

# Weak Lensing with The Dark Energy Survey Status & Plans

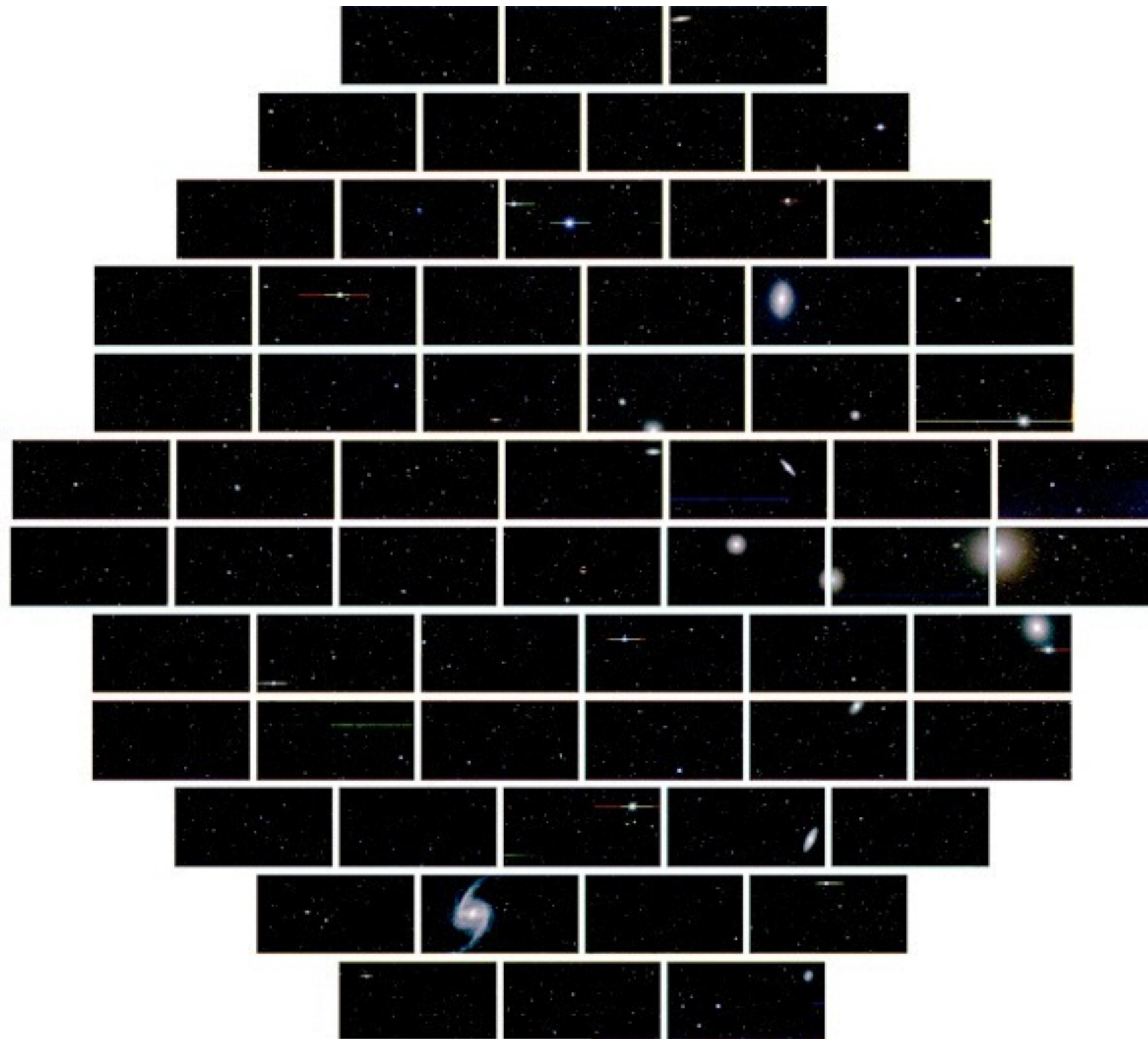
Joe Zuntz

# Dark Energy Survey

- DECam on Blanco ->
- 5000 sq degrees
- g, r, i, z, y
- 5 year mission  
525 nights
- 300 million galaxies
- $0.2 < z < 1.3$

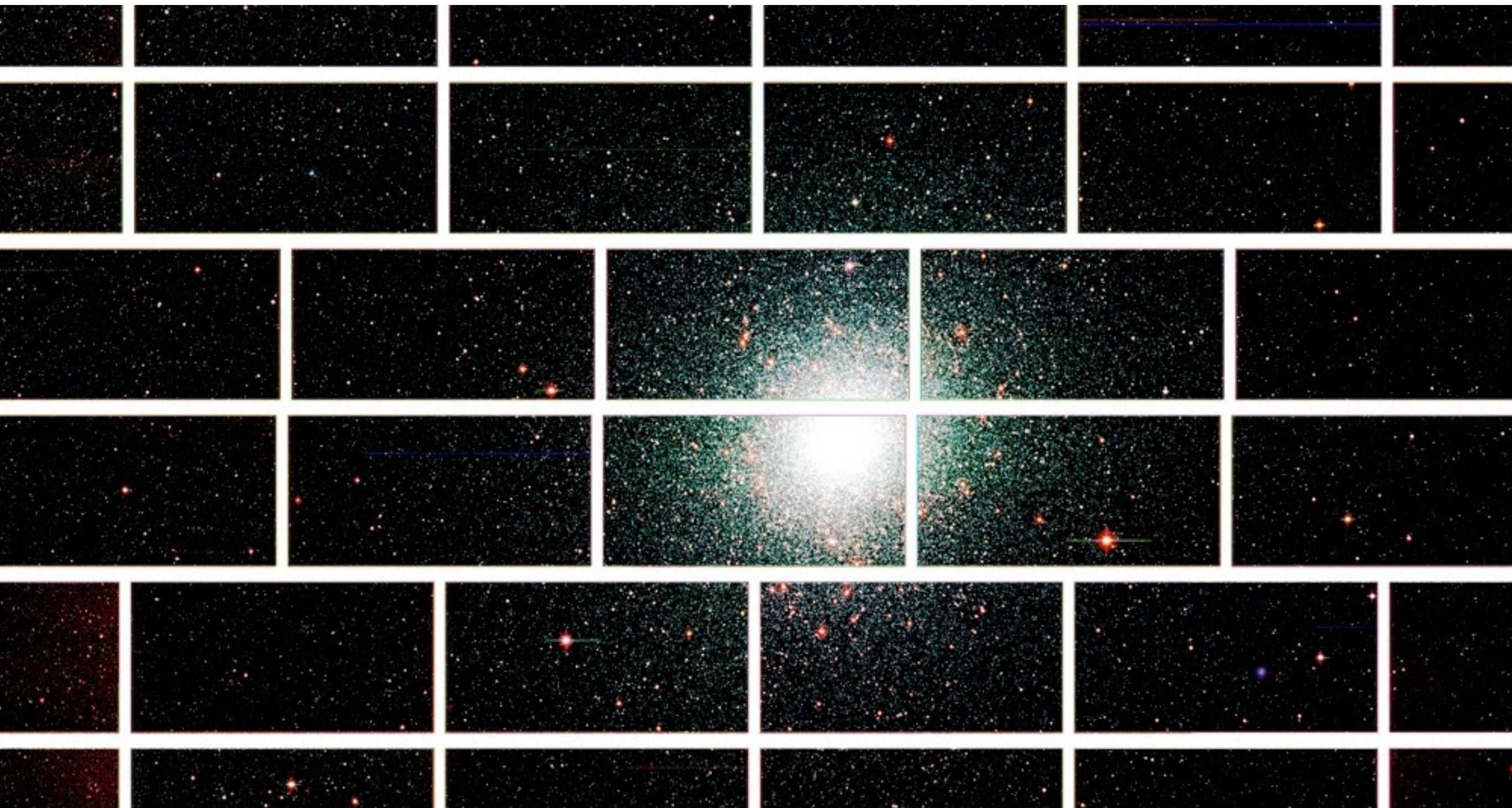


# Dark Energy Survey FoV





# Dark Energy Survey





# Survey Area

CFHT  
150 sq  
deg

DES SV  
~150 sq  
deg

**DES**  
**5000**  
**sq. deg.**

# DES Killer Application

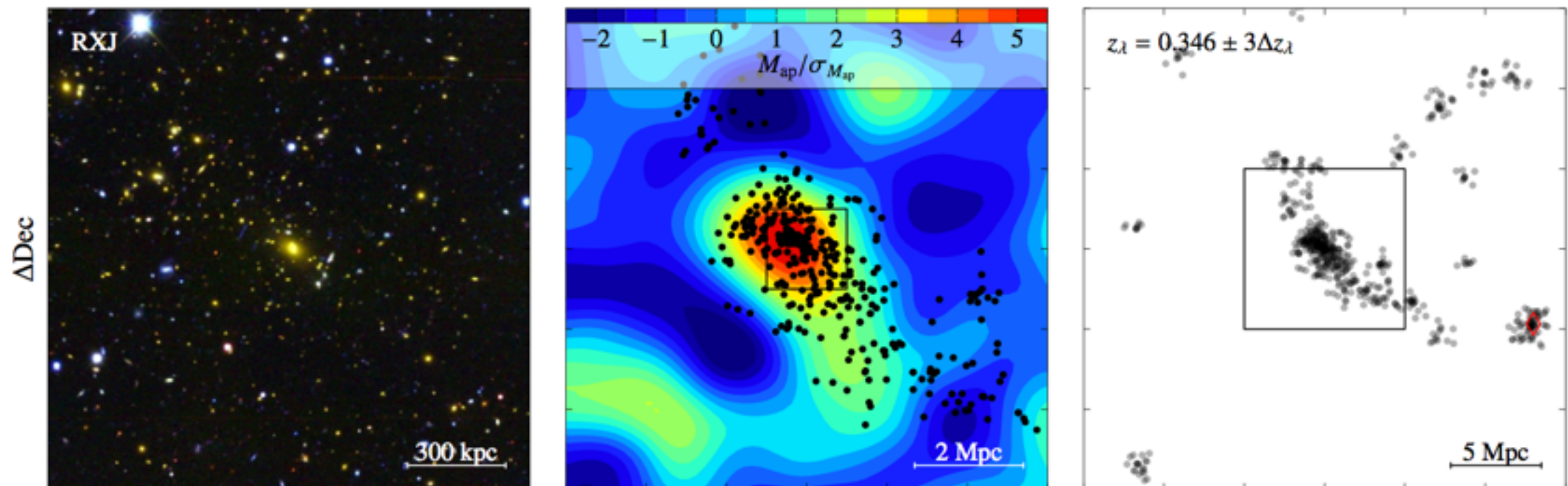
- Wide area survey
- Precision PSF
- Good depth
- No time wasted on spectroscopy 😊

# Early Science: Cluster Masses

Melchior et al arxiv 1405.4285

# Cluster Masses

- Measure mass of four massive clusters  
90 second exposures in g,r,i,z and 50 sec y
- Photo-z from Oyaizu et al 2008 (SDSS pipeline)
- im3shape galaxy shape measurements (Zuntz et al 2013)





# Cluster Masses

- Sample NFW parameters with emcee  
(fix cosmology  $h=0.7$ ,  $\Omega_m=0.3$ )
- Predict projected surface density hence mean shear

