Cosmological weak lensing with COSMOS
A&A 516, A63, 2010

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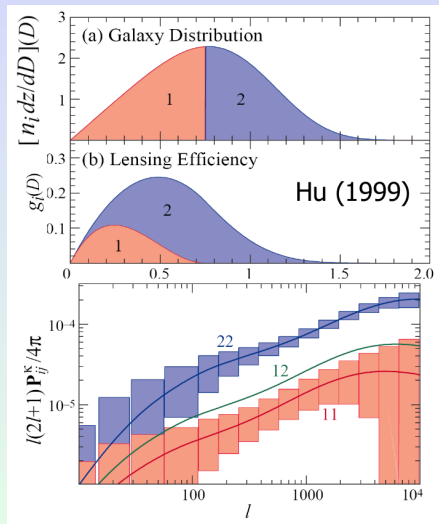Elisabetta Semboloni[2,1]   Ludovic Van Waerbeke[12]   Malin Velander[1]

[1]Leiden [2]Bonn [3]Paris [4]Shanghai [5]Edinburgh [6]UC Davis [7]UC Santa Barbara [8]OSU Columbus [9]Harvard [10]MPA Garching [11]Stanford [12]UBC Vancouver

DUEL: 10 Years of Cosmic Shear, Edinburgh, July 19, 2010

3D WL & Dark Energy

Hu (1999)

- DE **increases distances** (z) and **dampens growth of structure**.
- **WL sensitive to both** $\Rightarrow$ Constrain w *and* test gravity
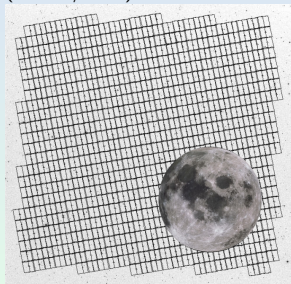- **Requires 3D lensing** $\Rightarrow$ Split according to photo-z. So far only COMBO-17, COSMOS!

COSMOS

- ▶ HST Cycle 12/13 Treasury project (PI: Nick Scoville)
- ▶ Largest survey imaged with HST: **1.64 deg^2** with ACS in i_{814} ⇒ PSF FWHM∼0.″11, ∼ 80 gal/arcmin^2
- ▶ **Excellent photo-zs** from ground: COSMOS-30, CFHTLS-D2 ⇒ 3D WL
- ▶ Area small ⇒ **Sampling variance**.
- ▶ Probably largest space-based WL survey until Euclid/JDEM ⇒ Test case

HST during SM 3B (NASA/ESA).

Tiling (Koekemoer+2007).
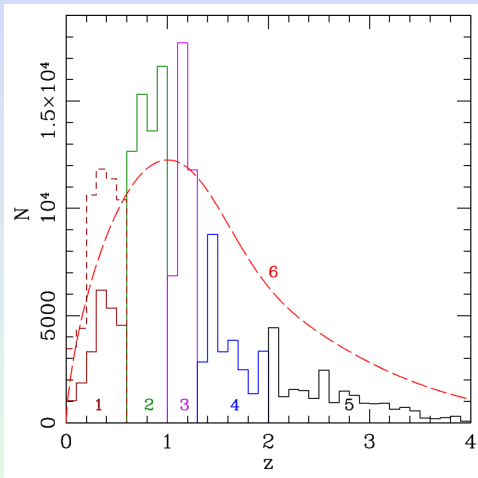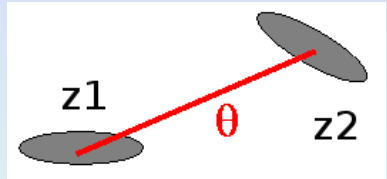
What's new compared to the initial COSMOS WL results?

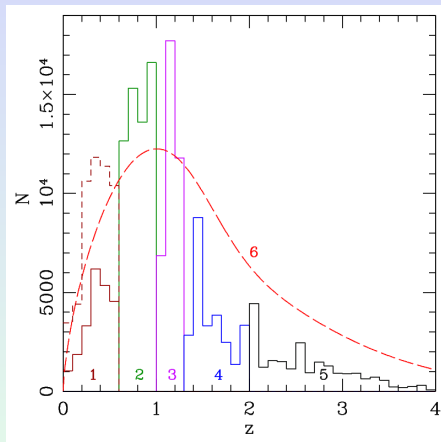|	**Massey+2007**	**Schrabback+2010**
	Rhodes+2007; Leauthaud+2007	
Shape estimate	RRG	KSB+, SN-dep. calib.
PSF interpolation	Stacks: Focus (tinytim)	Exposures: PCA
CTE cor.: Stars	—	Parametric
CTE cor.: Galaxies	Parametric	Parametric
Shape systematics	B-modes at small θ	Not significant
Photo-zs	Mobasher+2007	Ilbert+2009 (30 bands, i<25)
Ngal/arcmin^2	40 with photo-z	76, incl. 33 with photoz
Redshift bins	3	5+1
Covariance	Quadrant variation	Full ray-tracing
Power spectrum	Smith+2003	Smith+2003 + recalib. (RT)
Intrinsic alignments	Ignored	II: cross-correl.; GI: excl. LRGs
Cosmology	flat ΛCDM	flat ΛCDM, ΛCDM+curv., wCDM

