Cosmology with the submillimetre galaxies magnification bias: Proof of concept.

Bonavera L.[1,2], González-Nuevo J.[1,2], Cueli M. M.[1,2], Ronconi T.[3,4,5], Migliaccio M.[6,7], Dunne L.[8], Lapi A.[3,5], Maddox S.J.[8], Negrello M.[8]

Universidad de Oviedo

ICTEA
Instituto Universitario de Ciencias y Tecnologías Espaciales de Asturias

[1]Departamento de Fisica, Universidad de Oviedo, C. Federico Garcia Lorca 18, 33007 Oviedo, Spain
[2]Instituto Universitario de Ciencias y Tecnologias Espaciales de Asturias (ICTEA), C. Independencia 13, 33004 Oviedo, Spain
[3]International School for Advanced Studies (SISSA), via Bonomea 265, I-34136 Trieste, Italy
[4]INFN Sezione di Trieste, via Valerio 2, I-34127 Trieste, Italy
[5]Institute for Fundamental Physics of the Universe (IFPU), Via Beirut 2, I-34014 Trieste, Italy
[6]Dipartimento di Fisica, Università di Roma Tor Vergata, Via della Ricerca Scientifica, 1, Roma, Italy
[7]INFN, Sezione di Roma 2, Università di Roma Tor Vergata, Via della Ricerca Scientifica, 1, Roma, Italy
[8]School of Physics & Astronomy, Cardiff University, The Parade, Cardiff CF24 3AA, UK

Presented by: **L. Bonavera, M.M. Cueli, J. Gonzalez-Nuevo**
Universidad de Oviedo - Instituto Universitario de Ciencias y Tecnologias Espaciales de Asturias (ICTEA)

arXiv: 2006.09185

Brief Summary

We are successfully exploiting magnification bias through cross-correlation between

- **sub-millimetre galaxies** (SMGs) observed by Herschel at $1.2 < z < 4.0$ as background sources
- **galaxies in the GAMA II survey** at $0.2 < z < 0.8$ as foreground sources

to attempt the estimation of some of the main cosmological parameters (Ω_m, σ_8, H_0).

More constraining SMGs magnification bias data can offer a complementary and decisive cosmological probe.

Context

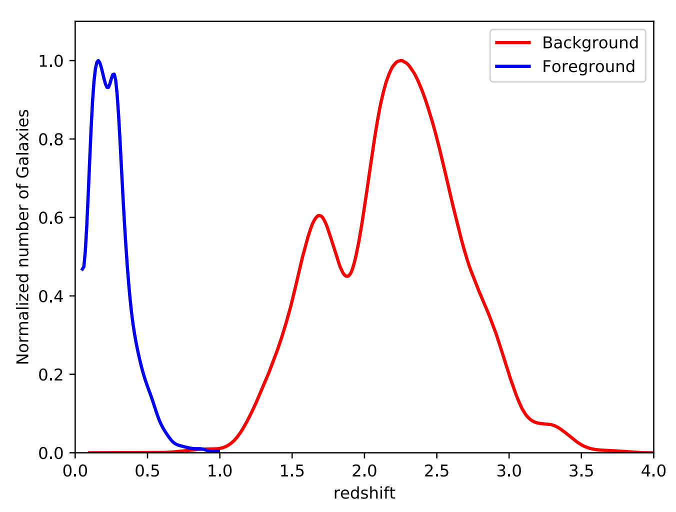
- Light rays coming from a distant source are deflected by the intervening gravitational field and the deflection amplify the flux of the background sources, increasing their chances of being included in a flux-limited sample.
    - This apparent excess number of high redshift sources seen near low redshift structures is the **magnification bias**.
- The **cross-correlation** between two source samples with non-overlapping redshift distributions is an unambiguous manifestation of magnification bias.
- An optimal choice of foreground and background samples can enhance the cross-correlation signal. In particular, **SMGs** are an optimal sample for lensing studies due to:

➢ the steep source number counts (β > 3): $N(S) = \frac{N_0}{\mu}\left(\frac{S}{\mu}\right)^{-\beta}$, where $\mu \cong 1 + 2k$

➢ high redshift (z > 1)

➢ very low cross-contamination with respect to the optical band

- Since the deflection depends on the cosmological distances, and on the galaxy halo properties, we can use these measurements to set constraints on **cosmological parameters**.



Redshift distributions of the background H-ATLAS sample (red) and the foreground GAMA sample (blue).

Methodology

- Estimated with modified version of the Landy & Szalay (1993) estimator in 62 mini-regions (mean values and their associated standard errors):

$$w_x(\theta) = \frac{D_1D_2 - D_1R_2 - D_2R_1 + R_1R_2}{R_1R_2}$$

where D_1D_2 , D_1R_2 , D_2R_1 , and R_1R_2 are the normalised data1- data2, data1-random2, data2-random1, and random1-random2 pair counts for a given separation θ.

