Cosmological Weak Lensing

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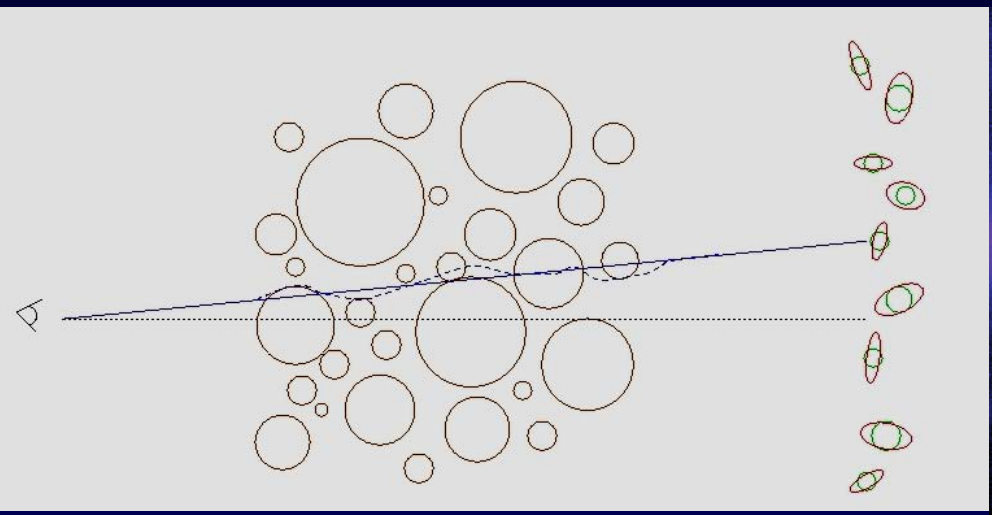
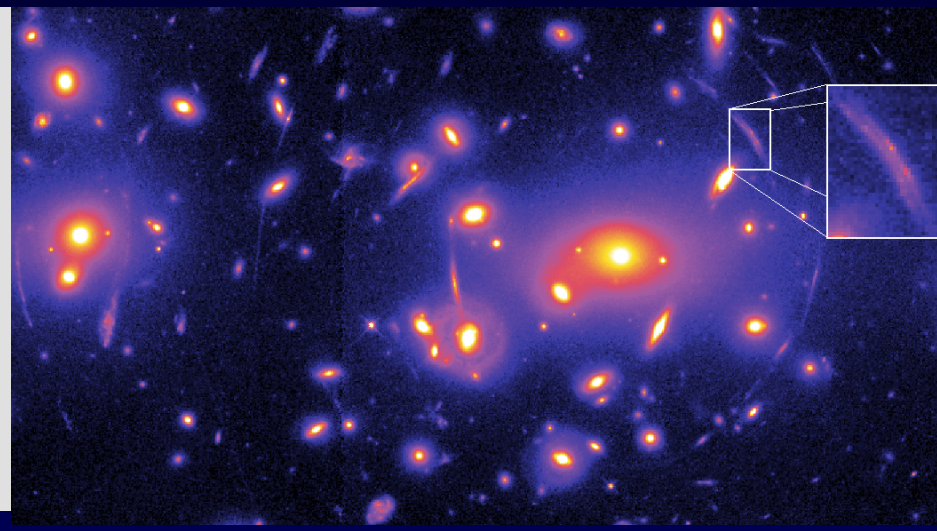
Weak Gravitational Lensing





Distortion Matrix:

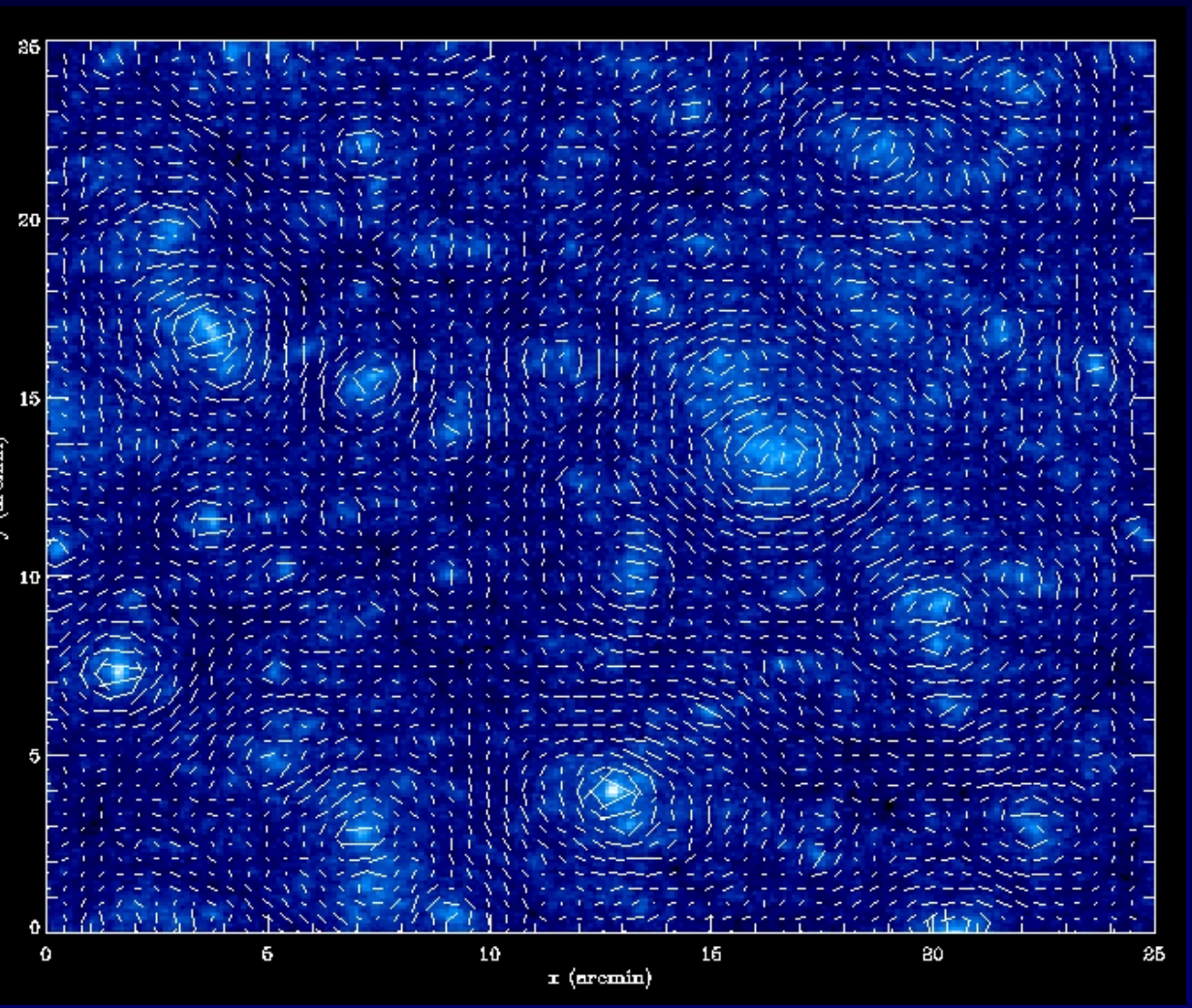
$$\Psi_{ij} = \frac{\partial \delta\theta_i}{\partial \theta_j} = \int dz\, g(z) \frac{\partial^2 \Phi}{\partial \theta_i \partial \theta_j}$$

Theory

→ Direct measure of the distribution of mass in the universe, as opposed to the distribution of light, as in other methods (eg. Galaxy surveys)

