# Weak Gravitational Lensing: shapes or magnitudes?
# With good photo-z

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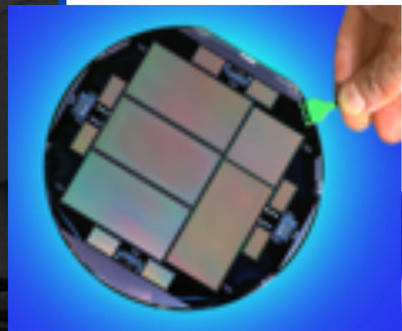
# Cartografiado de la Energía Oscura

## The Dark Energy Survey

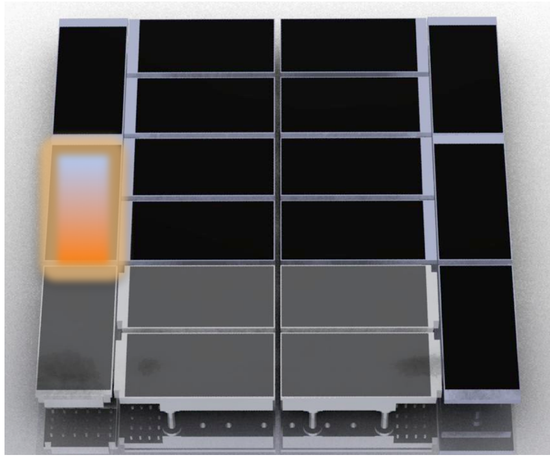
**Blanco 4m Telescope  Cerro-Tololo Observatorio Inter-Americano CTIO**

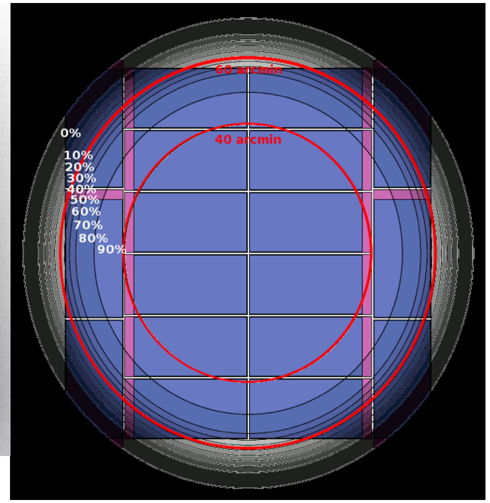



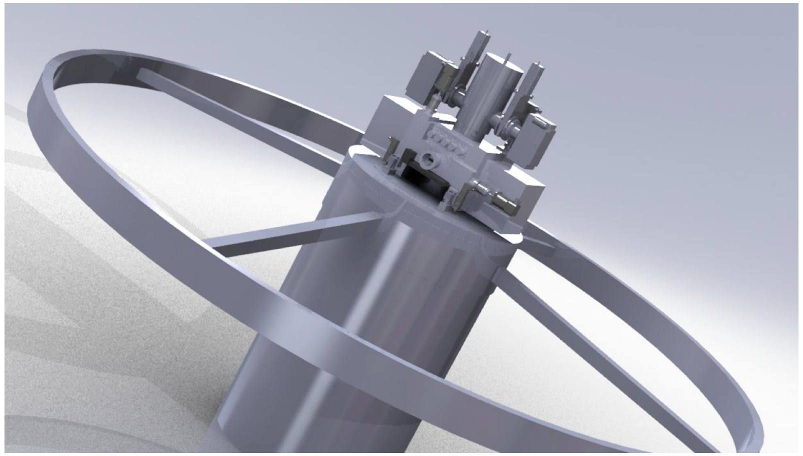
DES-Brazil
Dark Energy Survey

- **Perform a 5000 deg² *griz* survey of the SGC**
- **Study dark energy using 4  complementary techniques:** ***galaxy clusters, weak lensing, galaxy angular power spectrum, and Type Ia supernovae***
- **New Instrument:**
  - **Large 3 deg² mosaic CCD camera and optical corrector for the CTIO 4m Blanco telescope**
  - **Construction 2005-2011**
- **Survey:**
  - **30% of the telescope time from 2011-2016**
  - **Data released to public within a year of observations**