- The model is computed adopting standard Limber (Limber 1953) and flat-sky approximations (Kilbinger et al. 2017):

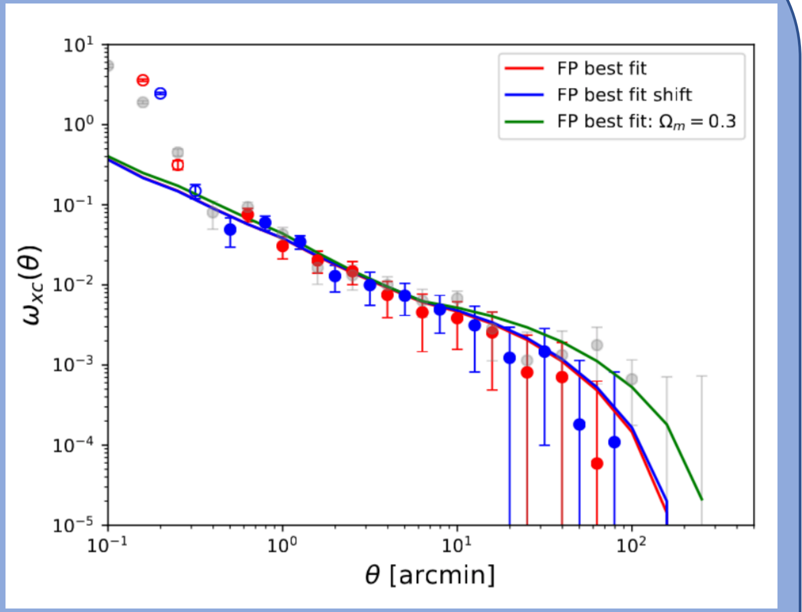
$$w_{fb} = 2(\beta - 1)\int_0^{z_s} \frac{dz}{\chi^2(z)}\frac{dN_f}{dz} W^{lens}(z) \int_0^{\infty} \frac{l dl}{2\pi} P_{gal-dm}\left(\frac{l}{\chi^2(z)}, z\right) J_0(l\theta)$$

unit-normalized foreground redshift distributions

lensing kernel

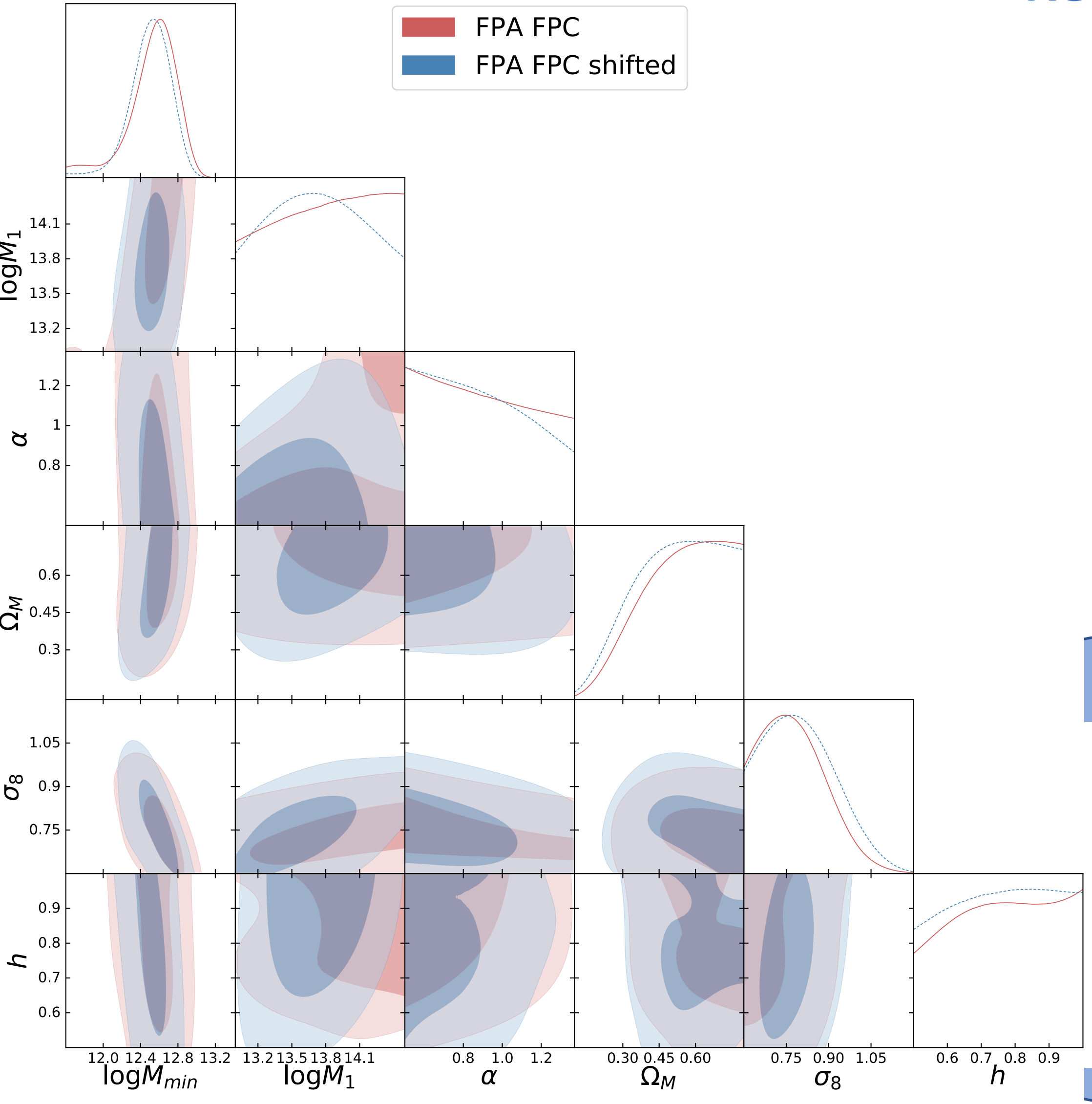
cross-spectrum between the galaxy and dark matter distributions

