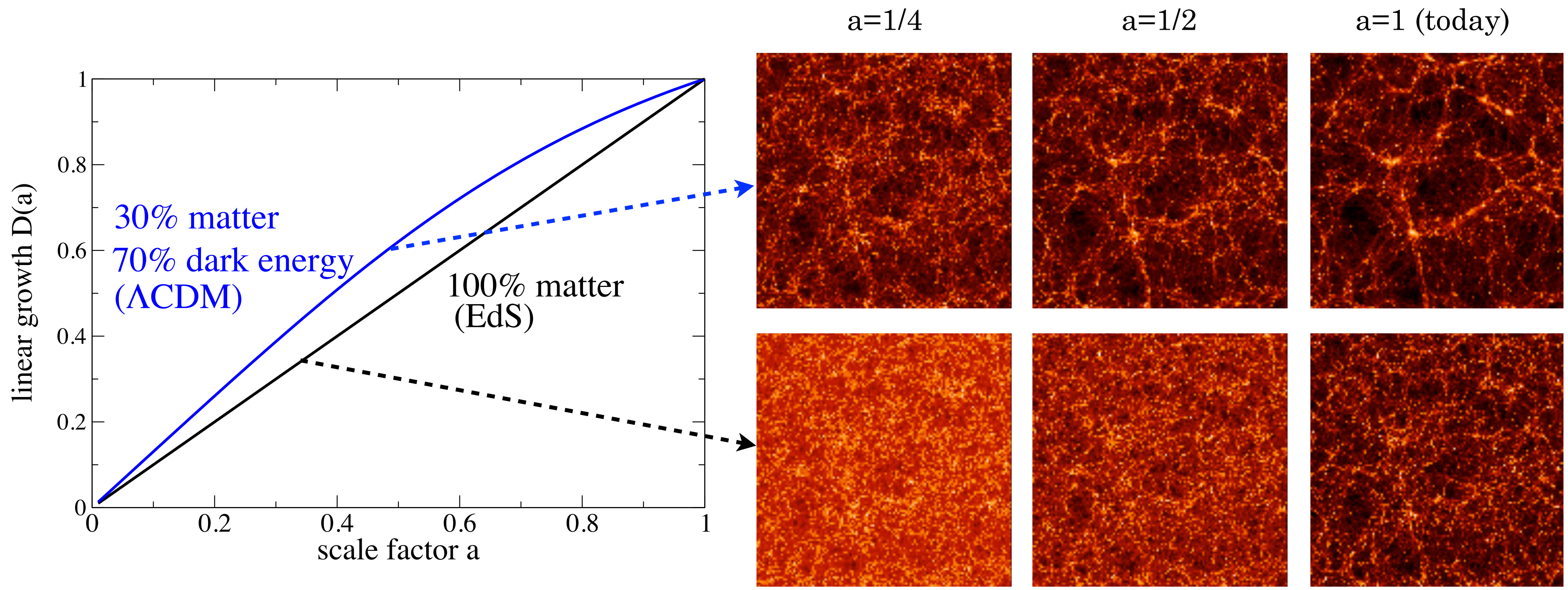
Journées Euclid France 2013

Euclid Weak lensing

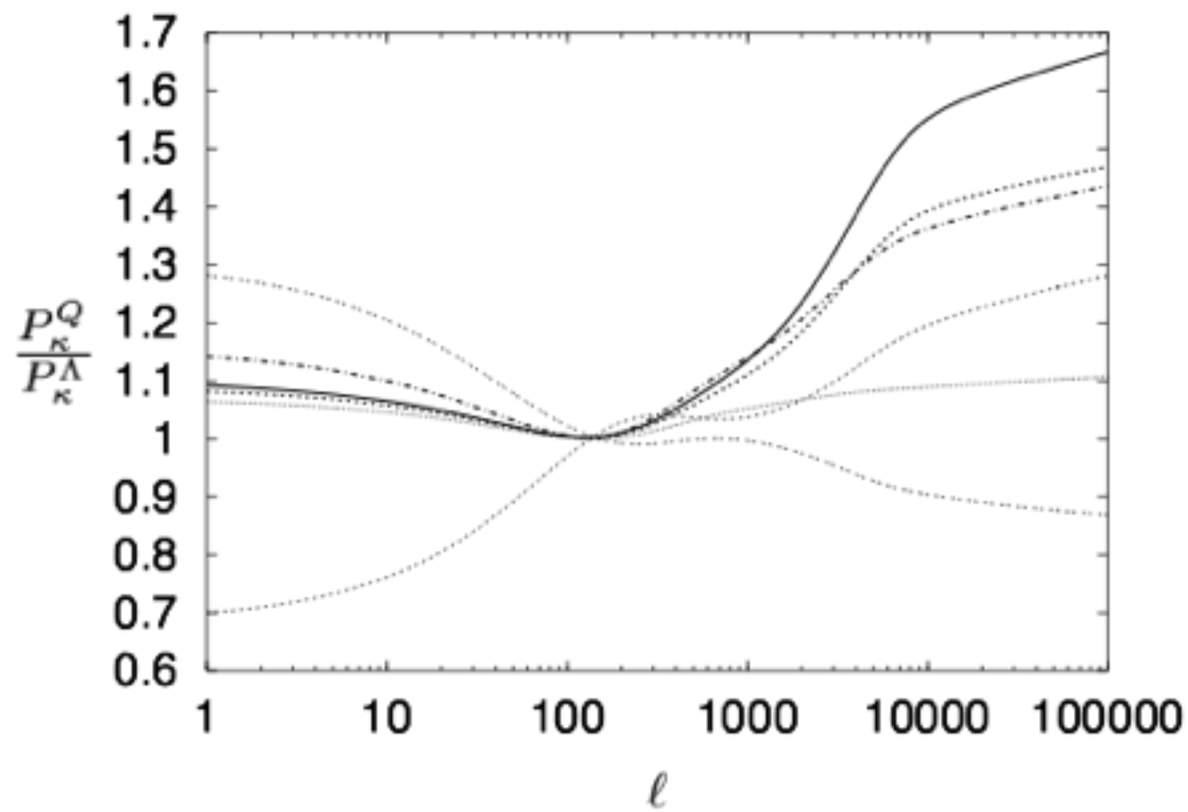
K. Benabed, IAP

Deputy lead, Science Working Group Weak lensing

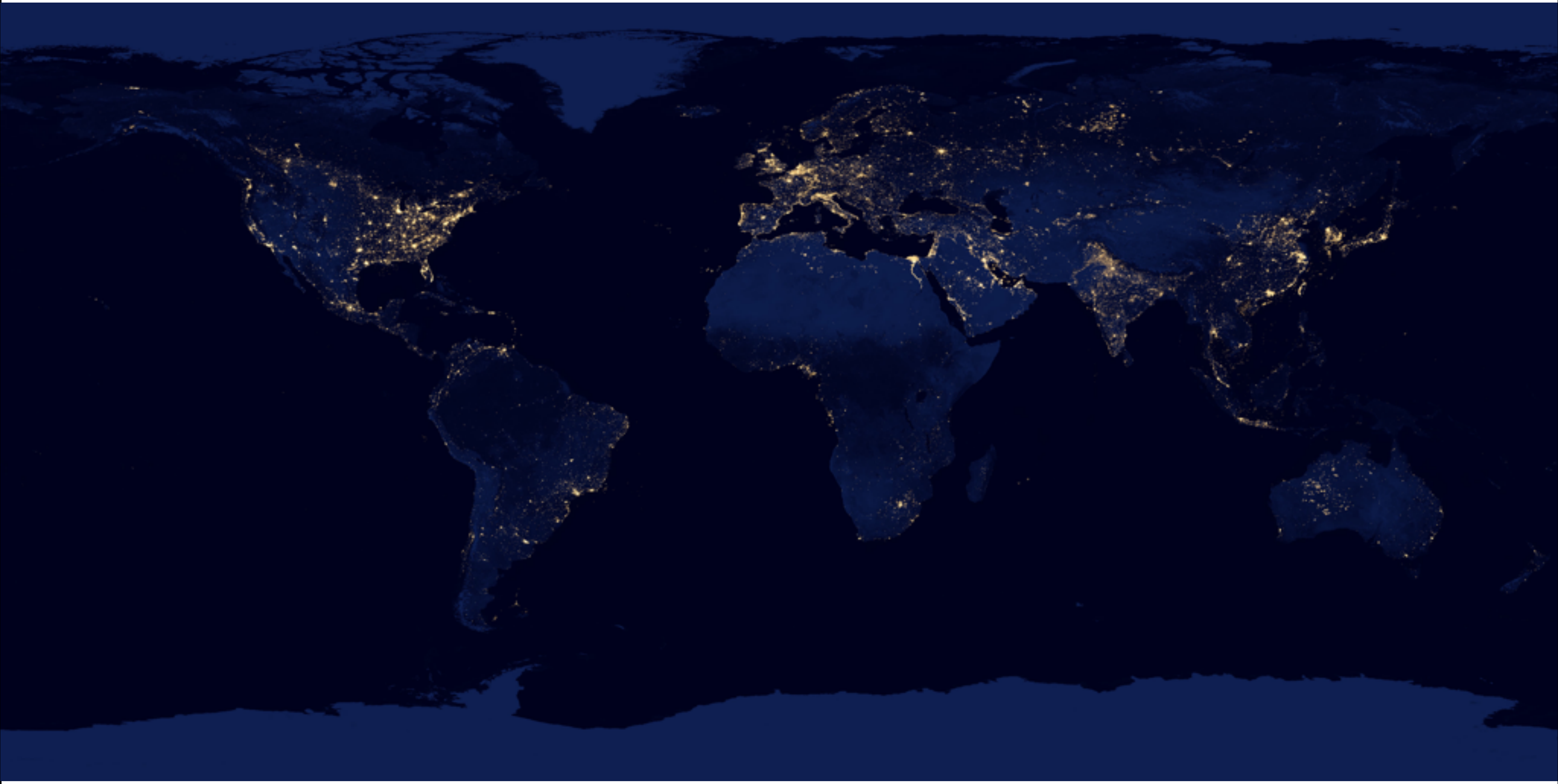
Test DE through DM clustering evolution



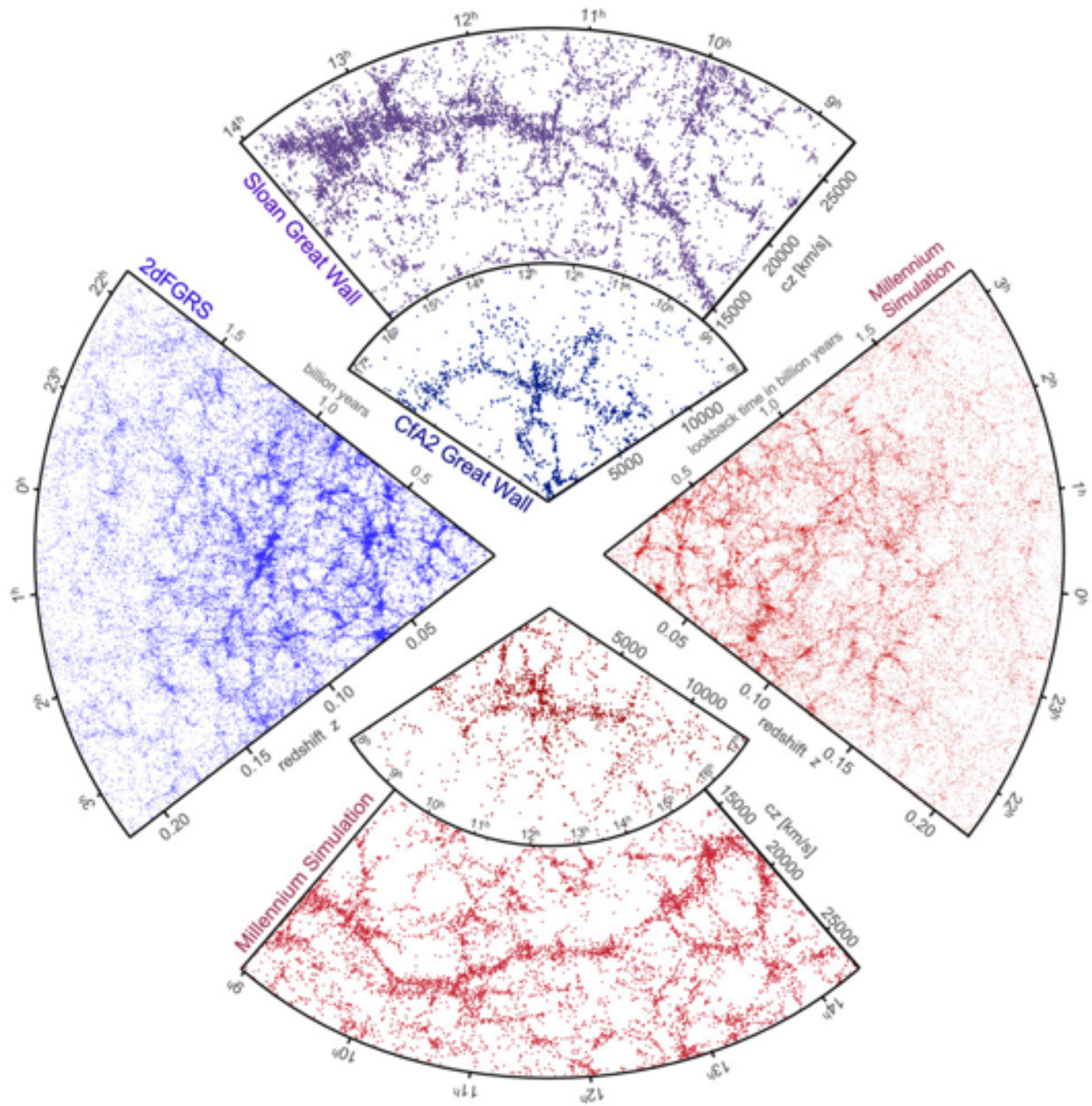
We want to observe the large scale structure distribution at different time (evolution) and at different scales (linear and non-linear regime) to extract the info on DE



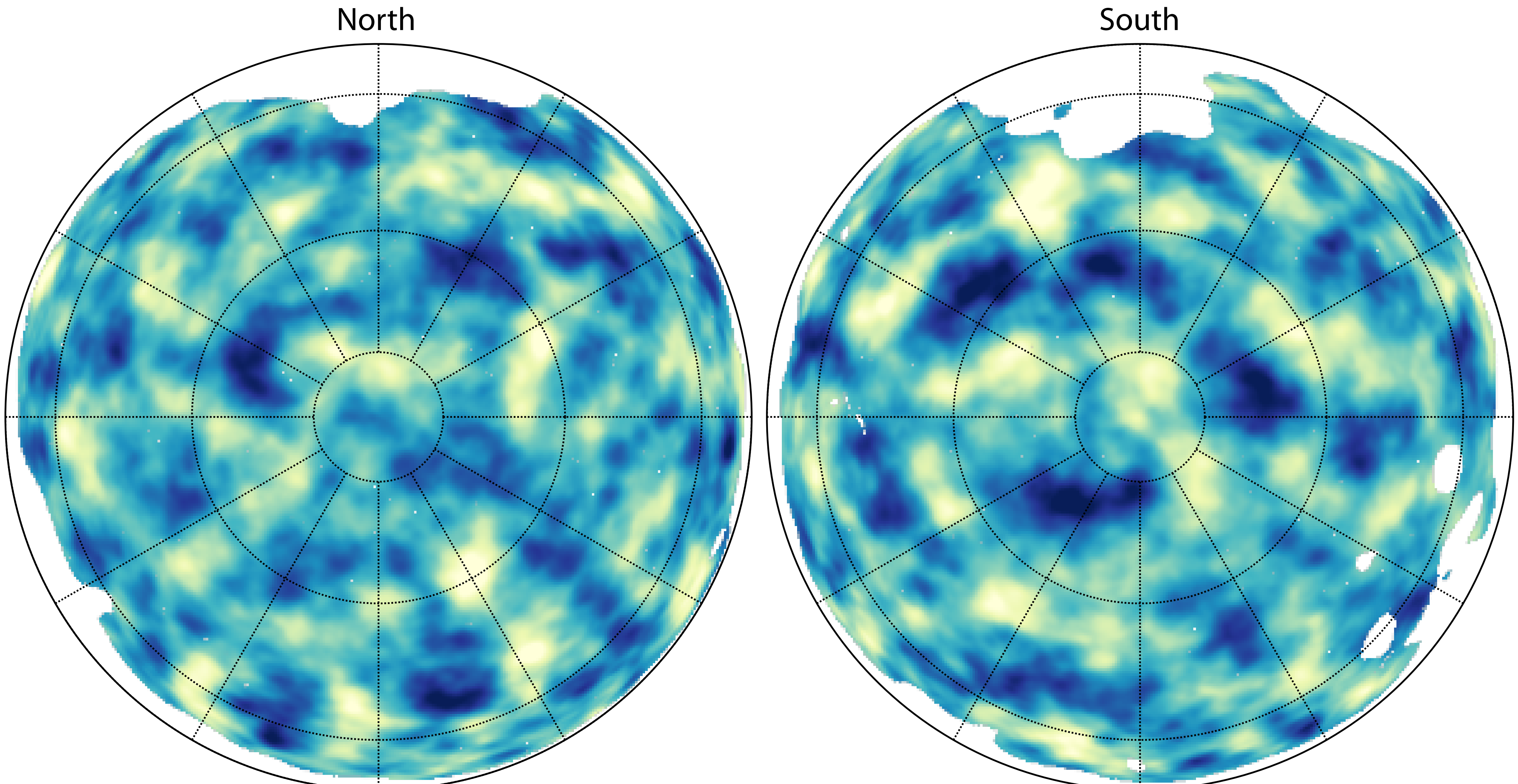
Light and DM



Light


Sloan Great Wall
2dFGRS
CfA2 Great Wall
Millennium Simulation
Millennium Simulation
cz [km/s]
cz [km/s]
redshift z
redshift z
lookback time in billion years
billion years

