CROSS-CORRELATING PLANCK CMB LENSING WITH HIGH-z SUB-MM H-ATLAS GALAXIES

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I. MOTIVATIONS

We present the first measurement of the correlation between the map of the CMB lensing potential derived from the Planck nominal mission data and $z \gtrsim 1.5$ galaxies detected by the Herschel-ATLAS (H-ATLAS) survey covering about 600 deg^2 ($f_{\rm sky} \simeq 0.014$).
CMB photons trajectories are gravitationally deflected by dark matter haloes along the line-of-sight that host galaxies. The study of cross-correlations between CMB lensing with other tracers of large scale structure allows us to:

cosmology: reconstruct the dynamics and spatial distribution of the cosmological gravitational potentials, tightening constraints on the dynamics of the dark energy at the onset of cosmic acceleration

astrophysics: derive the cosmic bias b, hence the effective halo masses associated to the tracer populations

systematics: uncover new systematics affecting the datasets

Since the CMB lensing efficiency is maximum at $z \sim 1.5-2$ (see Fig. 2), it represents a powerful probe of the dusty, violently star-forming galaxies, thought to be the progenitors of local massive elliptical galaxies (Lapi et al. 2011), as their redshift distribution peaks around these redshifts.

II. DATASETS

Planck: We use the publicly released Planck CMB lensing potential map $\hat{\phi}$ based on a minimum variance combination of the 143 and 217 GHz temperature anisotropy maps only and convert it to a convergence map ($\hat{\kappa} = \frac{1}{2}\nabla^2\hat{\phi}$) as well as the set of 100 lensing maps reflecting Planck noise properties (Planck Collaboration XVII 2014)

Herschel: We create a catalogue using H-ATLAS survey data collected from 100 to 500 μm bands, extracting the high-z population adopting selection criteria from Gonzalez-Nuevo et al. (2012). Our sample comprises all sources ($N_g \simeq 10^5$) with photo-z $z \geq 1.5$. The survey area is divided into five fields: three equatorial fields (GAMA fields, G09, G12 and G15), the North and South Galactic Pole (NGP and SGP).

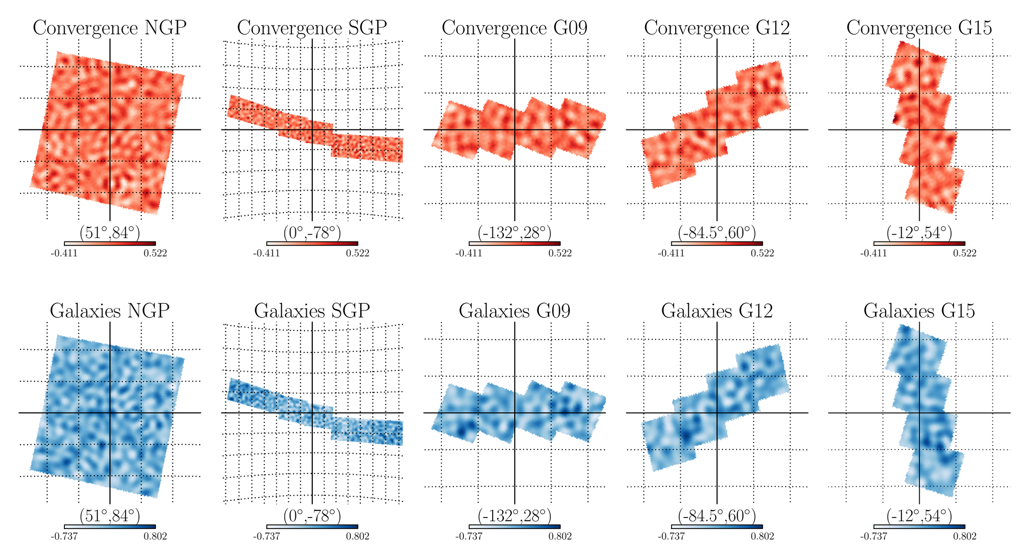

Figure 1: *Top panel*: CMB convergence maps κ. *Bottom panel*: Galaxy overdensity maps g. All maps are at $N_{\rm side} = 512$ resolution.

