Cosmology[1] from cross correlations of CMB lensing and galaxy power spectra

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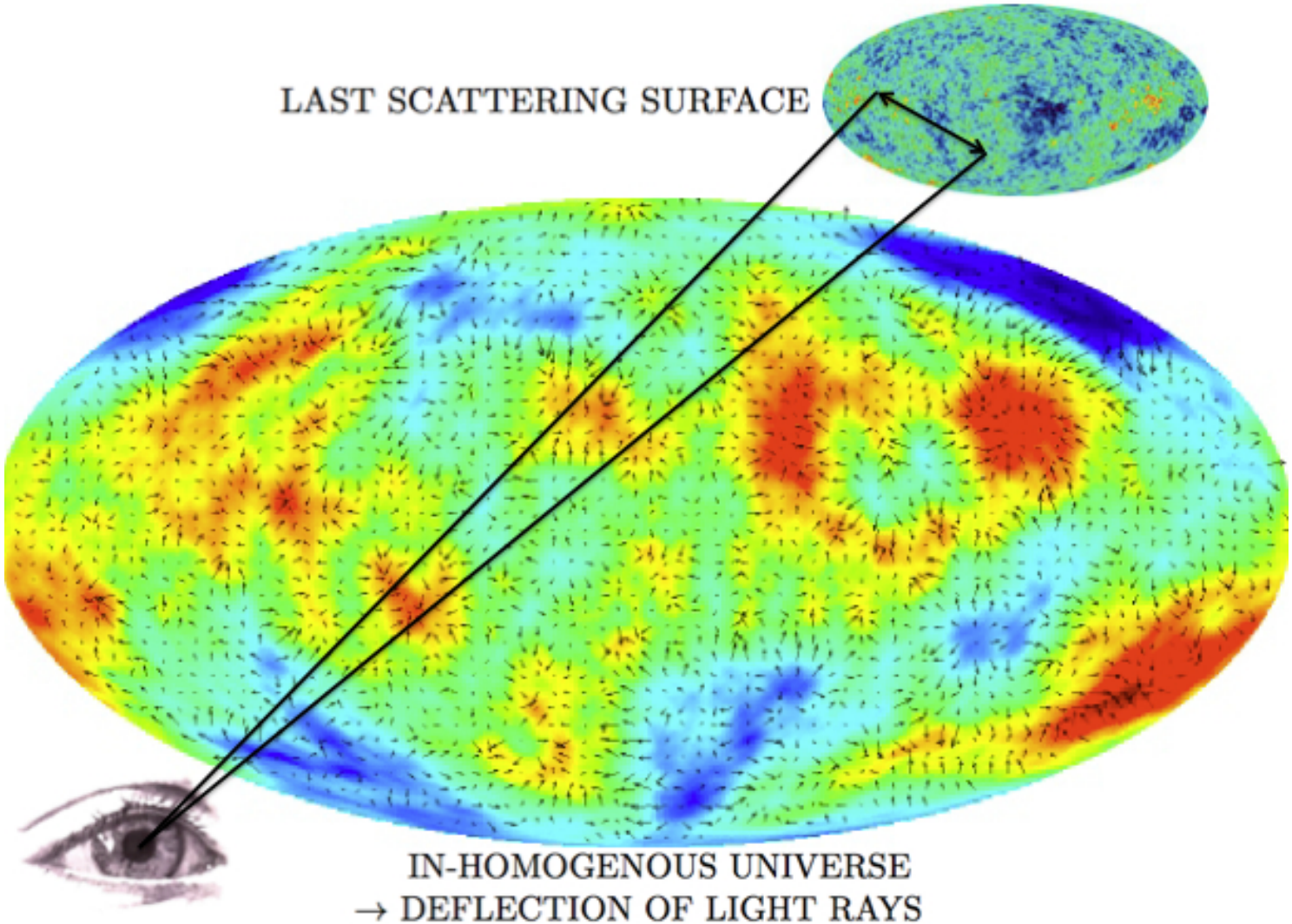
University of Sussex/SLAC

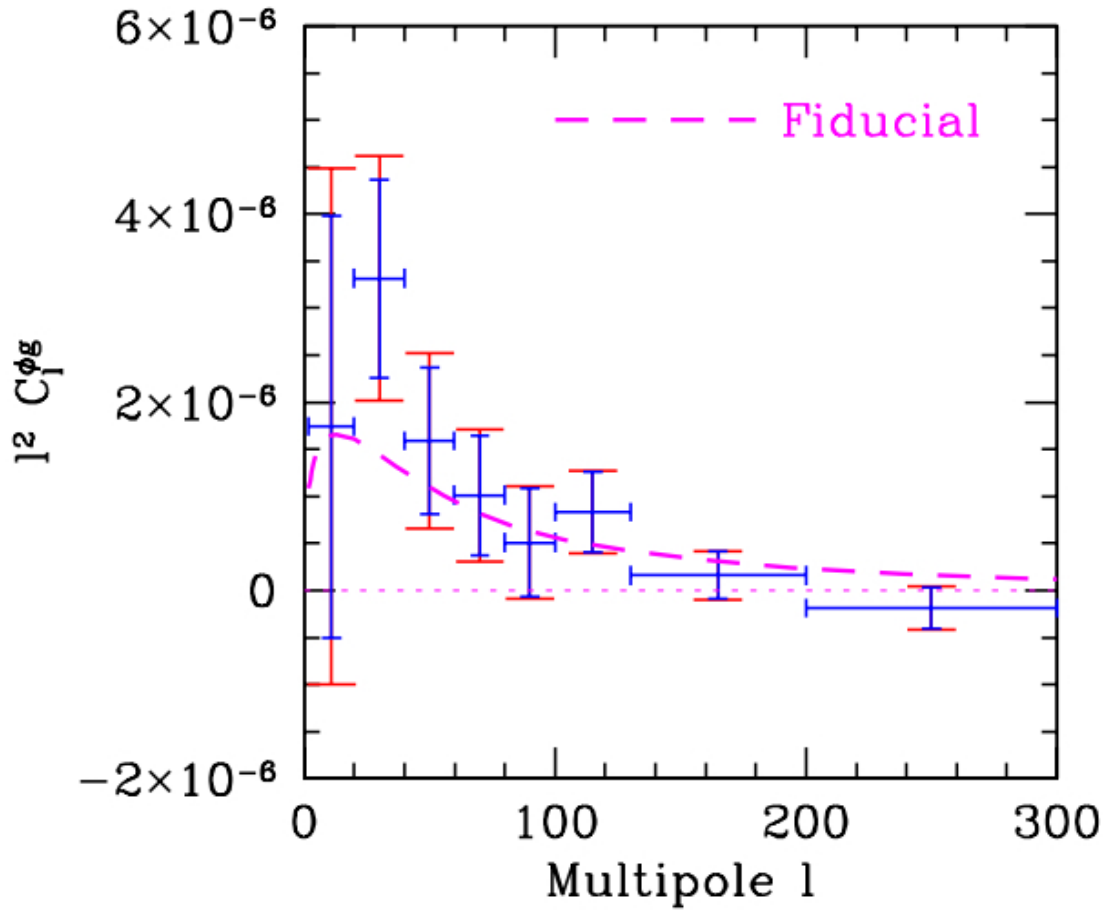
New Light in Cosmology from the CMB, ICTP July 2013