DM



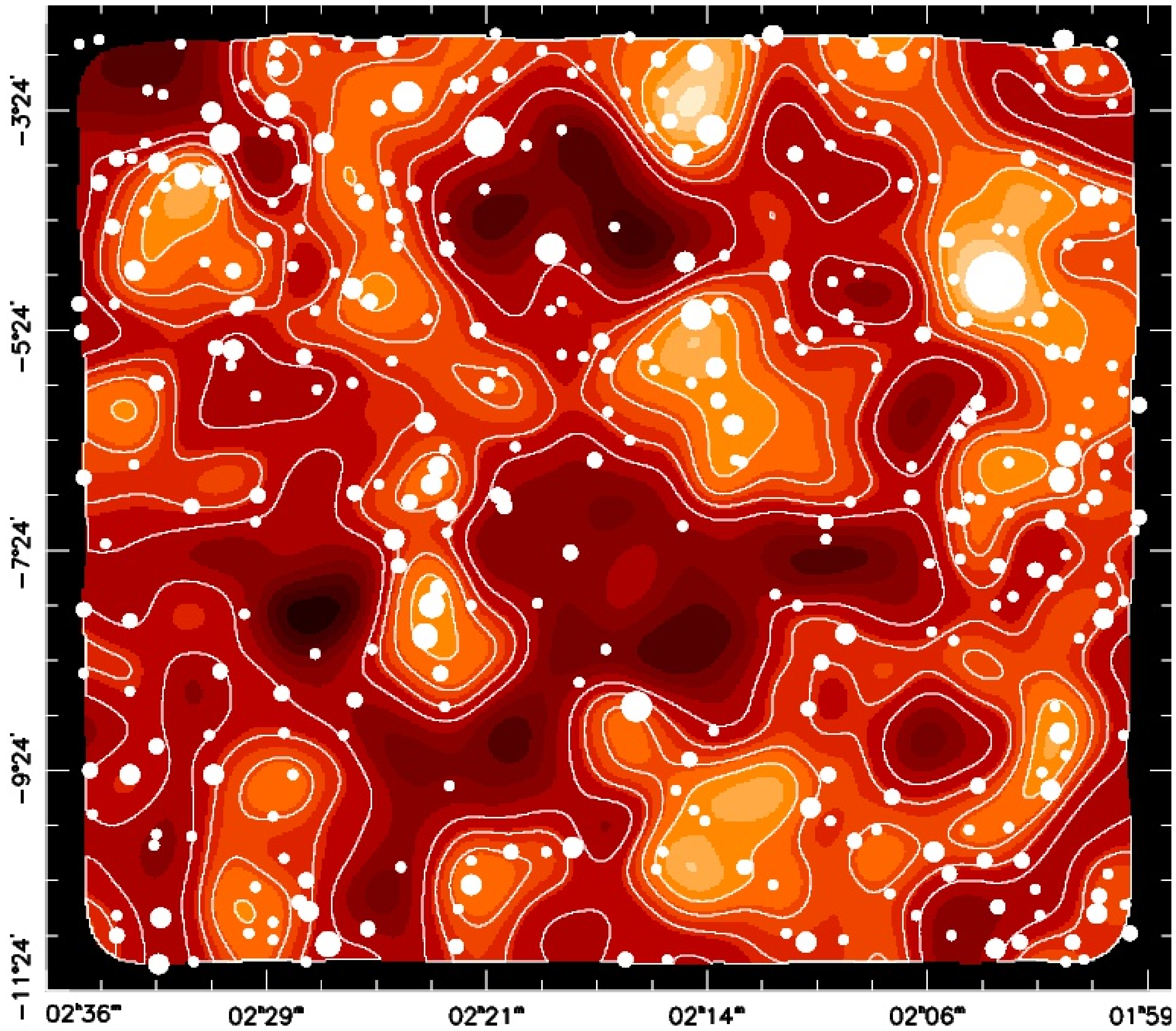
Planck 2013

According to Planck reconstruction of the lensing effect

25sigma detection

Almost full sky map of LSS at z~2

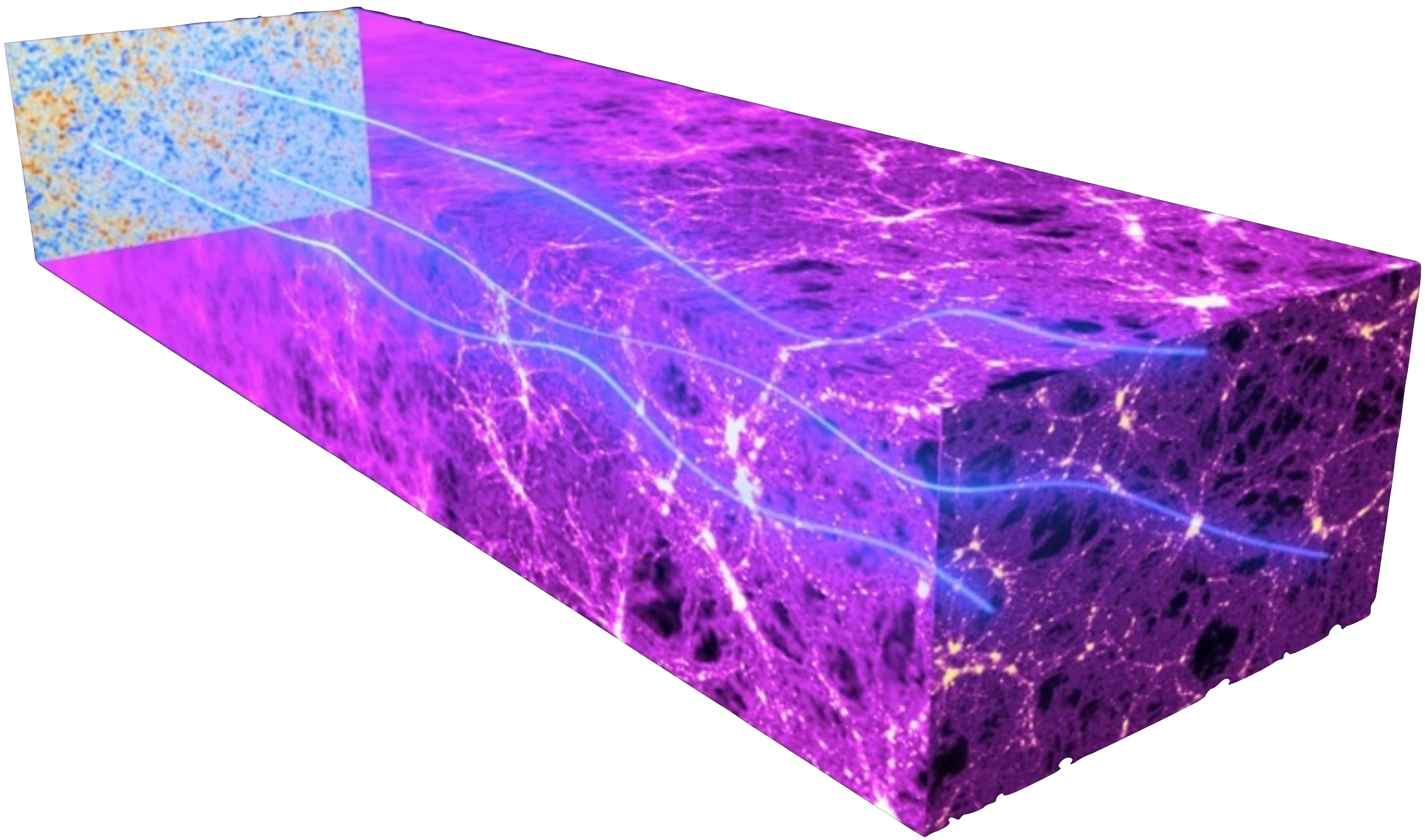
DM



According to CFHTLenS

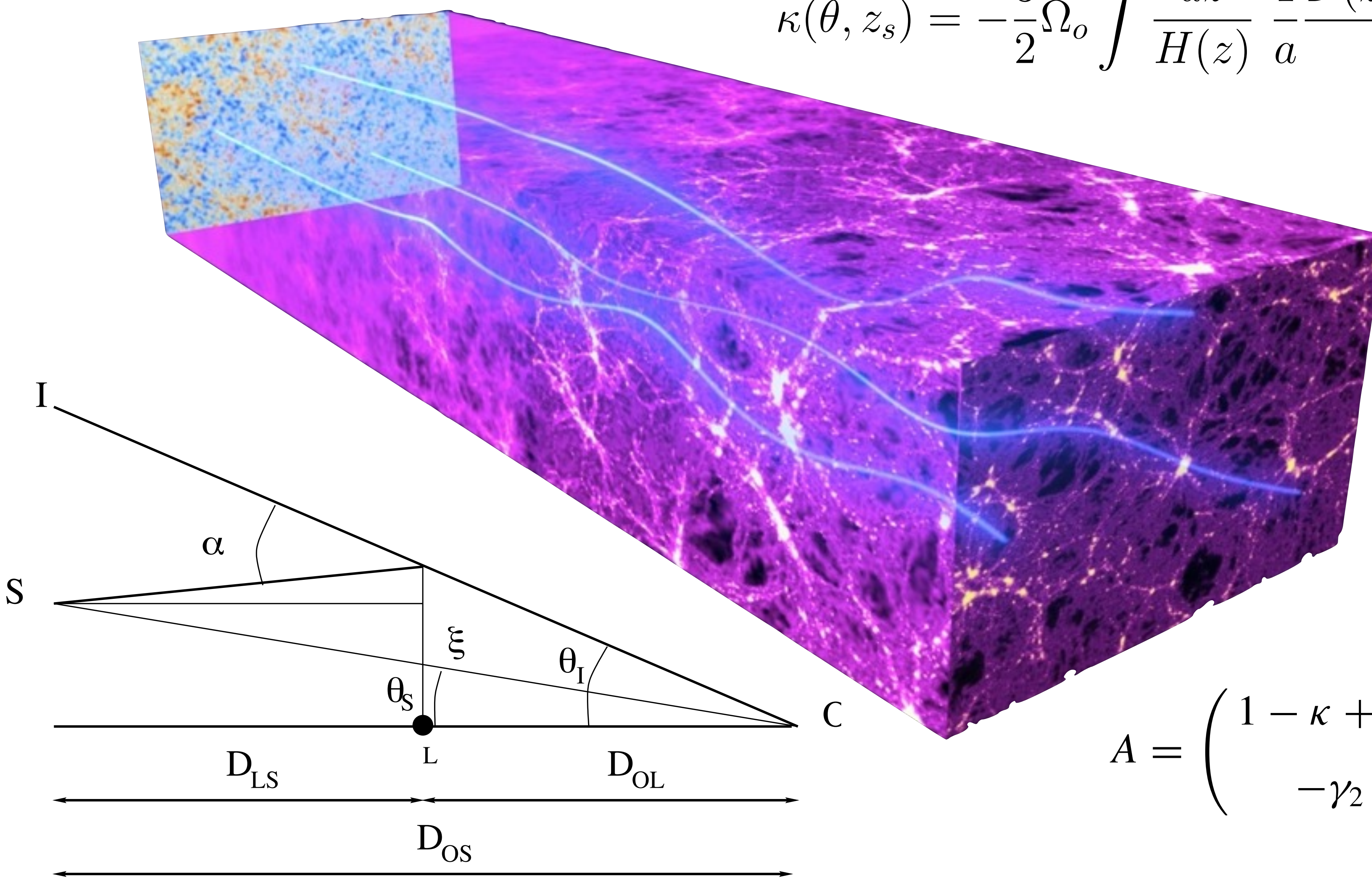
van Waerbeke et al 2013

Lensing effect on background images



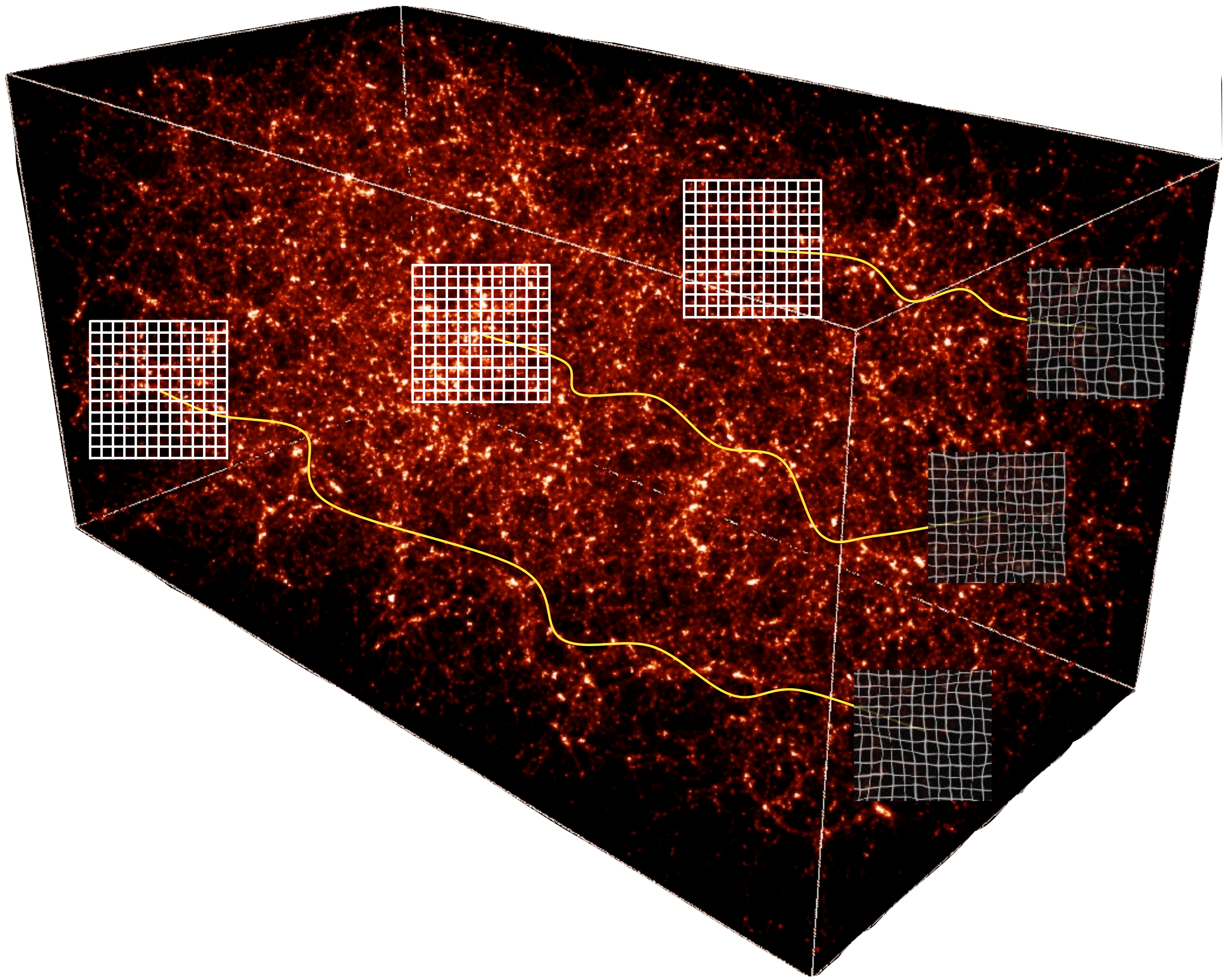
Weak Lensing

$$\kappa(\theta, z_s) = -\frac{3}{2}\Omega_o \int \frac{dz}{H(z)} \frac{1}{a}\frac{\mathcal{D}(z)\mathcal{D}(z, z_s)}{\mathcal{D}(z_s)}\delta(\theta, z)$$