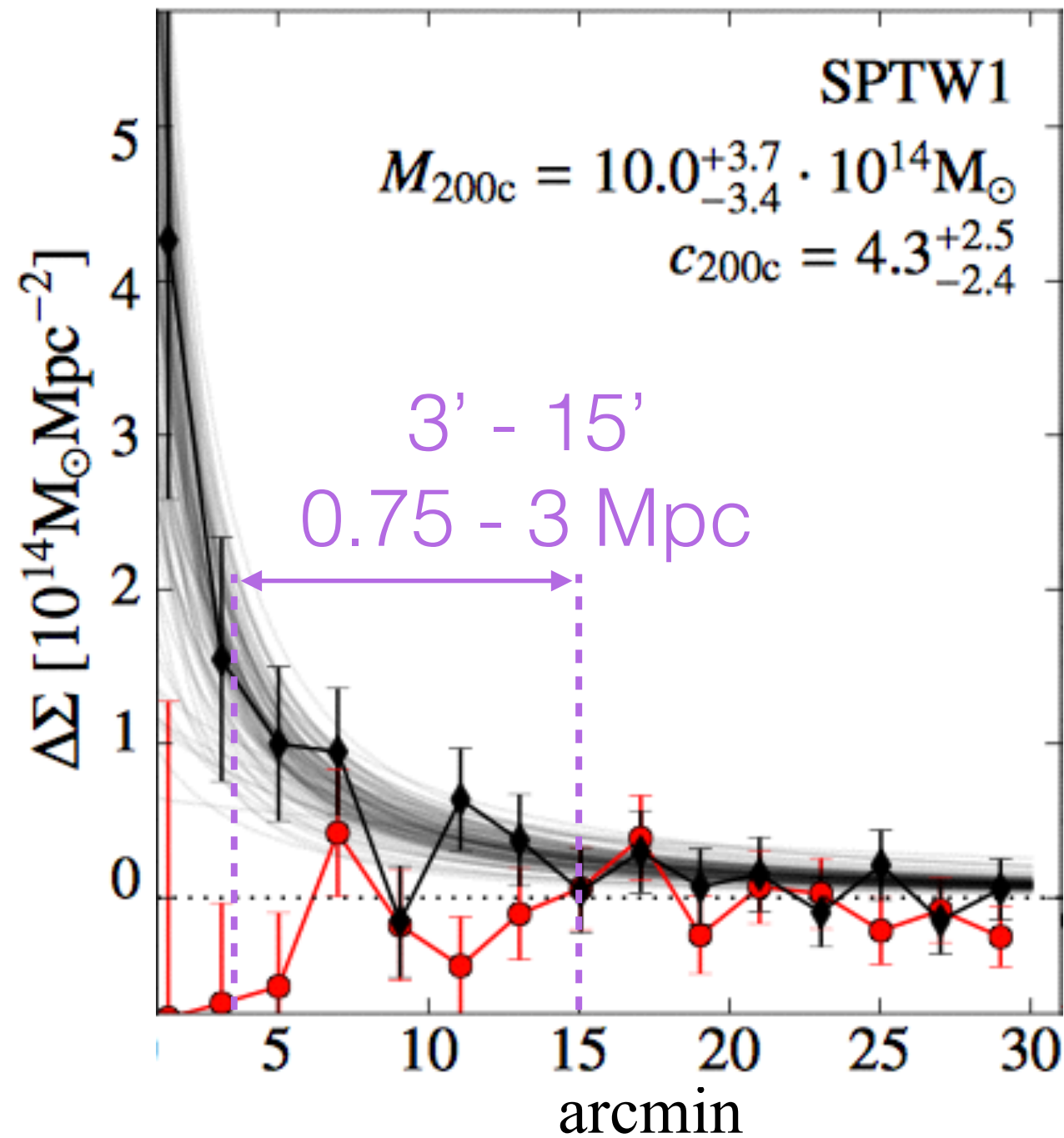
$$\rho(r) = \frac{\rho_0}{(r/r_s)(1 + r/r_s)^2}$$

$$\Sigma(R) = \int_{-\infty}^{\infty} \rho(r = \sqrt{\chi^2 + R^2}) d\chi$$

$$\gamma_t(r) = \frac{\bar{\Sigma}(< r) - \Sigma(r)}{\Sigma_c}$$

$$\ln \mathcal{L} = -\frac{1}{2} \sum_j \frac{[\Delta \hat{\Sigma}(r_k) - \Sigma_{\text{crit}}(j) \epsilon_t(j)]^2}{\Sigma_{\text{crit}}^2(j) [\sigma_j^2 + \sigma_\epsilon^2]}$$

# Cluster Masses



# Cluster Masses

Cluster name	$M_{200c}$
RXC J2248.7-4431	$17.6^{+4.5}_{-4.0}$
1E 0657-56	$14.2^{+10.0}_{-6.1}$
SCSO J233227-535827	$10.0^{+3.7}_{-3.4}$
Abell 3261	$8.6^{+8.6}_{-3.9}$

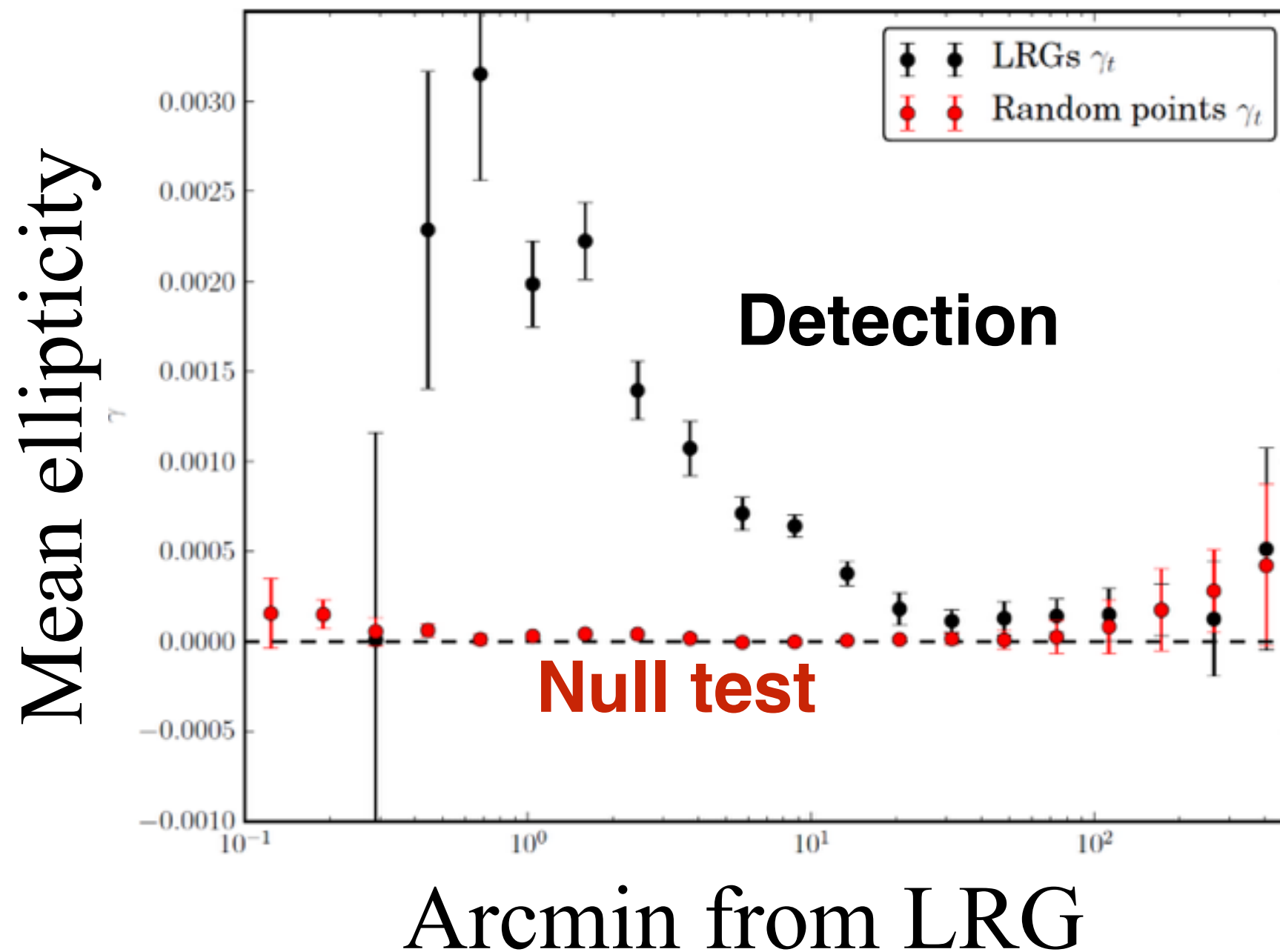
# Early Science: Galaxy-Galaxy Lensing



# Galaxy-Galaxy Lensing

- Correlate lensing and galaxy positions
- Do galaxies point at other galaxies?
- Expect LRGs in large halos

# Galaxy-Galaxy Lensing



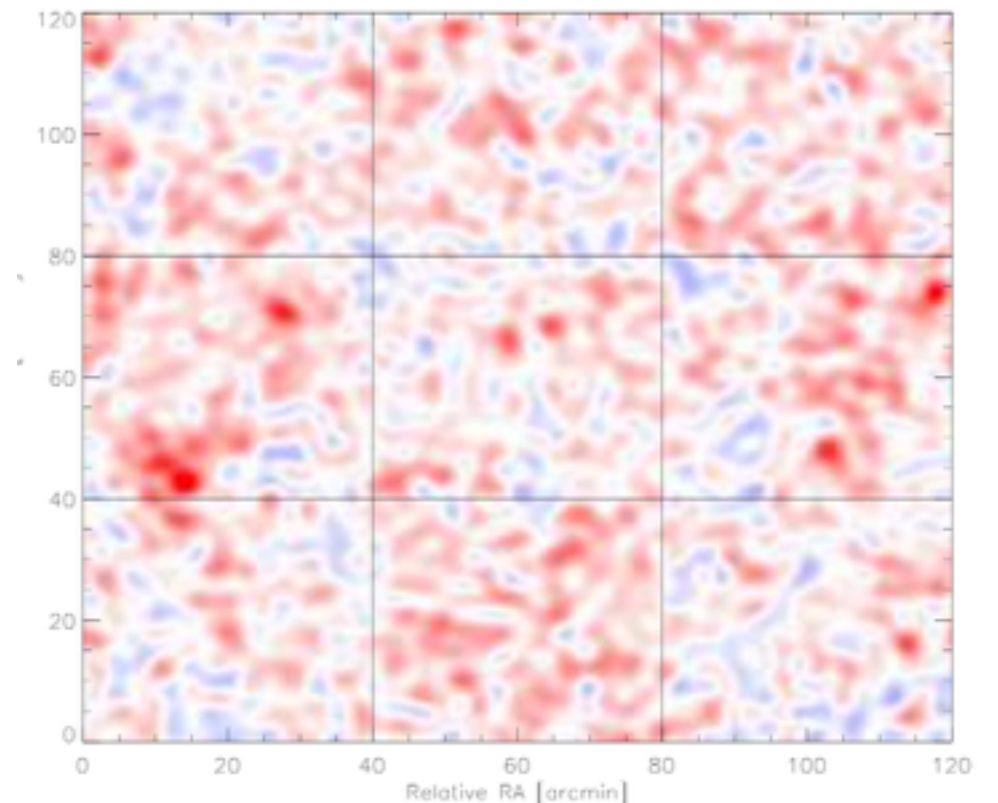
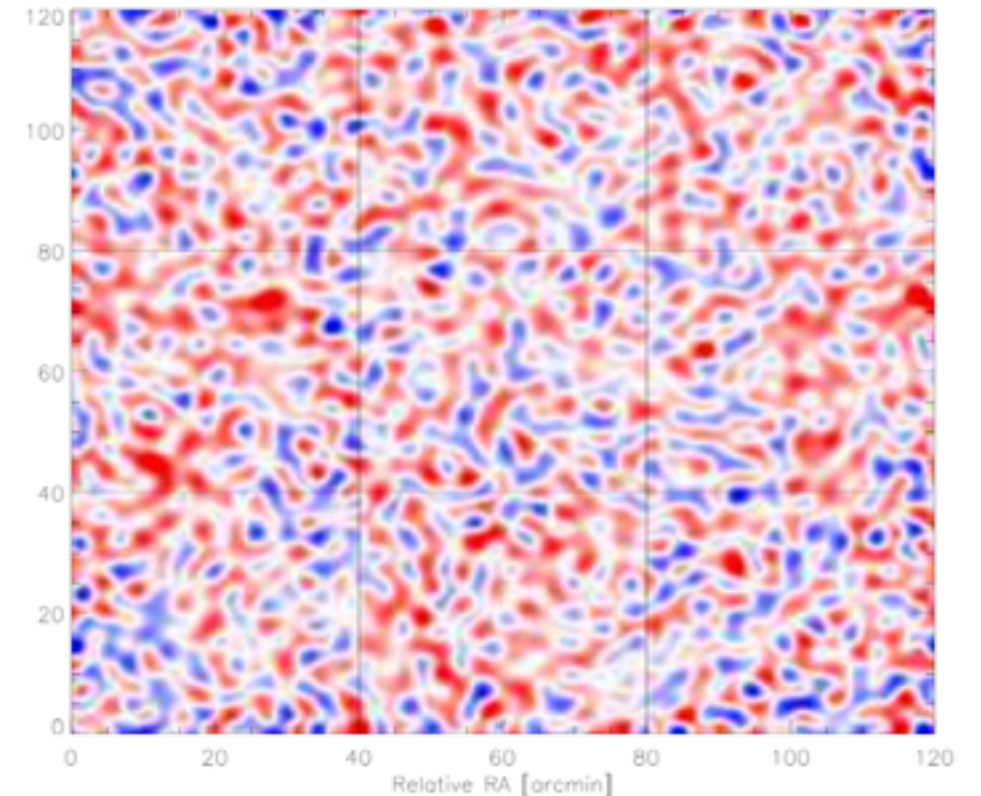
Carles Sánchez

