THE DARK ENERGY SURVEY: LATEST RESULTS

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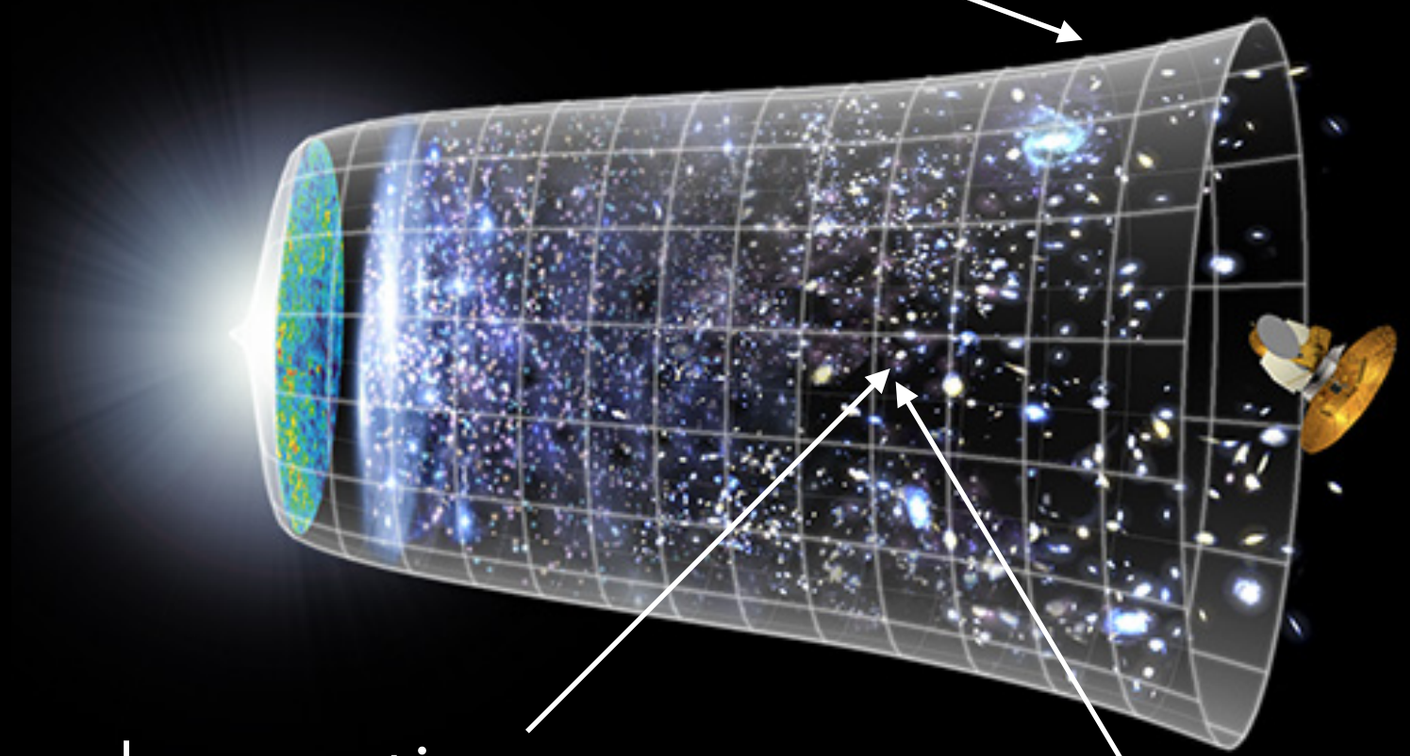
OBSERVATIONAL PROBES: INITIAL VIEW

Some observations constrain expansion history

$$H^2(z) = H_0^2 \left(\Omega_r (1+z)^4 + \Omega_m (1+z)^3 + \Omega_k (1+z)^2 + \Omega_{de} \exp\left(3 \int_0^z \frac{1+w(z')}{1+z'} dz' \right) \right)$$

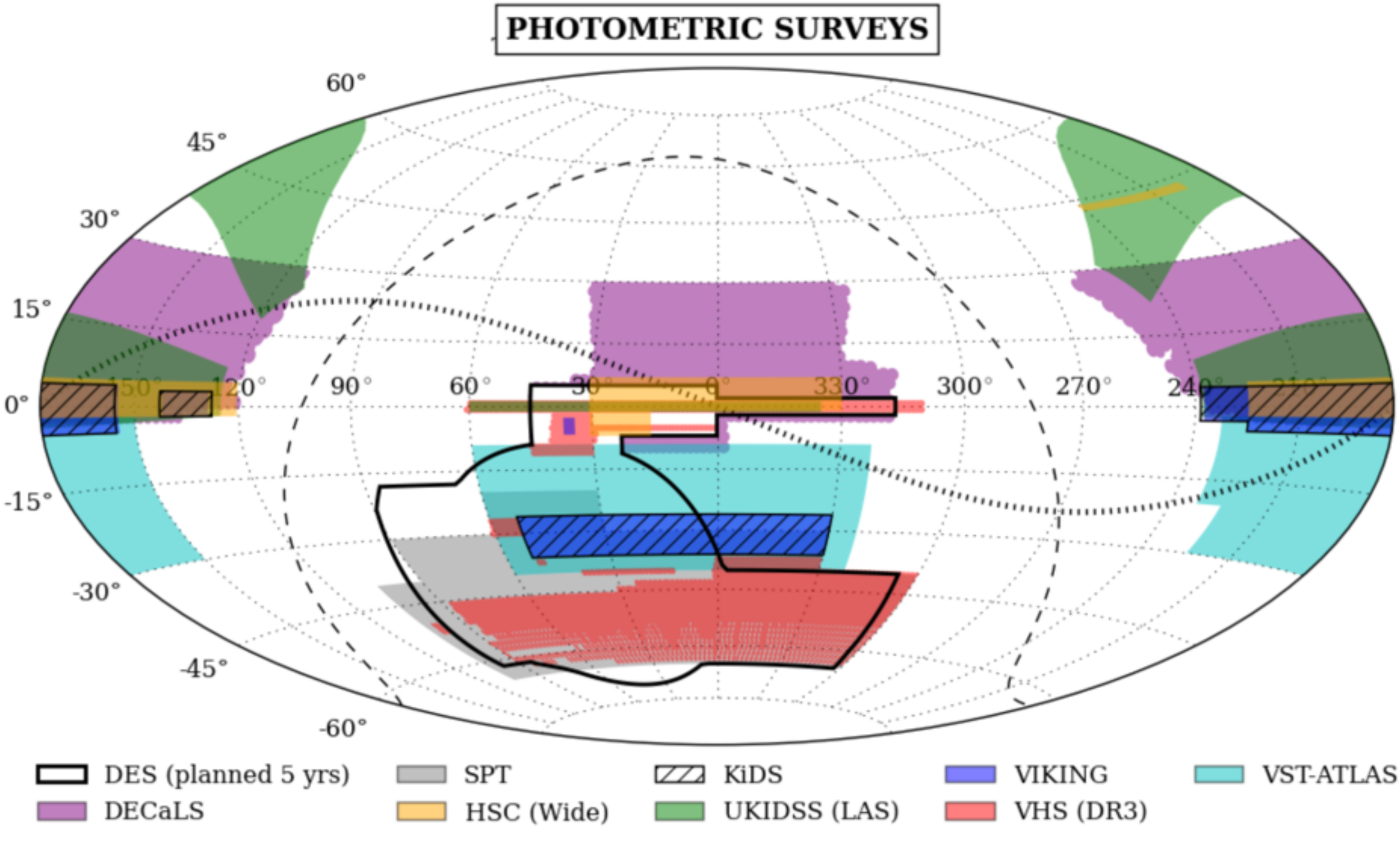


Some observations constrain growth history

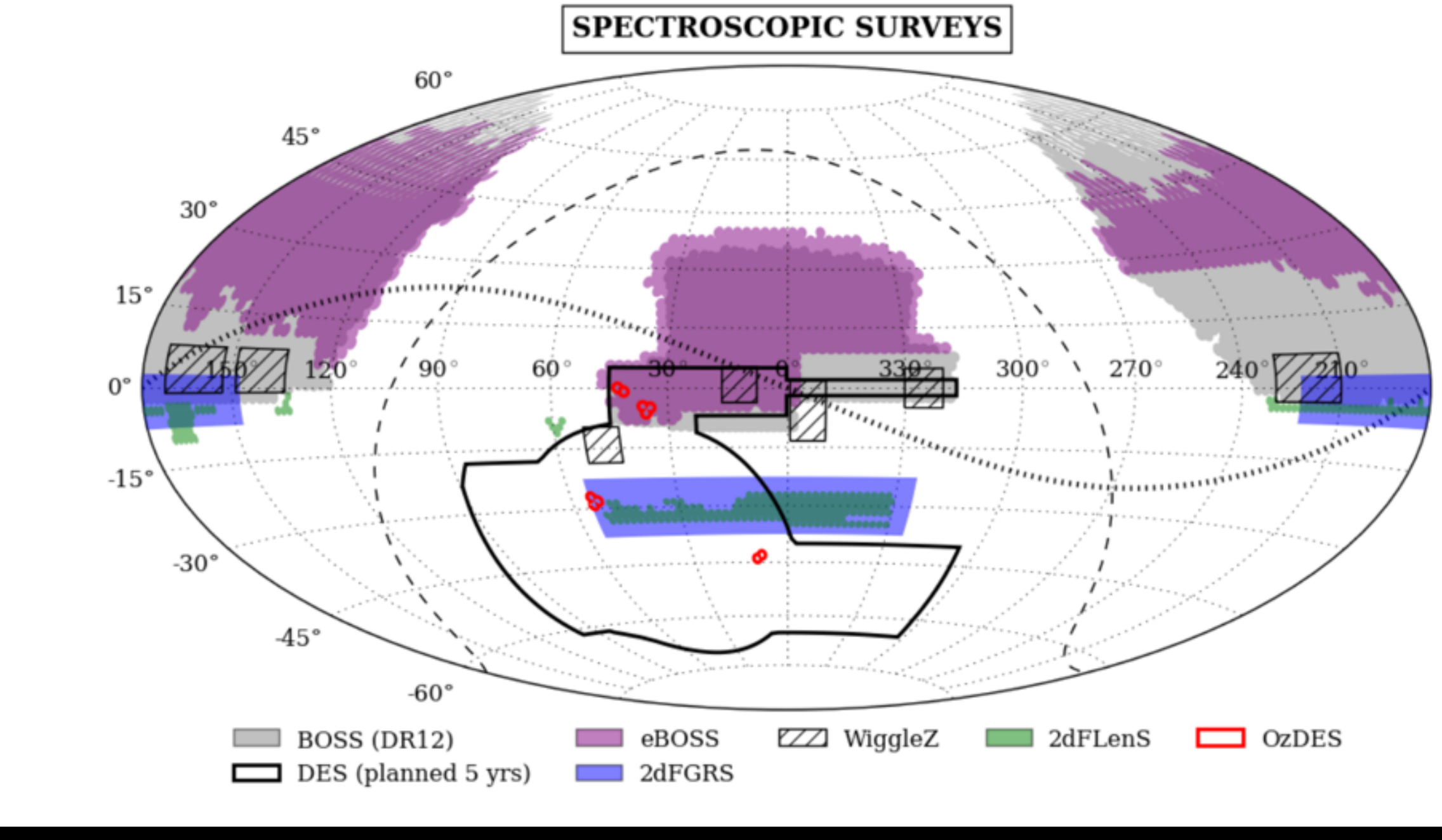
$$\ddot{\delta} + 2H\dot{\delta} - \frac{v_s^2}{a^2}\nabla^2\delta = 4\pi G \rho_b \delta$$

