Magnification Bias on the Sub-mm Galaxies (SMGs)

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Cosmology 2018 in Dubrovnik

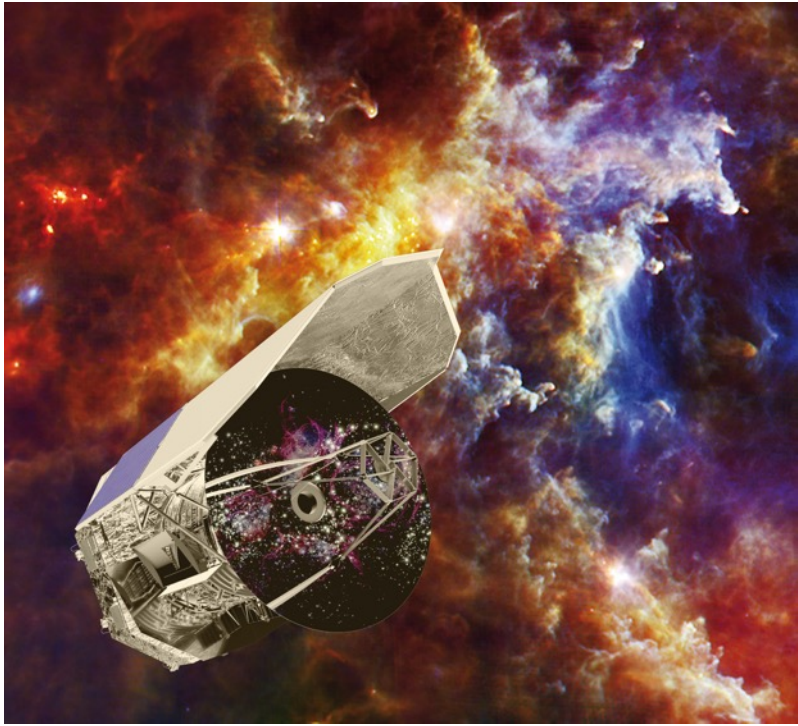
Dubrovnik 2018

Outline

- Introduction
- SMGs (sub-mm galaxies) main properties
- Cross-correlation (optical-SMGs) results
- SMGs Magnification Bias interpretation and results
- SMGs MagBias possible applications

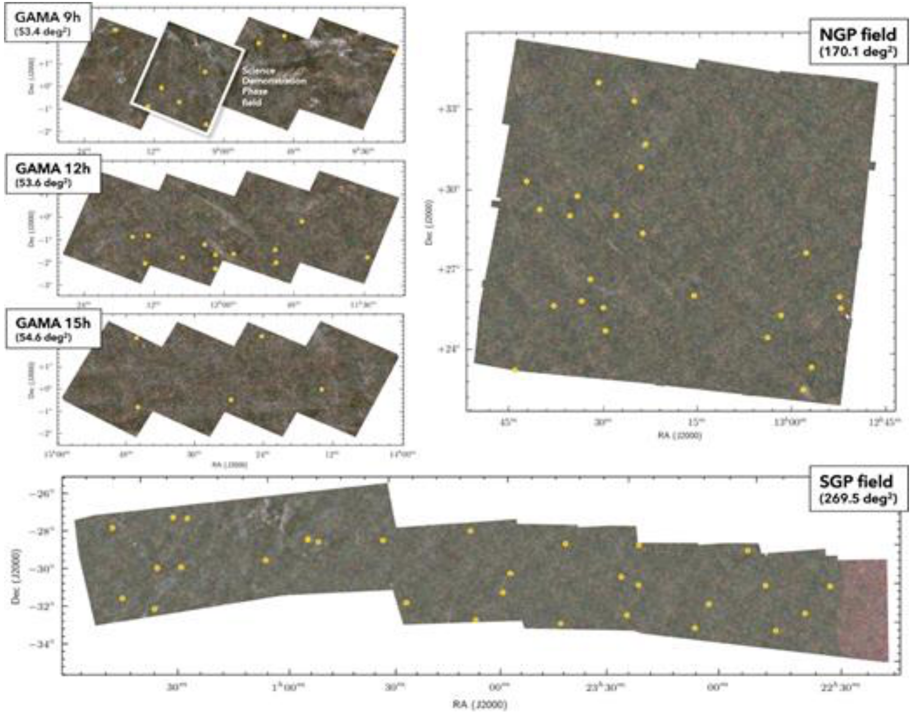
Introduction

- The first extragalactic submm/mm surveys using SCUBA and MAMBO revealed a population of very luminous high-redshift galaxies. (Blain+02). Confirmed later on by BLAST (Viero+09).
- *Herschel Space Observatory* (Pilbratt+10), mainly with the SPIRE instrument (Griffin+10), provided the sensitivity required to increase the number of extragalactic sub-mm sources.



Introduction

- Deep large area Herschel surveys as H-ATLAS (Eales+10) or HerMES (Oliver+12) detected thousands of such galaxies, by covering together ~1000 deg^2.
- A substantial fraction of those galaxies reside at z ~> 1.5 (Amblard+10; Lapi+11; Pearson+13)
- Surprisingly easy and effective way to identify Strongly Lensed Galaxies (Negrello+10, GN+12, Wardlow+13, Negrello+16, …)



