Cross-correlation science with COrE/PRISM

Paolo Serra
IAS - Universite' Paris Sud

COrE/PRISM workshop for a M4 ESA mission

Cross-correlation among dark matter tracers

- The measurement can be used to isolate and analyze a small redshift range in one observable if the other source is limited in redshift
- Measurement is not prone to systematics that are not correlated among datasets ~> a strong signal even in presence of strong contamination in each dataset
- The cross-correlation between tracers A and B can be modeled as:

$$C_{AB}(l) = \int_0^\infty d\chi \frac{g_A(\chi)\, g_B(\chi)}{\chi^2} \mathcal{P}_\delta \left(\frac{l}{\chi}, \chi \right)$$

g is the source term: encodes how each observable is related to the dark matter field

- **CMB lensing:**

$$g_\kappa(\chi) \equiv \frac{3\Omega_m H_0^2}{2c^2} \frac{D(\chi) D(\chi_{\rm CMB} - \chi)}{D(\chi_{\rm CMB})\, a(\chi)}$$

- **galaxy/CIB fields:**

$$g_{\delta,j}(\chi) \equiv \eta(\chi)\, b_j$$

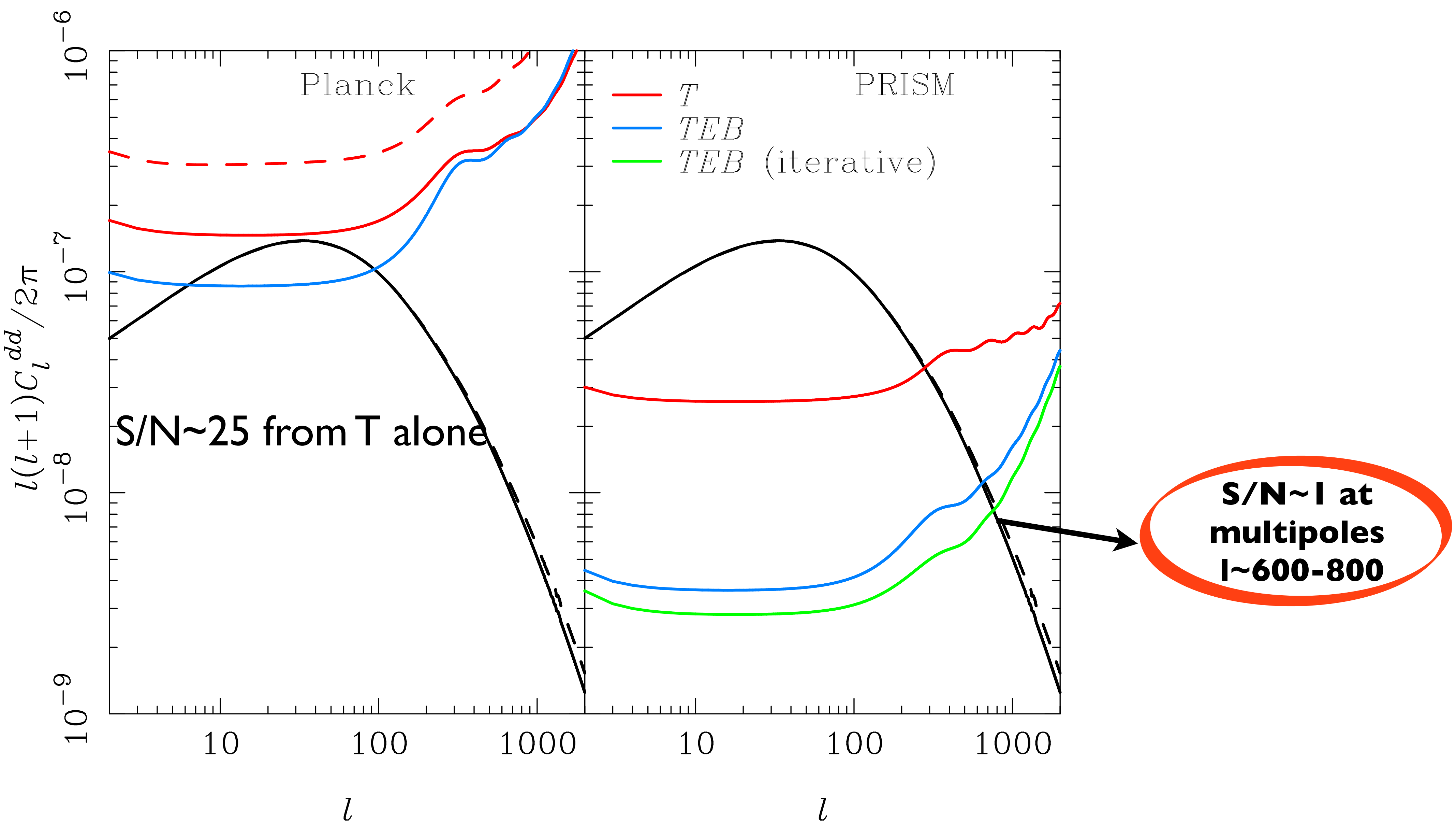
$$\eta(\chi) = \frac{dN_g(\chi)}{d\Omega}$$ **redshift distr. for galaxy field**

$$\eta(\chi) \propto \frac{dj_\nu(\chi)}{d\Omega}$$ **emissivity for CIB field**

Many cross-x among different dark matter tracers

CMB x CMB	kCMB x CMB	CIB x CMB	LSS x CMB
CMB x kCMB	kCMB x kCMB	CIB x kCMB	LSS x kCMB
CMB x CIB	kCMB x CIB	CIB x CIB	LSS x CIB
CMB x LSS	kCMB x LSS	CIB x LSS	LSS x LSS