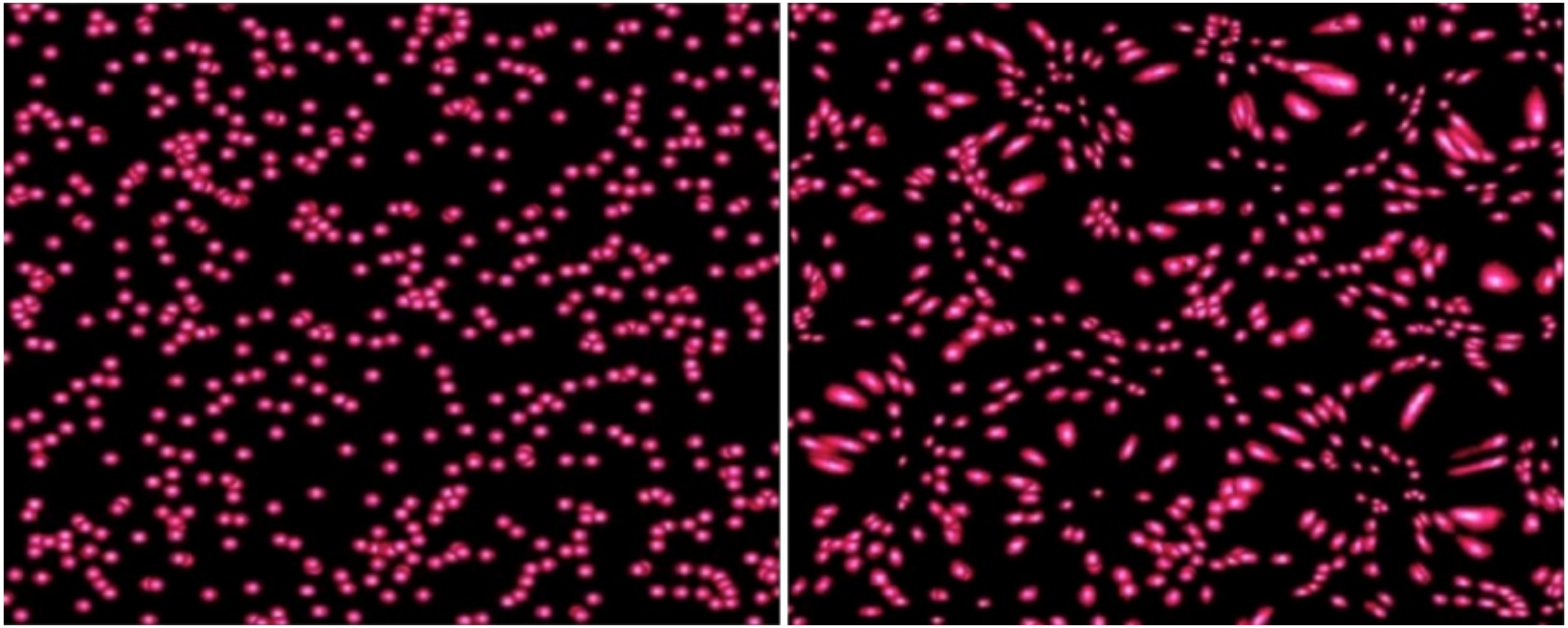
$$A = \begin{pmatrix} 1-\kappa+\gamma_1 & -\gamma_2 \\ -\gamma_2 & 1-\kappa-\gamma_1 \end{pmatrix}$$

Observing weak lensing



- We are looking for the breaking of a regular property of the background image
- We can select the depth of the large scale structure we want to probe by looking at different images/object populations
- By the way, the geometric kernel add some sensitivity to DE

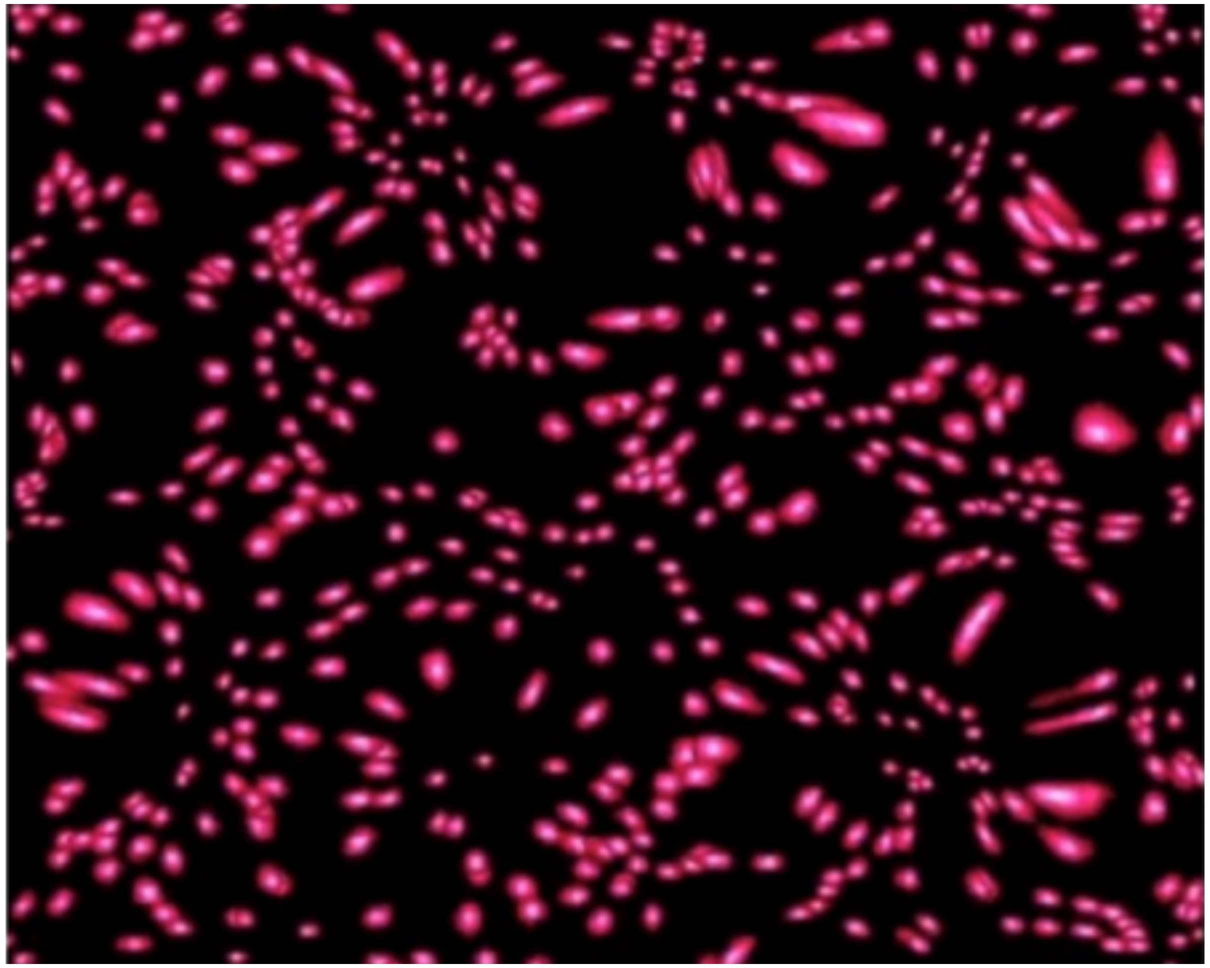
Weak lensing distorts background galaxies

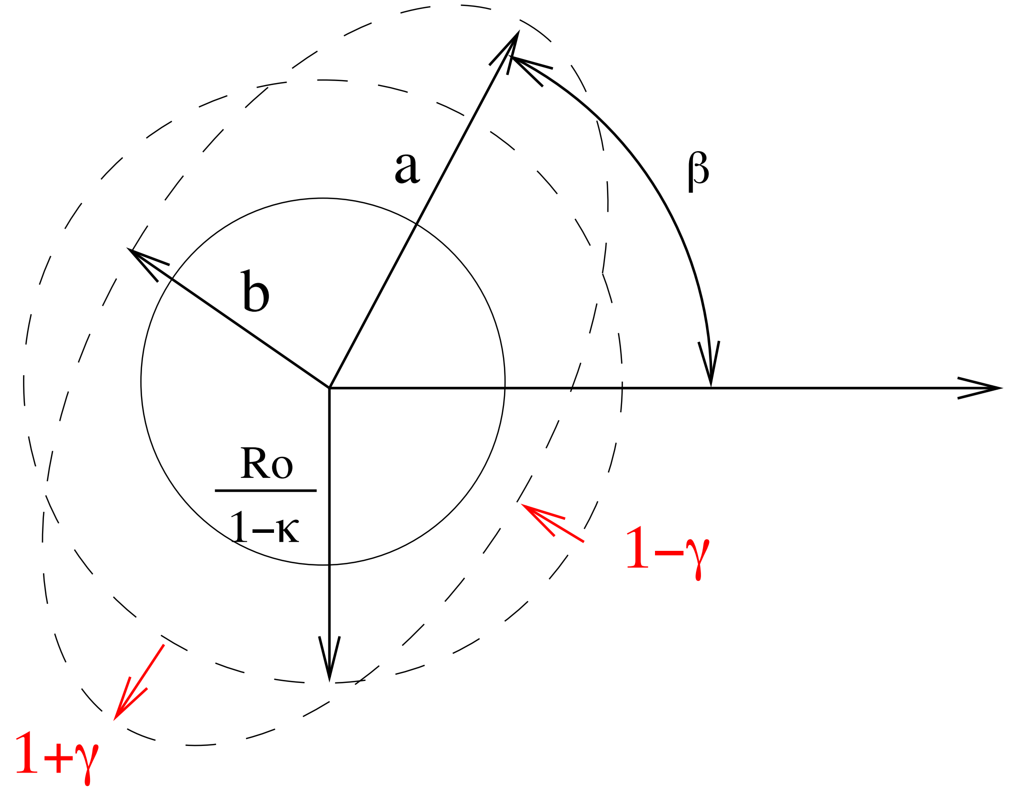


$$A = \begin{pmatrix} 1-\kappa+\gamma_1 & -\gamma_2 \\ -\gamma_2 & 1-\kappa-\gamma_1 \end{pmatrix}$$

$$\kappa(\theta, z_s) = -\frac{3}{2}\Omega_o \int \frac{dz}{H(z)}\ \frac{1}{a}\frac{\mathcal{D}(z)\mathcal{D}(z,z_s)}{\mathcal{D}(z_s)}\delta(\theta, z)$$

Weak lensing shear galaxies

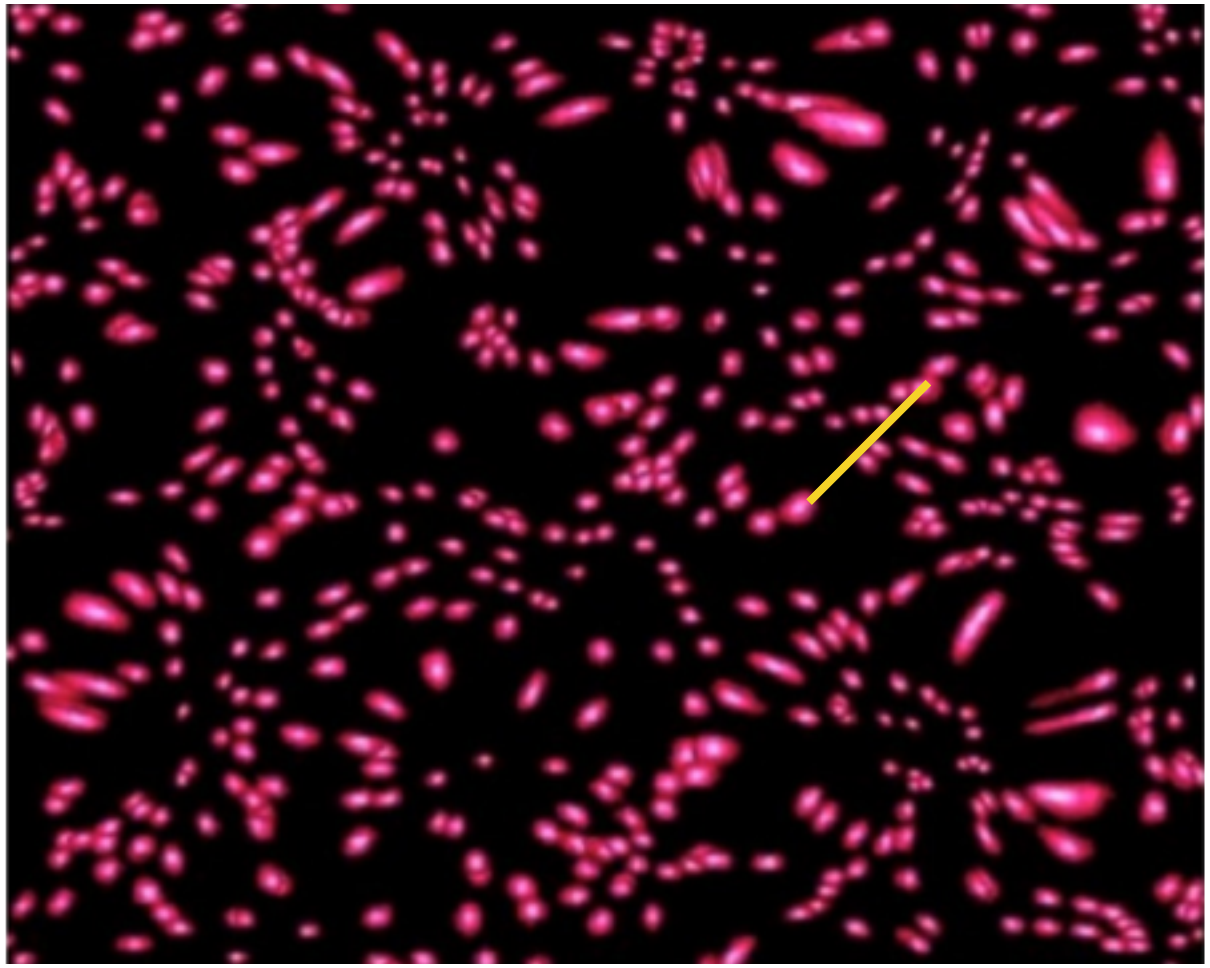


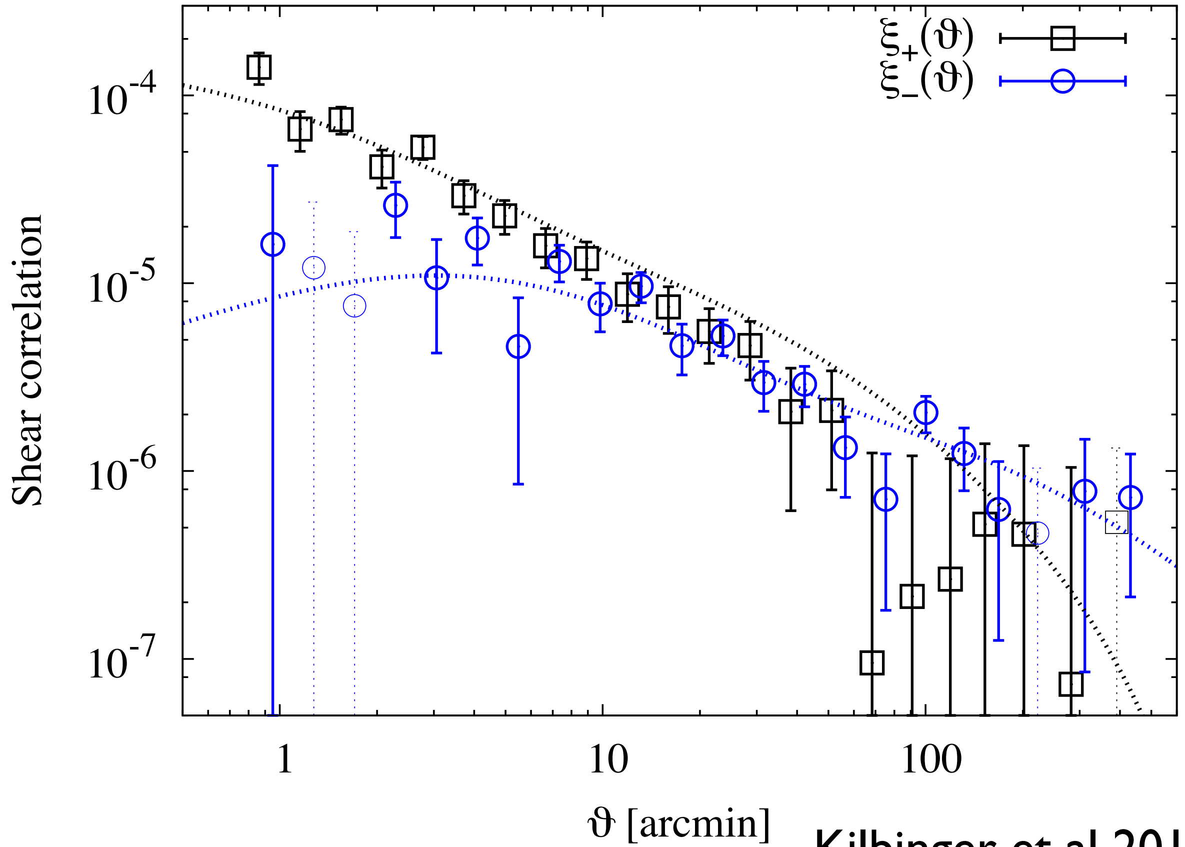


$$e^{\text{obs}} = \frac{e^{\text{int}} + \gamma}{1 + \gamma^* e^{\text{int}}},$$

$$\kappa(\theta, z_s) = -\frac{3}{2}\Omega_o \int \frac{dz}{H(z)} \, \frac{1}{a} \frac{\mathcal{D}(z)\mathcal{D}(z, z_s)}{\mathcal{D}(z_s)} \delta(\theta, z)$$