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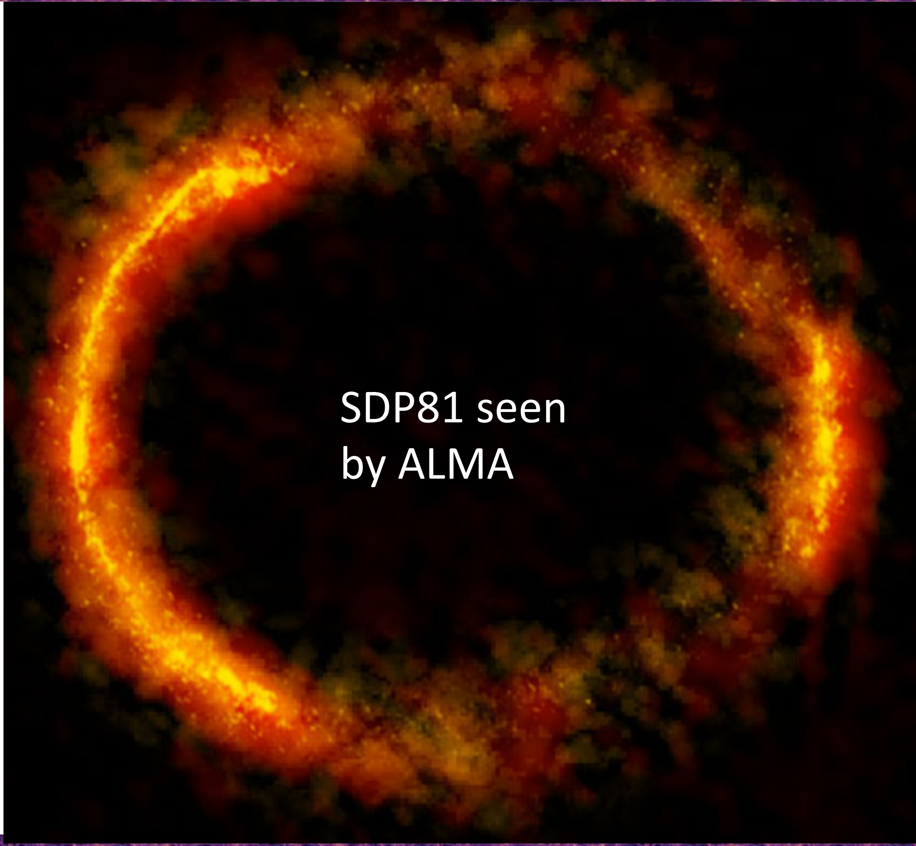
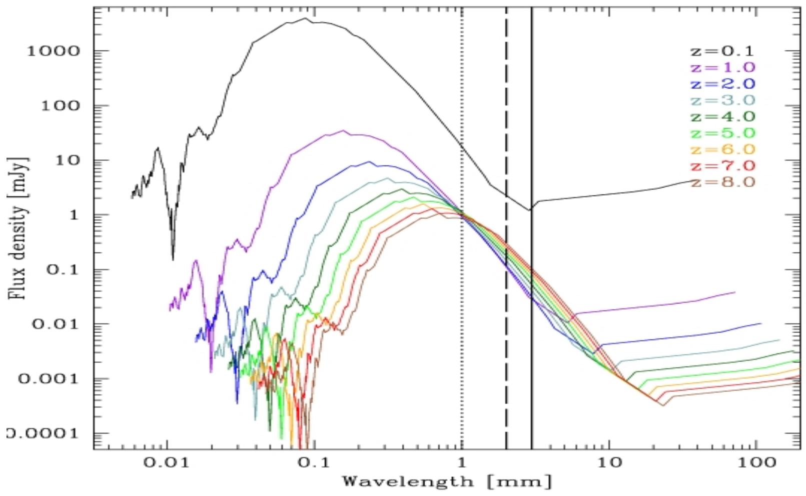


SMGs main properties

0. K-Correction: sub-mm magic
1. “Narrow” high redshift distribution
2. Steep Luminosity Function →Steep source number counts
3. Redshift distribution peaks around z=1.5
4. Invisible in the Optical band and vice versa
5. Strong correlation



With the same instrument we can observe the high-z Universe for free!

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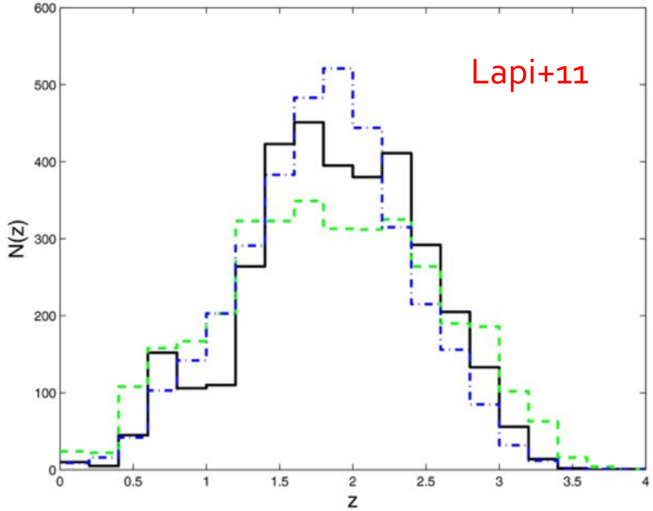

- Small dilution effect after projection.
- Photo-z estimation: Amblard+10, Lapi+11, GN+12, Pearson+13, Ivison+16

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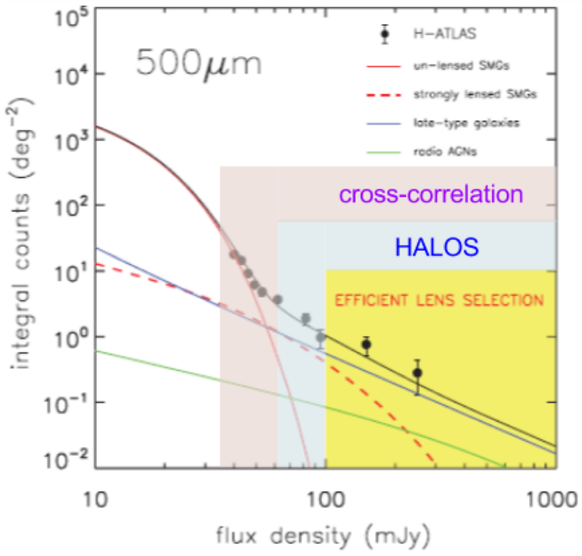

Optimal sample for lensing studies and lens selection: Negrello+10, GN+12 (HALOS), Wardlow+13, Negrello+17, …

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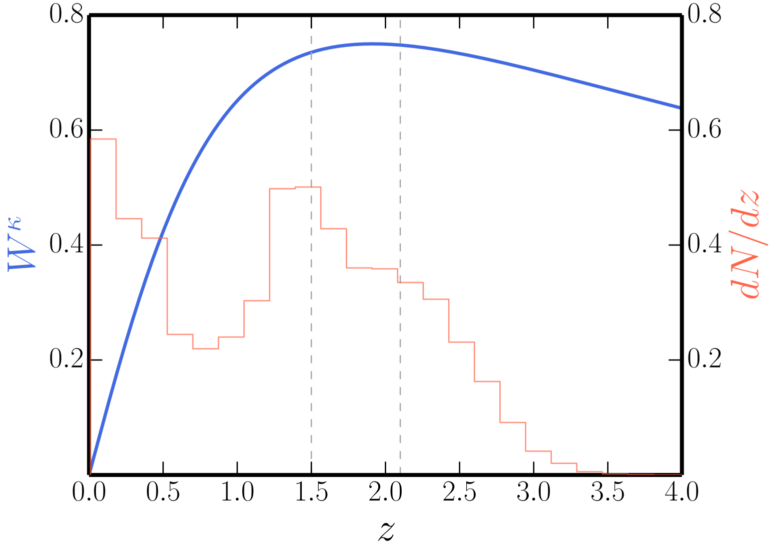

- Coincidence with maximum in the CMB lensing kernel.
- Ideal for CMB lensing cross-correlation studies

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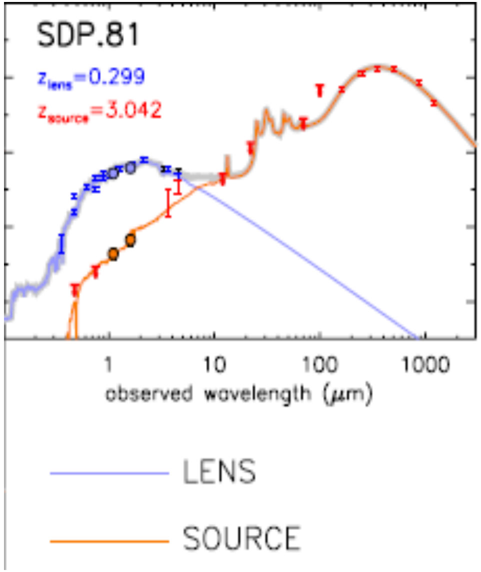