with Joseph Clampitt, Bhuv Jain, Niall MacCrann, Vinu Vikram, and many others

# Early Science: Mass Mapping

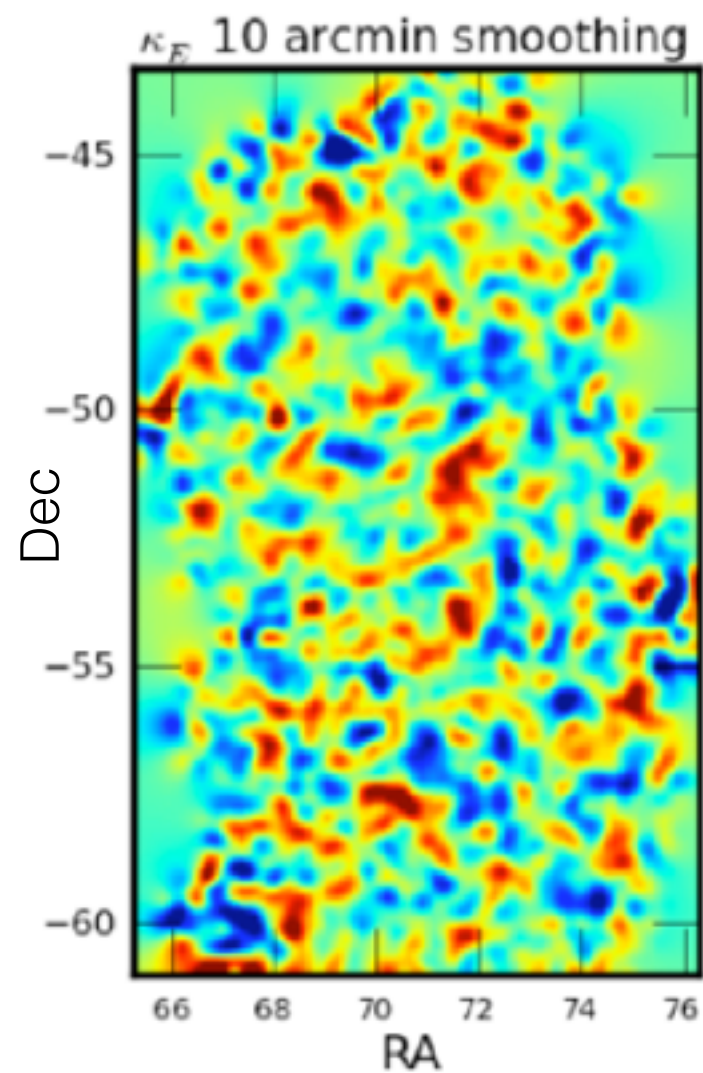
# Mass Mapping

- Invert lensing map => projected mass field
- Simple: 
$$\tilde{\Sigma}(\mathbf{k}) = k^{-2} \begin{pmatrix} k_1^2 - k_2^2 \\ 2k_1 k_2 \end{pmatrix} \cdot \begin{pmatrix} \tilde{e}_1 \\ \tilde{e}_2 \end{pmatrix}$$
- Advanced (Szepietowski et al):
  - Phase prior from number density

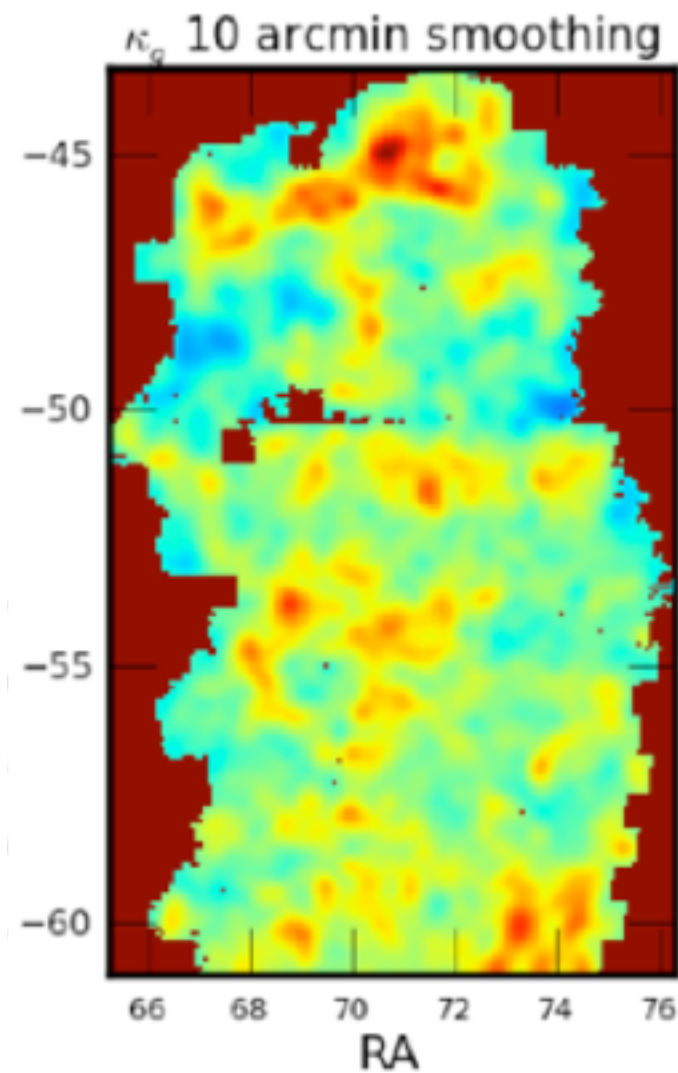




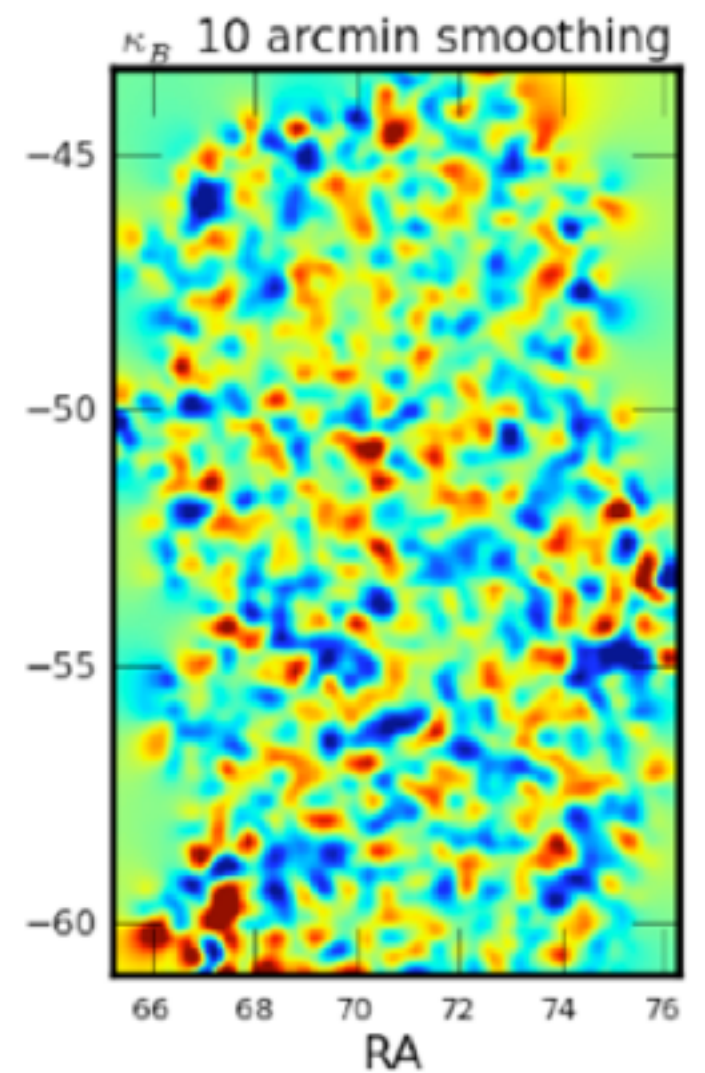
# Mass Mapping



Projected  
density



Galaxy  
Count



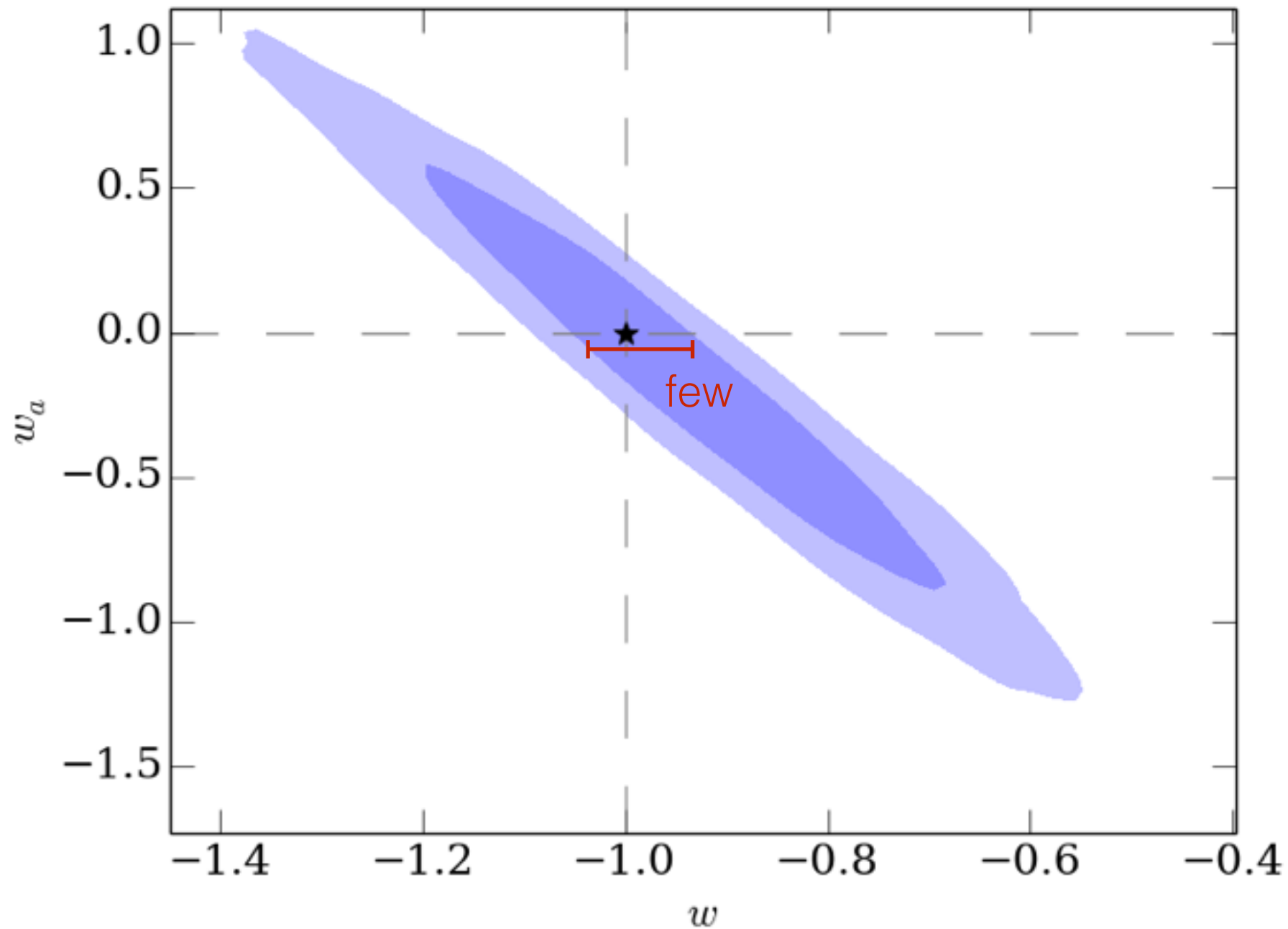
Null  
Test

DES Lensing Future

# Five Year Mission

- Dark Energy Equation of State  $w(z)$   
~ few % accuracy
- Combined probes
  - Covariances hard!

