EUCLID

Weak Lensing Measurements

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on behalf of the Euclid CEA-Saclay Team

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WL Measurements

- **PSF Modeling**
- Galaxy Shape Measurements (shear)
- Shear Catalog Creation

} OU-Shear

- **2D & 3D Mass Mapping**
- **Peak Counting & High Order Stat**
- **2 Point Correlation function**
- **Power spectra**

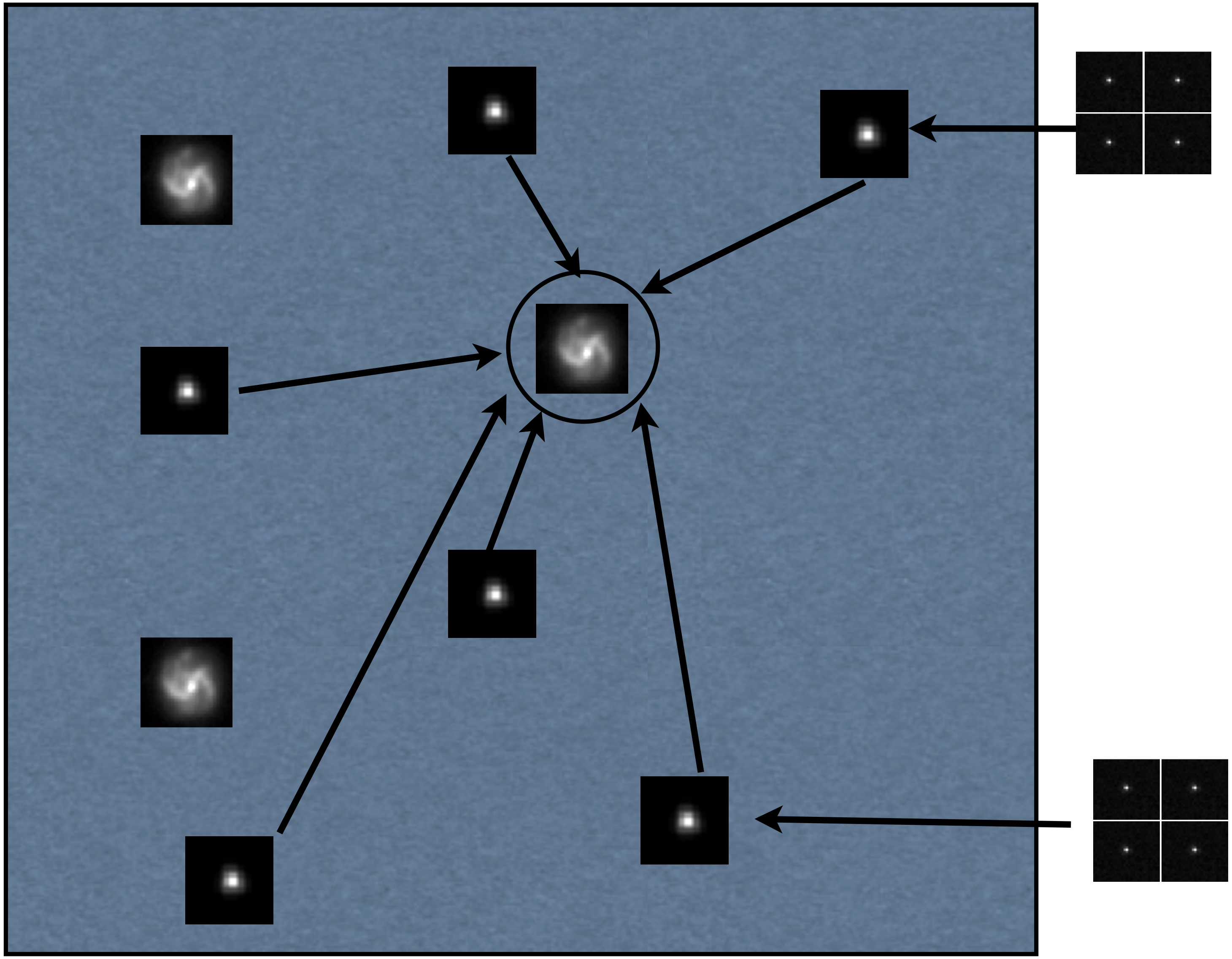
} OU-LE3

=> OULE3 Nice meeting, Dec 18-19, 2013

First evaluation results

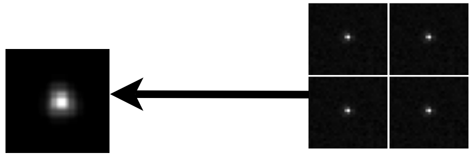
http://adlibitum.oats.inaf.it/meetings/EuclidNice2013

PSF Representation



Super Resolution in Astronomy

$$Y = HX + N$$



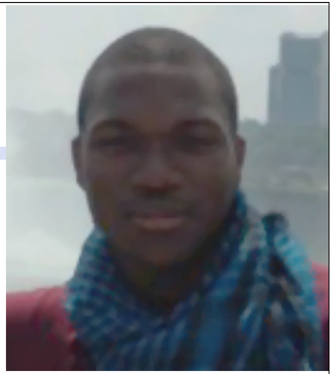
HR image $X = (x_{i,j}), 1 \leq i, j \leq NL$

LR Images $Y_k = (y_{k,i,j}), 1 \leq i, j \leq L$

- Shift-and-add or image stacking
  - ➡ Estimate the centroids (i_k, j_k) for each LR images Y_k
  - ➡ Oversample each image Y_k using a given interpolation method and shift it to match Y_1
  - ➡ Coadd all oversampled registered images
- PSFextractor (PSFext)

$$J(X) = \sum_{k=1}^{p} \sum_{i=1}^{L} \sum_{j=1}^{L} \frac{(y_{k,ij} - f_k \tilde{y}_{k,ij})^2}{\sigma_k^2} + \frac{\left\| X - X^{(0)} \right\|_{l_2}^2}{\sigma}$$

Sparse Regularization



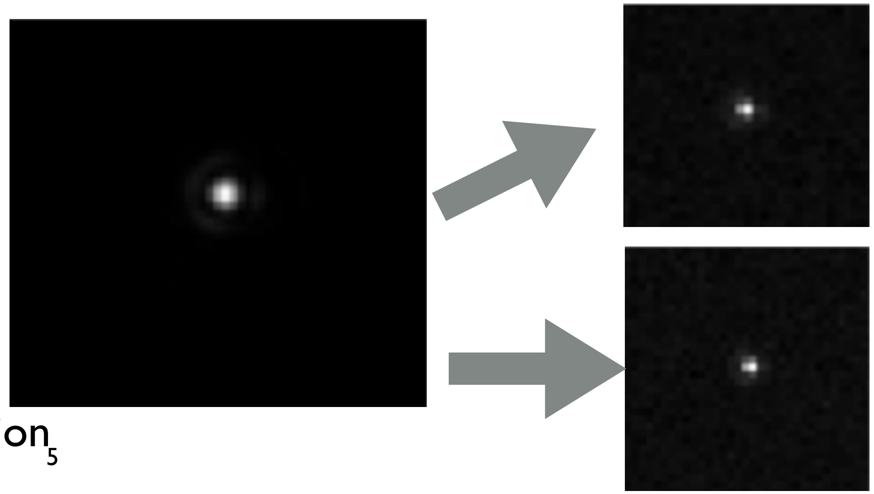
Fred Ngole

$$\left\{ \begin{array}{l} \min_{\Delta_X} \parallel Y - H(X^{(0)} + \Delta_X) \parallel_2^2 \\ \textbf{+ sparsity constraint} \quad \Delta_X = \Phi\alpha \\ X^{(0)} \quad \text{– calculated with shift-and-add} \\ \qquad\quad \text{– Registration based on centroids positions} \end{array} \right.$$

$$\min_{\Delta_X} \parallel Y - H(X^{(0)} + \Delta_X) \parallel_2^2 \quad s.t. \quad \lambda \parallel \Phi^t \Delta_X \parallel_1$$

