Cosmic magnification with submillimeter galaxies

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Cueli, M. M. et al. (submitted to A&A). Methodological refinement of the submillimeter galaxy magnification bias. Paper I: cosmological analysis with a single redshift bin

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SISSA

COSMOLOGY 2023 IN MIRAMARE

I. Introduction

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Weak gravitational lensing…

- … studies the **statistical correlations** of magnification/distortion
- … **probes *all* mater**
- … can be studied through
  - Cosmic shear ⟺ $\xi_+(\theta)$ and $\xi_-(\theta)$
  - Galaxy-galaxy lensing ⟺ $\langle\gamma_t\rangle(\theta)$
  - **Cosmic magnification** ⟺ $w_{fb}(\theta) = \langle\delta n_f(\varphi+\theta)\delta n_b(\theta)\rangle$

Due to magnification bias!

I. Introduction

Magnification causes two competing effects:

- Flux boosting
- Solid angle stretching

$$n_b(>S,\theta) = \frac{1}{\mu(\theta)} n_{b_0}\left(> \frac{S}{\mu(\theta)}\right)$$

Magnification bias is the net result and modifies the integral number counts!

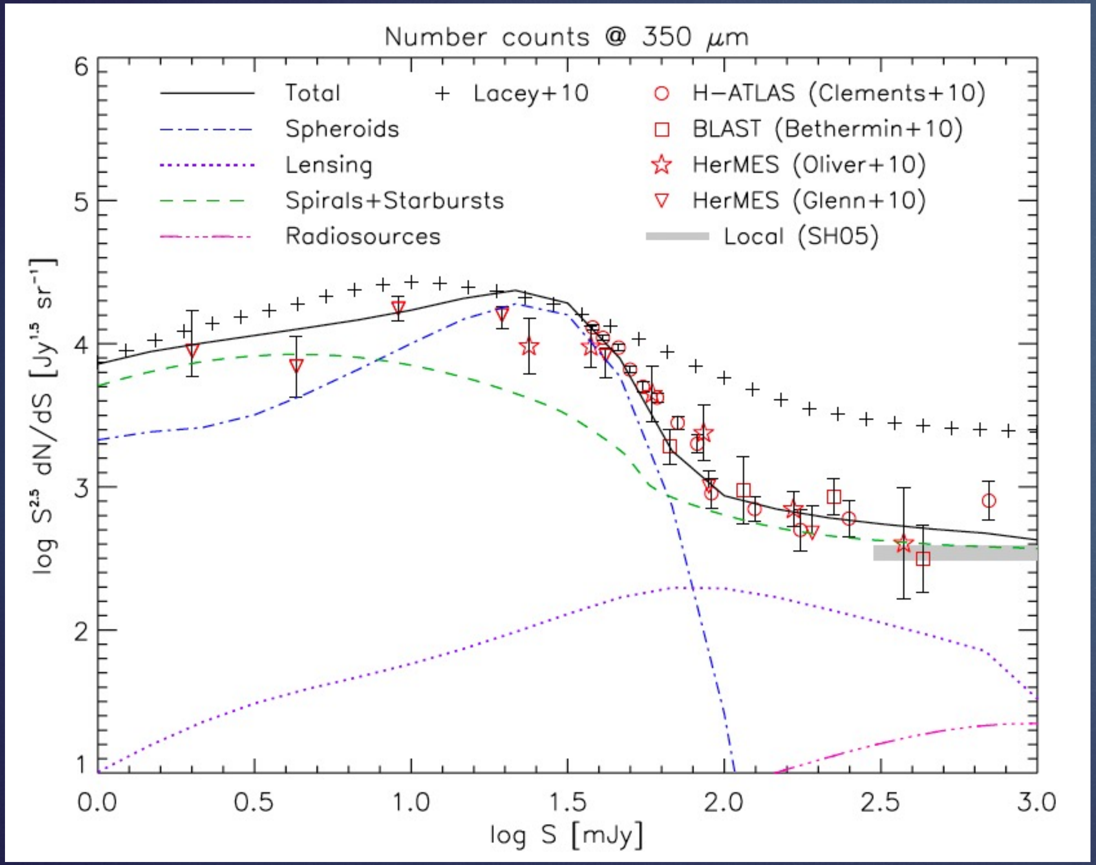
This induces a non-zero cross-correlation:

$$w_{fb}(\theta) = \langle \delta n_f(\varphi+\theta)\delta n_b(\theta)\rangle \approx 2(\beta-1)\,\langle \delta n_f(\varphi+\theta)\,\kappa(\theta)\rangle,$$

highly significant for **submillimeter galaxies!**

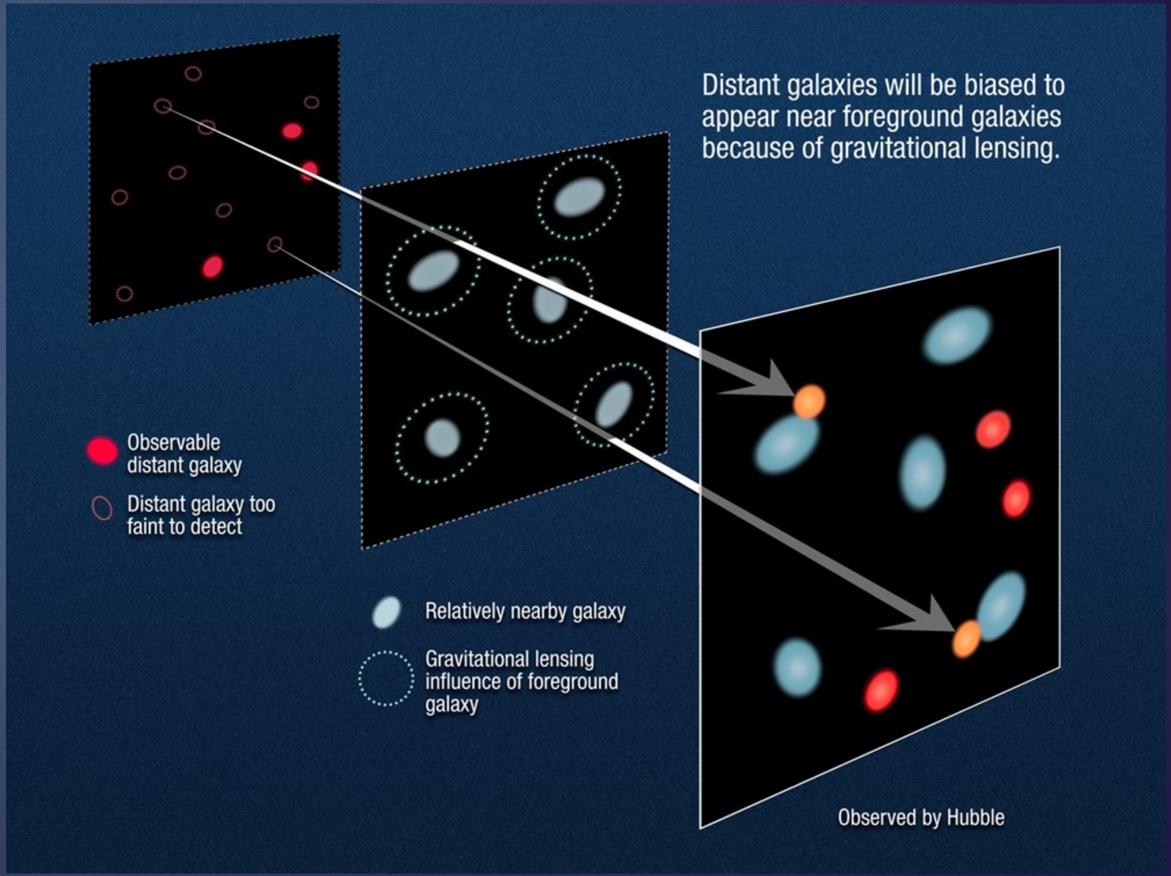
I. Introduction

These extremely IR-luminous **high redshift** galaxies have **very steep number counts…**