Shear is correlated on arcmin scale



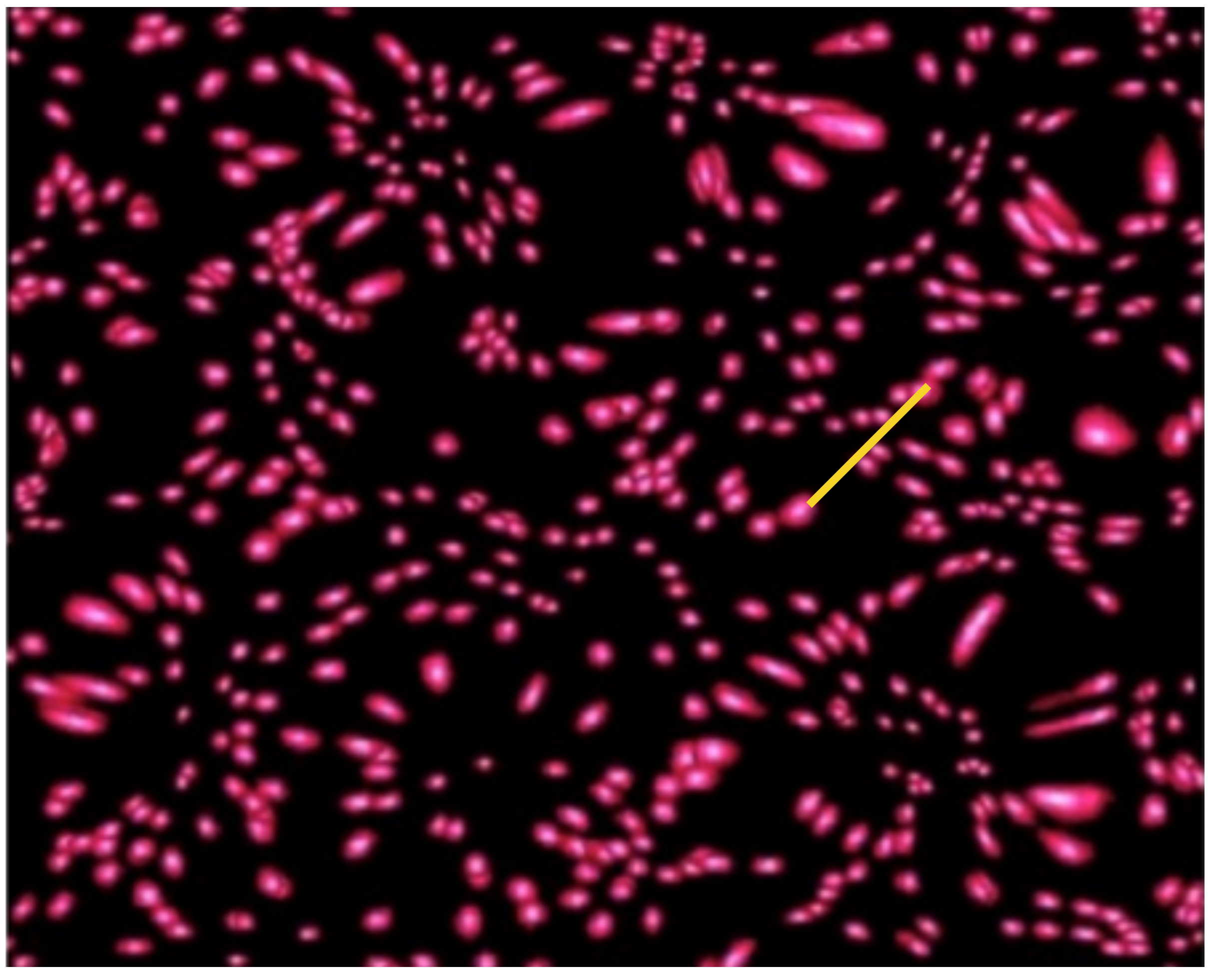


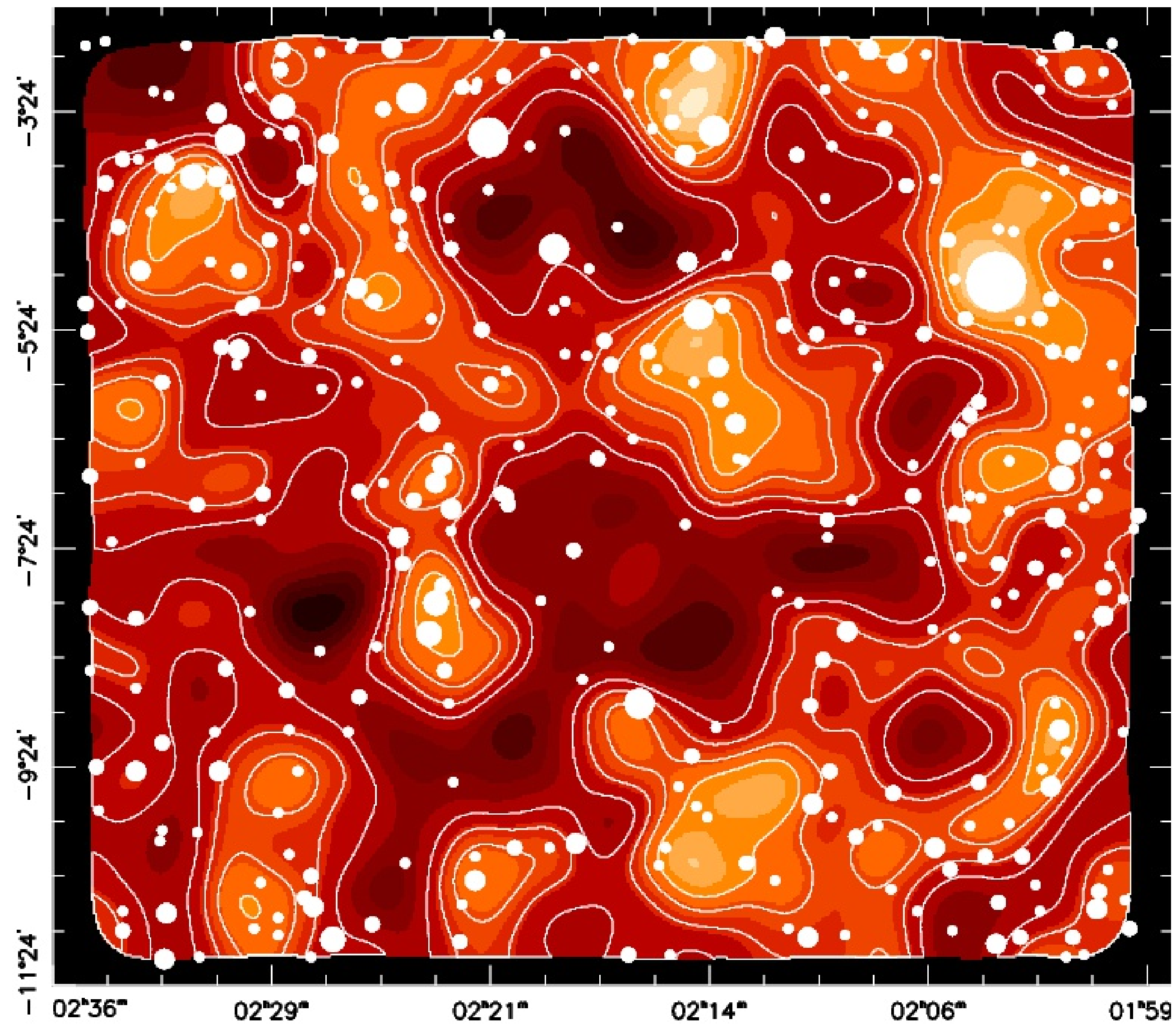
Kilbinger et al 2013

$$\kappa(\theta, z_s) = -\frac{3}{2}\Omega_o \int \frac{dz}{H(z)}\ \frac{1}{a}\frac{\mathcal{D}(z)\mathcal{D}(z,z_s)}{\mathcal{D}(z_s)}\delta(\theta, z)$$

Shear 2pt function bring information on the projected LSS 2pt function

Shear is correlated on arcmin scale



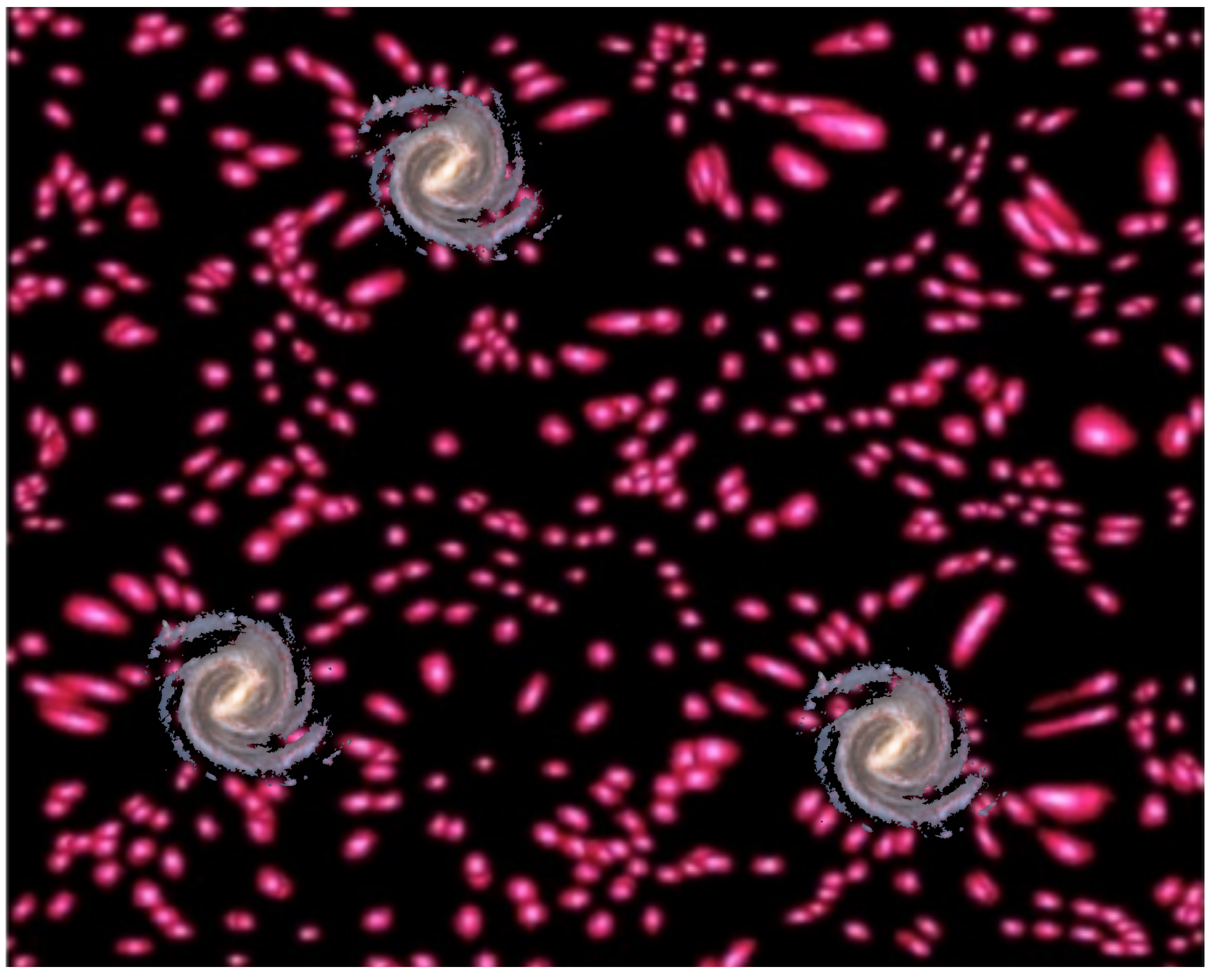


van Waerbeke et al 2013

Shear correlation allow for the reconstruction of DM mass map

But also, probe the NG properties of the DM : higher order statistics, peak and void counts…

Shear is correlated with foreground galaxies (galaxy galaxy lensing)



- Complements the shear-shear correlation
- Give access to the galaxy bias
- Can provide robustness tests for shear-shear systematics
- It’s there for free !

First Measurement of the Cross-Correlation of CMB Lensing and Galaxy Lensing

Nick Hand,[1,*] Alexie Leauthaud,[2] Sudeep Das,[3,4] Blake D. Sherwin,[5,6,4] Graeme E. Addison,[7]
J. Richard Bond,[8] Erminia Calabrese,[9] Aldée Charbonnier,[10,11] Mark J. Devlin,[12] Joanna Dunkley,[9]
Thomas Erben,[13] Amir Hajian,[8] Mark Halpern,[7] Joachim Harnois-Déraps,[7,8,14] Catherine Heymans,[15]
Hendrik Hildebrandt,[13] Adam D. Hincks,[7] Jean-Paul Kneib,[16,17] Arthur Kosowsky,[18] Martin Makler,[11]
Lance Miller,[19] Kavilan Moodley,[20] Bruno Moraes,[11] Michael D. Niemack,[21] Lyman A. Page,[22]
Bruce Partridge,[23] Neelima Sehgal,[24] Huanyuan Shan,[16] Jonathan L. Sievers,[20,22,8] David N. Spergel,[25]
Suzanne T. Staggs,[22] Eric R. Switzer,[26,8] James E. Taylor,[27] Ludovic Van Waerbeke,[7] and Edward J. Wollack[26]