Experiments

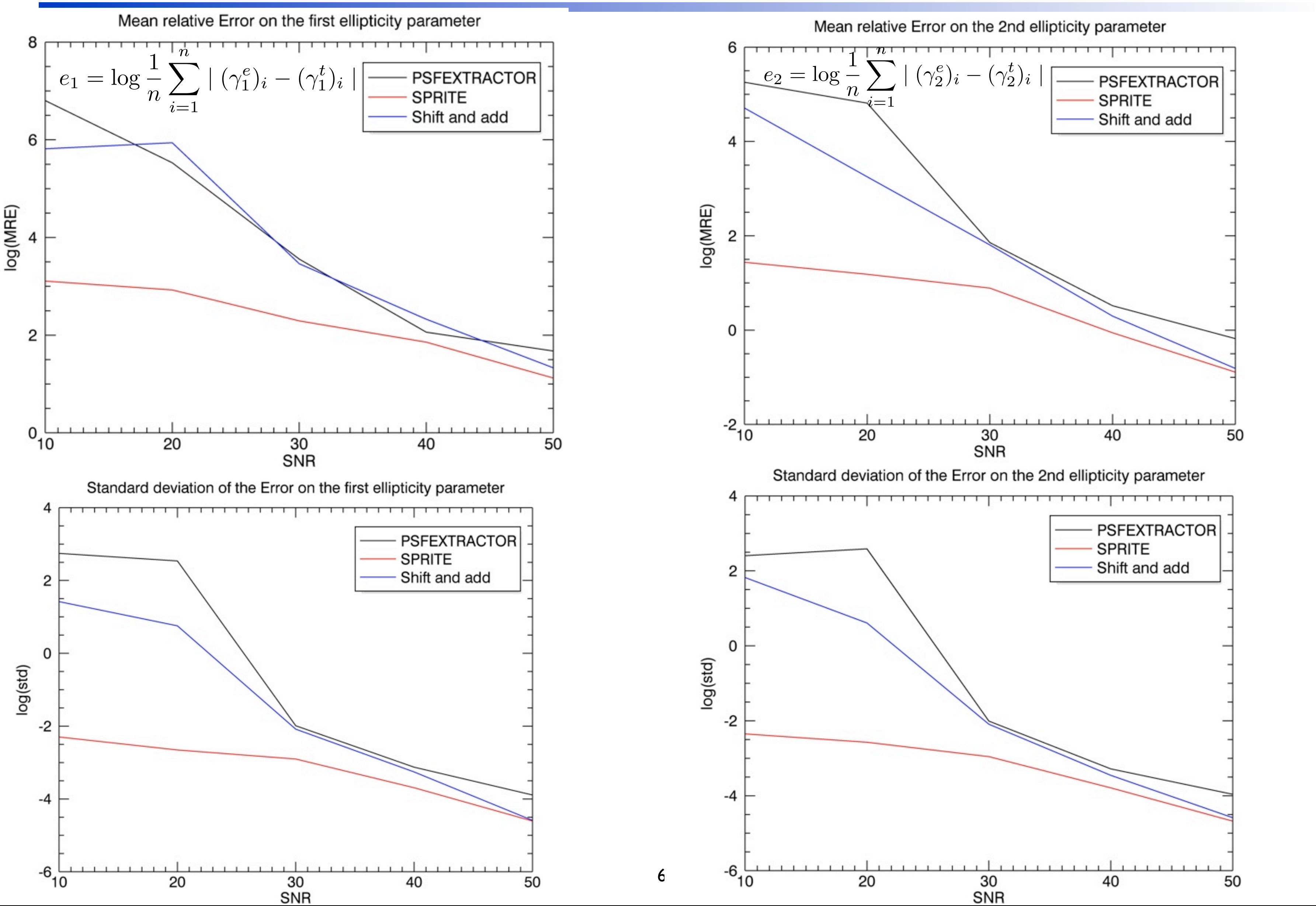
- 150 Zemax PSF at 12 x Euclid Resolution
- For each PSF, 4 randomly shifted and noisy PSF at Euclid resolution