# Five Year Mission



Made with CosmoSIS! <http://bitbucket.org/joezuntz/cosmosis>



# **Weak Lensing Systematic Errors/Physics**

**Baryons & Dark Matter  
Structure**

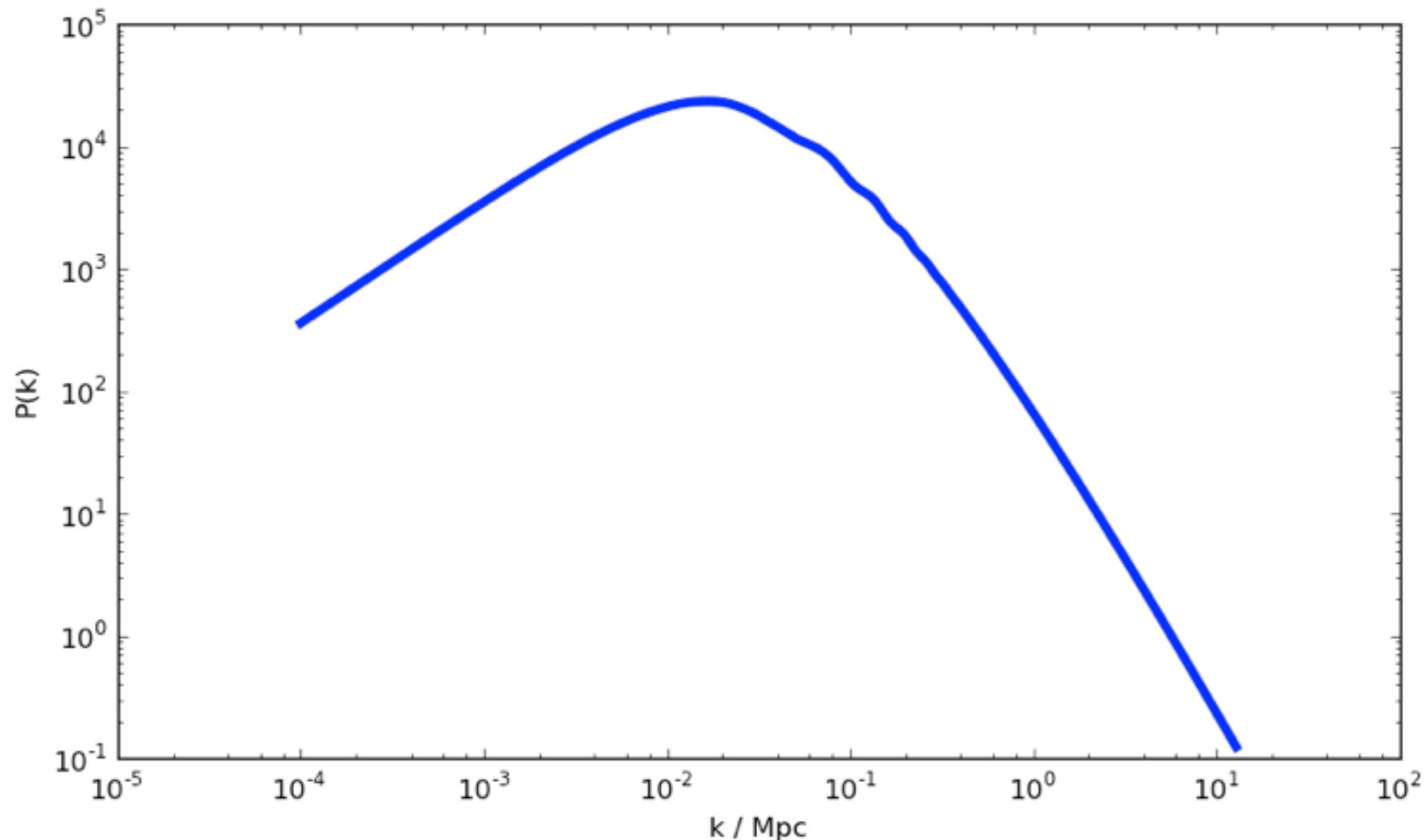
**Intrinsic Galaxy  
Alignments**

**Photometric redshifts**

**Galaxy shape  
measurements**

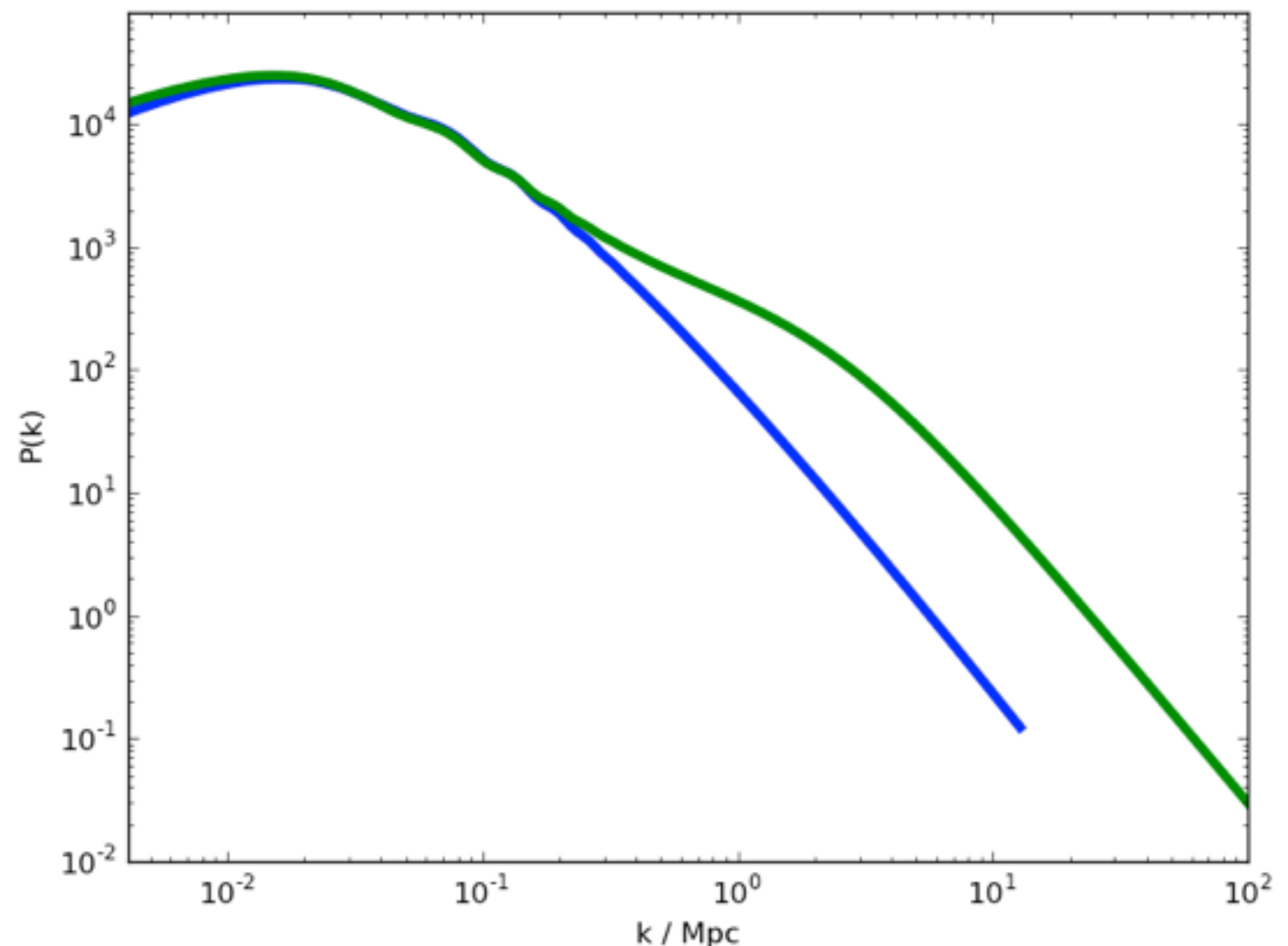
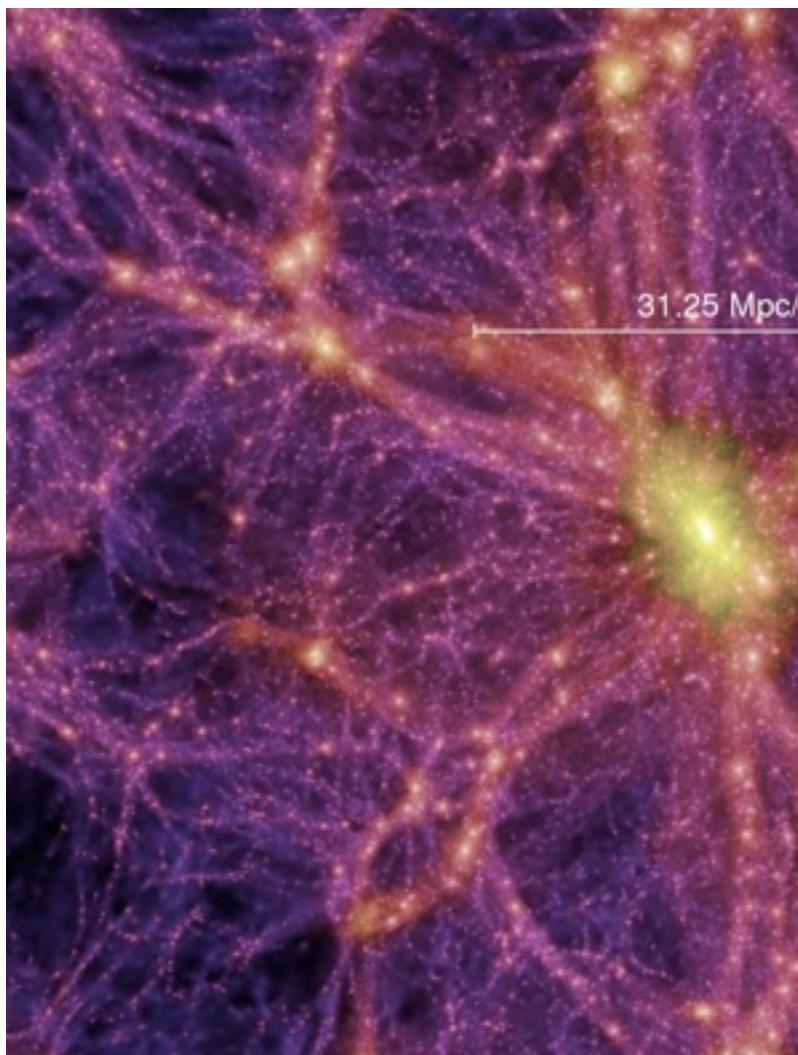
# Baryons & Dark Matter