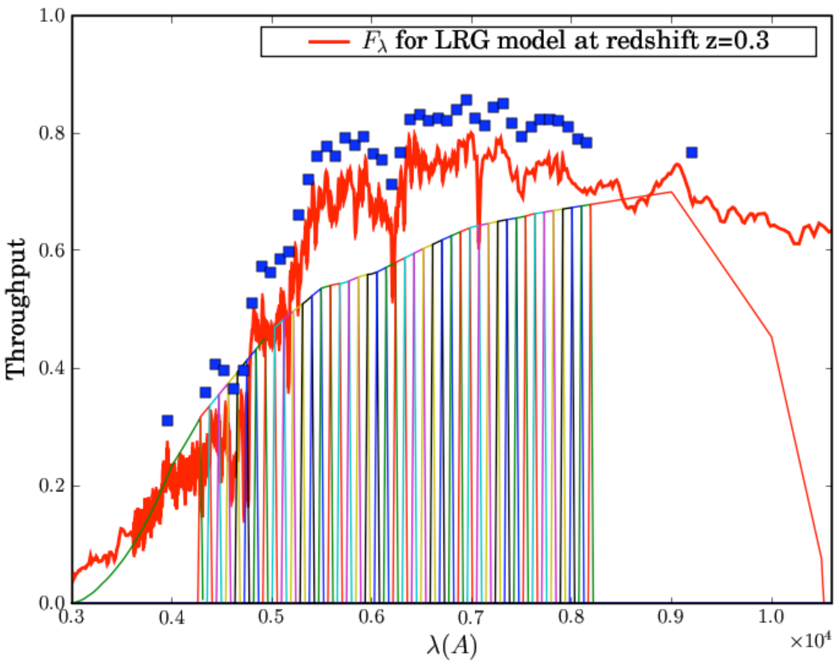
# PAU Camera @ WHT

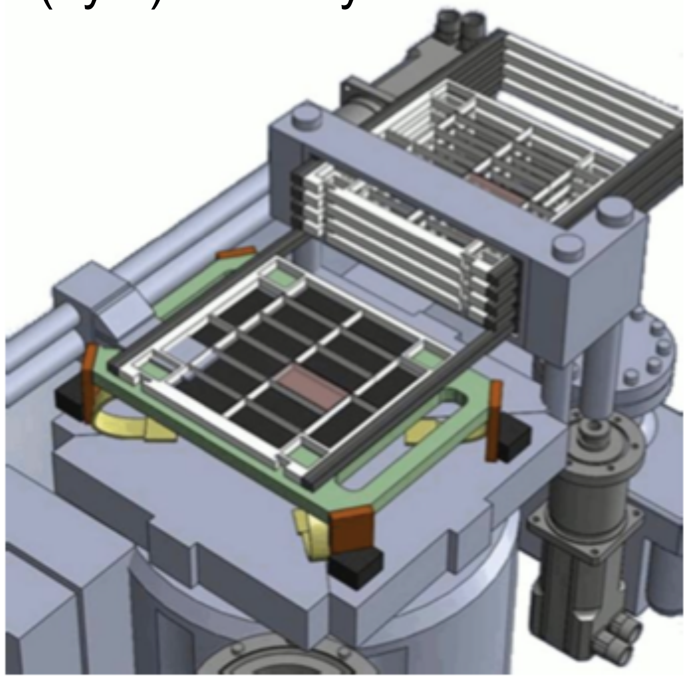




1 night= 2 sqr.deg. To i~23
in 40 narrow + 4 broad
Low R spectra for 30,000 galaxies
No selection effects
Being build (2yrs) and fully funded



# Weak Lensing Magnification

$$\boxed{\delta_n = \delta_g + \delta_{wl}}$$

$$\delta_{wl}(\theta;\bar z) = \int dz_1\; \delta_m(z_1,\theta)\; p_{wl}(z_1;\bar z)$$

$$\delta_g(\theta;\bar z) = b(\bar z)\int dz\; \delta_m(z,\theta)\; p_g(z;\bar z)$$

$$p_{wl}(ij) = p_{wl}(\bar z_i;\bar z_j) = K_j \frac{H_0}{H_i}\frac{\chi_i}{a_i \chi_{H0}}\,\eta_{ij} \qquad \eta_{12} \equiv \frac{\chi_2-\chi_1}{\chi_2} \equiv \frac{\chi(z_2)-\chi(z_1)}{\chi(z_2)}$$