- Low cross-contamination
- Ideal for lensing studies: Bussmann+12, Dye+14, Negrello+14, … (long list here)

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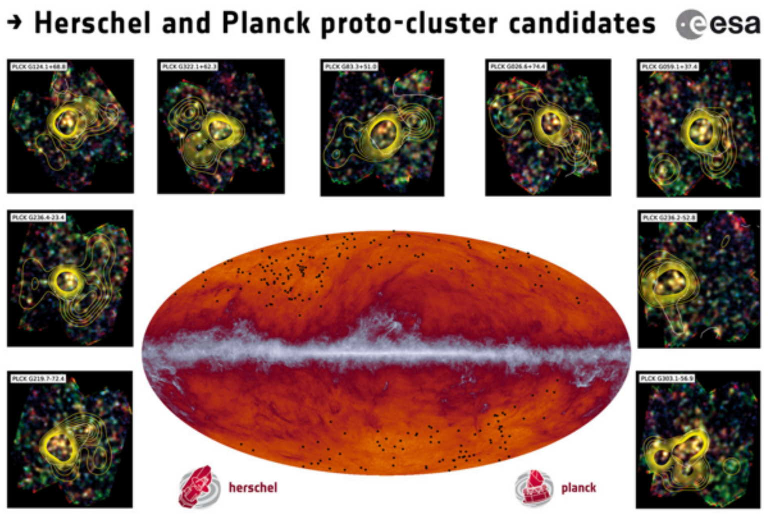

- Planck satellite became an optimal finder of high-z proto-clusters!! (PHZ catalogue)
- Important synergy with Herschel: Herranz+13, Fu+12, Clements+14, PIPXXVII,

Weak lensing: magnification bias

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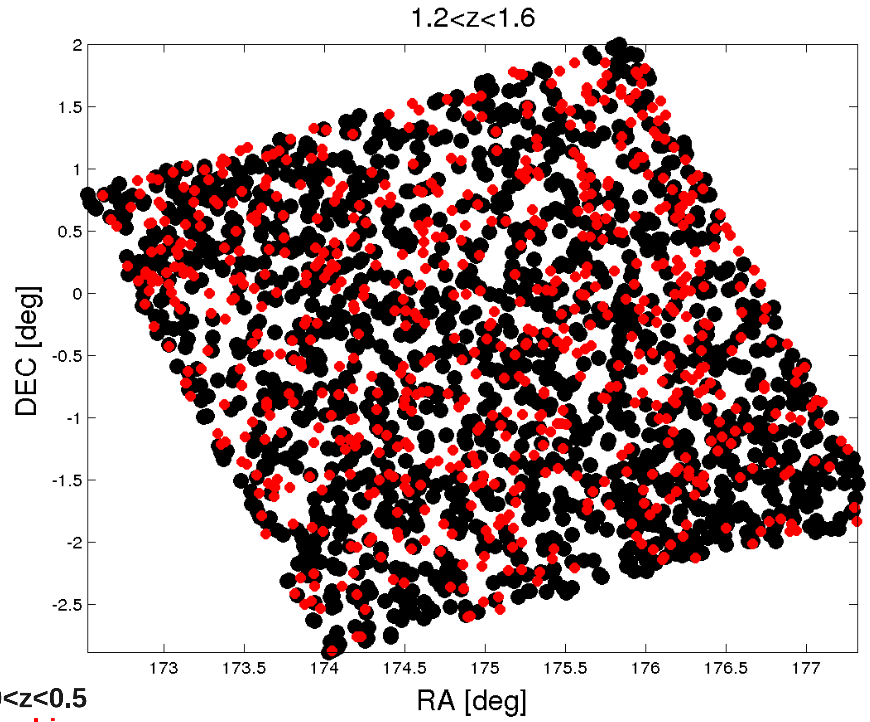
SDSS/GAMA cross-correlation

[Wang+11, GN+14, Bourne+14, GN+17]

... while dealing with HALOS ...

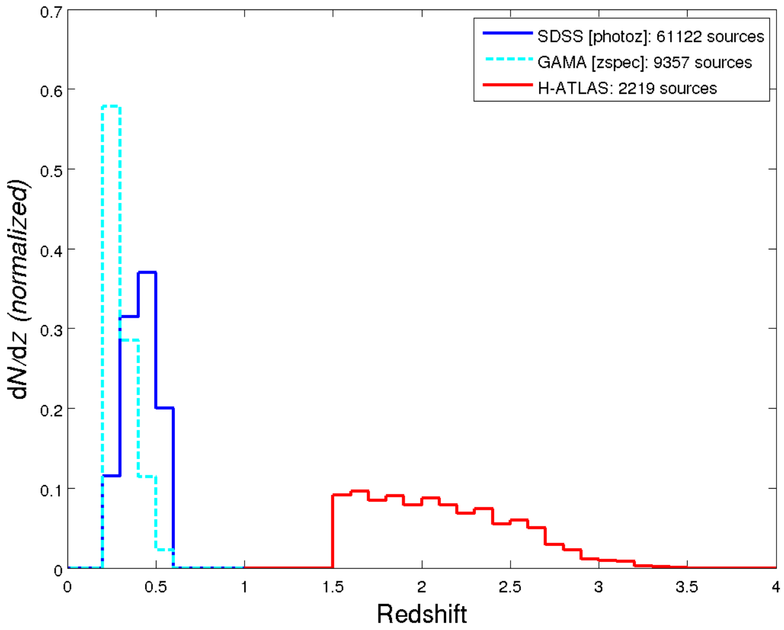
Example: G12 (tile 1; low cirrus)



Black.- 0.0<z<0.5
Red.- high-z bin

SDSS/GAMA XC: Sample selection

- **Background** → H-ATLAS
  - ~ 2.4×10^4 sources
  - photo-z> 1.5
- **Foreground** → SDSS
  - ~ 7.2×10^5 sources
  - $0.2 <$ photo-z < 0.6
- **Foreground** → GAMA
  - ~ 1.1×10^5 sources
  - $0.2 < z_{spec} < 0.6$