Some care about time part, some +space part of metric

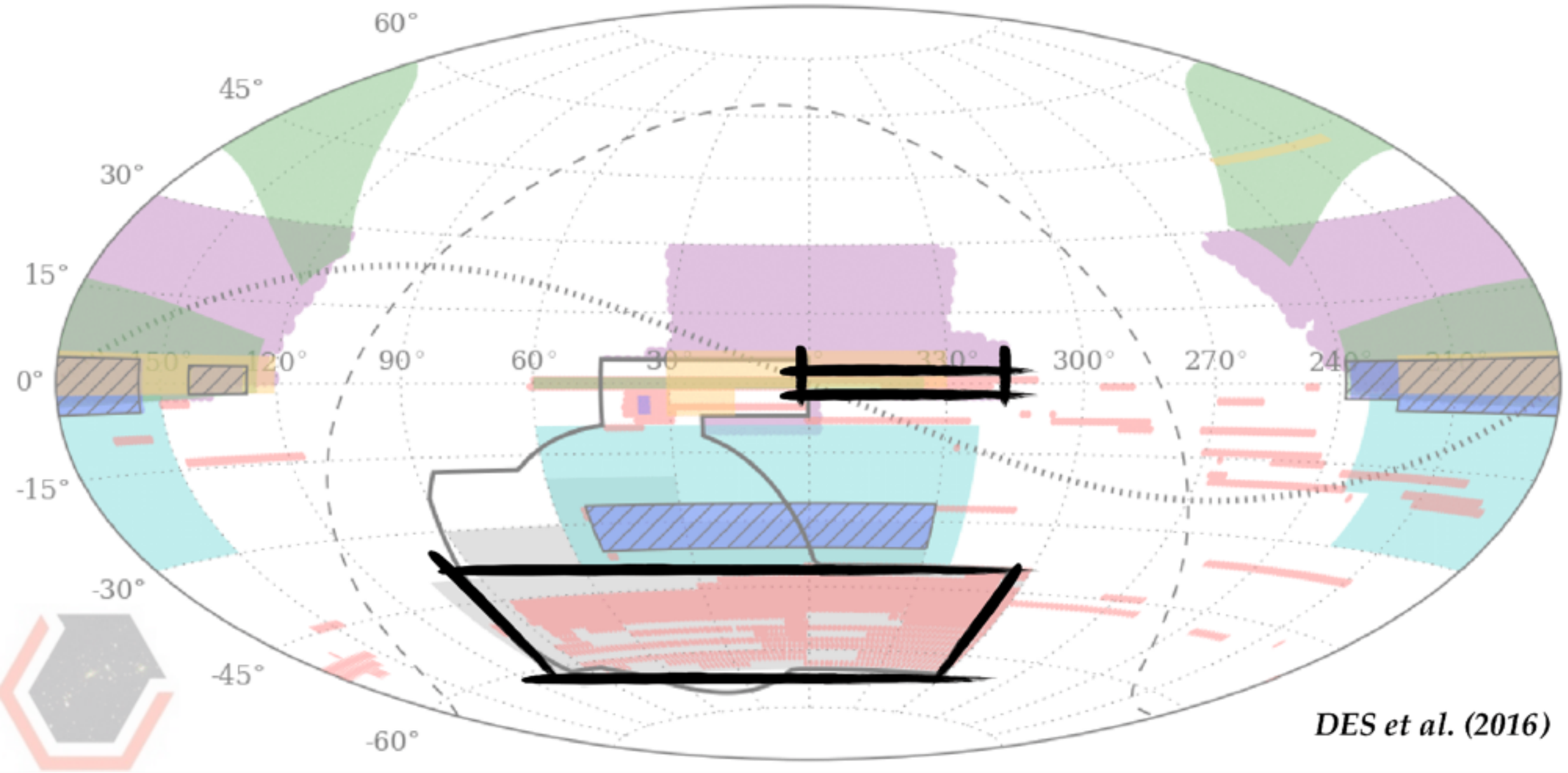
DARK ENERGY SURVEY



DARK ENERGY SURVEY



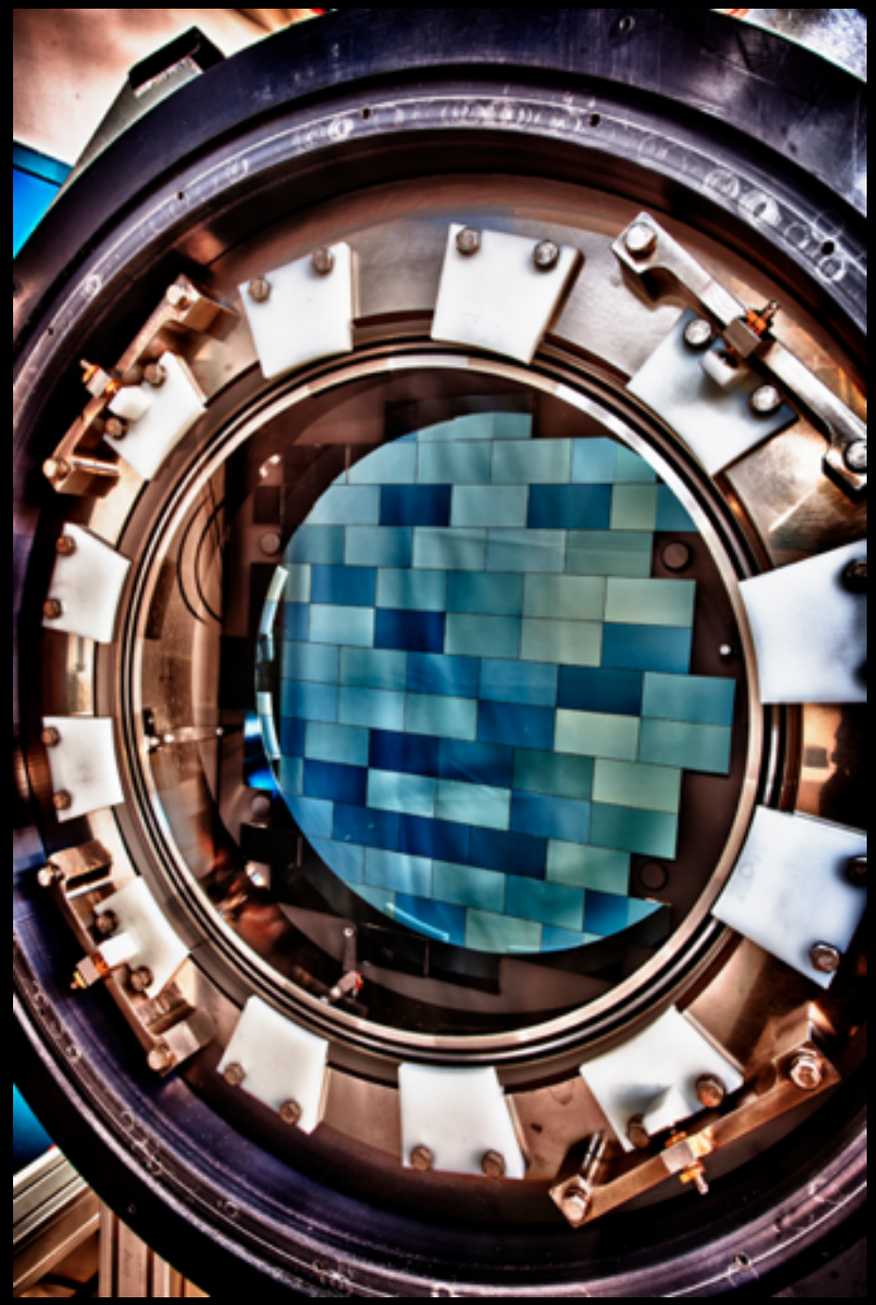
THIS TALK: YEAR 1



DES et al. (2016)

DARK ENERGY SURVEY

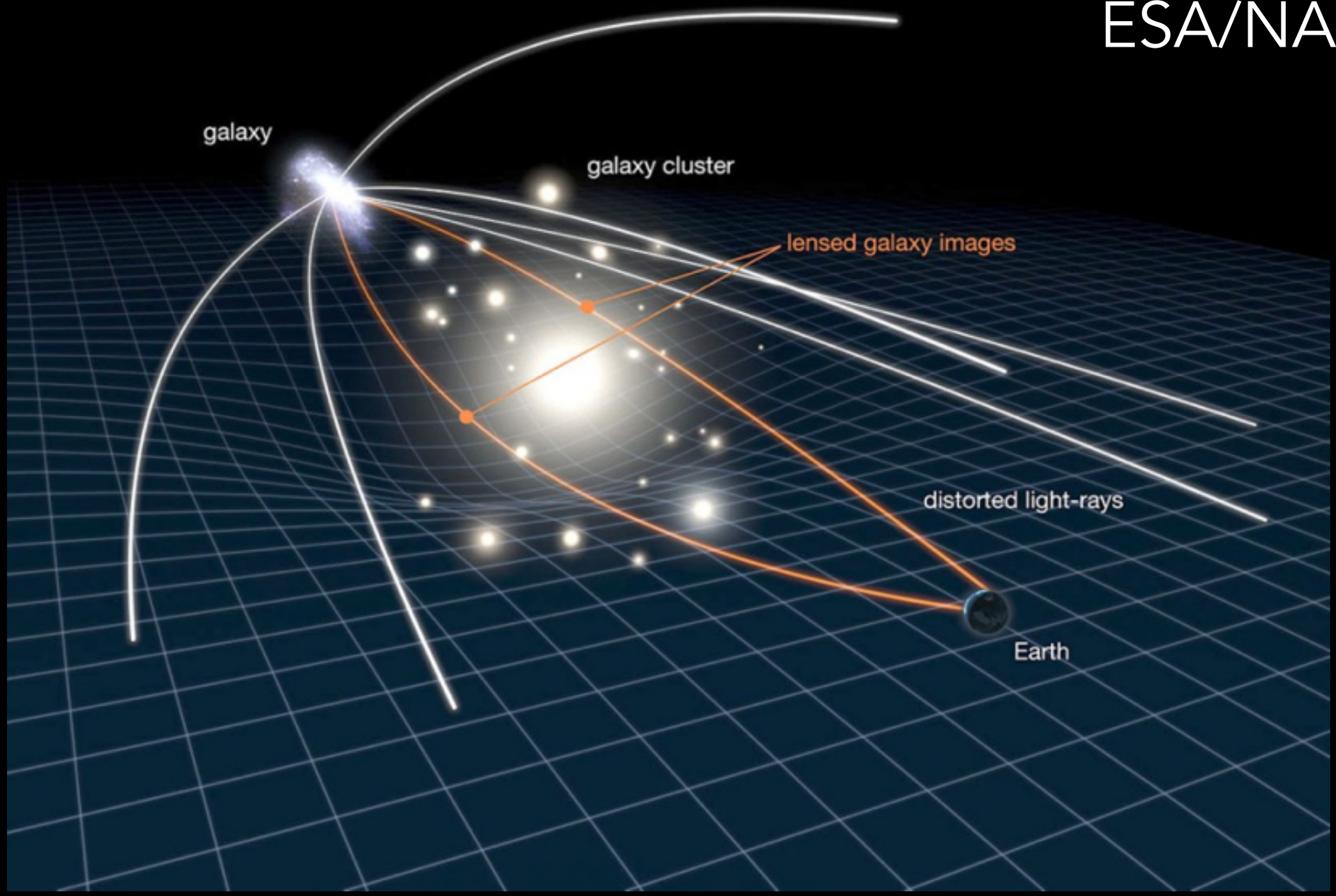
CTIO, Chile
5000 sq degree
map, 8 billion ly
deep, i~24, 5 filter
bands (grizY)