Lapi, A. et al. (2011)

… and are optimal to measure a cross-correlation as an **excess of background galaxies around foreground galaxies**



A. Feild / STScI / NASA / ESA

II. Data and methodology

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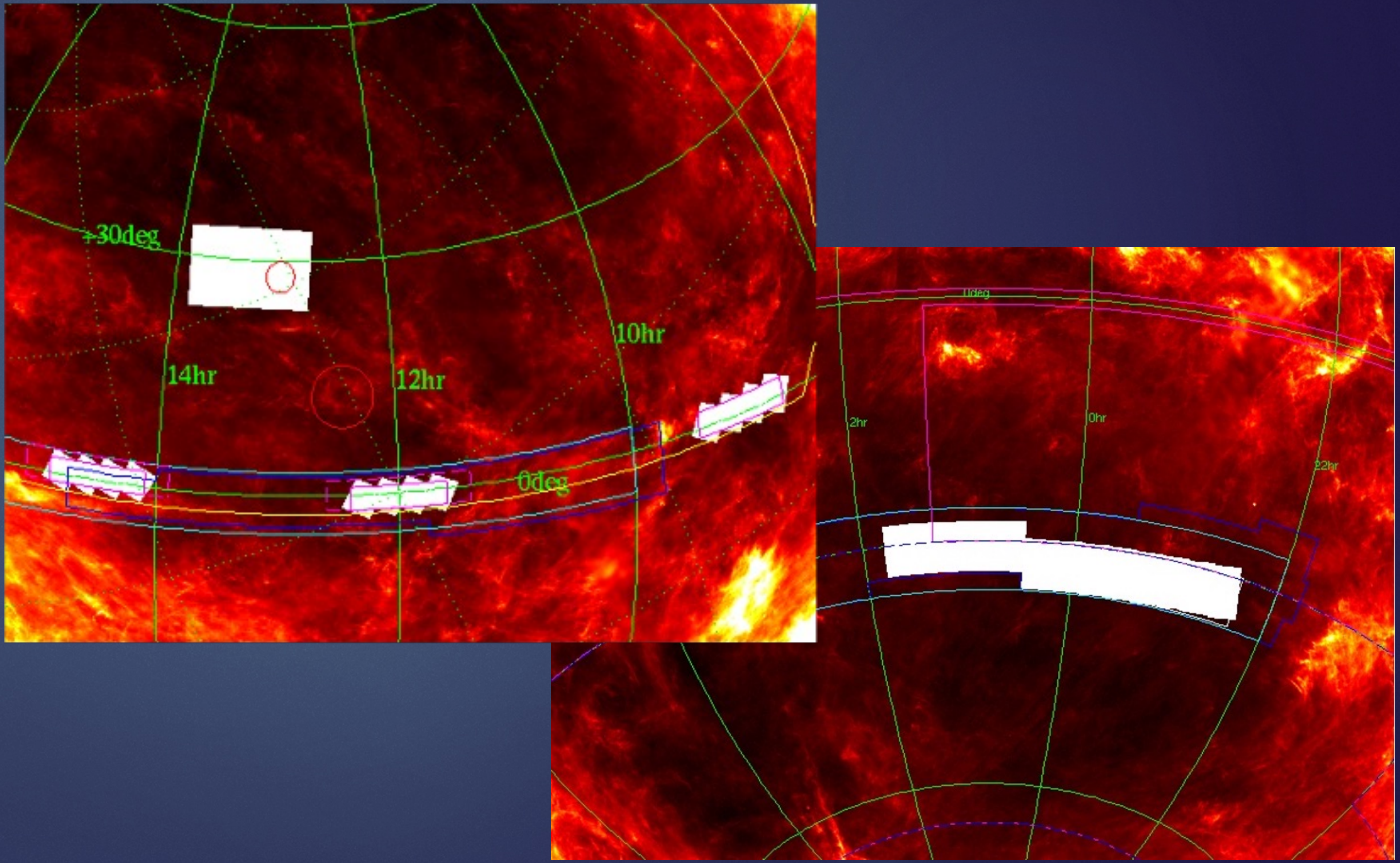
The **background** galaxy sample is extracted

from the ***Herschel*-ATLAS** survey

- Photometric redshifts $1.2 < z < 4.0$
- Flux density $S_{250} > 29$ mJy
- G09, G12, G15 and (part of) SGP



www.h-atlas.org

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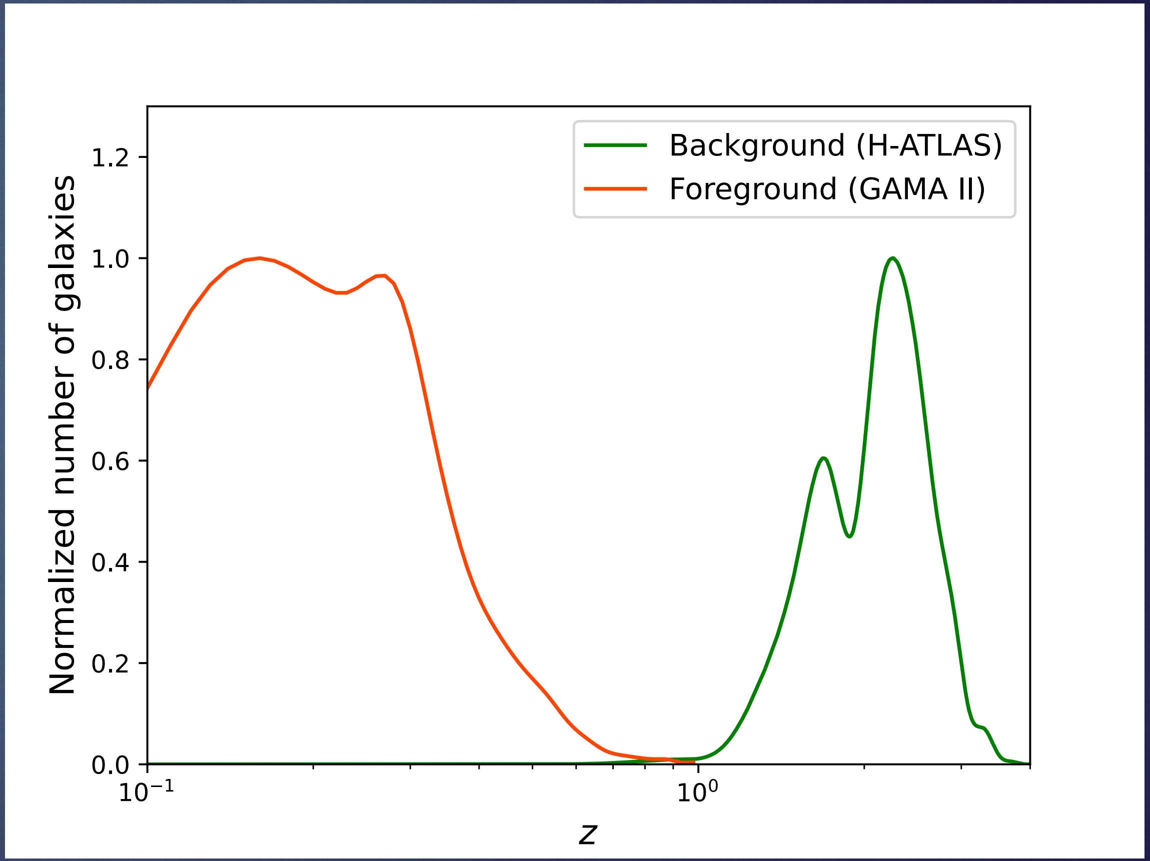