III. CROSS-CORRELATION FORMALISM

The lensing convergence κ along a line-of-sight and the galaxy density fluctuations g can be expressed as an integral over the fractional overdensity of matter $\delta(\chi(z)\hat{\mathbf{n}}, z)$ weighted by the corresponding kernel $W^{\kappa,g}(z)$.
Theory Cross-power spectrum (Limber $\rightarrow \ell \gtrsim 20$):

$$C_\ell^{\kappa g} = \int_0^{z_*} \frac{dz}{c} \frac{H(z)}{\chi^2(z)} W^\kappa(z) W^g(z) P\Big(k = \frac{\ell}{\chi(z)}, z\Big),$$

where $P(k,z)$ is the matter power spectrum.

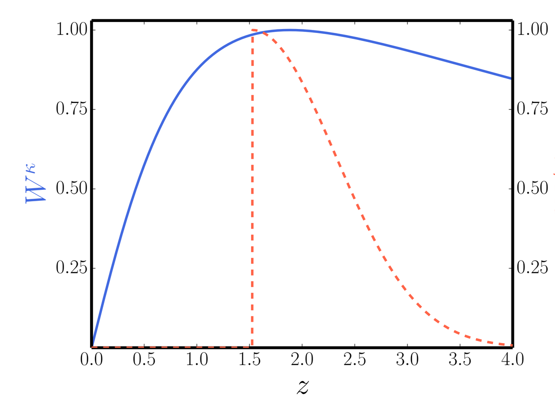

Figure 2: Estimated redshift distribution of the H-ATLAS galaxies sample (dashed red line) compared with the CMB lensing kernel W^κ (blue solid line)

IV. RESULT: CMB LENSING- GALAXY CROSS-SPECTRUM

- We measure the cross-power $C_\ell^{\kappa g}$ within the regions covered by the H-ATLAS survey using a pseudo-C_ℓ estimator based on the MASTER algorithm (Hivon et al. 2002) and bin it in seven linearly spaced bandpowers between $100 < \ell < 800$ (see Fig. 3)
- Error bars are estimated cross-correlating 500 Monte Carlo realizations of simulated CMB convergence maps (consisting of signal and noise) with the real H-ATLAS galaxy density map; uncertainties are checked using Planck real lensing map and set of 100 realistic simulated noise maps (see Fig. 4)
- $\chi^2_{\rm null}/\nu = 11.9$ for $\nu = 7$ degrees of freedom, corresponding to a no correlation hypothesis rejection at a 20σ significance
- As a null test we cross-correlate the simulated galaxy maps with Planck κ map and vice versa, recovering signal consistent with null (see Fig. 4)