- The estimation of parameters is performed with a MCMC analysis (at least 60000 posterior samples) and flat priors.



Cross-correlation data computed on Herschel SMGs and GAMA galaxies: grey points by Gonzalez-Nuevo 2017, red and blue by Bonavera 2020 (larger area). The solid lines are the best fit of the two data-sets (red and blue). The green line is the best fit to the red case, but adopting Ω_m = 0.3.

Results - Ω_m σ_8 H_0



- lower bound on $\Omega_m > 0.24$ at 95% CL

Since Ω_m was allowed to vary in the range [0.1-0.8], this lower bound is a very robust conclusion against the choice of priors.

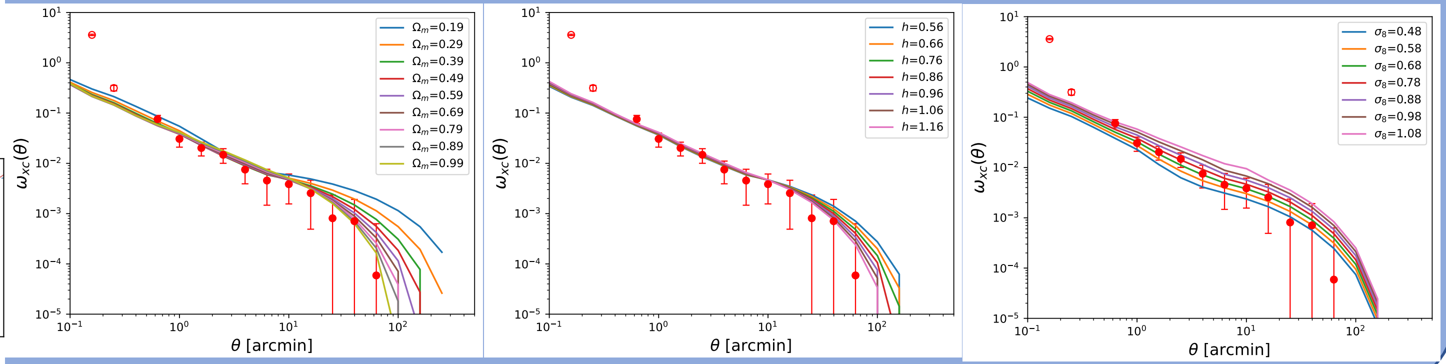
- interesting upper limit of $\sigma_8 \lesssim 1$ at 95% CL

Tentative peak on σ_8 around 0.75.

- mild preference towards higher H_0 values.

H_0 parameter is still not accurate.

Dependency of the cross-correlation function with each of the cosmological parameters.