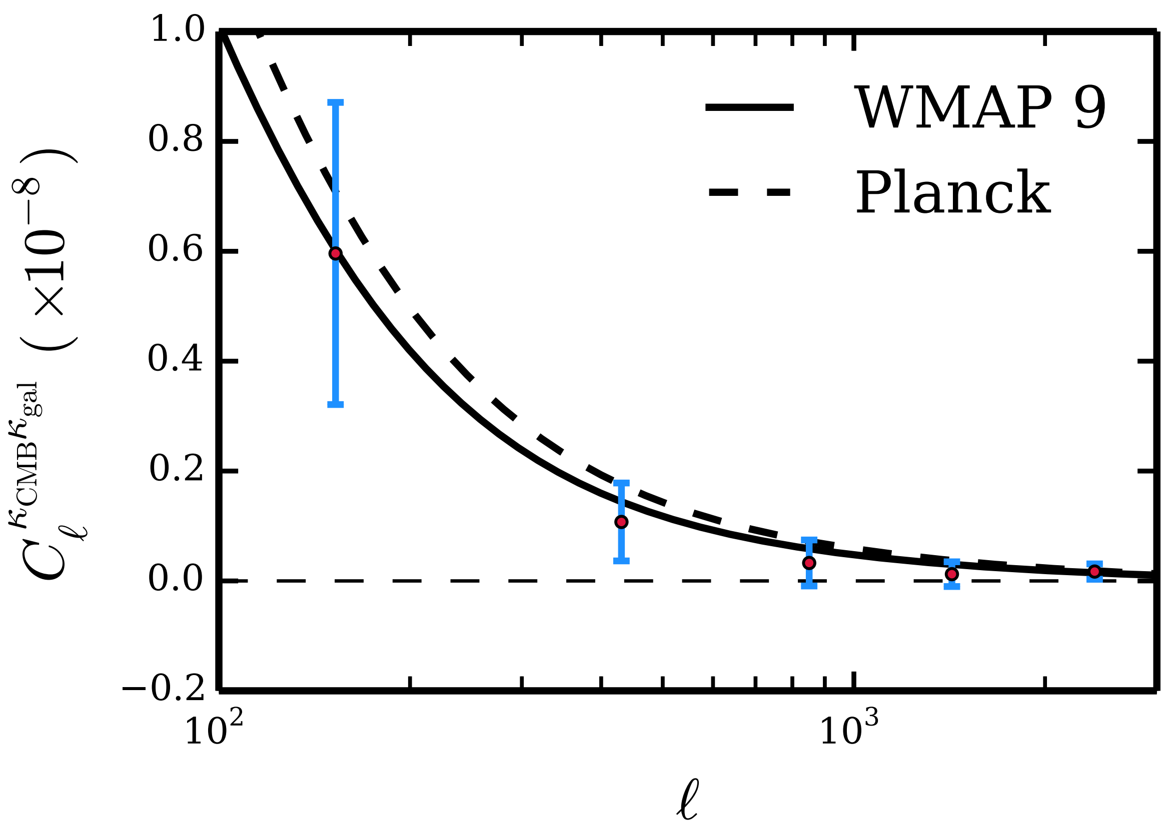
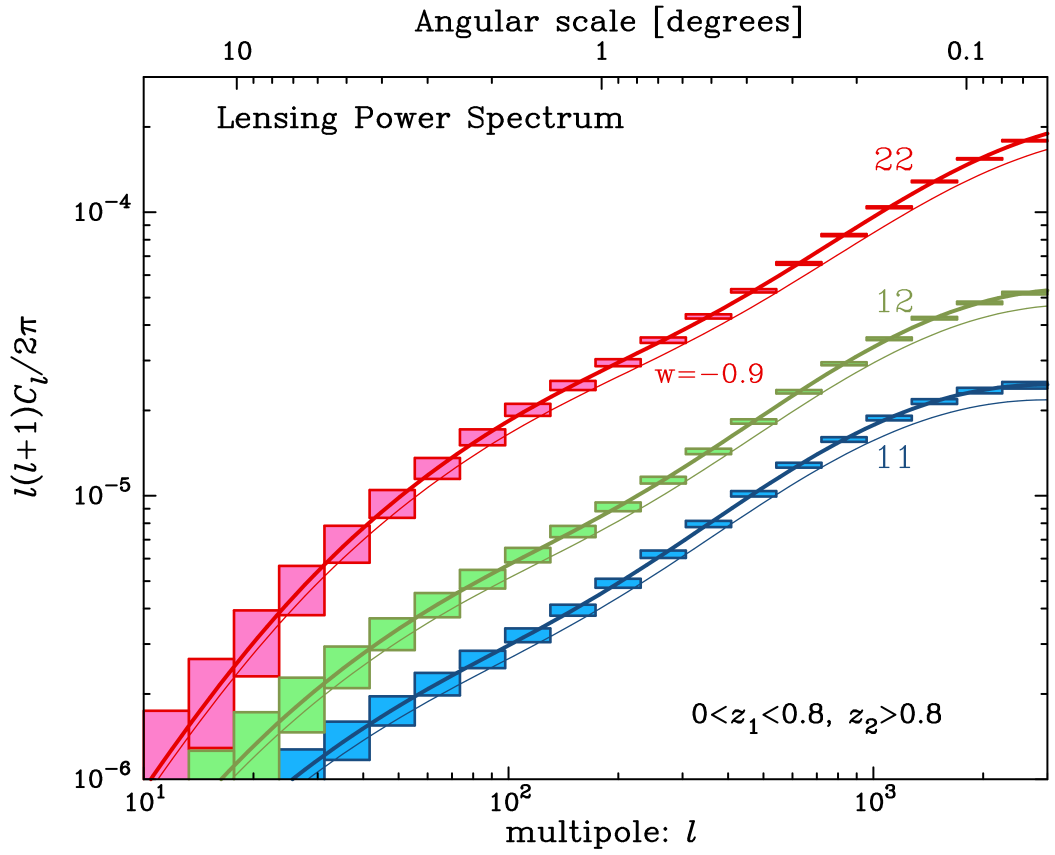


FIG. 4. The CMB lensing - galaxy lensing convergence cross power spectrum (red points), measured using ACT and CS82 data. Error bars are computed using Monte Carlo methods (see text), and the significance of the measurement is 3.2σ. The dashed and solid black lines show the expected power spectra assuming the *Planck* + lensing + WP + highL and *WMAP*9 + eCMB cosmological models, respectively. The theoretical spectra shown correspond to $A = 1$, and relative to these models, the best-fit amplitudes to our data are $A^{\rm Planck} = 0.61 \pm 0.19$ and $A^{\rm WMAP} = 0.74 \pm 0.23$.

How to get evolution

- Vary the redshift selection function of the observed galaxy to access to growth evolution



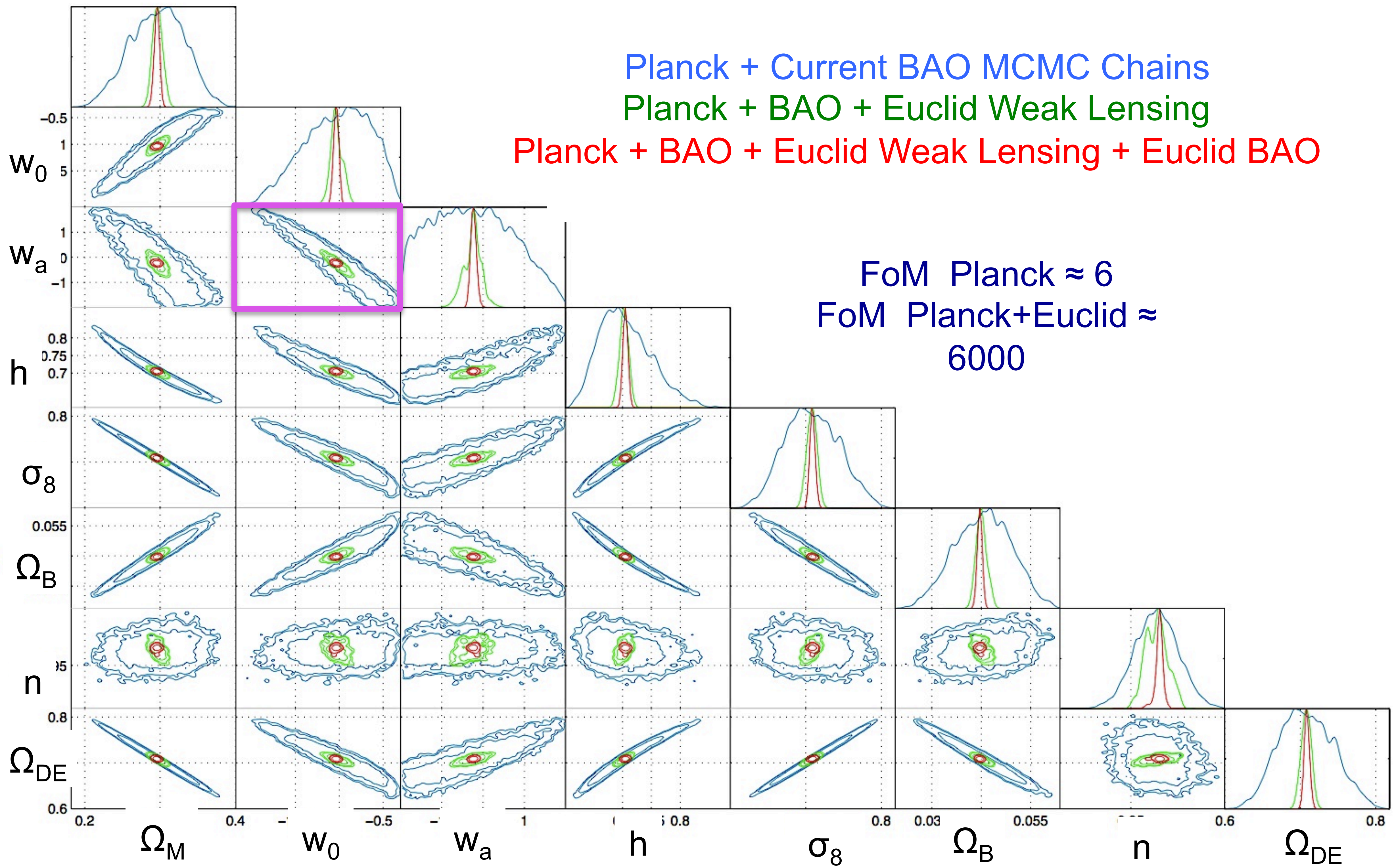
- Build redshift bins using photometric redshifts
- The more the better
- The more precise the better

An idealized Weak Shear pipeline

- Observe background galaxies
- Measure their ellipticities
- Measure their redshifts and build redshift bins
- Correlate their ellipticities/redshift bins
- Fit your preferred cosmological model
- Solve the mysteries of the universe

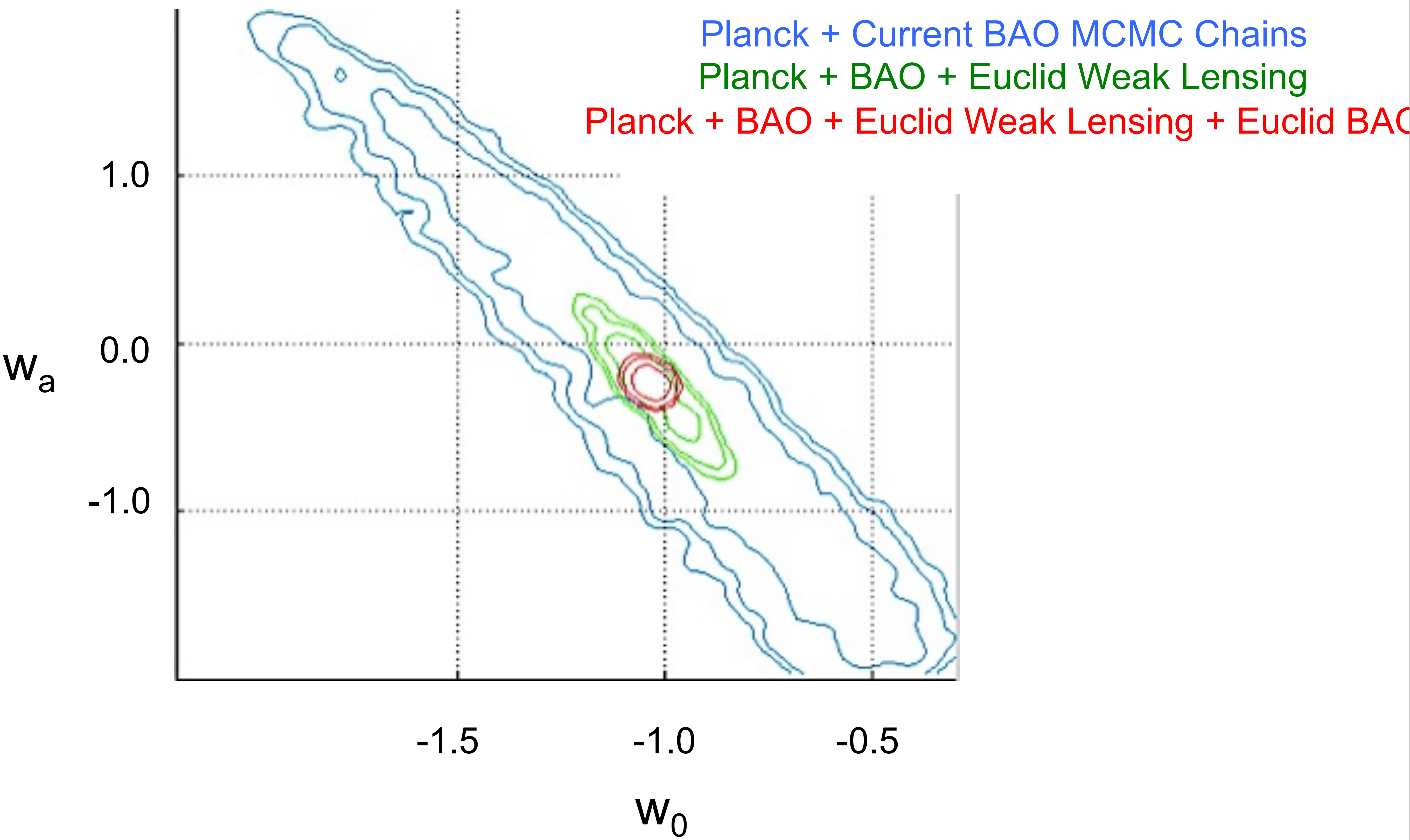
Building Euclid WL

- Large scale survey : 15000deg^2
  - Large scales accessible - improves statistic at small scales
- Space is the place
  - small and stable PSF <0.2arcsec
- A broad VIS band : sensitivity and resolution
  - >30 galaxy/arcmin i.e. 1.5 10^9 usable galaxies
  - Median redshift >0.8
- 3 NIR bands + ground visible data + ground spectroscopy : Photo-Z
  - accuracy $\sigma(z)/(1+z) < 0.05$
  - 10 redshift bins for tomography up to z~2 (Red book forecasts)



FoM Planck ≈ 6

FoM Planck+Euclid ≈ 6000


Planck + Current BAO MCMC Chains
Planck + BAO + Euclid Weak Lensing
Planck + BAO + Euclid Weak Lensing + Euclid BAO
1.0
0.0
-1.0
w_a
-1.5
-1.0
-0.5
w_0

An idealized Weak Shear pipeline

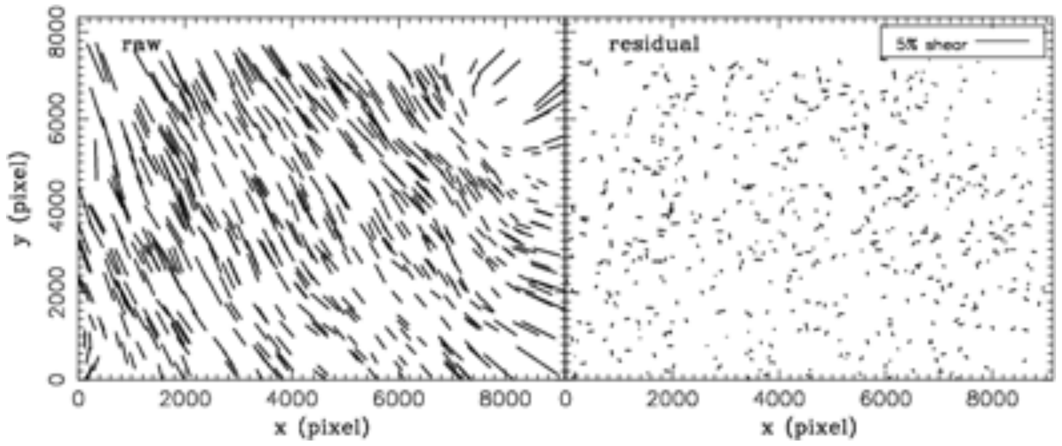
- Observe background galaxies
- Measure their ellipticities
- Measure their redshifts and build redshift bins
- Correlate their ellipticities/redshift bins
- Fit your preferred cosmological model

Life is complicated

- Observe background galaxies
  - First observe images, and correct for instrument effects (PSF…)
- Measure their ellipticities
  - Do we really know how to do that ?
- Measure their redshifts and build redshift bins
  - Are they precise enough ?
- Correlate their ellipticities/redshift bins
  - Am I only seeing WL when I do that ?
- Fit your preferred cosmological model
  - What statistical description for the data ?
  - Is my theoretical knowledge sufficient ?