Scientific Promise of Weak Lensing

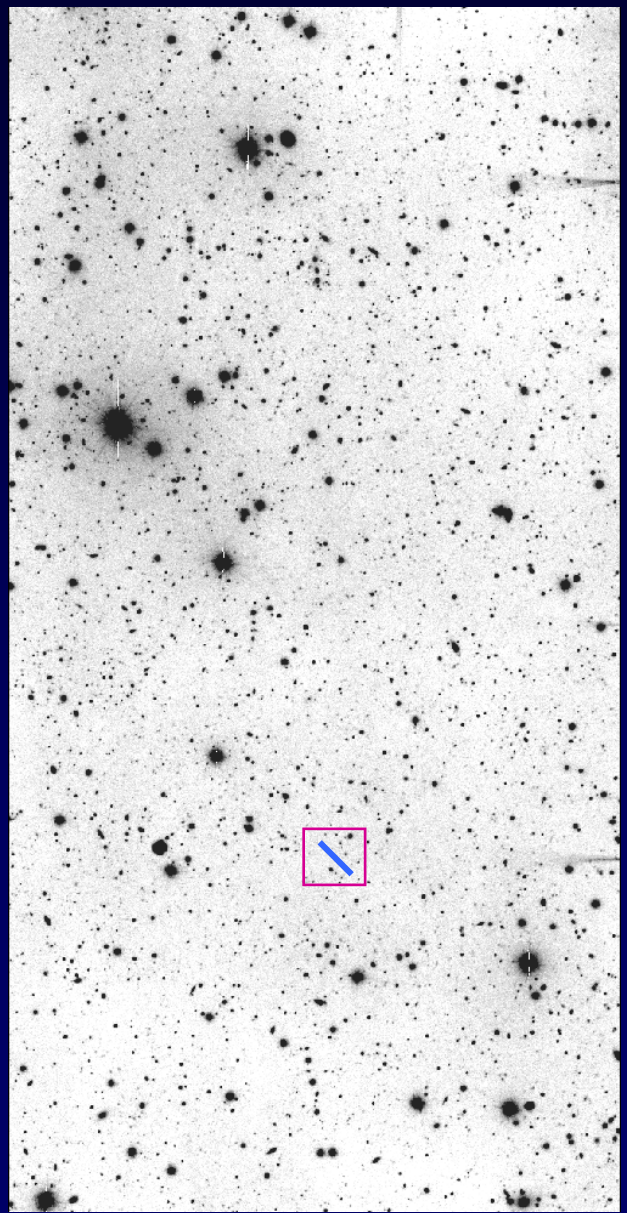
From the statistics of the shear field, weak lensing provides:



- Mapping of the distribution of Dark Matter on various scales
- Measurement of the evolution of structures
- Measurement of cosmological parameters, breaking degeneracies present in other methods (SNe, CMB)
- Explore models beyond the standard osmological model (ΛCDM)

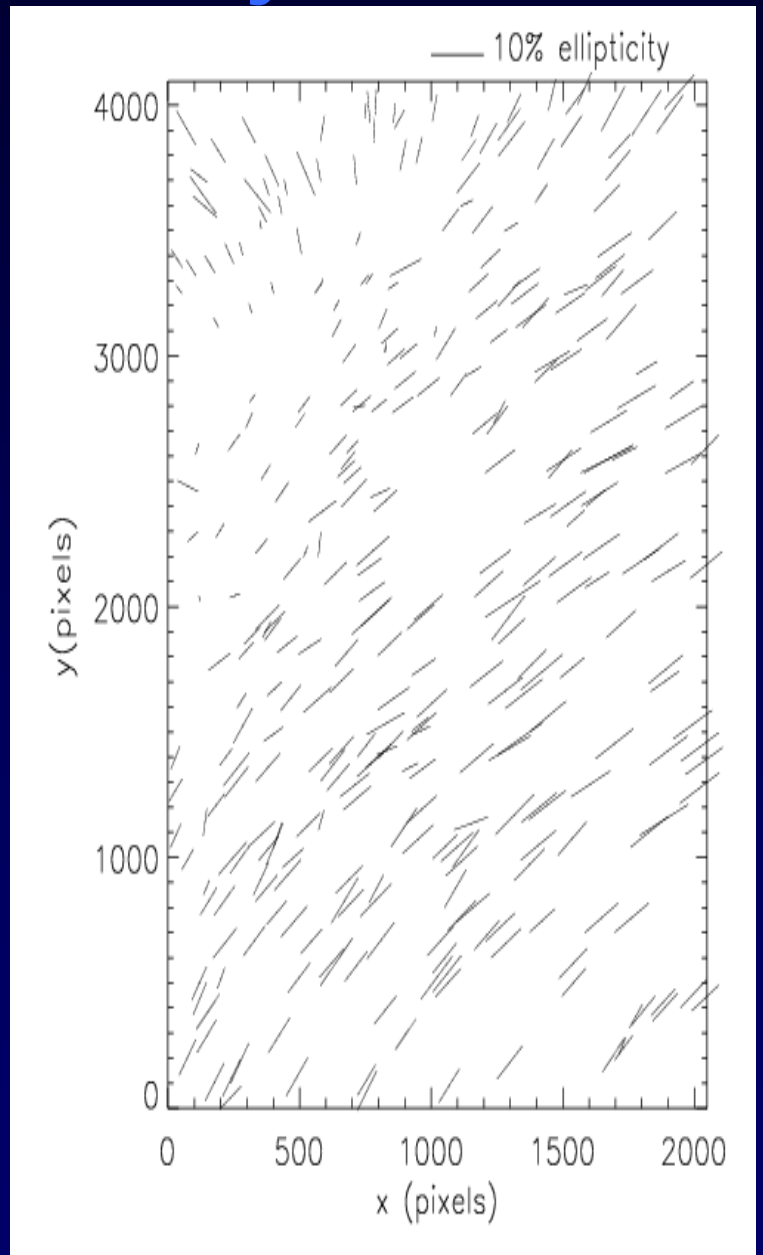
Jain, Seljak & White 1997, 25'x25', SCDM