3D Weak lensing: The principle
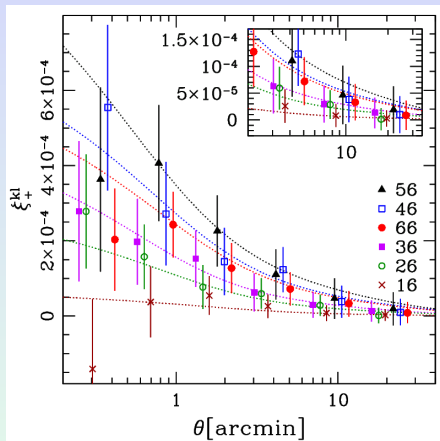

Redshift bins

Cross-correlate galaxy ellipticities between redshift bins.
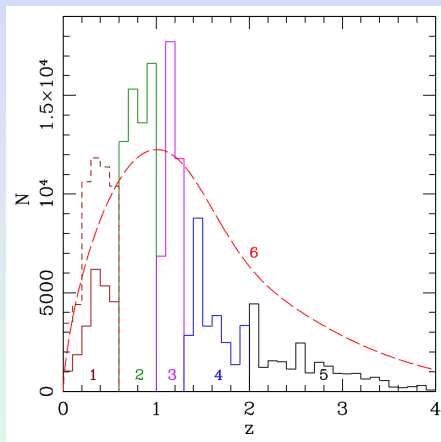
3D Weak lensing: Shear-shear cross-correlation

Redshift bins

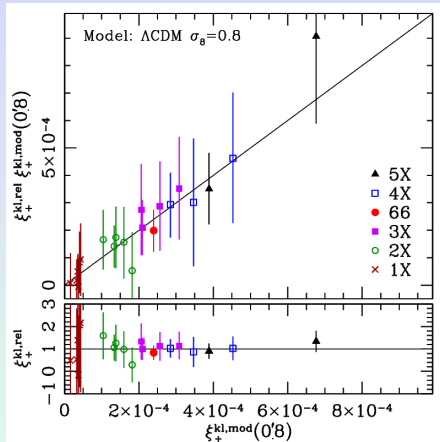Shear-shear cross-correlations with bin 6. Model: ΛCDM, $\sigma_8 = 0.8$

3D Weak lensing: Combined redshift-scaling: ξ_+

Redshift bins

Combined redshift-scaling.

Shear signal scales with redshift as expected for GR & ΛCDM!

3D Weak lensing: Combined redshift-scaling: ξ_-

Redshift bins

Combined redshift-scaling.

Slight deviations OK: other filter fct., few massive low-z structures
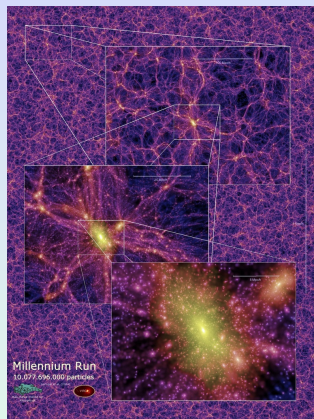
Parameter estimation: Covariance from ray-tracing

▶ Parameter estimation with Population Monte Carlo $\Rightarrow$ M. Kilbinger's talk

▶ Dominant non-Gaussian contribution to sampling variance $\Rightarrow$ **Covariance from ray-tracing!**

▶ Millennium Simulation: (Hilbert+2009): $\Rightarrow$ **n = 288 COSMOS-like fields**

▶ Correction for **inverse covariance** (Anderson 2003, Hartlap+ 2007): $\hat{\mathbf{C}}^{-1} = c\,\hat{\mathbf{C}}_*^{\ -1} = \frac{n-p-2}{n-1}\hat{\mathbf{C}}_*^{\ -1}$ for $p < n - 2$

▶ Here: $n = 288$, $p = 160$, $c \simeq 0.44 \Rightarrow$ OK

▶ Massey+2007: $n = 4 \ll p \Rightarrow$ Expect unstable and too small statistical errors
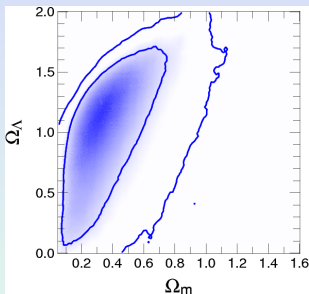
▶ Important for future cosmic shear studies!!