$$\boxed{K \equiv 3(2.5s-1)\Omega_m}$$

$$\boxed{\begin{aligned} C_{ij}(\ell) &= \left[\frac{\Delta_i}{b_i}\,p_{wl}(ij) + \frac{\Delta_{ij}}{\Delta_j}\right] C_{ii}(\ell) \\ w_{ij}(\theta) &= \left[\frac{\Delta_i}{b_i}\,p_{wl}(ij) + \frac{\Delta_{ij}}{\Delta_j}\right] w_{ii}(\theta) \end{aligned}}$$

$$\boxed{C_{gn_igm_j} \simeq \left[b_{n_i} b_{m_j}\frac{\delta_{ij}}{\Delta_i} + \alpha_{m_j} b_{n_i} p_{ij}\right]\mathcal{P}_i}$$

$$\mathcal{P}_i \equiv \frac{P(k_i,\bar z_i)}{\chi_i^2 \chi_{H_i}}$$

$$r_{ijk} \equiv \frac{C(\ell)(ij)}{C(\ell)(ik)} = \frac{w_{ij}(\theta)}{w_{ik}(\theta)} = \frac{\eta_{ij}}{\eta_{ik}}\frac{(2.5s_j-1)}{(2.5s_k-1)}$$

$$\frac{C_{ii}(\ell)}{C_{ij}(\ell)} = \frac{w_{ii}(\theta)}{w_{ij}(\theta)} = \frac{b_i}{K_j\Delta_i}\frac{\chi_{H0}}{\chi_i}\frac{H_i}{H_0}\frac{a_i}{\eta_{ij}}$$

Measure radial distances
To redshift shells
Ratio is independent of bias
Or power spectrum!
(Hu & Jain 2004 for GK)

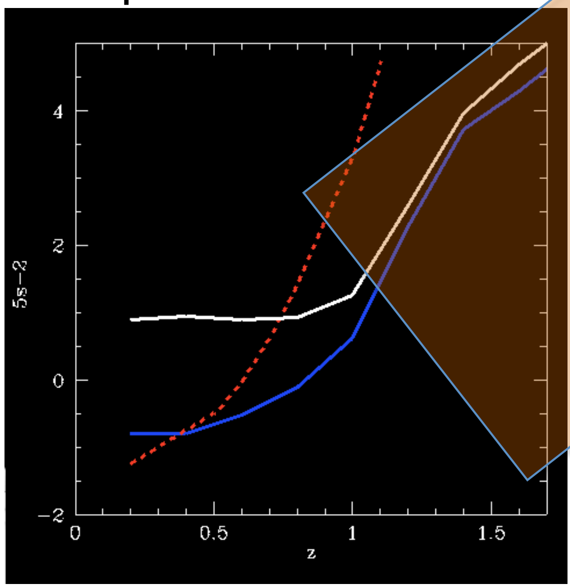
$$\langle \delta_g(i)\delta_{wl}(j)\rangle$$