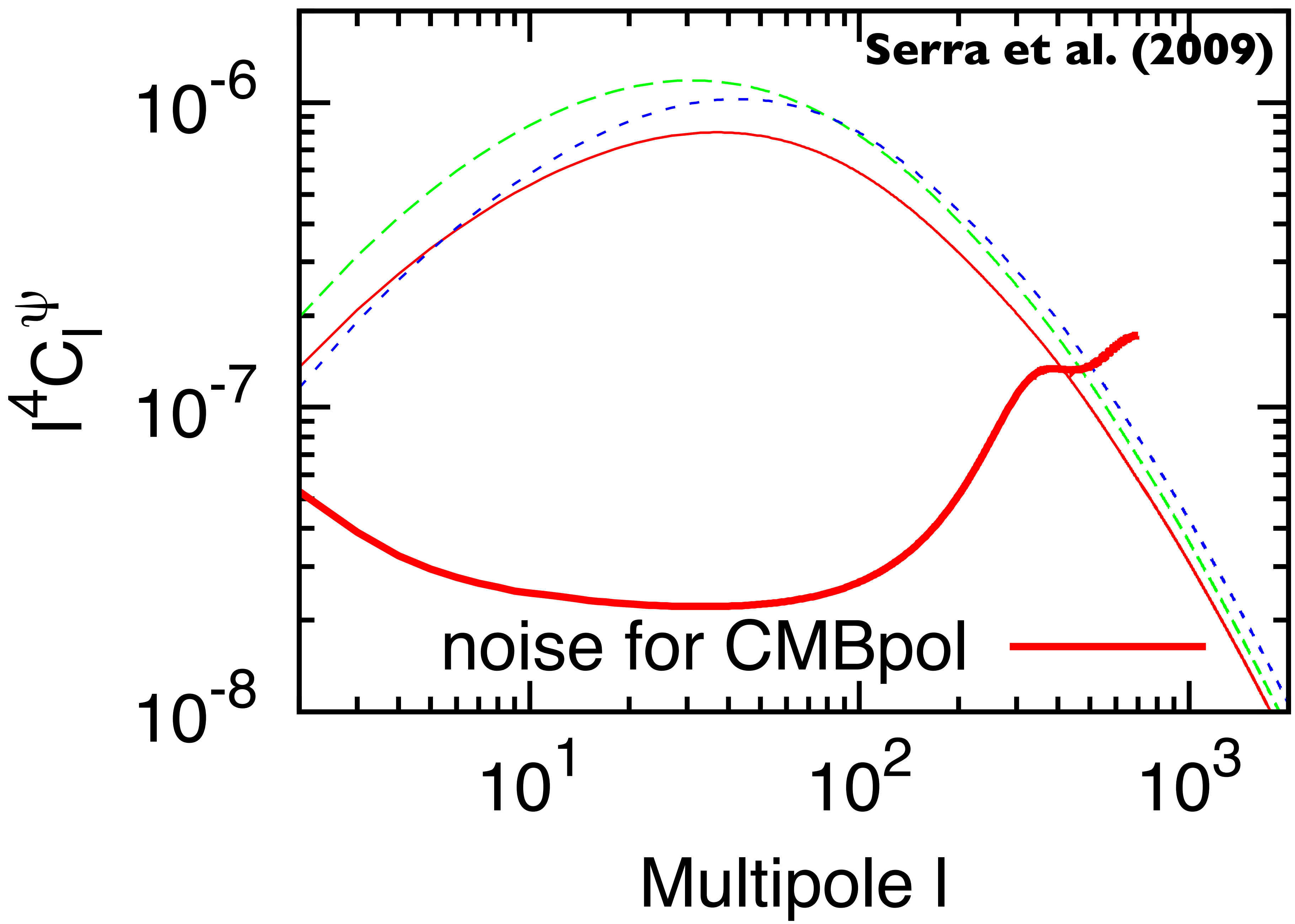
Lensing Power spectrum from PRISM



- **Auto-power spectrum**: Science case already very rich: constraints on neutrino masses, and not only that
- **Cross-power spectra**: Map is a weighted projection of the gravitational field over the visible universe with peak sensitivity in 1<z<3 ~> significant correlation with many other tracers of the dark matter field, with possibility of tomographic studies

Not only neutrino masses from lensing: strong constraints on modified gravity models from lensing data alone