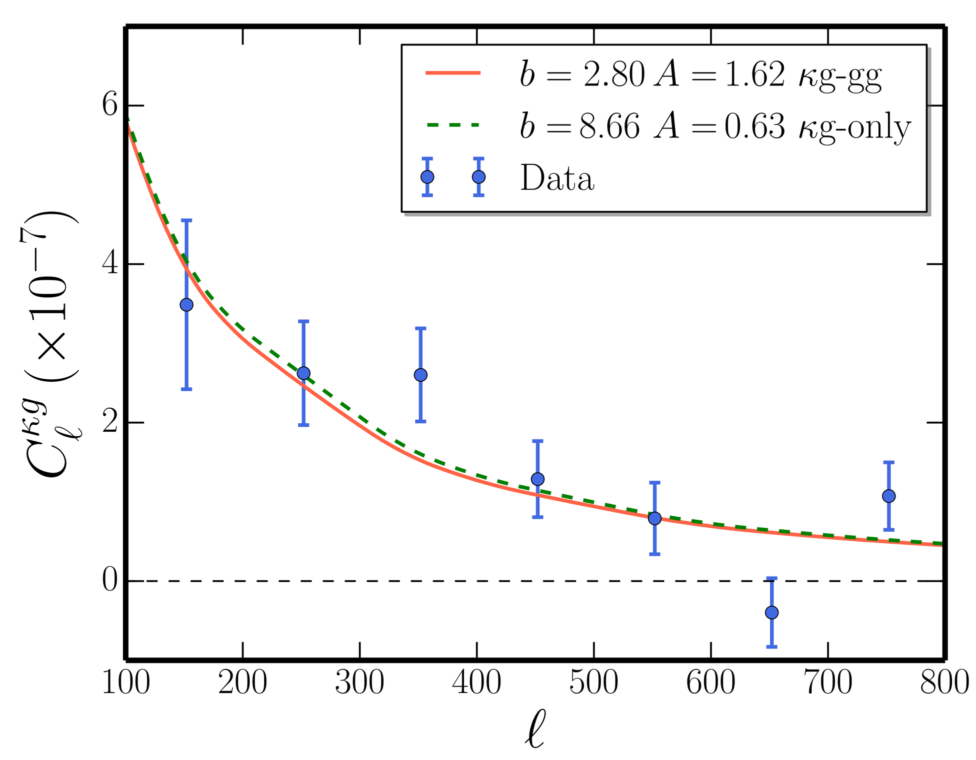

Figure 3: The CMB convergence - galaxy density cross-spectrum as measured from Planck and Herschel data. The null (no correlation) hypothesis is rejected at the 20σ level.

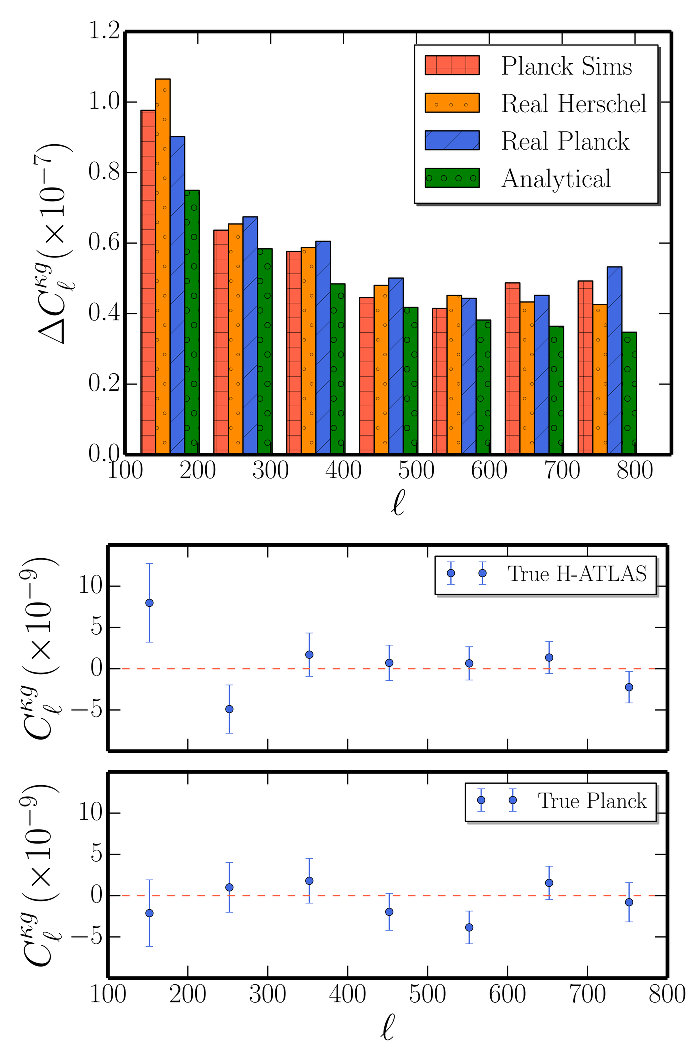

Figure 4: *Top panel:* Comparison of error estimates for the cross-power spectrum bandpowers. *Bottom panel:* Null tests performed.