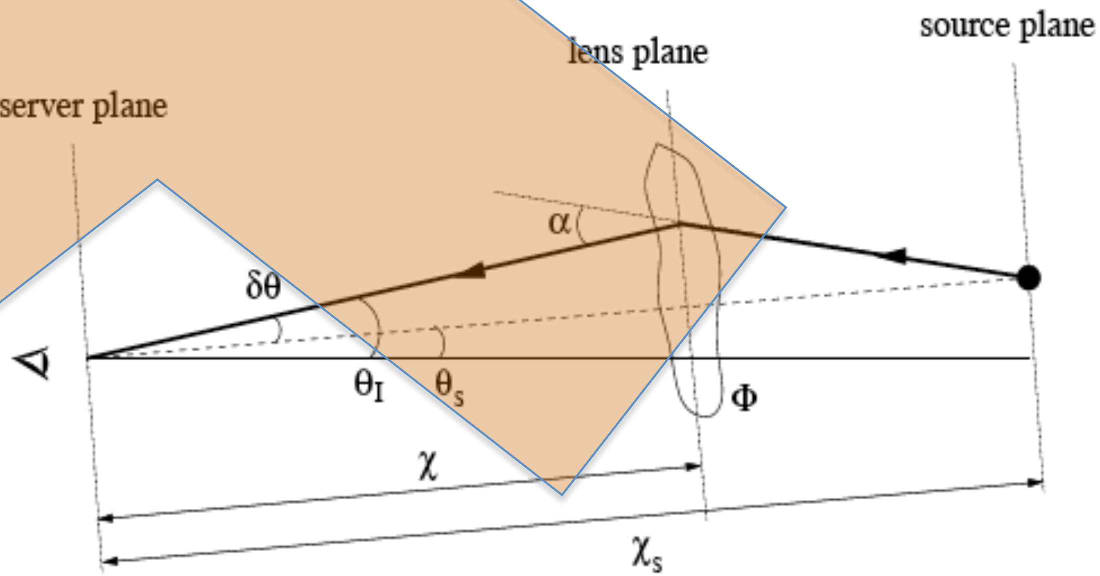
slope

r<23

22<i<23

i<24

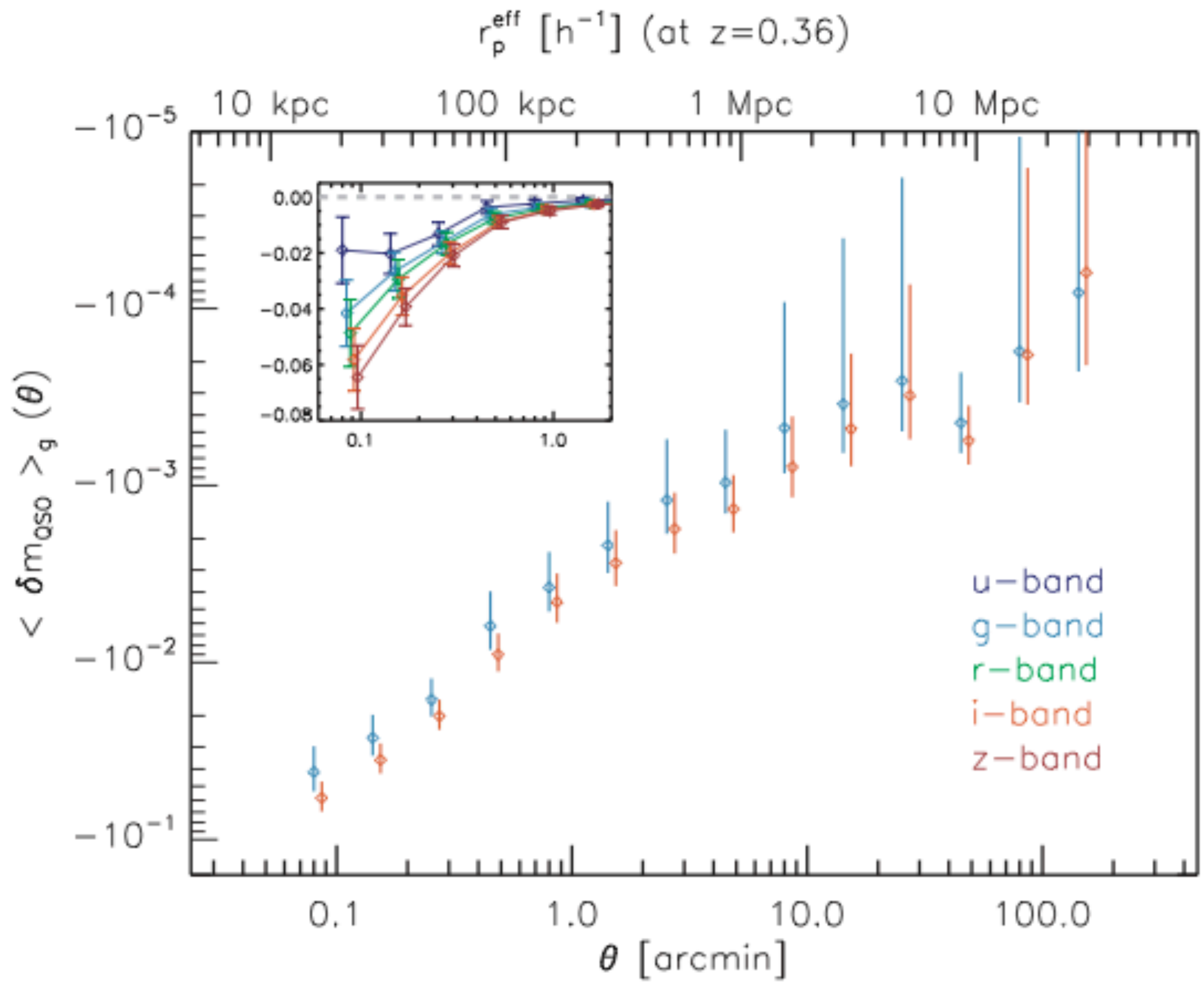


# Current measurements

SDSS: galaxy position with QSO magnitude