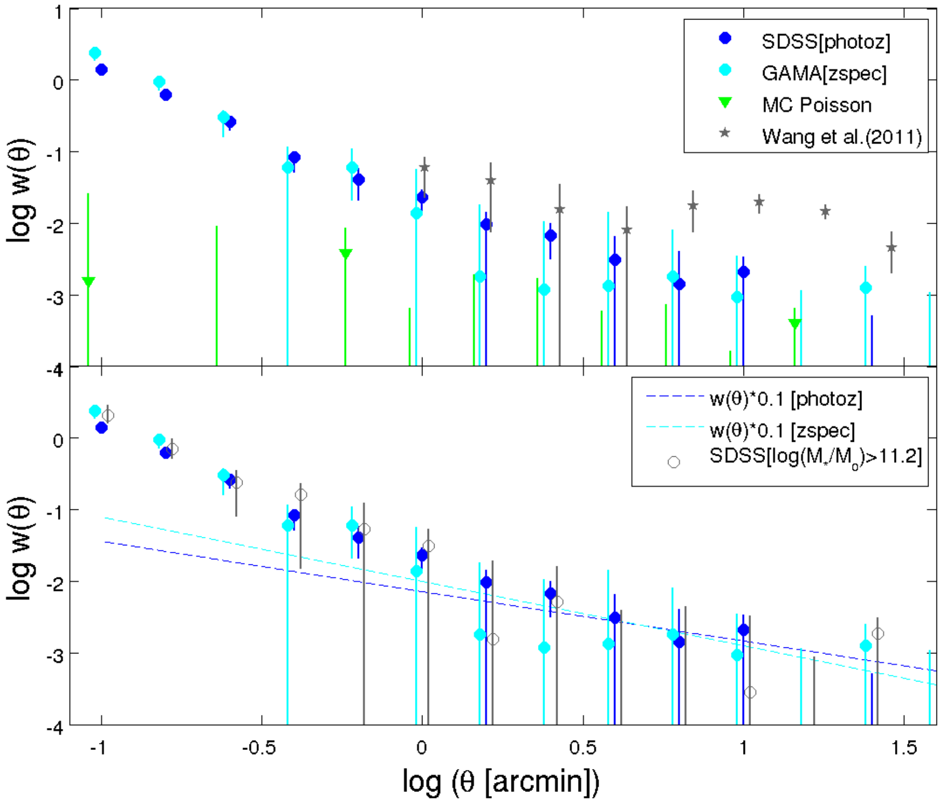
GAMA (Galaxy And Mass Assembly; Driver+11)

Cross-correlation (H-ATLAS vs SDSS/GAMA)
[Gonzalez-Nuevo et al. 2014]

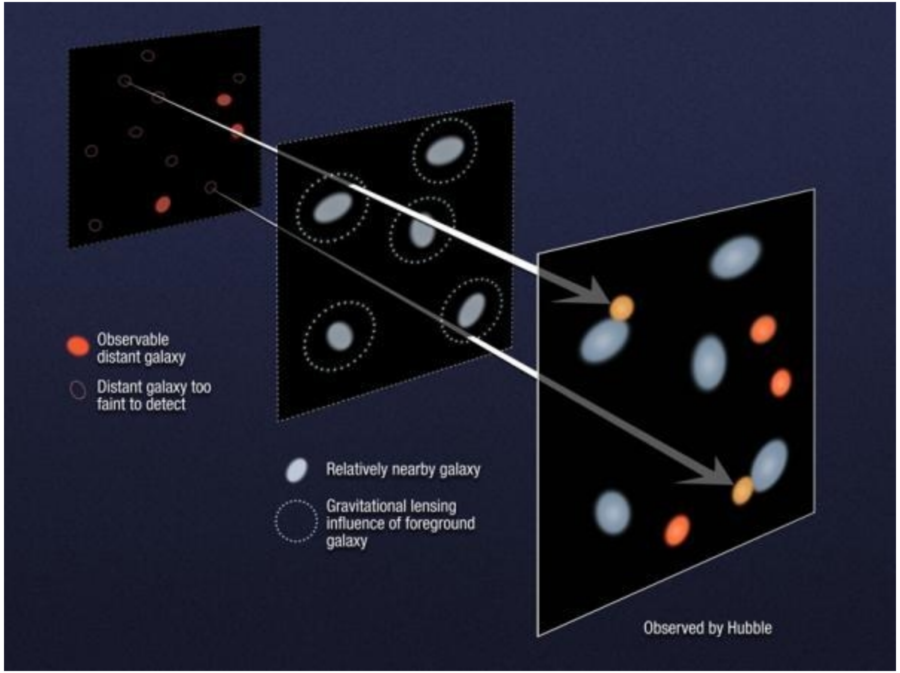
- Modified LS estimator

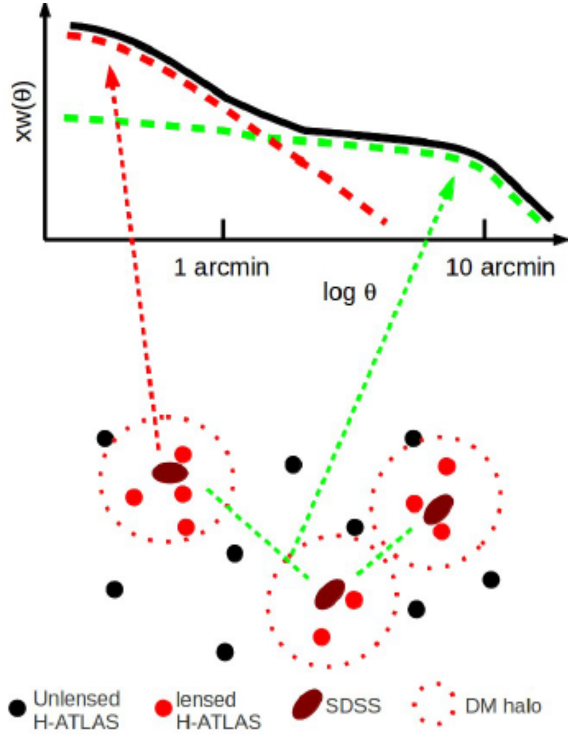
$$w_{\rm cross}(\theta) = \frac{D_1D_2 - D_1R_2 - D_2R_1 + R_1R_2}{R_1R_2}$$

- Signal detected up to ~30 arcmin
  - Highly significant below a few arcmin (>10σ)
- Signal produced mainly by massive galaxies
  - $\log(M_*/M_\odot) > 11.2$; [grey circles]



Simple interpretation: magnification bias



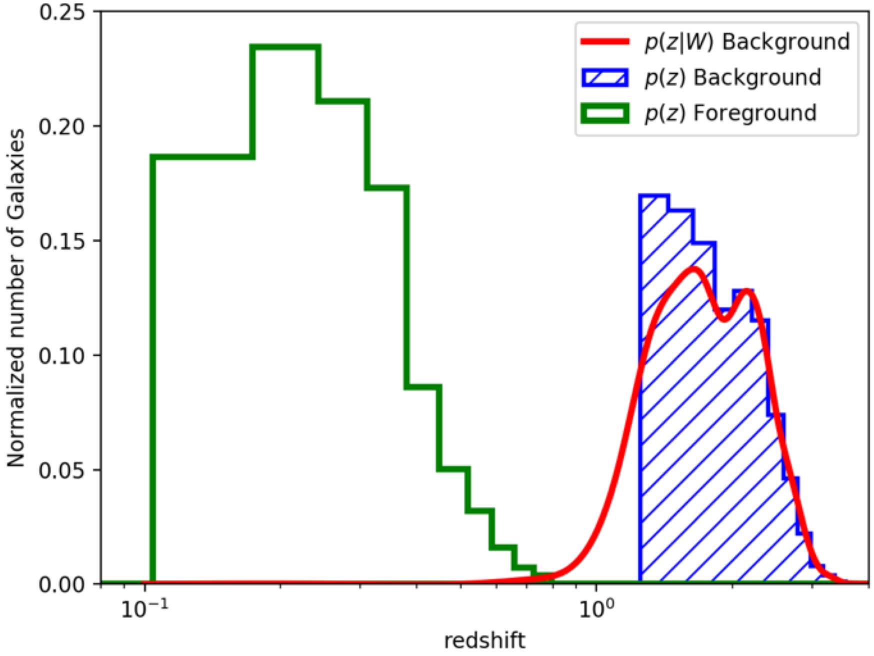


XC signal produced by weak lensing from super-galactic halos being signposted by the SDSS sources.