The **foreground** galaxy sample is extracted from the **GAMA** survey:

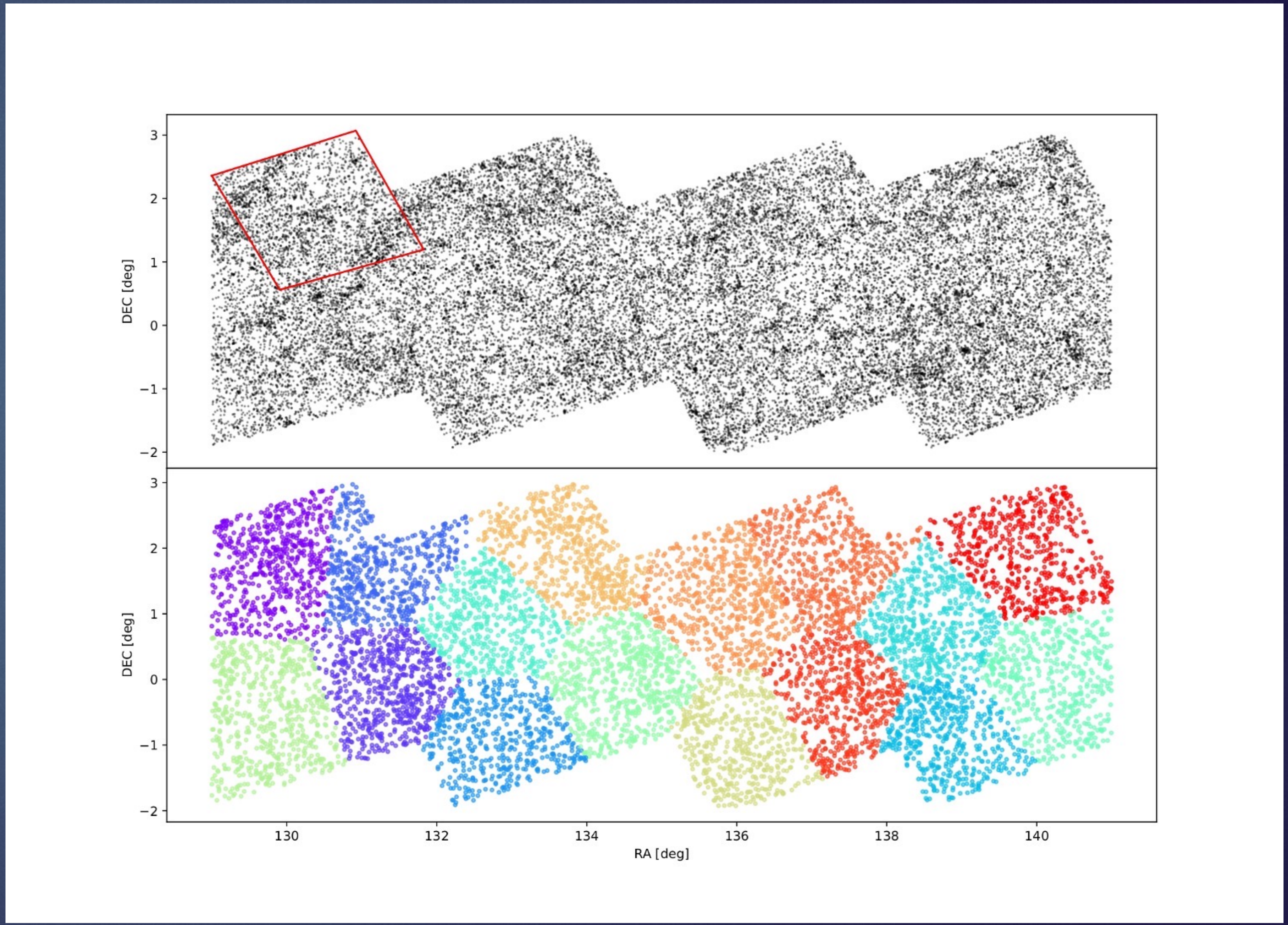
- Spectroscopic redshifts $0.2 < z < 0.8$
- G09, G12, G15 and (part of) SGP

II. Data and methodology

We measure the angular cross-correlation via

$$\tilde{w}_{fb}(\theta) = \frac{\mathrm{D_f D_b}(\theta) + \mathrm{D_f R_b}(\theta) - \mathrm{R_f D_b}(\theta) + \mathrm{R_f R_b}(\theta)}{\mathrm{R_f R_b}(\theta)}$$

but how exactly?



- "Split and average": Integral constraint bias?
  - Bonavera et al. (2020; 2021)
  - González-Nuevo et al. (2022)
  - Cueli et al. (2021; 2022)
- "Global measurement": ?
  - This work
  - Bonavera et al. (2023; in review process)