570Megapixels, 3 sq deg field
0.26” per pixel

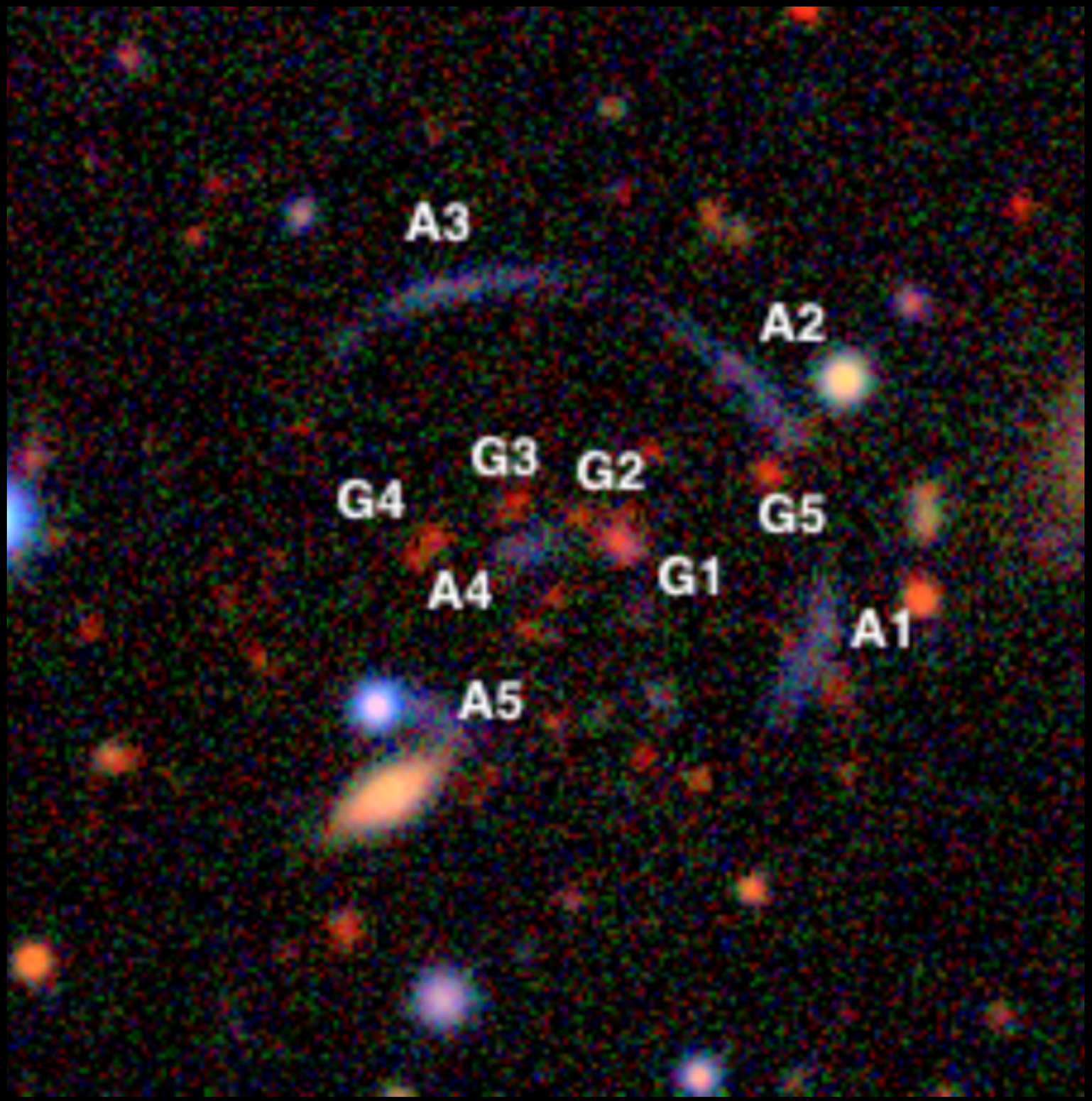
GRAVITATIONAL LENSING

ESA/NASA



Allows detailed ‘view’ of inhomogeneities

STRONG GRAVITATIONAL LENSING

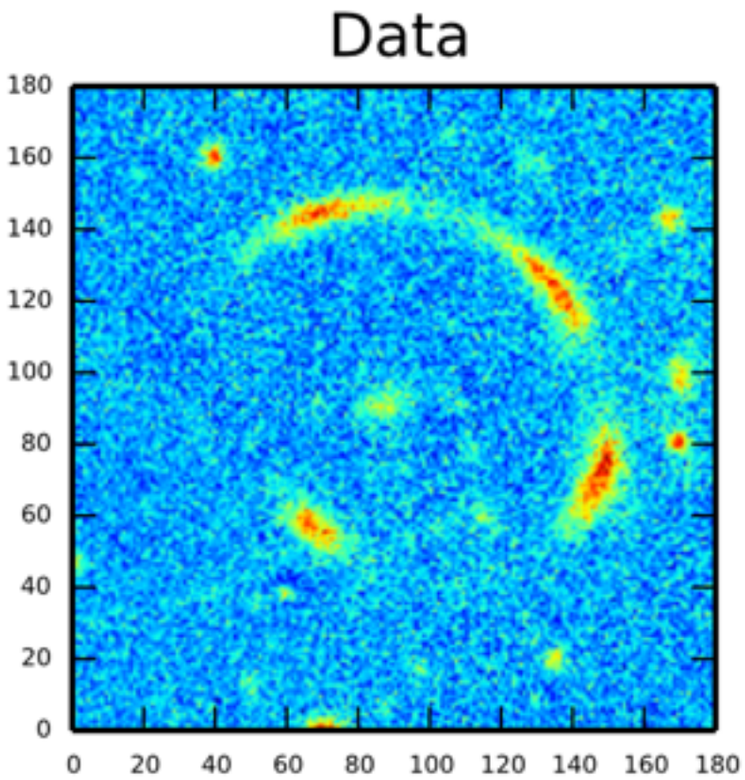


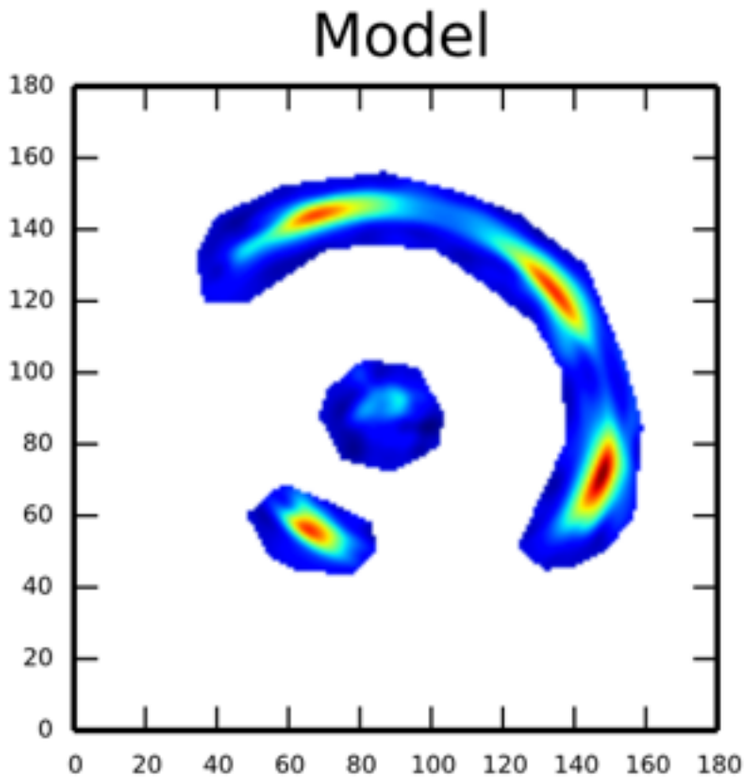
z_l=1.06

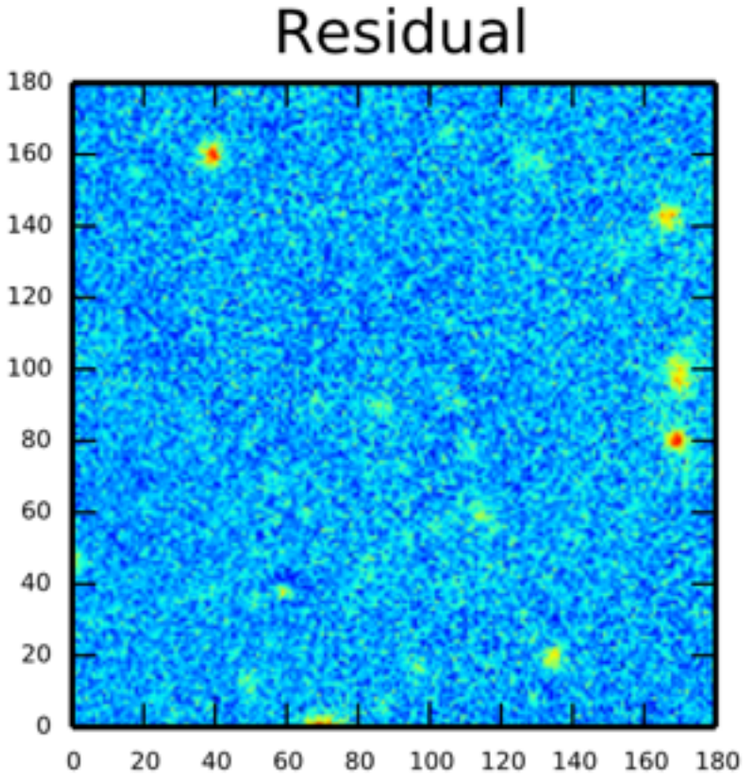
z_s=2.39

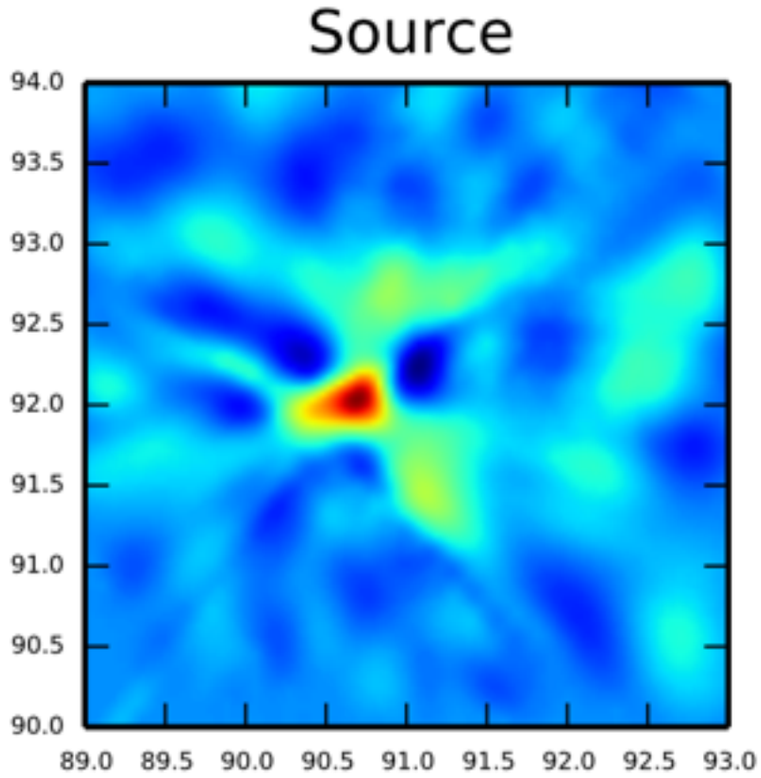
Collett et al 17

MODELLING





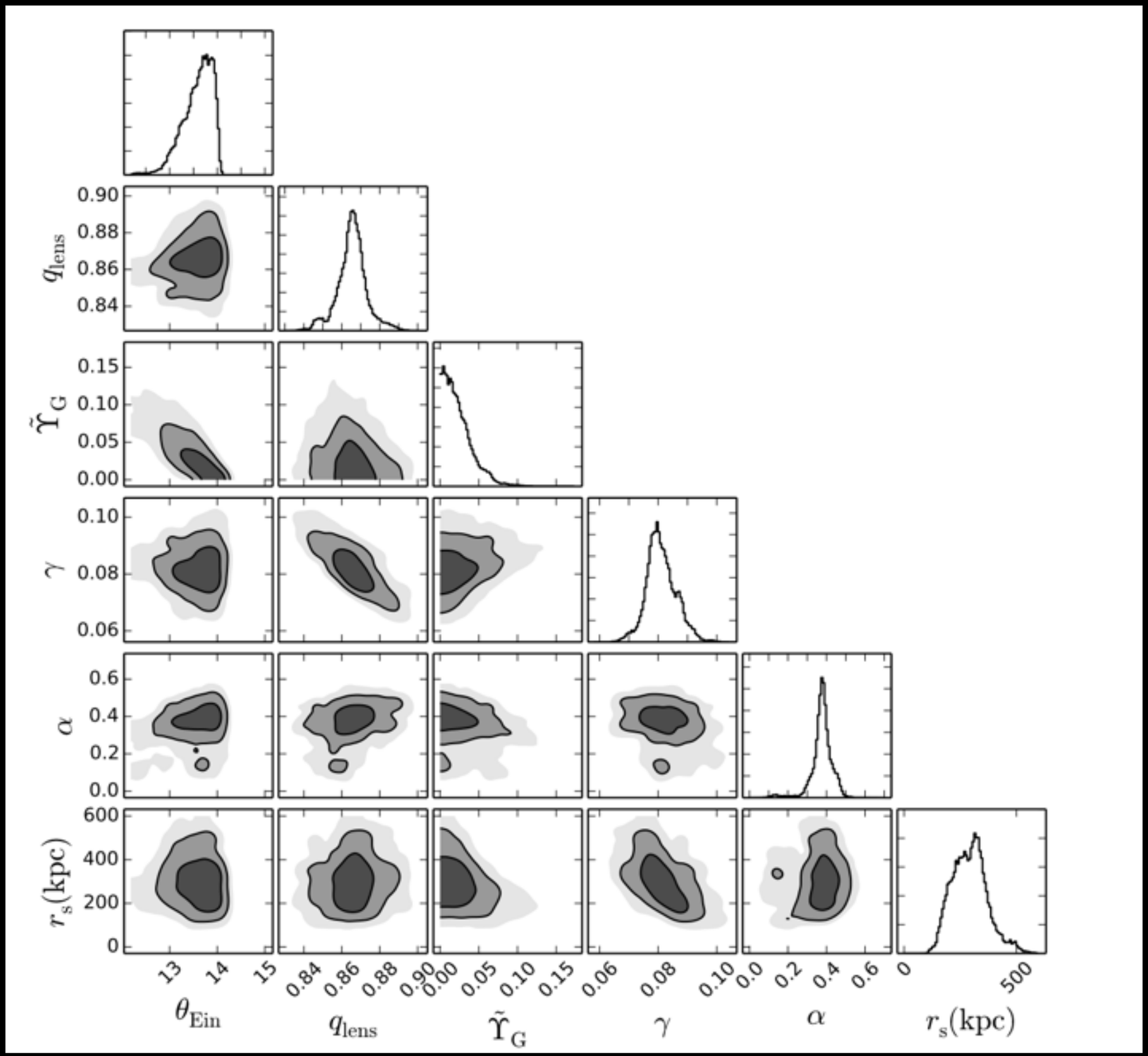




$$\rho(r) = \frac{\rho_0}{r^{\alpha}(r_s^2 + r^2)^{(3-\alpha)/2}}$$

Collett et al 17

MODEL PARAMETERS



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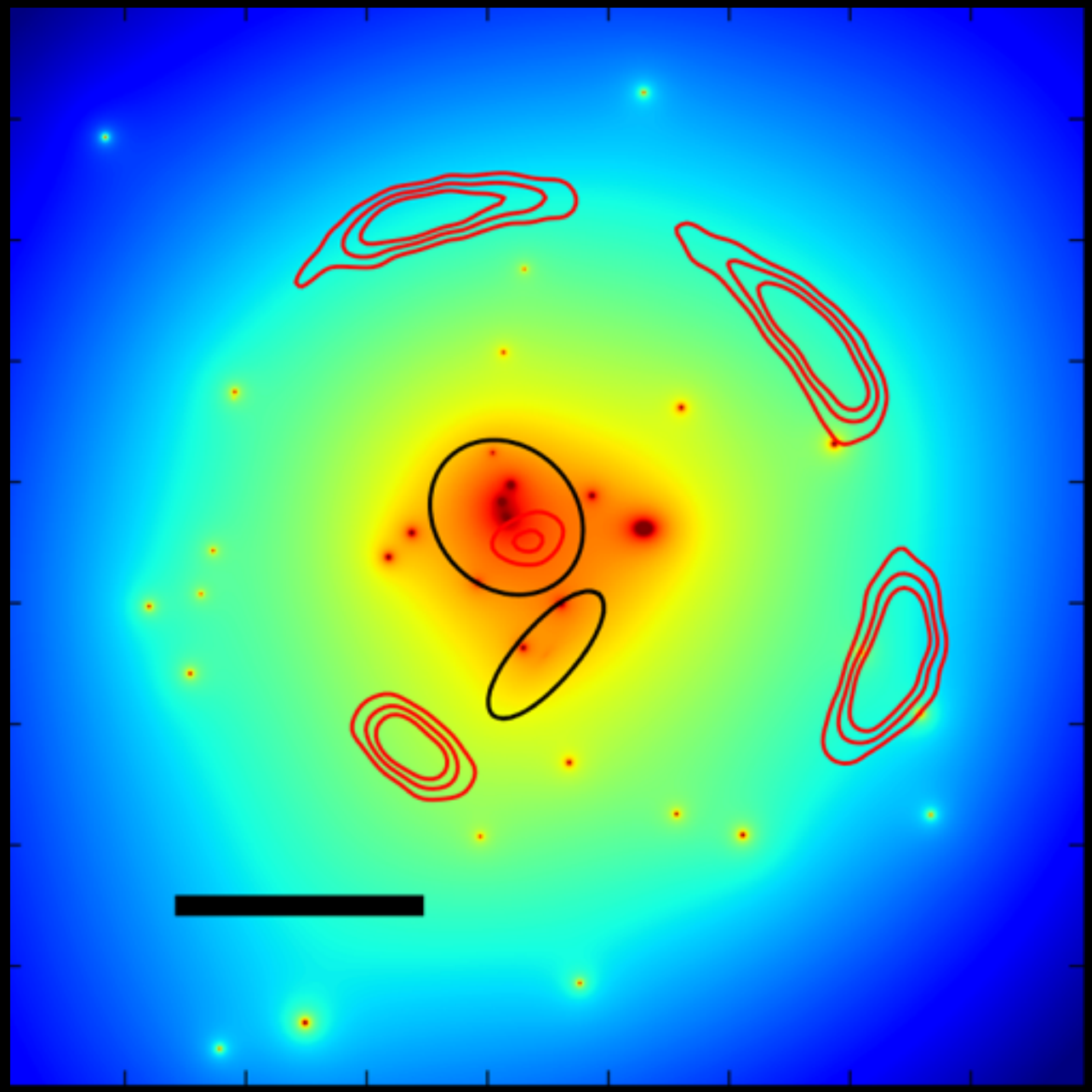
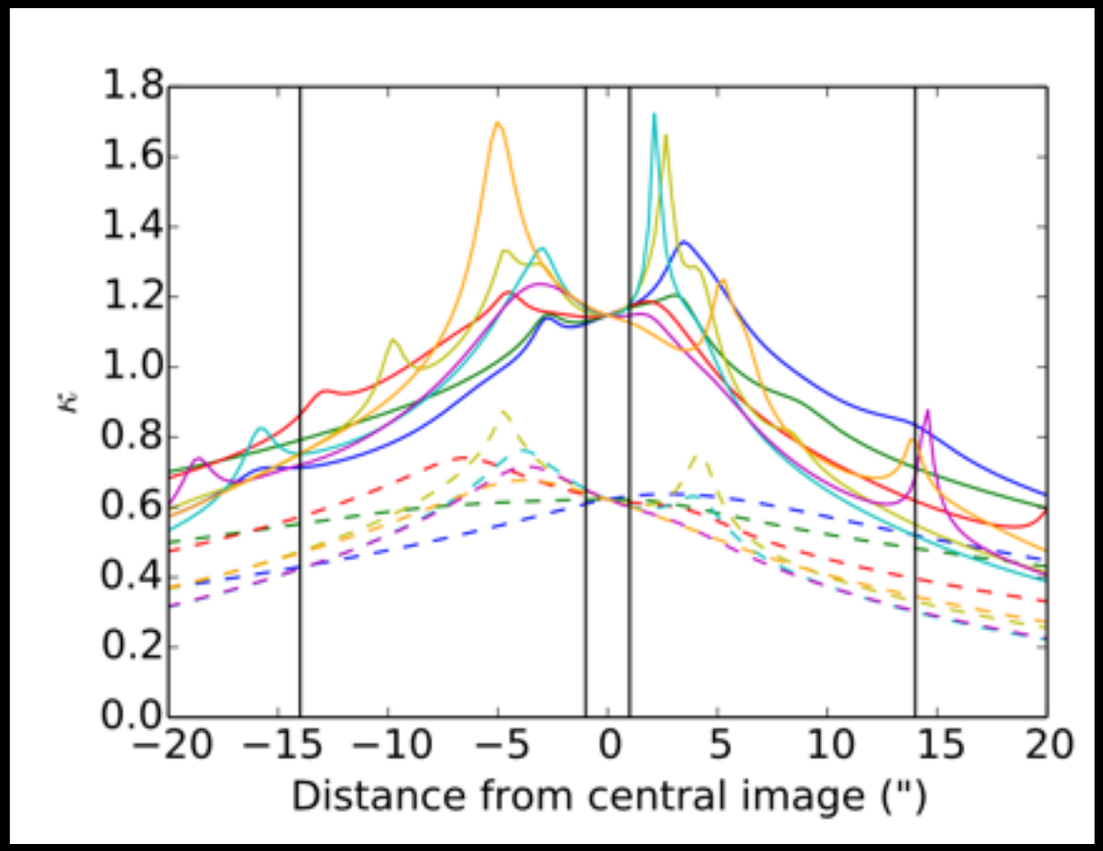
2 CLUMP MODEL





Need to be very careful about lens modelling

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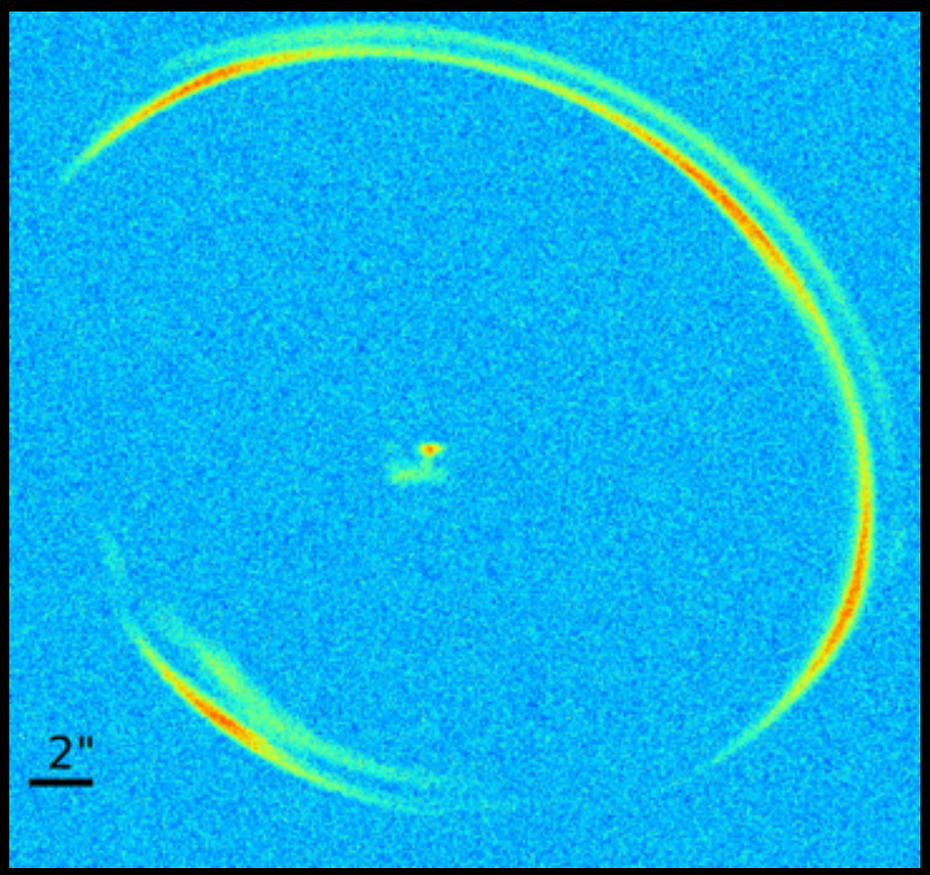
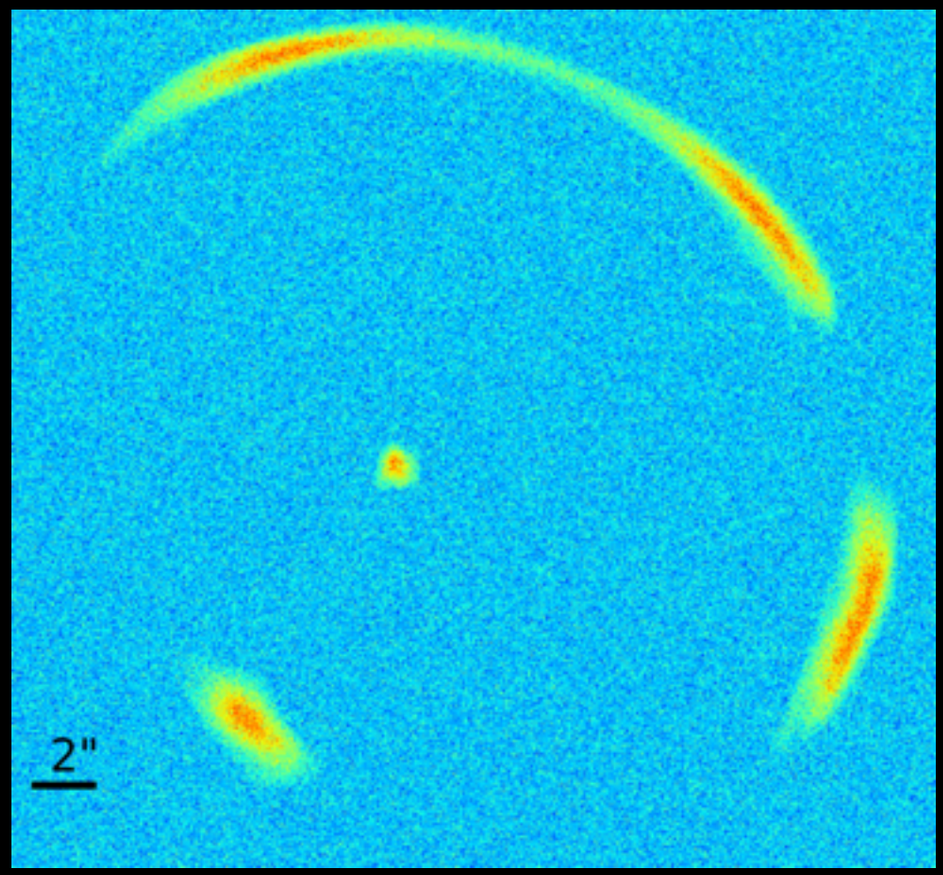
PREDICTIONS