[1] and some astrophysics


LAST SCATTERING SURFACE
IN-HOMOGENOUS UNIVERSE
→ DEFLECTION OF LIGHT RAYS

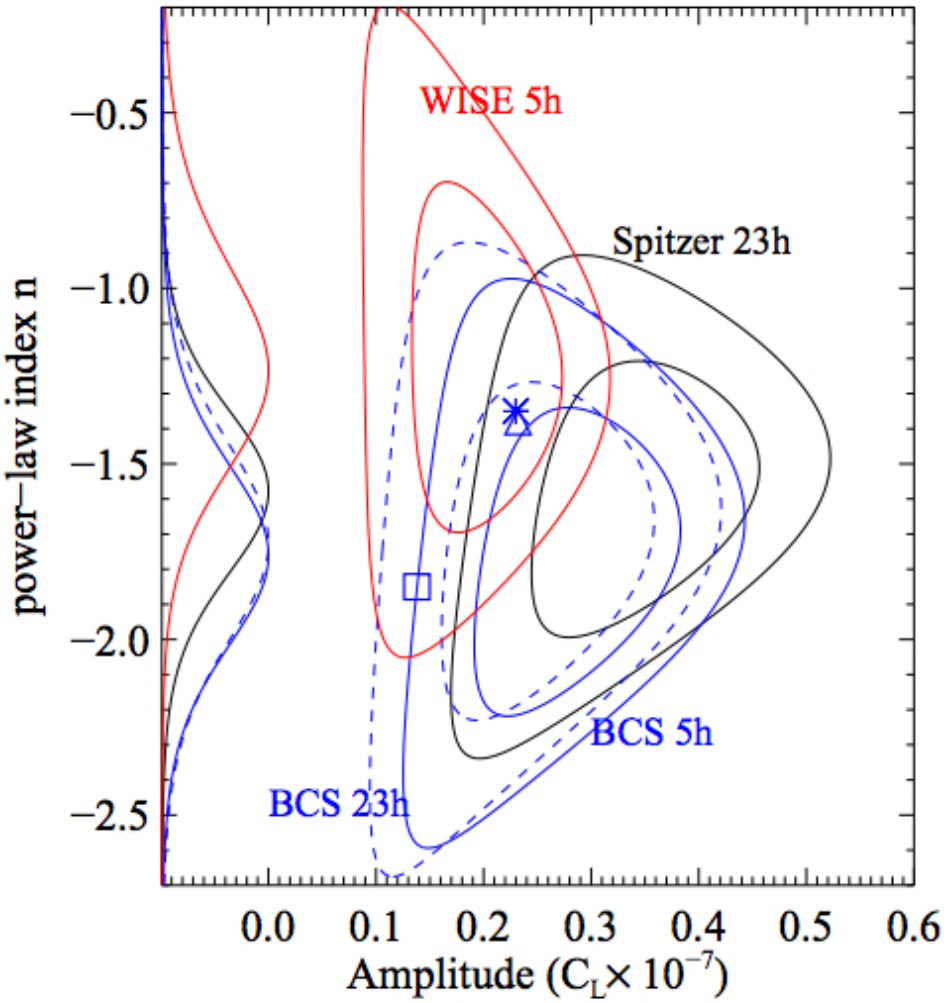
previous work - radio

3.4σ lensing detection - WMAP X NVSS (Smith et al. 2007)