Cosmic Shear Surveys

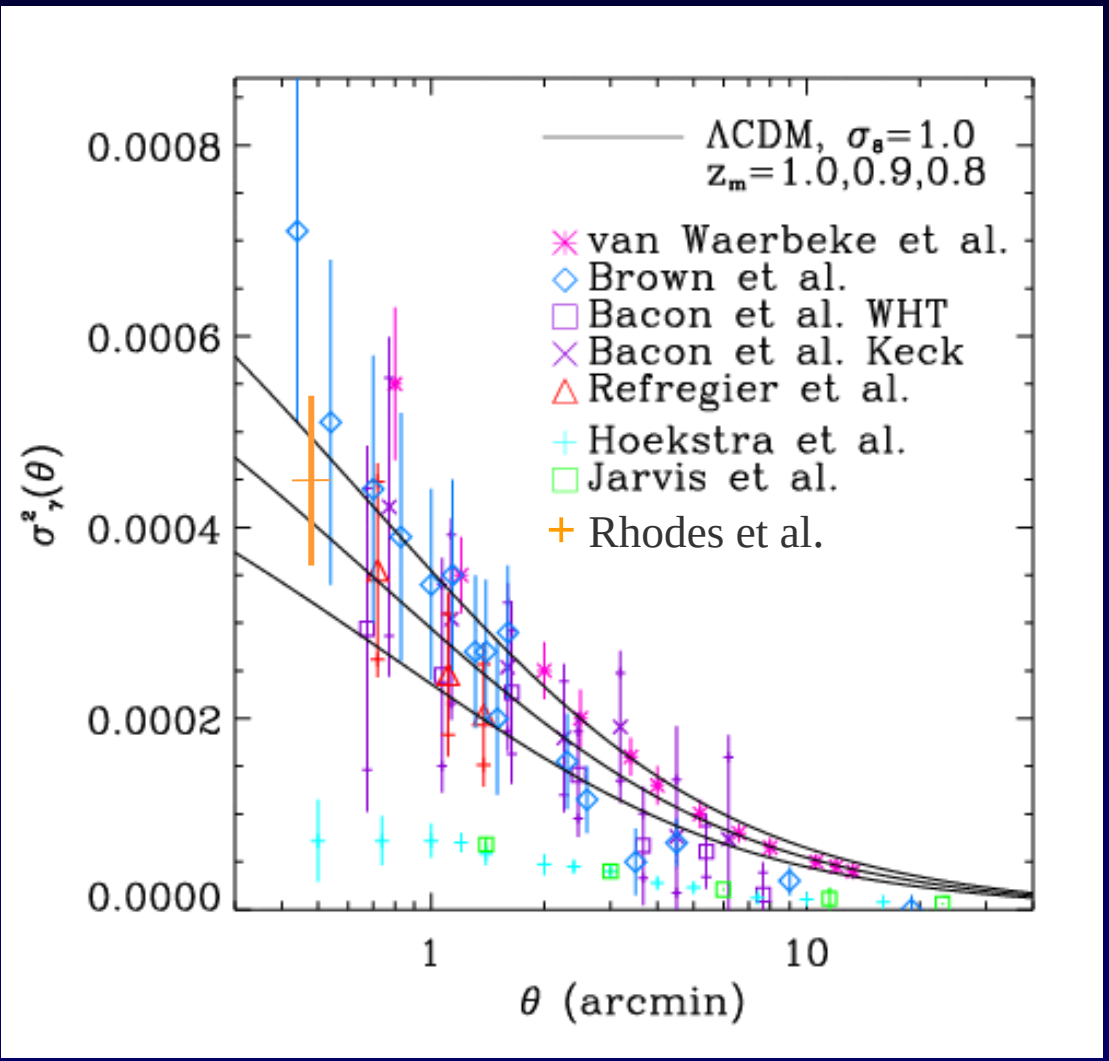


WHT survey:
16’x8’
R<25.5
20 gals/amin^2

Systematics:
Anisotropic
PSF



Cosmic Shear Measurements



Shear variance in circular cells:

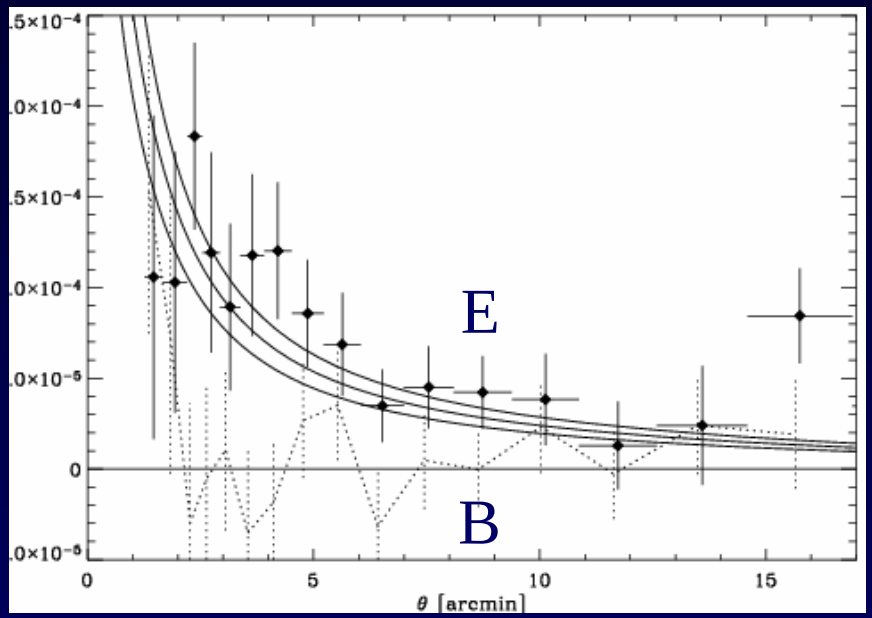
$\sigma^2_\gamma(\theta)=\langle\gamma^2\rangle$

Bacon, Refregier & Ellis 2000*
Bacon, Massey, Refregier, Ellis 2001
Kaiser et al. 2000*
Maoli et al. 2000*
Rhodes, Refregier & Groth 2001*
Refregier, Rhodes & Groth 2002
van Waerbeke et al. 2000*
van Waerbeke et al. 2001
Wittman et al. 2000*
Hammerle et al. 2001*
Hoekstra et al. 2002 *
Brown et al. 2003
Hamana et al. 2003 *
Jarvis et al. 2003
Casertano et al 2003*
Rhodes et al 2004
Massey et al. 2004*

