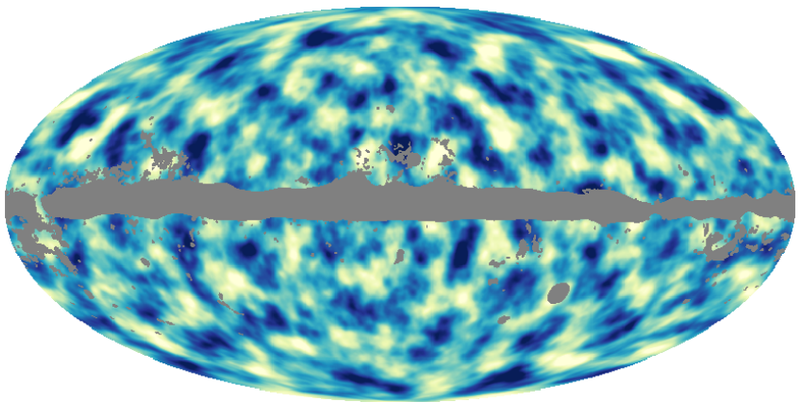
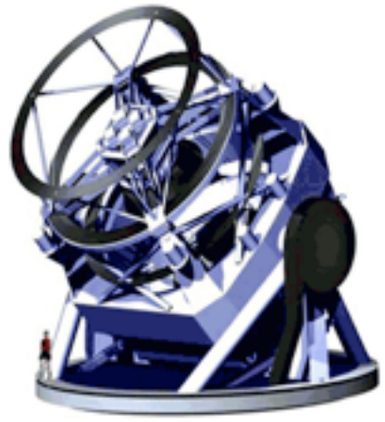
Synergies between CMB and LSST





A. Benoit-Lévy

University College London

Colloque LSST France 2014

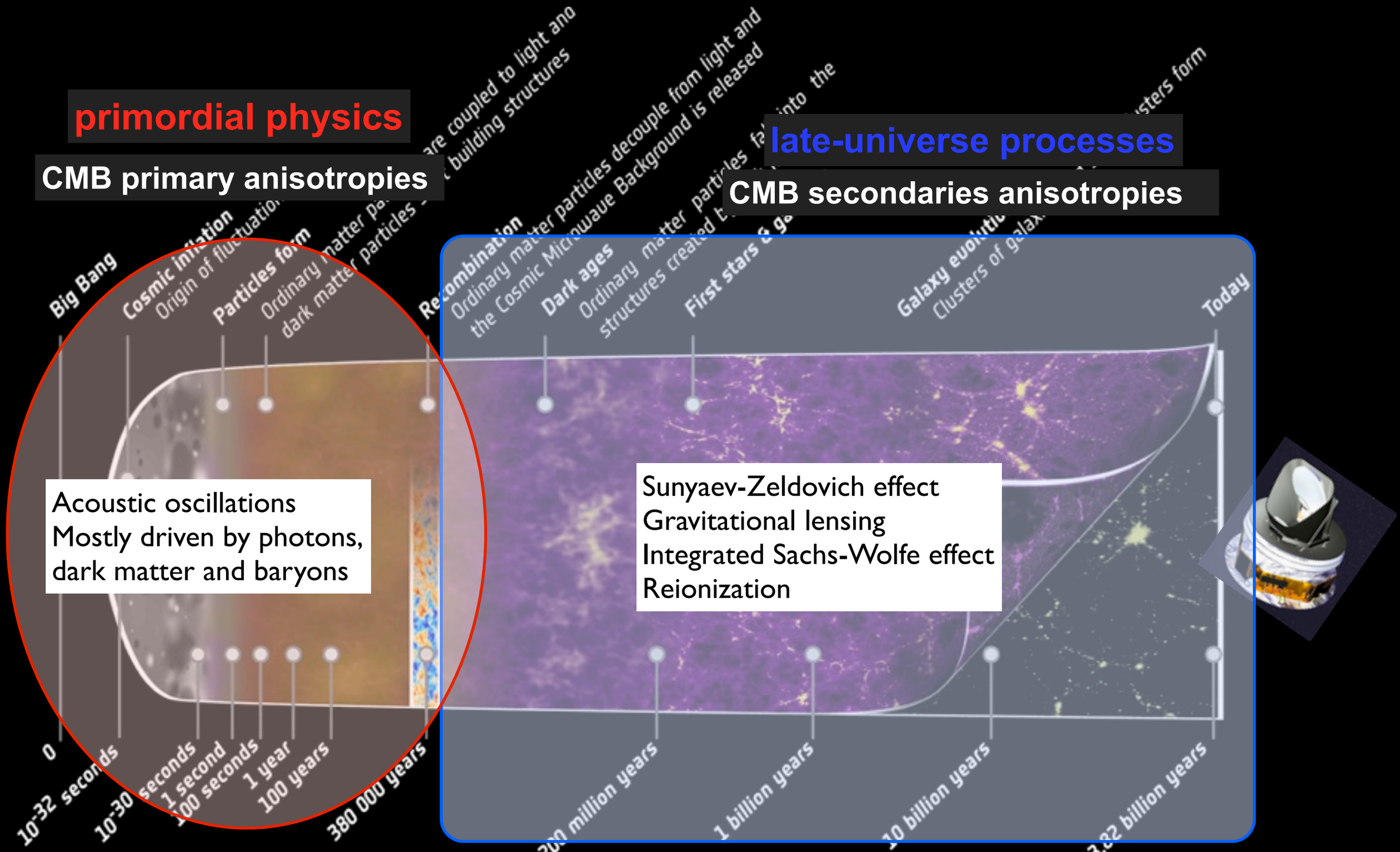
A quick summary of the current status of cosmology

primordial physics

CMB primary anisotropies

late-universe processes

CMB secondaries anisotropies



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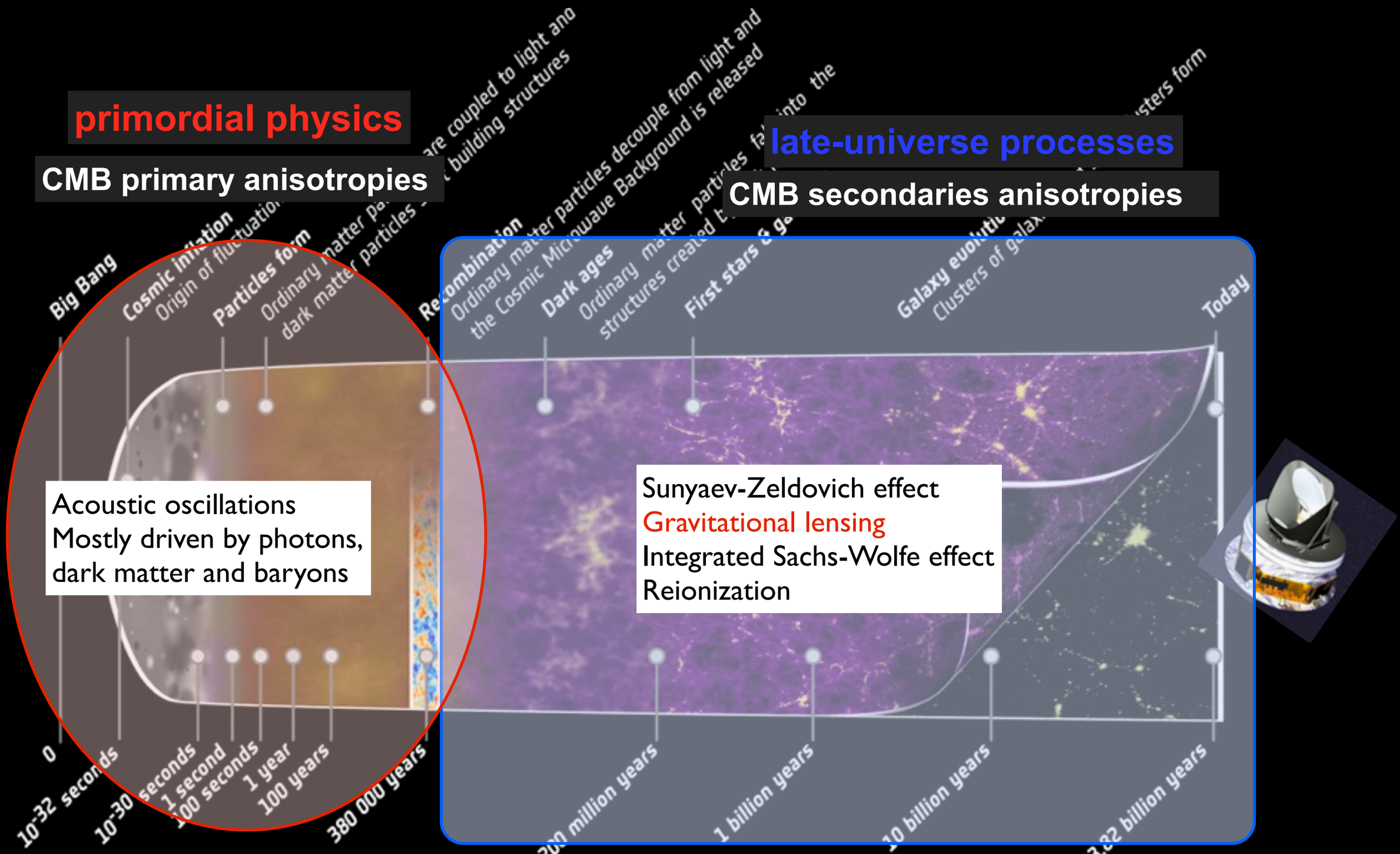
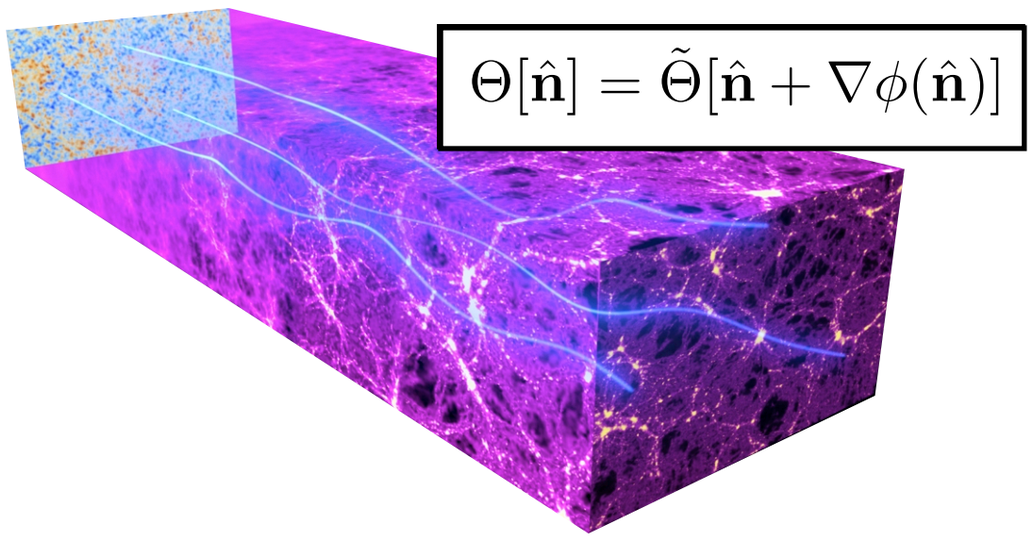