$$\psi(\tau,\,\vec{x}) = [1 + \varpi(\tau, x)] \times \phi(\tau,\,\vec{x})$$

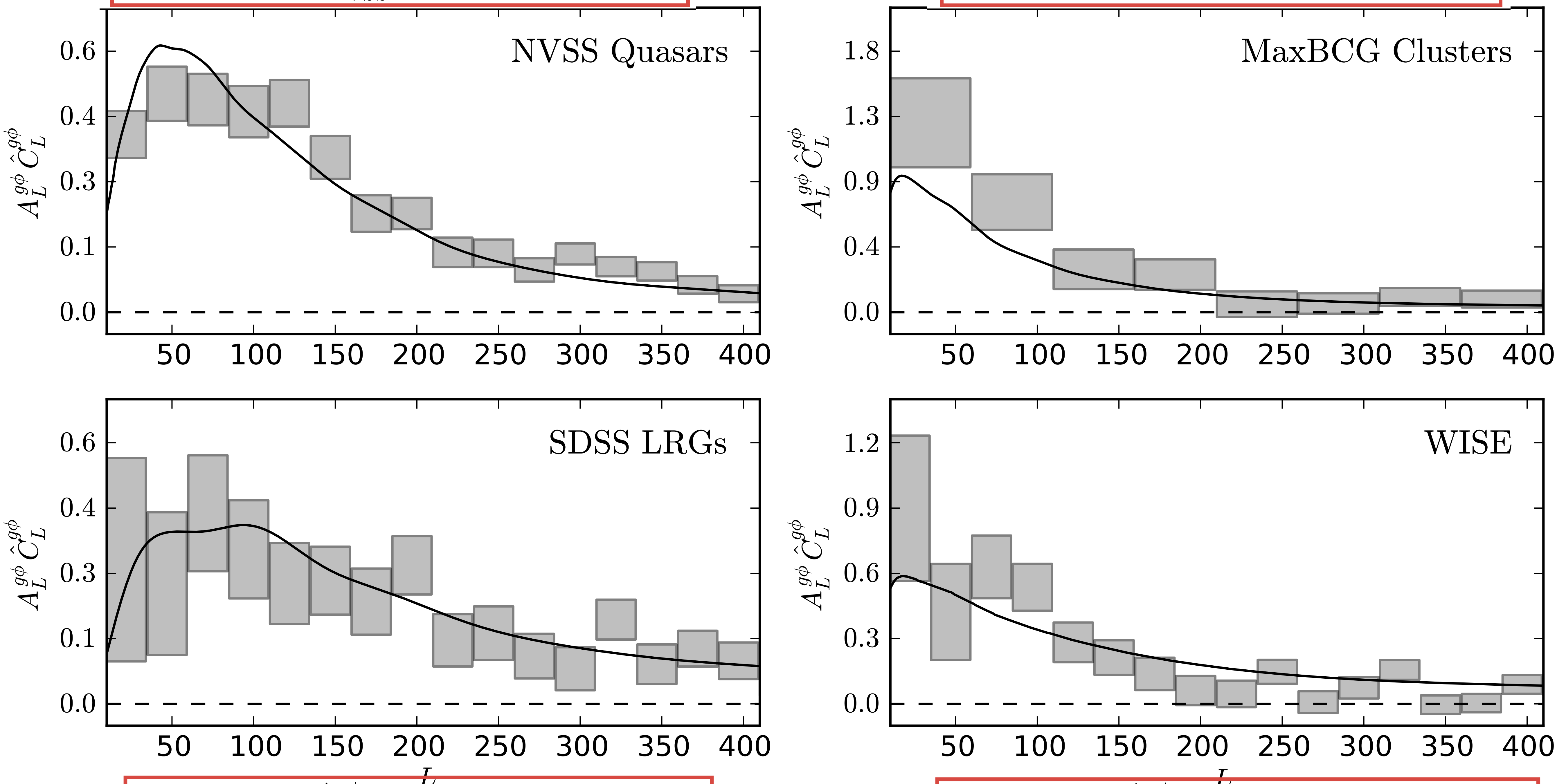


CMB lensing - Galaxy surveys correlations

Planck collaboration XVII

$b(z) = 1.7 \rightarrow \hat{A}^{g\phi}_{\rm NVSS} = 1.03 \pm 0.05$ $(\approx 20\sigma)$

$b(z) = 3 \rightarrow \hat{A}^{g\phi}_{\rm MaxBCG} = 1.54 \pm 0.21$ $(\approx 7\sigma)$



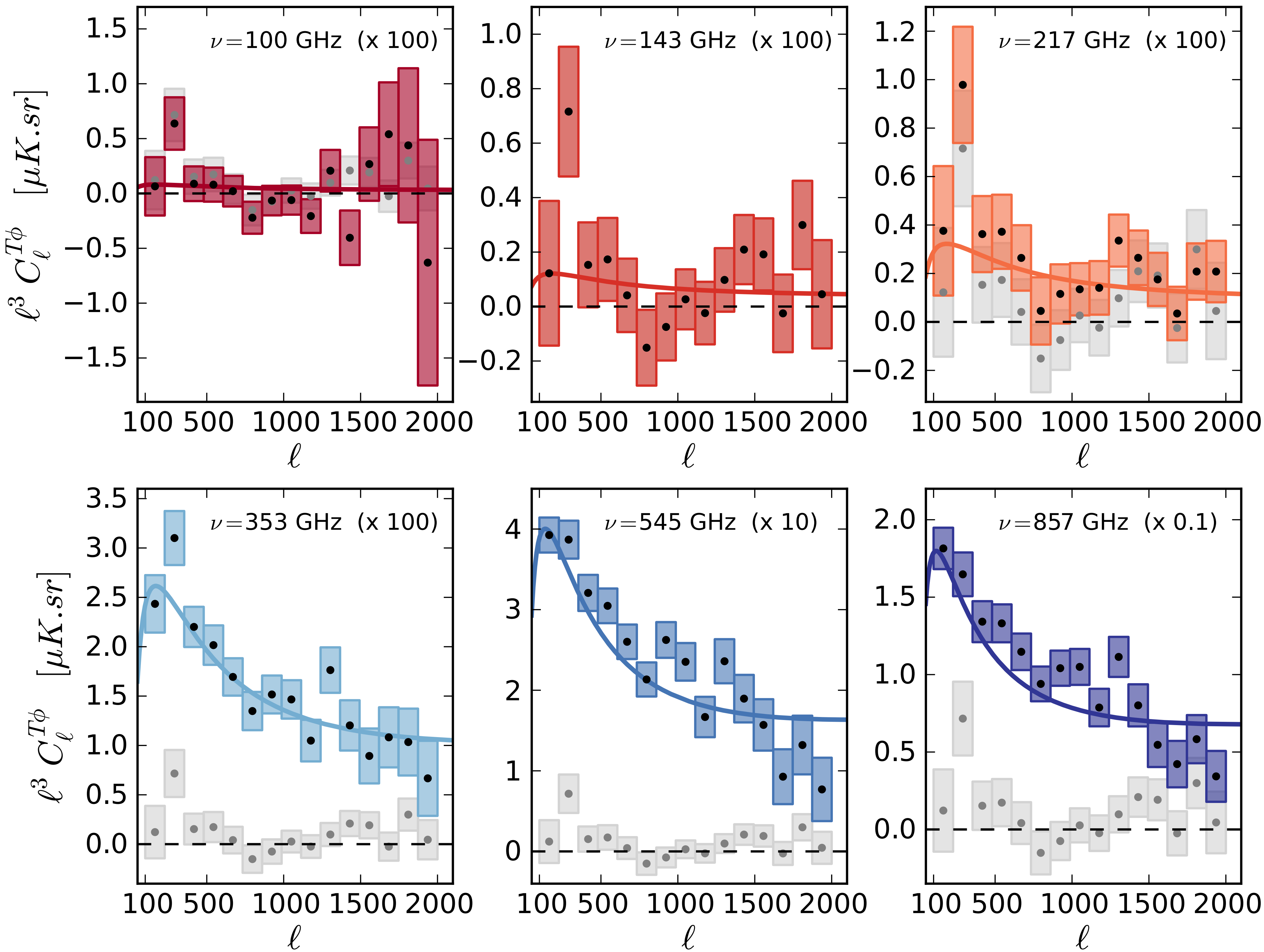
$b(z) = 2 \rightarrow \hat{A}^{g\phi}_{\rm LRGs} = 0.96 \pm 0.10$ $(\approx 10\sigma)$

$b(z) = 1 \rightarrow \hat{A}^{g\phi}_{\rm WISE} = 0.97 \pm 0.13$ $(\approx 7\sigma)$

Constraints on the bias(z), at the percent level for multiple sources in multiple redshift bins is important per se (tests of galaxy formation theories, f_NL, etc…) but also useful to break degeneracies in future surveys (see Vallinotto (2013))