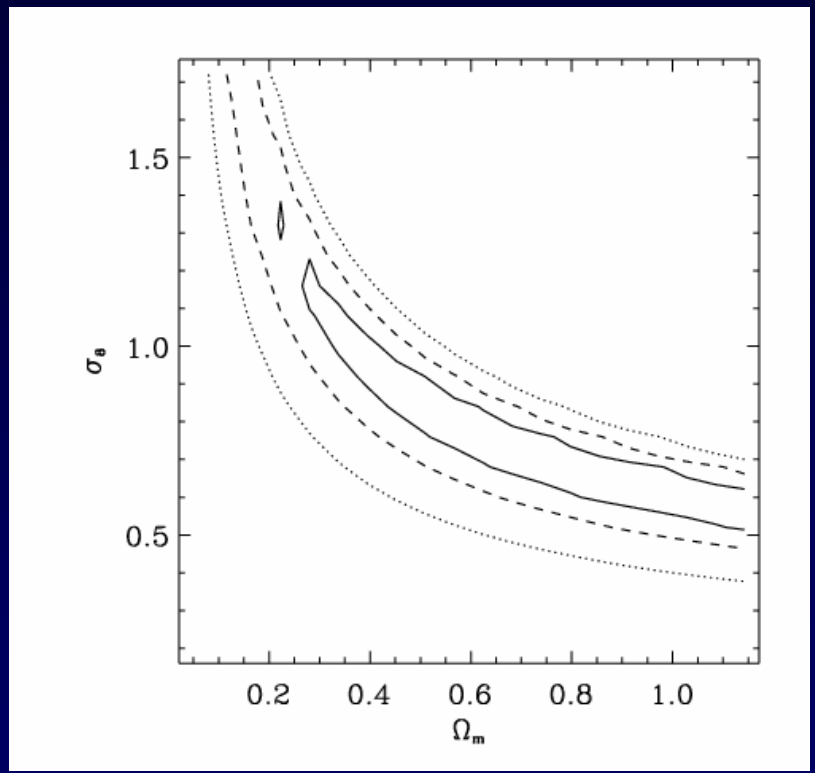
* not shown

Cosmological Constraints

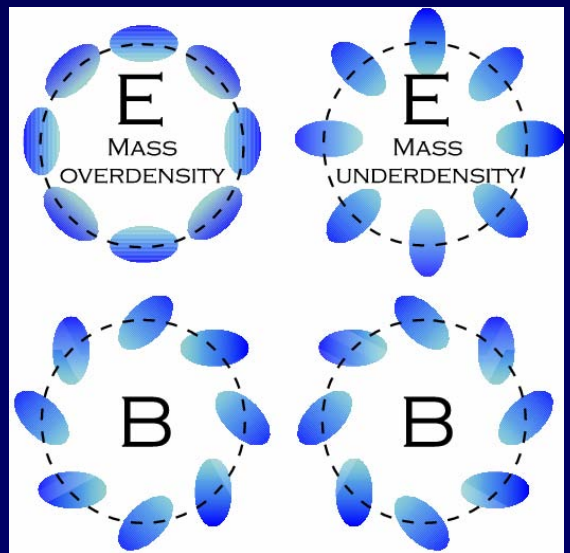
Shear correlation functions



Massey, Refregier, Bacon & Ellis 2004

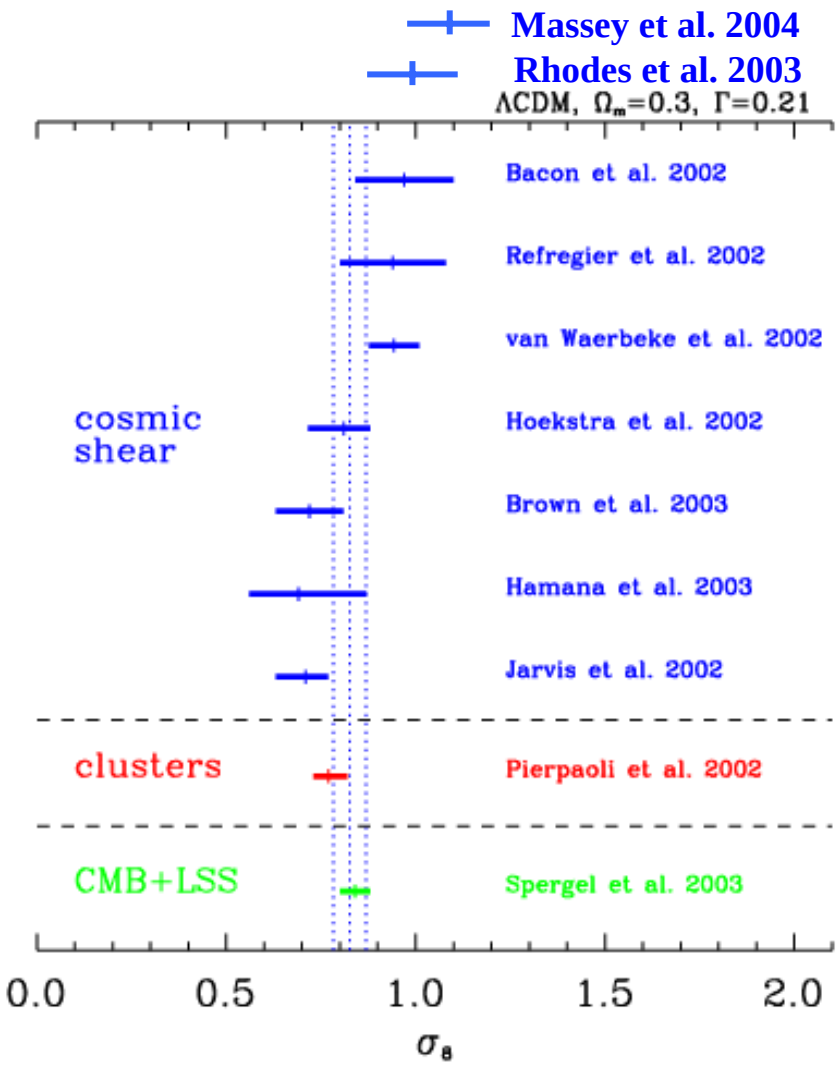


E/B decom-position



$$\sigma_8\left(\frac{\Omega_m}{0.3}\right)^{0.51} = 1.09 \pm 0.12$$

Normalisation of the Power Spectrum



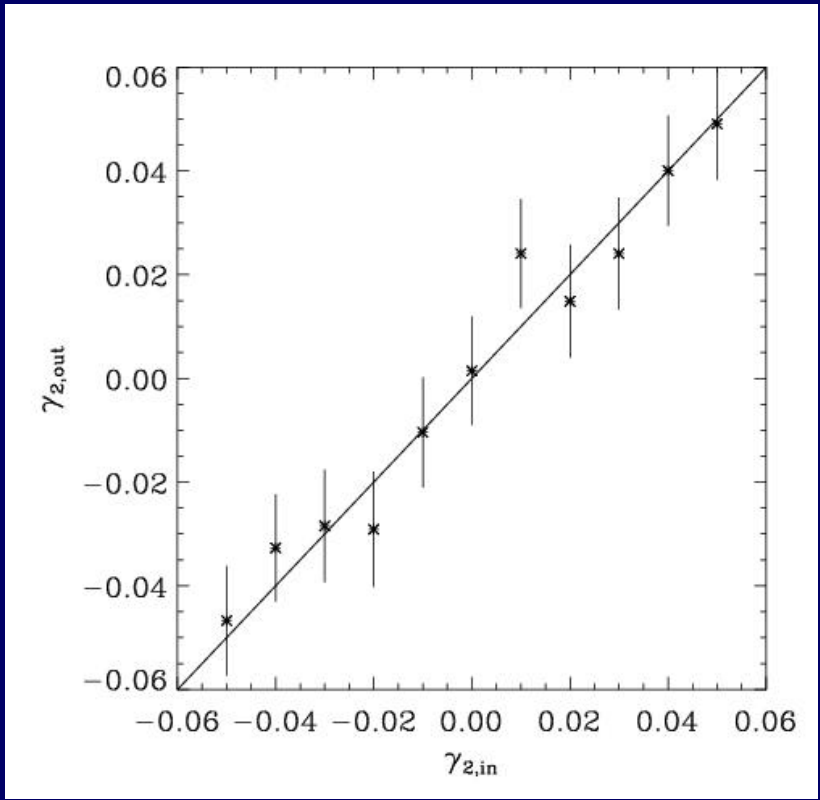
→ Moderate disagreement among cosmic shear measurements (careful with marginalisation)

→This could be due to residual systematics (shear calibration?)

→Agreement on average with CMB constraints

→ moderate inconsistency with cluster abundance (systematics or new physics?)

Shear Measurement Methods



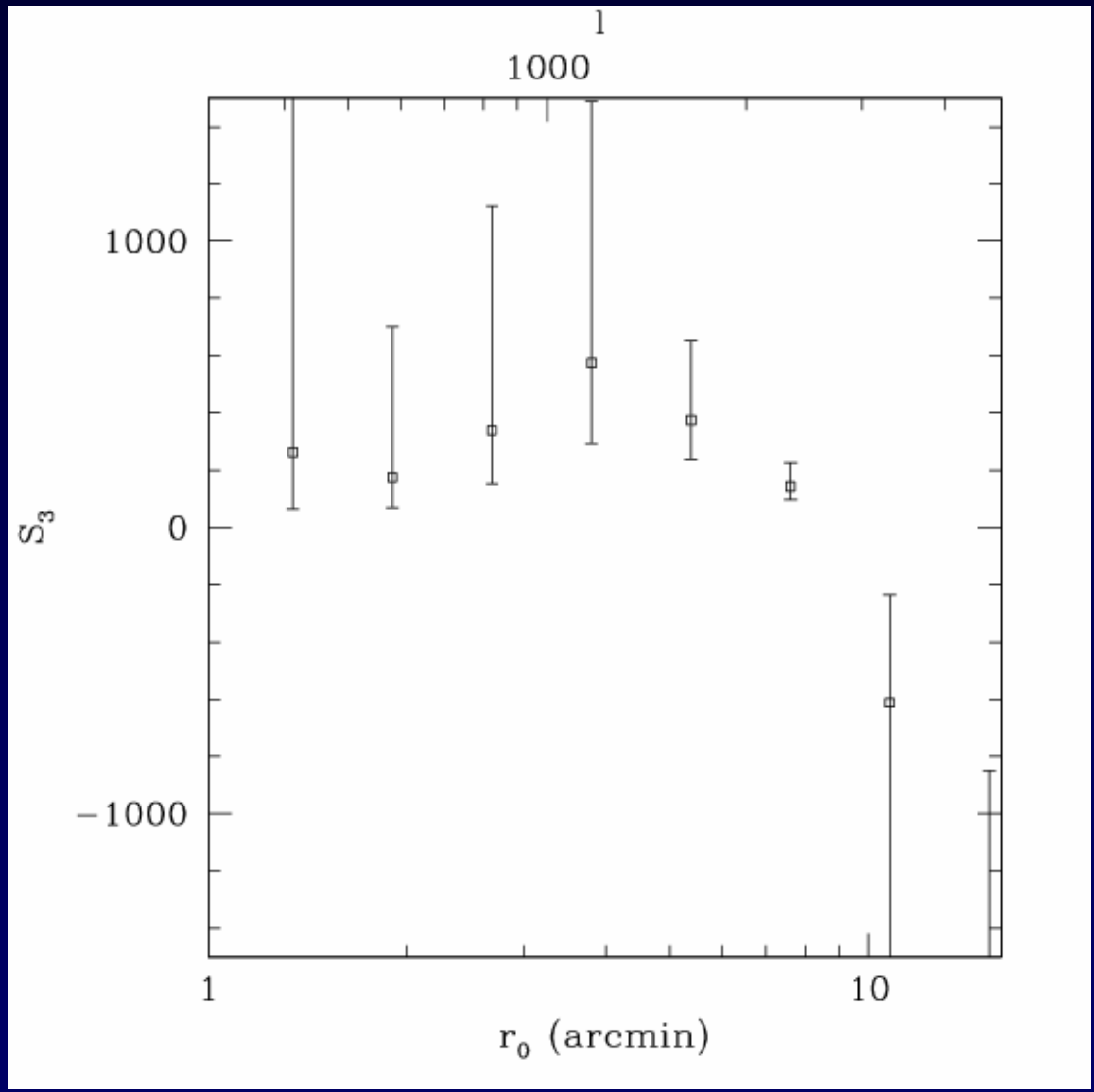
Methods:

Kaiser, Squires & Broadhust (1995)
Kuijken (1999)
Kaiser (2000)
Rhodes, Refregier & Groth (2000)
Bridle, Marshall et al. (2001)
Refregier & Bacon (2001)
Bernstein & Jarvis (2001)

→ STEP comparison project:
simulations and real data

→ Joint analysis of COSMOS field:
with HST/ACS, CFHT, Subaru

Skewness



Pen et al. 2003

Cf. Bernardeau et al. 1997,
Bernardeau et al. 2002

Variance: $\langle \kappa^2 \rangle$

Skewness:

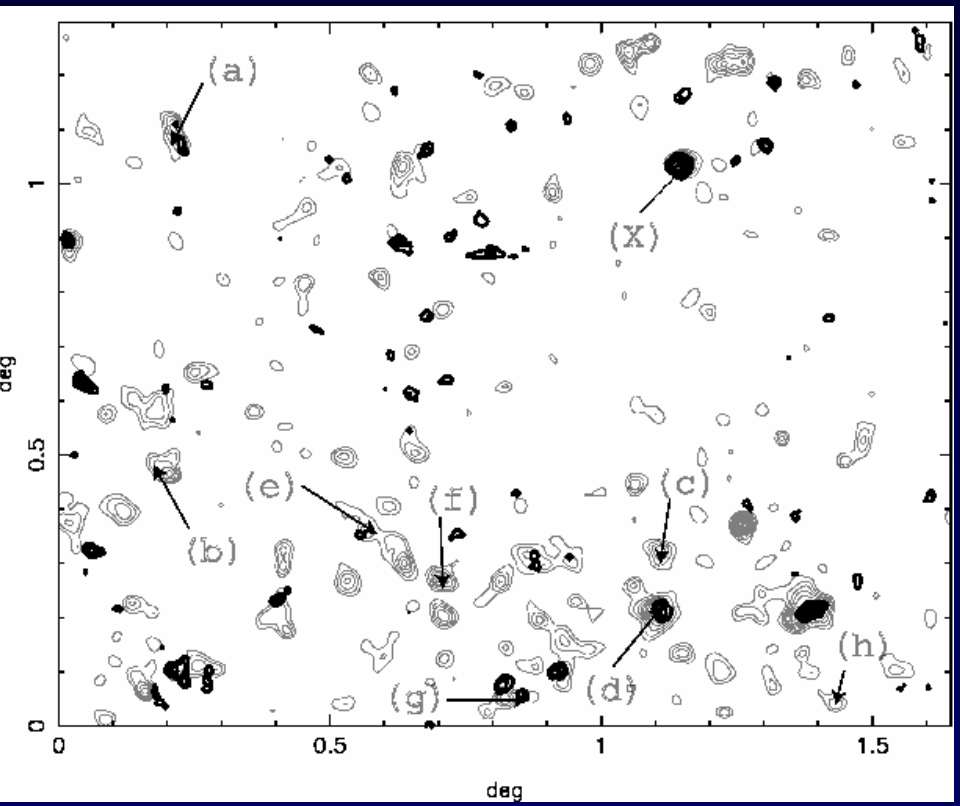
$$S_3 = \langle \kappa^3 \rangle / \langle \kappa^2 \rangle^2$$

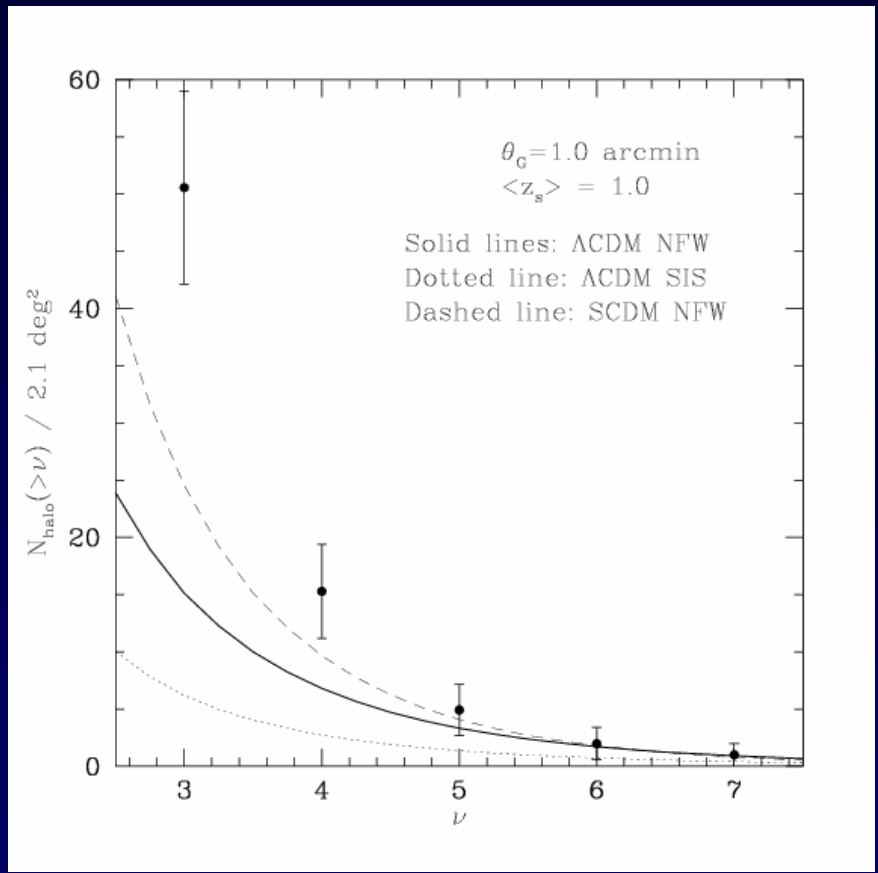
→ Skewness depends only weakly on σ_8 and h
→ break degeneracies

→ Pen et al. find
Ω_m<0.5 (90%CL)