1 halo



2 halo

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WEAK LENSING

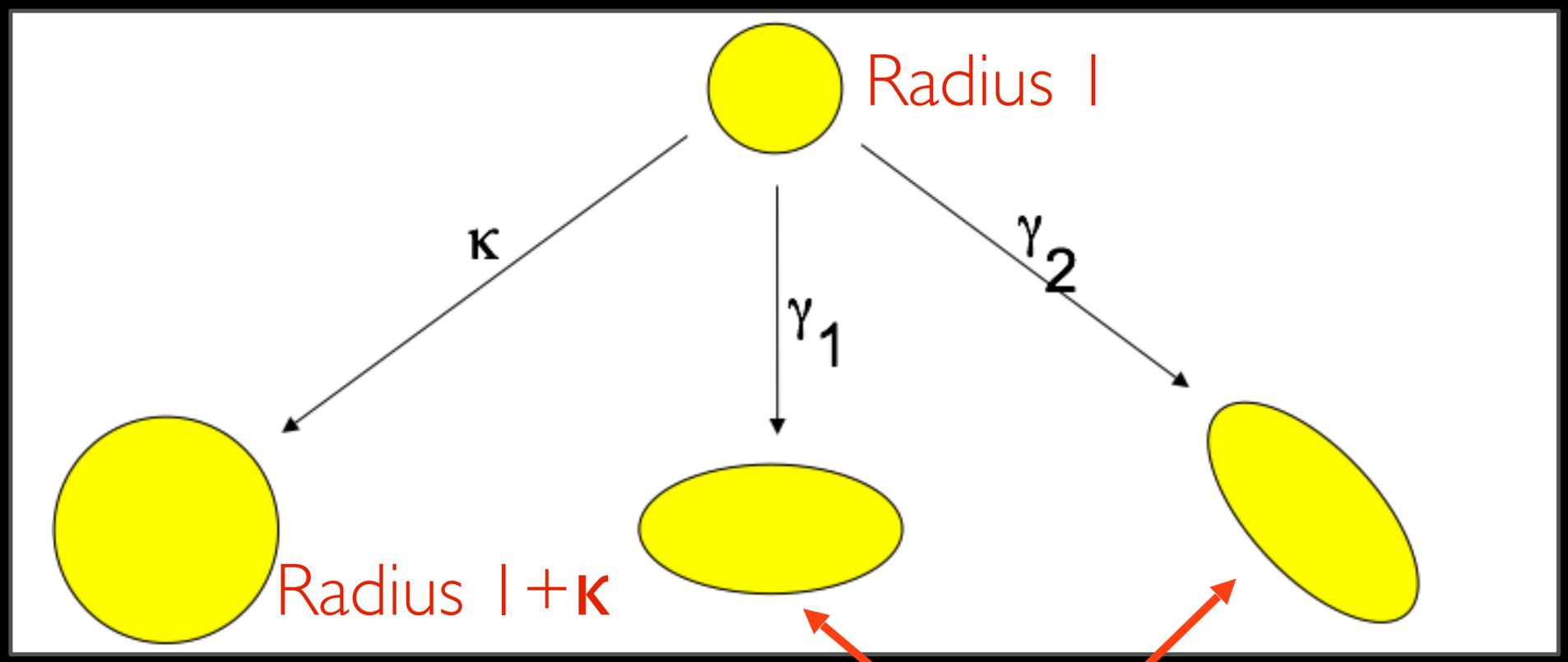
Small angle deflections and gradients of deflections (important to examine assumptions):

$$\beta_i = A_{ij}\theta_j$$

Source plane

Image plane

$$A = \begin{pmatrix} 1-\kappa & 0 \\ 0 & 1-\kappa \end{pmatrix} + \begin{pmatrix} -\gamma_1 & -\gamma_2 \\ -\gamma_2 & \gamma_1 \end{pmatrix}$$



Convergence

Shear

RELATION TO POTENTIAL

Introduce lensing potential $\psi = \int g(z)(\Psi(z) + \Phi(z))dz$

Geometry

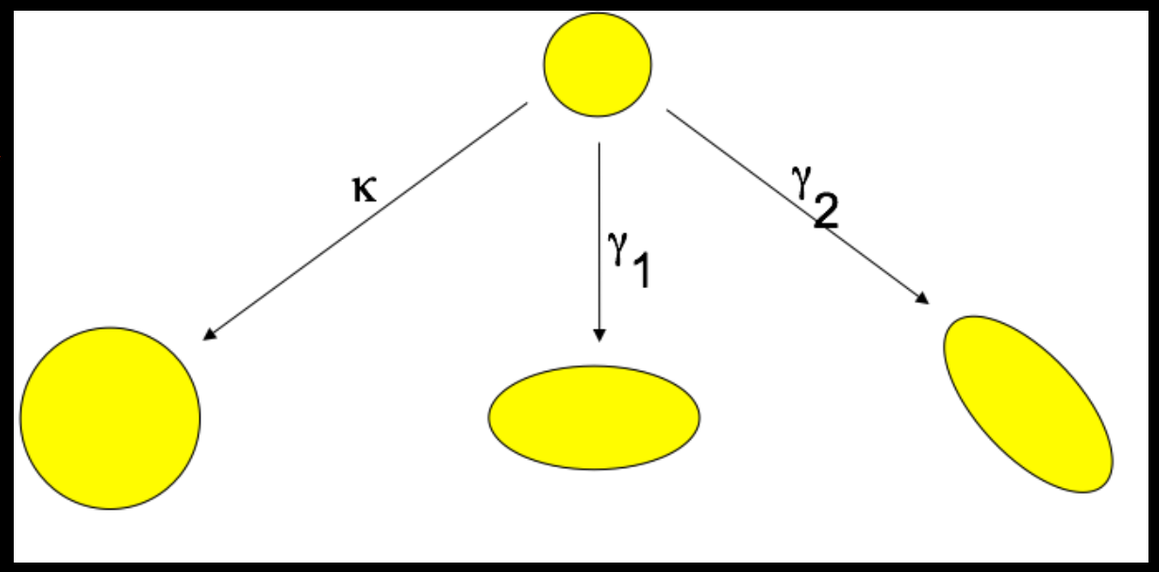
Potentials in perturbed FRW

Also introduce $\partial = \partial_1 + i\partial_2$ NB spin raising and lowering

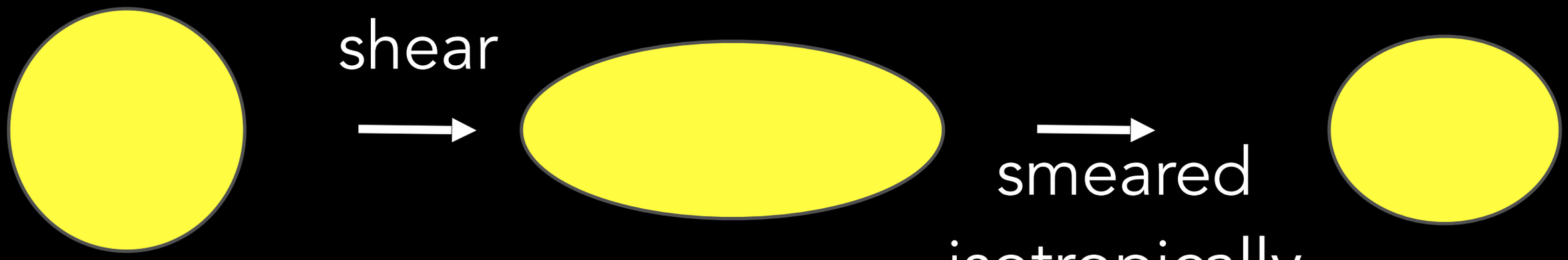
Then $\kappa = \frac{1}{2}\partial^*\partial\psi$

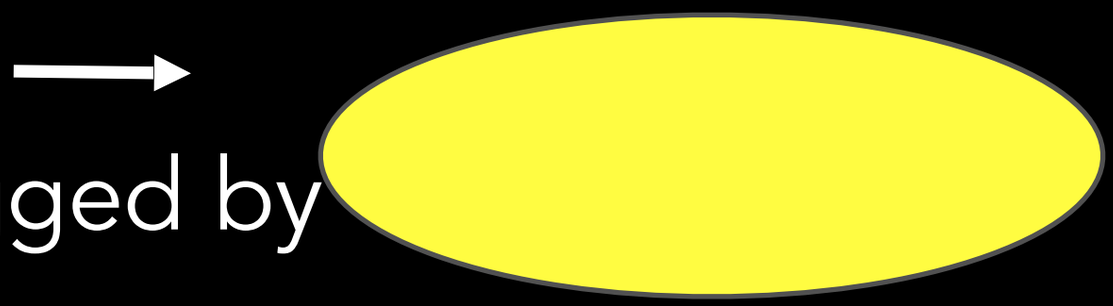
NB both dilation, and projected density

$$\gamma = \gamma_1 + i\gamma_2 = \frac{1}{2}\partial\partial\psi$$



THE MEASUREMENT PROBLEM



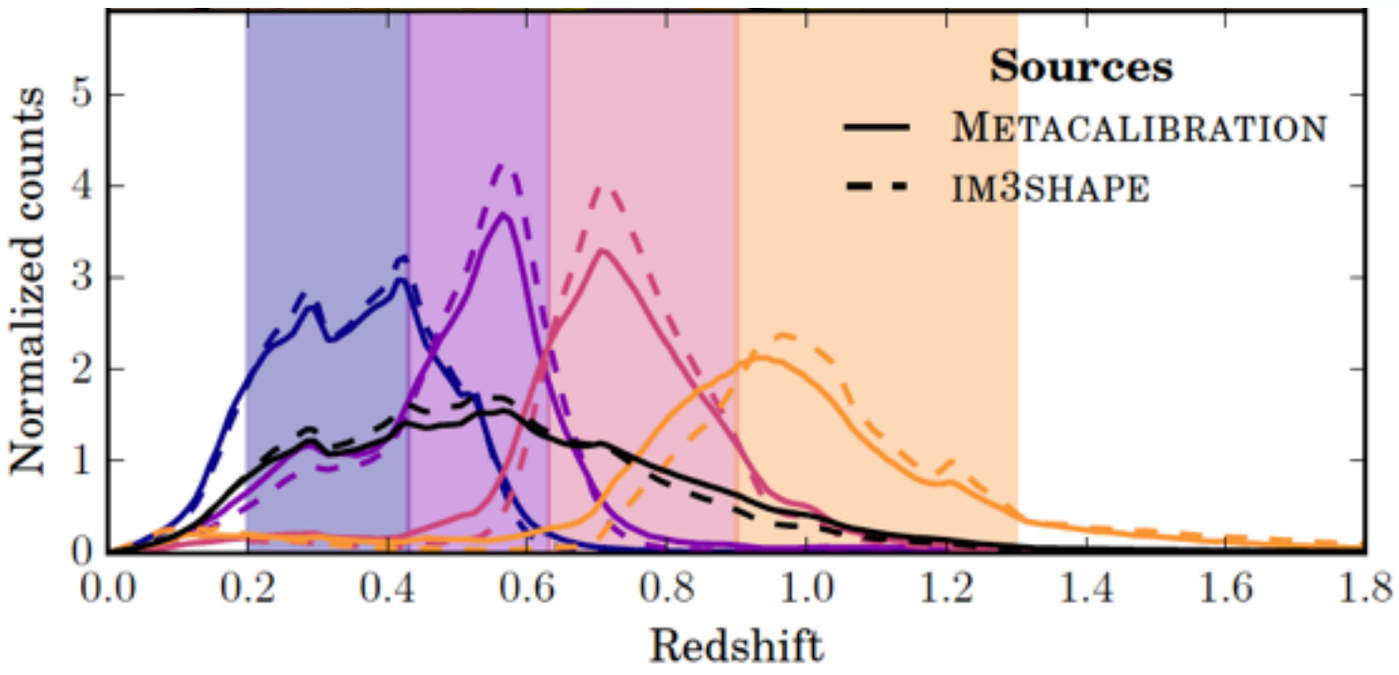


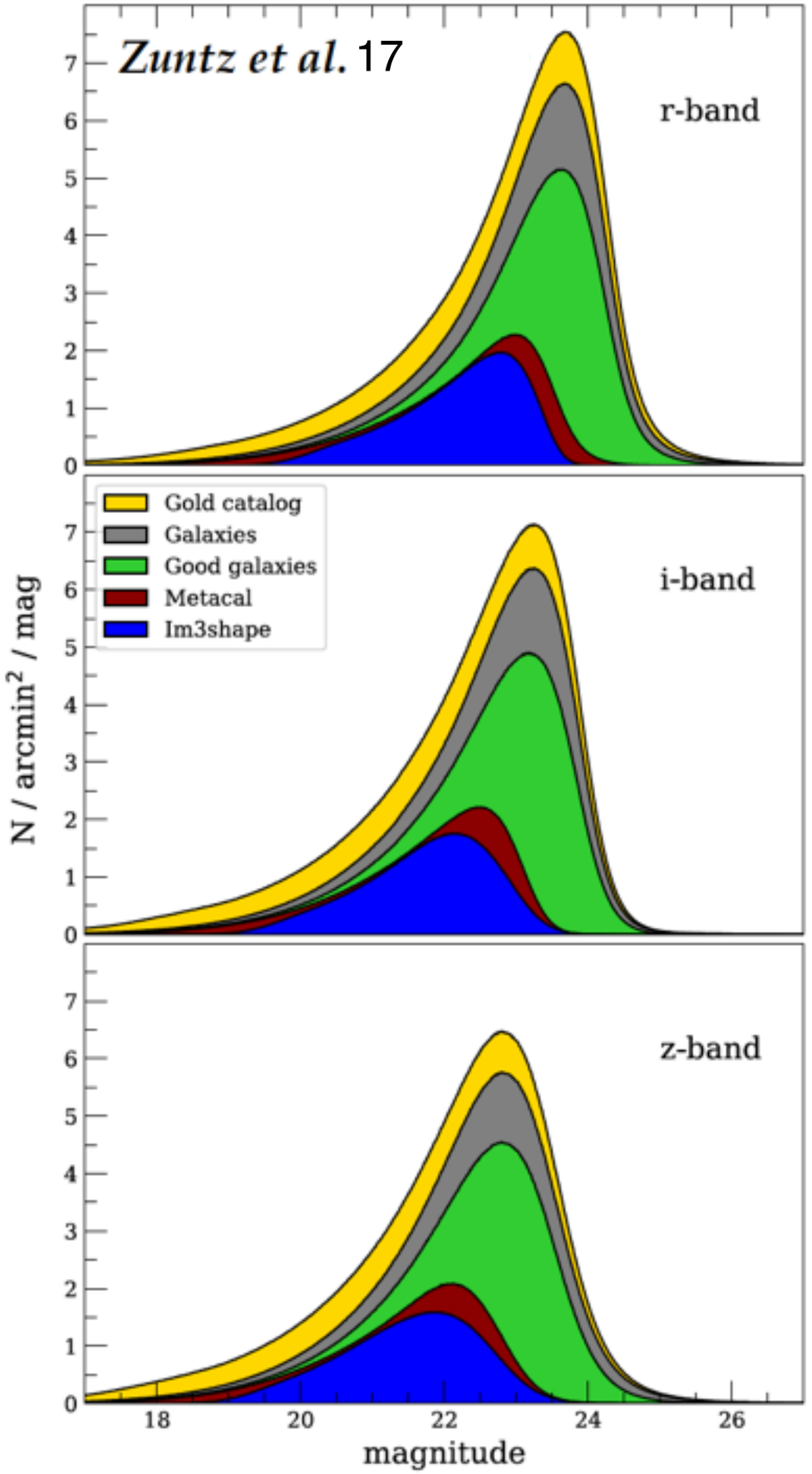
Measure PSF smearing from stars; fit for shape in presence of PSF