Menard etal 2010

*B. Ménard et al.*



# Current measurements



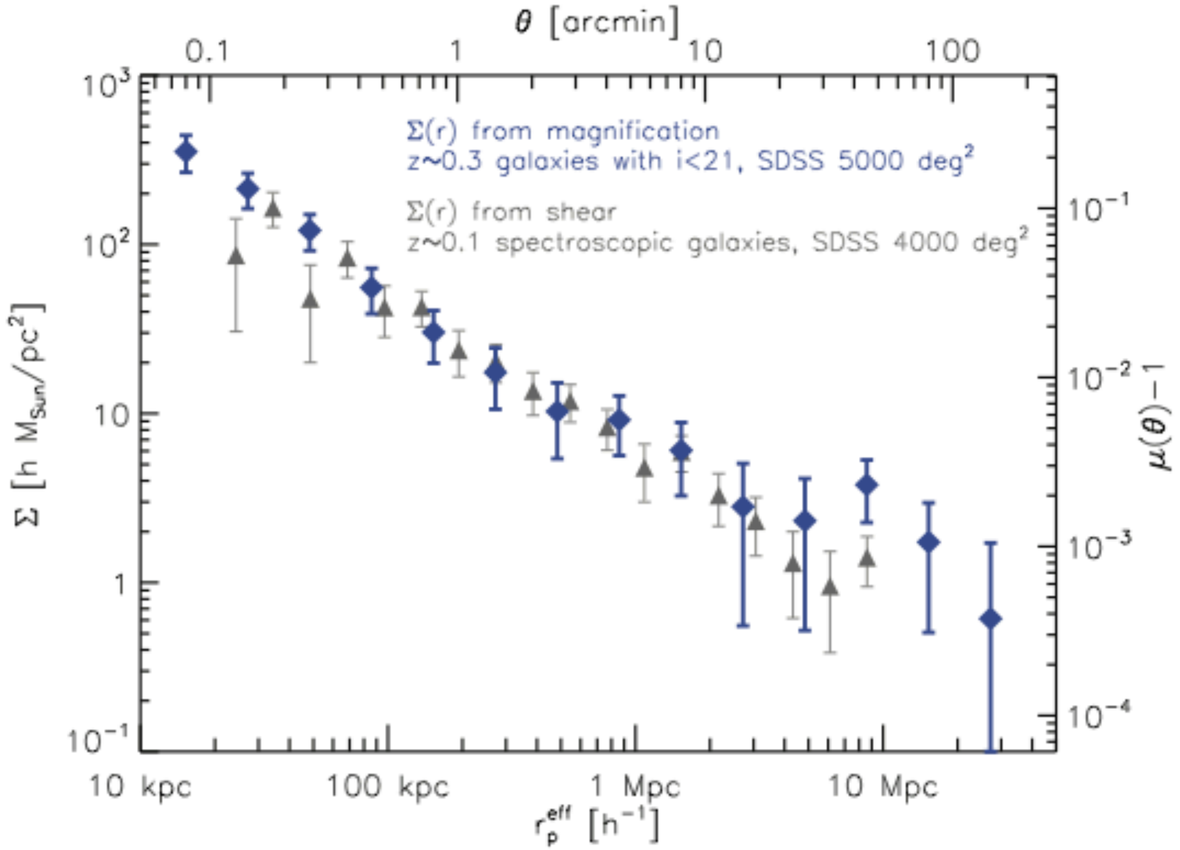
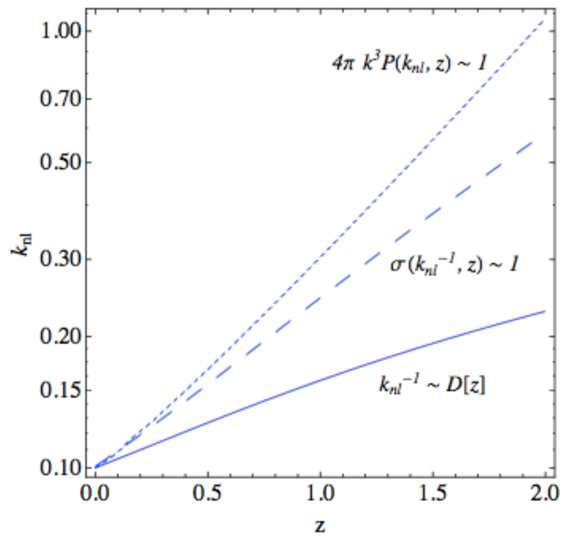