II. Data and methodology

We model the galaxy-matter cross-correlation via the halo model

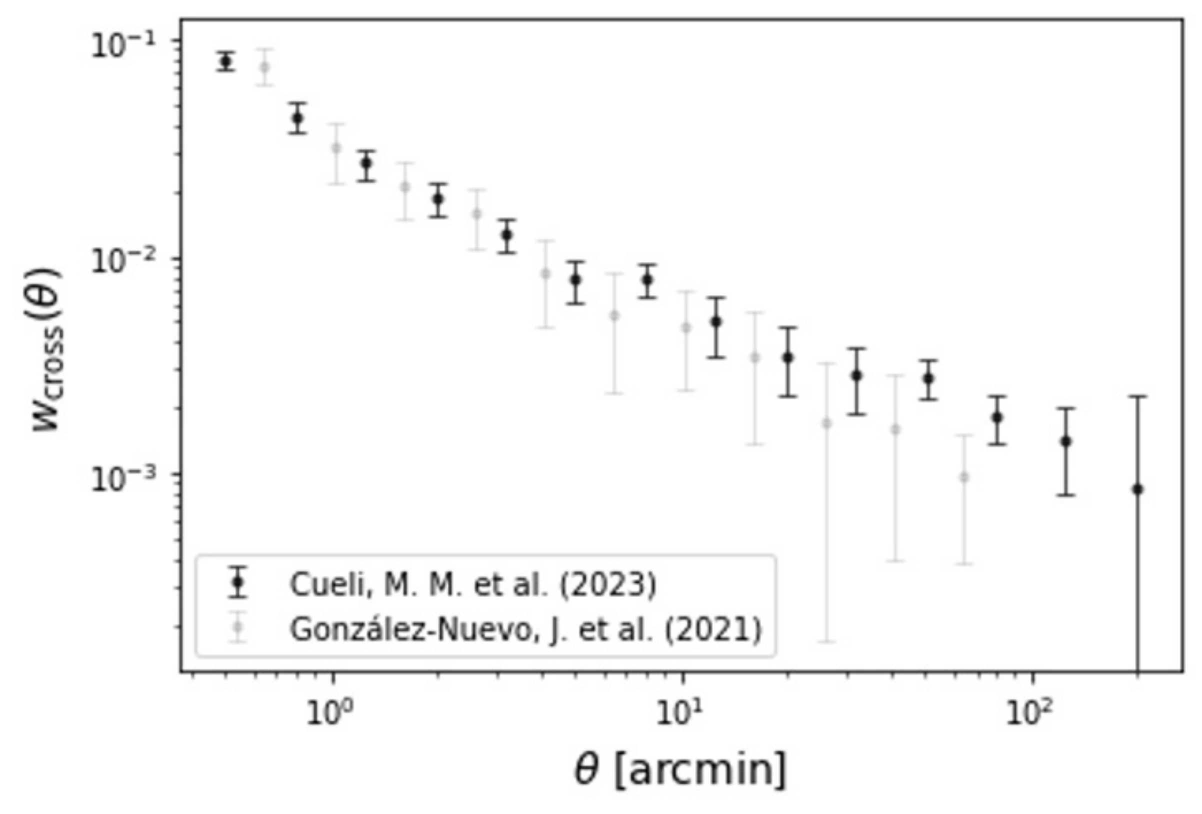
$$w_{fb}(\theta) = 2(\beta - 1)\int_0^\infty \frac{dz}{\chi^2(z)}\frac{dN_f}{dz}W^{lens}(z)\cdot$$
$$\cdot\int_0^\infty dl\,\frac{l}{2\pi}P_{gm}\left(\frac{l}{\chi(z)},z\right)J_0(l\theta)$$

, where the galaxy-halo connection follows the 3-parameter HOD

$$\langle N\rangle_M = \Theta(M - M_{min})\left[1+\left(\frac{M}{M_1}\right)^{\alpha}\right]$$

Therefore:

$$w_{fb}(\theta) = w_{fb}(\theta; \Omega_m, \sigma_8, h, \alpha, M_{min}, M_1, \beta)$$



III. Results

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According to the Lapi, A. et al. (2006) model,

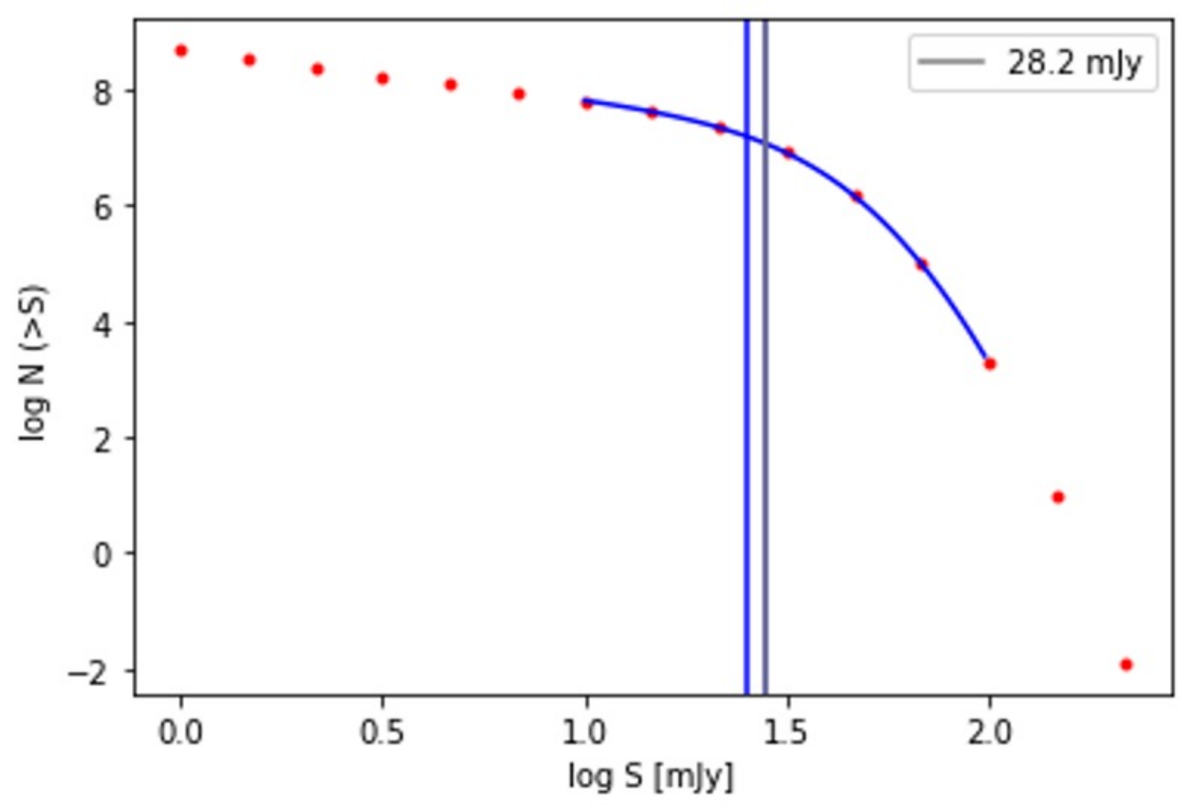
$$\beta(S_{350} = 29\ \mathrm{mJy}) \approx 3$$

but we need the behavior **in the neighborhood of the detection limit**…

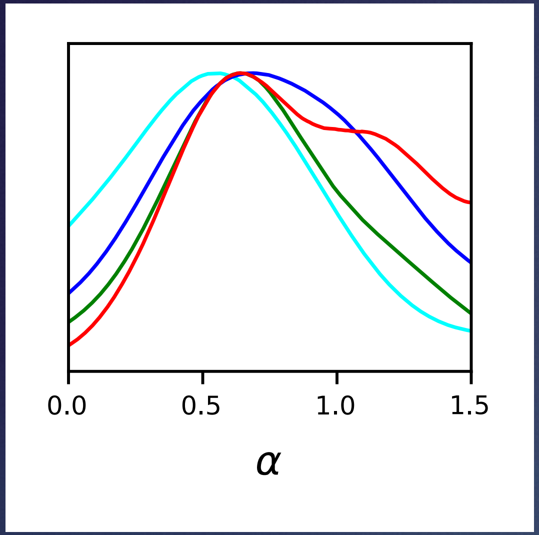
Our base case will be

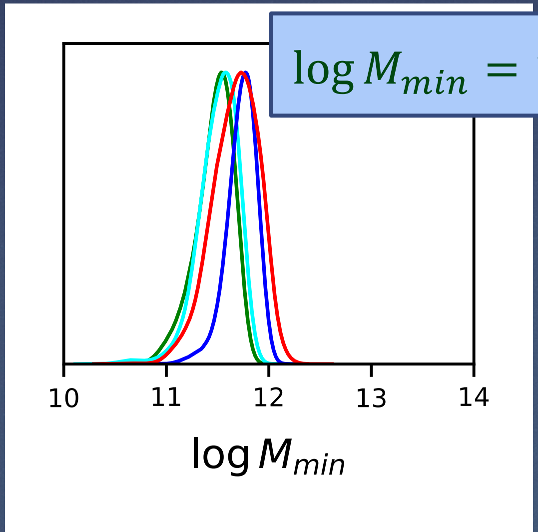
$$\beta = 2.90 \pm 0.04$$

How does the value impact the results?