CMB lensing - CIB correlations detected at more than 50σ

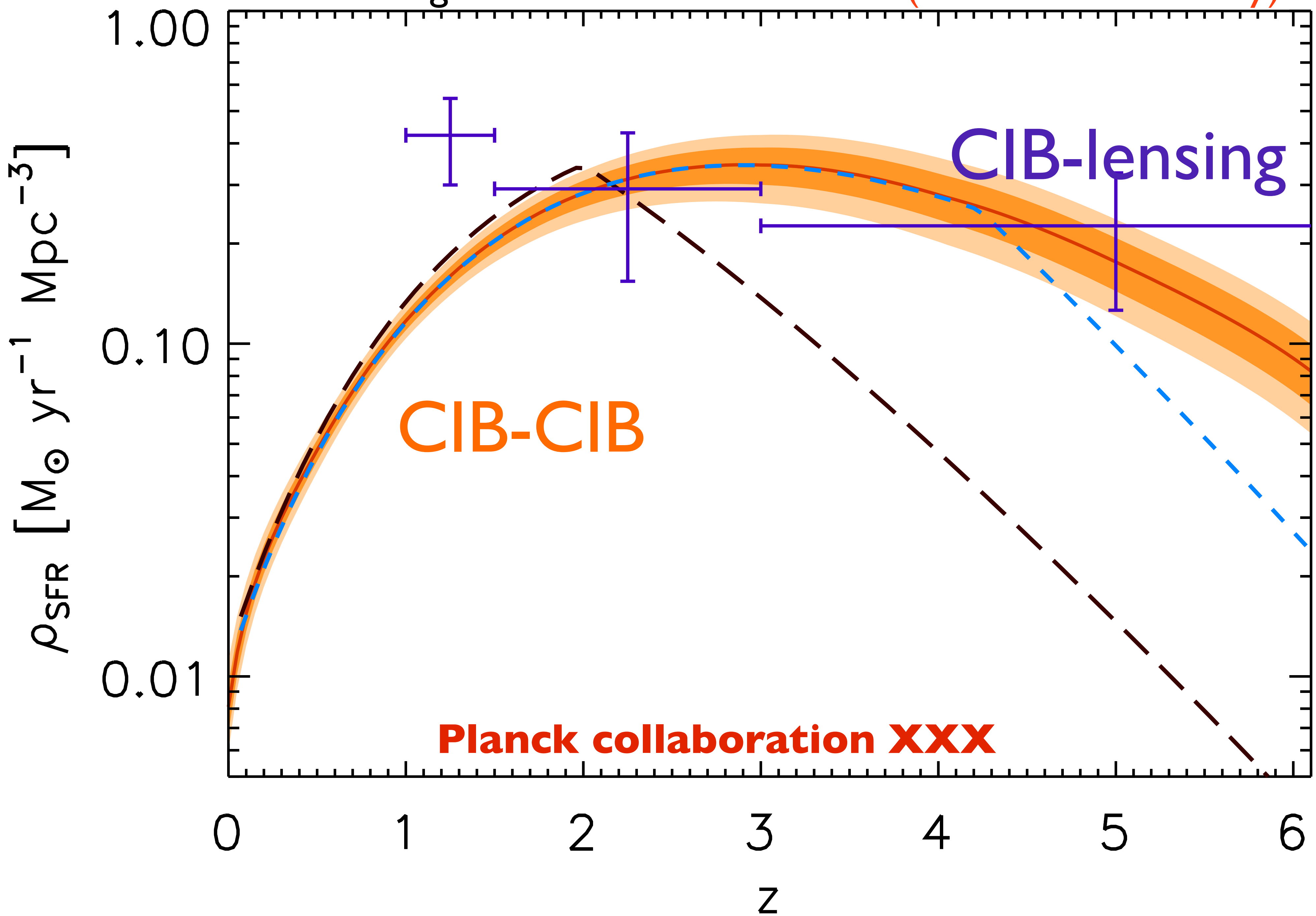
Planck collaboration XVIII



Constraints on the CIB bias x emissivity j(z)

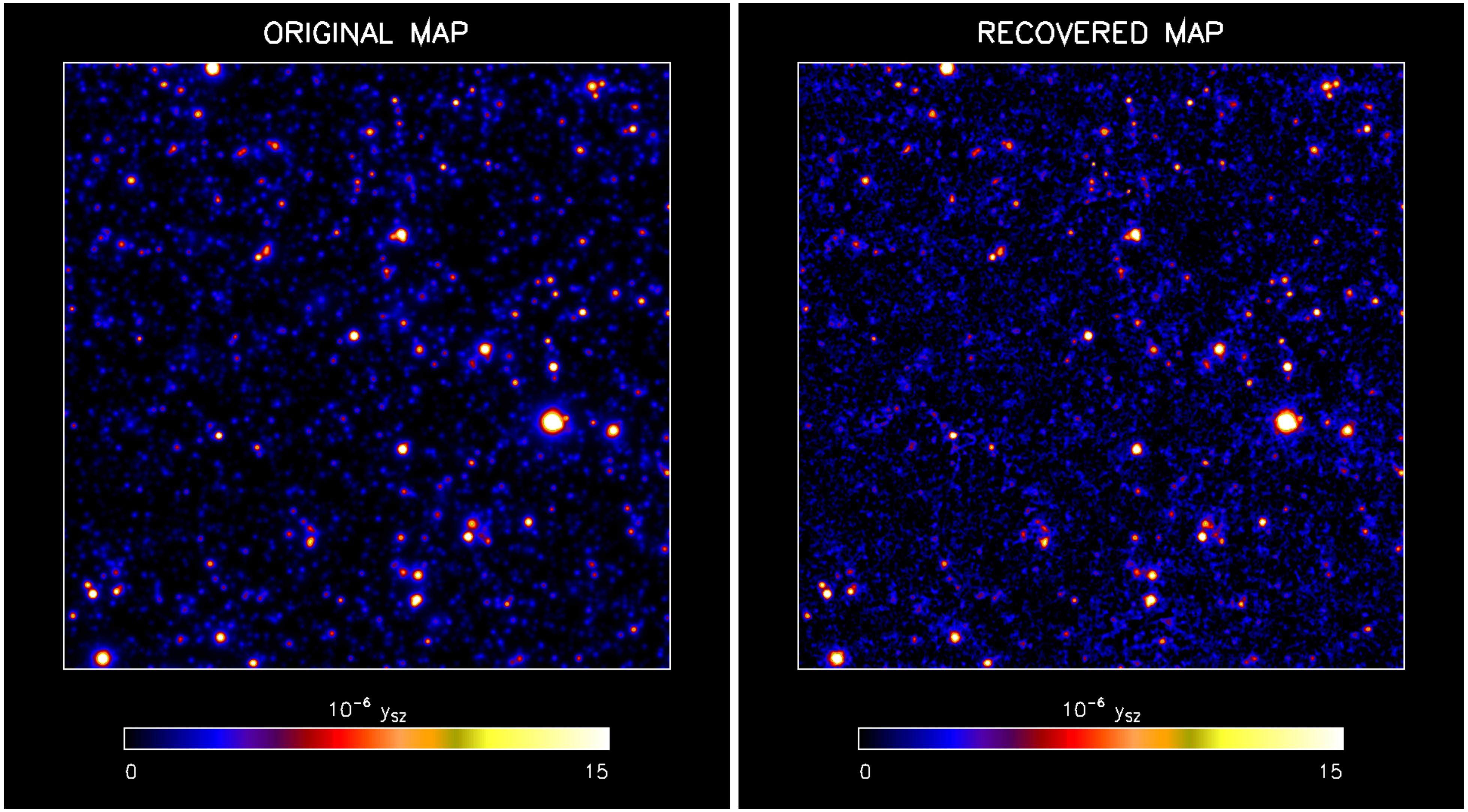
Constraints on high-z Star Formation History