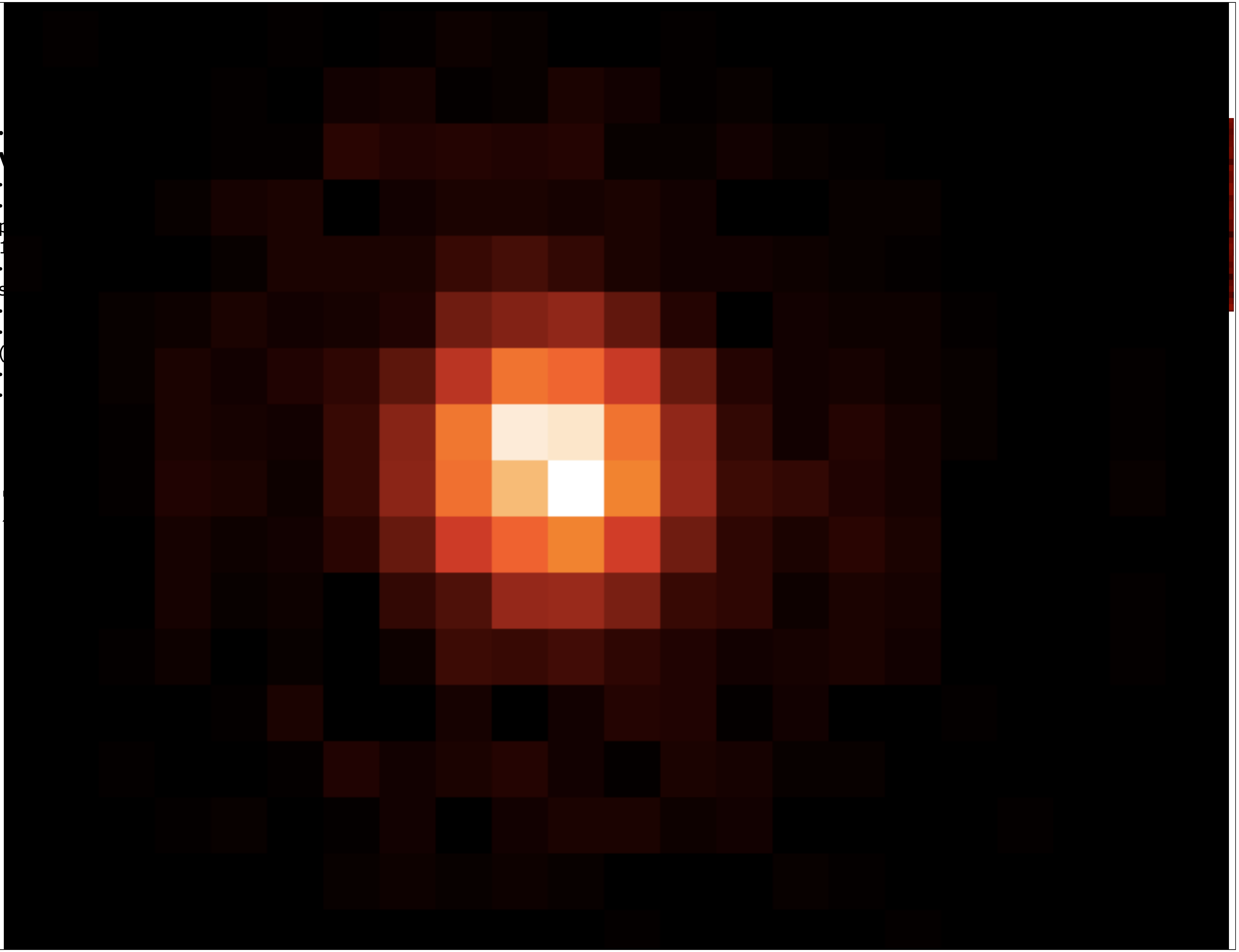


GOAL: PSF modeling at twice Euclid resolution

Numerical Experiment

==> Goal: Reconstruction these PSF at 2 x Euclid Resolution from 4 subsample noisy images.





Mass Mapping

The shear is related to the convergence through the relation:

$$\gamma(\boldsymbol{\theta}) = \frac{1}{\pi}\int d^2\boldsymbol{\theta}'\mathcal{D}(\boldsymbol{\theta}-\boldsymbol{\theta}')\kappa(\boldsymbol{\theta}') \quad \text{with} \quad \mathcal{D}(\boldsymbol{\theta}) \equiv \frac{\theta_2^2-\theta_1^2-2i\theta_1\theta_2}{|\boldsymbol{\theta}|^4} = -\frac{1}{(\theta_1-i\theta_2)^2}$$

The convergence is related to the 3D density contrast

$$\boxed{\kappa(\boldsymbol{\theta},w) = \frac{3H_0^2\Omega_M}{2c^2}\int_0^w dw'\,\frac{f_K(w')f_K(w-w')}{f_K(w)}\,\frac{\delta[f_K(w')\boldsymbol{\theta},w']}{a(w')}} \quad \text{with} \quad \boxed{\delta(\boldsymbol{r}) \equiv \rho(\boldsymbol{r})/\overline{\rho}-1}$$

where $\overline{\rho}$ is the mean density of the Universe, H_0 is the Hubble parameter, Ω_M is the matter density parameter, c is the speed of light, $a(w)$ is the scale parameter evaluated at comoving distance w, and

$$f_K(w) = \begin{cases} K^{-1/2}\sin(K^{1/2}w), & K>0 \\ w, & K=0 \\ (-K)^{-1/2}\sinh([-K]^{1/2}w) & K<0 \end{cases},$$

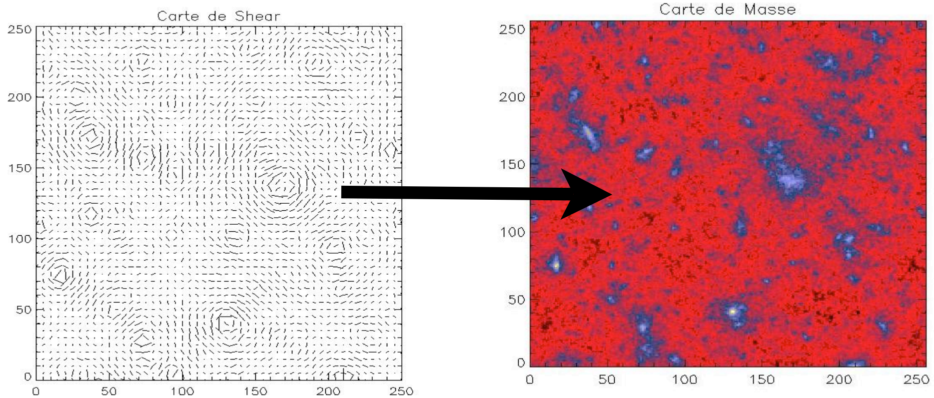
gives the comoving angular diameter distance as a function of the comoving distance and the curvature, K, of the Universe.

2D Mass Mapping

Aperture mass maps or Convergence (kappa) maps ?

$$\begin{cases} M_{ap}(\boldsymbol{\theta}) = \int d^2\boldsymbol{\vartheta}\ \kappa(\boldsymbol{\vartheta})U(|\boldsymbol{\vartheta}|) \\ M_{ap}(\boldsymbol{\theta}) = \int d^2\boldsymbol{\vartheta}\ \gamma_t(\boldsymbol{\vartheta})Q(|\boldsymbol{\vartheta}|) \\ Q(\vartheta) \equiv \frac{2}{\vartheta^2}\int_0^{\vartheta} \vartheta' U(\vartheta')d\vartheta' - U(\vartheta) \end{cases}$$

$$\begin{cases} \gamma(\boldsymbol{\theta}) = \frac{1}{\pi}\int d^2\boldsymbol{\theta}'\mathcal{D}(\boldsymbol{\theta}-\boldsymbol{\theta}')\kappa(\boldsymbol{\theta}') \\ \mathcal{W}_j(x,y) = \int_{-\infty}^{+\infty} \kappa(x,y)\psi_j(x,y)dxdy \end{cases}$$



$\Rightarrow$ Wavelets filters are formally indentical to Mass aperture

S. Pires, A. Leonard, J.-L. Starck, "Cosmological Parameters Constraint from Weak Lensing Data", **MNRAS**, 423, pp 983-992, 2012.
A. Leonard, S. Pires, J.-L. Starck, "Fast Calculation of the Weak Lensing Aperture Mass Statistic", **MNRAS**, 423, pp 3405-3412, 2012.
A. Leonard, J.-L. Starck, S. Pires , F.-X Dupe, Exploring the Components of the Universe Through Higher-Order Weak Lensing Statistics, Open Questions in Cosmology, Gonzalo J. Olmo (Ed.), ISBN: 978-953-51-0880-1, InTech, DOI: 10.5772/51871, 2012.