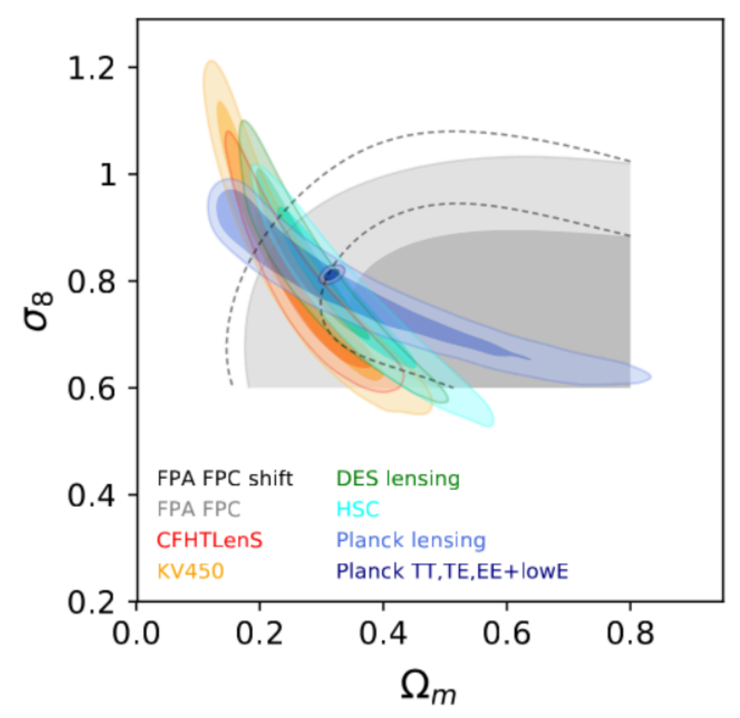


MCMC posterior distributions, obtained with **flat priors** with the two cross-correlation data sets.

Results – comparison with other results

On Ω_m- σ_8 :

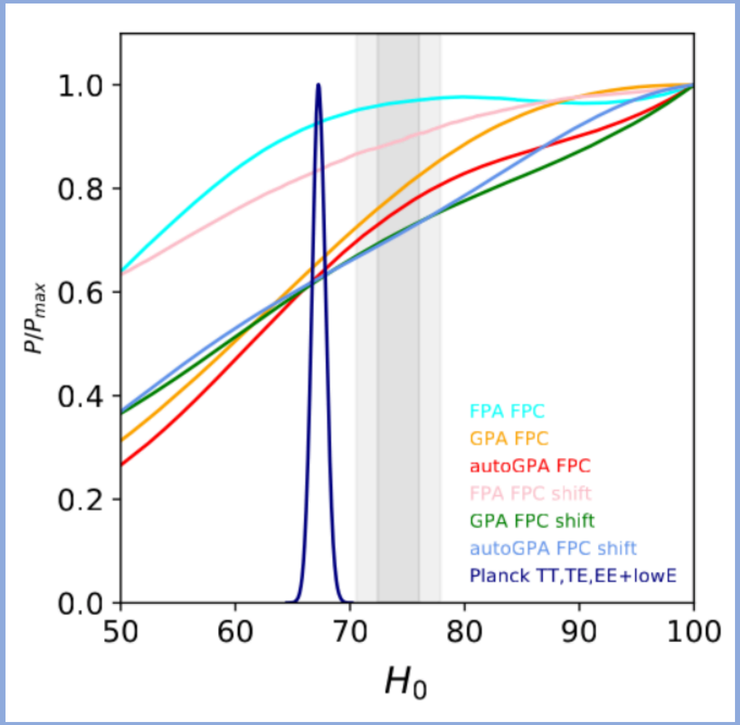
- Our lower/upper bounds still imposes restrictions to the other weak lensing results.



Ω_m-σ_8 plot comparing our results (grey and black countours) with *Planck* (blue and dark blue for the lensing and all *Planck* cases), CFHTLens (red), KV450 (orange), DES lensing (green) and HSC (cyan)

On H_0:

- Due to the current large error bars the results are still inclusive of both *Planck and* Riess et al. (2019) results.



Posterior distributions on H_0 using the two data sets and different priors. Results from Riess et al. 2019 and *Planck* are also shown.

Future

- Any method that constrains cosmological parameters using a new set of observables is worth pursuing in the effort to resolve the tensions. Our current constraints from the magnification bias are not yet competitive, but the use of new independent observables makes it a **valuable technique**.

- Remarkably, our results do not show the typical degeneracy that characterises the cosmic shear results: future, more constraining, SMGs magnification bias data can offer a **complementary cosmological probe**.

- Improvements are expected by **reducing the error-bars** on the cross-correlation measurements, especially on larger scales where the Ω_m and H_0 parameters mostly affect the cross-correlation function. In order to achieve this, the statistics can be increased enlarging both the lenses and the background source samples.

- Moreover, a **tomographic analysis** might help in better constrain of the cosmological parameters. Dividing the sample into redshift bins might counterbalance the increase of error-bars by easier constraining of the cosmological parameters: only sources with very similar redshift and the known evolution of the cosmological parameters are being taken into consideration.