DES data - need to estimate ellipticities for these galaxies

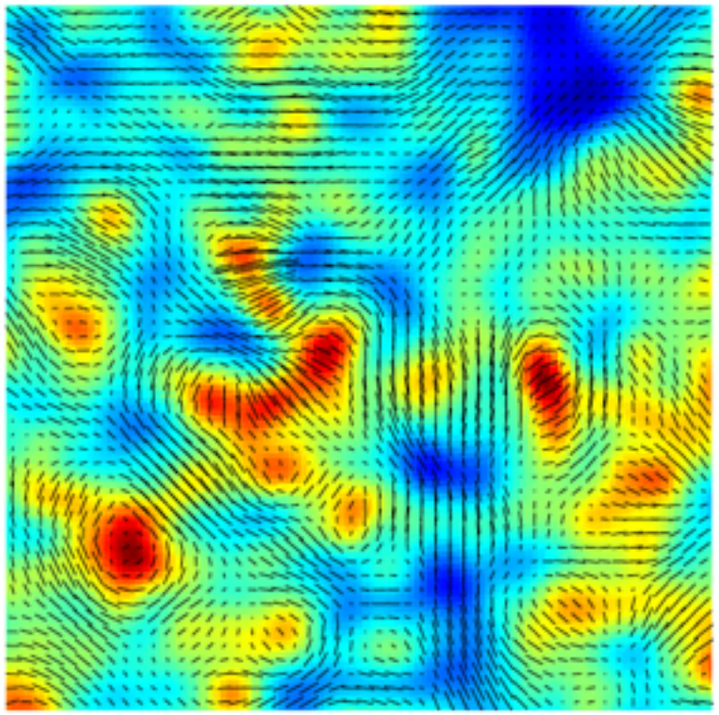
DES Y1 WL

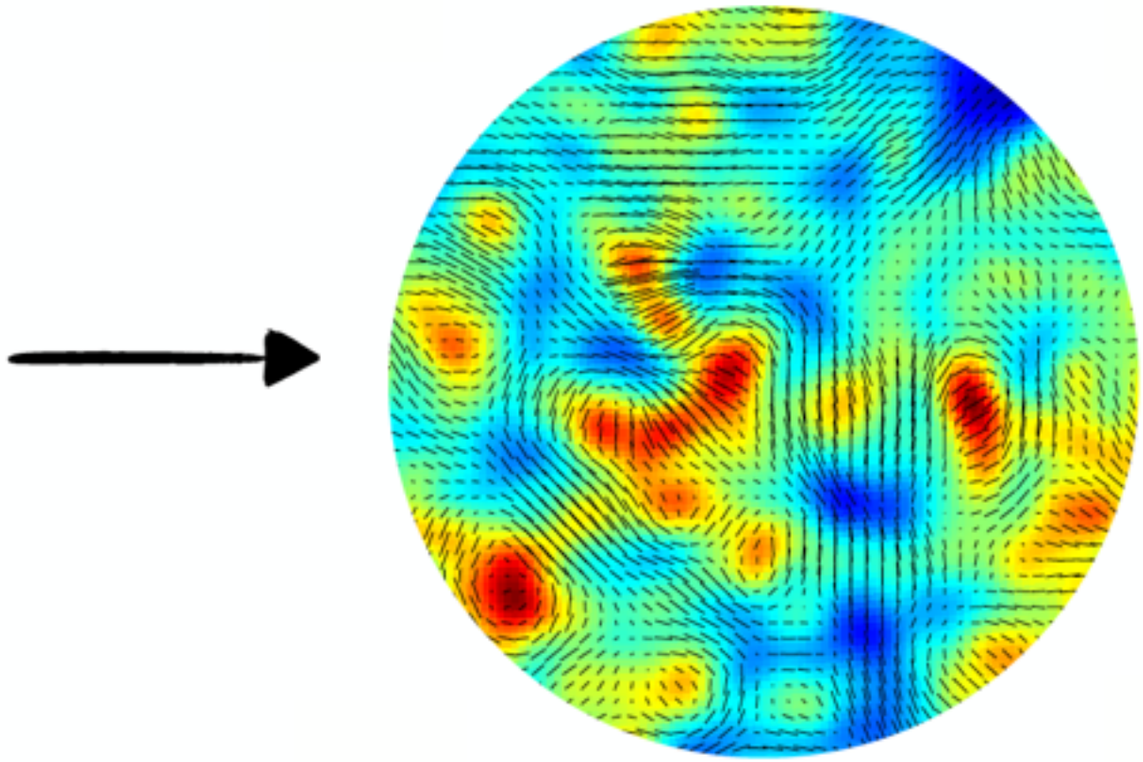
- **MetaCalibration** (Sheldon & Huff 2017)
  - 34.8 M galaxies
  - self-calibrate noise and selection bias
- **Im3shape** (Zuntz et al. 2013)
  - 21.9 M galaxies
  - maximum likelihood fitting calibrated with sophisticated simulations





Wide-Field Mass Maps





$$\tilde{\kappa}(\boldsymbol{\ell}) - \tilde{\kappa_0} = D^*(\boldsymbol{\ell})\tilde{\gamma}(\boldsymbol{\ell})$$

$$D(\boldsymbol{\ell}) = \frac{\ell_1^2 - \ell_2^2 + i2\ell_1\ell_2}{|\boldsymbol{\ell}|^2}$$

Kaiser & Squires 93

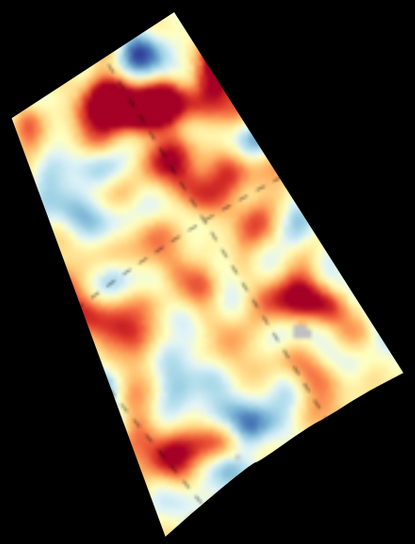
$$\hat{\gamma}_{\ell m} = \hat{\gamma}_{E,\ell m} + i\hat{\gamma}_{B,\ell m}$$

$$= \frac{1}{2}\sqrt{\frac{(\ell+2)(\ell-1)}{\ell(\ell+1)}}\left(\hat{\kappa}_{E,\ell m} + i\hat{\kappa}_{B,\ell m}\right)$$

Curl-free: signal

Divergent-free: noise

THE NEW DARK MATTER MAP



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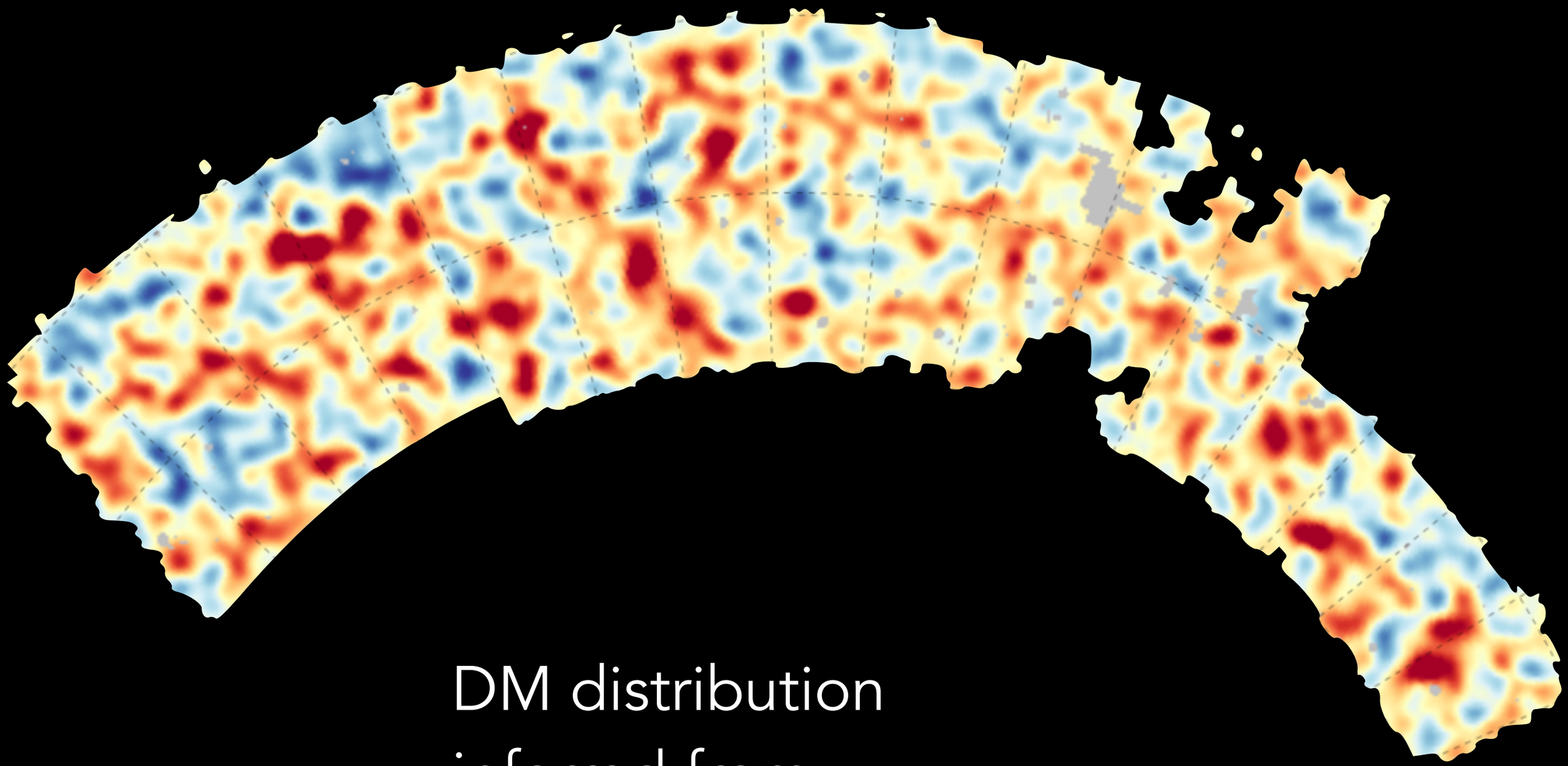
THE NEW DARK MATTER MAP