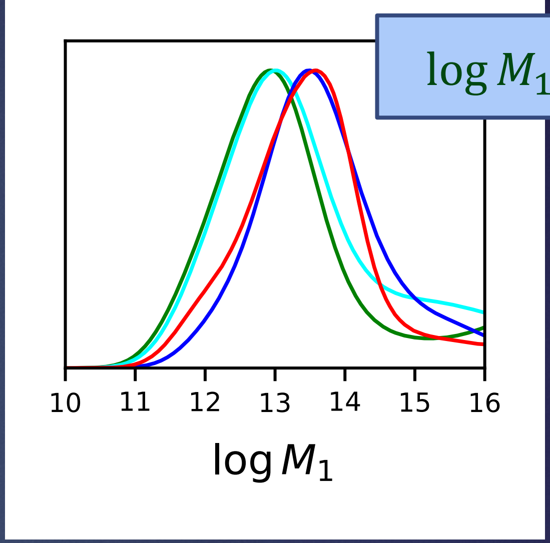


III. Results

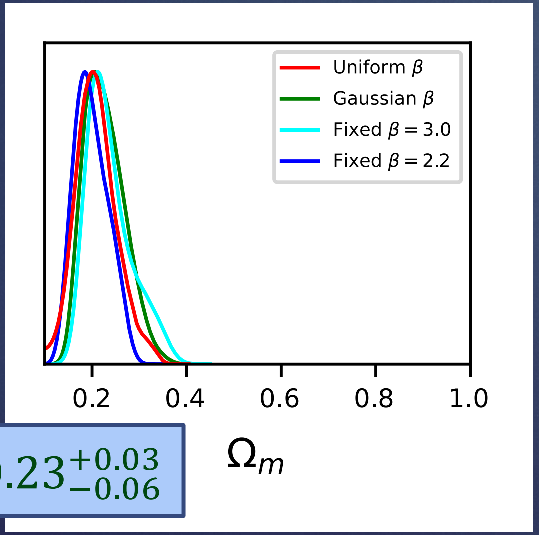




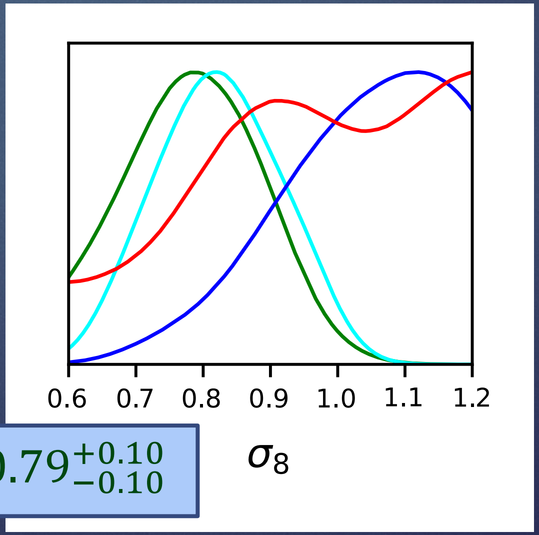
$\log M_{min} = 11.47^{+0.22}_{-0.13}$



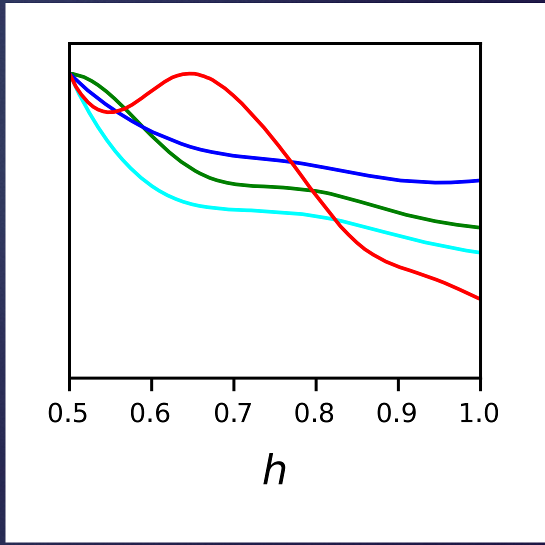
$\log M_1 = 13.04^{+0.67}_{-1.02}$



$\Omega_m = 0.23^{+0.03}_{-0.06}$