CMB lensing

- **Photons from last scattering surface deflected by gravitational potential of large-scale structure**



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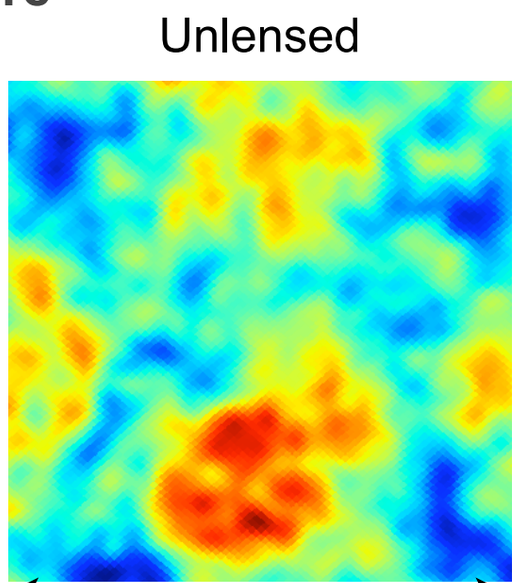

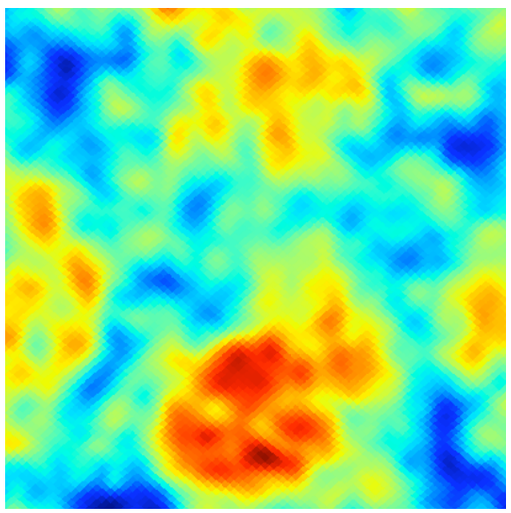

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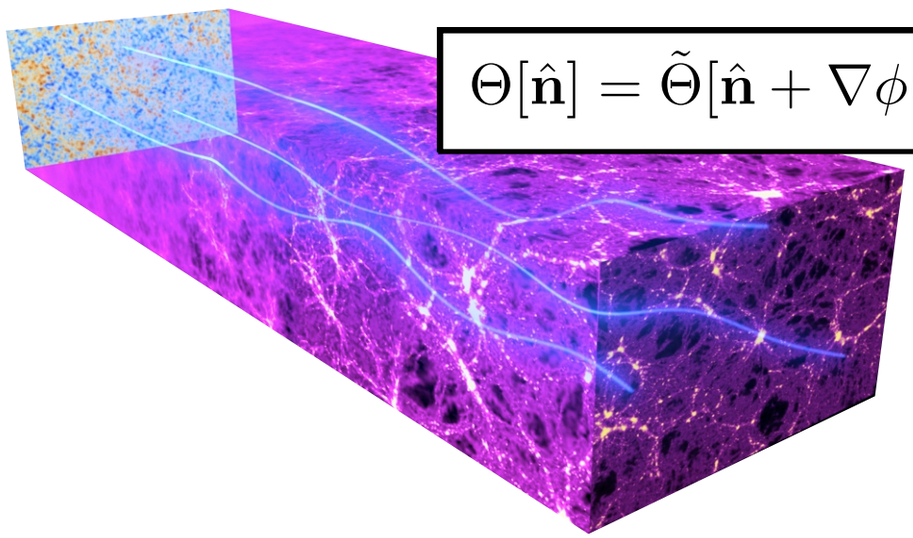

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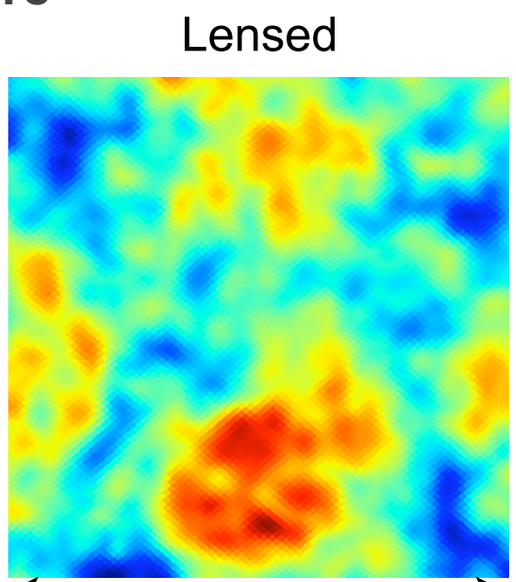