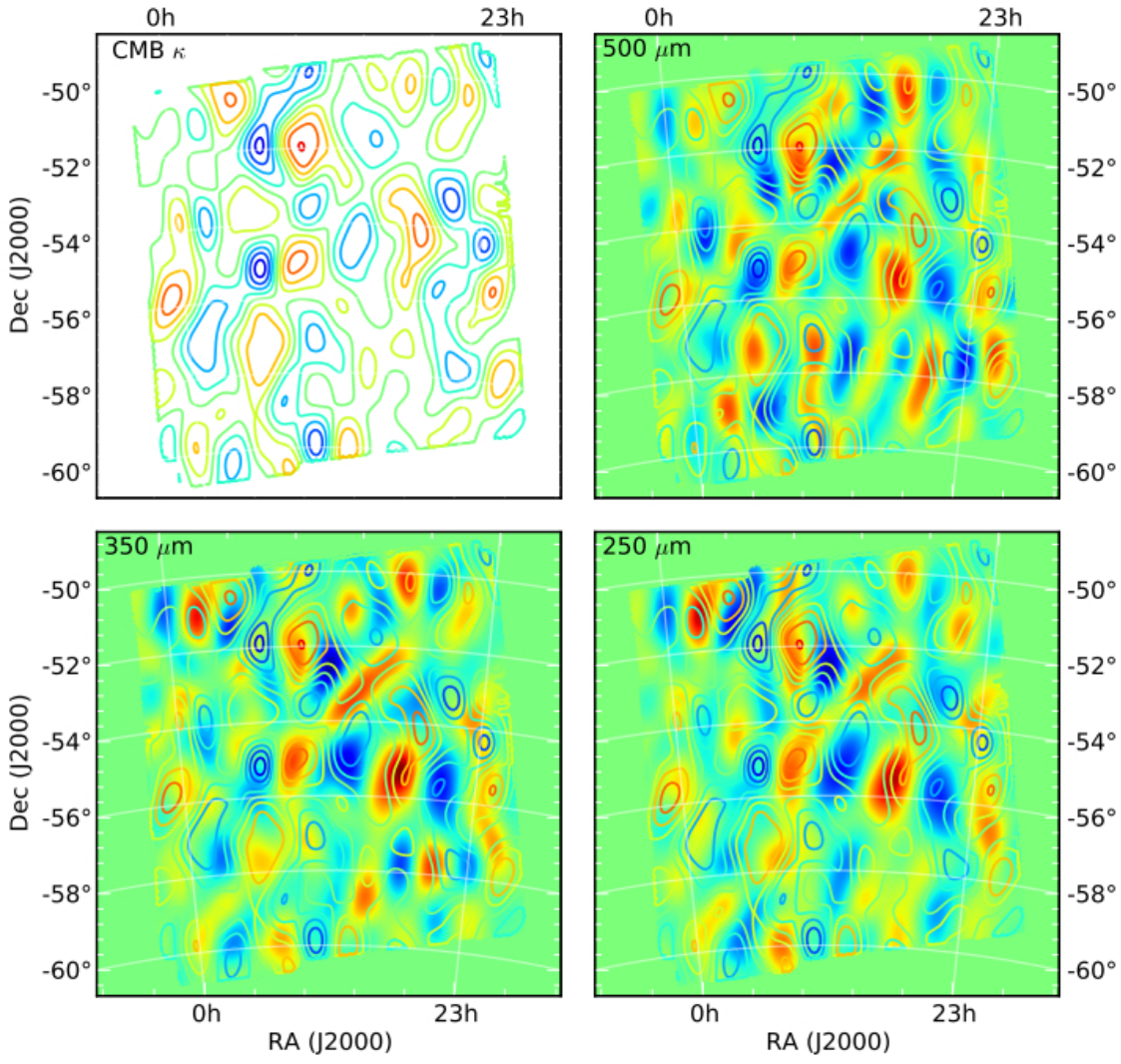
NVSS, SDSS (Hirata et al. 2008 arXiv:0801.0644)
NVSS (Feng et al. 2012 arXiv:1207.3326)

previous work- IR, optical



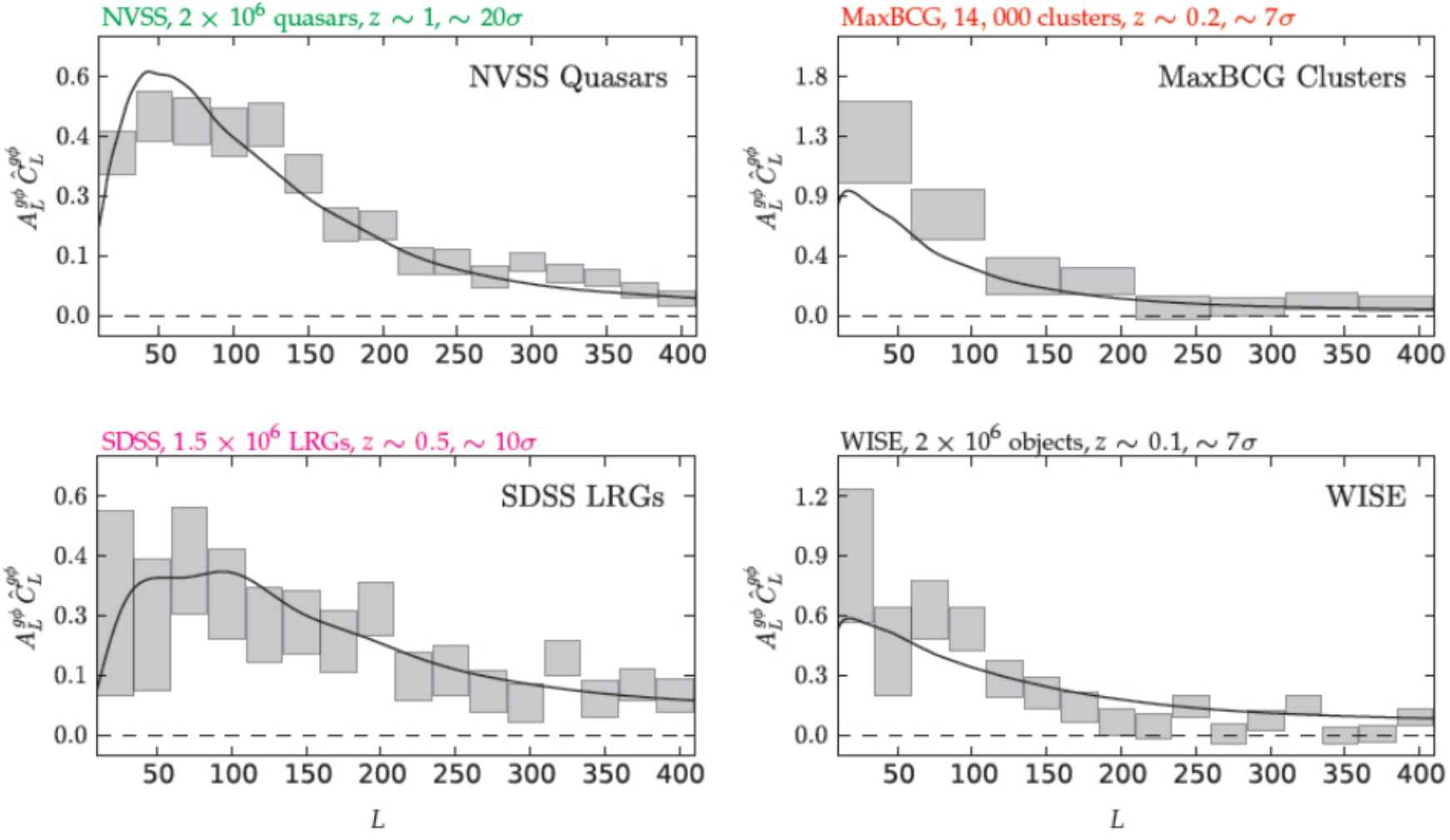
SPT, BCS, WISE, Spitzer - Bleem et al. 2012 arXiv:1203.4808
ACT, SDSS (Sherwin et al. 2012 arXiv:1207.4543)