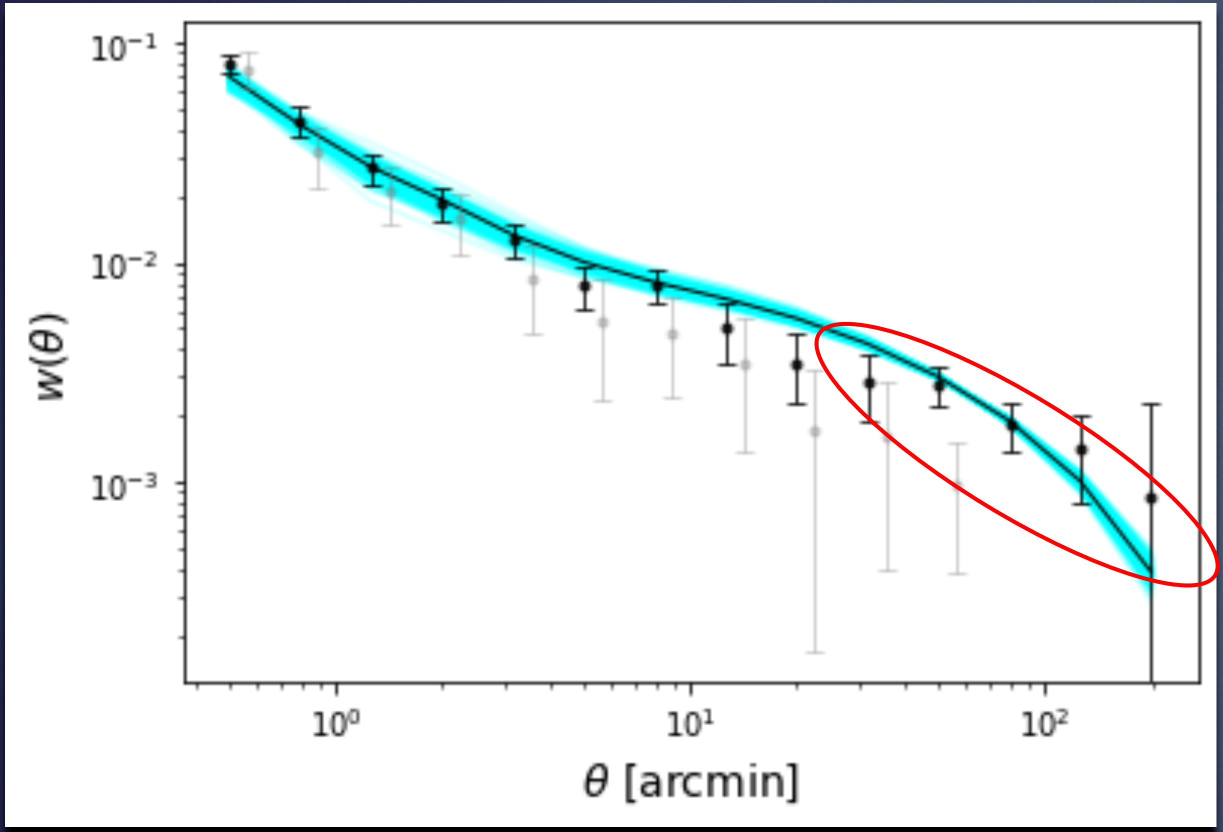


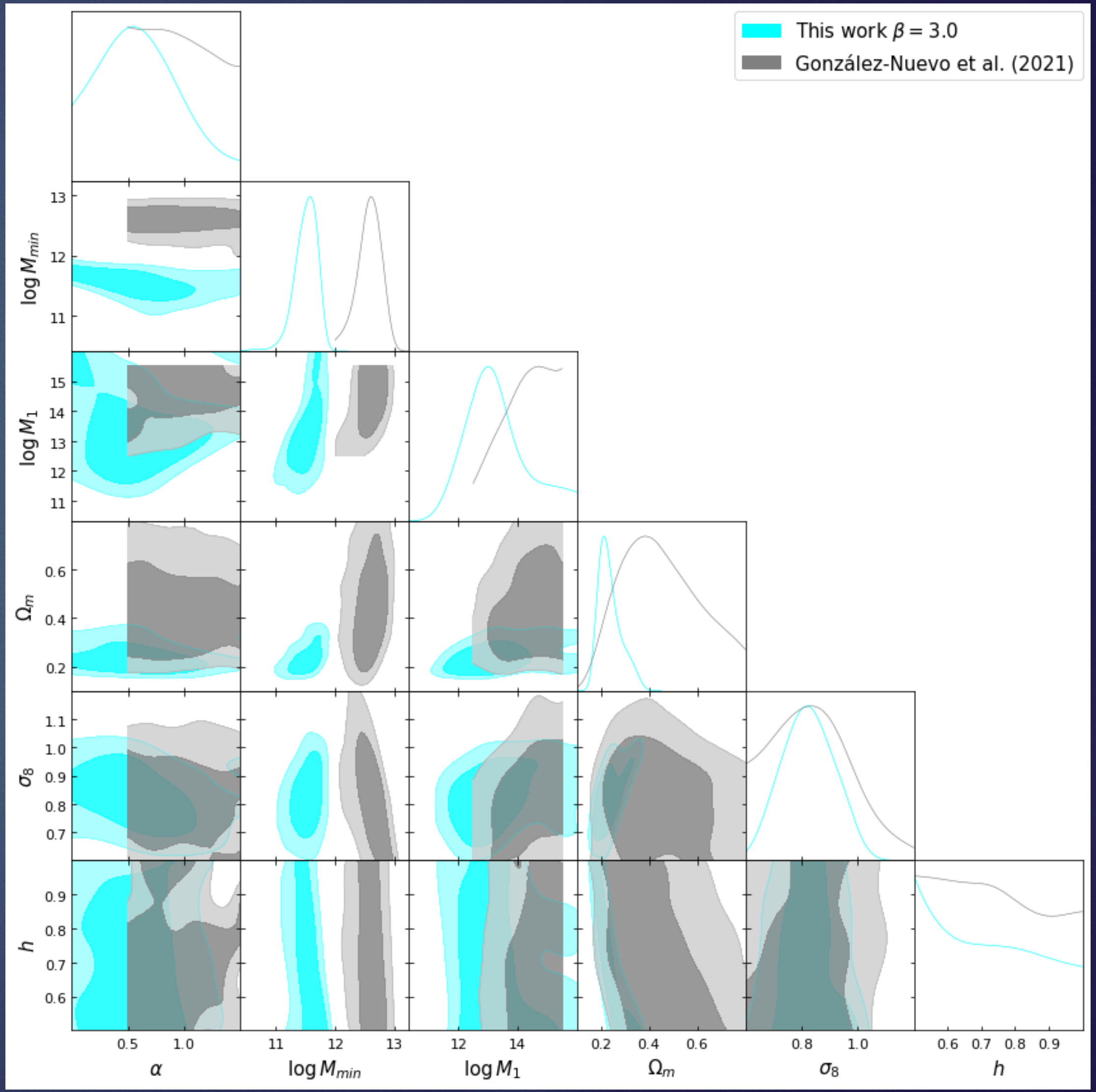
$\sigma_8 = 0.79^{+0.10}_{-0.10}$



III. Results

Improvement with respect to previous approach…

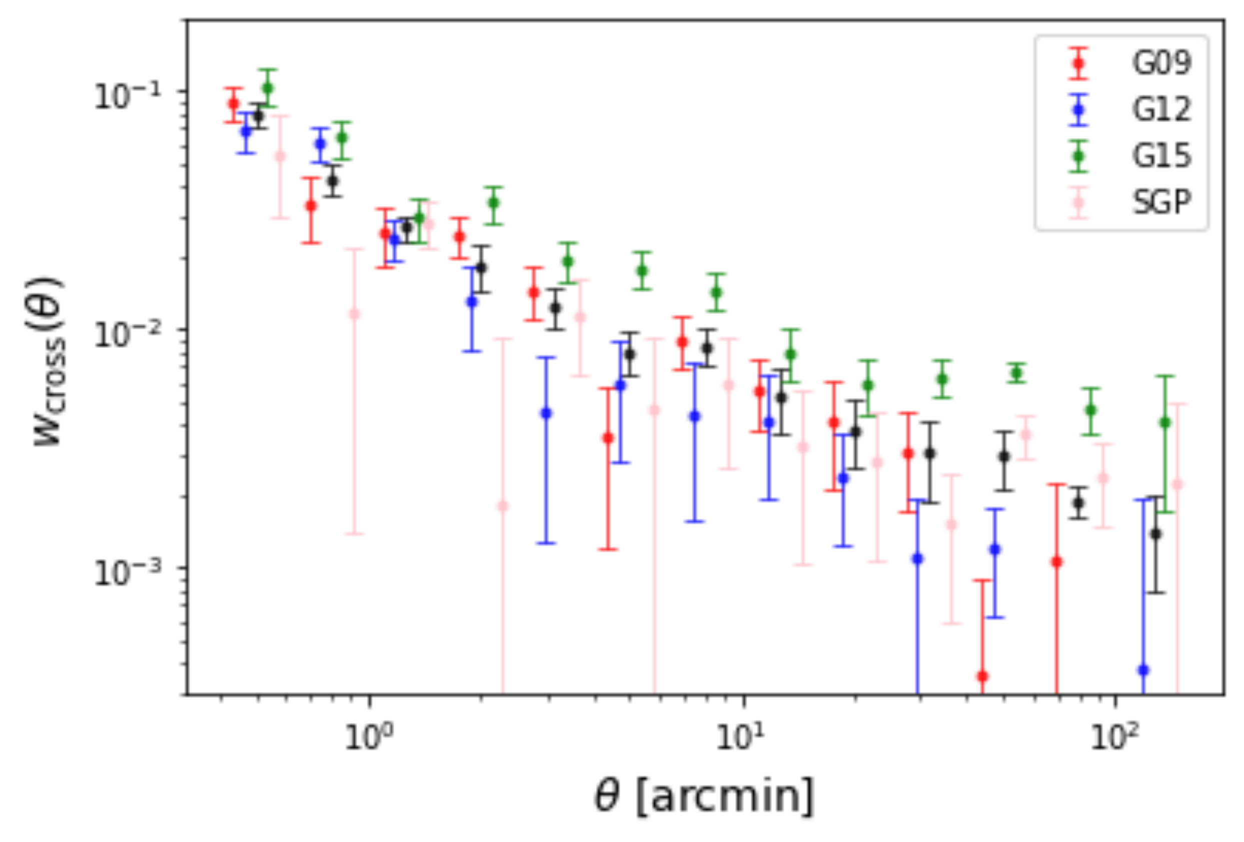




but different large-scale behavior?