more than an update: Gonzalez-Nuevo et al. 2017

- **Background** → H-ATLAS
  ~ 4.2×10^4 sources
  photo-z> 1.2
- **Foreground** → GAMA
  ~ 1.5×10^5 sources
  $0.1 < z_{spec} < 0.8$

(KiDS450 or DES require $>10^6$ galaxies!)



more than an update: Gonzalez-Nuevo et al. 2017

- High S/N Cross-correlation measurements
- Physical Interpretation (Cooray & Sheth, 2002):

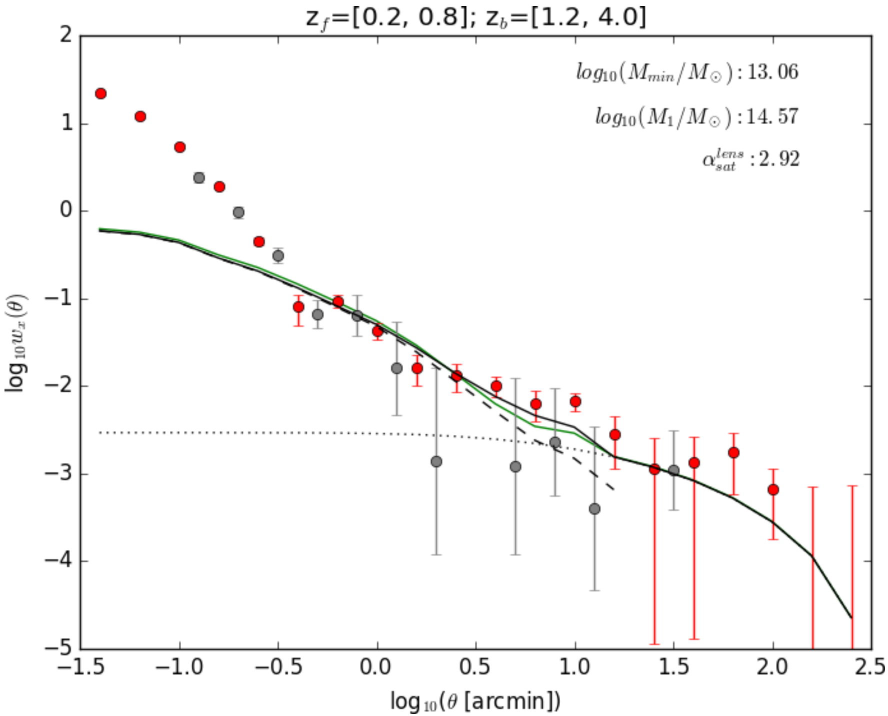
$$\omega_{fb}(\theta) = 2(\beta-1)\int_0^{z_s} dz\,\frac{dN_f}{dz}\mathrm{W}^{\mathrm{lens}}(z)\langle\delta_{\mathrm{gal}}(\hat{n},z)\delta_{\mathrm{dm}}(\hat{n}+\theta,z)\rangle$$
$$= 2(\beta-1)\int_0^{z_s}\frac{dz}{\chi^2(z)}\frac{dN_f}{dz}\mathrm{W}^{\mathrm{lens}}(z)\int_0^{\infty}\frac{\ell d\ell}{2\pi}P_{\mathrm{gal-dm}}(\ell/\chi(z),z)J_0(\ell\theta),$$

- MCMC framework to derive lenses HOD parameters:

$$\log_{10}(M_{\mathrm{min}}^{\mathrm{lens}}/M_{\odot}) = 13.06^{+0.05}_{-0.06}$$

$$\log_{10}(M_1^{\mathrm{lens}}/M_{\odot}) = 14.57^{+0.22}_{-0.16}$$

$$\alpha_{\mathrm{sat}}^{\mathrm{lens}} = 2.92^{+1.12}_{-0.78}$$

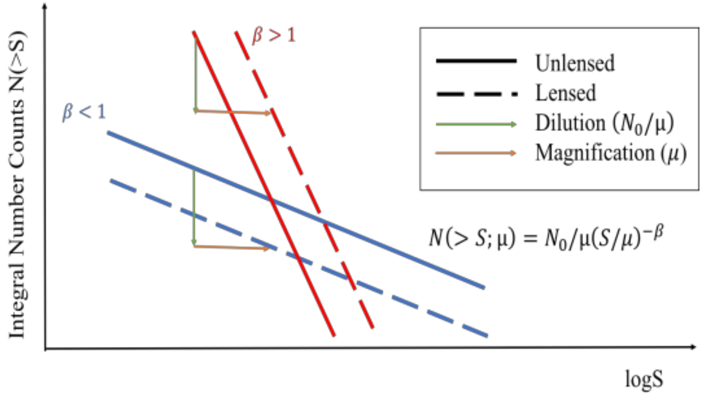


Magnification bias tomography: why?

- In the weak lensing regime, assuming that $\kappa \approx |\gamma|$ as for isothermal spheres (Bartelmann & Schneider 2001):

$$\frac{(S/N)_{shear}}{(S/N)_{mb}} = \frac{|\gamma|}{\kappa} \frac{1}{2\sigma_\epsilon |\alpha - 1|}$$