previous work- submm



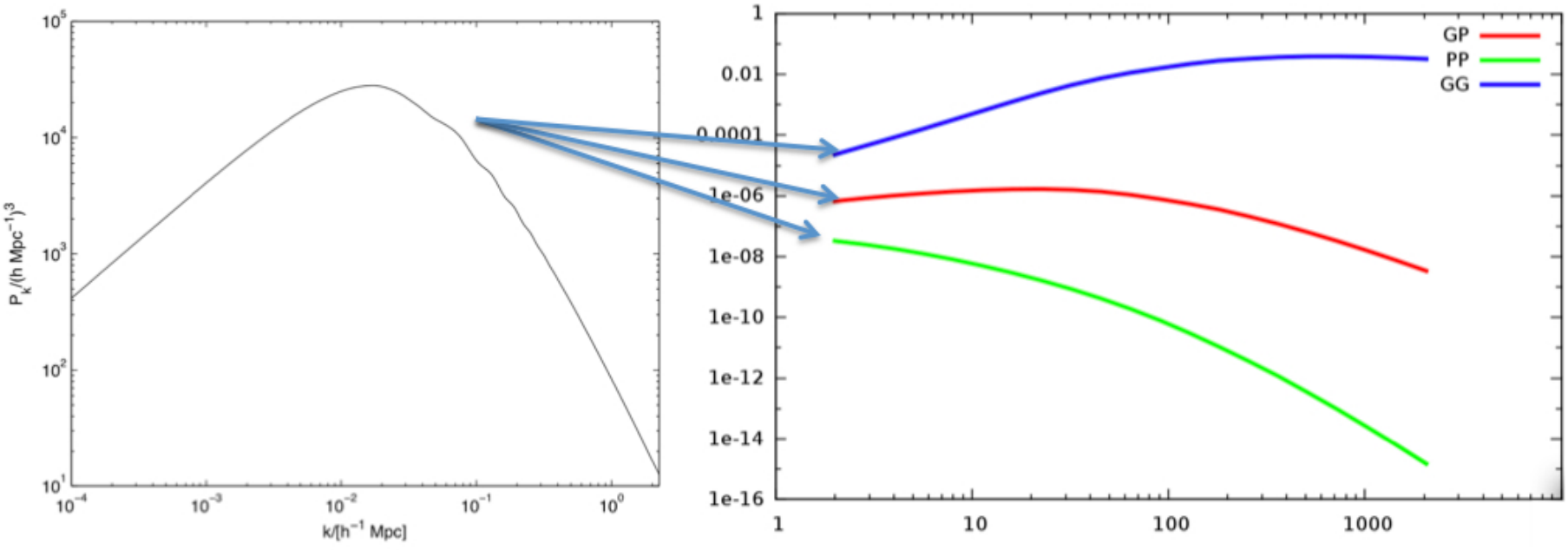
SPT, Herschel/SPIRE (Holder et al. arXiv:1303.5048)

previous work



Planck collaboration (arXiv:1303.5077)

Large Scale Structure from the Matter Power Spectrum



Can we use combination of spectra to constrain cosmology and astrophysics simultaneously?

power spectra and parameters

$C_l^{\phi\phi} \propto \int$ matter power f(lens,source)^2

$C_l^{gg} \propto \int$ matter power $b^2(z)(\frac{dn}{dz})^2$

$C_l^{\phi g} \propto \int$ matter power $b(z)\ (\frac{dn}{dz})$ f(lens,source)

Cosmology:

$\Omega_B h^2$
$\Omega_{CDM} h^2$
Ω_Λ
$\Omega_\nu h^2$
A_s
n_s
τ

Astrophysical:

bias
$\frac{dn}{dz}$

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$\frac{dn}{dz}$

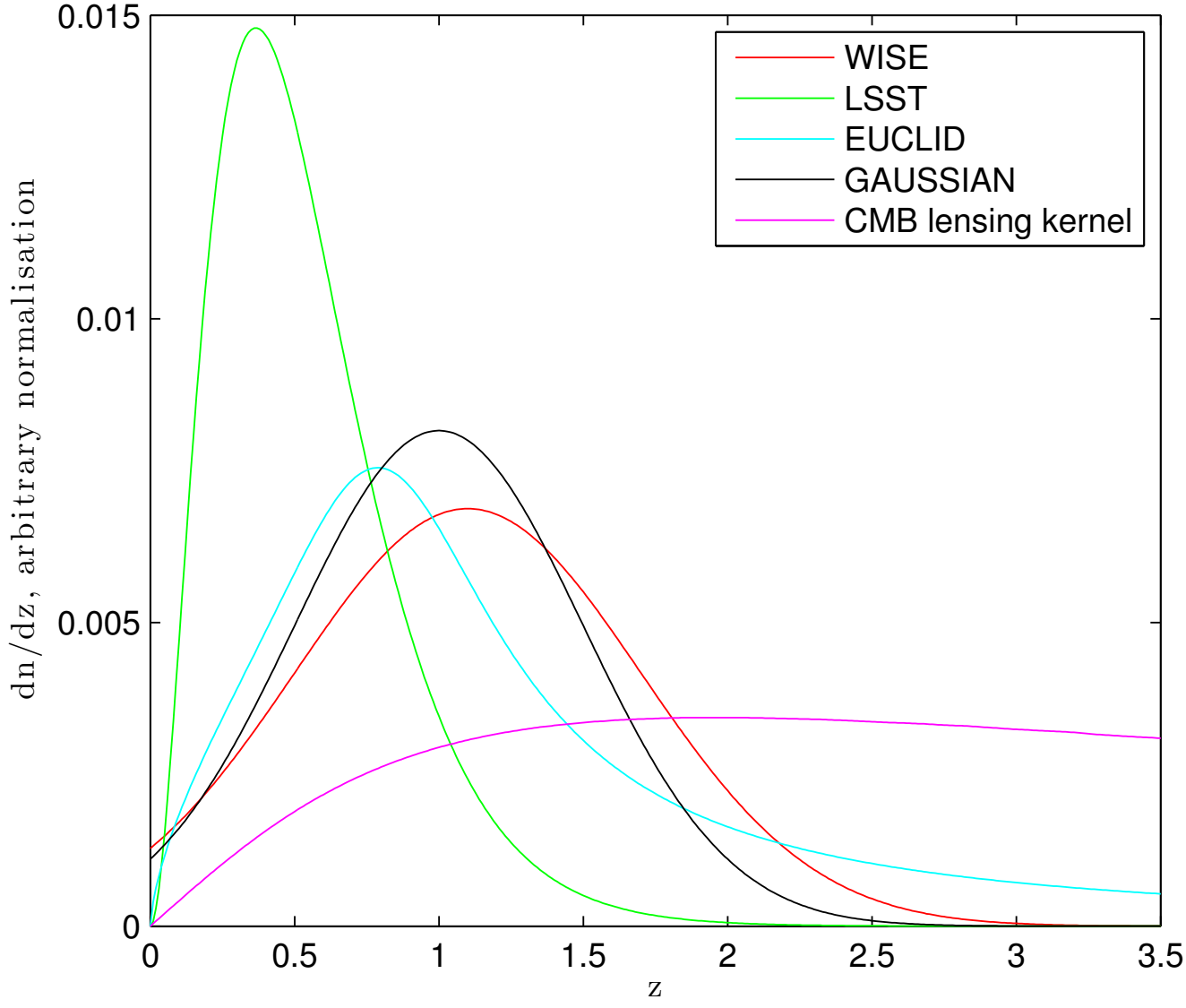
experimental scenarios

CMB

	Current	3rd generation	4th generation
temperature noise (μK-arcmin)	30	2.5	2.5
polarisation noise (μK-arcmin)	60	3.5	3.5
beam (arcmin)	7	1	1
F_{sky}	0.75	0.1	0.5

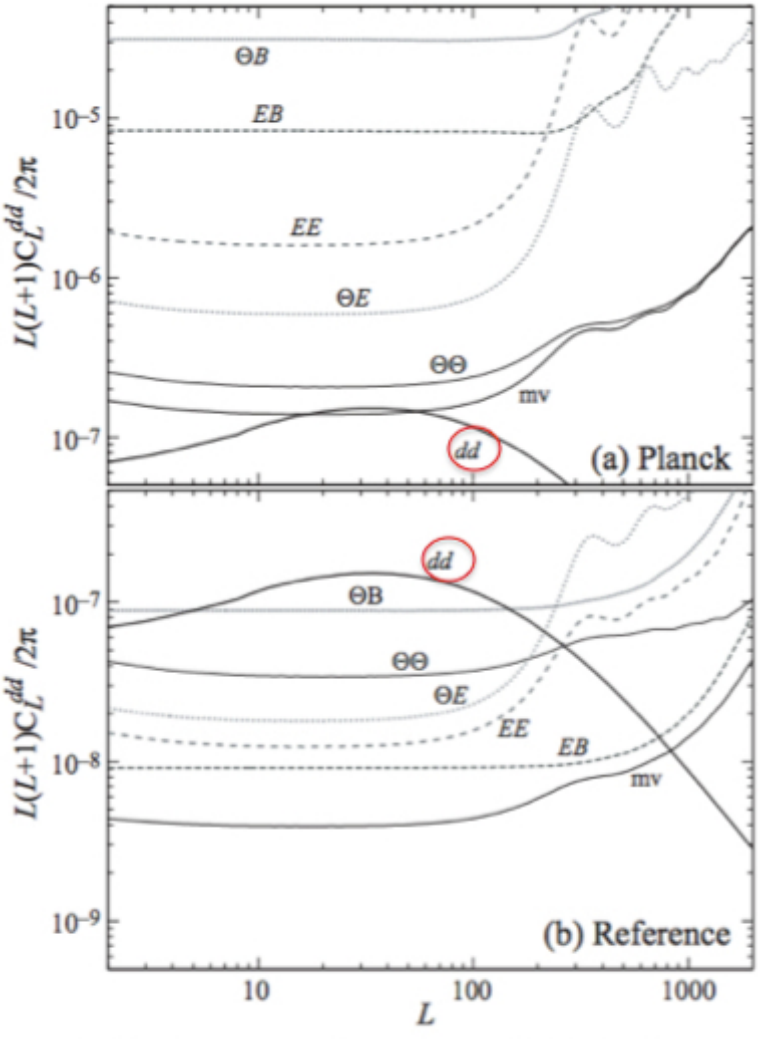
GALAXY

	f_{sky}	number density (gal/sq deg)
WISE	0.75	90
LSST	0.485	198000
EUCLID	0.375	108000


0.015
0.01
0.005
0
dn/dz, arbitrary normalisation
0
0.5
1
1.5
2
2.5
3
3.5
z
WISE
LSST
EUCLID
GAUSSIAN
CMB lensing kernel

sensitivity

N0 BIAS



Hu & Okamoto arXiv:astro-ph/0111606

SHOT NOISE

$$C_l^{noise} = \frac{1}{n}$$

n is number density per steradian

Some assumptions & things to consider

- Reliable $\sum m_\nu$ constraint? (Audren et al. arXiv:1210.2194)
  1. Non-linearities in the power spectra
  2. Scale dependent bias

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  1. WISE, Hershel no z info
  2. LSST, Euclid yes z info

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- Alberto Vallinotto (eg arXiv:1110:5339)

$\sum m_\nu$ constraints - $\frac{dn}{dz}$ fixed LSST like

Varied: $\Omega_B h^2$, $\Omega_{CDM} h^2$,Ω_λ, $\Omega_\nu h^2$, A_s, n_s, τ, *bias* (20% prior)

	Current + 3rd generation(ev)	Current + 4th generation(ev)
CMB only	0.317	0.193
CMB + $\phi\phi$	0.049	0.034
CMB + ϕG	0.216	0.118
CMB + $\phi\phi$ + ϕG	0.048	0.033