III. Results

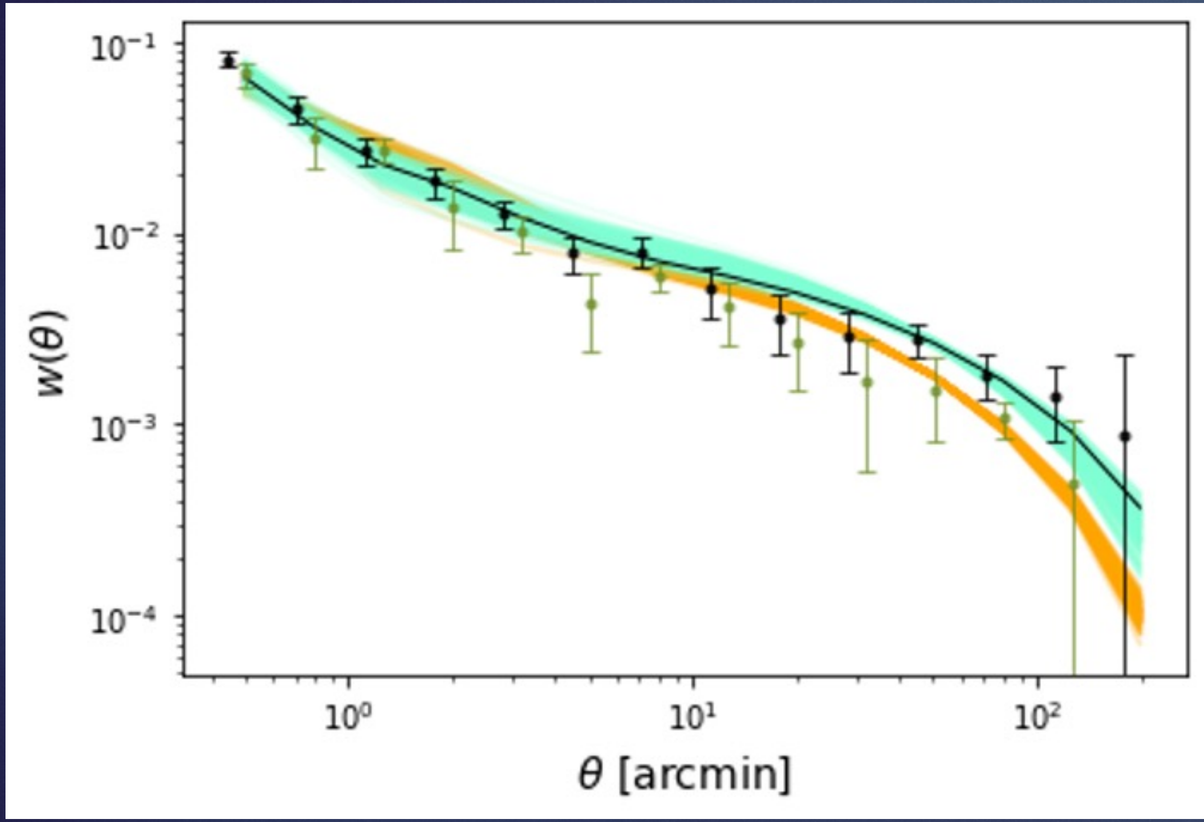
Dissecting the signal by fields…

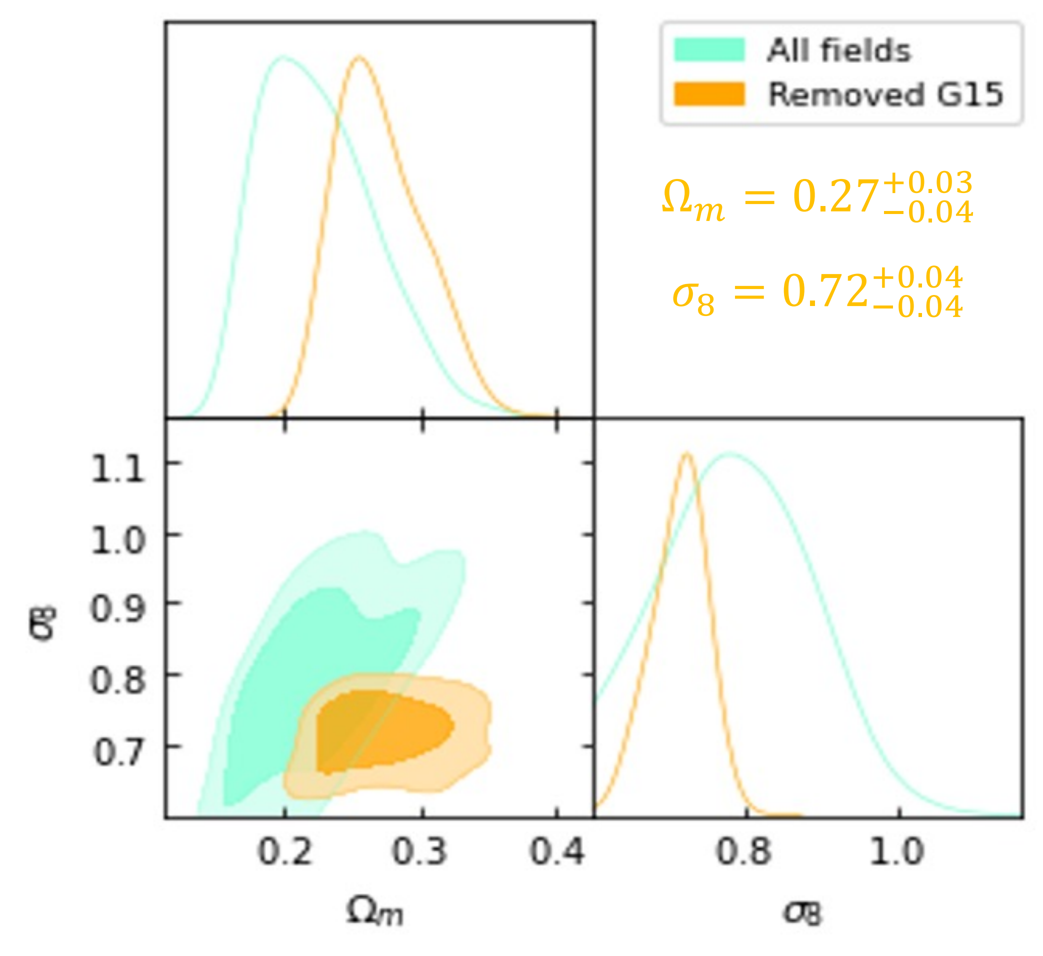


… we can observe a systematically higher cross-correlation in the G15 region **(sampling variance?)**