- Predicting dark matter power spectra  
EASY: Linear DM-only structure



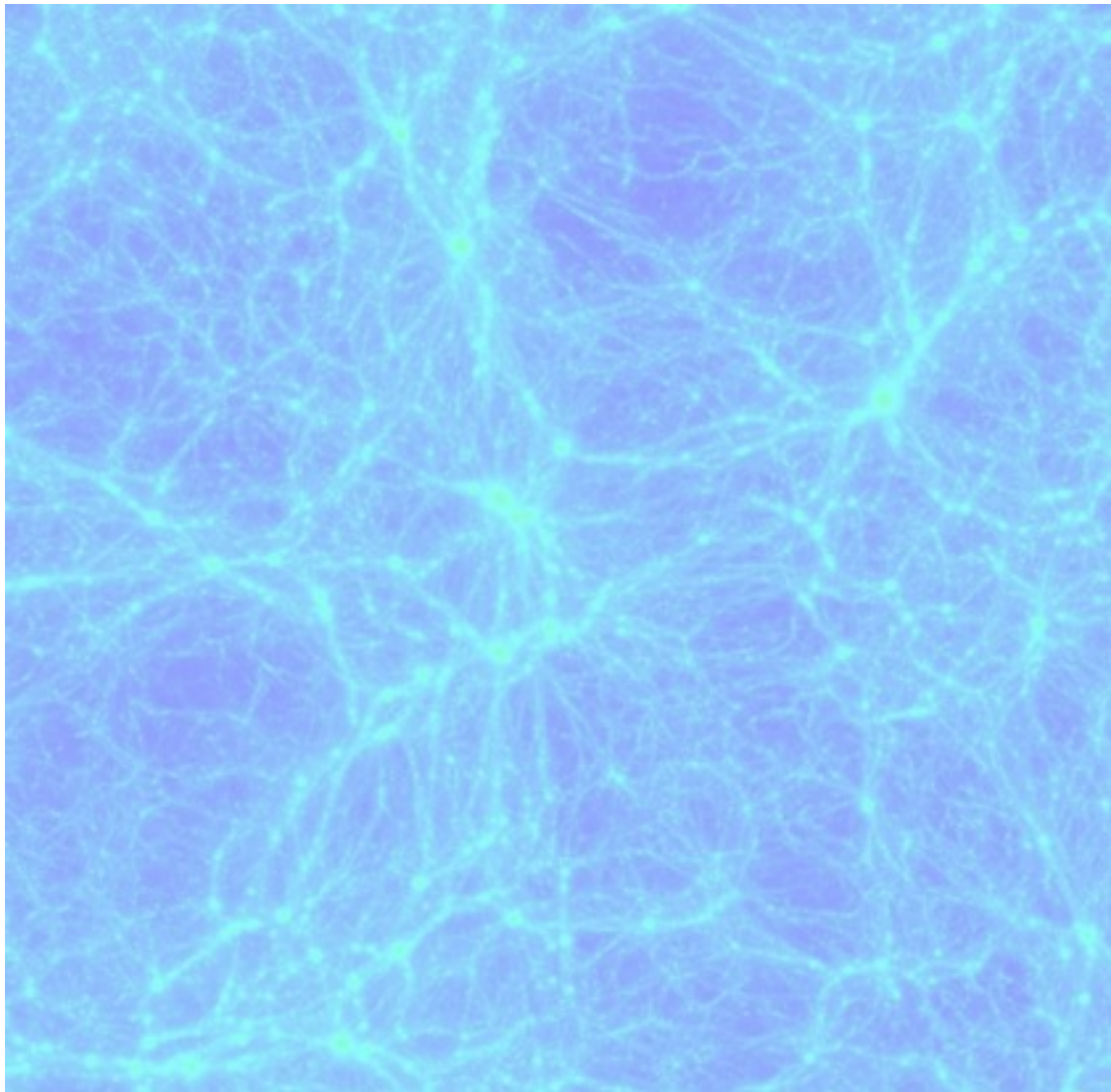
# Baryons & Dark Matter

- Predicting dark matter power spectra  
**HARD: Non-Linear DM-only structure**



# Baryons & Dark Matter

- Predicting dark matter power spectra  
**VERY HARD: Structure with Baryons**



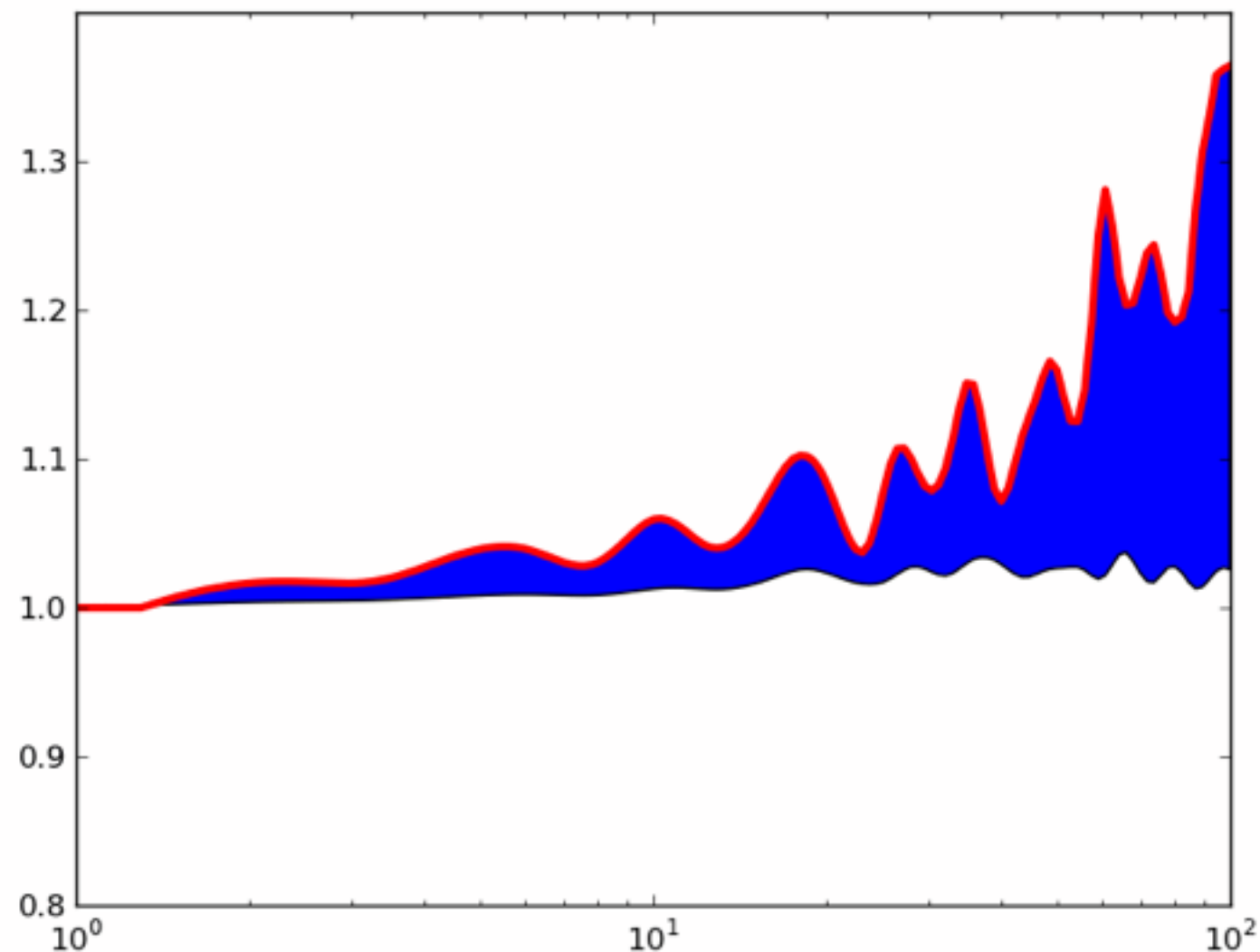
- Supernova feedback
- Star formation law
- Gas equation of state
- AGN numbers & feedback
- Reionization
- Cooling function