CMB lensing x CIB allows to constrain (bias x CIB emissivity)



- PRISM great frequency coverage and sensitivity will allow to strongly constrain CIB models and especially the star formation history at high redshift
- Strongest constraints might come from CIBxCIB data, while CMB lensing x CIB will give a complementary probe of CIB clustering and emissivity

CMB lensing - Clusters correlation

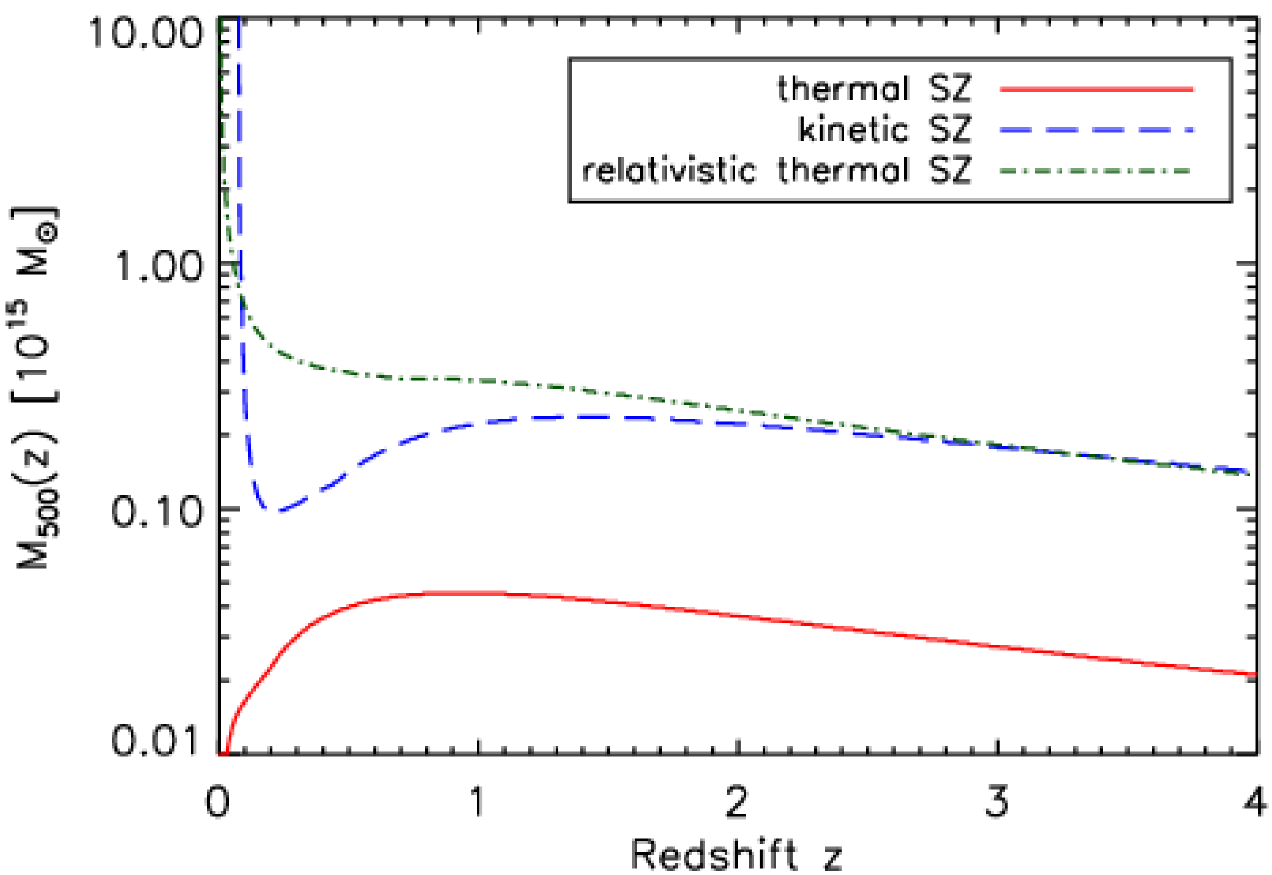


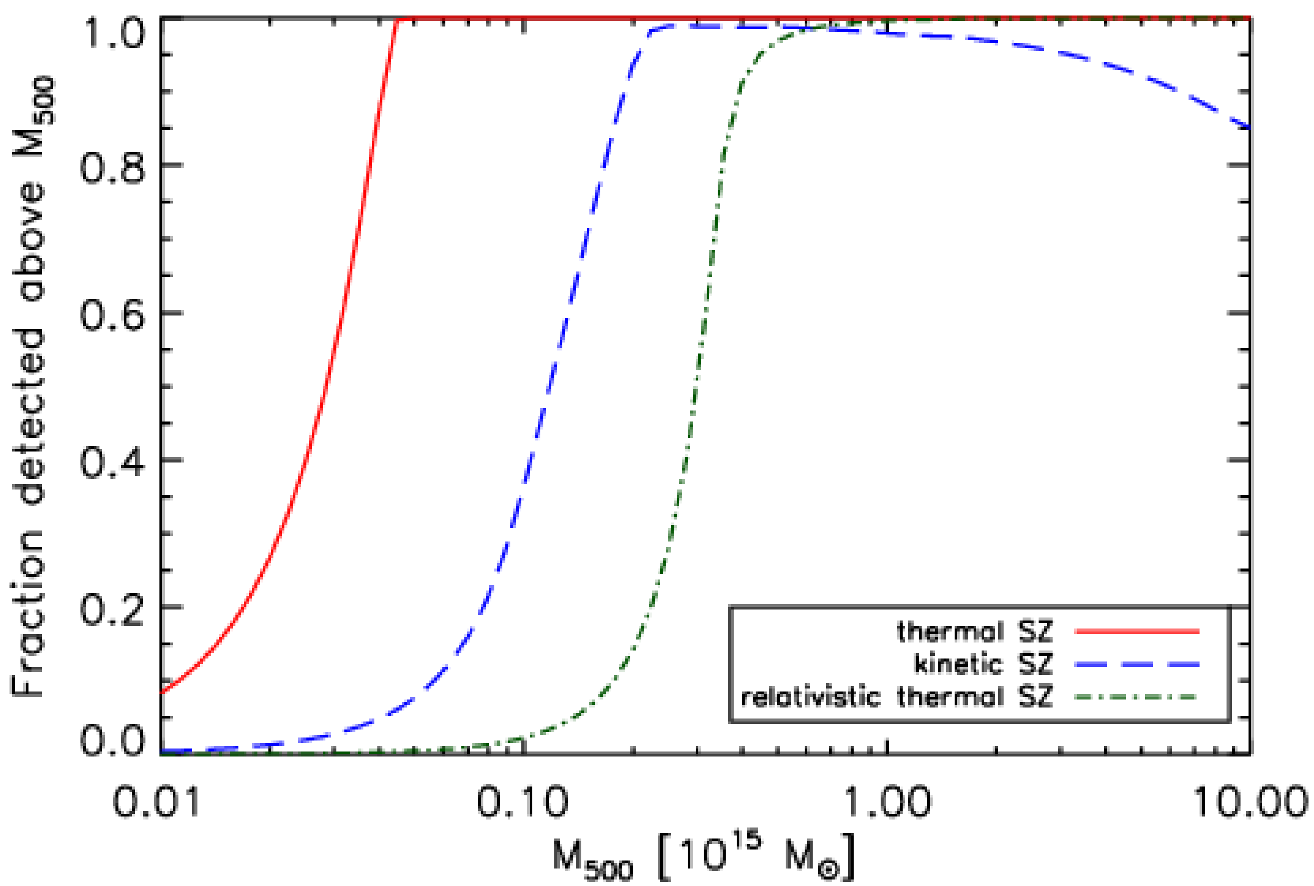
- Prism will find about 10^6 clusters (through tSZ effect), 10 times more than eROSITA and Euclid, many thousands at z > 2, all clusters in the Universe with M>5x10^13 M⊙. Main problem in is to calibrate the mass-observable relation

- Correlation of cluster detections through tSZ with CMB lensing will allow to:
1) calibrate cluster scaling laws (also possible synergies with Euclid's to measure cluster masses up to z~1) ~>Strong constraints on dark energy models (sensitive to dN/dM/dV/dz through a combination of geometrical and clustering effects)
2) Compton Ymap x CMB lensing to constrain **cluster bias** and **physics of the ICM**

Dark matter tracers - cluster correlations through kSZ

$$\frac{\delta T}{T_0}(\hat{\boldsymbol{n}}) = -\int dl\,\sigma_{\mathrm{T}}\,n_{\mathrm{e}}\frac{\boldsymbol{v}_{\mathrm{e}}\cdot\hat{\boldsymbol{n}}}{c}$$





- Prism will obtain velocity measurements for 2~10^5 clusters out to the highest redshift
- in GR the velocity - mass relation is fixed but it is violated in modified gravity theories
- Comparing velocities with mass concentrations from Euclid lensing and other tracers of the dark matter filed will allow strong tests of GR

- CMBxCIB: using PRISM IR galaxy catalog for detection of ISW at high z ~> constraints on early dark energy models
- CIBxLSS: constraints on IR models and bias. Cross check results coming from CIBxCIB only
- CMB lensing x Ly-α
- you name it...