V. MEASURING GALAXY BIAS

Using a Bayesian approach, we fix cosmology to ΛCDM and derive constraints on bias b and on a nuisance parameter A that scales theory $C_L^{\kappa g}$ and data $\hat{C}_L^{\kappa g}$ as $\hat{C}_L^{\kappa g} = A C_L^{\kappa g}(b)$. Combining cross-correlation and clustering data we find an effective bias $b = 2.80^{+0.12}_{-0.11}$ and $A = 1.62 \pm 0.16$. Significance is computed as $A/\sigma_A \simeq 10$, corresponding to a 10σ detection.

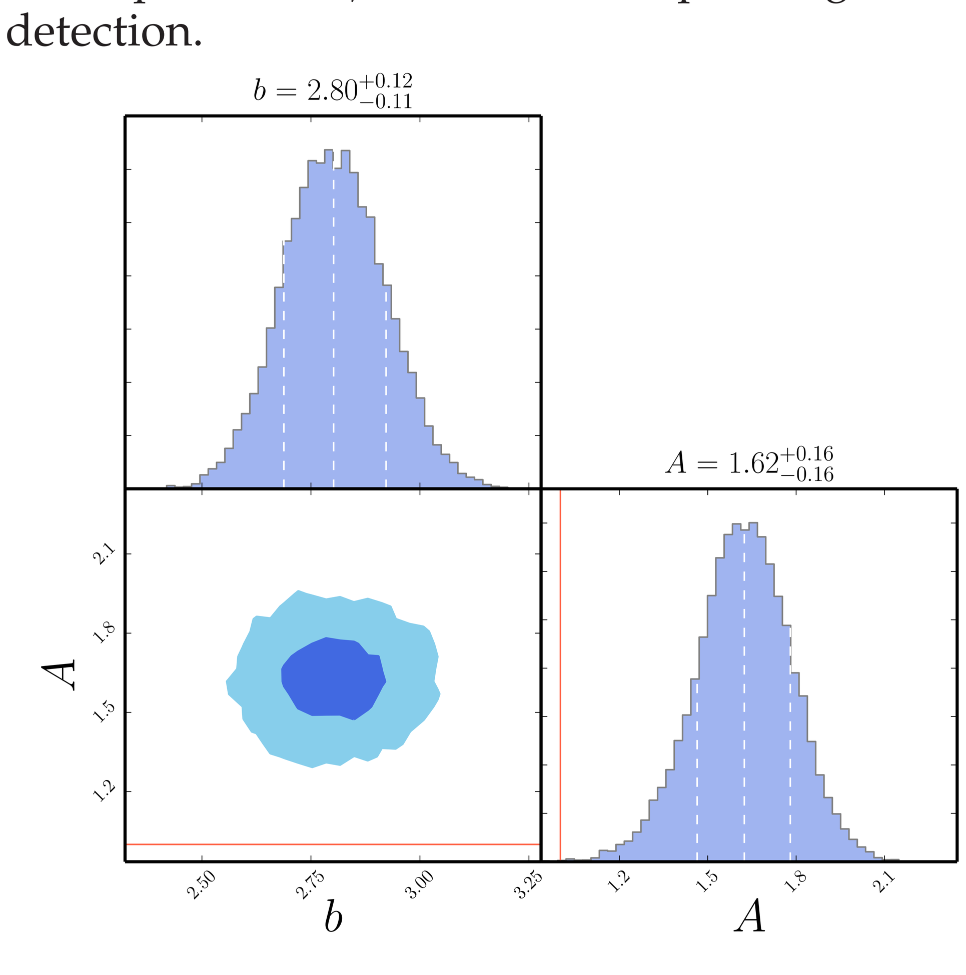

Figure 5: Posterior distribution in the b − A plane with the 68% and 95% confidence contours.