$\sum m_\nu$ fiducial = 0.19 ev

$\sum m_\nu$ constraints - $\frac{dn}{dz}$ fixed LSST like

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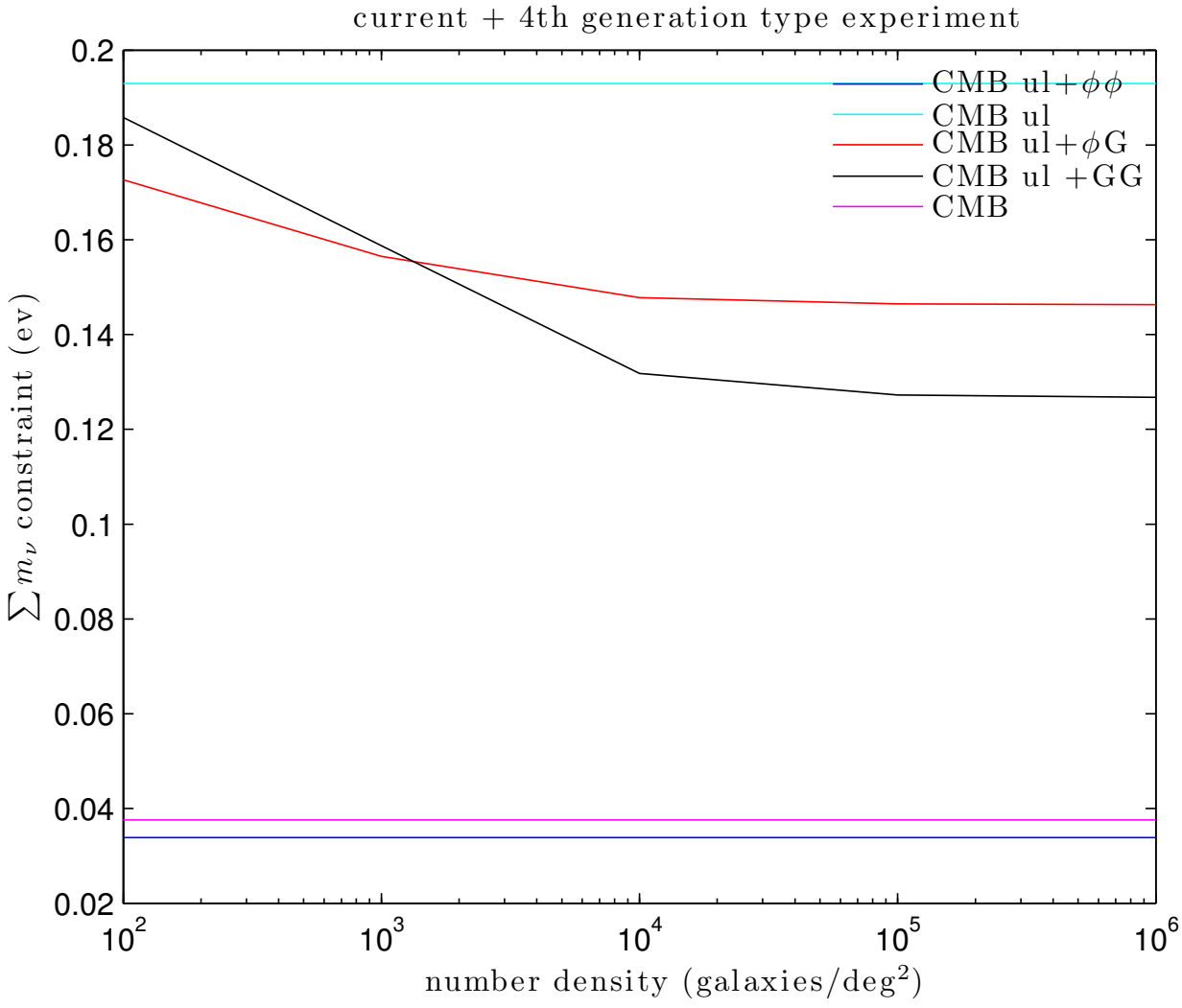
$\sum m_\nu$ fiducial = 0.19 ev minimum $\sum m_\nu$ = 0.06 ev

$\sum m_\nu$ constraints - $\frac{dn}{dz}$ Gaussian like - current + 4th gen.



Varied: $\Omega_B h^2$, $\Omega_{CDM} h^2$,Ω_λ, $\Omega_\nu h^2$, A_s, n_s, τ, *bias*, $\frac{dn}{dz}$: *mean* (20% priors)

τ constraints - $\frac{dn}{dz}$ fixed LSST like

Varied: $\Omega_B h^2$, $\Omega_{CDM} h^2$,Ω_λ, $(\Omega_\nu h^2)$, A_s, n_s, τ, *bias* (20% prior)

	Current	Current + 4th generation
TT (7 param)	0.084	0.034
TT (6 param)	0.027	0.012
CMB (7 param)	0.004	0.003
CMB (6 param)	0.004	0.002
TT + $\phi\phi$ (7 param)	0.042	0.014
TT + $\phi\phi$ (6 param)	0.020	0.010
TT + ϕG (7 param)	0.057	0.030
TT + ϕG (6 param)	0.026	0.012
TT + $\phi\phi$ + ϕG (7 param)	0.040	0.014
TT + $\phi\phi$ + ϕG (6 param)	0.020	0.010