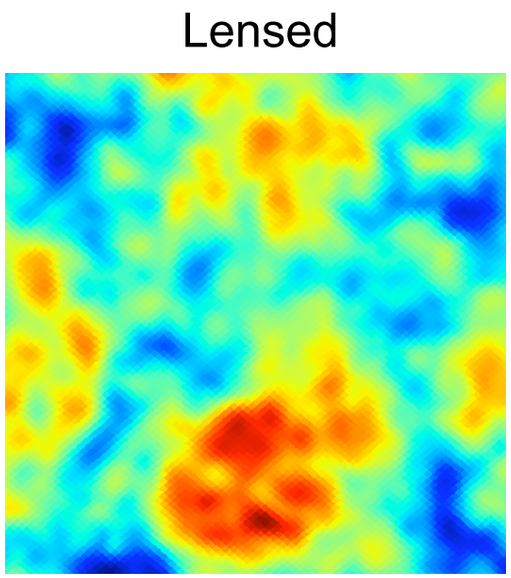

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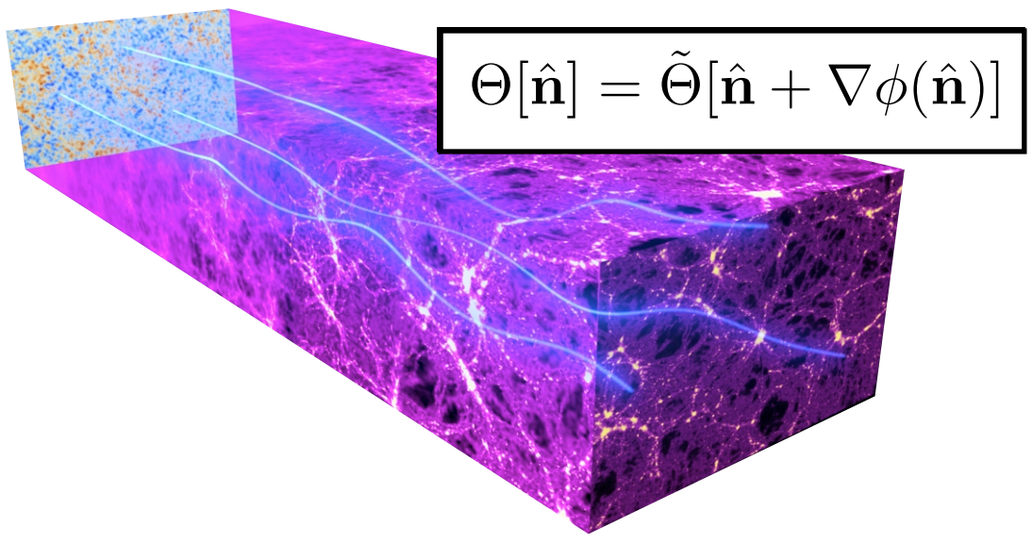

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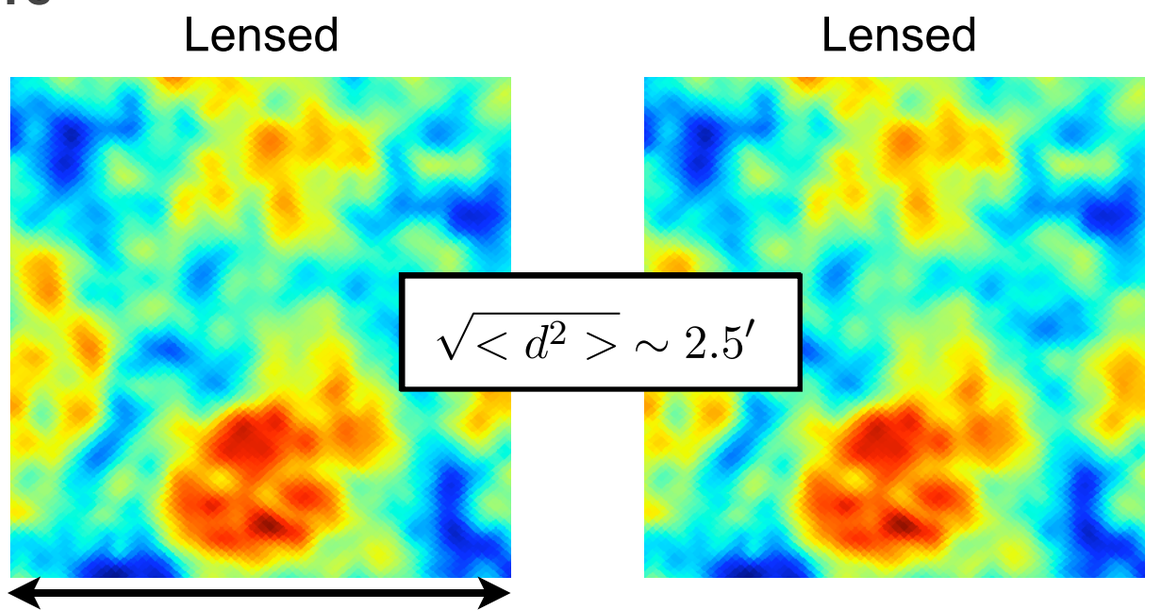


$$\phi(\hat{\mathbf{n}}) = -2 \int d\eta \frac{\chi(\eta - \eta_{\rm rec})}{\chi(\eta_{\rm rec})\chi(\eta)} \Psi(\chi\hat{\mathbf{n}}, \eta)$$

- Typical deflections: ~2.5 arcmin
- Coherent on the degree scale
- CMB lensing induces temperature-gradient correlations

$$\Theta[\hat{\mathbf{n}}] = \tilde{\Theta}[\hat{\mathbf{n}} + \nabla\phi(\hat{\mathbf{n}})] \approx \tilde{\Theta}[\hat{\mathbf{n}}] + \nabla\phi[\hat{\mathbf{n}}]\ \nabla\tilde{\Theta}[\hat{\mathbf{n}}] + \cdots$$

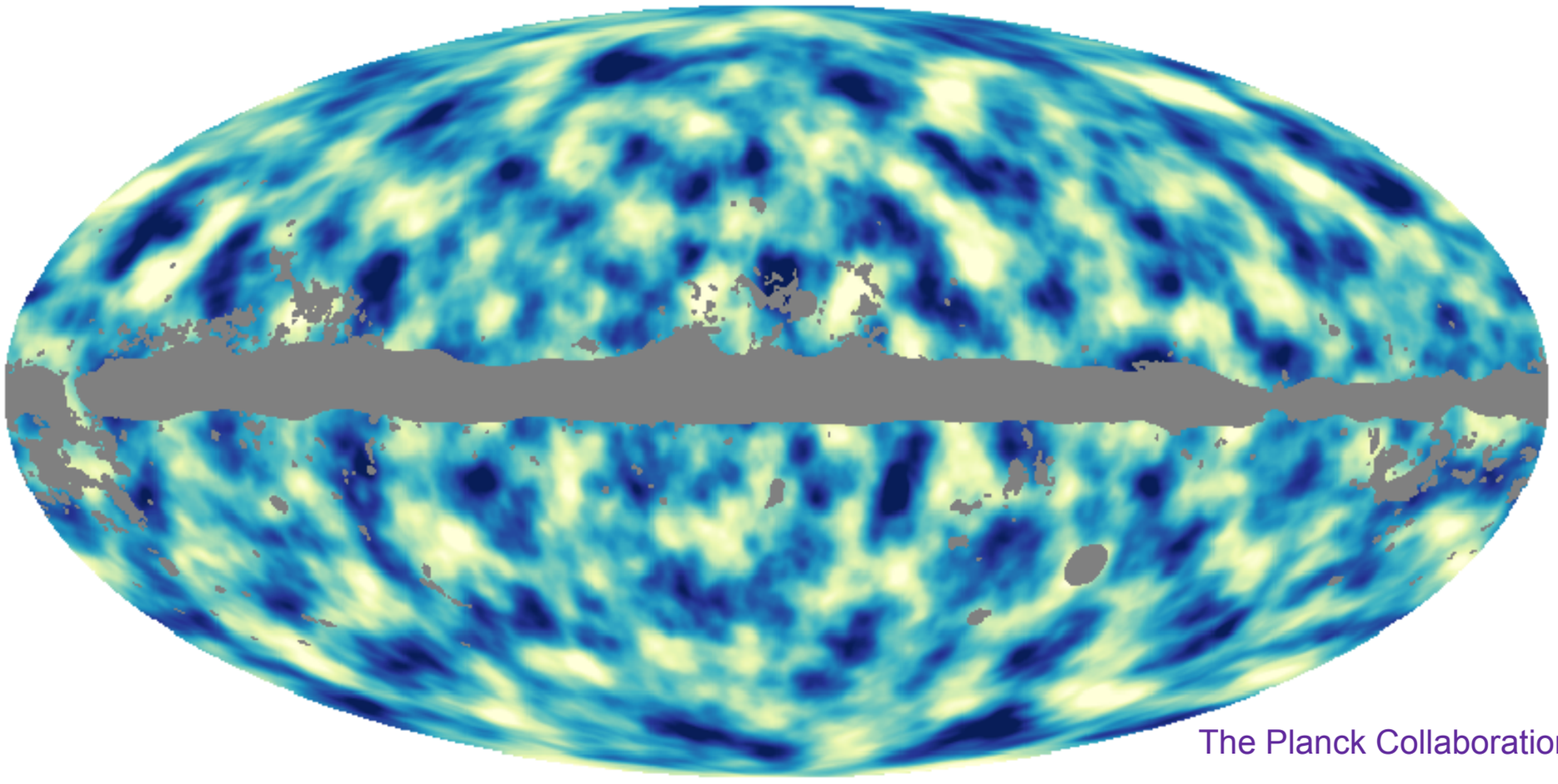
Lensing potential reconstruction

The matter in the Universe as seen by Planck

$$\bar{x}_{LM} = \frac{1}{2} \sum_{\ell_1 m_1, \ell_2 m_2} (-1)^M \begin{pmatrix} \ell_1 & \ell_2 & L \\ m_1 & m_2 & -M \end{pmatrix} W^x_{\ell_1 \ell_2 L} \bar{T}^{(1)}_{\ell_1 m_1} \bar{T}^{(2)}_{\ell_2 m_2}.$$