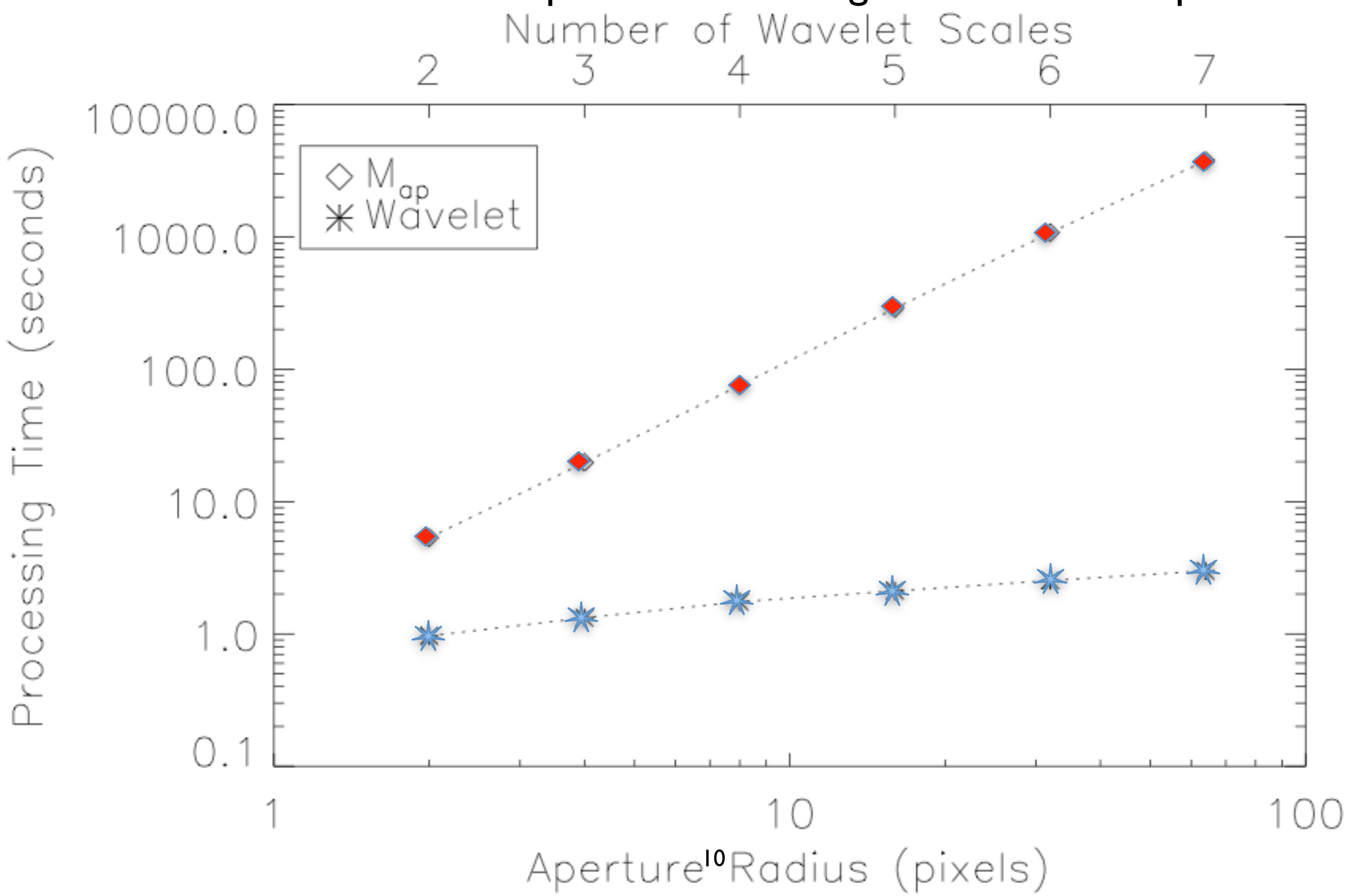
S. Pires

Mass Mapping

A. Leonard

but wavelets presents many advantages:

- compensated and **compact** support filters
- **fast** calculation: $N \log N$ instead of N^2
- **all scales** processed in one step.
- **reconstruction** is possible ==> image restoration for peak counting



3D Mass Mapping

$$\gamma(\boldsymbol{\theta}) = \frac{1}{\pi} \int d^2\boldsymbol{\theta}' \mathcal{D}(\boldsymbol{\theta} - \boldsymbol{\theta}')\kappa(\boldsymbol{\theta}')$$

Kappa (or convergence) is a dimensionless surface mass density of the lens

$$\kappa(\boldsymbol{\theta}, w) = \frac{3H_0^2\Omega_M}{2c^2} \int_0^w dw' \frac{f_K(w')f_K(w-w')}{f_K(w)} \frac{\delta[f_K(w')\boldsymbol{\theta}, w']}{a(w')},$$

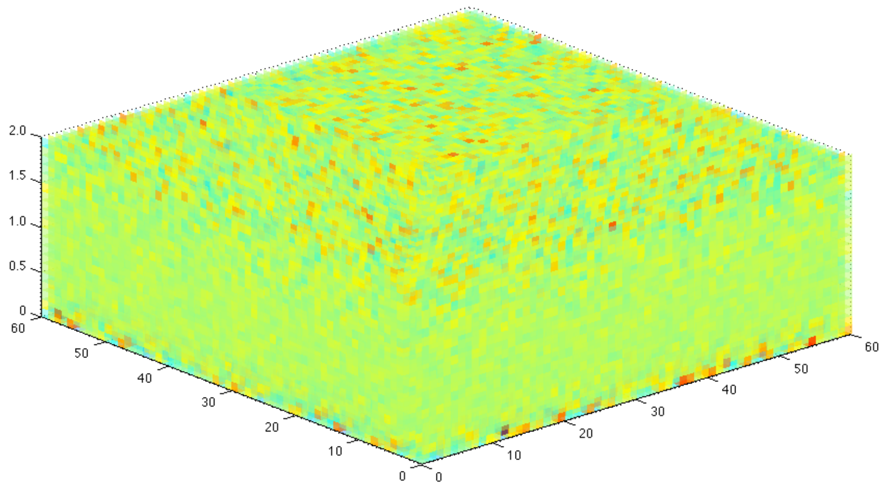
f_K is the angular diameter distance, which is a function of the comoving radial distance r and the curvature K.

$$\boldsymbol{\gamma} = \mathbf{P}_{\gamma\kappa}\boldsymbol{\kappa} + \boldsymbol{n}_\gamma,$$

$$\kappa = Q\delta + n$$

$$\boxed{\gamma = \mathbf{R}\delta + n}$$

- Galaxies are not intrinsically circular: intrinsic ellipticity ~ 0.2-0.3; gravitational shear ~ 0.02
- Reconstructions require knowledge of distances to galaxies