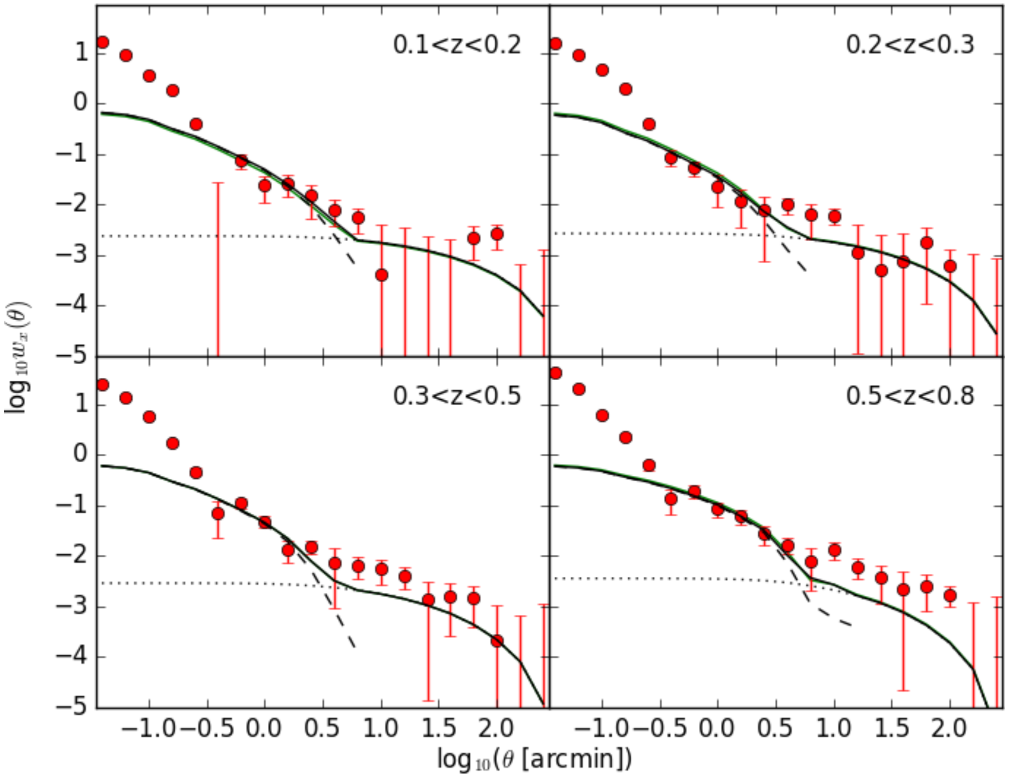
  - For σ_ε~0.3 and $\alpha \lesssim 2$ → shear > MagBias (QSO; Scranton+05)
  - For σ_ε~0.2 and $\alpha \gtrsim 3.5$ → **shear ≲ MagBias !!**

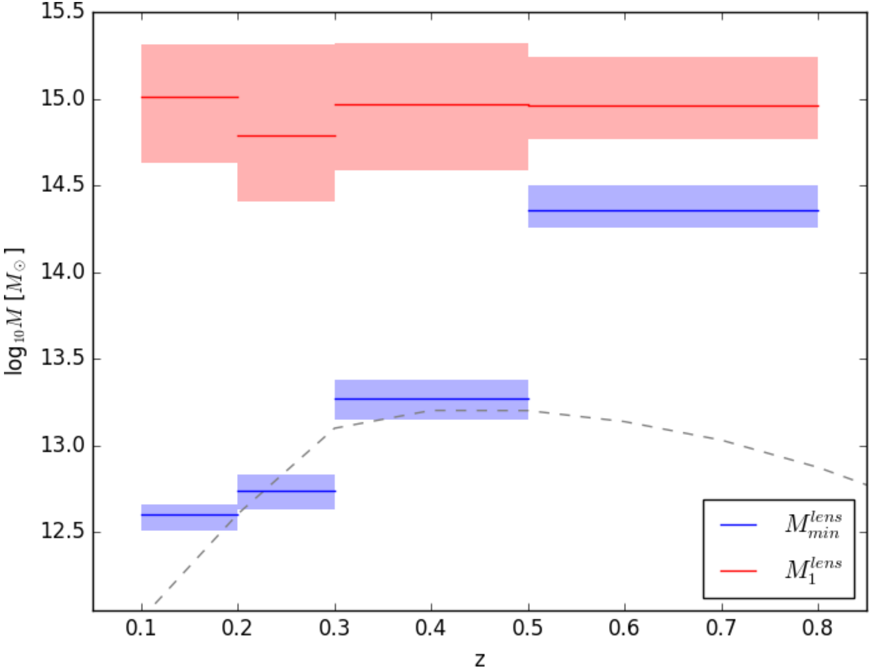


- The magnification bias can be as powerful as shear but with lower systematic effects.

- Ideal technique for tracing the mass density profiles and for probing their evolution with cosmic time.

MagBias tomography: results



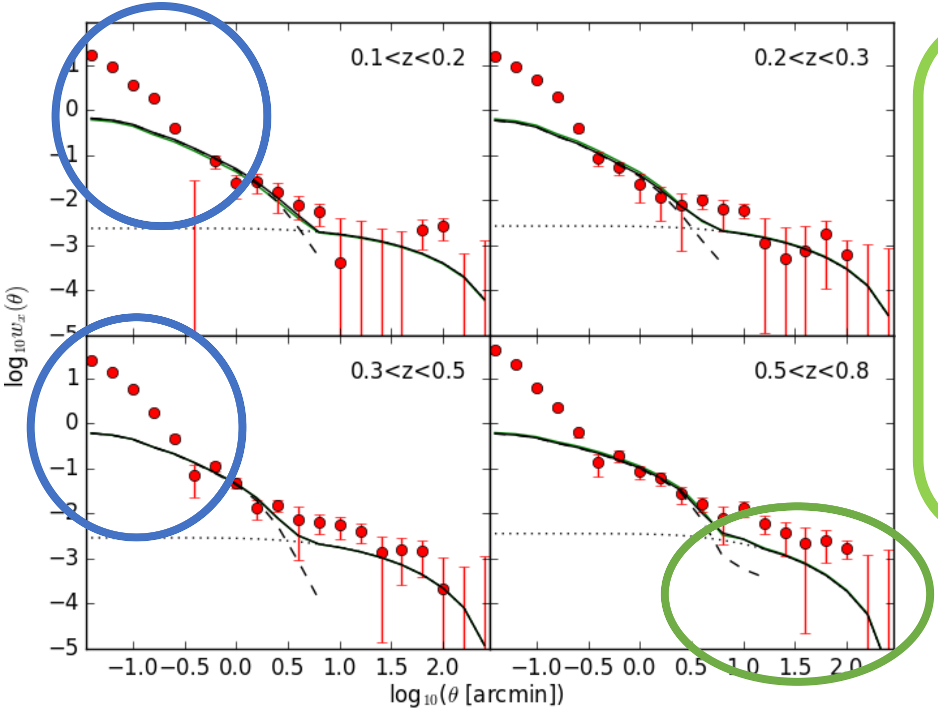


MagBias tomography: issues

Strong lensing regime

No theoretical analytical formulation

Needed for physical interpretation at sub-kpc scales!



Large scale excess of power

Review astrophysical initial hypothesis: HOD, neutrino role, … ?

Cosmology?