DM distribution
inferred from
30M galaxies

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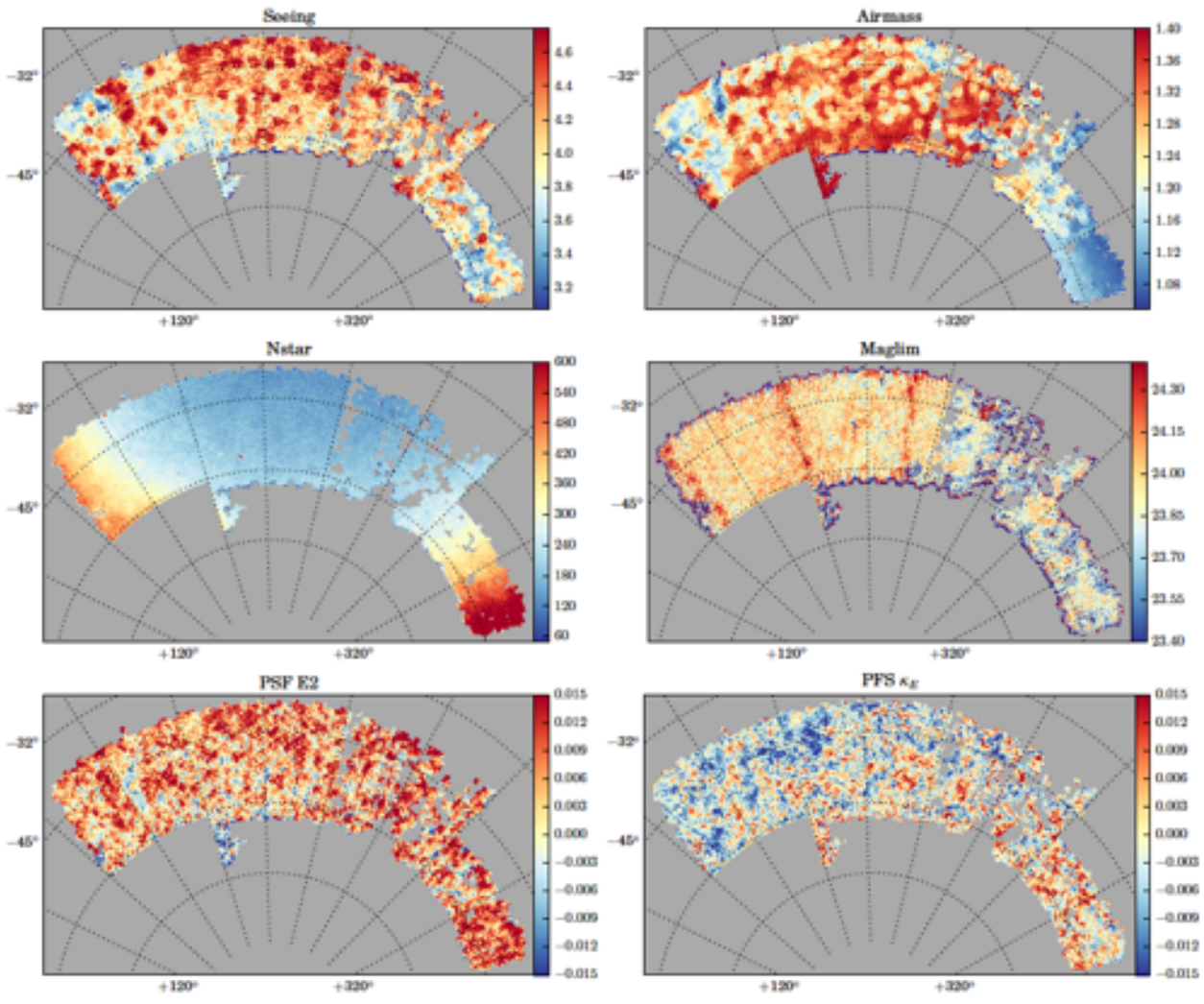
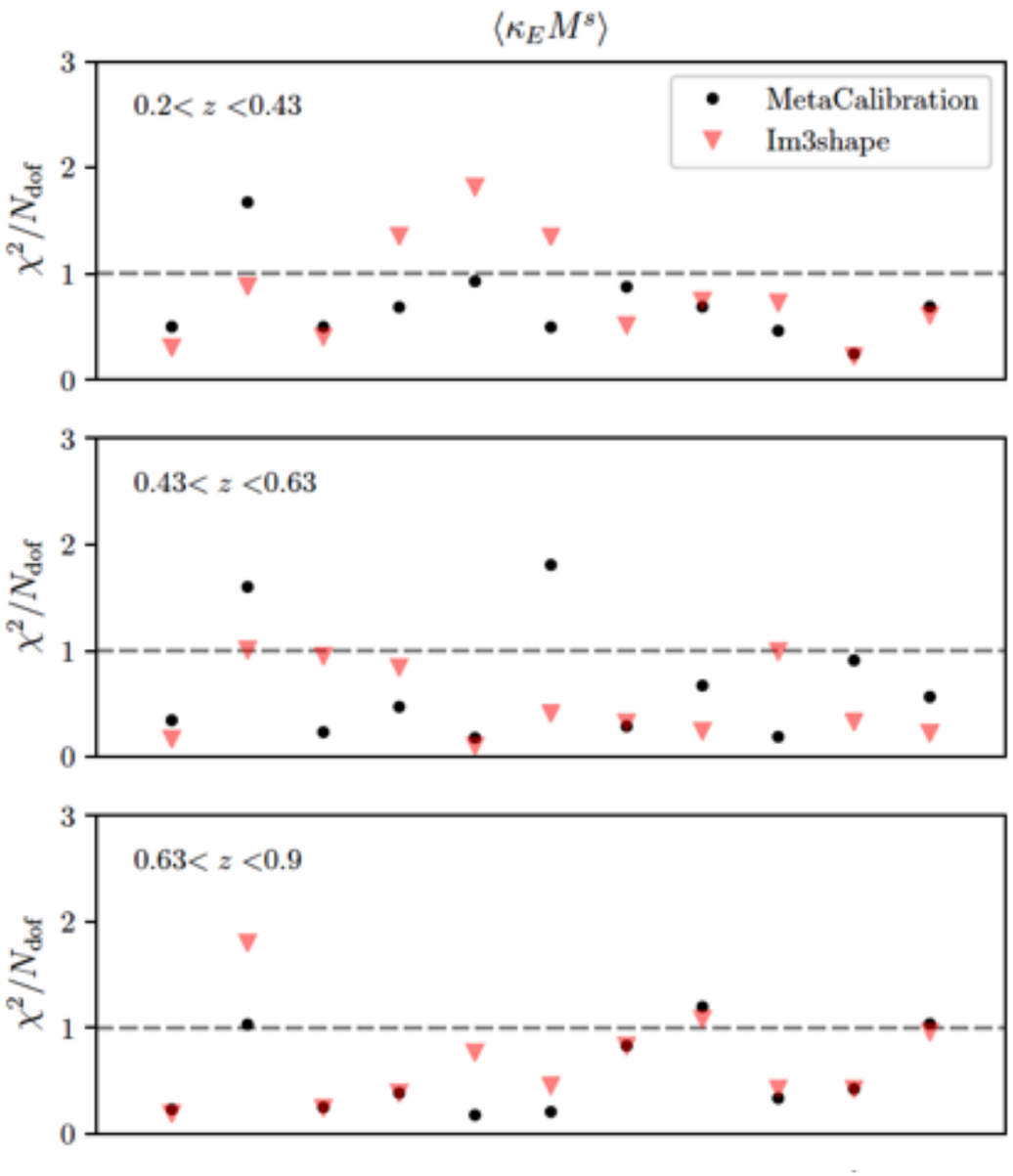
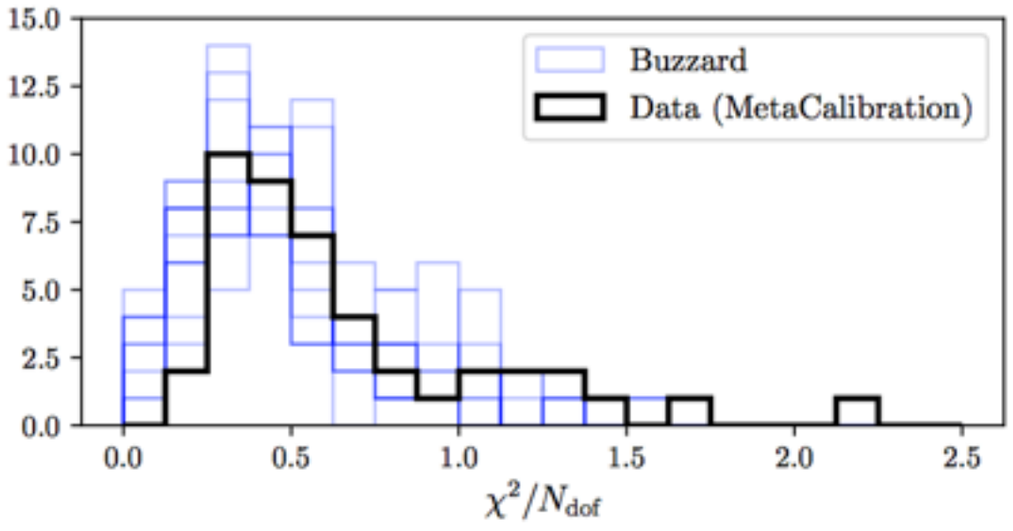
Wide-Field Mass Maps