Okamoto & Hu, 2003

The Planck Collaboration XVII, 2013

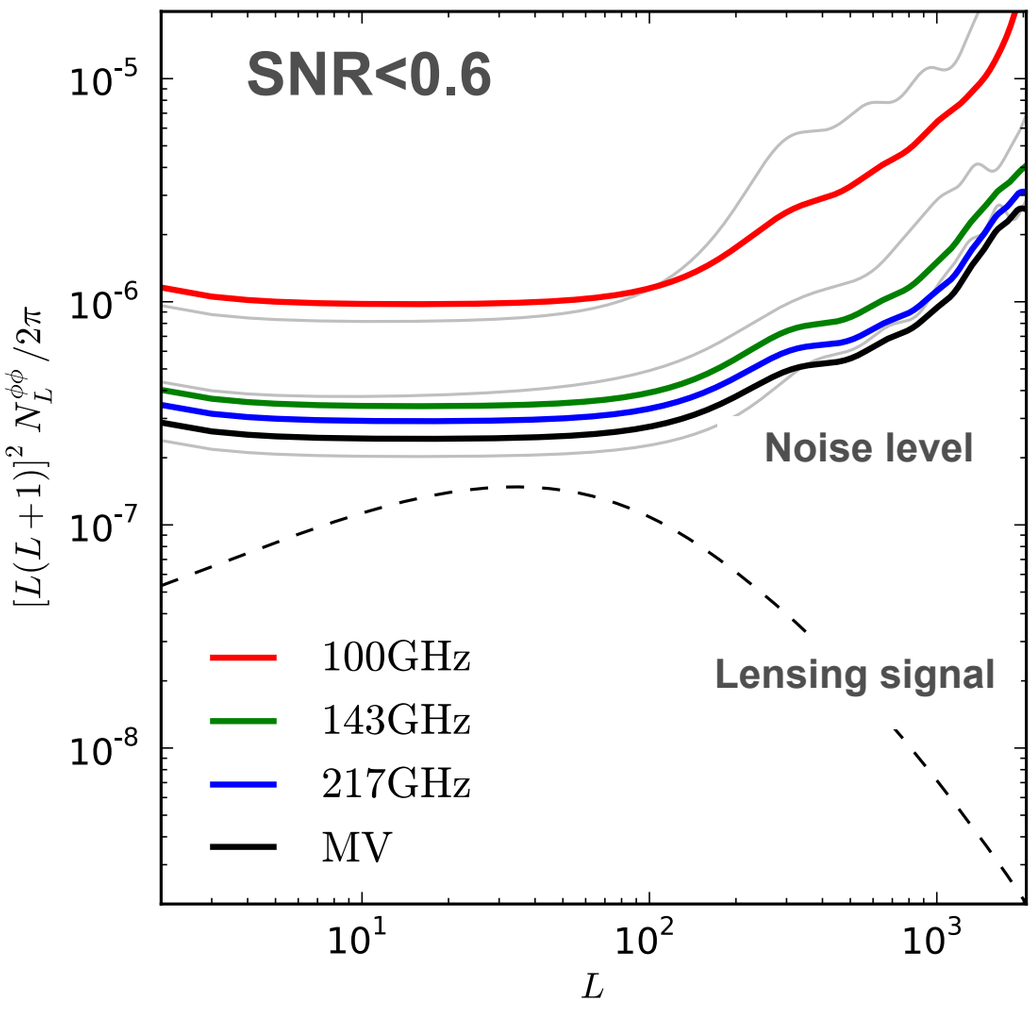


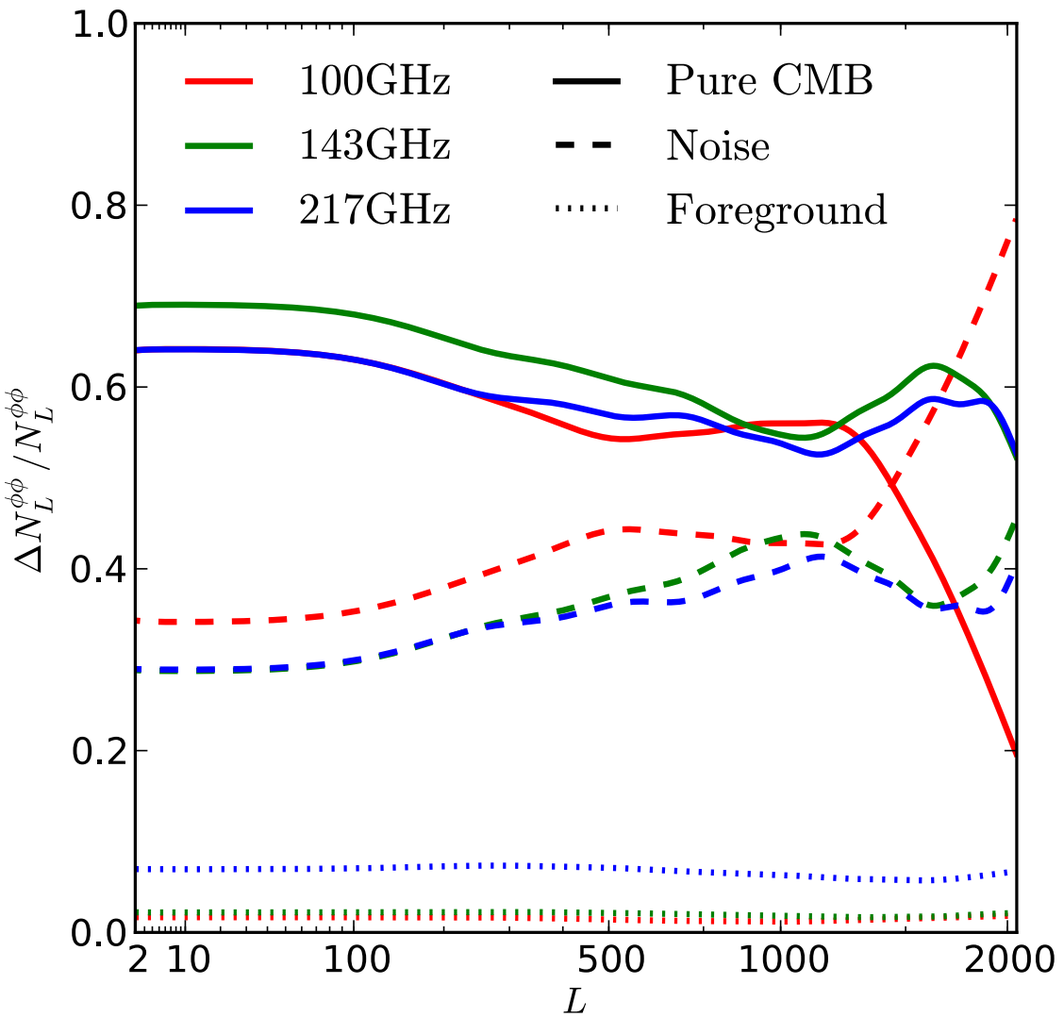
The Planck Collaboration XVII, 2013

(noisy) Map of the matter distribution at z ~ 2

CMB lensing reconstruction

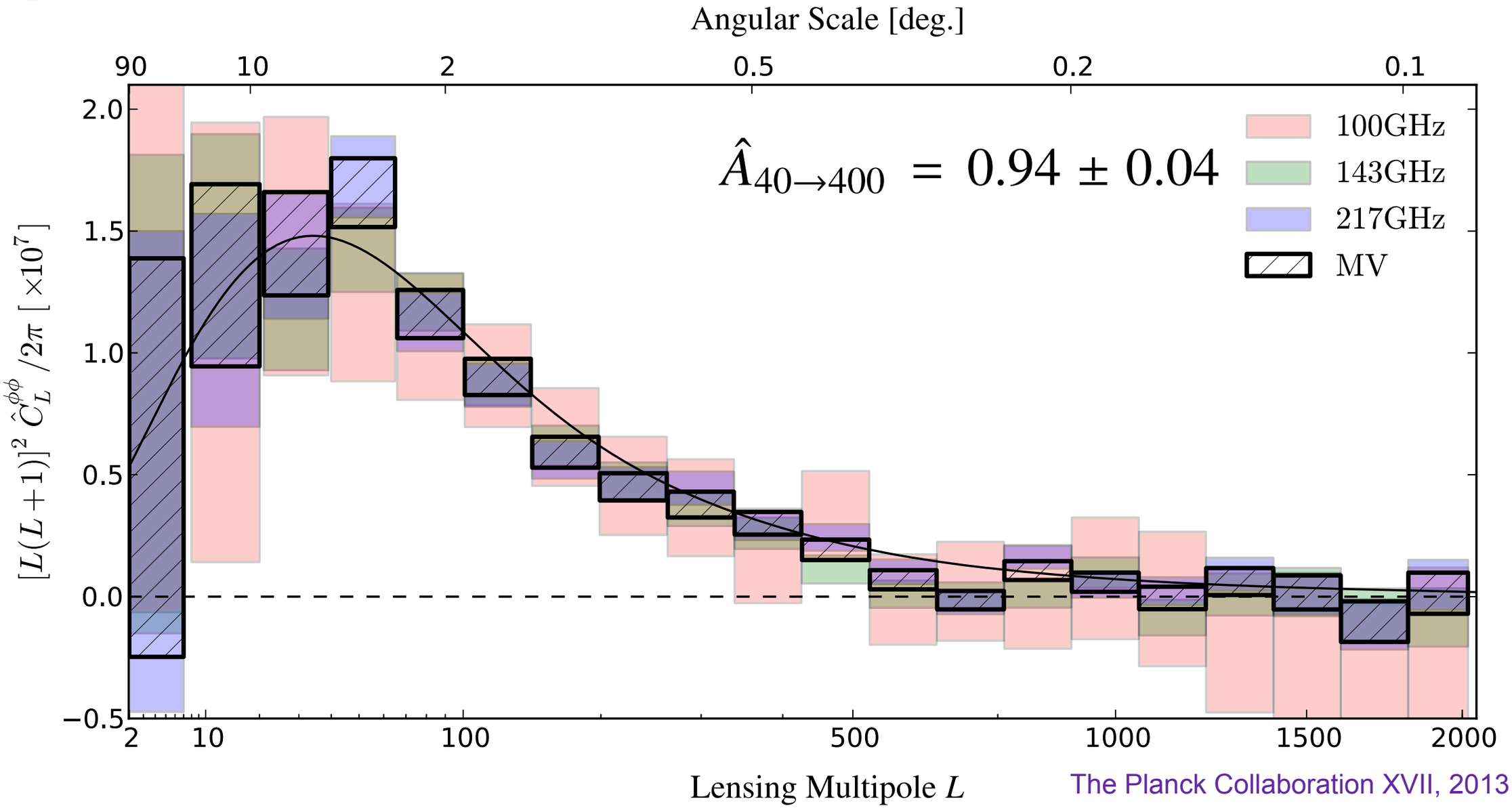
$$\mathrm{var}(\hat{\phi}) \sim \langle \hat{\phi}\hat{\phi}^{*} \rangle \sim \langle \mathrm{TTTT} \rangle \sim \mathrm{C}_{\ell}^{\phi\phi} + \mathrm{N}_{\ell}^{0}$$





The Planck Collaboration XVII, 2013

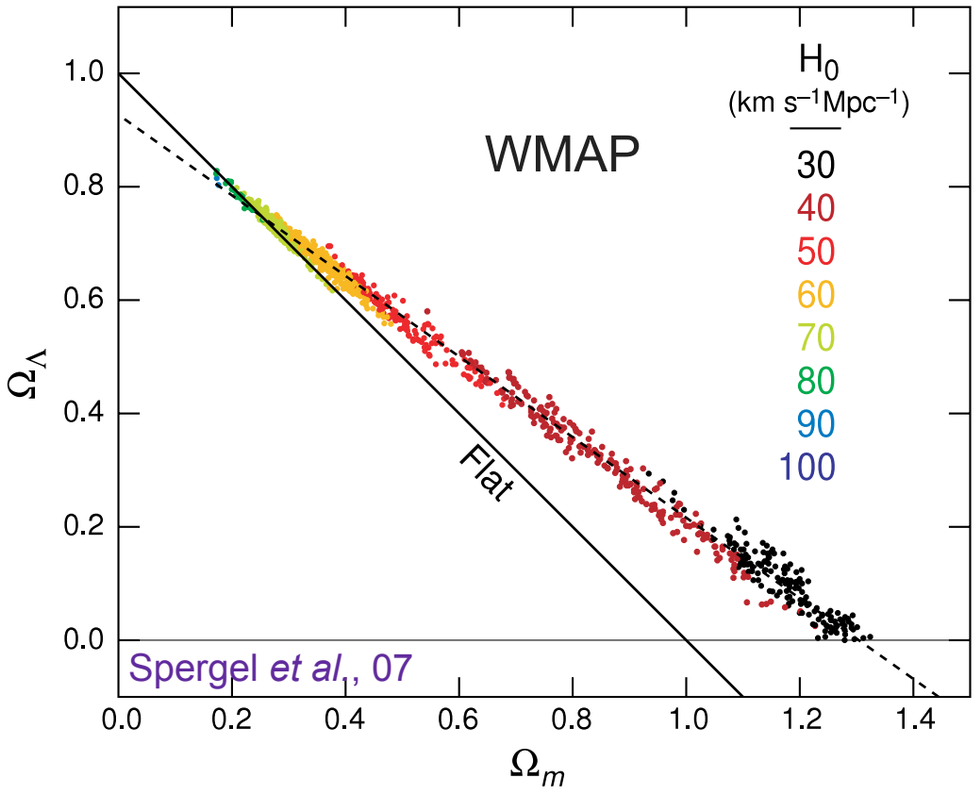
Best reconstruction



The Planck Collaboration XVII, 2013

Large-scale structure needed

- «Lensing breaks diameter degeneracy»



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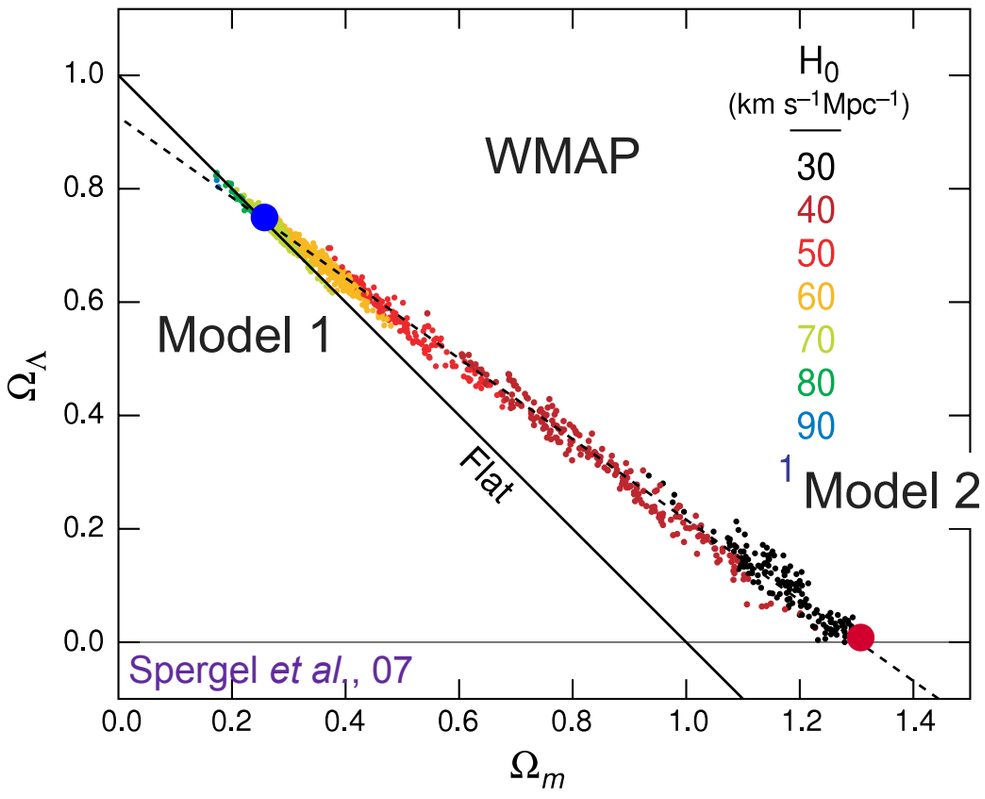