OverWhelmingly Large Simulation OWLS

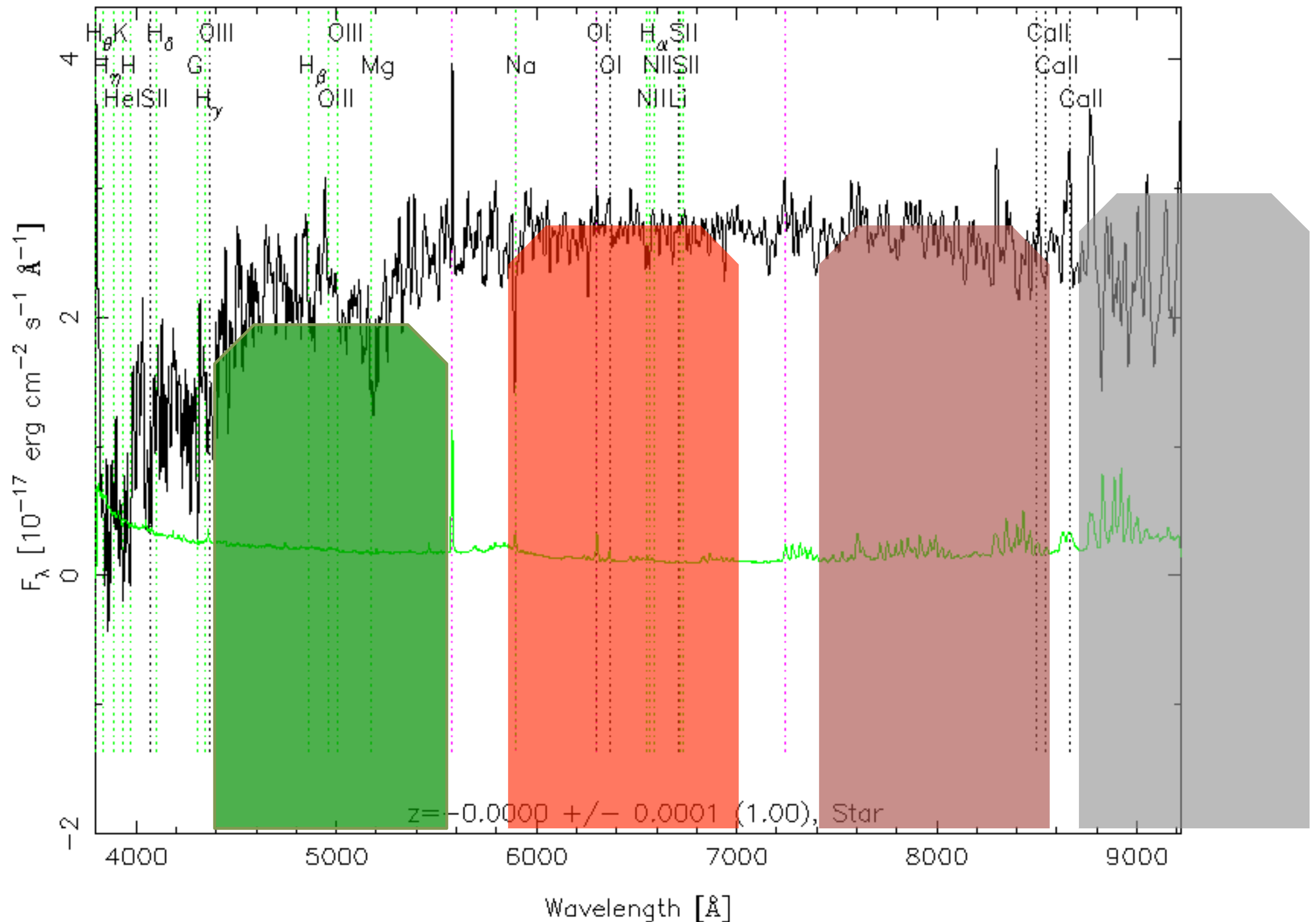


# Baryons & Dark Matter

- Predicting dark matter power spectra  
**VERY HARD: Structure with Baryons**

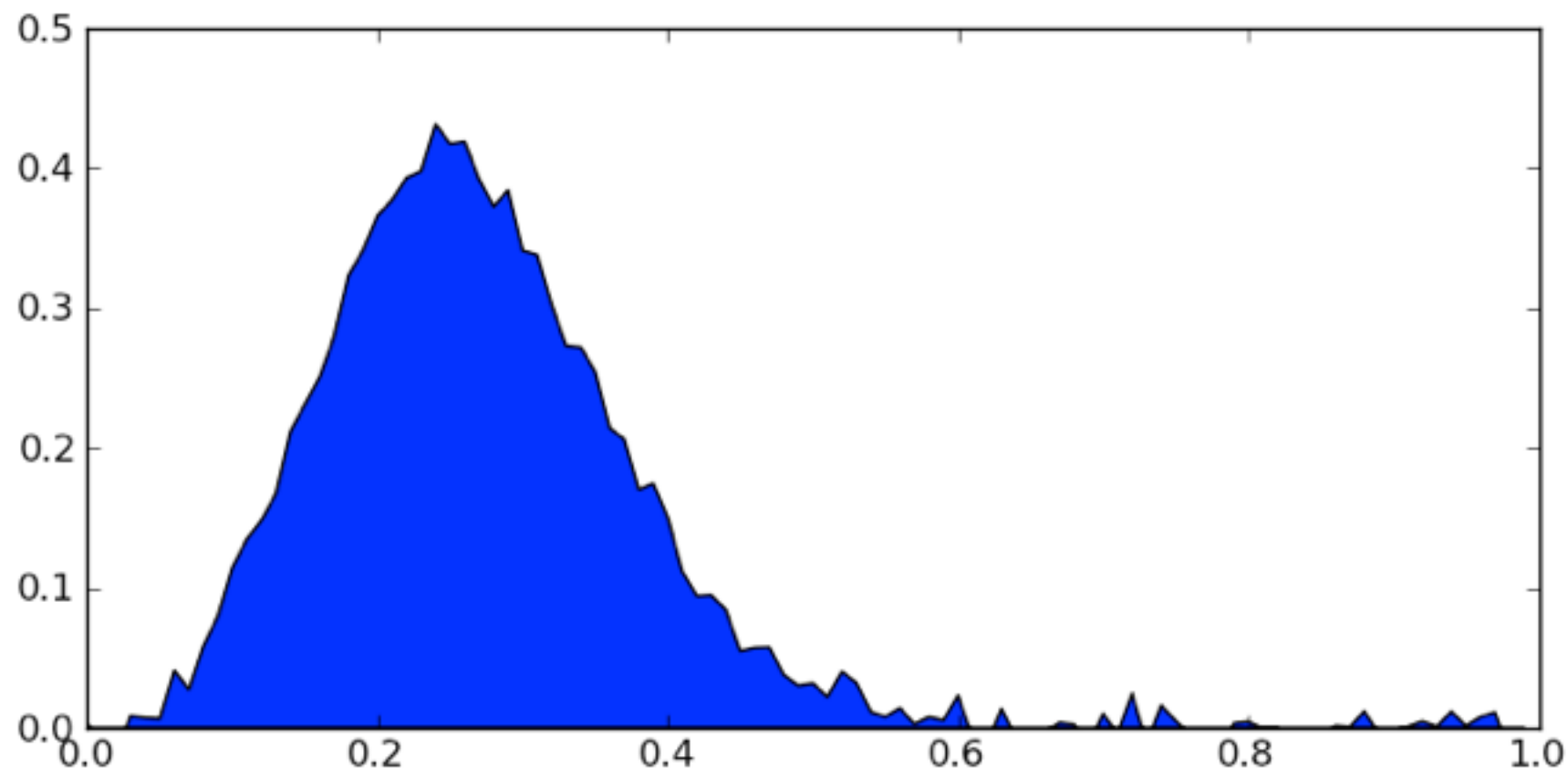


# Photometric Redshifts



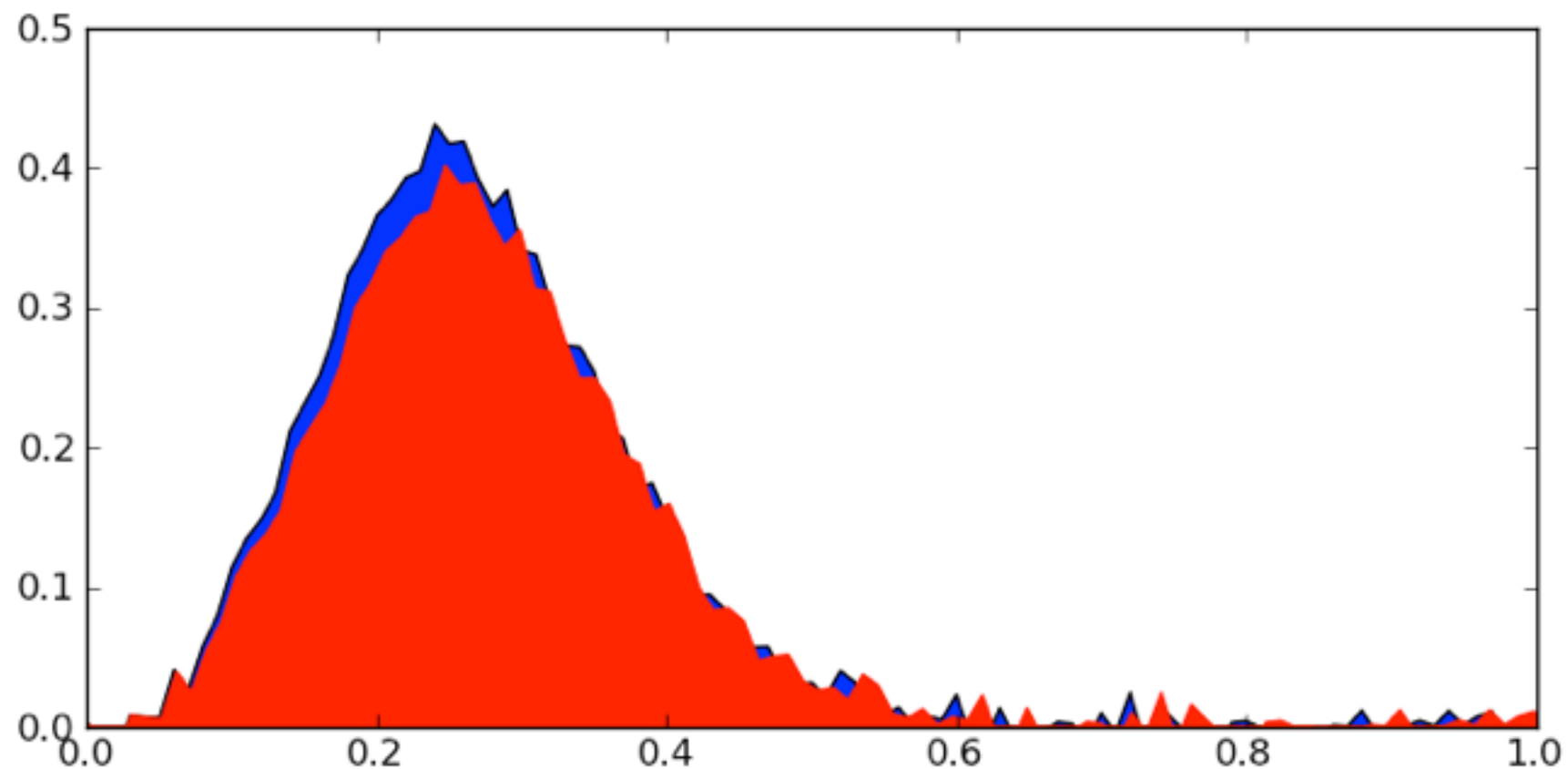
# Photo-z

- Photo-z codes estimate  $z$ 
  - Or better still  $p(z)$
- Get  $n(z)$  of bin of galaxies
- Calibrate with spectroscopy



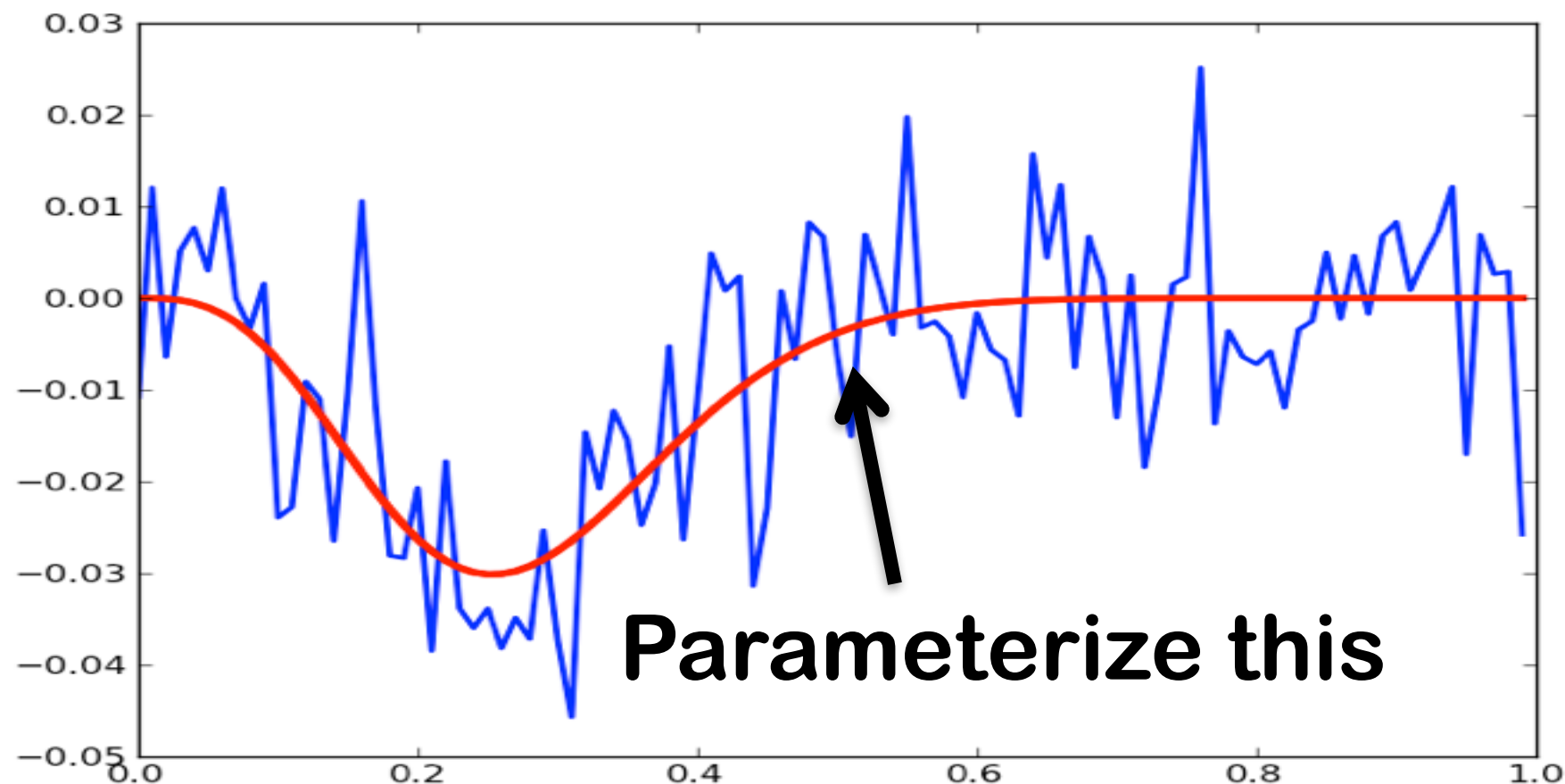
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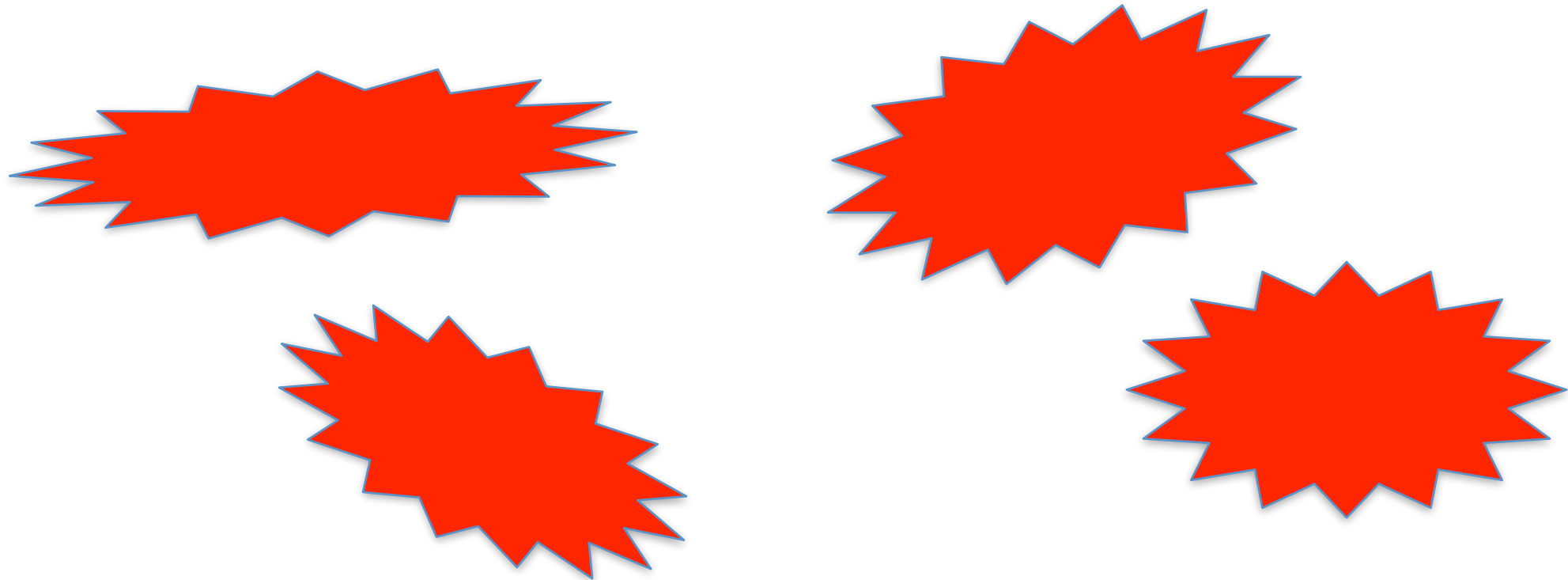
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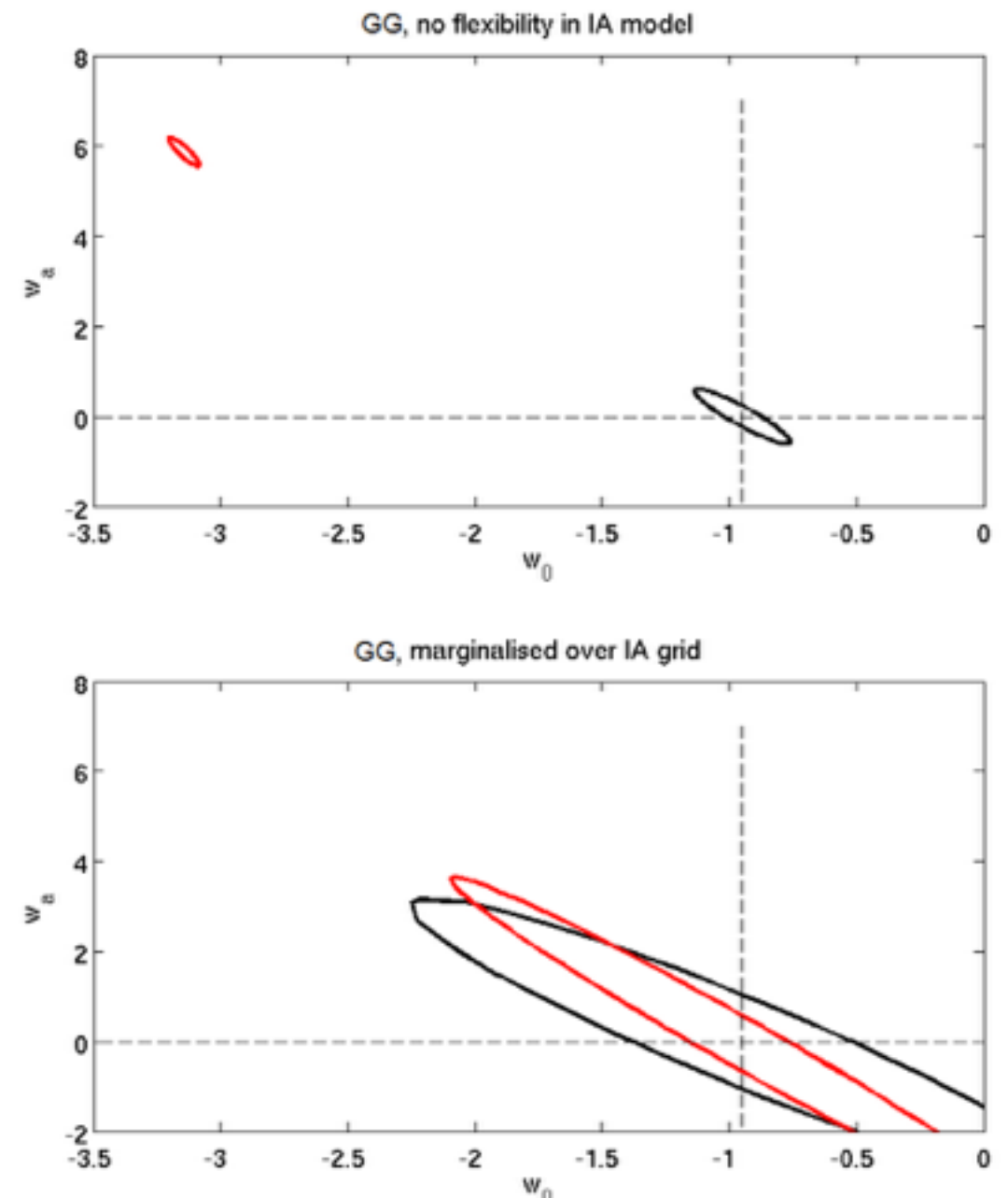
# Intrinsic Alignments