**Figure 7.** The mean surface density of galaxies (with $i < 21$) measured through the magnification of background quasars and corrected for dust extinction (blue points). In comparison, we show the mean surface density of a sample of $\sim L^{\star}$ galaxies at $z \sim 0.1$ obtained from the gravitational shear of background galaxies from Sheldon et al. (2004). Non-linear magnification effects have not been included and result in an overestimation of the mass on the smallest scales.

# Forecast for DES & PAU
(with M.Eriksen & Spain DES/PAU team)

$$F_{\mu\nu} = \sum_{ij,mn,\Delta\ell} \frac{\partial C_{ij}}{p_\mu} \Theta^{-1}_{ij;mn} \frac{\partial C_{mn}}{p_\nu}$$




L_max= k_max X(z)

DES :

$f_{sky} = 0.125$ (5000 sqr deg)
$0.1 < z < 1.5$
$dn/dz = A(z/z_0)^\alpha \exp\left[-(z/z_0)^\beta\right]$ (all galaxies $m_{AB} \sim 24$)
$A = 5.63 \times 10^8, z_0 = 0.65, \alpha = 1.07, \beta = 1.77$
$z_m = 0.5$
$N_{gal} = 1.84 \times 10^8$ (all)
photo $-$ z $= 0.035(1+z)$ (LRGs) - $0.07(1+z)$ (all)
$b_1 = 1.52$, $dbdz_1 = 0.6423$, $b(0) = 1.2$
$b_2 = 2.53$, $dbdz_2 = 1.07$, $b(0) = 2$

$$b(z) = b(z_m) + \frac{db}{dz}|_{z=z_m}(z - z_m).$$

Dz= 4*photo-z error

Our fiducial cosmology is given by,

Baryon density today, $\Omega_b = 0.044$
**Matter density today**, $\Omega_m = 0.25$
Dark-energy density today, $\Omega_\Lambda = 0.75$
Scalar spectral index, $n_s = 0.95$
**Rms matter fluctuation amplitude**, $\sigma_8 = 0.8$
Hubble parameter (in units of 100 km/sec/Mpc), $h = 0.7$
**Dark-energy eq. of state**, $w = -1$

Planck Fisher Matrix (8)
Jochen Weller
Ω_m, Ω_DE h σ8 Ω_b w0 wa ns

+ bias dbdz

Hu & Jain 2004

## *Survey Specifications*

### PAU : *all-galaxies*

$f_{sky} = 0.0048$ (200 sqr deg)
$0.1 < z < 1.4$
$N_{gal} = 4 \times 10^6$
$\mathrm{photo-z} = 0.005(1+z)$
$b = 1.2264,\ db/dz = 0.5266,\ z_m = 0$
$b(0) = 1$

### PAU : *LRGs*

$f_{sky} = 0.0048$ (200 sqr deg)
$0.1 < z < 1.1$
$N_{gal} = 3.66 \times 10^5$
$\mathrm{photo-z} = 0.0035(1+z)$
$b = 2.88,\ db/dz = 1.13,\ z_m = 0.78$
$b(0) = 2$