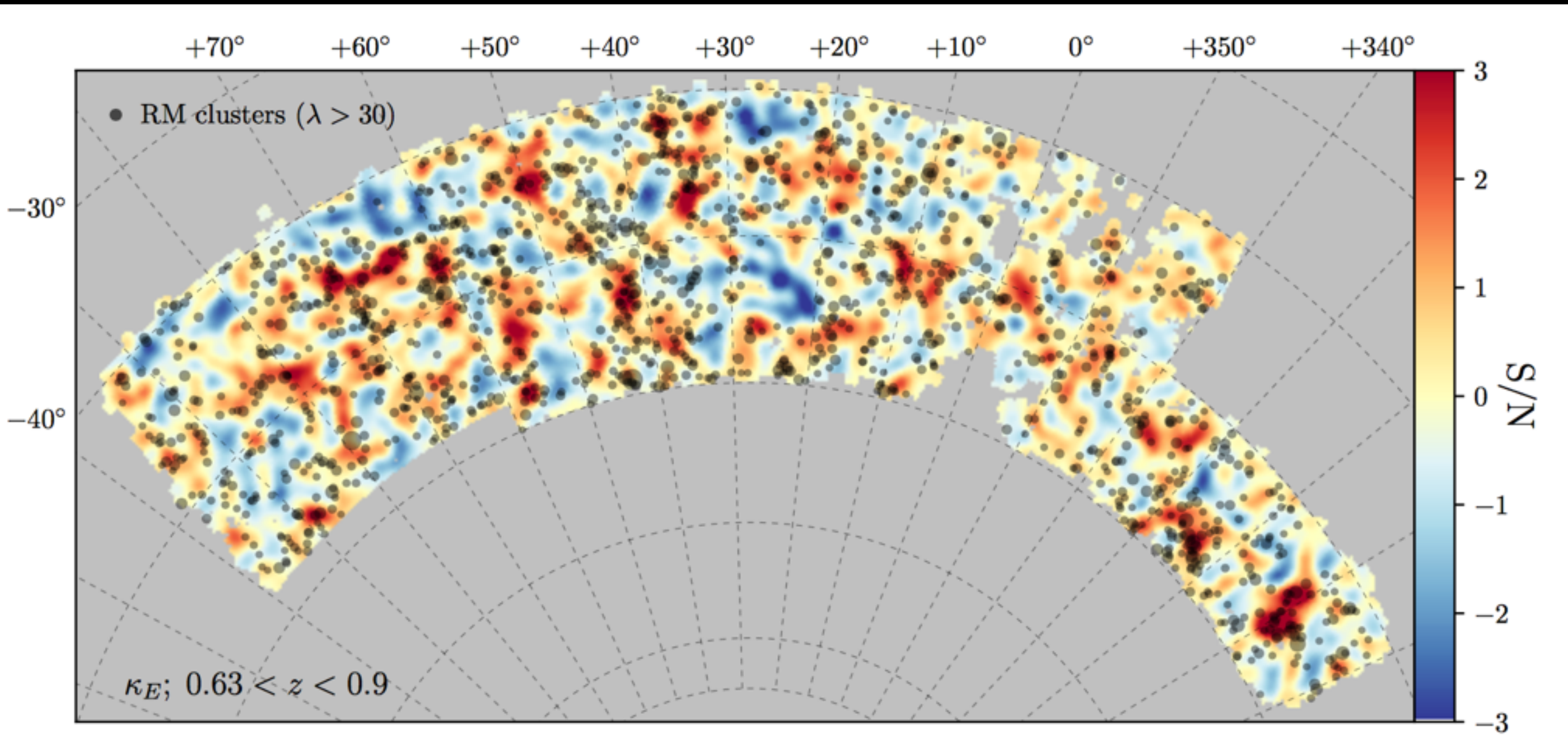
Cross-correlation with systematics maps







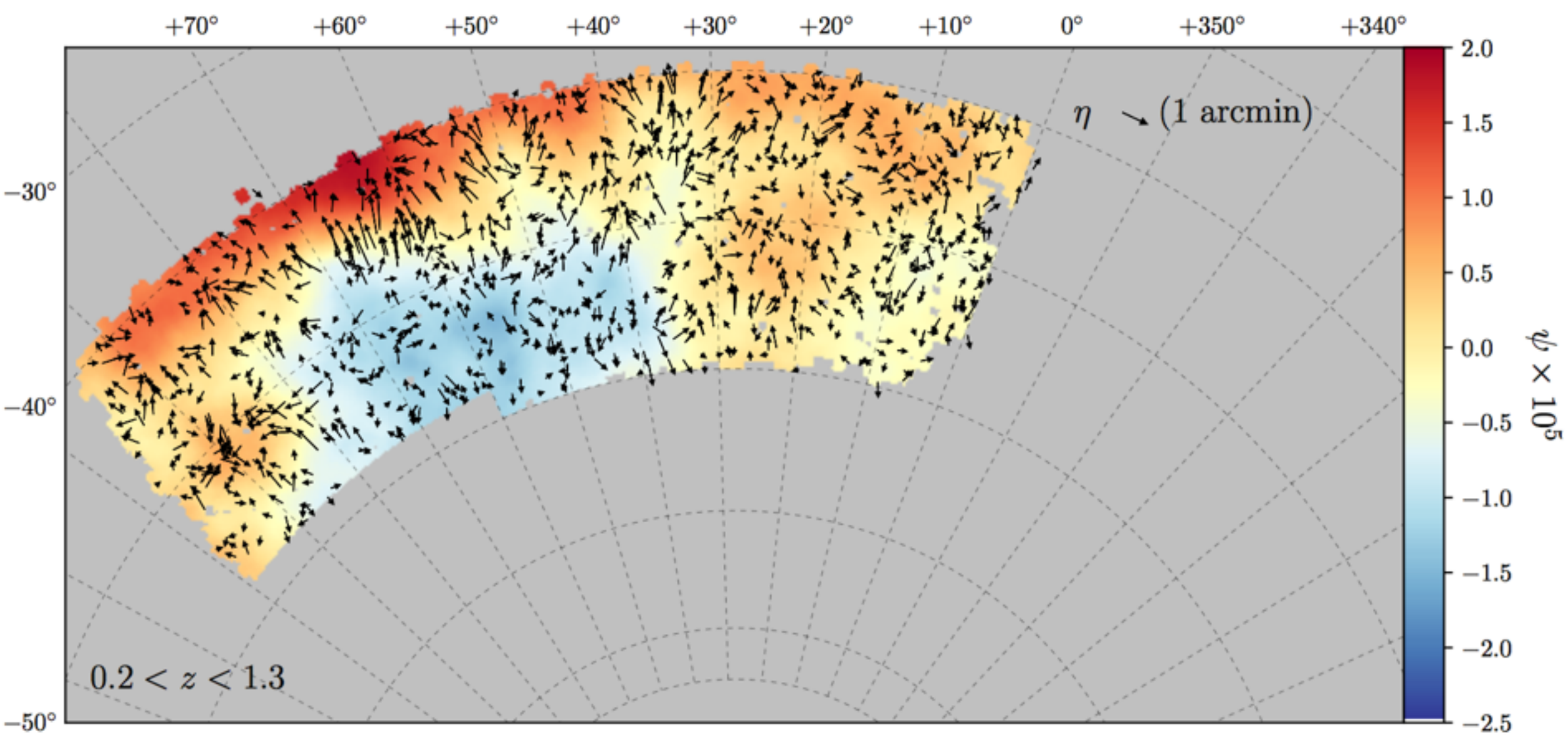
RELATION TO GALAXY CLUSTERING



SEE TOM GIBLIN'S TALK

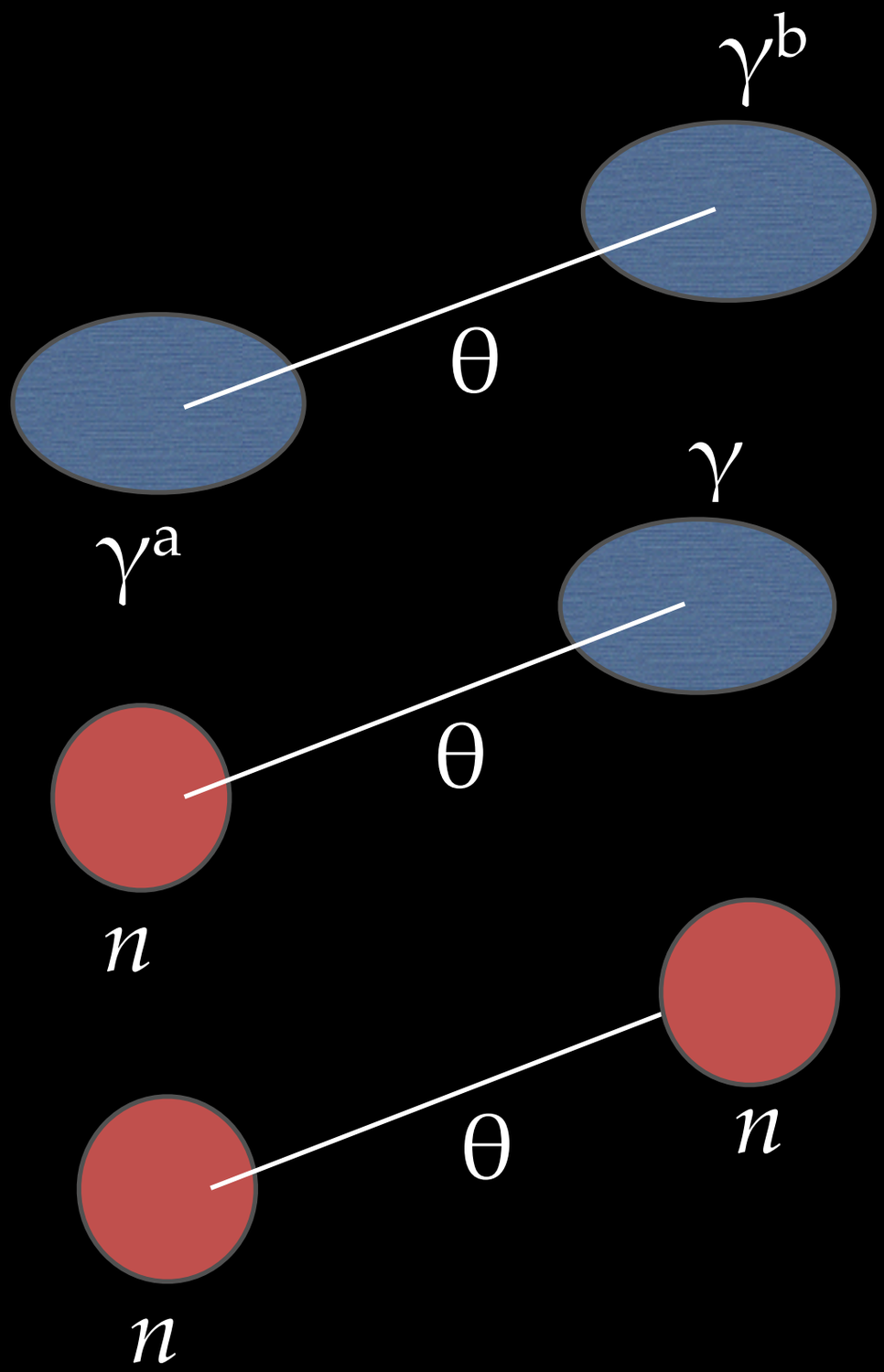
Chang et al 17

DISPLACEMENT AND POTENTIAL MAPS



SEE NICK KAISER'S TALK

LENSING AND CLUSTERING STATISTICS



Sensitive to matter power spectrum, geometry

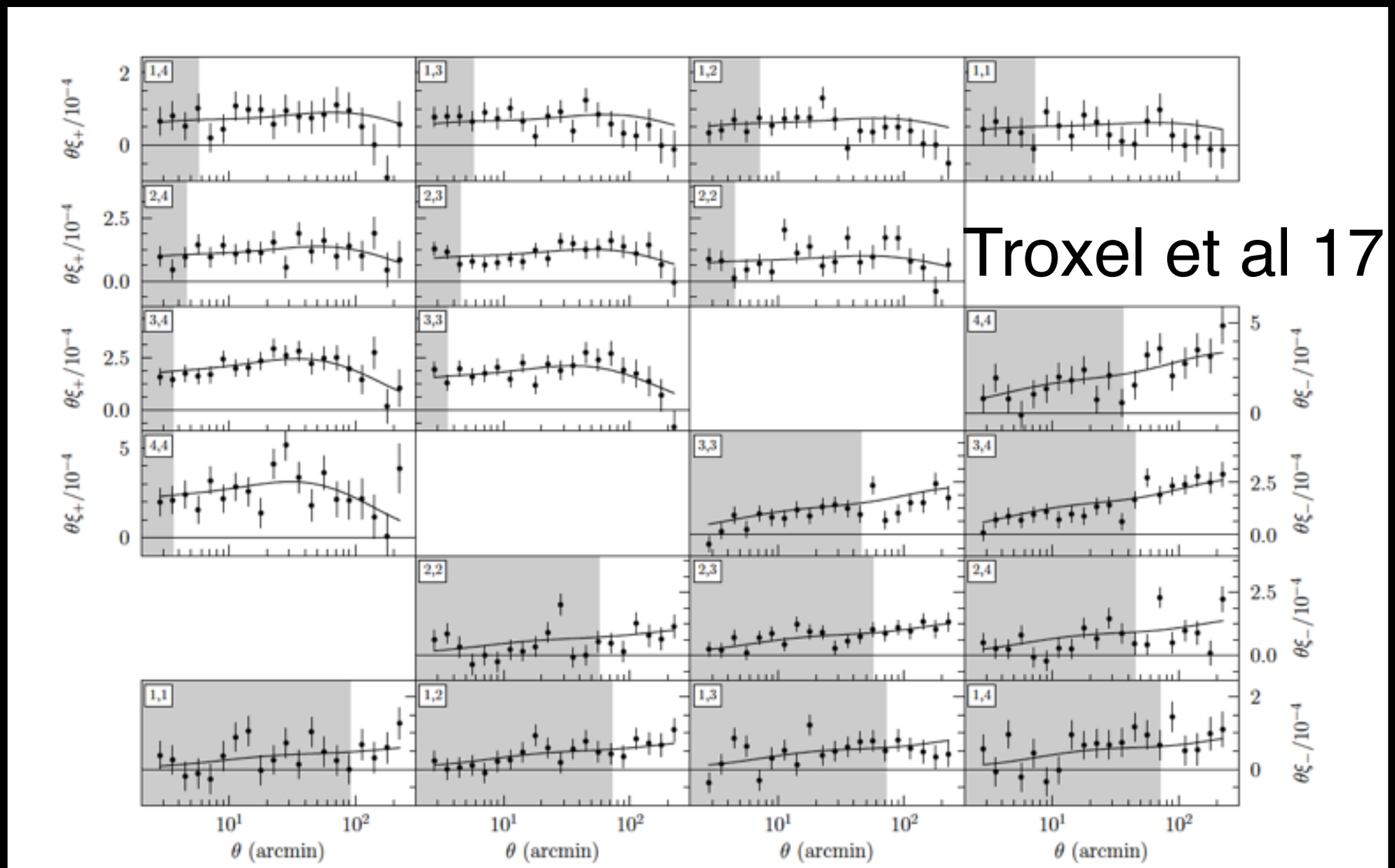
$$P_\kappa(l,\chi_s) = \frac{9H_0^4\Omega_m^2}{4c^4}\int_0^{\chi_s} d\chi \frac{(\chi_s-\chi)^2}{\chi_s^2}\frac{P_\delta(l/\chi,\chi)}{a(\chi)^2}$$

Sensitive to matter power spectrum, geometry, bias

Sensitive to matter power spectrum, bias

$$w^i(\theta) = (b^i)^2 \int \frac{dl\, l}{2\pi} J_0(l\theta) \int d\chi \times \frac{\left[n_{\rm i}^i(z(\chi))\right]^2}{\chi^2 H(z)} P_{\rm NL}\left(\frac{l+1/2}{\chi}, z(\chi)\right)$$

COSMIC SHEAR RESULTS

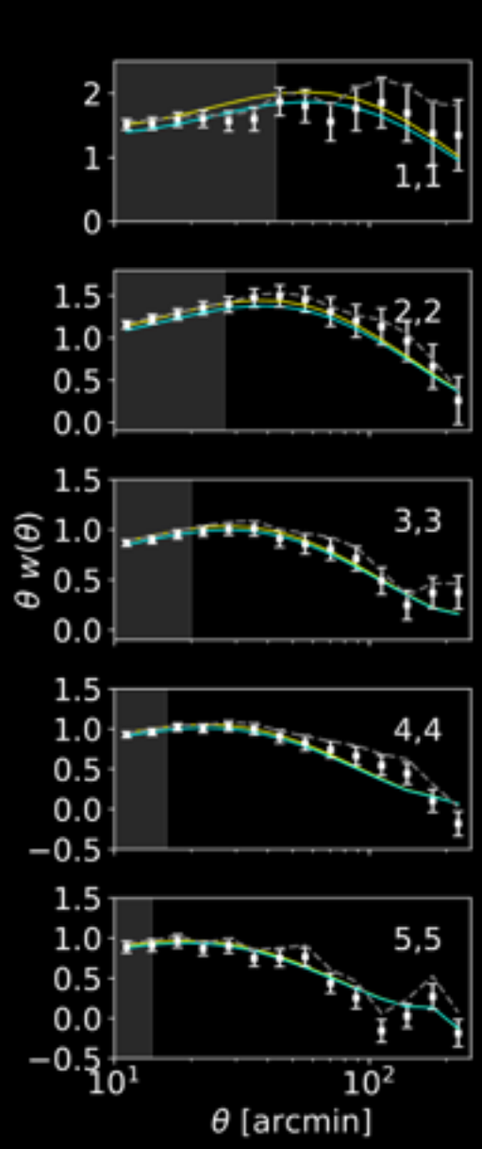


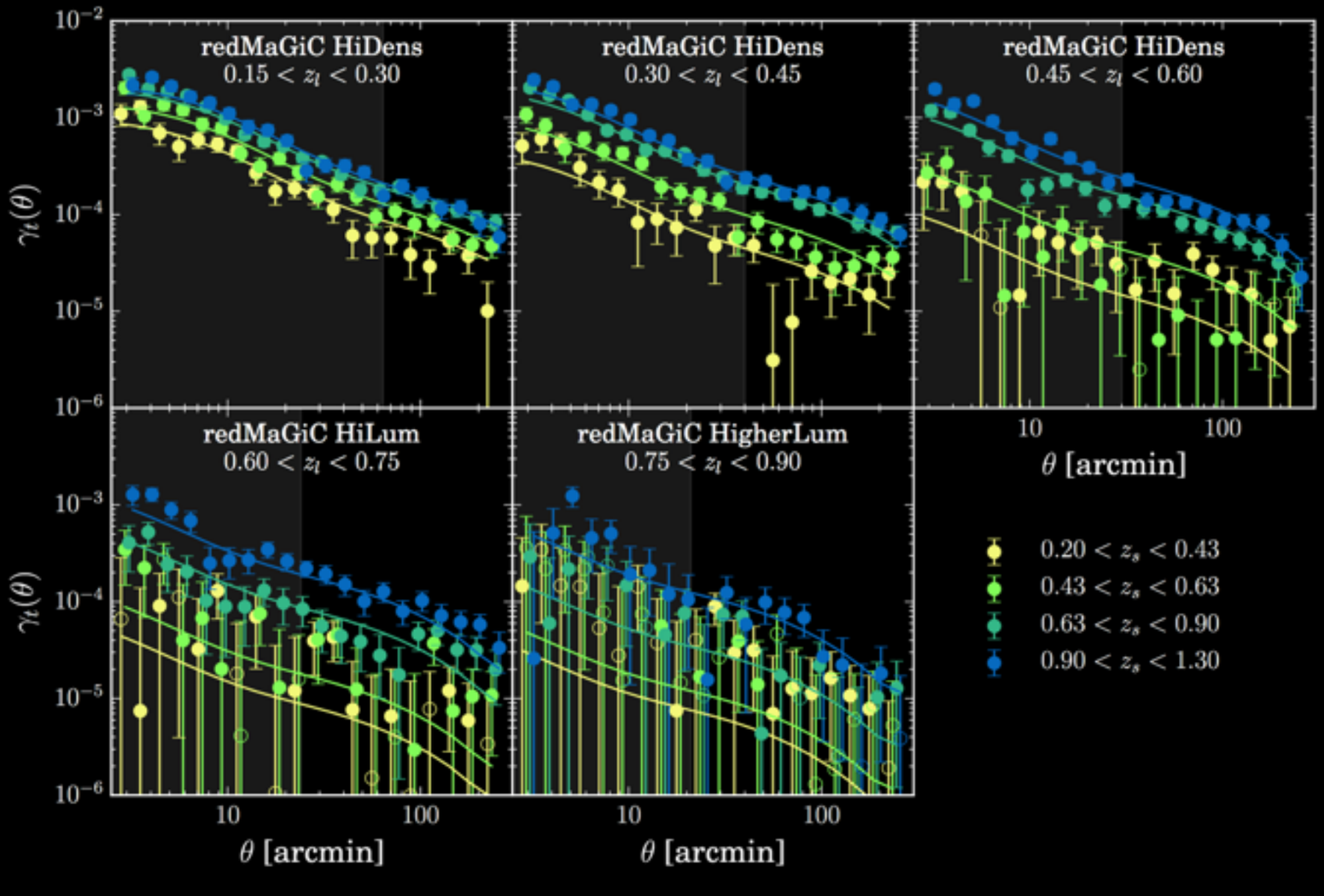
BEWARE OF BARYONIC EFFECTS AND INTRINSIC ALIGNMENTS - SEE MARIKA ASGARI'S TALK

MEASUREMENTS: GALAXY CLUSTERING AND GALAXY-GALAXY LENSING

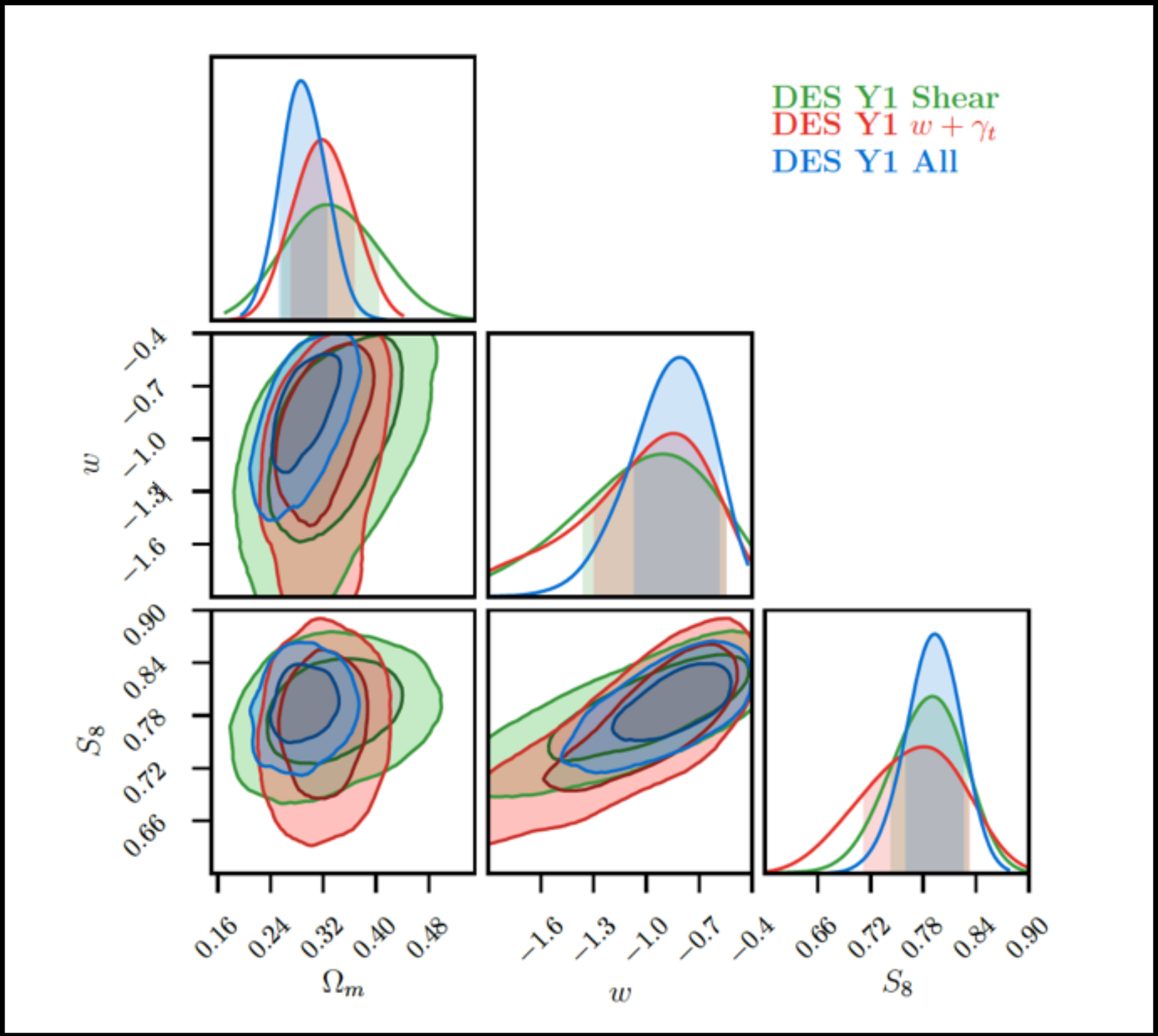
ELVIN-POOLE+; PRAT, SANCHEZ+

Lens galaxies: redMaGiC LRGs with high-quality photometric redshift estimates (Rozo, Rykoff+2016)