- Before lensing, galaxies already aligned with each other



# Intrinsic Alignments

- Review: Troxel & Ishak
- Linear & Nonlinear Alignment models
  - Assume laid down at early times ~ linear
  - Extensible
- Can certainly mitigate using density spectra

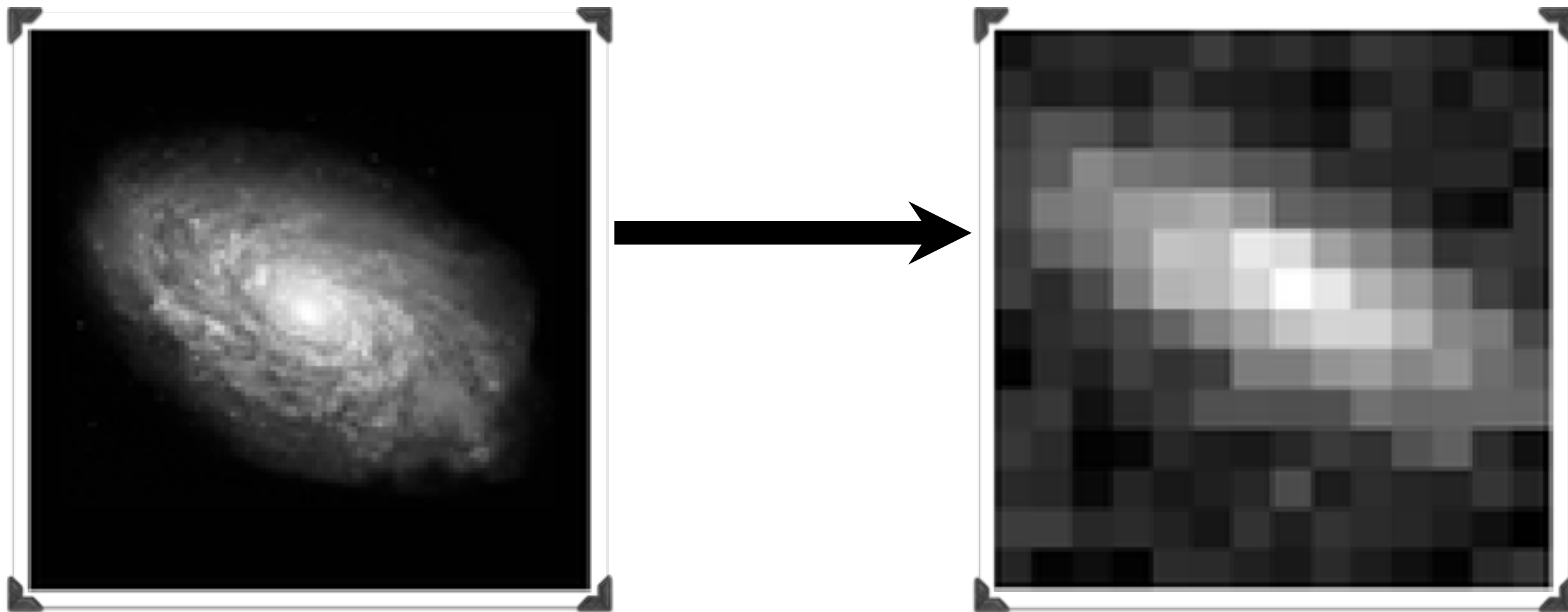


# Intrinsic Alignments

- **Linear alignment model**
  - Assume galaxy orientations laid down during linear era
- **One parameter – correlation amplitude**
  - Can extend

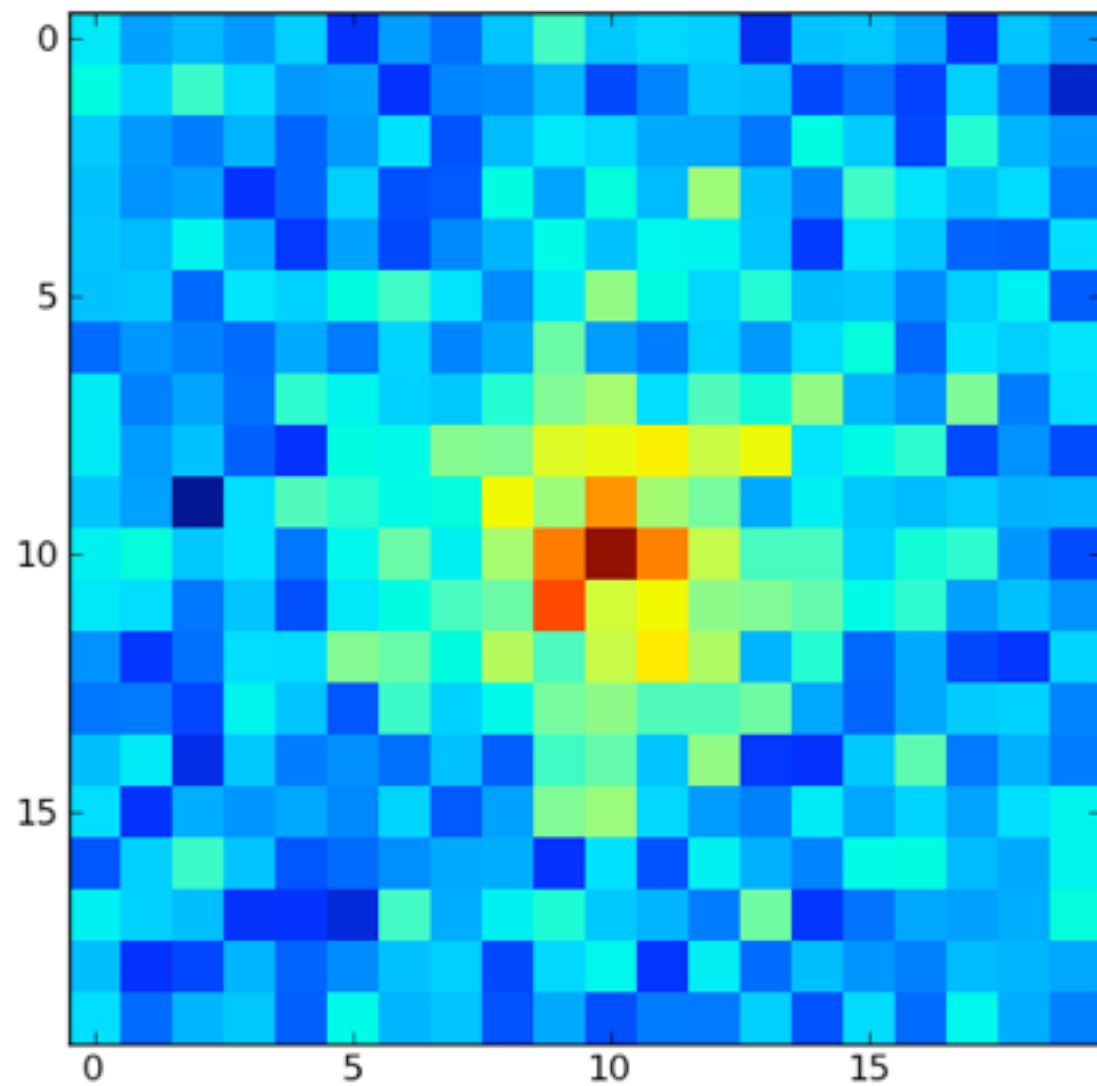
$$C_\ell = C_\ell^{gg} + C_\ell^{gi} + C_\ell^{ii}$$