Mass-Selected Clusters

Miyazaki et al. 2002 2.1 deg^2 survey with Subaru



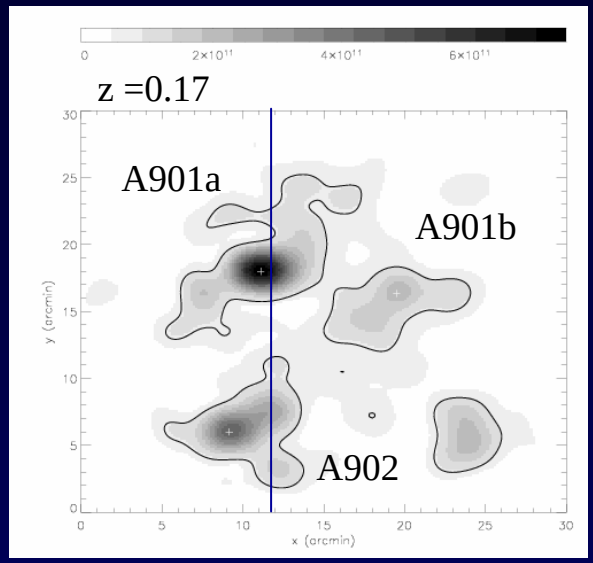


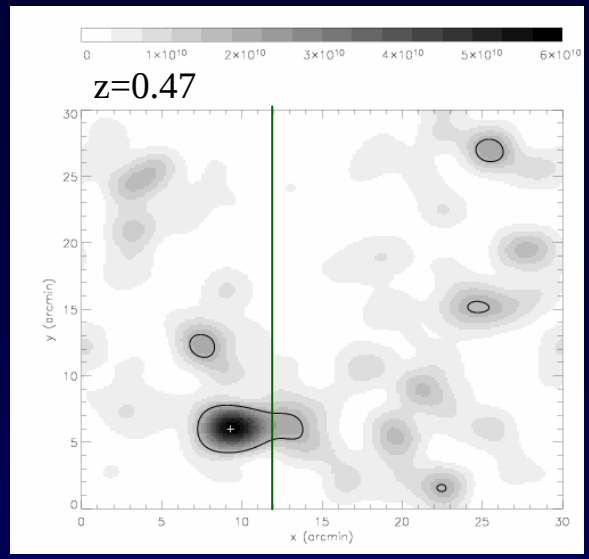
- complex relation between mass and light
- bright cluster counts in agreement with CDM models
- discovery of new clusters

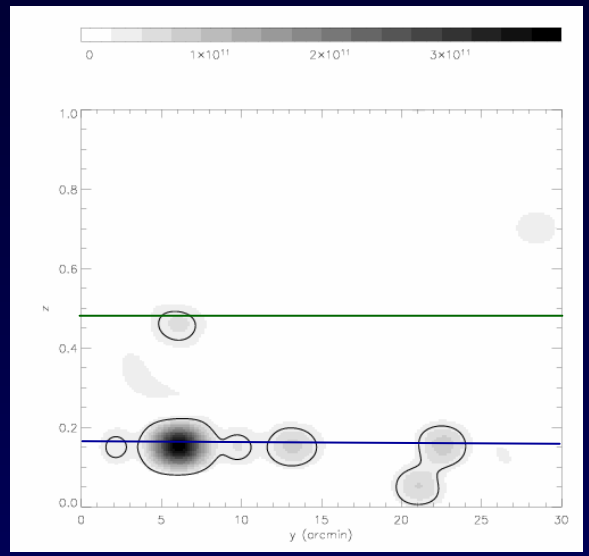
3D Lensing: Mapping

Luminosity

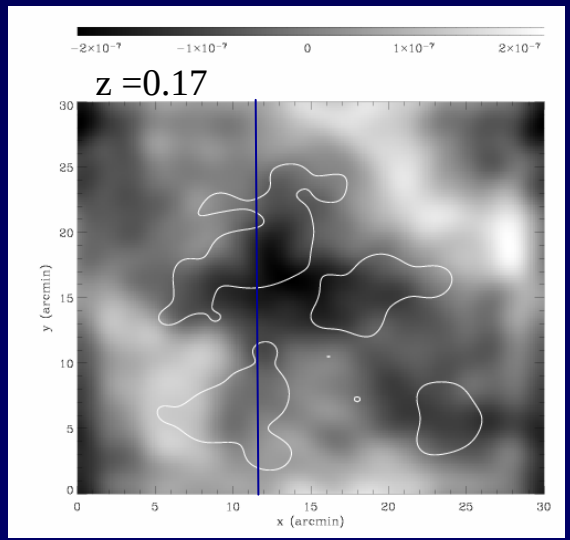
COMBO17: Taylor, Bacon et al. 2004

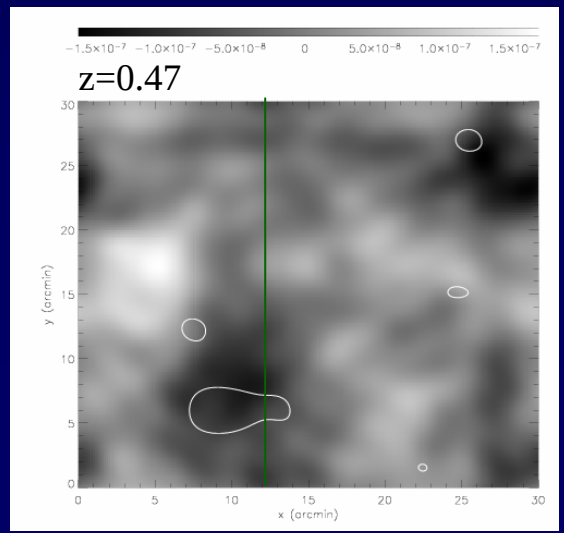


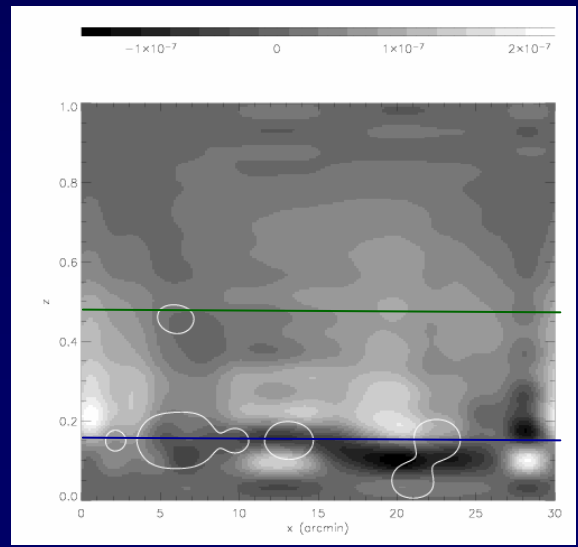




Gravitational potential







Future Surveys

Survey	Diameter (m)	FOV (deg^2)	Area (deg^2)	start	
DLS	2×4	2×0.3	28	1999	COSMOS
					← ACS Parallels
CFHTLS	3.6	1	172	2003	GOODS
VST	2.6	1	x100	2004	
VISTA	4	2	10000	2007	
Pan-STARRS	4×1.8	4×4	31000	2008	
LSST	8.4	7	30000	2012	
SNAP/JDEM DUNE	2 (space)	0.7	1000	2014	

