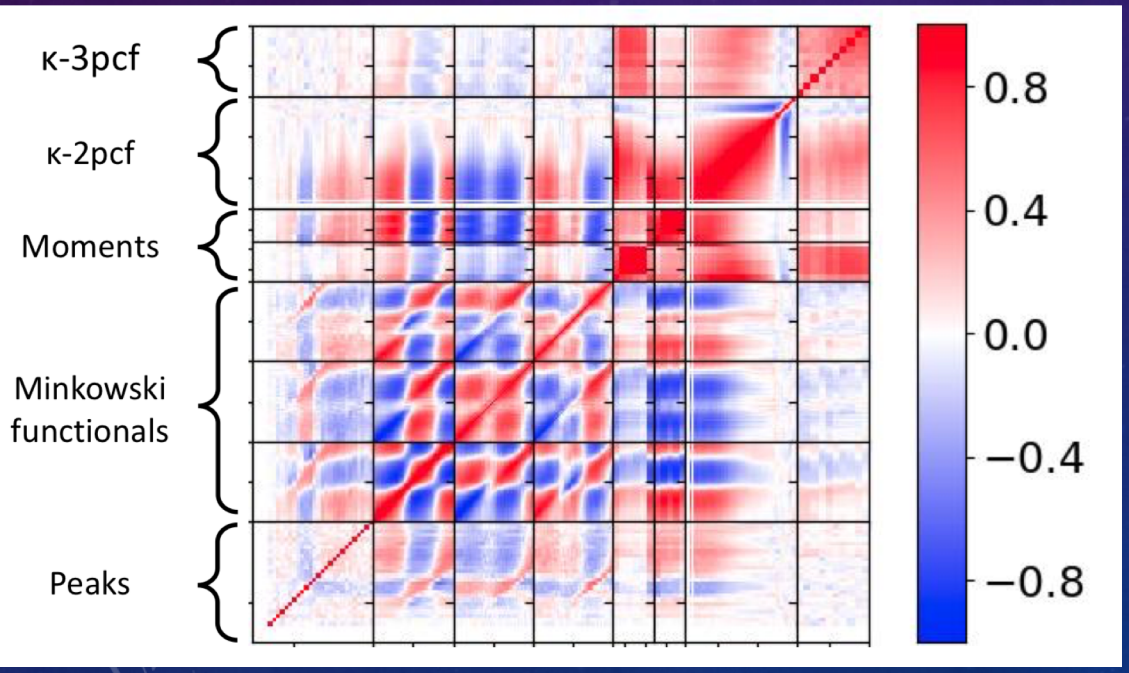


On behalf of the Howl's project members

HOWL'S PROJECT

STEP 1 [NOVEMBER 2018]

Participants (step 1): Nicolas Martinet, Sandrine Pires, Vincenzo F. Cardone, Ismael Tereno, Carlo Giocoli, Marco Baldi, Carolina Parroni, Martina Vicinanza, Austin Peel.



- High correlation between statistics
- Importance of the filtering (Gaussian vs wavelet)

On behalf of the Howl's project members

HOWL'S PROJECT

STEP 2 [IN PROGRESS]

Participants (step 2): Nicolas Martinet, Sandrine Pires, Vincenzo F. Cardone, Ismael Tereno, Carlo Giocoli, Marco Baldi, Carolina Parroni, Martina Vicinanza, Austin Peel, Martin Kilbinger.