Millennium Simulation: 10^{10} particles, $L = 500h^{-1}$ Mpc (Springel+2005)
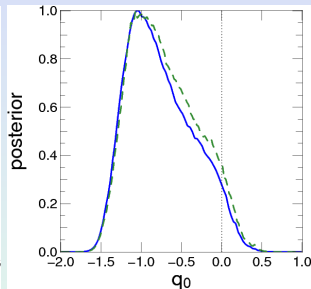
Model recalibration

- ▶ **Problem:** Rely on fitting functions for non-linear power spectrum
- ▶ Smith+ 2003 seem to underestimate at small scales (Heitmann+ 2008; Hilbert+ 2009) $\Rightarrow$ Lensing results **overestimate σ_8**
- ▶ Our approximate solution for flat ΛCDM: Recalibrate by analysing Millennium Simulation ($\Omega_{\mathrm{m}} = 0.25$, $\sigma_8 = 0.9$):
  $\Rightarrow \sigma = 0.947 \pm 0.006$ (0.936 if $g = \gamma/(1 - \kappa)$ considered).
  $\Rightarrow$ Lensing: $\sigma_8 \rightarrow 0.95 \times \sigma_8$
- ▶ **Future CS:** Lawrence+2010 ("Coyote Universe"): New fitting functions for NL power spectrum accurate to $\sim 1\%$ for $k < 1h\mathrm{Mpc}^{-1}$ (DM only, also $w \neq -1$).
- ▶ Future models should also account for effects of baryons!

Constraints for flat ΛCDM and comparison to WMAP

Flat ΛCDM, lensing recalibrated to
MS, WMAP=WMAP5

COSMOS (S10) + WMAP5:
$\mathbf{\Omega_m = 0.266^{+0.025}_{-0.023}}, \mathbf{\sigma_8 = 0.802^{+0.028}_{-0.029}}$

WMAP7 Mean (Komatsu+ 2010):
$\Omega_m = 0.266 \pm 0.029, \sigma_8 = 0.801 \pm 0.030$

Comparison:
COSMOS (S10) alone:
$\sigma_8 \left(\Omega_m/0.266\right)^{0.51} = 0.80 \pm 0.09$

Massey+2007 with S10 recalibration:
$\sigma_8(\Omega_m/0.266)^{0.44} = 0.867 \pm 0.033 \,(\mathrm{stat.})$
$\phantom{\sigma_8(\Omega_m/0.266)^{0.44} = 0.867} {}^{+0.052}_{-0.035} \,(\mathrm{sys.})$

Cosmological constraints: Dark Energy

Non-flat ΛCDM

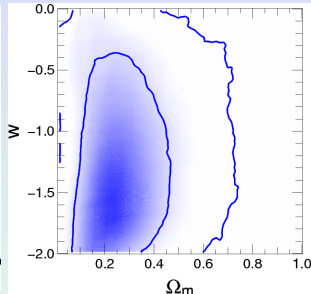**Flat *w*CDM**

$\Omega_{\mathrm{m}} - \Omega_{\Lambda}$

$q_0 = -\frac{\ddot{a}a}{\dot{a}^2} = \frac{\Omega_{\mathrm{m}}}{2} - \Omega_{\Lambda}$

$q_0 < 0$ (96.0 % conf.)

or   94.3 %   with   Key-Project+BBN prior

Prior: $w \in [-2, 0]$

Conclusions

▶ Correction for systematics works for current data: **So far no showstopper.**

▶ The cosmic shear signal **scales with z as expected** for ΛCDM

▶ Constraints agree very well with WMAP5/7 $\Rightarrow \mathbf{\Omega_m \simeq 0.27, \sigma_8 \simeq 0.8}$

▶ The data already provide weak constraints on dark energy.
  It's time for larger surveys to get something really competitive!

▶ Can use the tomographic data to test modified gravity (see also Ismael Tereno's poster!)

▶ **Simulations needed**: Covariance; Further work on fitting formulae (baryons)