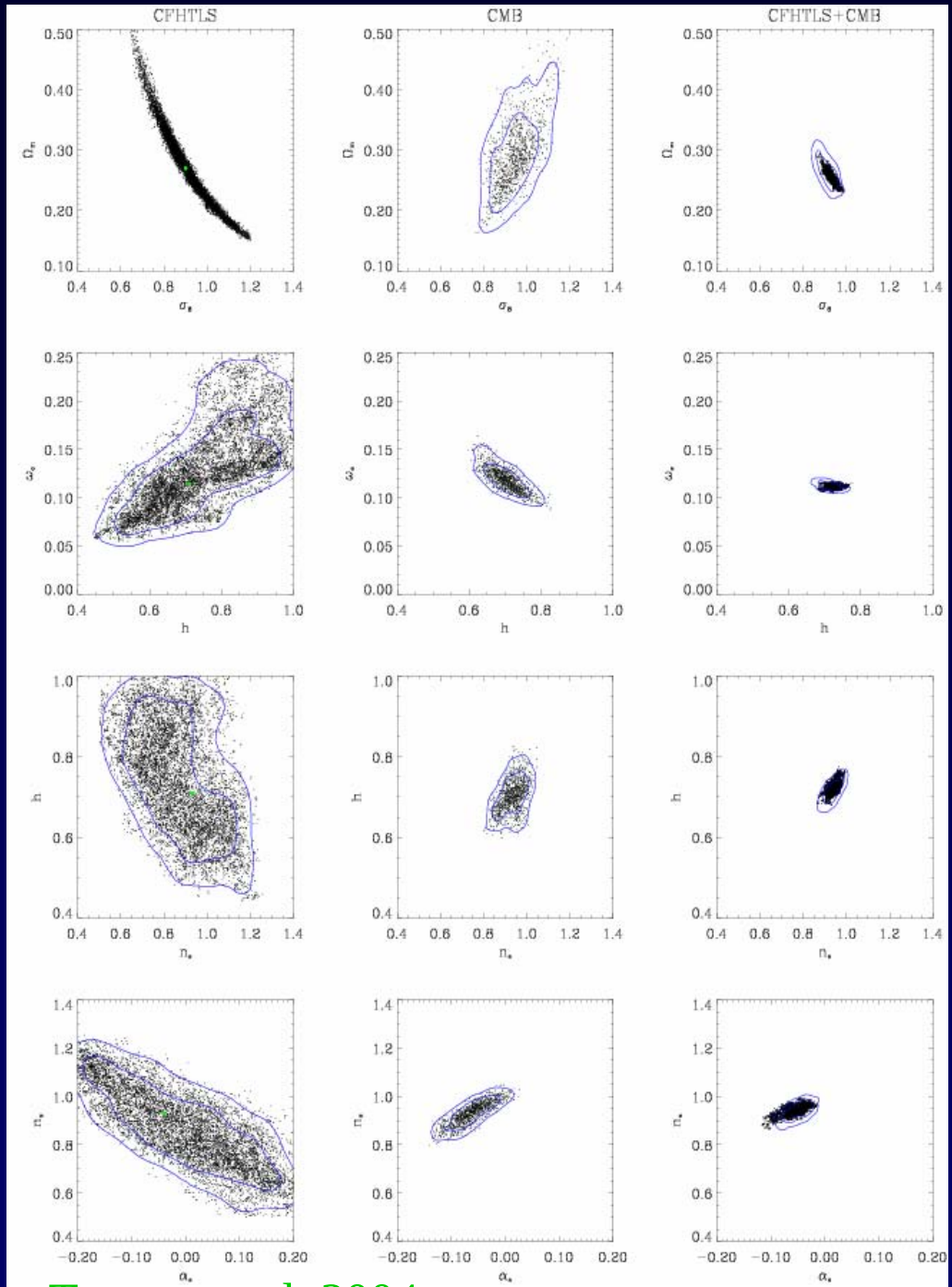
CFHTLS Survey

Telescope: Canada-France-Hawaii 4m

Camera: Megacam 1 deg^2

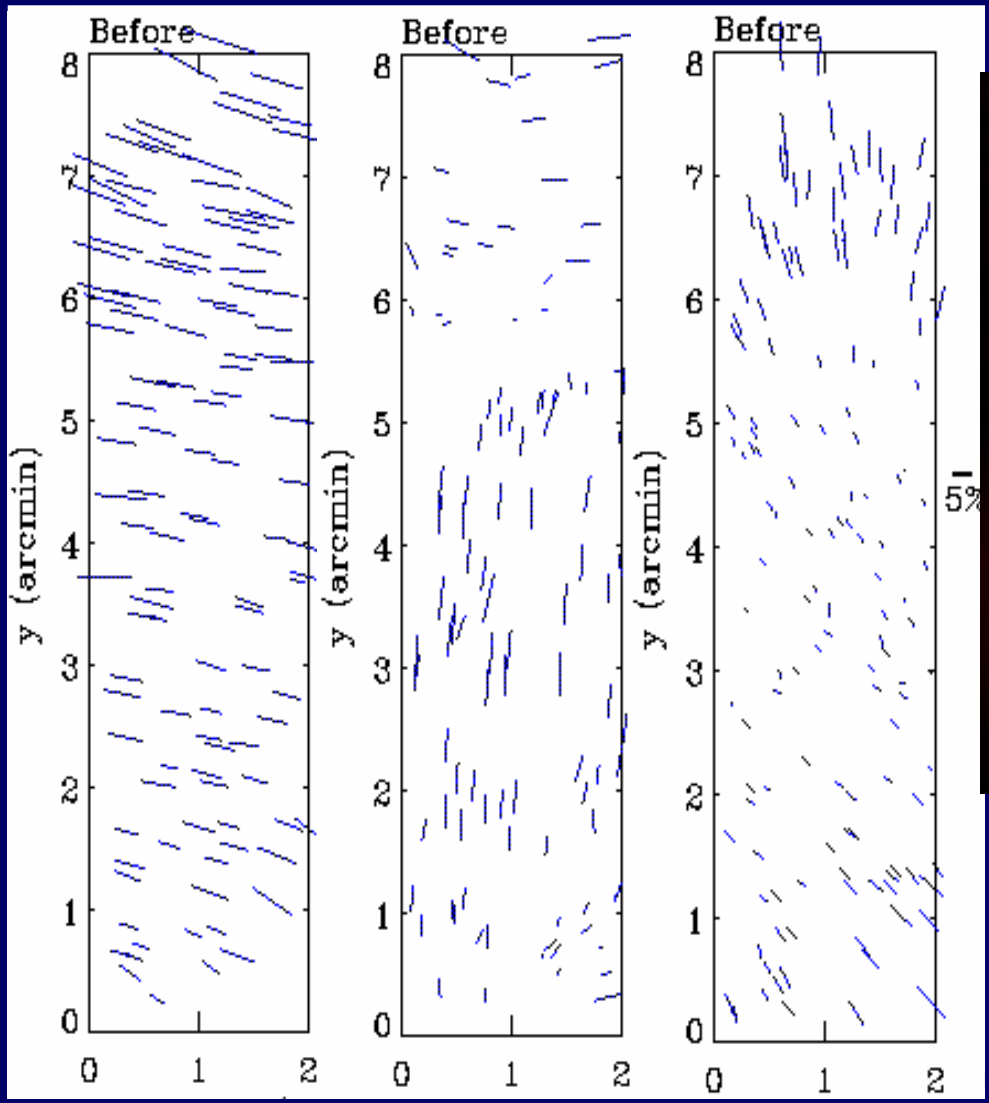
Survey: 170 deg^2 in 5 bands

November 2004 data release



Tereno, et al. 2004

Ground vs Space

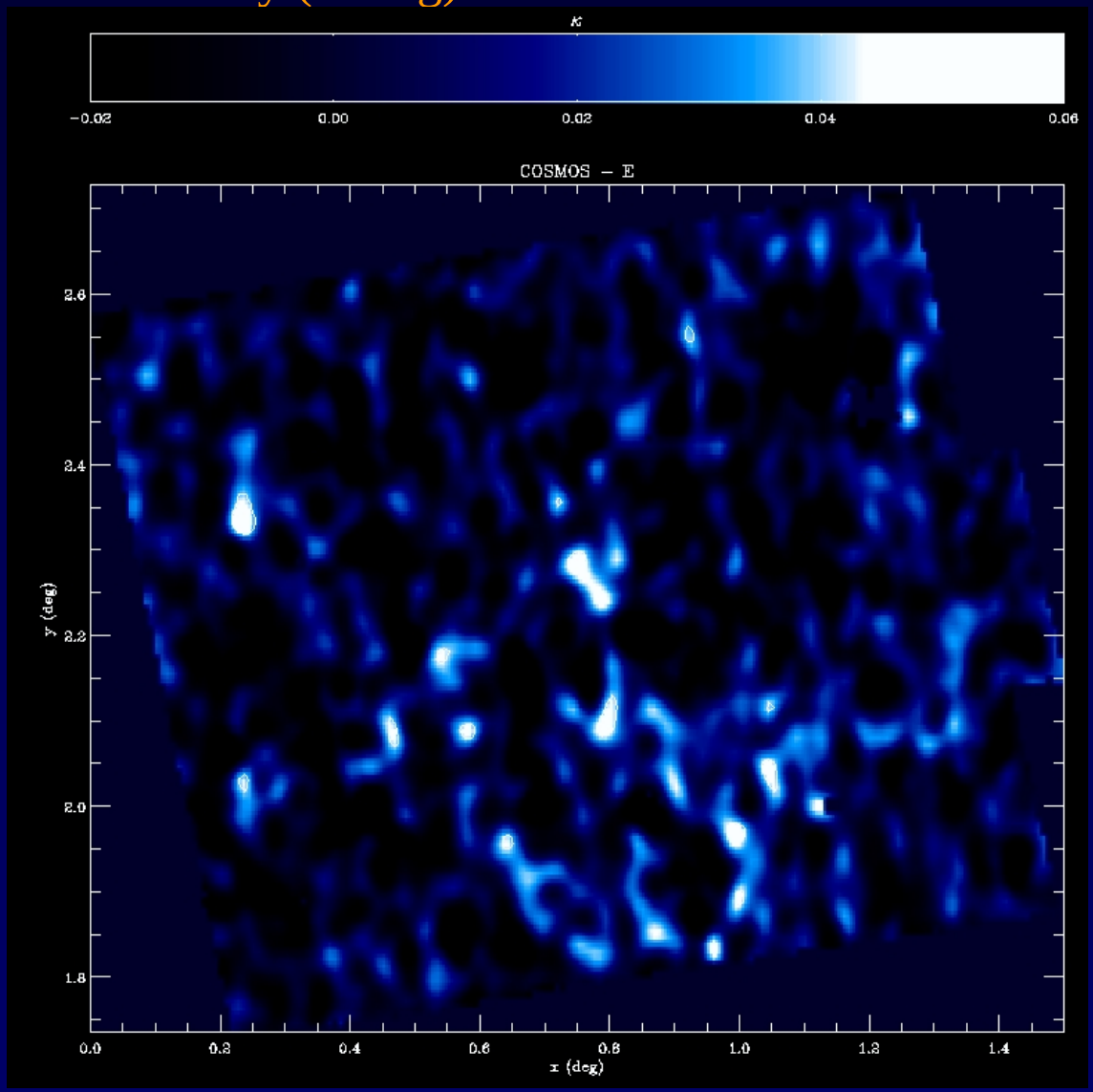


Ground Based PSF systematics

Space: small and stable PSF
→larger number of resolved galaxies
→ reduced systematics

COSMOS Mass Map

Preliminary (wrong)!

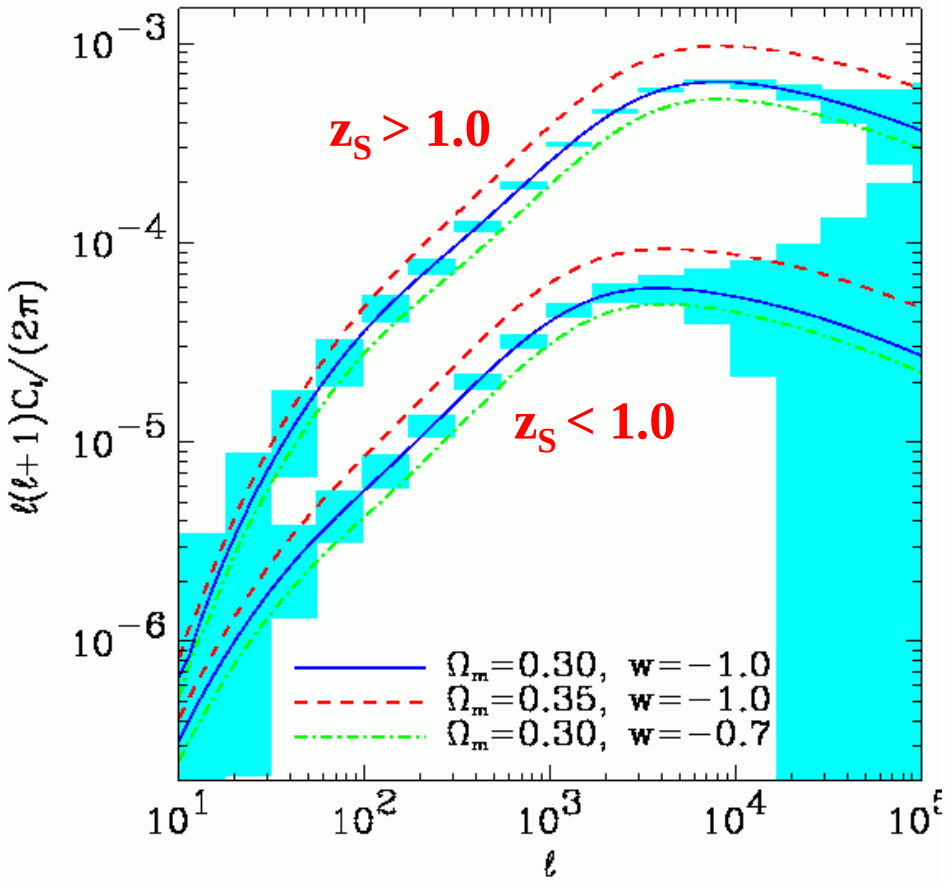


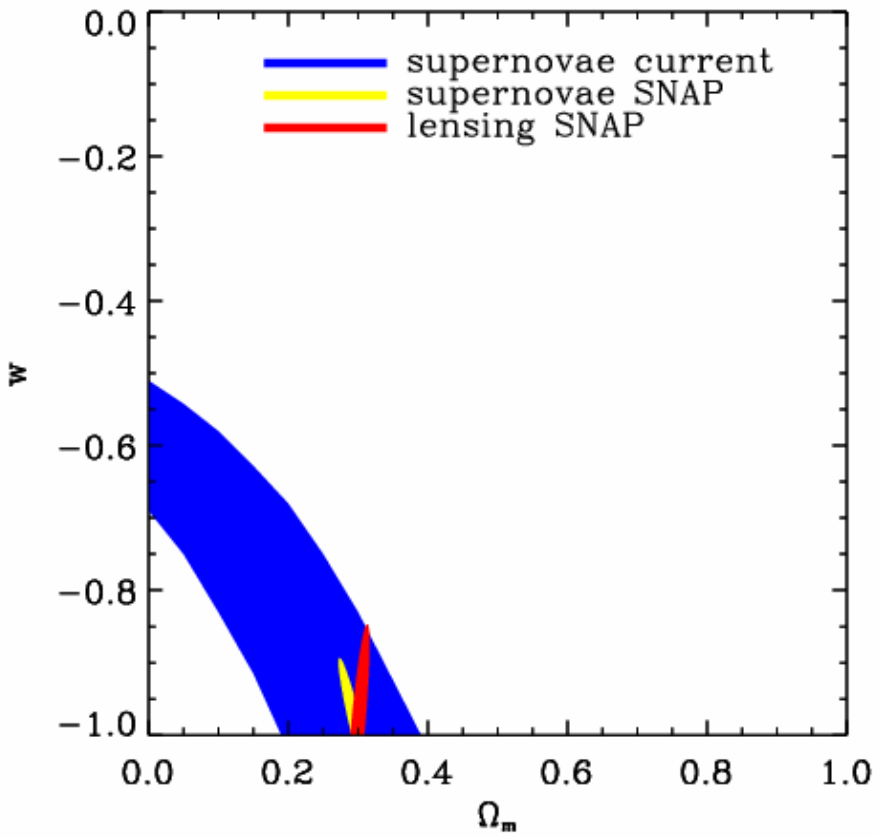
COSMOS Survey:
2 sq. deg. with HST/ACS
1 orbit/pointing

→ Mapping the Dark Matter

Rhodes, Albert, Massey, Kneib, Leathaud, Elllis, Marshall, Refregier, Pires, Starck, et al. 2005

Prospects for SNAP/JDEM





SNAP wide survey Rhodes et al. 2003, Massey et al. 2003, Refregier et al. 2003

→ SNAP will measure the evolution of the lensing power spectrum and set tight constraints on dark energy

Conclusions

• Weak lensing is a measure of metric fluctuations: distortions of the order of 10^{-2}, non gaussian field, 3D information, probes linear (>10') and non-linear (<10') scales

• Cosmic shear has now been measured with ground-based, space-based and radio telescopes and used to constrain the amplitude of the power spectrum

• Future ground-based and space-based dedicated instruments will yield high precision measurements of dark matter and dark energy