VI. ASTROPHYSICAL SYSTEMATICS

- Magnification bias by weak lensing is substantial for our galaxy sample (Gonzalez-Nuevo et al. 2014) and responsible for part of the observed signal; its impact on cross-spectrum is more prominent than on galaxy auto power spectrum
- Neglecting errors on photometric redshift estimates we find $A = 1.70^{+0.16}_{-0.17}$, consistent within 1σ
- Considering a redshift dependent bias factor would change constraints by $\simeq 6\%$
- CIB leakage emission into the lensing map through the temperature ones used for the lensing estimation may bias our measurements

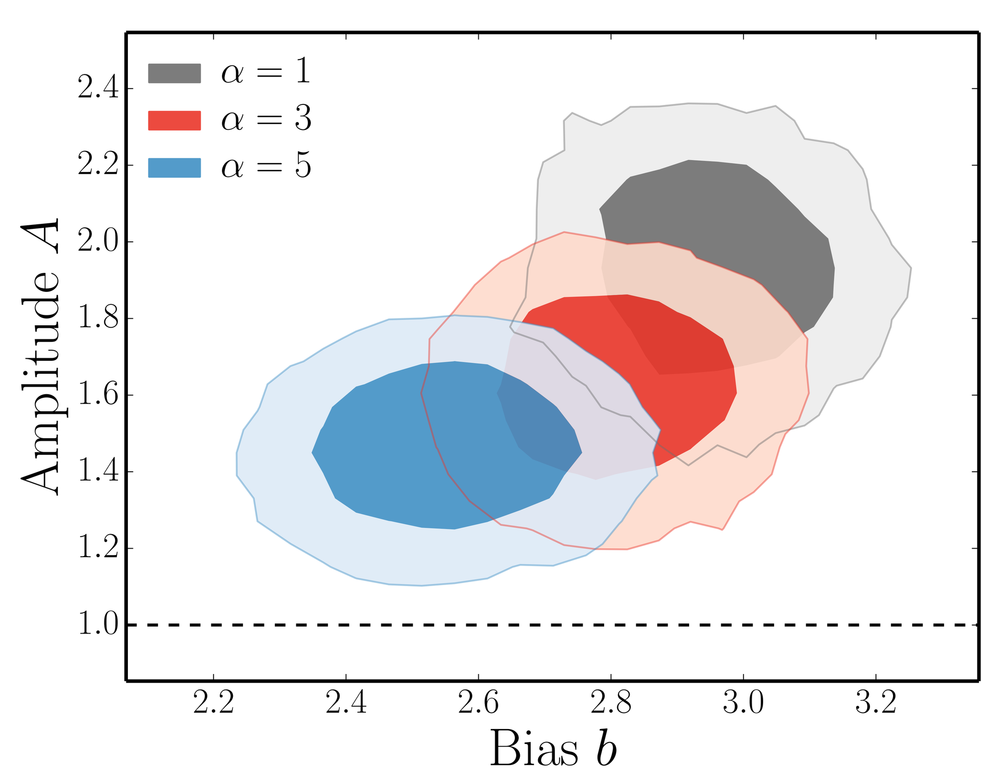

Figure 6: Effect of fixed slope of number counts α on the inferred values of cross-correlation amplitude A and bias b: we measure $\alpha \simeq 3$ for our sample and use it as baseline value.

VII. CONCLUSIONS

✓ We claim detection of Planck CMB lensing - sub-mm H-ATLAS galaxies at 10σ level

✓ The combination of clustering and cross-correlation data yields a bias of sources $b = 2.80^{+0.12}_{-0.11}$ close to theoretical expectations

! Pure cross-correlation data reveals excess signal at $\sim 3-4\sigma$ level which is being investigated in terms of unresolved systematics

∗ **Future plans:** Planck 2014/2015; high-sensitivity and resolution CMB lensing data from sub-orbitals; tomographic analysis of large-scale simulations and data; cosmological constraints

MAIN REFERENCES

[1] Lapi *et al.* *ApJ*, 742:24, 2011.
[2] Planck Collaboration, XVII. *A&A*, 571:A17, 2014.
[3] González-Nuevo *et al.* *ApJ*, 749:65, 2012.
[4] Hivon *et al.* *ApJ*, 567:2–17, 2002.
[5] González-Nuevo *et al.* *MNRAS*, 442:2680–2690, 2014.