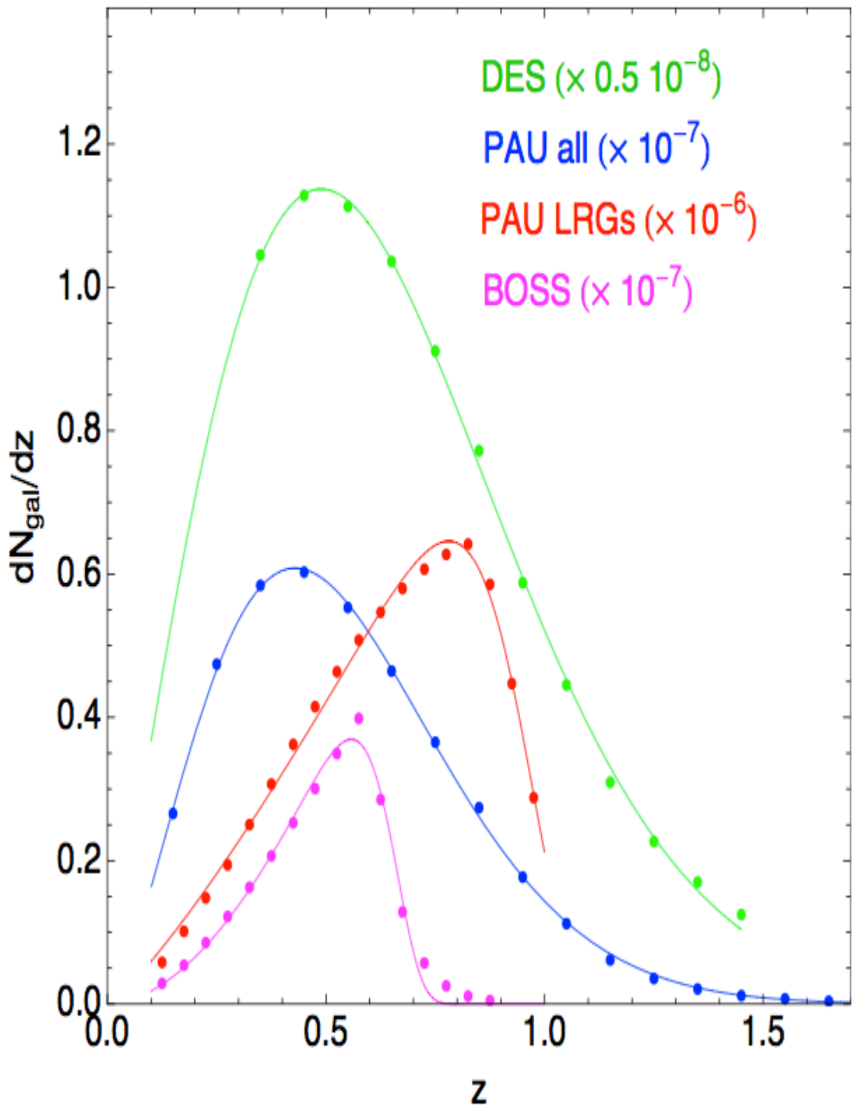
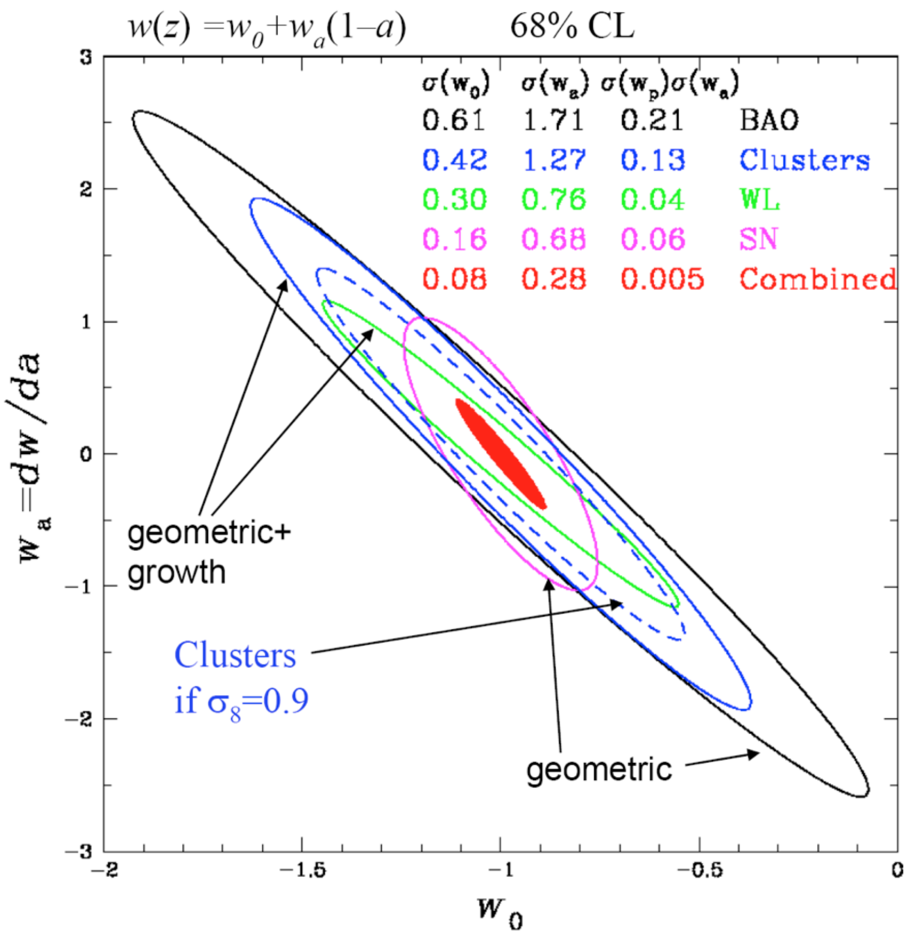