# Shape Measurement



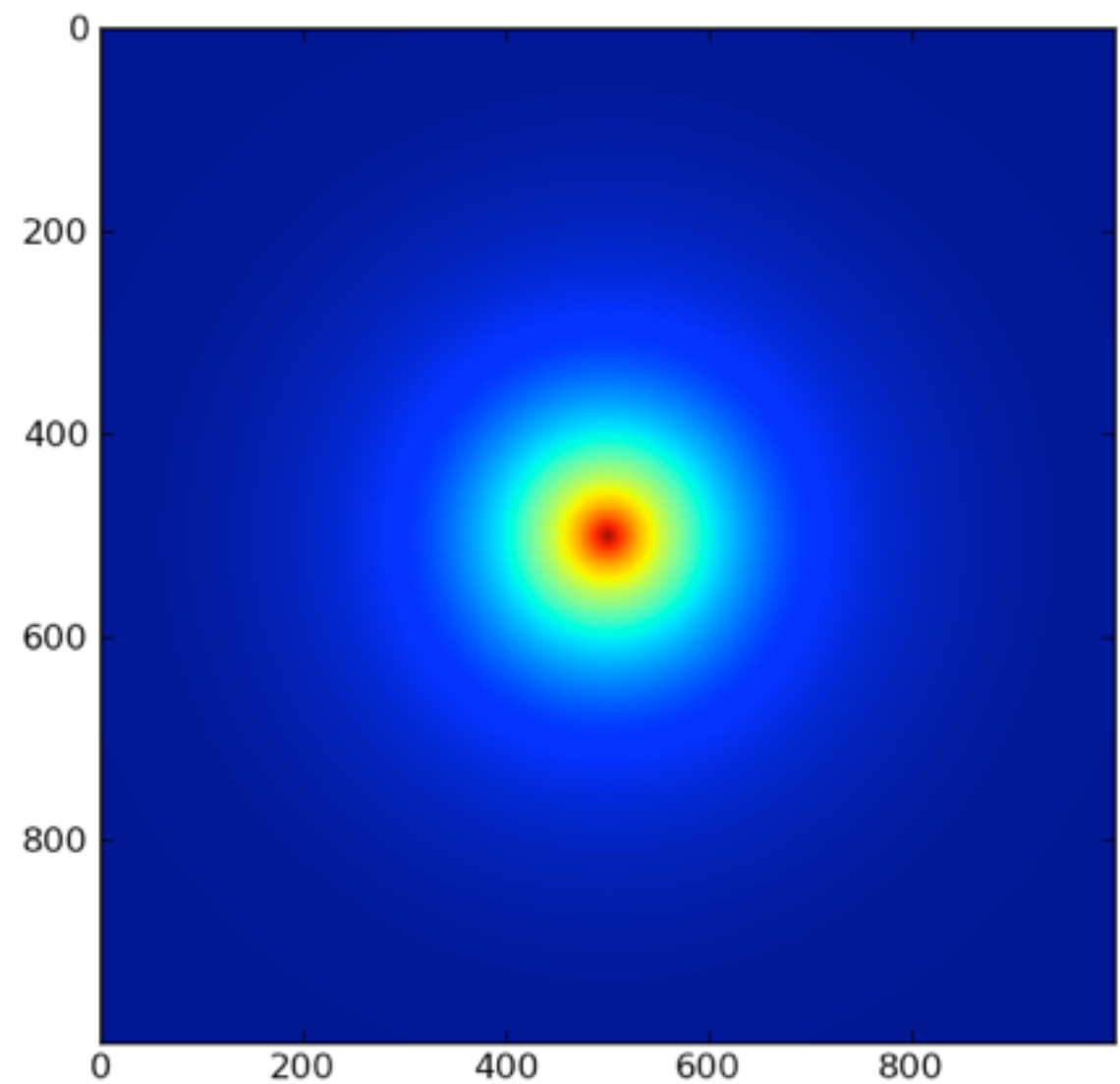
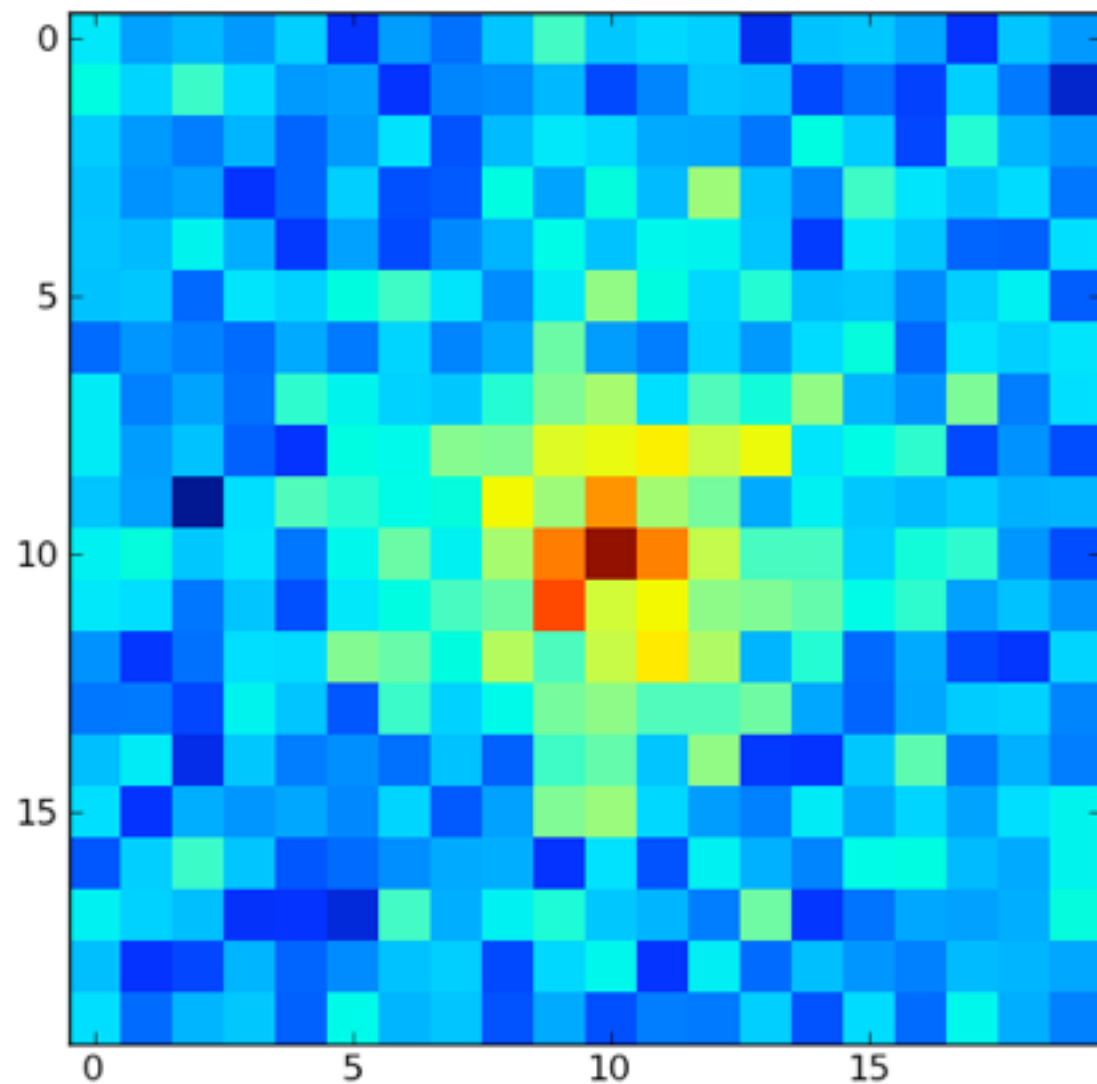
**Galaxy with shear, PSF,  
pixelization and noise**

# Requirements



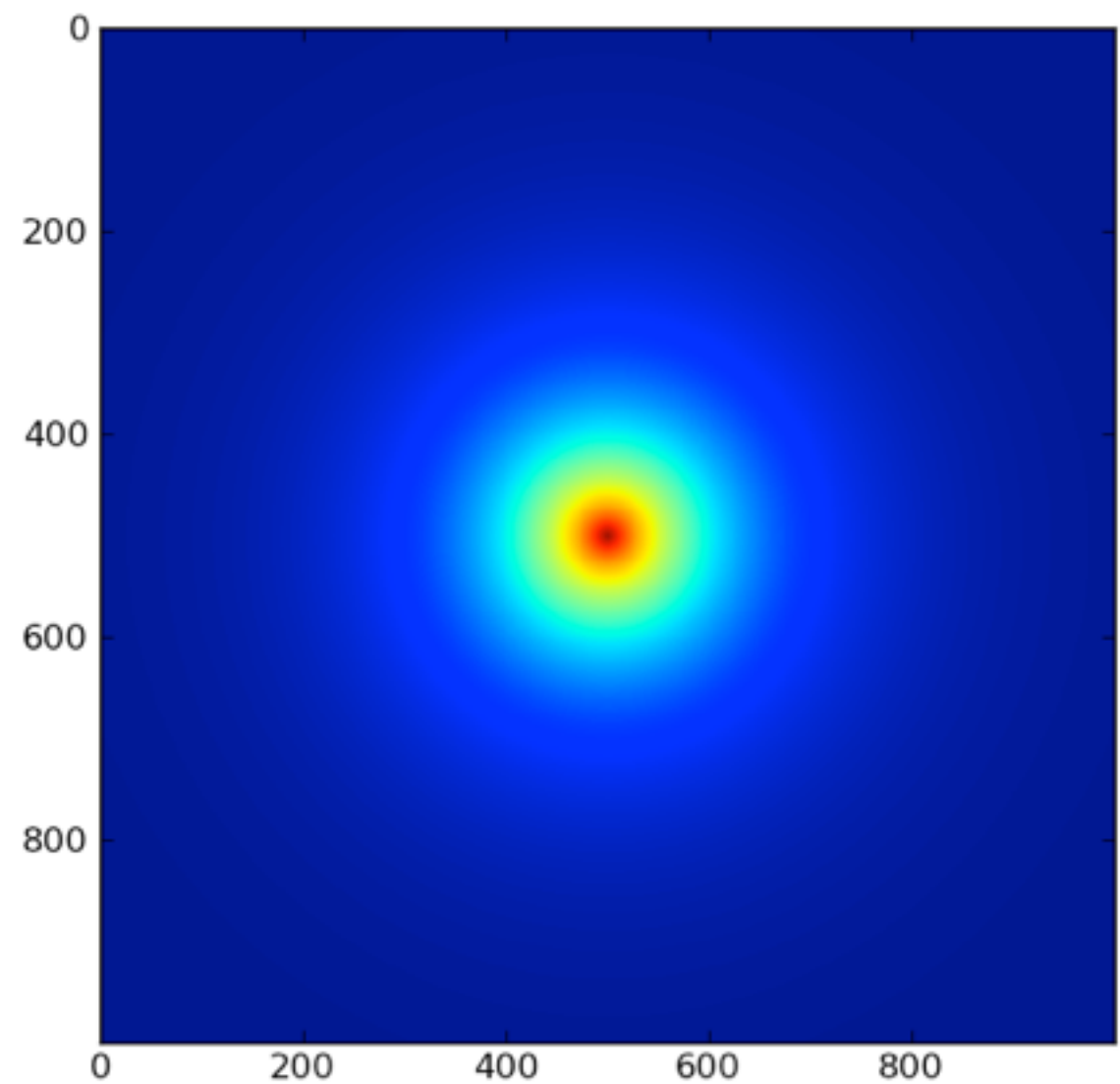
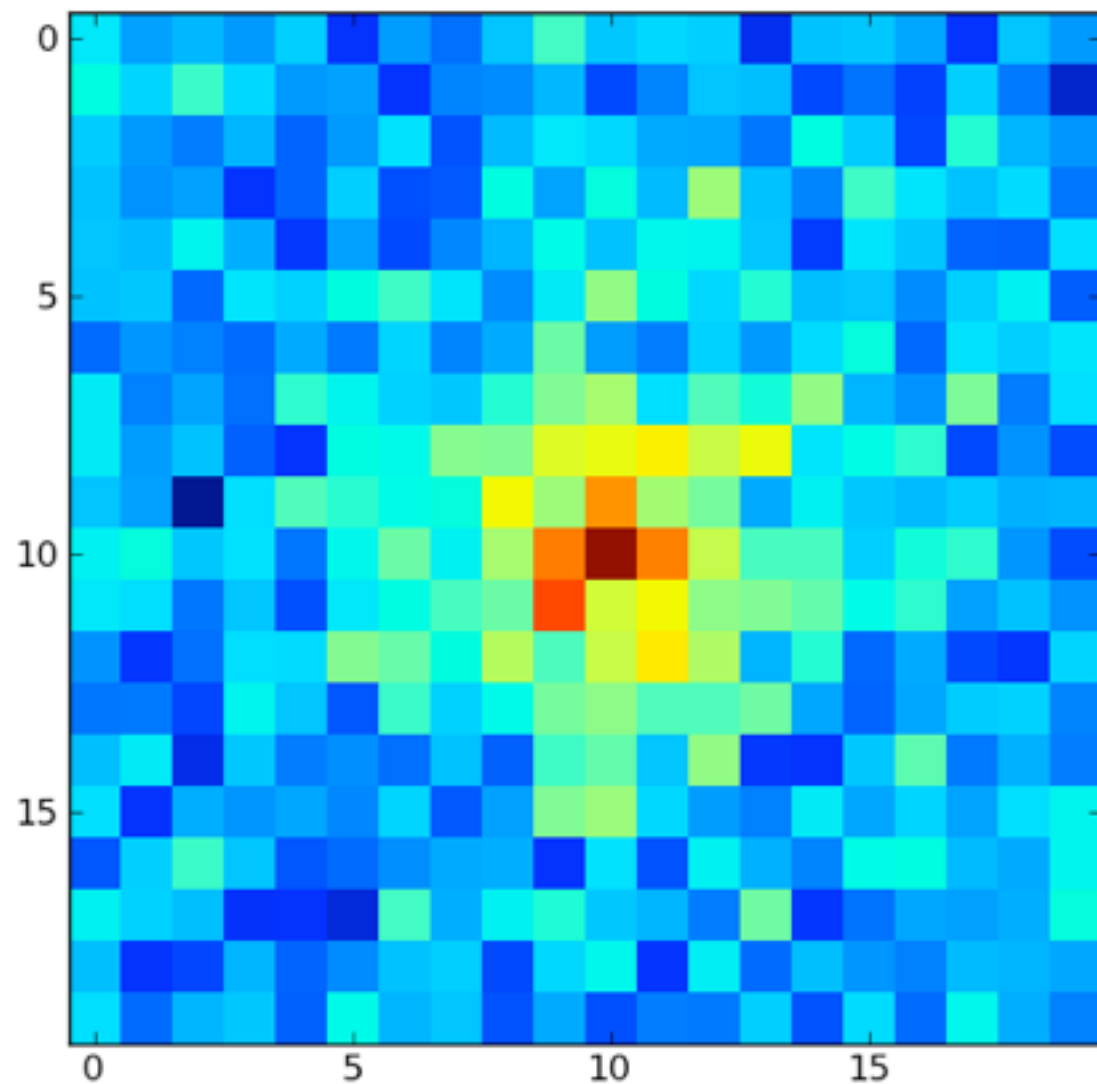


# Requirements



# Nobel Prize-Worthy Discovery

# Requirements



**Very Embarrassing Retraction**

# Basic Galaxy Model

**Exponential  
Disc**



$$\exp - \left( x^T M x \right)^{\frac{1}{2}}$$

# Basic Galaxy Model

De  
Vaucouleurs  
Bulge



$$\exp - \left( x^T M x \right)^{\frac{1}{8}}$$

# Im3shape

- **Fit with Levenberg-Marquadt**
- **PSF and Image at high res**
- **Deal with bias from resolution**
- **Calibrate bias from noise**
- **Consider bias from wrong model**
- **Model error effect on shear spectrum with a few parameters**



# Thank you