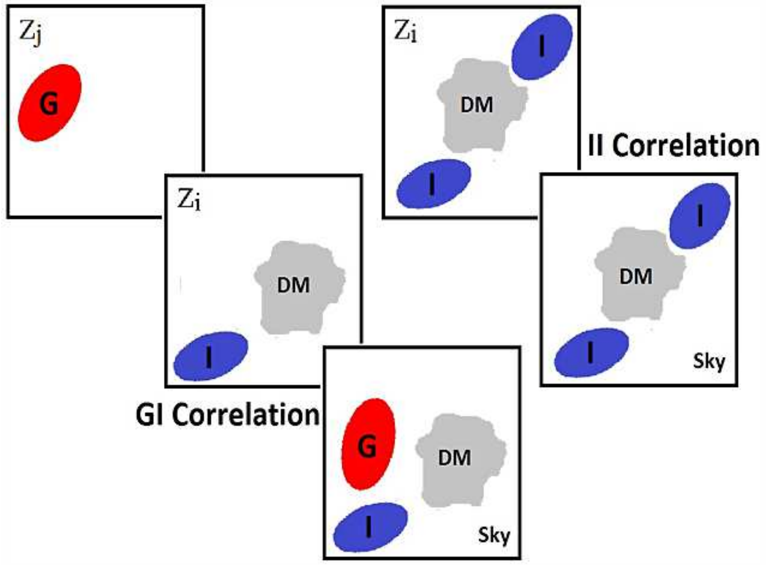
A (shortened) systematic list

- PSF
- Shear Calibration



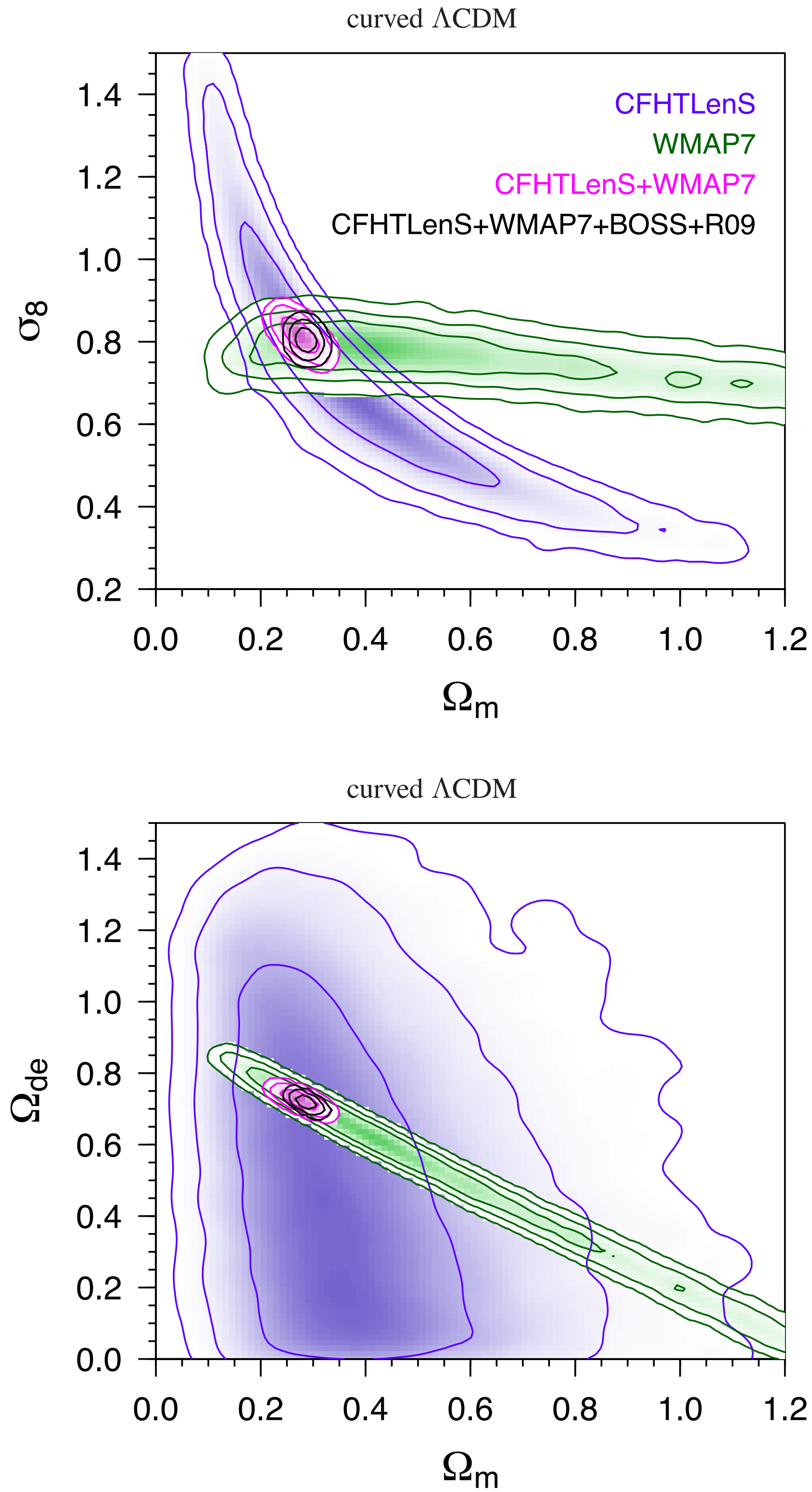
$$\tilde{e} = \gamma + e_{\rm intrinsic} + c + m\ (\gamma + e_{\rm intrinsic}) + q\ (\gamma + e_{\rm intrinsic})^2 + o(\gamma^3, e^3)$$

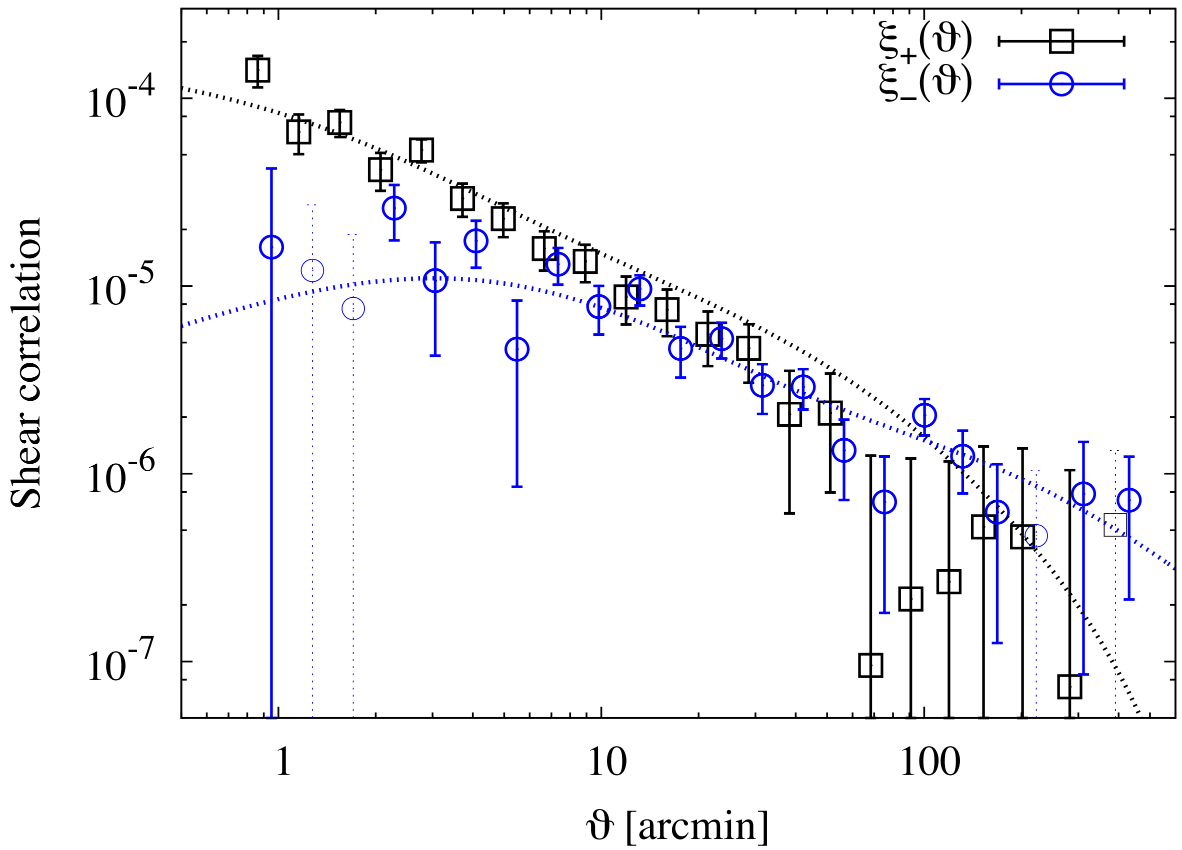
- Intrinsic alignement
- Photo-z
- non-linear physics
- baryon physics



- 2pt function Likelihood - covariance matrix

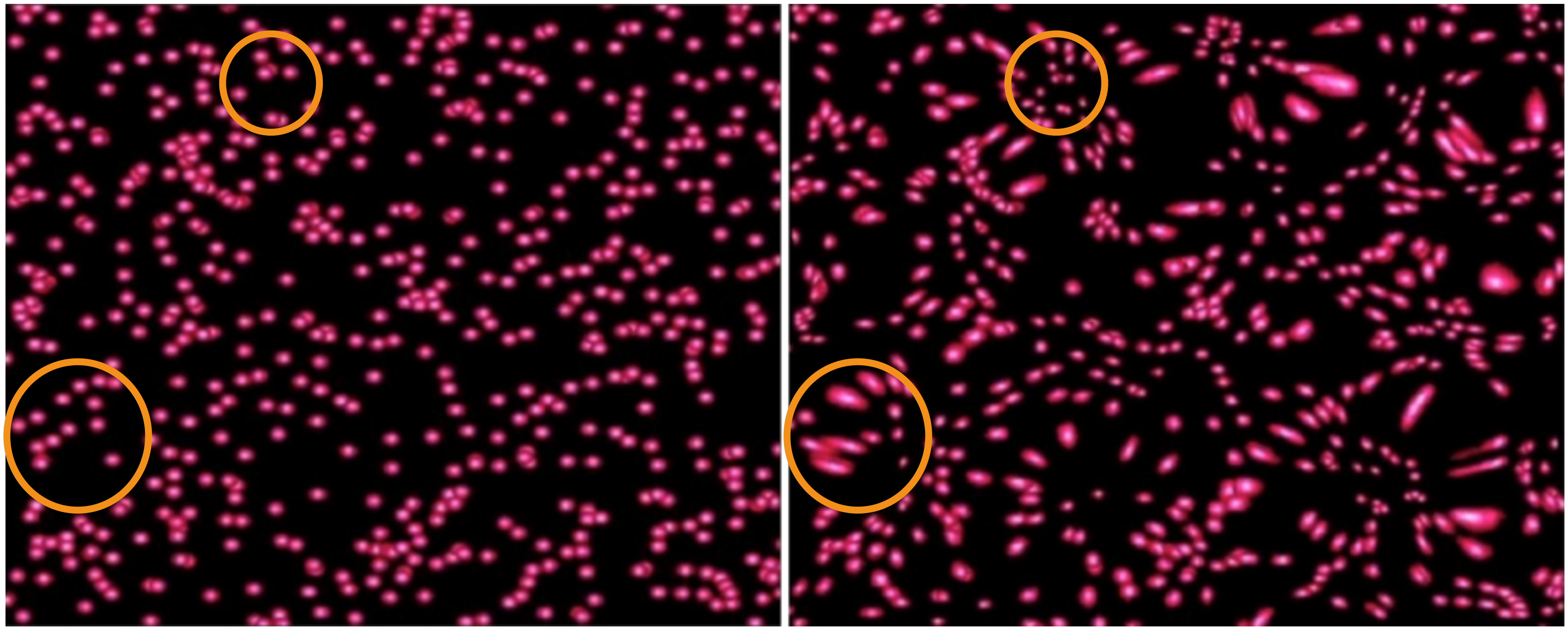
CFHTLenS





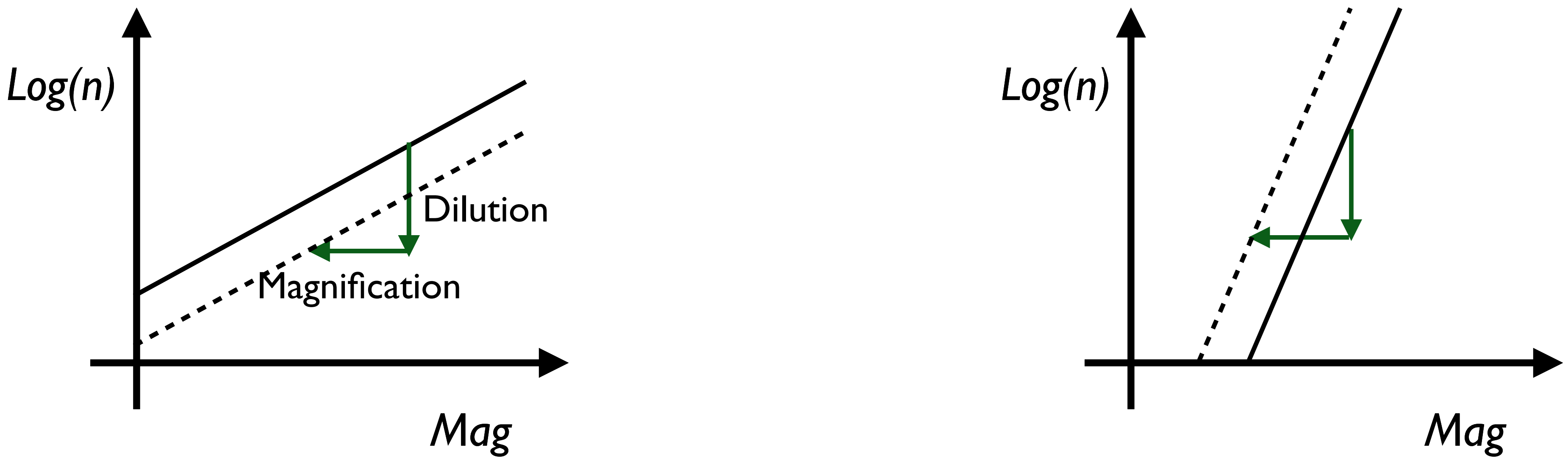
Kilbinger et al 2013

Weak lensing magnifies galaxies



Collect more (or less) light
Concentrate (or dilute) objects

Magnification and Number counts



$$\mu \simeq 1 + 2\kappa + \mathcal{O}(\kappa^2).$$

$$n(> f, \boldsymbol{r}) = \bar{n}(> f, r)\mu(\boldsymbol{r})^{\alpha-1}.$$

$$\delta n^{(i)}(\boldsymbol{\theta}) = \delta n_m^{(i)}(\boldsymbol{\theta}) + \delta n_g^{(i)}(\boldsymbol{\theta}) + \delta n_{rn}^{(i)}(\boldsymbol{\theta}),$$

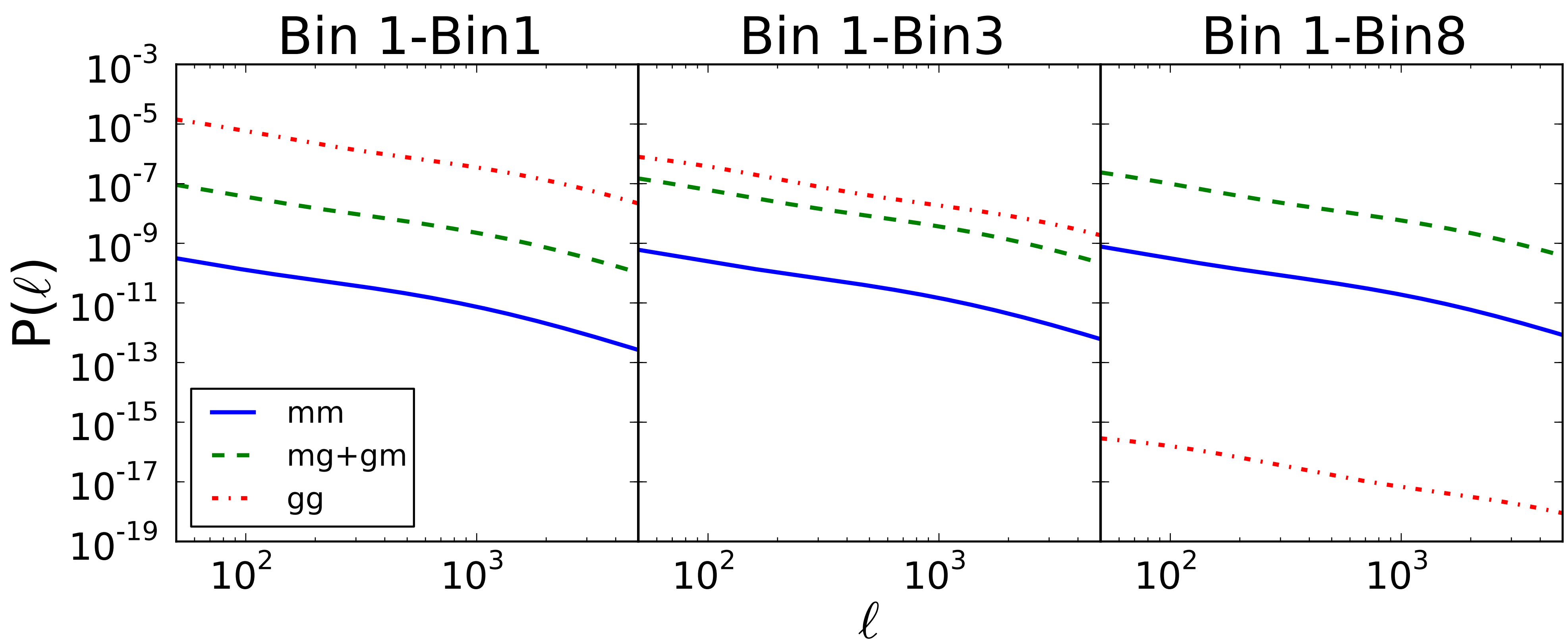
$$\begin{aligned} P_{\delta n \delta n}^{(ij)}(\boldsymbol{\ell}) &= P_{mm}^{(ij)}(\boldsymbol{\ell}) + P_{gg}^{(ij)}(\boldsymbol{\ell}) + P_{mg}^{(ij)}(\boldsymbol{\ell}) + P_{gm}^{(ij)}(\boldsymbol{\ell}) \\ &\quad + \delta_K^{ij} P_{\delta n}^{SN}. \end{aligned}$$