Statistics	$\delta\Omega_{\rm m}$ for $\Delta\Omega_{\rm m} = 0.2$	$\delta\Omega_{\rm m}$ (%) for $\Delta\Omega_{\rm m} = 0.2$
peaks	4.12×10^{-4}	0.13
MFs	7.33×10^{-4}	0.23
Betti	-	-
moments	4.51×10^{-4}	0.14
κ2pcf	6.45×10^{-4}	0.21
peaks+MFs+moments	6.02×10^{-4}	0.19
peaks+MFs+moments+κ2pcf	4.34×10^{-4}	0.14

On behalf of the Howl's project members

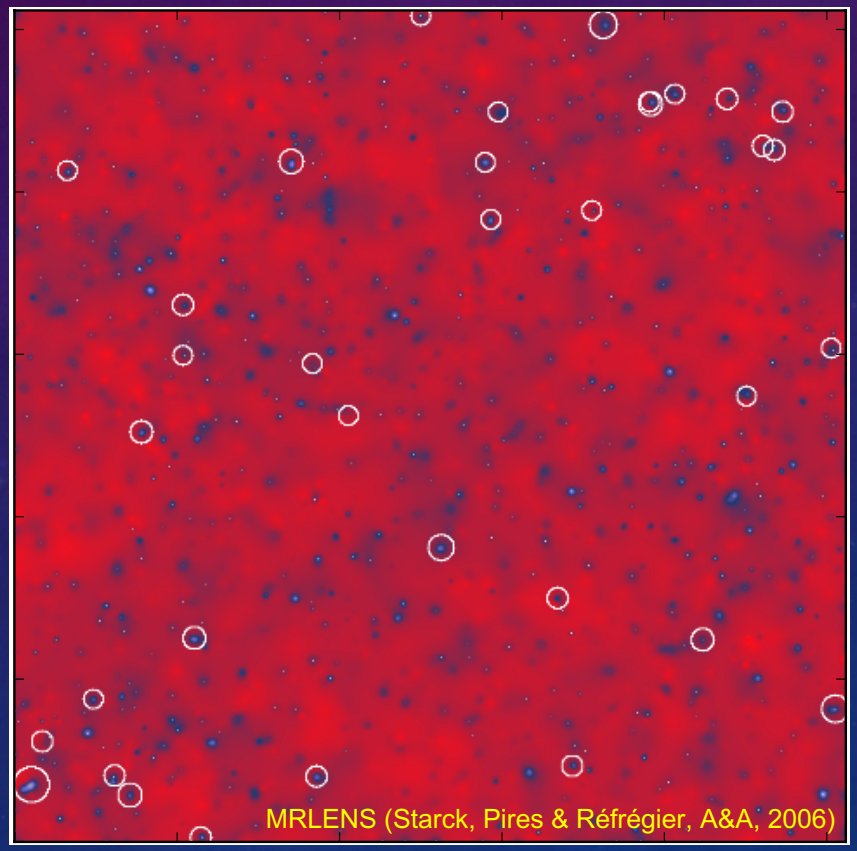
WEAK LENSING CLUSTER CATALOG

Contributors: L. Leroy, S. Pires, G. Pratt, M. Arnaud, J.-B. Melin, R. Gavazzi, B. Sartoris

- WL cluster detection
  - Mass aperture : ra, dec
  - 2D denoised convergence maps: ra, dec
- WL cluster mass estimation
  - NFW profile
  - Mass aperture