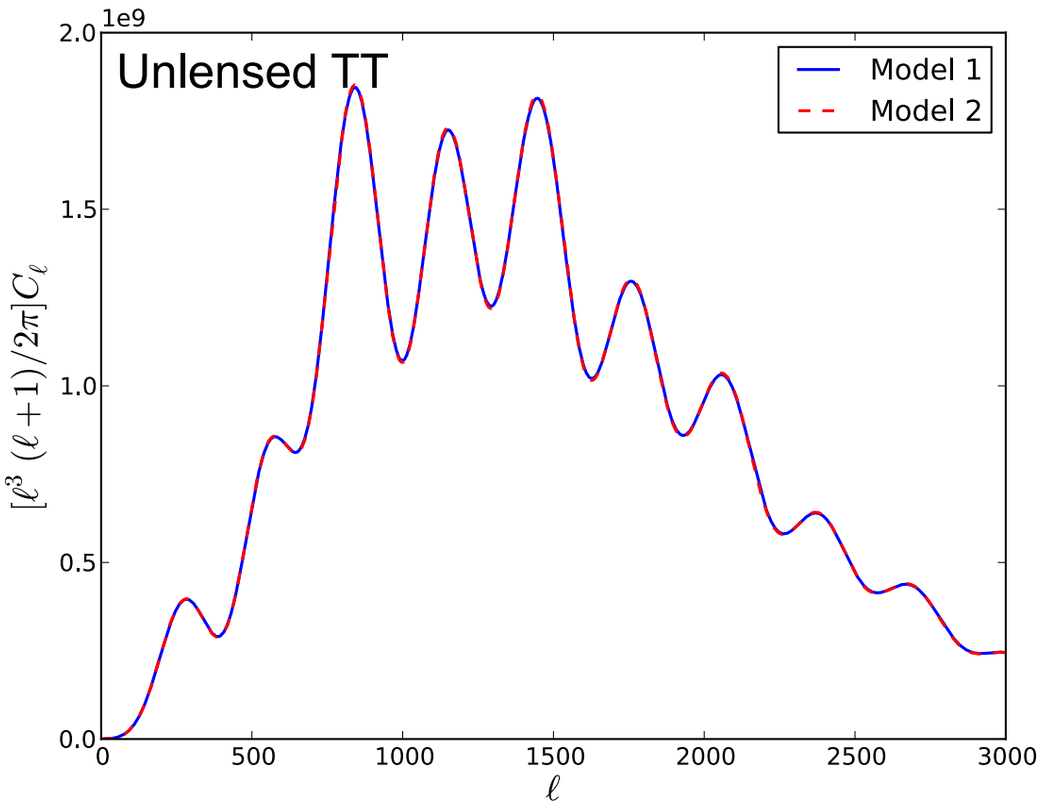

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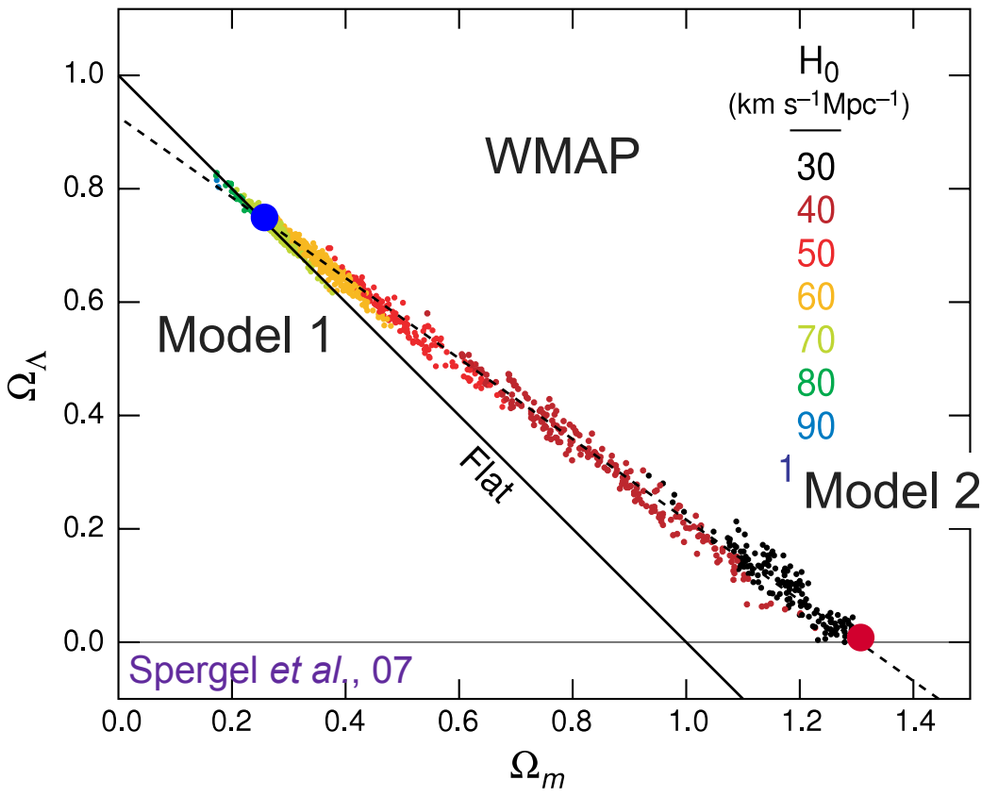