2.0
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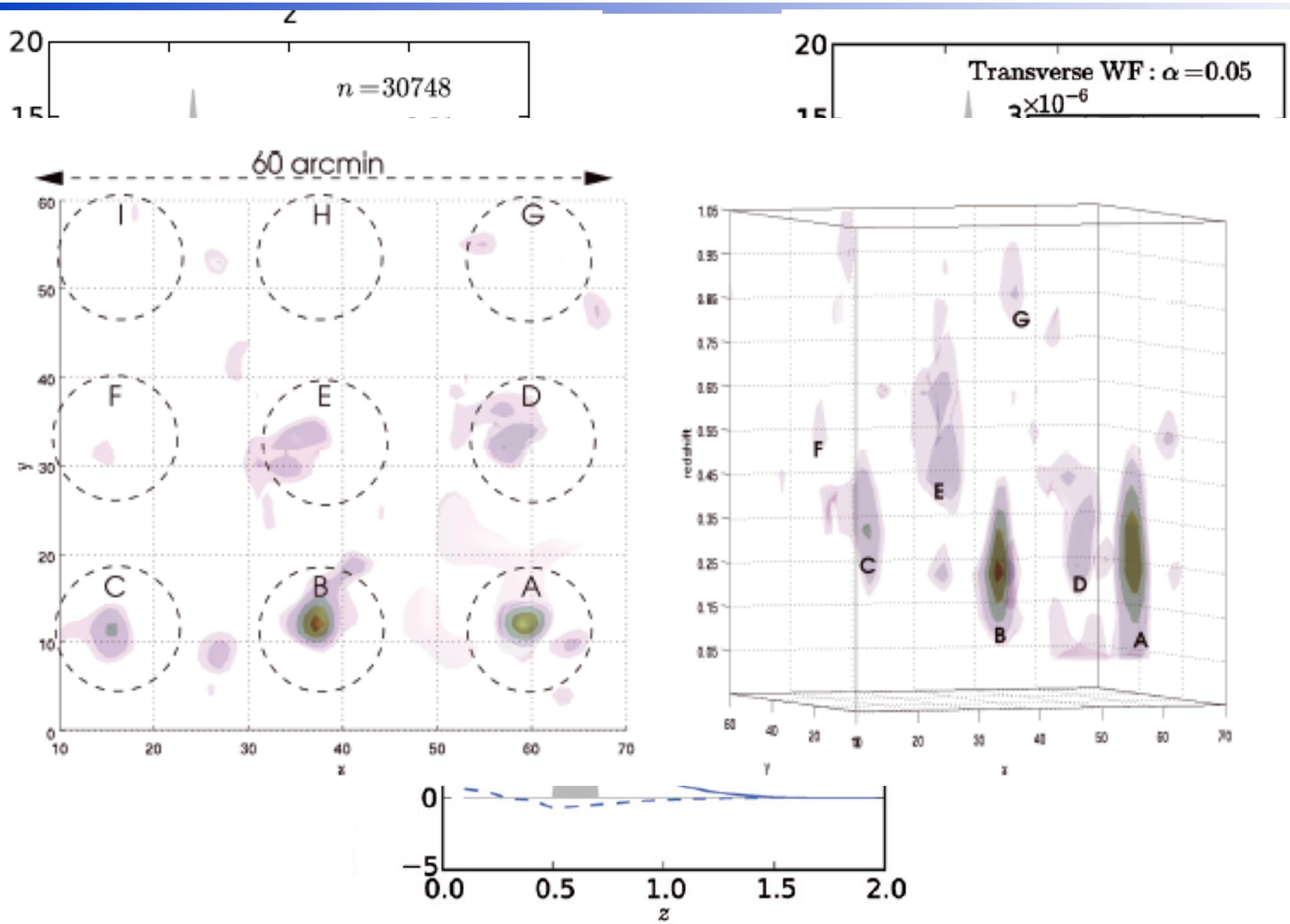
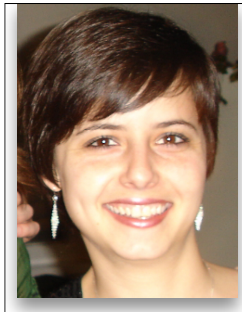
60

3D Reconstruction: Linear Approach

Vaı



Simon et al. 2009, MNRAS, 399, 48

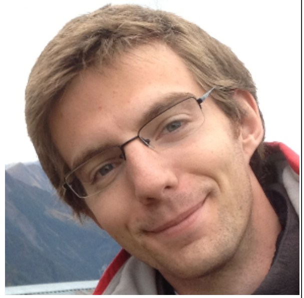


A. Leonard

Full 3D Weak Lensing

A. Leonard, F.X. Dupe, and J.-L. Starck, "A Compressed Sensing Approach to 3D Weak Lensing", **Astronomy and Astrophysics** , 539, A85, 2012.

A. Leonard, F. Lanusse, J-L. Starck, **GLIMPSE**: Accurate 3D weak lensing reconstruction usiing sparsity, Astronomy and Astrophysics, submitted, 2013



F. Lanusse

$$\min_{\alpha} \| \alpha \|_1 \quad s.t. \quad \frac{1}{2} \| \gamma - R\Phi\alpha \|^2_{\mathbf{\Sigma}^{-1}} \leq \epsilon$$