Conclusions

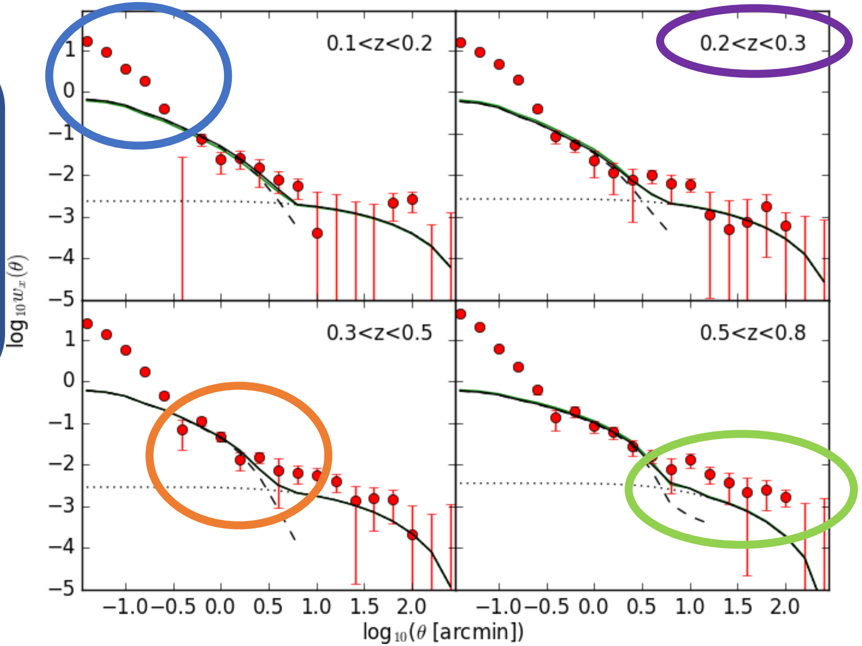
The SMGs main characteristics are perfect to enhance the MagBias sensitivity

Sub-kpc physical scales:

- Mass density profile
- Small scale issues
- …

kpc physical scales:

- Satellites statistics



Tomographic measurements

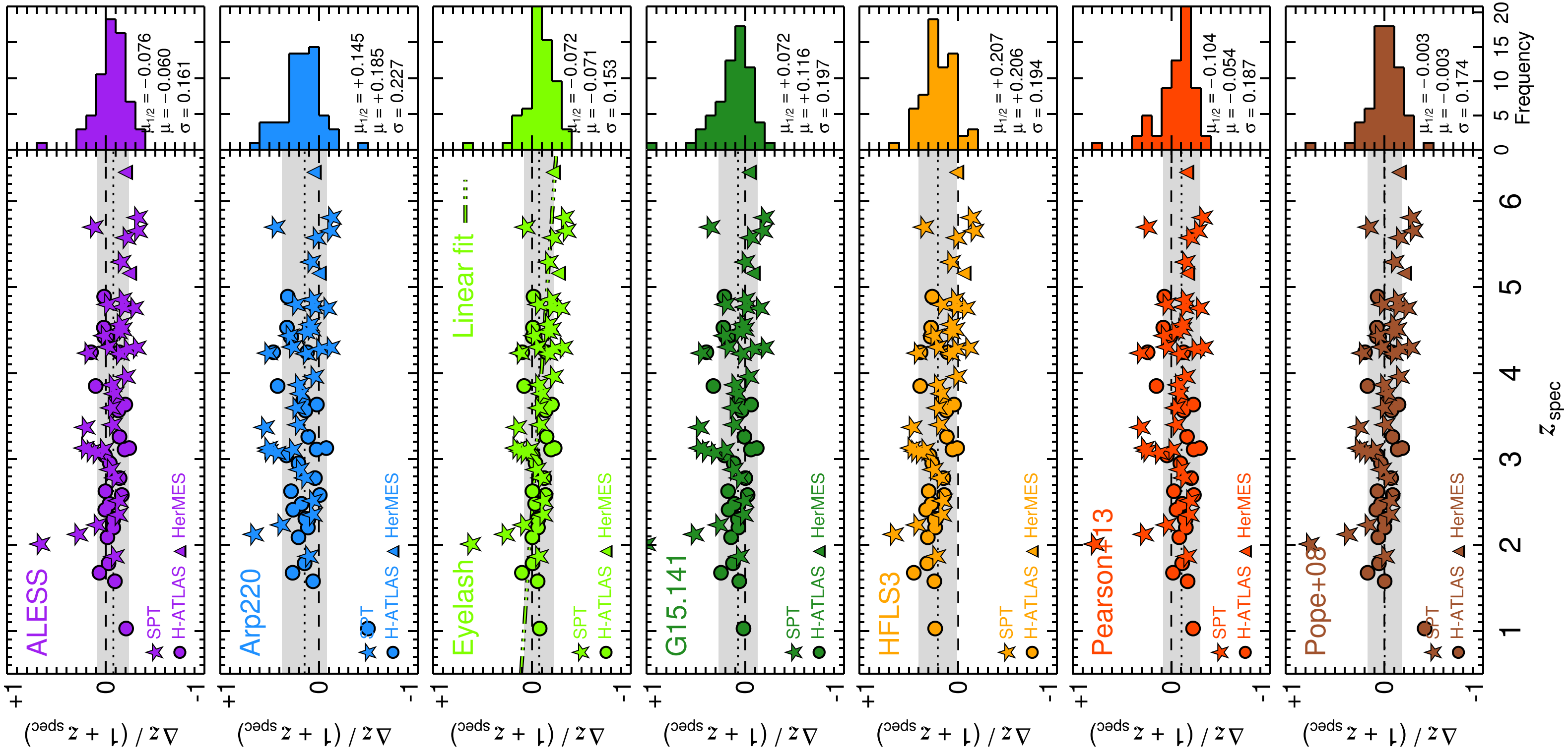
Mpc physical scales:

- Astrophysical issues

The SMGs MagBias can became a possible **cosmological probe**

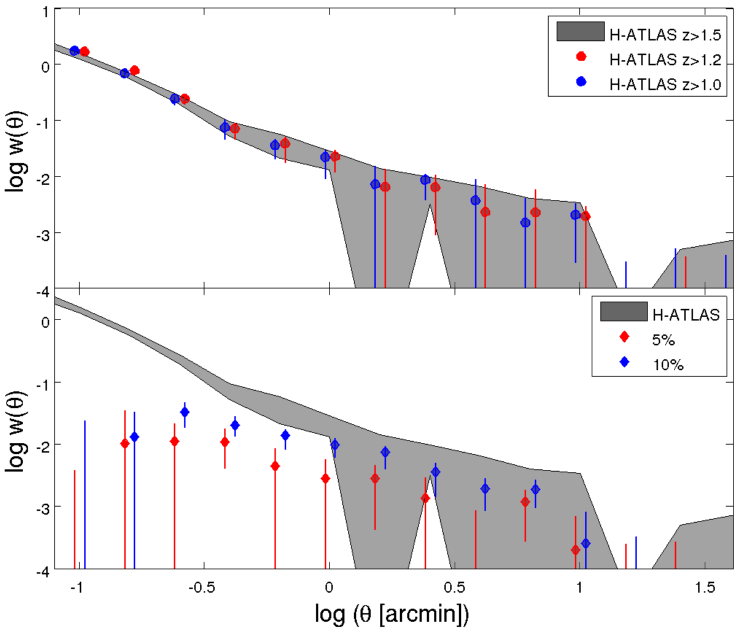
Sub-mm high-z photo-z

Ivison+16

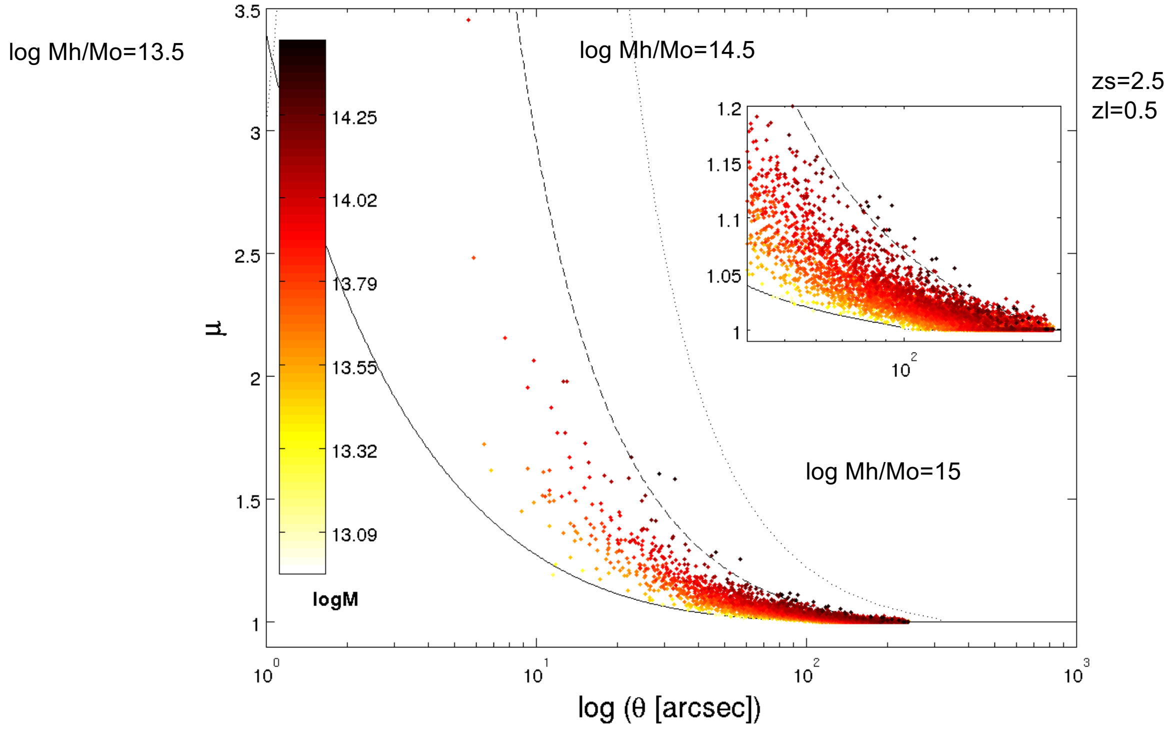


Cross-contamination?

- SED considerations(<0.3%)
  - Foreground magnitudes are too faint to account for the optical and the far-IR emissions at the same time
- VLA follow-up results (<10%)
  - 24/27 with z>0.9
- Sample redshift lower limit "mismatched" simulations (<10%)
  - a fraction of background sources are randomly selected and moved at the position of randomly selected foreground ones

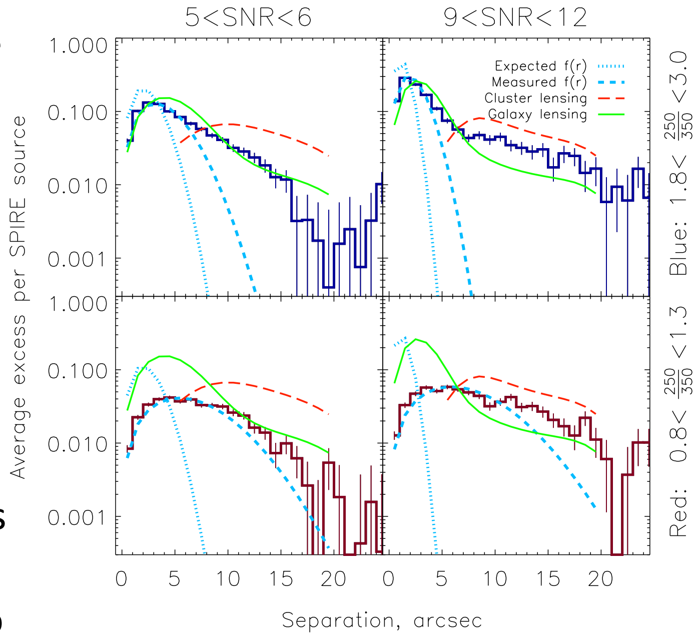


Lensing amplification diagram



Colour matters: Bourne et al. (2014)

- Study of the effect of lensing on the positional offsets between optical and sub-mm galaxies
- Misidentification of high-z counterparts is more common than thought!
- Not only by rare "*strongly lensed galaxies*" but also due to ubiquitous weak lensing.
  - ALMA observational proposal to verify this hypothesis



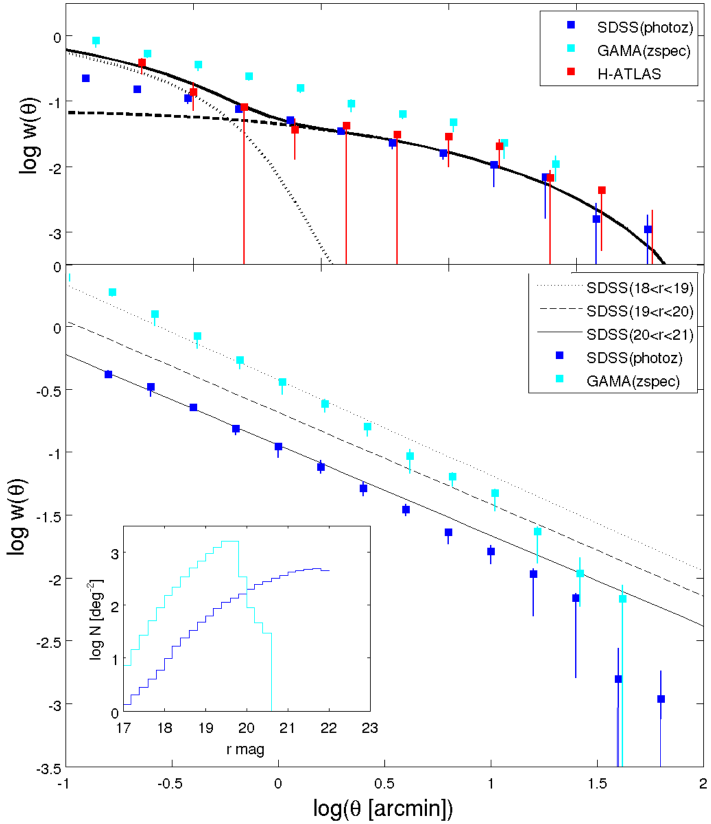
Lensing *simulated* predictions are upper-limits

auto-correlation results

- Landy-Szalay estimator

$$w(\theta) = \frac{\mathrm{DD}(\theta) - 2\mathrm{DR}(\theta) + \mathrm{RR}(\theta)}{\mathrm{RR}(\theta)}$$

- H-ATLAS
- Signal detected up to ~50 arcmin
- Good agreement with the halo model based on photo-z distribution (Xia+12)
- SDSS/GAMA:
- Good agreement with auto-correlation of full SDSS split by r-magnitude interval (Connolly+02, Wang+13)



Auto-correlation induced by lensing