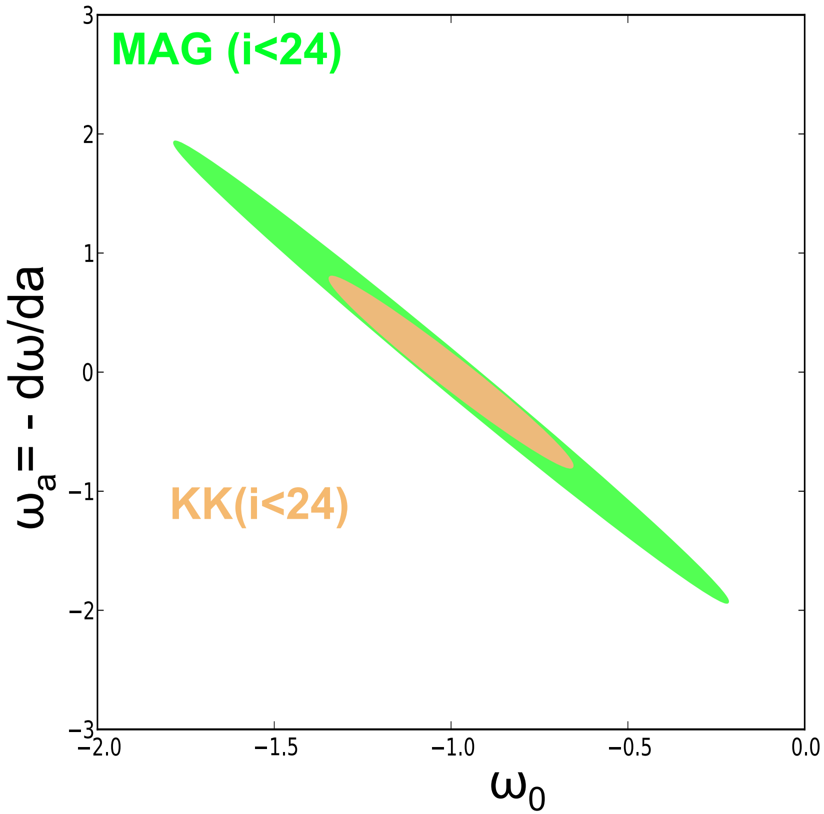

FIG. 4: *Galaxy Redshift Distribution assumed for the surveys considered.*

| | KK | KK 20% | KK +GG | MAG (5s-2=1) | GK+GG |
|---|---|---|---|---|---|
| DES (+bias) | 41 | 14 | (79) | 13 (74) | 32 (155) |
| DES+z (+bias) | 46 | | (390) | 77 (379) | 147 (680) |
| PAU200 (+bias) | 5 | | (48) | 9 (50) | 19 (91) |
| PAU5000 (+bias) | 24 | | (573) | 117(587) | 227(1045) |

FoM= 1/ (σ_wp * σ_wa) (With Planck Priors)




| FoM |
|---|
| 5 |
| 8 |
| 25 |
| 17 |
| 200 |



# Conclusion: shapes or magnitudes?

- Magnitudes are easier and can be measured to a depper depth
- Shapes are unbiased tracers. Signal is very small-> small noise. Non-trivial reconstruction (shear -> kappa)
- (With good photo-z) magnitudes trace 3D, while shapes only 2D.
- Galaxy-galaxy (GG or magnification) has ½ the FoM of Galaxy-Shear (GK), assuming same depth and shot-noise.
- Magnification (or GK) can be used to simultaneously measured bias and a FoM similar to KK for broad (4sigmaz=0.1) z-bins.
- For more accurate photo-z (10 times better or spectroscopic z), magnification (or GK) can give 10 times larger FoM than KK.
- When bias is known, above FoM can increase by another factor of 5. This is not the case for KK (because is 2D and unbias).
- Do both.