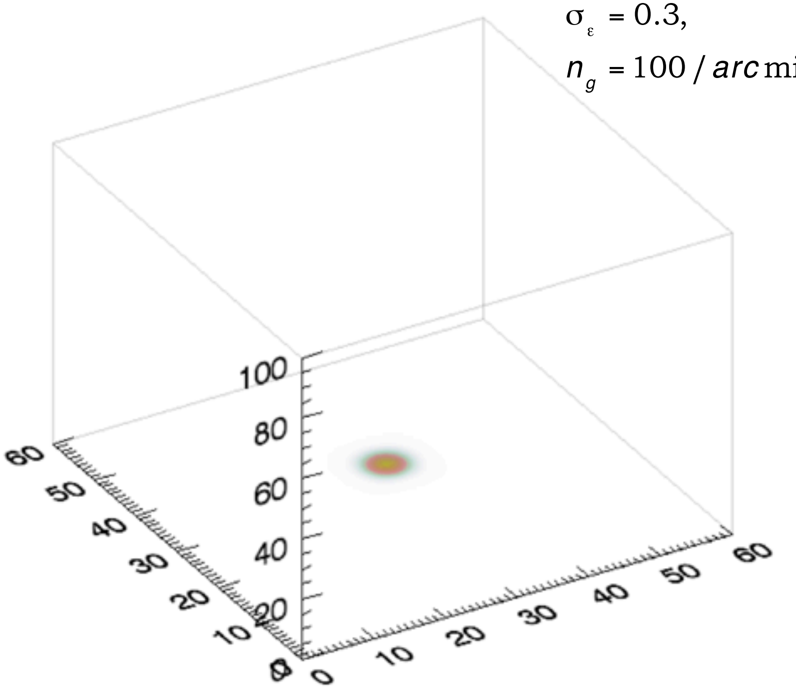
$$\delta = \Phi\alpha$$

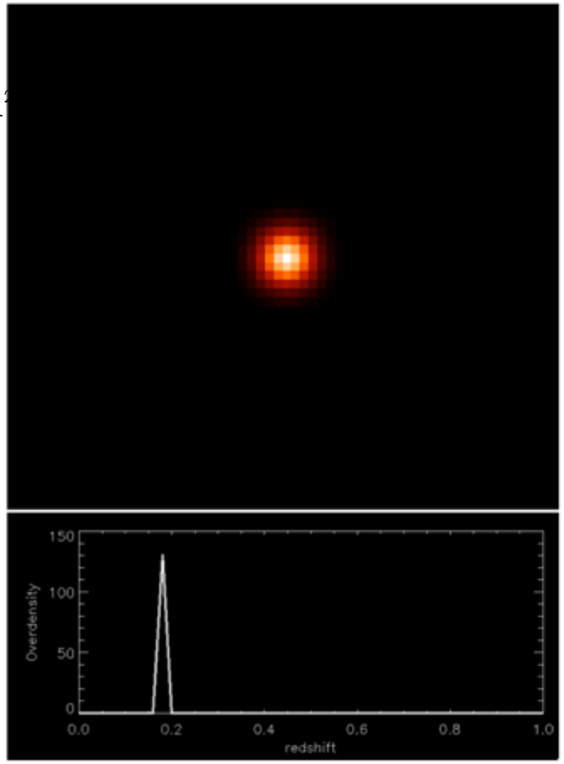
Φ = 2D Wavelet Transform on each redshift bin

Example of the reconstruction of a cluster at redshift z=0.2 using 5 times more reconstruction bin:

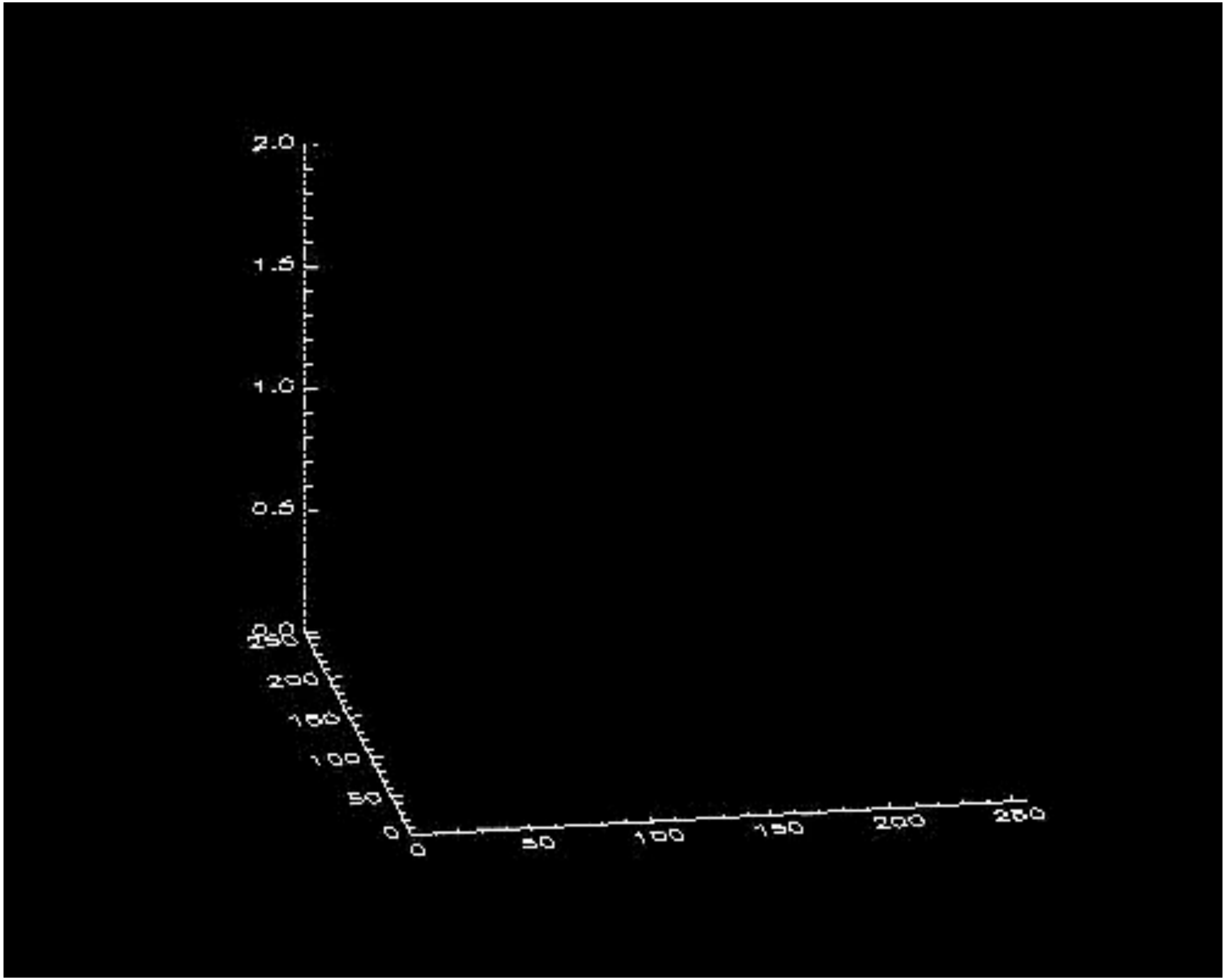
$\sigma_\varepsilon = 0.3,$

$n_g = 100 / arc\min^2$





http://cosmostat.org/glimpse.html


2.0
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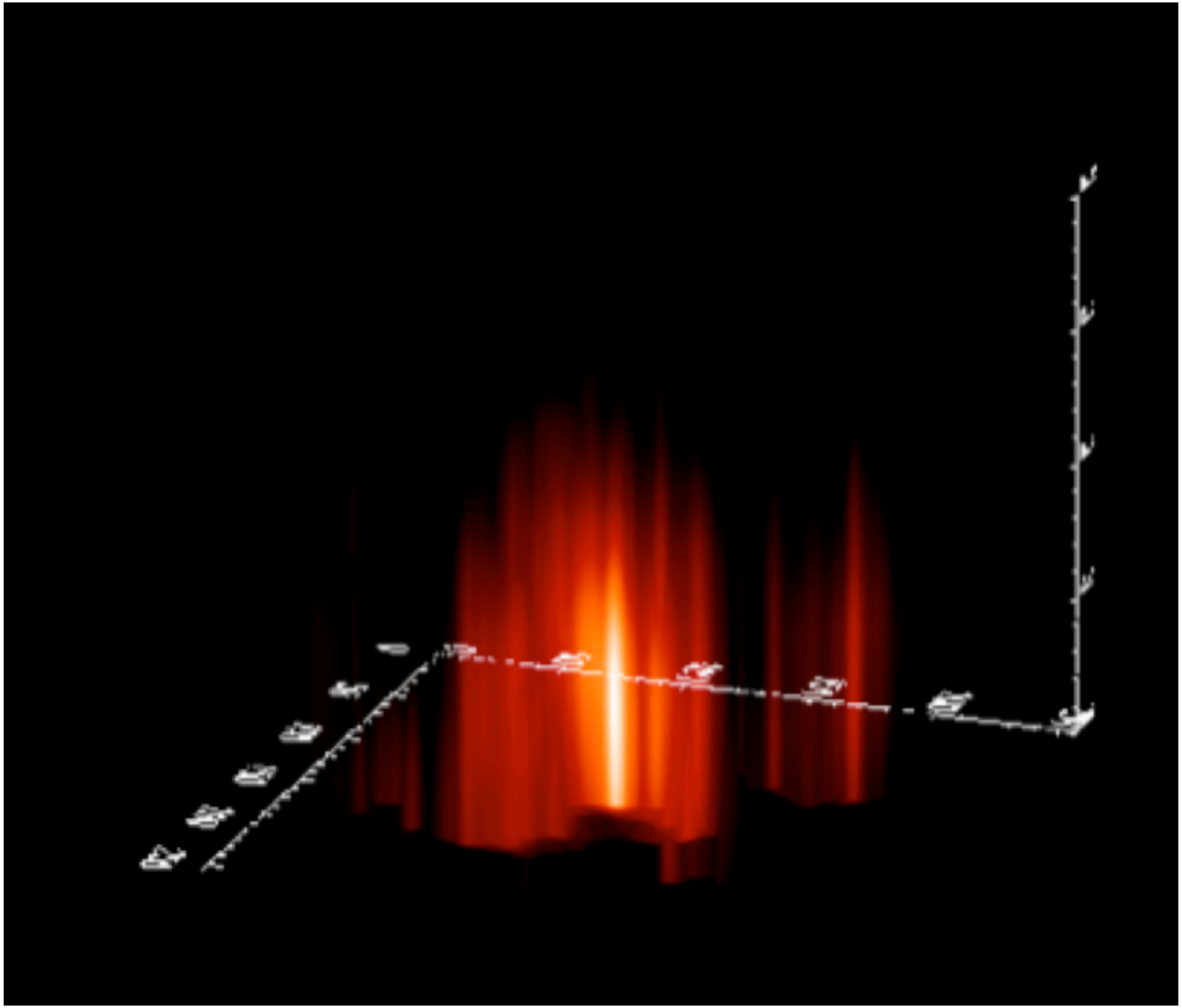
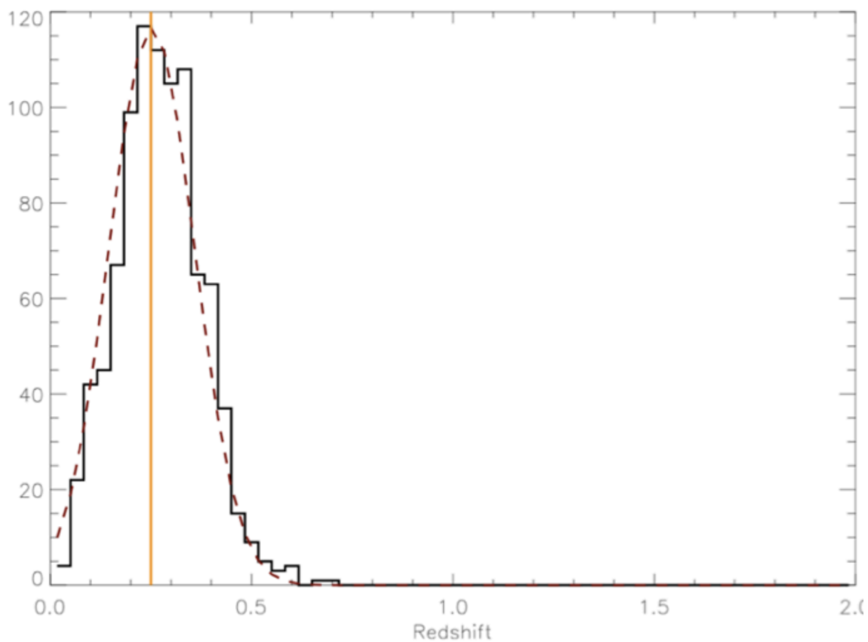


Mass &Redshift Estimation

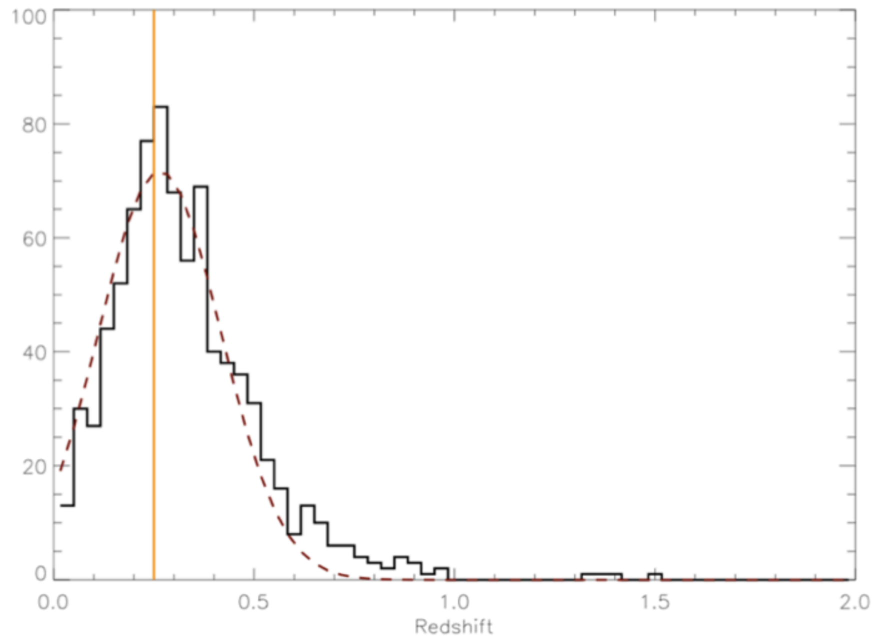
Single halo simulations
• One NFW profile at the center of a 60x60 arcmin field
• Noise and redshift errors corresponding to an Euclid-like survey
• Mass varying between 3.1013 and 1.1015 h−1M⊙ • Redshifts between 0.05 and 1.55
We ran 1000 noise realisations on each of the 96 fields.