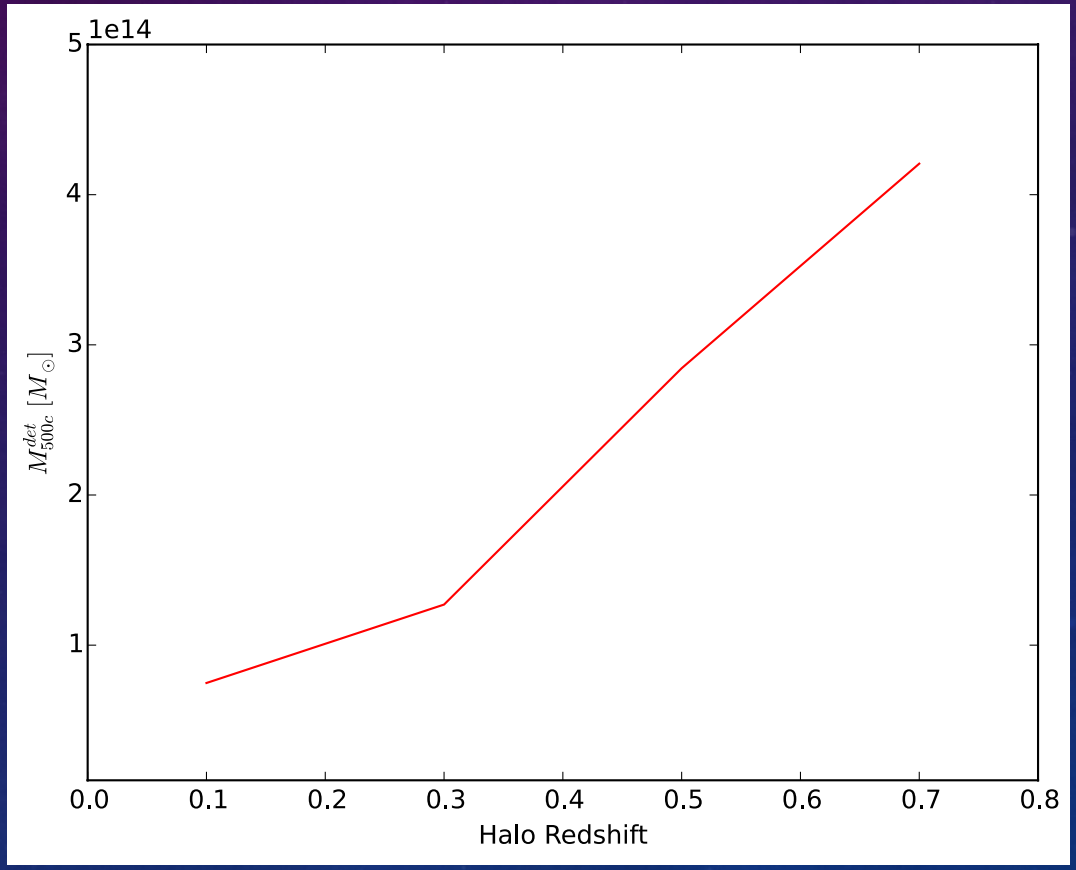
Characterization of the weak lensing systematic effects

WEAK LENSING CLUSTER DETECTION
[2D CONVERGENCE MAP OF 10°X10° FIELD]

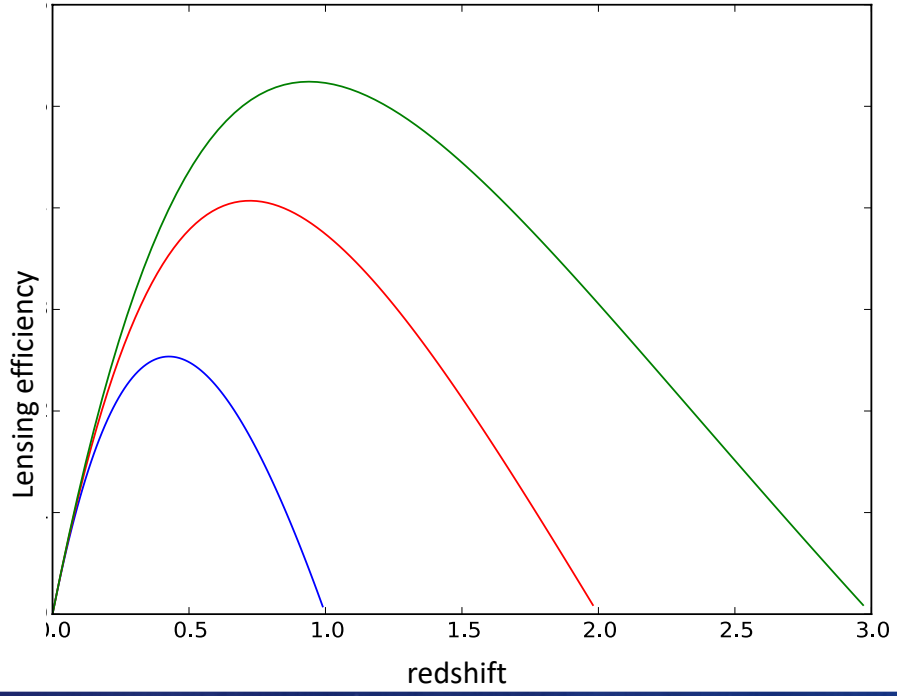


Clusters with (M_{500c} > 10^{14} $M_\odot$/h and 0.2 < z_h < 0.4) overplotted on the WL mass map (0.5 < z_s < 2.3)