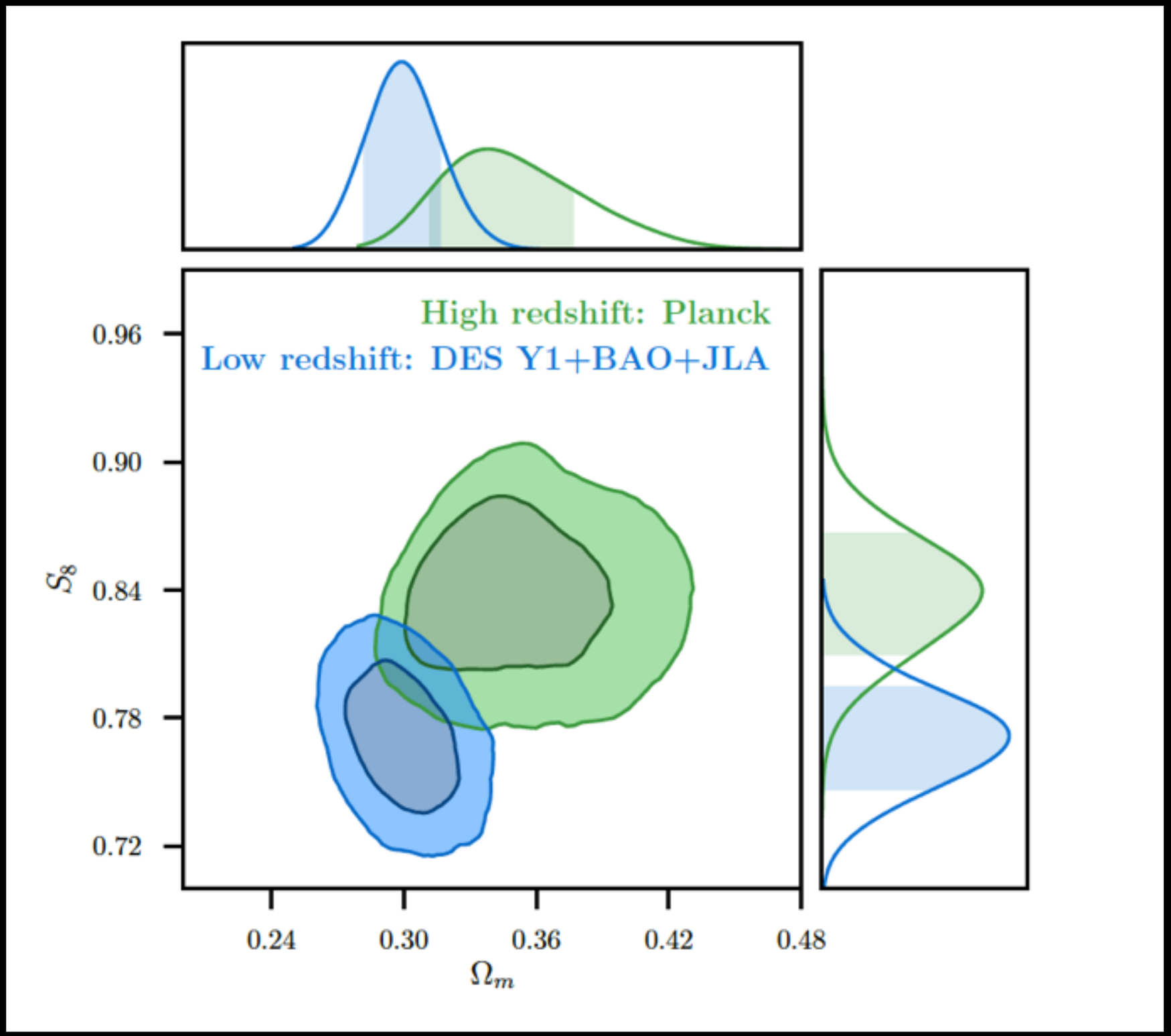


COMBINED RESULTS



DES 17

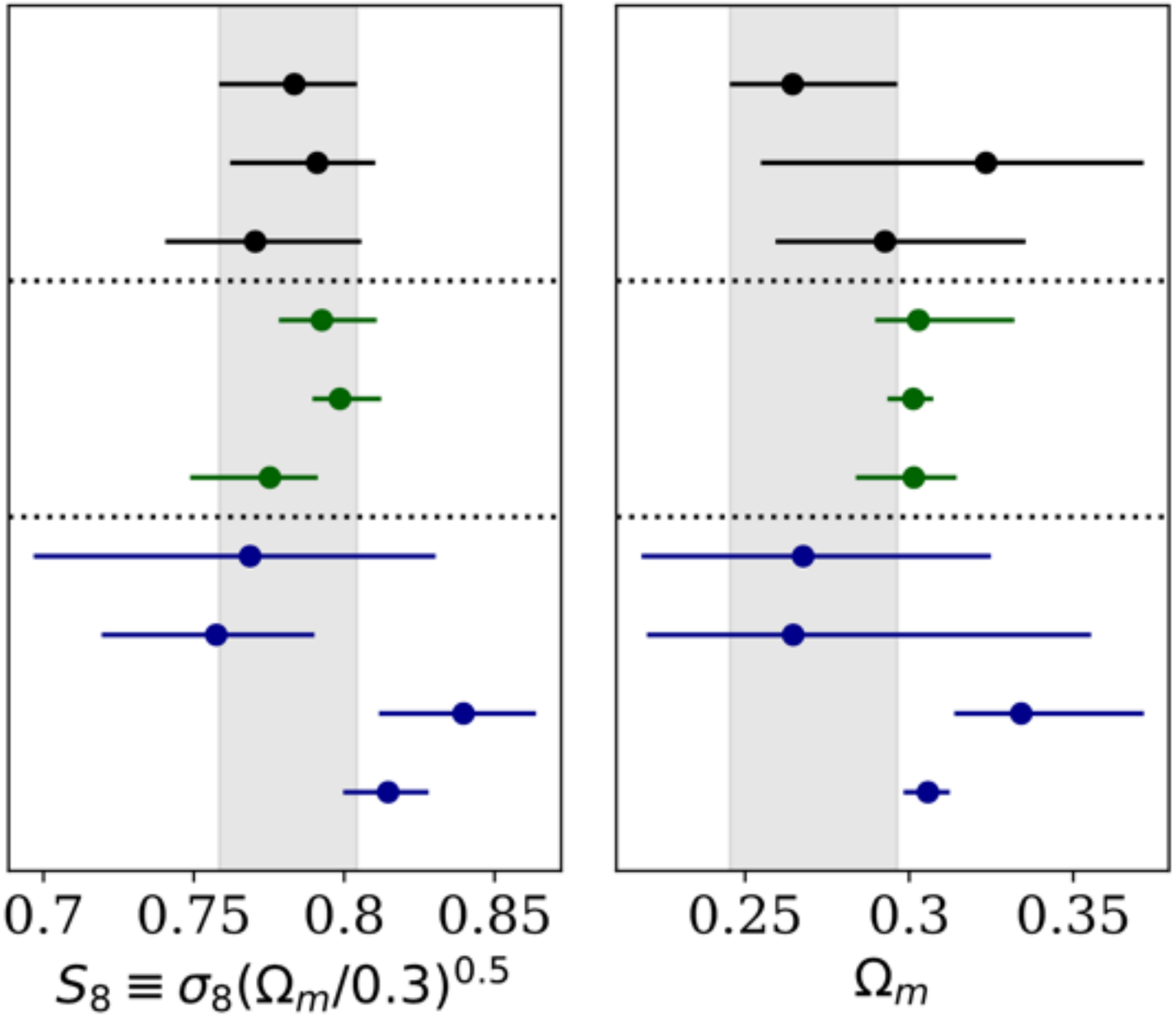
COMBINED RESULTS



COMPARE KRZYSZTOF BOLEJKO'S TALK

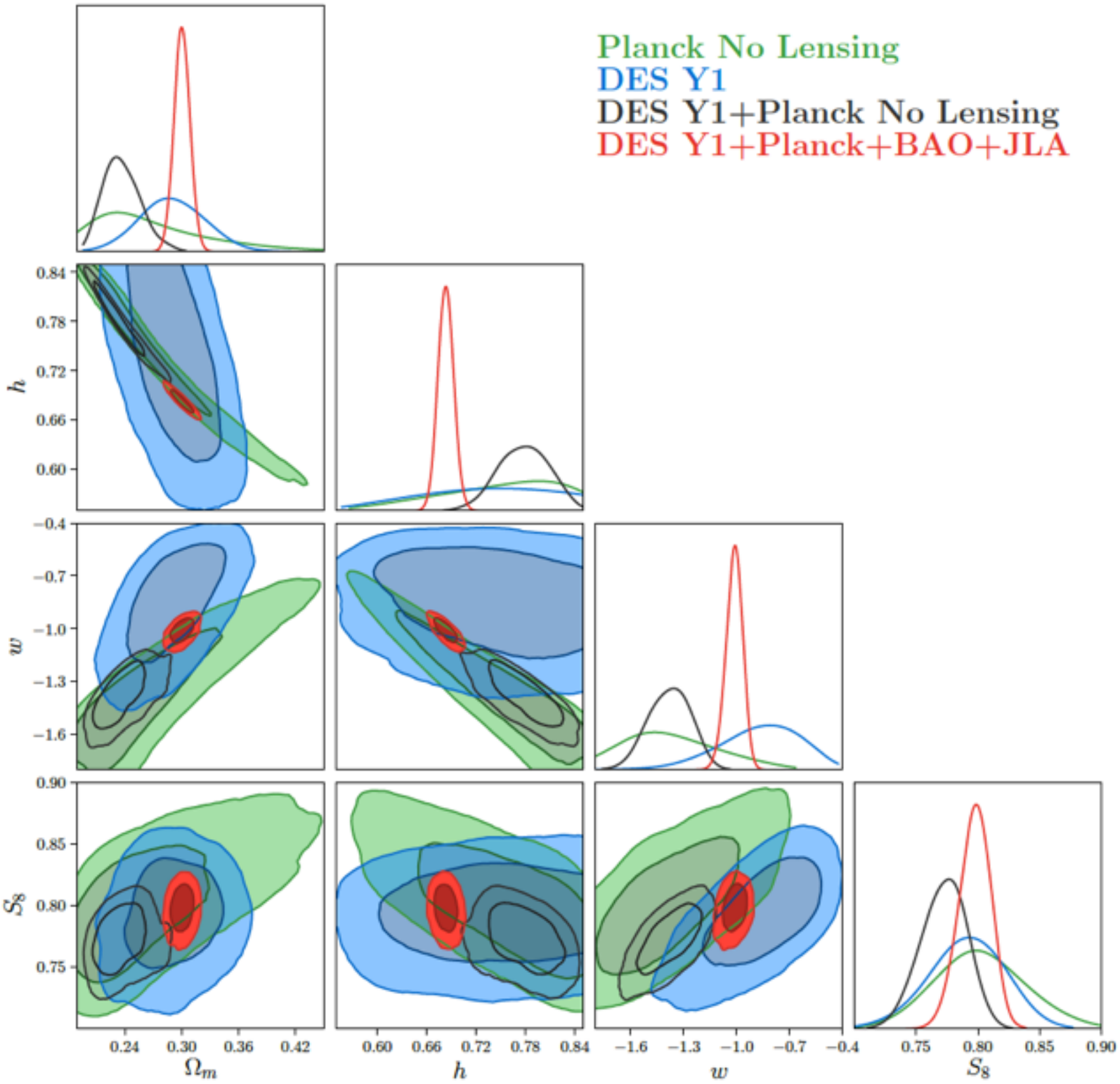
DES 17

COMBINED RESULTS



DES Y1 All
DES Y1 Shear
DES Y1 $w + \gamma_t$
DES Y1 All + Planck (No Lensing)
DES Y1 All + Planck + BAO + JLA
DES Y1 All + BAO + JLA
DES SV
KiDS-450
Planck (No Lensing)
Planck + BAO + JLA

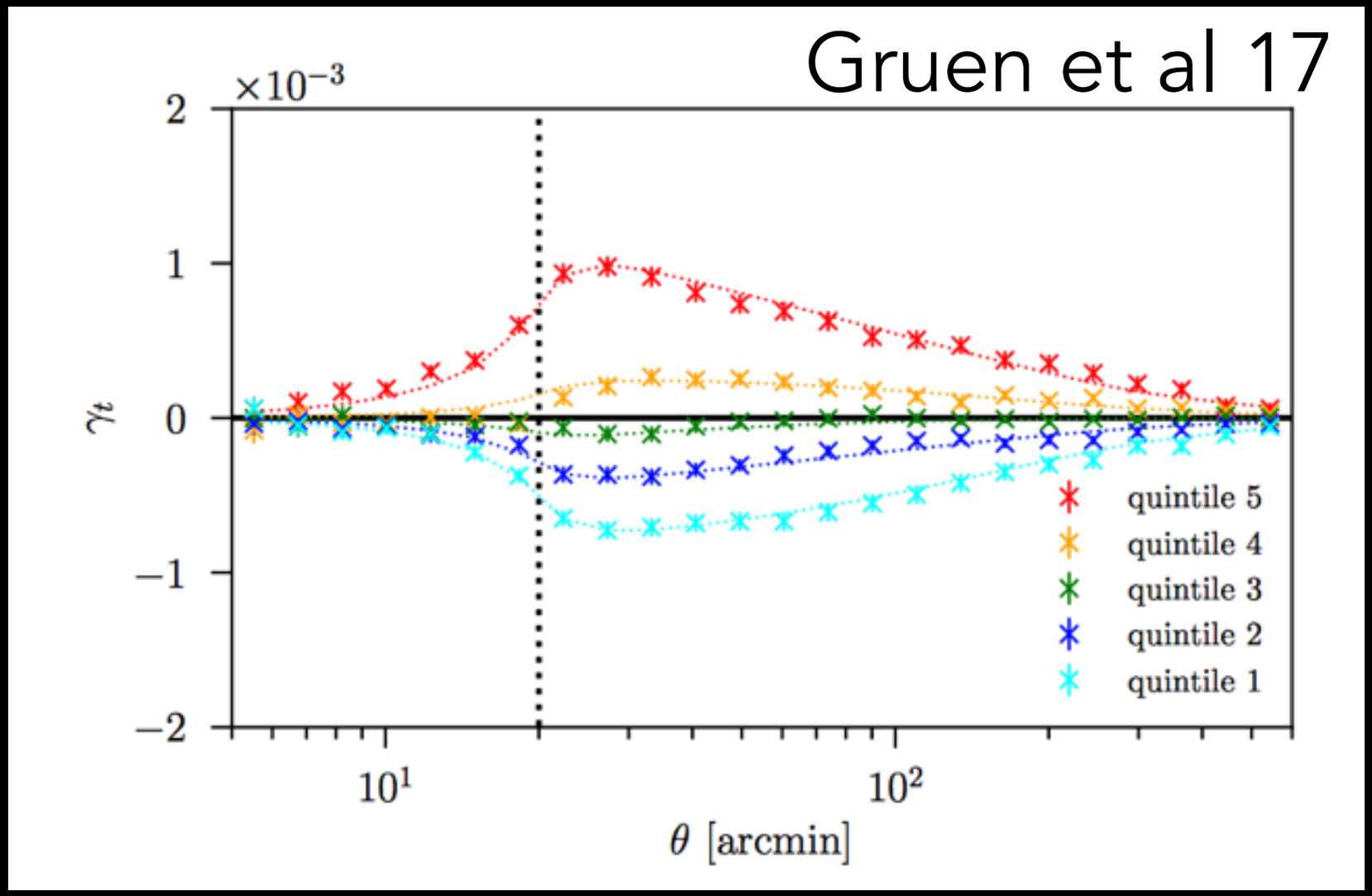
COMBINED RESULTS



DES 17

DENSITY SPLIT STATISTICS

Projected galaxy count map, find columns of a given range in projected density. Measure lensing due to these columns.



Are these predictions sensitive to back-reaction?

SUMMARY

- Strong lensing studies allow detailed look at inhomogeneities; lens modelling needs great care.

- DES weak lensing has added a precise measurement of structure in the evolved Universe
  - Competitiveness and consistency with Planck CMB in ΛCDM; mild offset in the direction of e.g. KIDS
  - Precise joint measurements close to Ω_m=0.30, σ_8=0.80, w=-1.0
  - Systematics in shape measurement, small-scale baryonic effects, intrinsic alignments need great care.

- Density split statistics may be of interest to the back-reaction community - please calculate what is expected in your models.