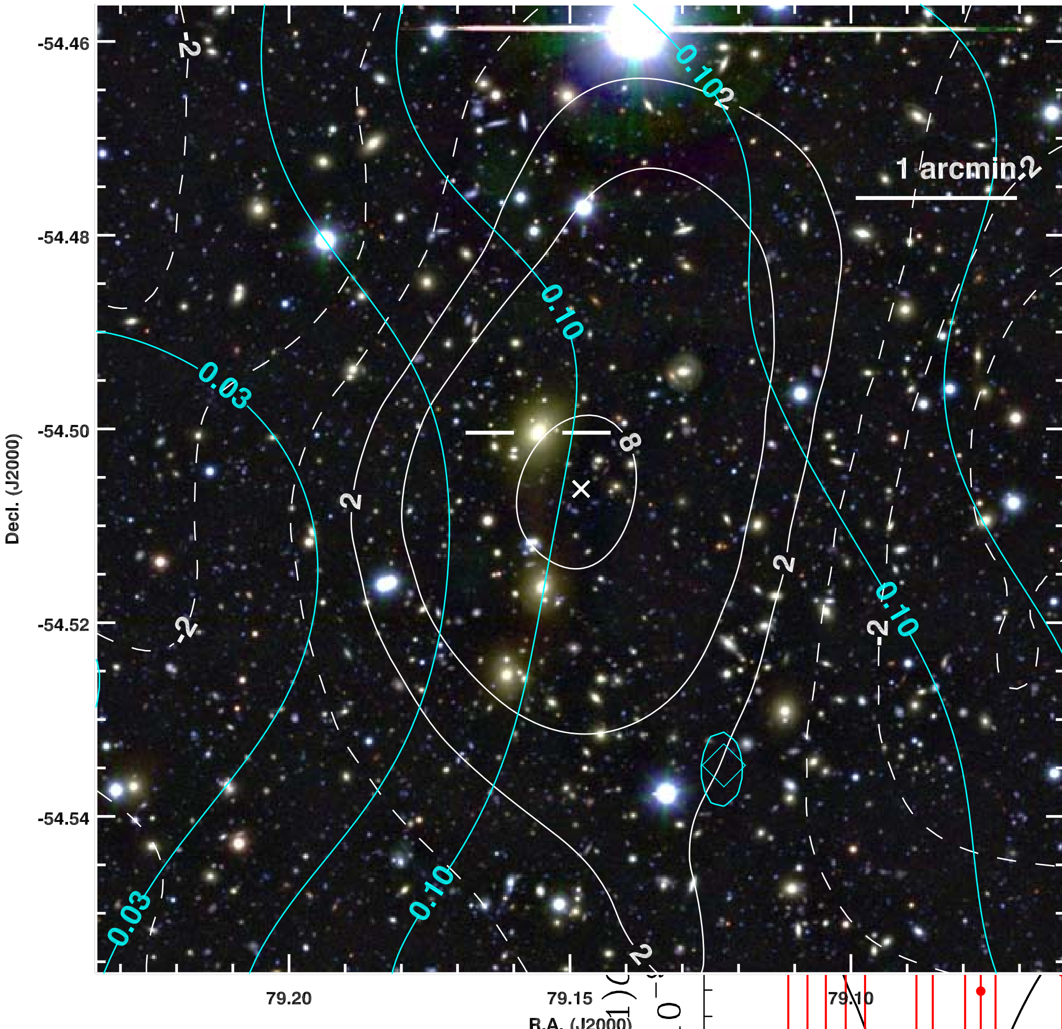
- The end

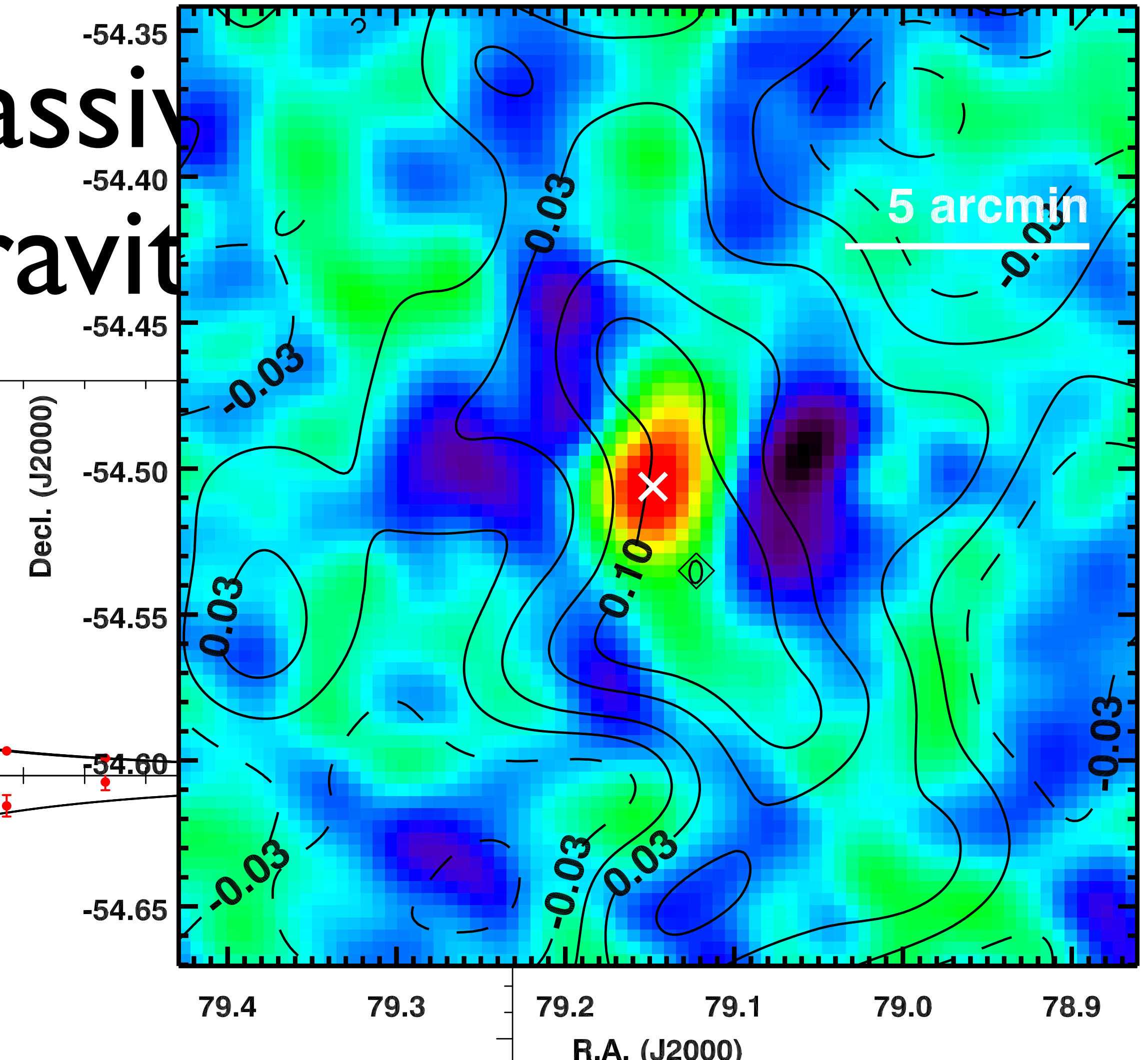
ISW from CIB-CMB cross-correlations

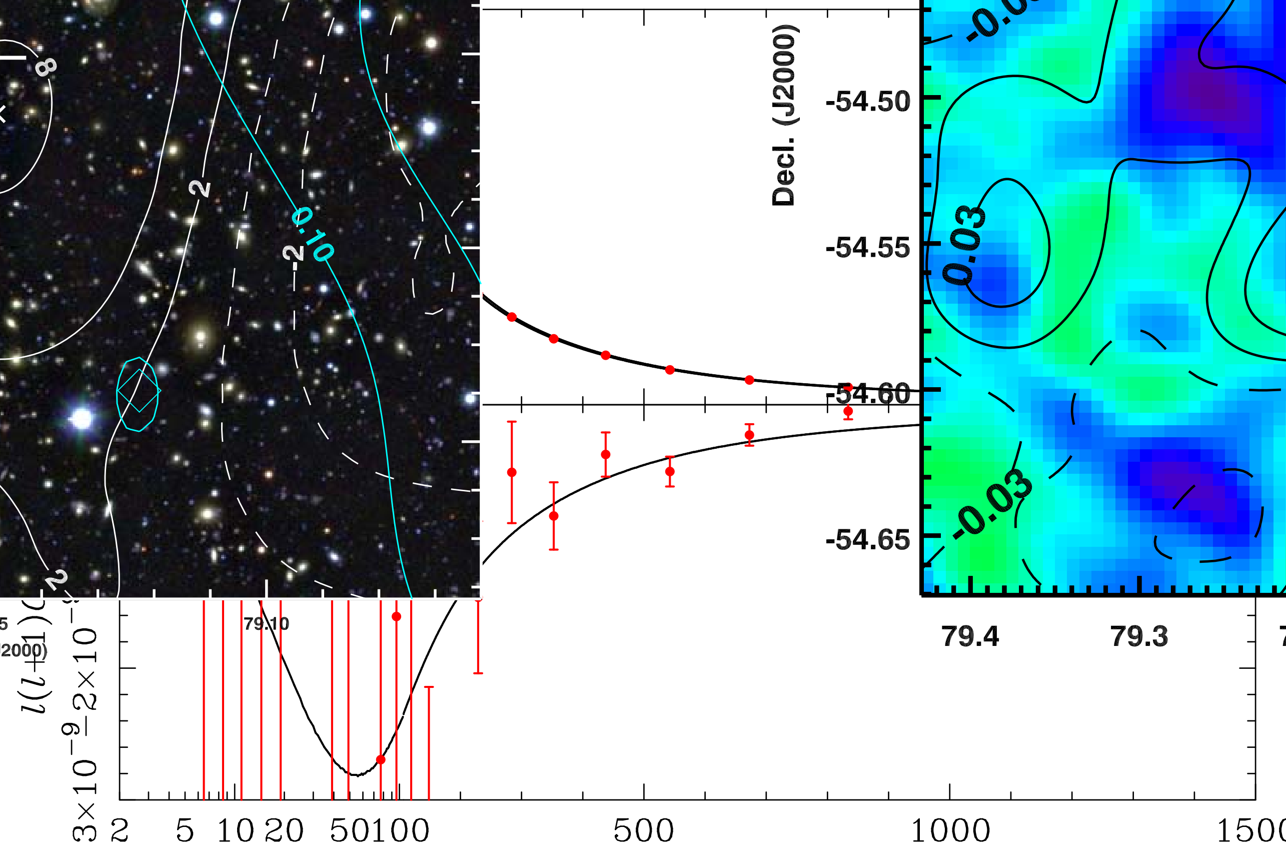
- Redshift distribution of CIB peaks at z ~2.5. The ISW detection obtained from the cross-correlation of the extragalactic IR catalog with PRISM