CLUSTER DETECTION MASS LIMIT
[95% COMPLETUDE]



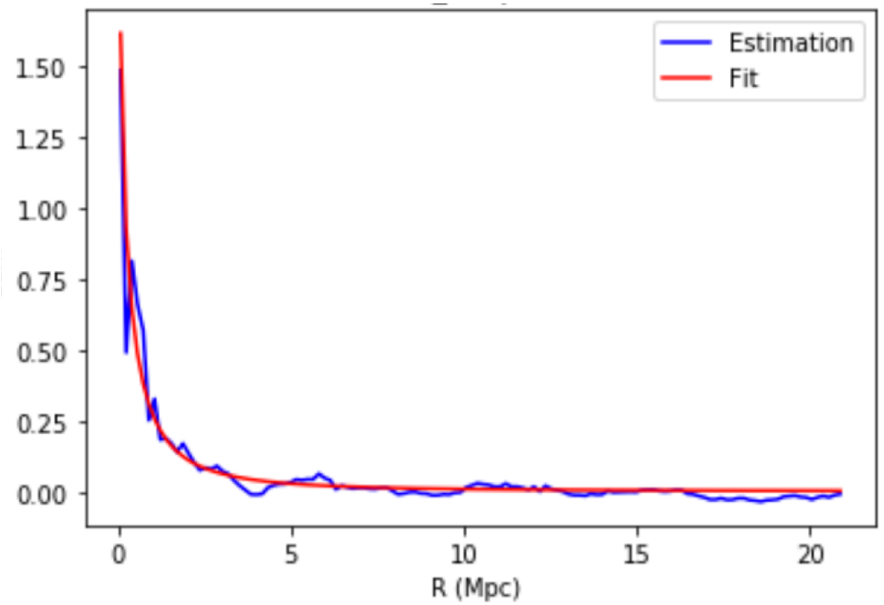
WL CLUSTER MASS ESTIMATION



$$\kappa(\theta) = \frac{\Sigma(\theta)}{\Sigma^{\infty}_{\rm crit}}$$

$$\Sigma^{\infty}_{\rm crit} = \frac{c^2}{4\pi G}\frac{D_S}{D_L D_{LS}}$$

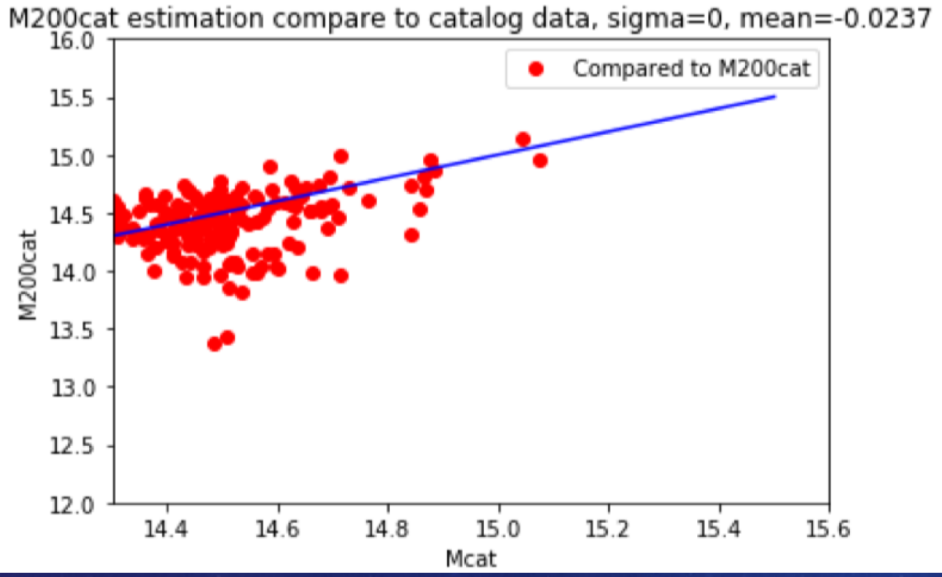
SURFACE MASS DENSITY FIT



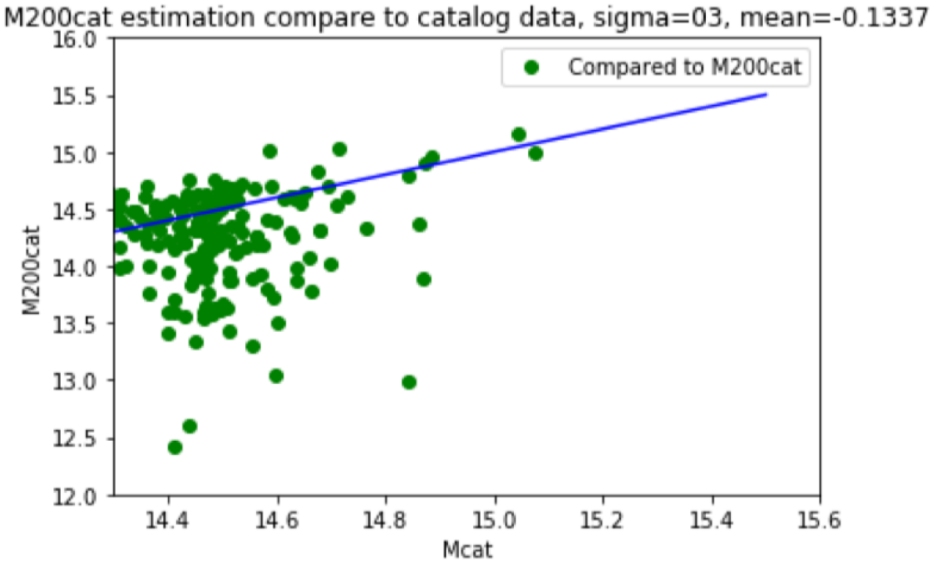
$$\Sigma_{\mathrm{NFW}}(x) = \begin{cases} \dfrac{2r_s\delta_c\rho_c}{(x^2-1)}\left[1 - \dfrac{2}{\sqrt{1-x^2}}\operatorname{arctanh}\sqrt{\dfrac{1-x}{1+x}}\right] & x < 1 \\ \dfrac{2r_s\delta_c\rho_c}{3} & x = 1 \\ \dfrac{2r_s\delta_c\rho_c}{(x^2-1)}\left[1 - \dfrac{2}{\sqrt{x^2-1}}\arctan\sqrt{\dfrac{x-1}{1+x}}\right] & x > 1 \end{cases}$$

Wright, C.O. & Brainerd T.G. 2000

SURFACE MASS DENSITY APERTURE



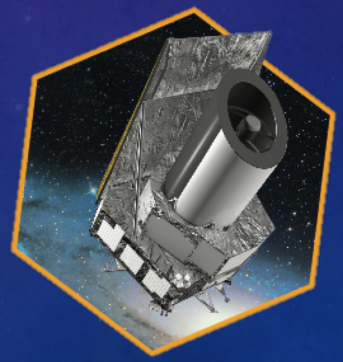
Without noise



With noise

CONCLUSION

- Second-order statistics are not sufficient to constrain the weak lensing field
- The convergence maps contain the same infomation than the shear maps
- The non-Gaussian information is easier to extract from the convergence maps
- Mass Mapping Systematic effects can be controlled during the mass inversion
- The convergence maps are a very promising tool



THANK YOU FOR YOUR ATTENTION