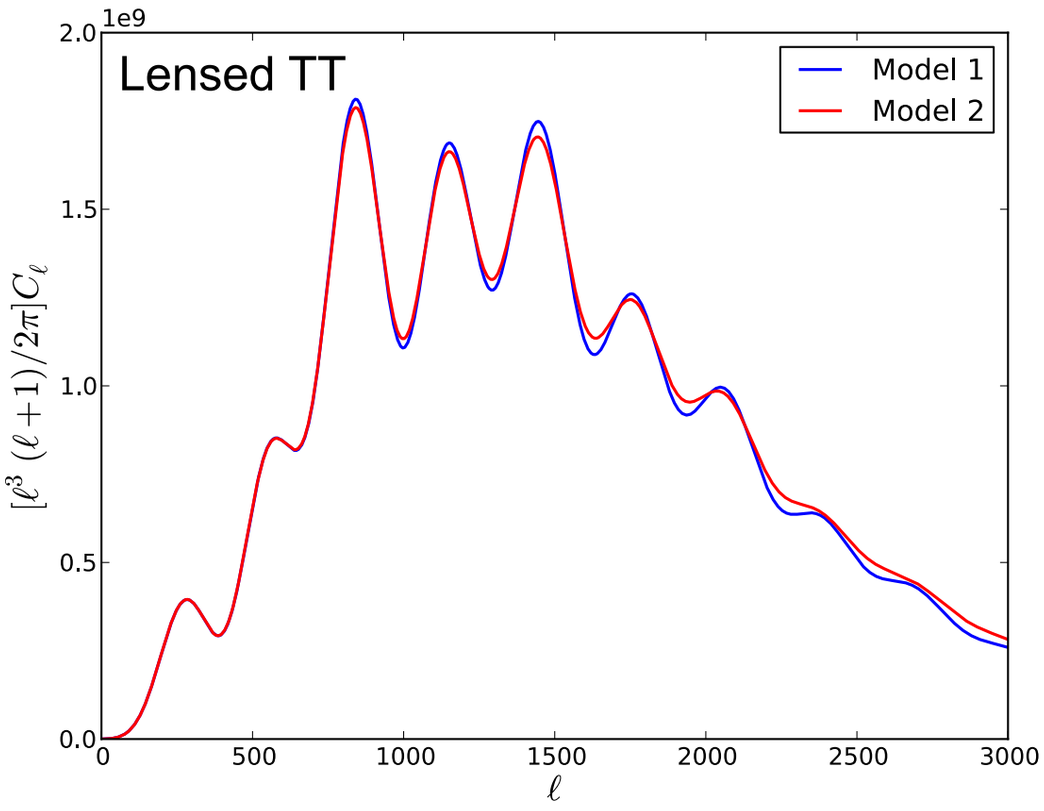

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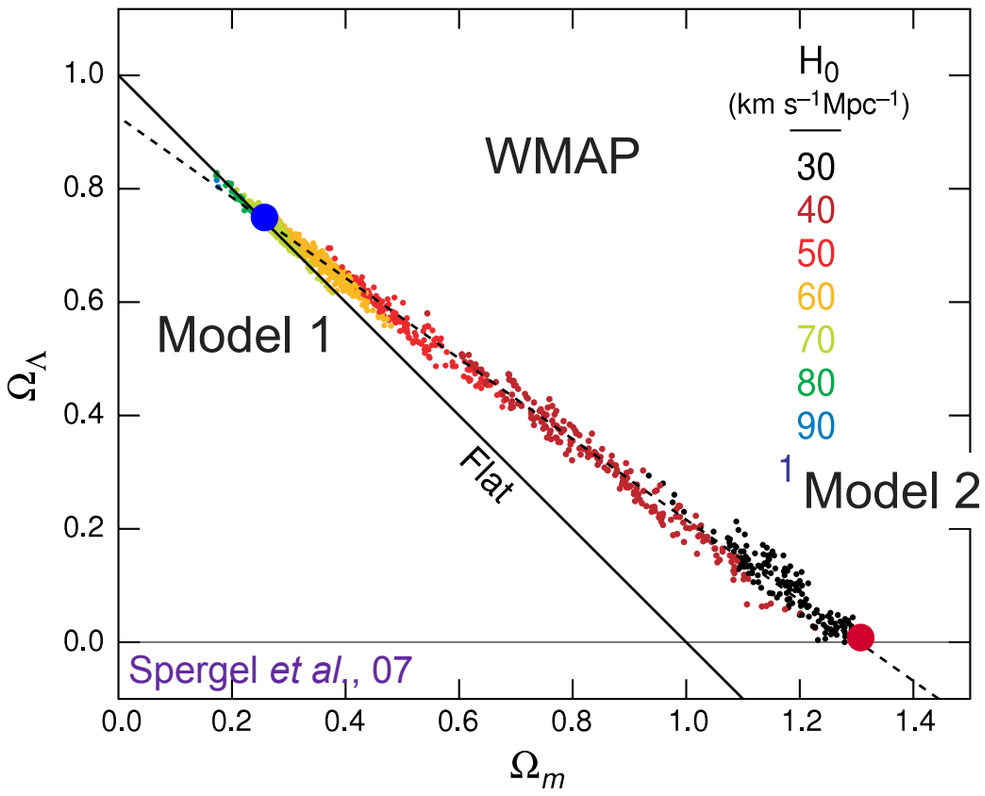

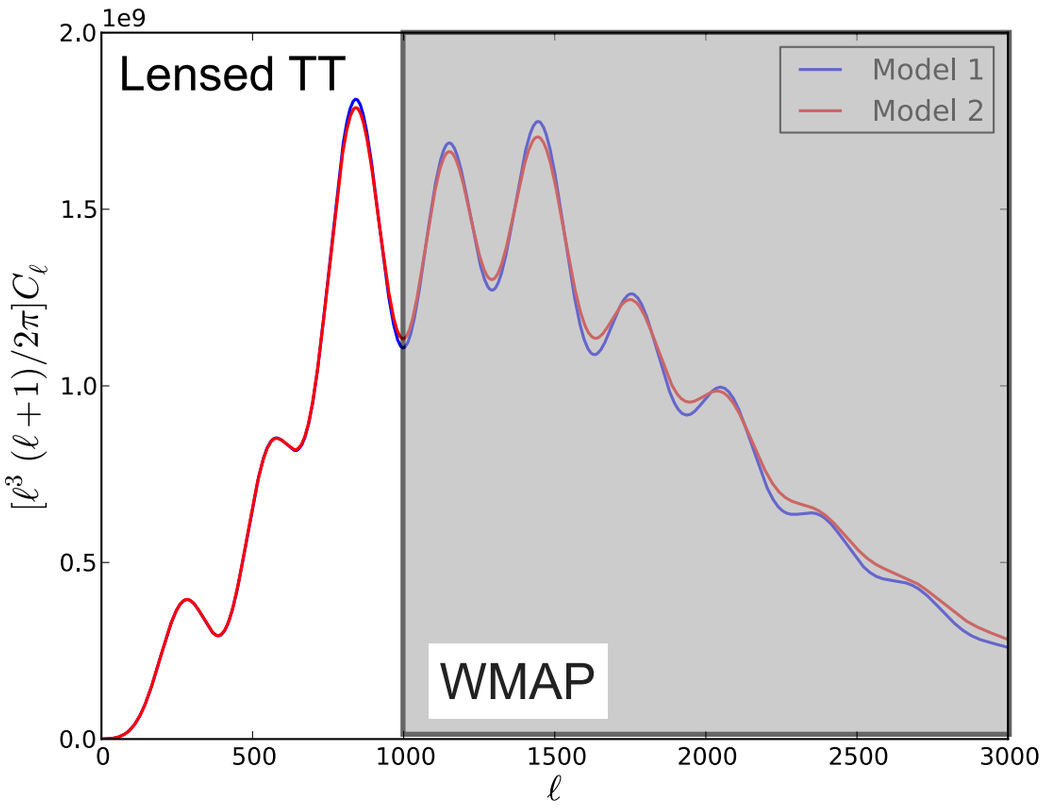

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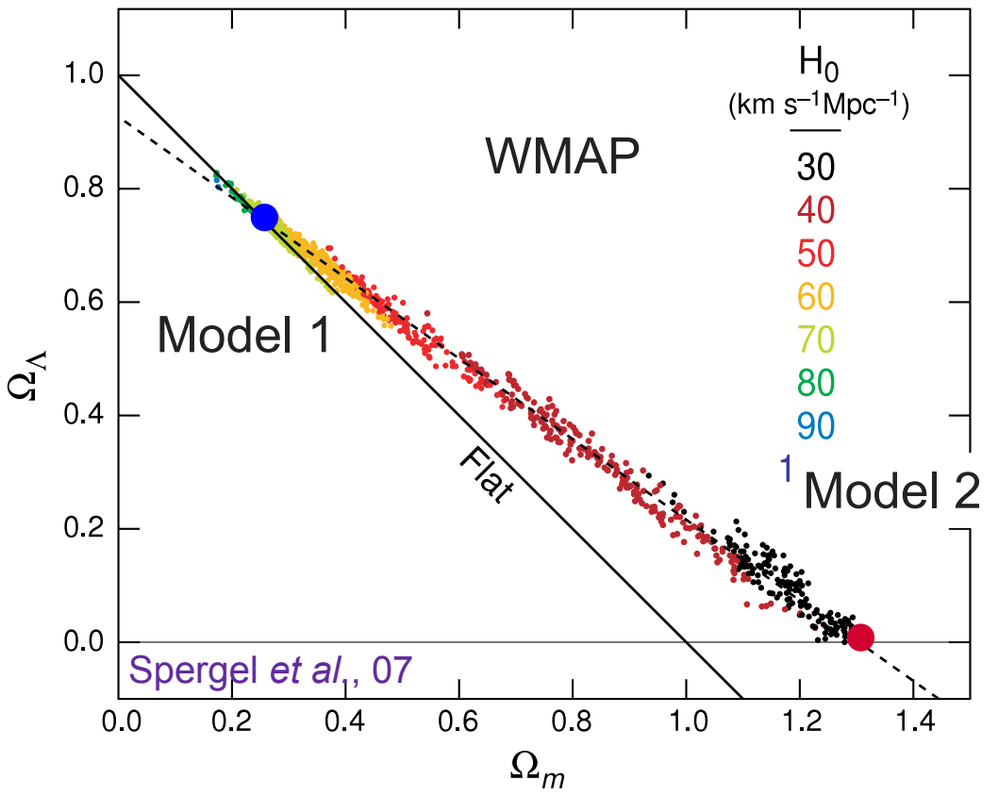