τ fiducial=0.088

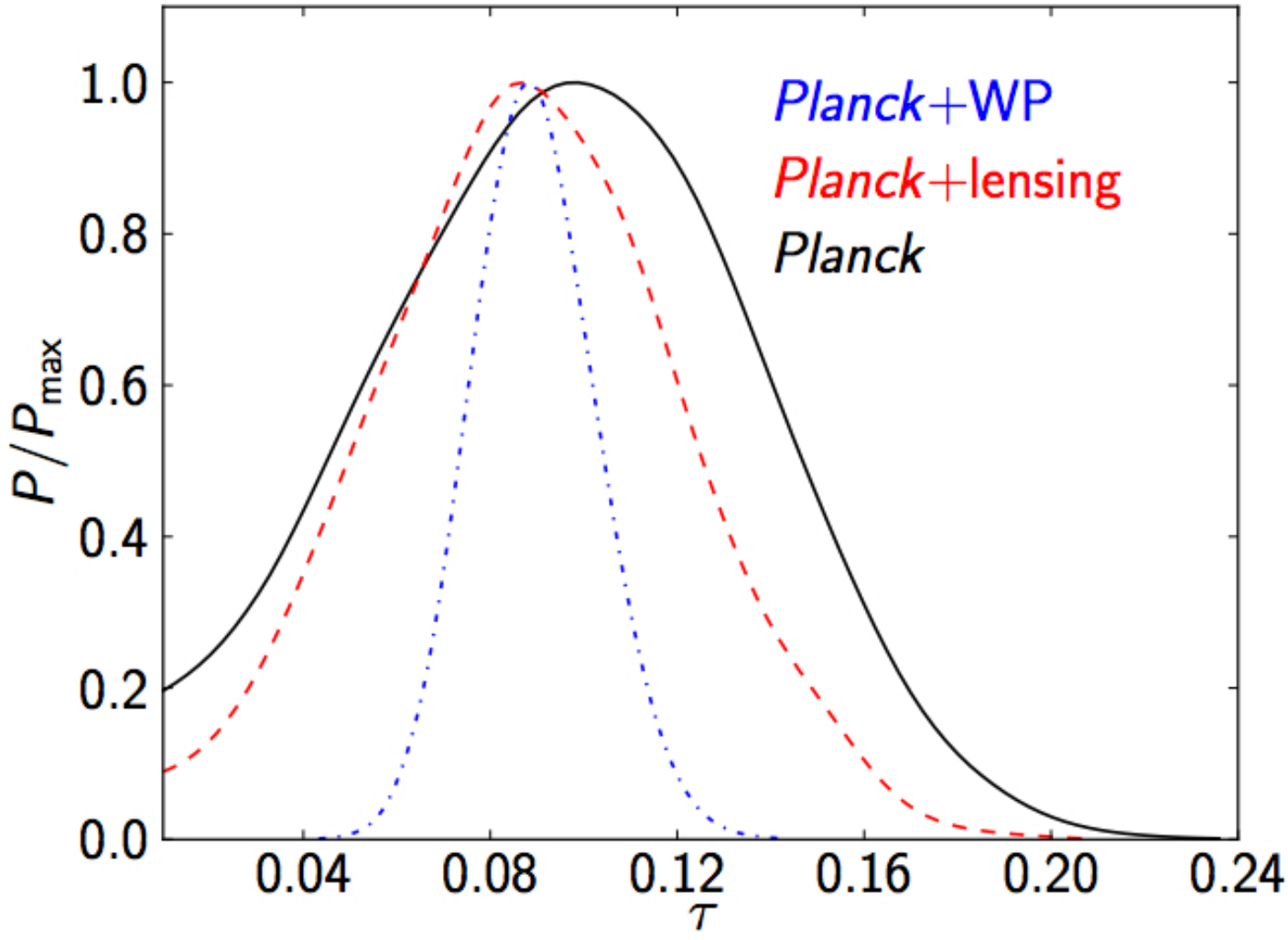
τ constraints - $\frac{dn}{dz}$ fixed LSST like

Varied: $\Omega_B h^2$, $\Omega_{CDM} h^2$,Ω_λ, $(\Omega_\nu h^2)$, A_s, n_s, τ, *bias* (20% prior)

	Current	Current + 4th generation
TT (7 param)	0.084	0.034
TT (6 param)	0.027	0.012
CMB (7 param)	0.004	0.003
CMB (6 param)	0.004	0.002
TT + $\phi\phi$ (7 param)	0.042	0.014 $\sim 16\%$
TT + $\phi\phi$ (6 param)	0.020	0.010 $\sim 11\%$
TT + ϕG (7 param)	0.057	0.030
TT + ϕG (6 param)	0.026	0.012
TT + $\phi\phi$ + ϕG (7 param)	0.040	0.014
TT + $\phi\phi$ + ϕG (6 param)	0.020	0.010

τ fiducial=0.088

$\tau = 0.097 \pm 0.038$ (68%; Planck)
$\tau = 0.089 \pm 0.032$ (68%; Planck+lensing)



Planck collaboration (arXiv:1303.5077)

bias constraints - $\frac{dn}{dz}$ LSST - current+4th gen.

Varied: $\Omega_B h^2$, $\Omega_{CDM} h^2$,Ω_λ, $\Omega_\nu h^2$, A_s, n_s, τ, z_0, *bias*

	δbias
CMB +GG	0.010
CMB + ϕG	0.061
CMB + $\phi\phi$ + ϕG	0.008
CMB + ϕG + GG	0.010
CMB + $\phi\phi$ + GG	0.008
CMB + $\phi\phi$ + GG + ϕG	0.006

fiducial bias=1.84

bias constraints - $\frac{dn}{dz}$ LSST - current+4th gen.

Varied: $\Omega_B h^2$, $\Omega_{CDM} h^2$,Ω_λ, $\Omega_\nu h^2$, A_s, n_s, τ, z_0, *bias*