III. Results

Excluding the G15 region induces **non-negligible changes!**





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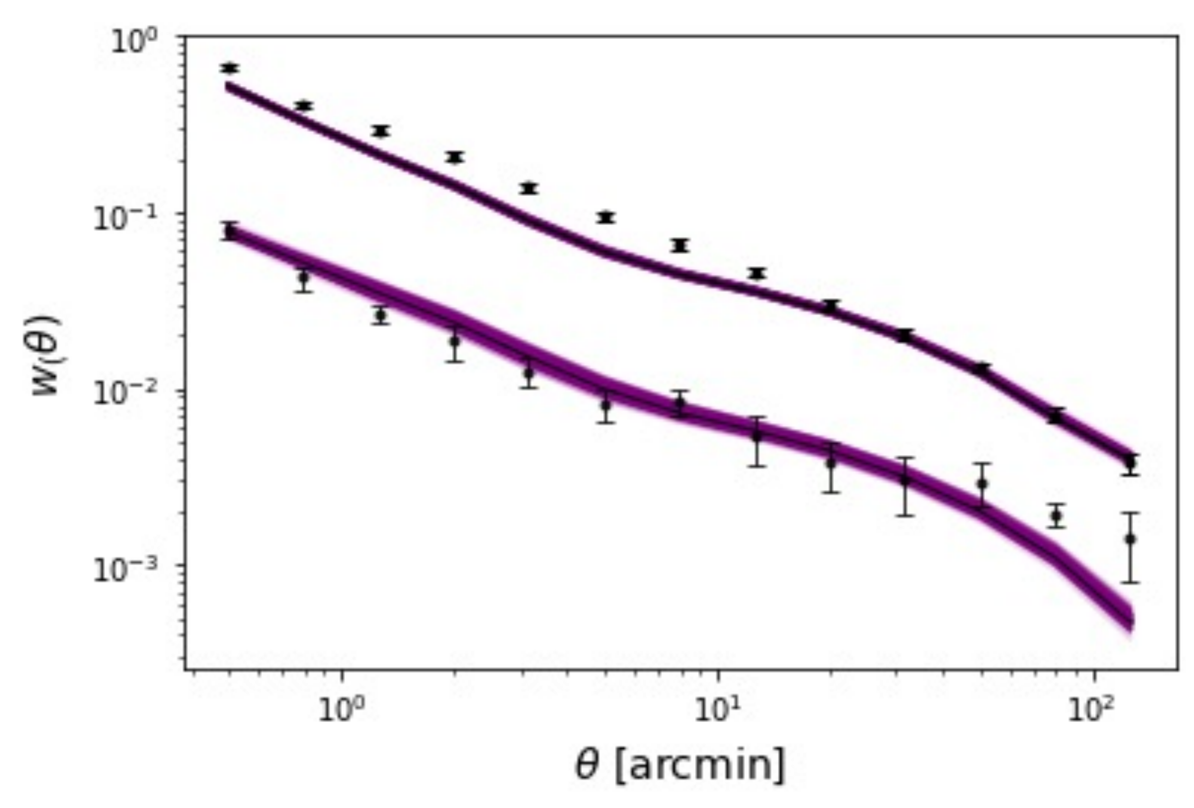
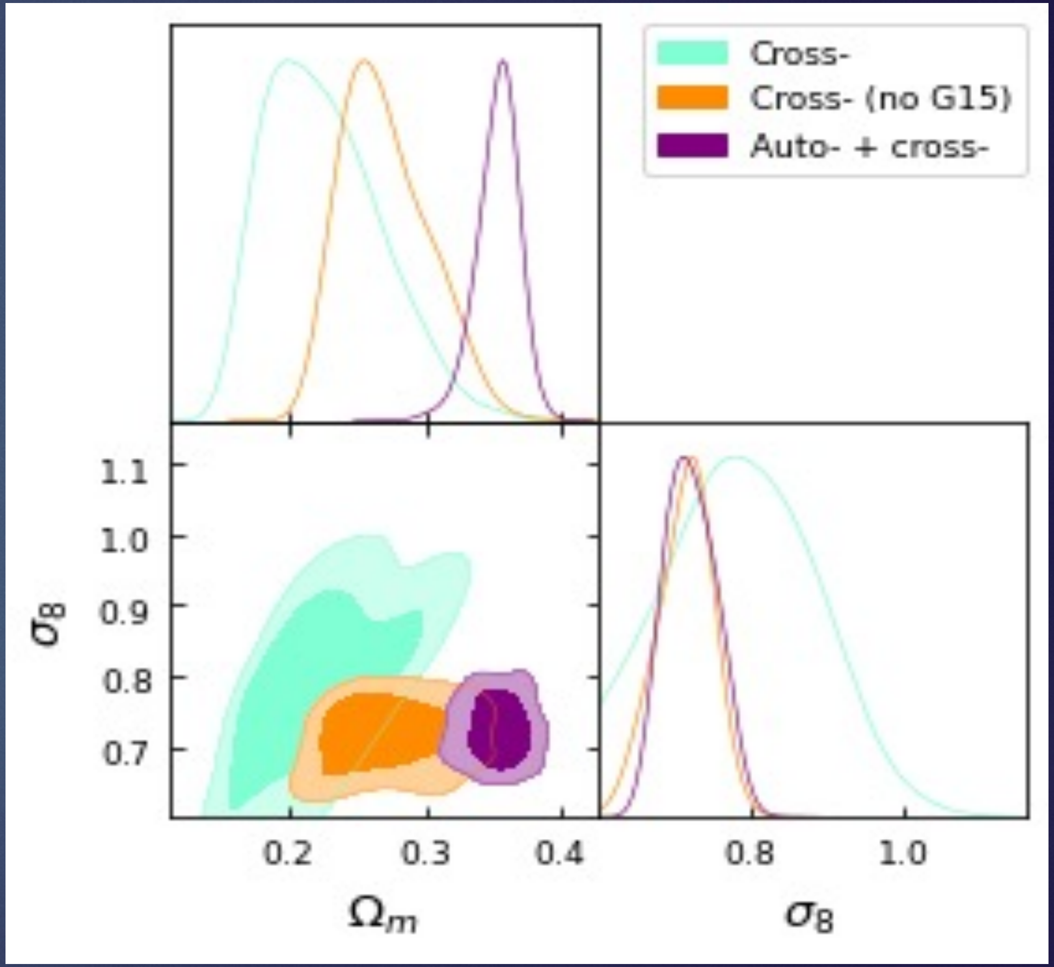
A joint analysis with galaxy clustering yields tighter constraints





but the fit is not good… inconsistency between both observables? (Leauthaud et al. 2017; Amon et al. 2023…)

IV. Conclusions

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- Magnification bias induces an excess of background galaxies foreground galaxies

- Submillimeter galaxies are an optimal background sample (very steep number counts)

- Cosmic magnification on submillimeter galaxies can be exploited as an independent and complementary cosmological probe:

$$\Omega_m = 0.23^{+0.03}_{-0.06} \qquad \sigma_8 = 0.79^{+0.10}_{-0.10}$$

  - No sign of the usual $\Omega_m - \sigma_8$ degeneracy
  - Prior information on the slope of the number counts is crucial
  - Sampling variance…?

- Further work implies tomographic analyses, larger samples and better theoretical modeling