What can we do

- Angular correlation of the galaxy distribution and estimate the magnification bias, using different redshift bins
- Estimate the magnification bias on a population of objects, and correlate it
  - with another population of objects at different redshift
  - with the magnification bias of another population of objects at different redshift

$$P^{(ij)}_{\delta n \delta n}(\boldsymbol{\ell}) = P^{(ij)}_{mm}(\boldsymbol{\ell}) + P^{(ij)}_{gg}(\boldsymbol{\ell}) + P^{(ij)}_{mg}(\boldsymbol{\ell}) + P^{(ij)}_{gm}(\boldsymbol{\ell}) + \delta^{ij}_{K} P^{SN}_{\delta n} .$$

Different redshifts ?



$$P_{\delta n \delta n}^{(ij)}(\boldsymbol{\ell}) = P_{mm}^{(ij)}(\boldsymbol{\ell}) + P_{gg}^{(ij)}(\boldsymbol{\ell}) + P_{mg}^{(ij)}(\boldsymbol{\ell}) + P_{gm}^{(ij)}(\boldsymbol{\ell}) + \delta_K^{ij} P_{\delta n}^{SN}.$$

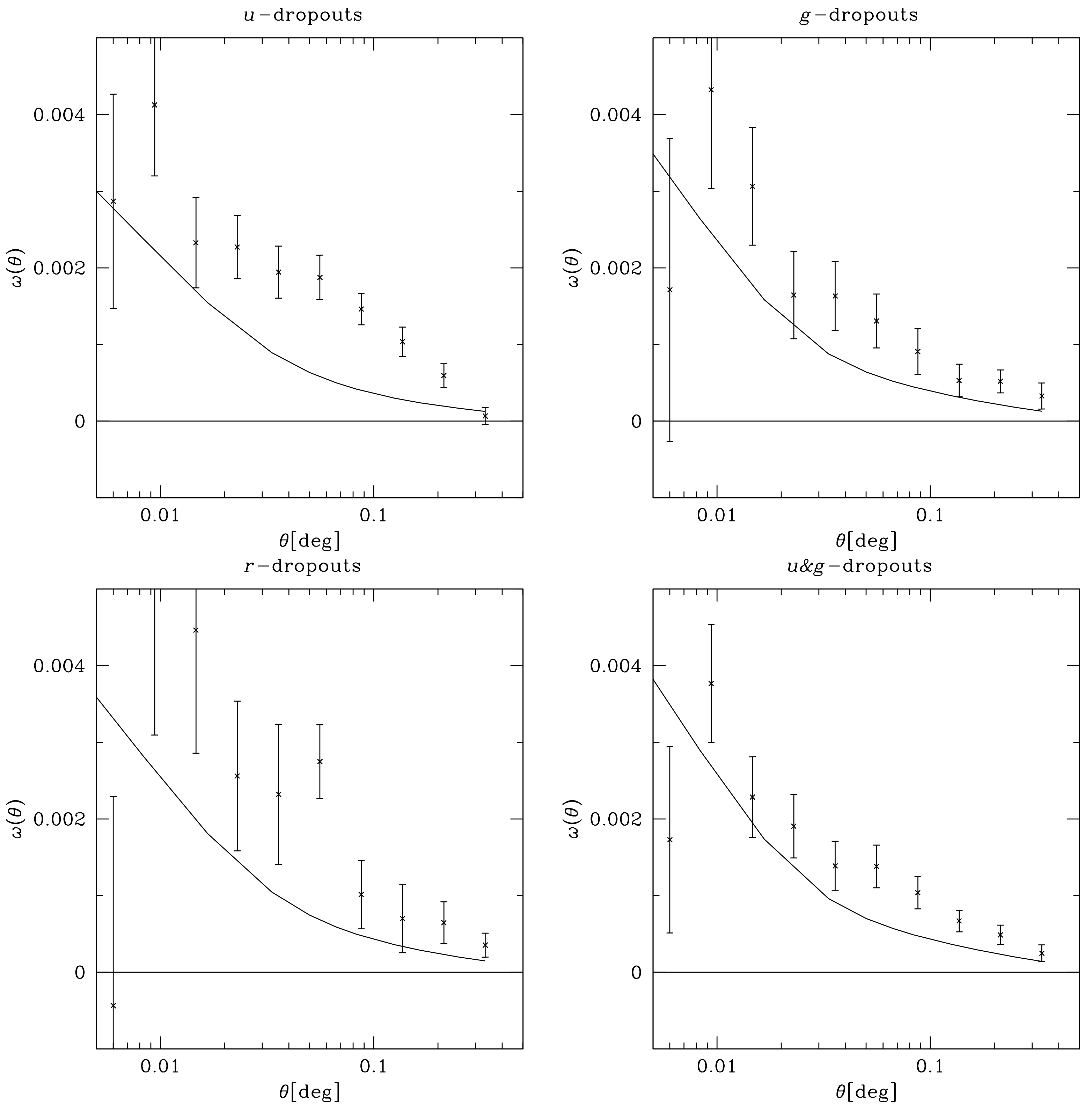
Duncan et al 2013

Comparison to Shear

- Different systematics
  - Magnitude VS shapes
    - Don't care about intrinsic alignments
    - Care less about PSF
- More galaxies with magnitude, higher redshift
- Much more sensitive to photometry, dust…
- Need to know the magnitude distribution of the population

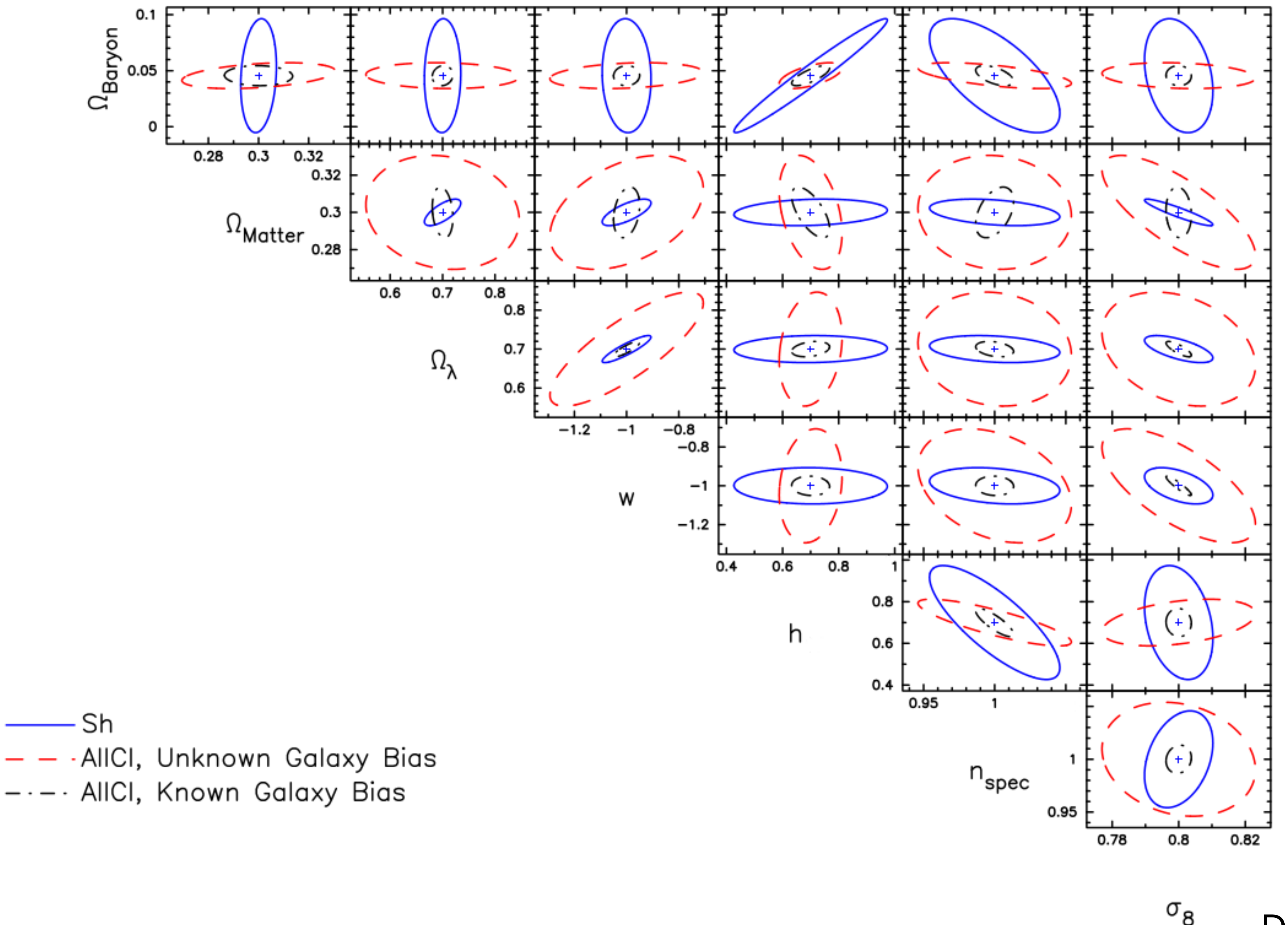
- But the nice thing is that we get that for ***free***.

From CFHTLenS



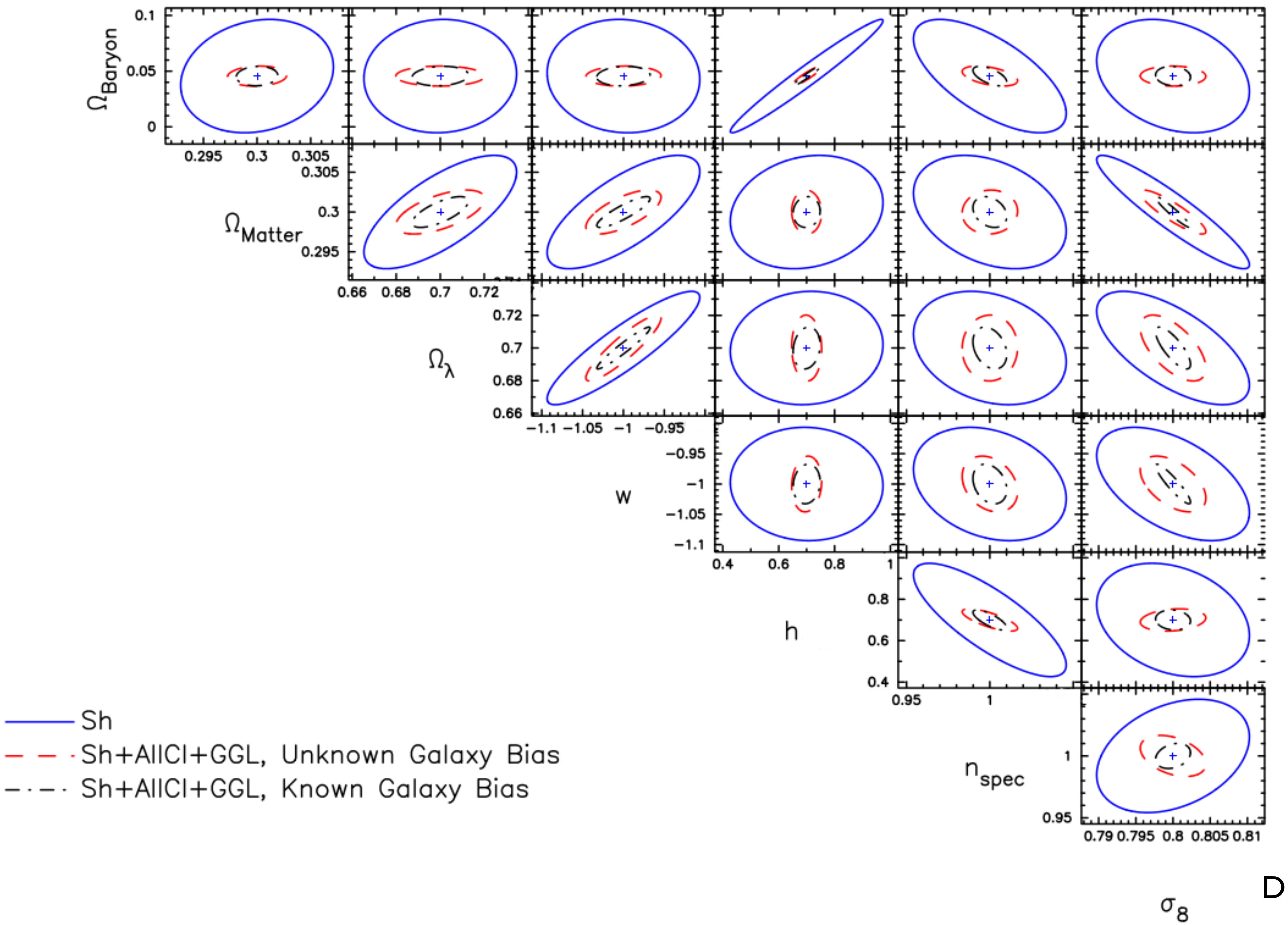
Hildebrand et al 2009

forecast Shear VS Clustering (+mag)



Duncan et al 2013

forecast including GGL



Duncan et al 2013

The SWG

- Lead : T. Kitching & H. Hoekstra - Dpty : K. Benabed
- Mailing list - Biweekly general teleconferences (altern with topic oriented ones, mostly OU-SHEAR)- Dedicated pages on the redmine

- Bi yearly meeting (one in sync with Euclid consortium meeting).
  - Last meeting in Frascati, in october.

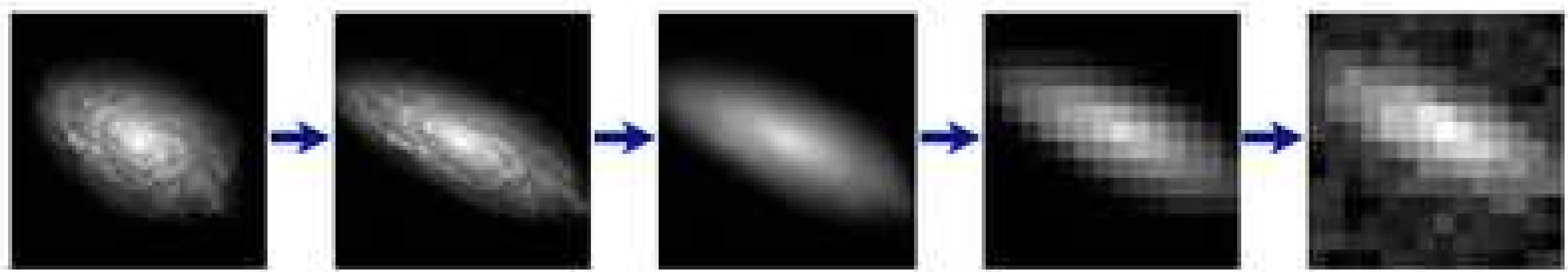
- Goal of the group is to explore new directions in WL estimate and use, follow and federate the OU work.