CMB maps will allow to dark energy/ modified gravity models at high redshifts.
- HI galaxies from SKA will also be cross-correlated with Prism CMB maps to detect ISW

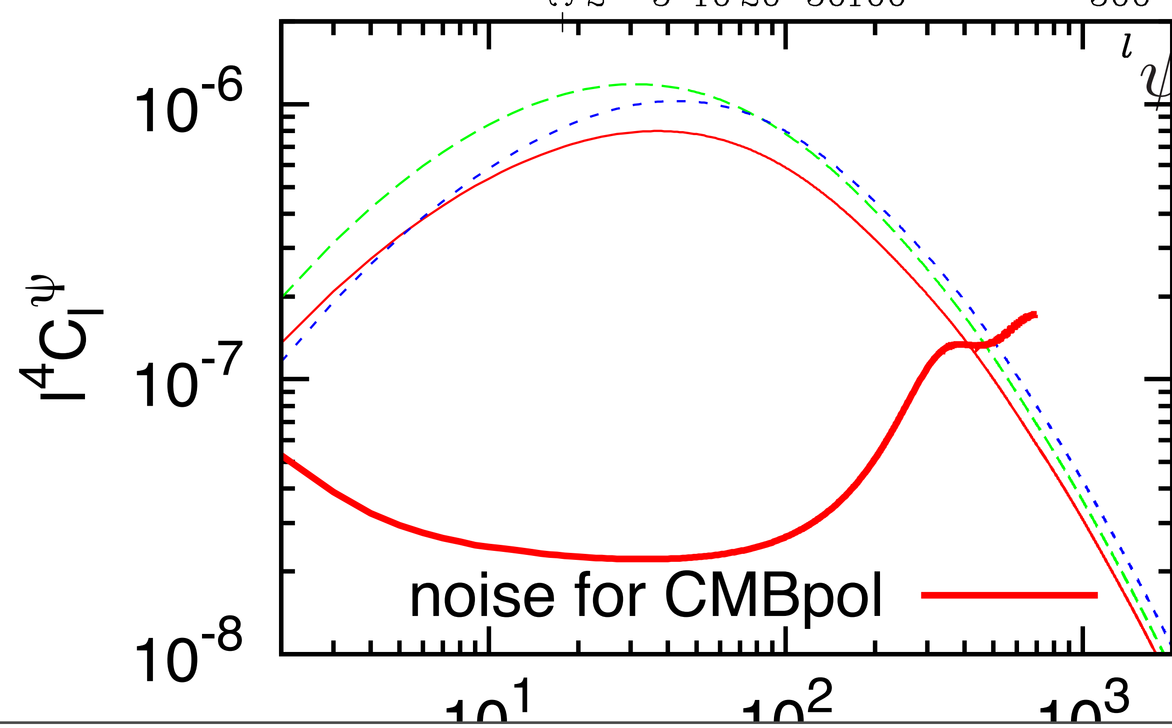
on massiv

ed gravit









$$\psi(\tau,\, \vec{x}) = [1 + \varpi(\tau, x)] \times \phi(\tau,\, \vec{x})$$