$m_{vir} = 8.10^{14} h^{-1} M_{\odot}$



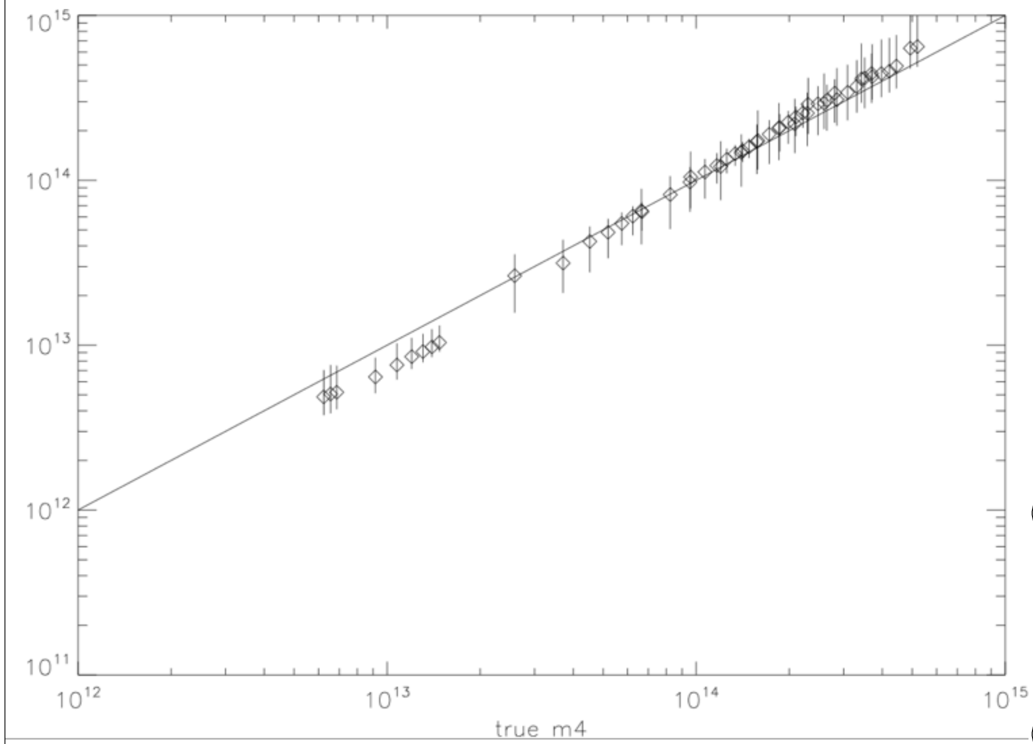
$\sigma_z = 0.1$

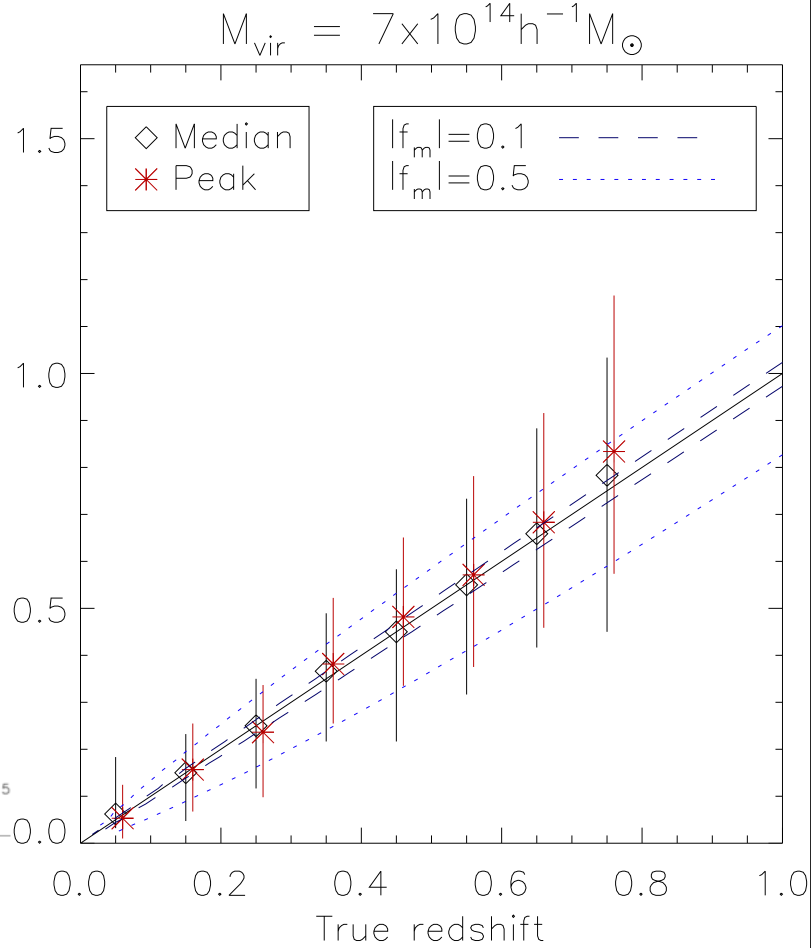
$m_{vir} = 4.10^{14} h^{-1} M_{\odot}$



$\sigma_z = 0.15$

Mass Estimation





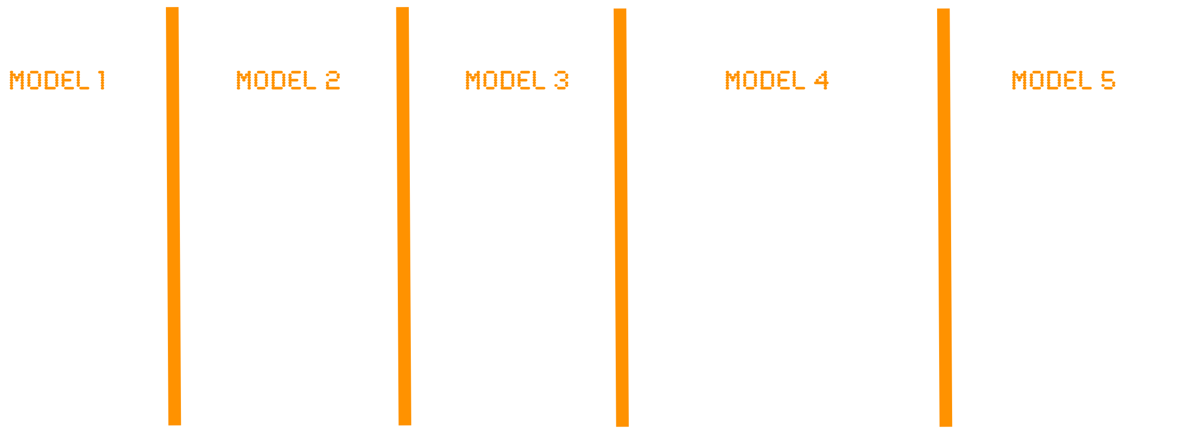
Conclusions

- PFS Modeling using Sparsity (SPRITE method) seems to be very efficient.

- 2D map: Aperture mass map = wavelets, but wavelets calculation is between 10 and 1000 times faster.

- 3D map: GLIMPSE solves many problems related to linear methods:
Redshift bias, Smearing, Damping, Resolution limited by data

- Wavelet Denoising + Wavelet Peak Counting is the most efficient statistical tool to discriminate Cosmological Models.



WAVELET PEAK COUNTING ON MRLENS FILTRED MAPS (AT SCALE OF ABOUT 1 ARCMIN)

S. Pires, A. Leonard, J.-L. Starck, "Cosmological Parameters Constraint from Weak Lensing Data", **MNRAS**, 423, pp 983-992, 2012.