Name	Managers	Brief Remit/Overview
WP01: Shape Estimation (link to OU-SHE)	Henk Hoekstra, Tom Kitching	Requirements on shape measurement, test experimental methods, link to OUSHE
WP02: Redshift Estimation (link to OU-PHZ)	Filipe Abdalla, Hendrik Hildebrandt	Requirements on photoz measurement, test experimental methods, link to OUPHZ
WP03: Image Simulations (link to OU-SIM)	Massimo Meneghetti,Frederic Courbin	Requirements and roadmaps for image sims; link to E2E group, OUSIM
WP04: Cosmological Simulations (link to SIM-SWG)	Alina Kiessling, Robert Smith	Link to CosmoSimSWG requirements on simulations
WP05: Lensing estimators (link to OU-LE3)	Martin Kilbinger, Peter Schneider	Estimator investigations, links to OULE3
WP06: Joint Probes	to be initiated once IST situation is set	TBD
WP07: Cosmological Exploitation	to be initiated once IST situation is set	TBD
WP08: Systematic Tests	Patrick Simon, Konrad Kuijken	Systematic tests overview, links to all OUs and instrument teams
WP09: Cluster lensing (link to CL-SWG)	Jim Bartlett	Maintain and investigate cluster lensing issues, link to Cluster SWG
WP10: Galaxy-Galaxy lensing (link to GEV-SWG)	Malin Velander, Marcello Cacciato	Maintain and investigate galaxy-galaxy lensing issues, link to Legacy SWGs
WP11: Magnification (internal + CL & GEV)	Alan Heavens	Maintain and investigate magnification lensing issues
WP12: PSF Measurement	Lance Miller	Requirements on PSF measurement, test experimental methods, link to OUSHE

Name	Managers	Brief Remit/Overview
SP01: Intrinsic Alignments	Benjamin Joachimi	Tiger Team on IA
SP02: Mass Mapping	Sandrine Pires, Eric Jullo	Tiger Team on Mass Mappin
SP03: EMA use cases and SGS use cases	Karim Benabed, Mario Radovich	Tiger Team on EMA use Cases
SP04: Flexion	David Bacon , Adreinne Leonard	Tiger Team on Flexion

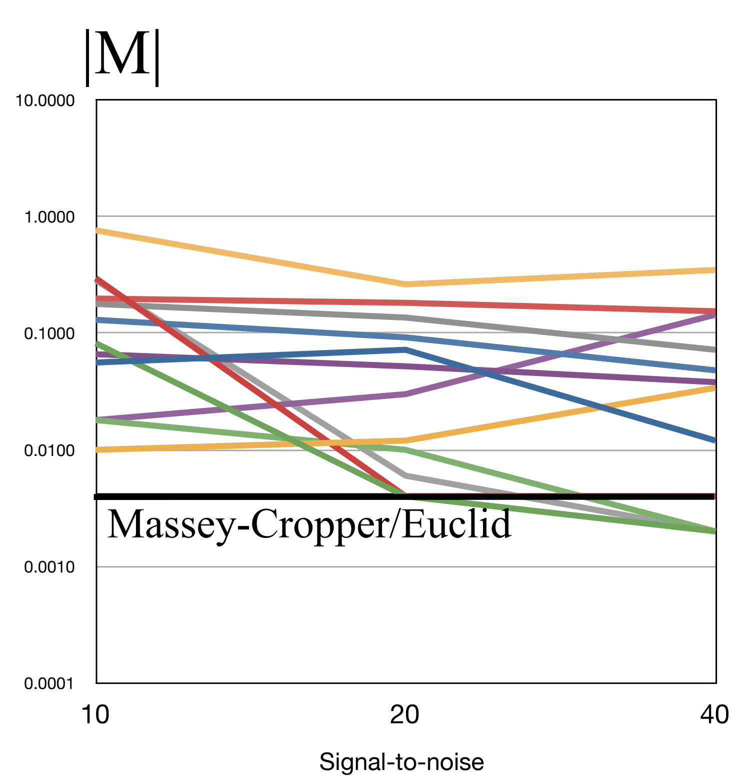
Shear

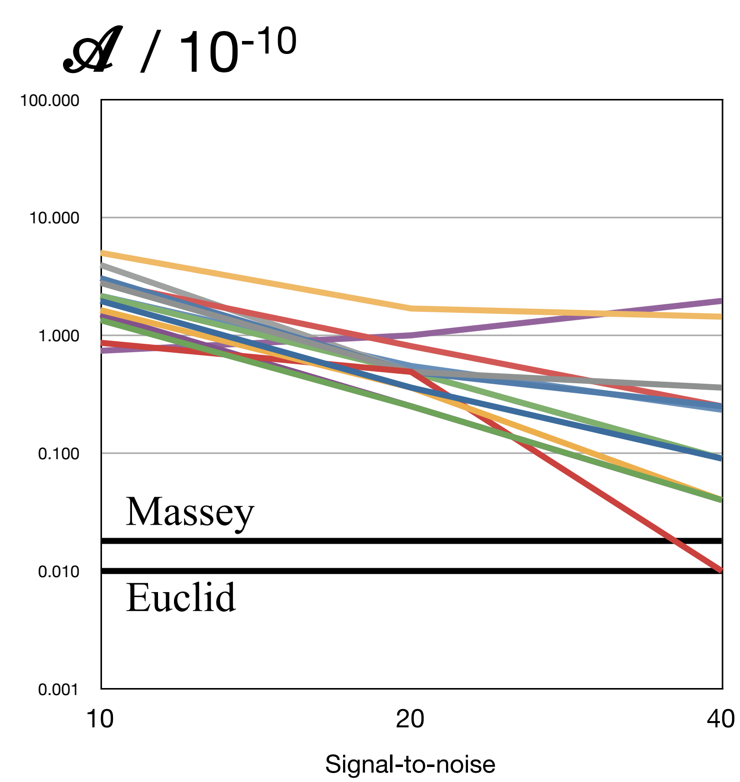
Intrinsic shape | shear | diffraction | pixelization | noise



$$\tilde{e} = \gamma + e_{\text{intrinsic}} + c + m\ (\gamma + e_{\text{intrinsic}}) + q\ (\gamma + e_{\text{intrinsic}})^2 + o(\gamma^3, e^3)$$

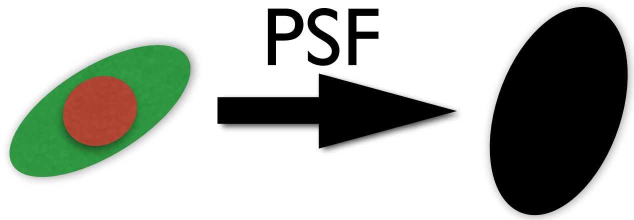
$$|m| < 2 \times 10^{-3} \qquad \sigma_c < 3.5 \times 10^{-5}$$



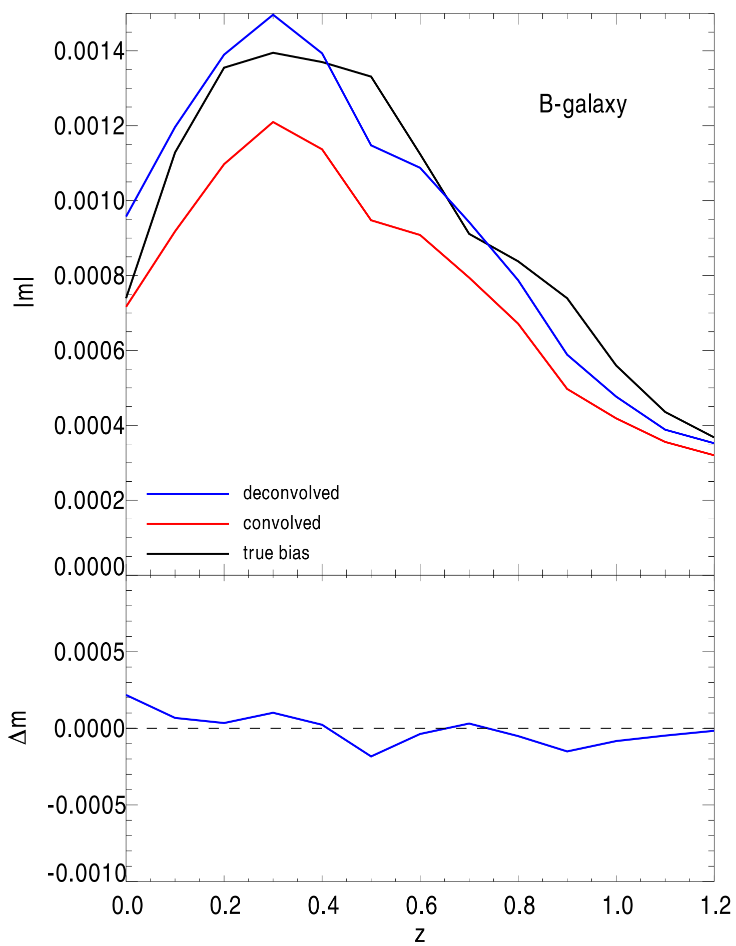


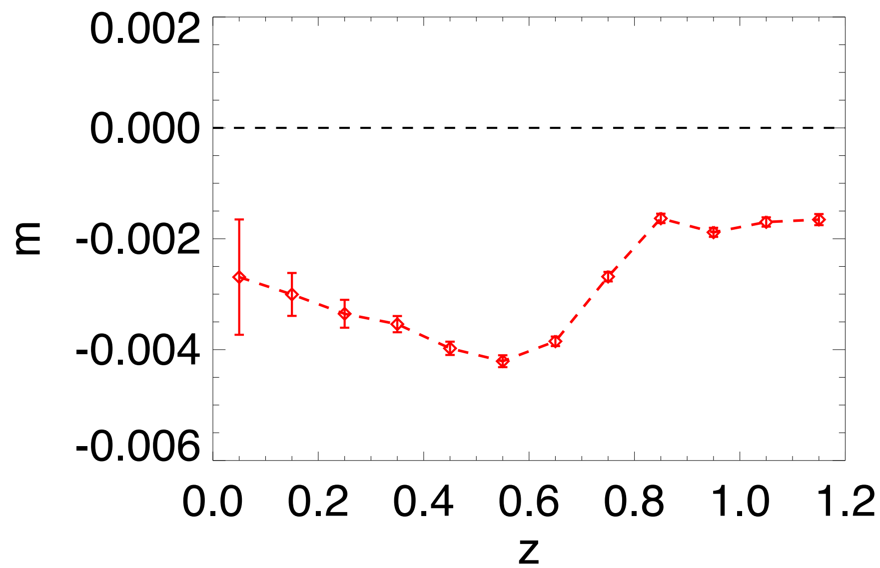
GREAT10

Galaxy colors and PSF



$$\tilde{e} = \gamma + e_{\mathrm{intrinsic}} + c + m\,(\gamma + e_{\mathrm{intrinsic}}) + q\,(\gamma + e_{\mathrm{intrinsic}})^2 + o(\gamma^3, e^3)$$





Semboloni et al 2012

Shear bias

- Can we really measure/calibrate it ?
- Which is best a low unknown bias or a high known one
- How can we build a good calibration
  - simulation
  - external surveys
  - deep survey in Euclid
- Intense and historical activity
  - STEP
  - GREATXX

Table 1. Requirements for calibration data of upcoming and future weak-lensing surveys. For four on-going and planned surveys we list the expected effective galaxy number density $n_{\rm eff}$, the relative error on the width of the intrinsic ellipticity distribution $\Delta\sigma/\sigma$, the derived number of galaxies required for calibration N_S, the corresponding survey area, the minimum signal-to-noise required in the calibration survey $\nu_{\rm min}^{\rm deep}$, and the magnitude difference $\Delta{\rm Mag}_{\rm lim}$ between the calibration data and the main survey. Note that for KiDS, DES, and HSC we assumed $N_{\rm bin} = 5$ redshift bins, while for Euclid $N_{\rm bin} = 10$ was chosen. The minimum signal-to-noise in the wide survey was set to $\nu_{\rm min}^{\rm wide} = 10$ throughout.

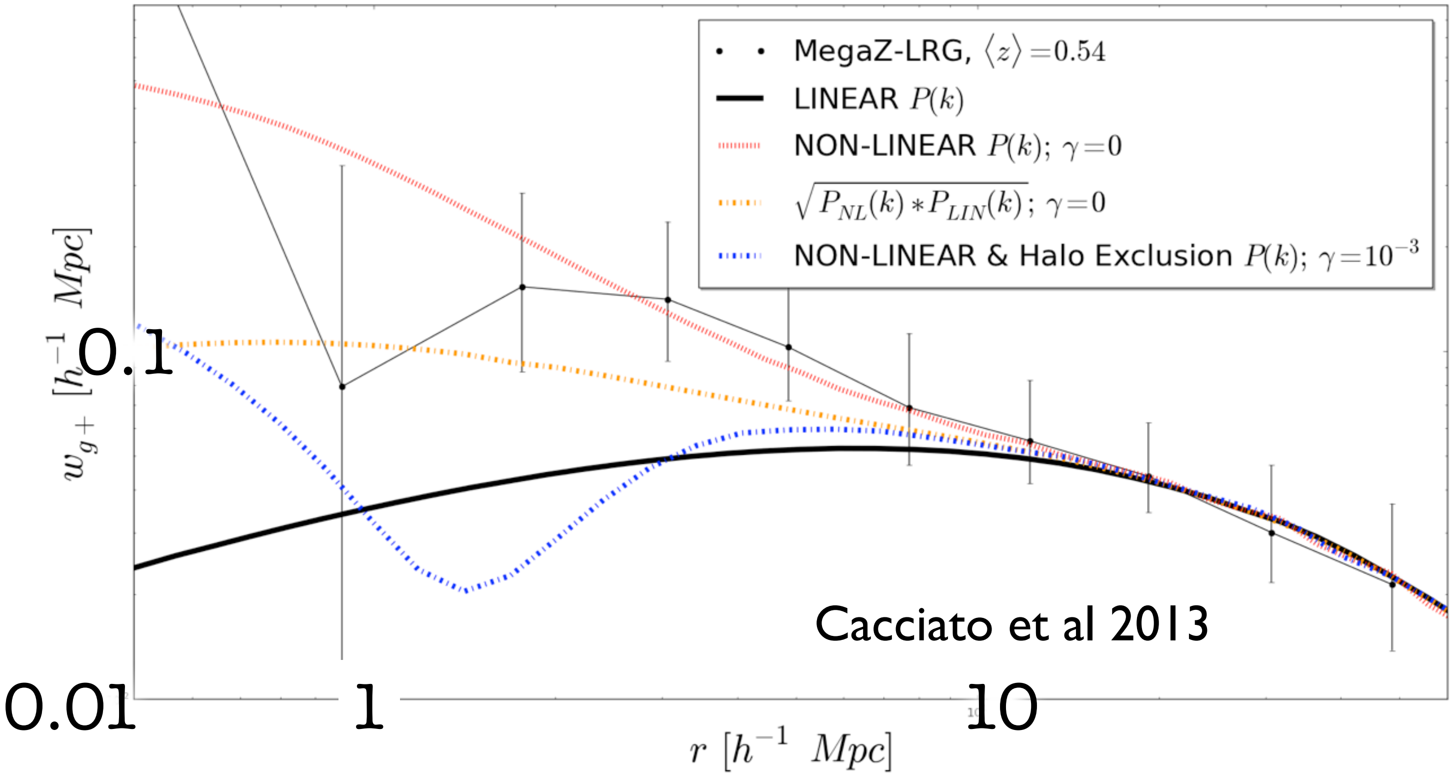
Quantity	KiDS	DES	HSC	Euclid
$n_{\rm eff}$ [arcmin^{-2}]	9[a]	12[b]	15[c]	30[d]
$\Delta\sigma/\sigma$	7×10^{-3}	7×10^{-3}	7×10^{-3}	2.2×10^{-3}
N_S	2×10^5	2×10^5	2×10^5	5×10^6
Area of calibration field [deg^2]	6.1	4.6	3.7	45
$\nu_{\rm min}^{\rm deep}$	30	30	30	60
$\Delta{\rm Mag}_{\rm lim}$	1.2	1.2	1.2	1.9

[a] Preliminary measurement (KiDS team, priv. comm.). This is the number density of objects having a *reliable* shape measurement.
[b] Prediction taken from https://www.darkenergysurvey.org/reports/proposal-standalone.pdf
[c] From Fig. 6 of Chang et al. (2013)
[d] Prediction taken from Laureijs et al. (2011)

Viola et al 2013

IA

- Lot's of activity
- Dedicated one week meeting in Bern a few weeks ago, another one planned in the spring 2014.
- Model improving rapidly (Halo model, n-body simus with hydro)
- Data coming in (DEEP2/VVDS, BOSS, GAMA, VIPERS, COSMOS)
- Improvement on the science performance forecast
- With better modeling, better performance forecast, there's the possibility to relax some photo-z accuracy requirements
  - Agnostic treatment of IA requires excellent photo-z
- Calibrating mitigation strategies



Cacciato et al 2013

And also

- Validation: How to validate OU products, how to organize us
- PSF modeling
- Image simulation
- Photo-Z calibration
- Data management and access
- GGL
- Flowdown to forecast (performance calculator TM)
- Survey (dithering, holes…)
- VIS (Ghosts, CTI…)
- Mass Map reconstruction
- Lensing in N-Body simulation

Anticipation

- Not much activity on the n-body simu
- Not much activity on the likelihood/cosmo use
- Not much activity on the probe combination
  - but this is also due to an organization problem…
- What to do with the reconstructed maps