	δbias
CMB +GG	0.010
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CMB + ϕG + GG	0.010
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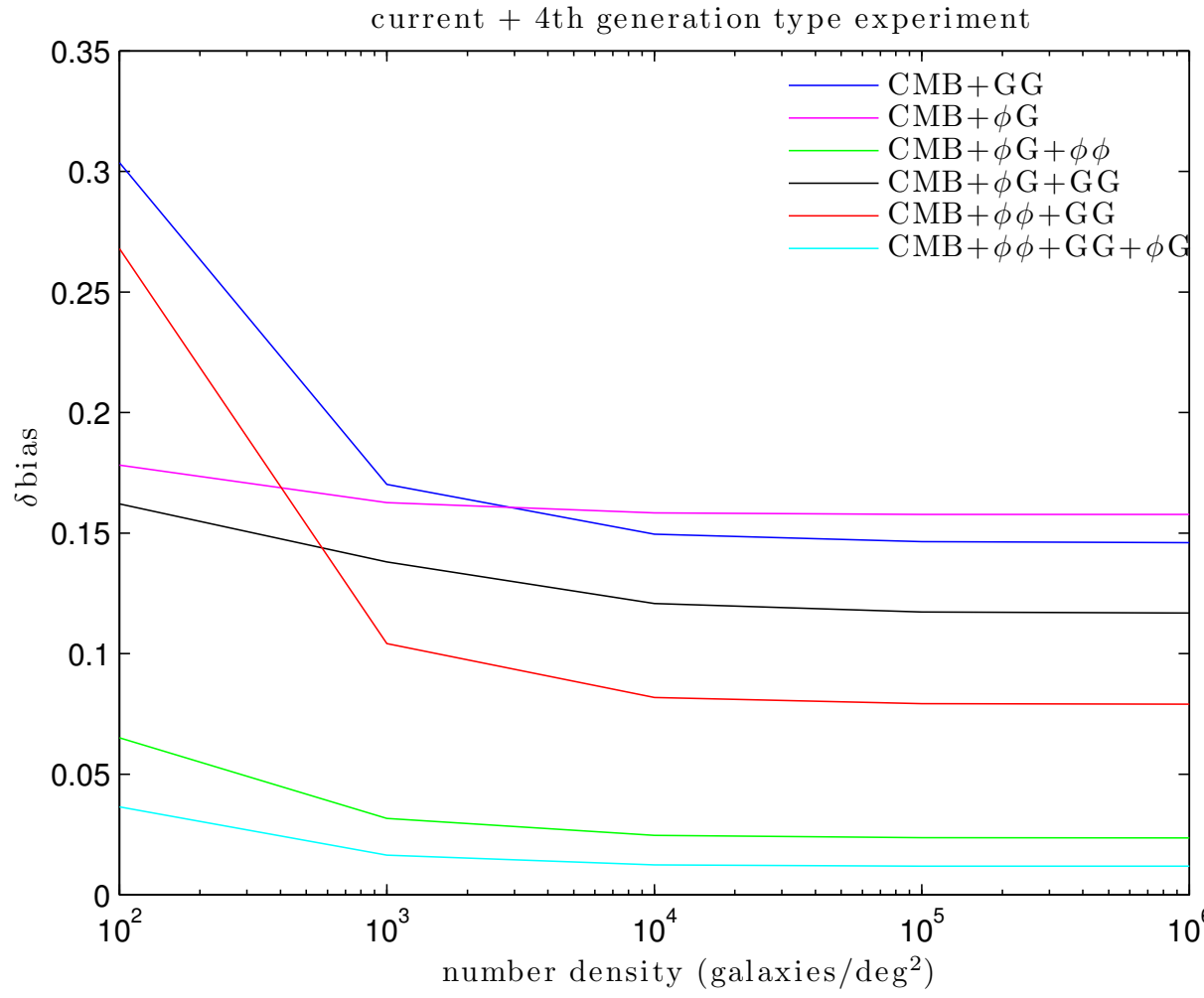
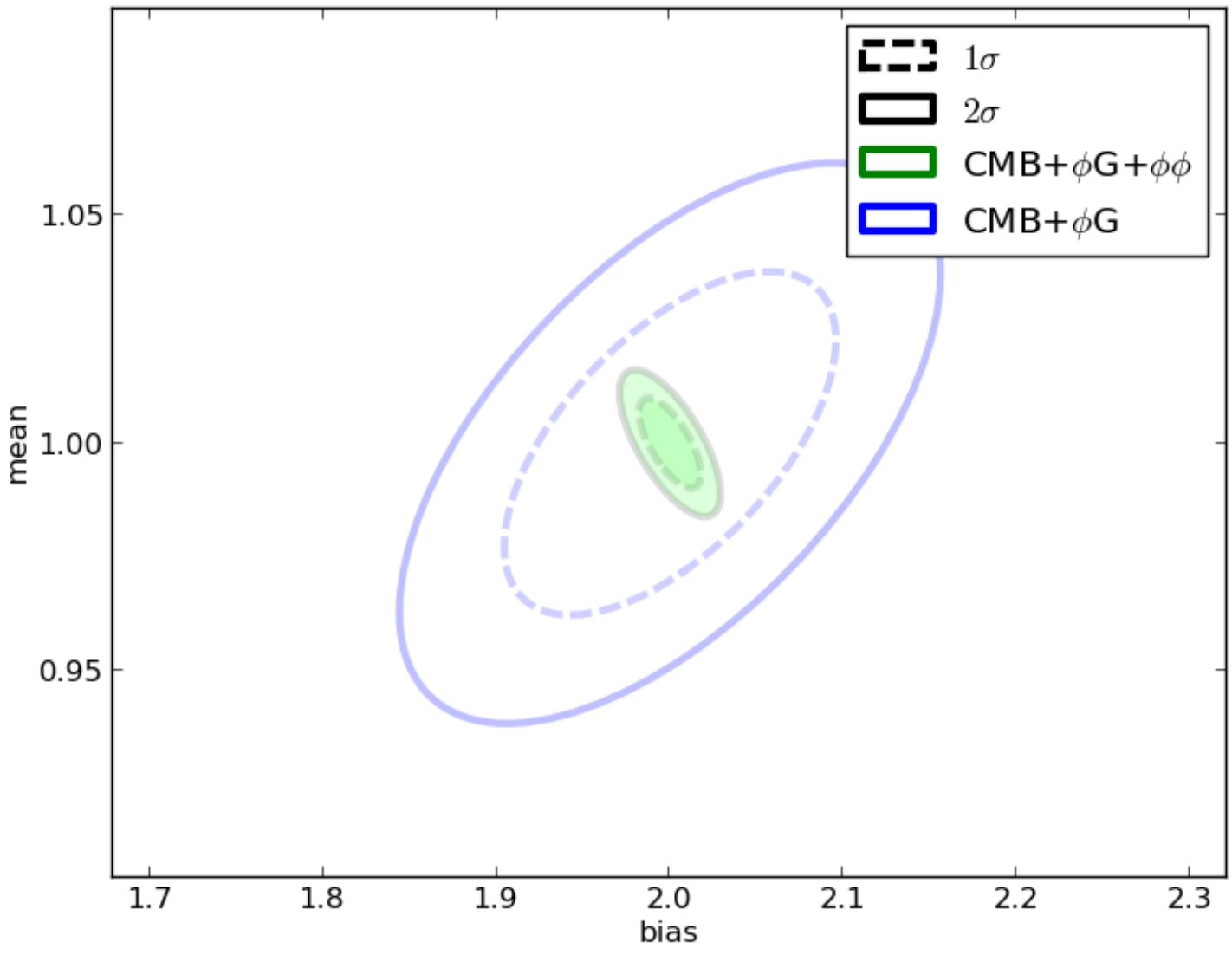
CMB + $\phi\phi$ + GG + ϕG	0.006

fiducial bias=1.84

bias constraints - $\frac{dn}{dz}$ Gaussian like - current + 4th gen.



$\frac{dn}{dz}$ Gaussian like - current + 4th gen. - num. den. 10^6



future

- more realistic scale dependent bias modelling
- bin redshifts for better C_l^{GG} constraints
- include fully BAO and weak lensing shear
- More...

THE END

LSST $\frac{1}{2z_0}\left(\frac{z}{z_0}\right)^2 \exp(-z/z_0)$