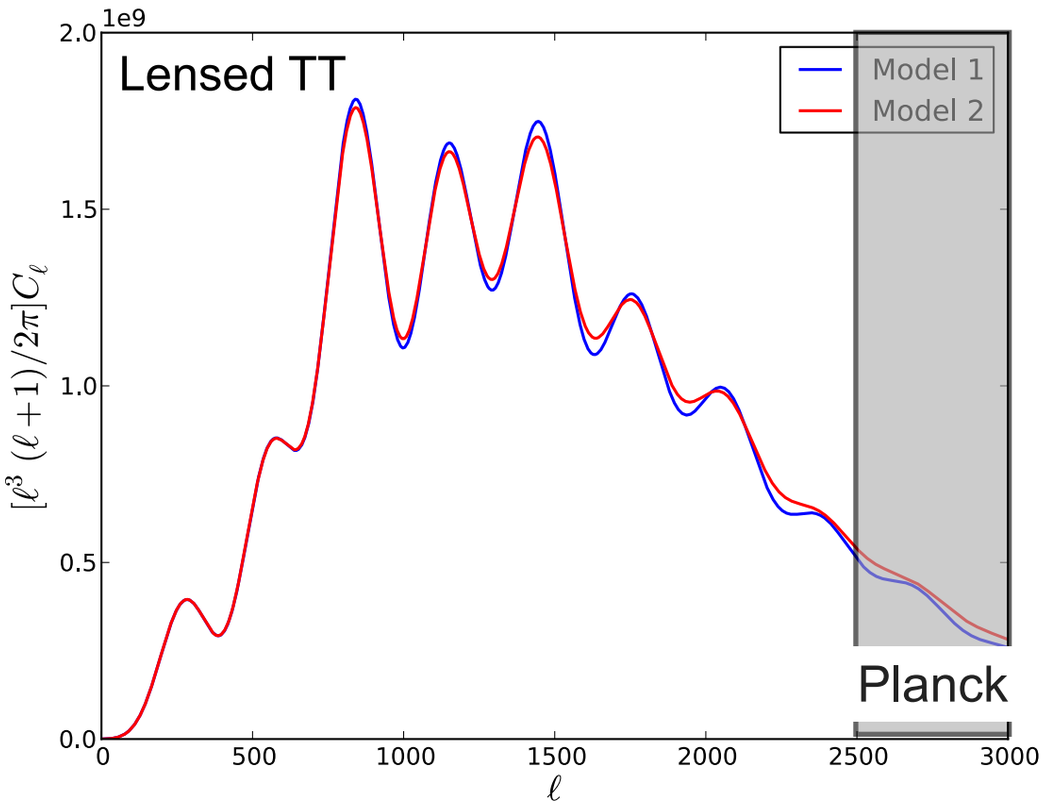

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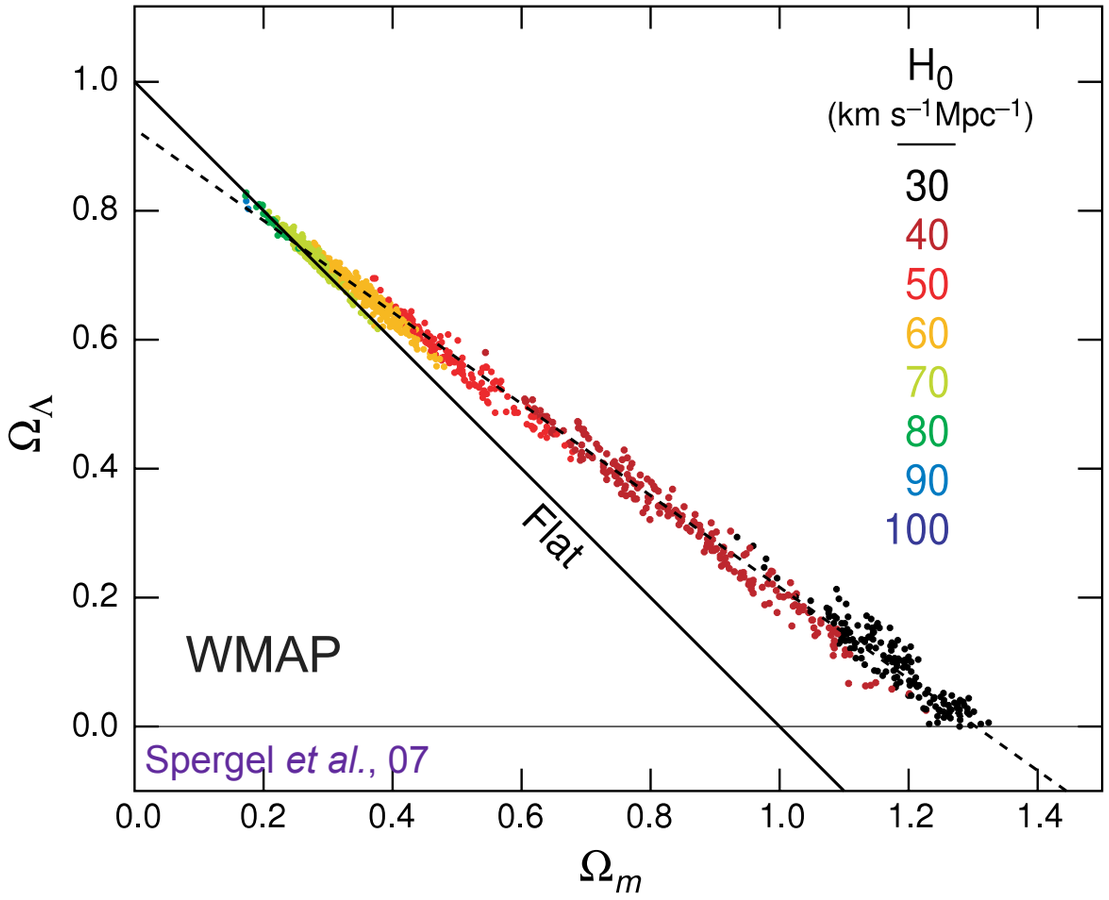
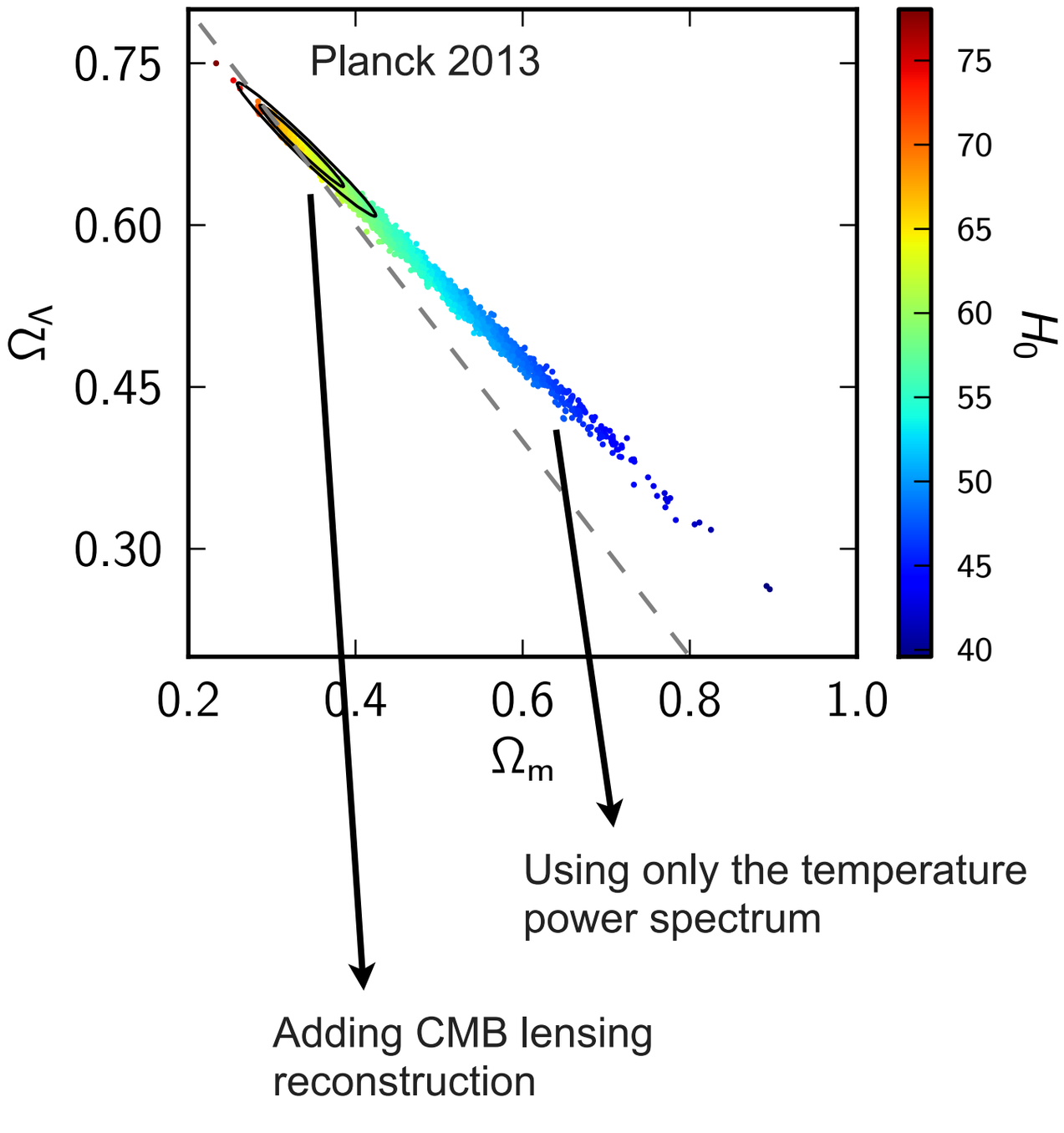
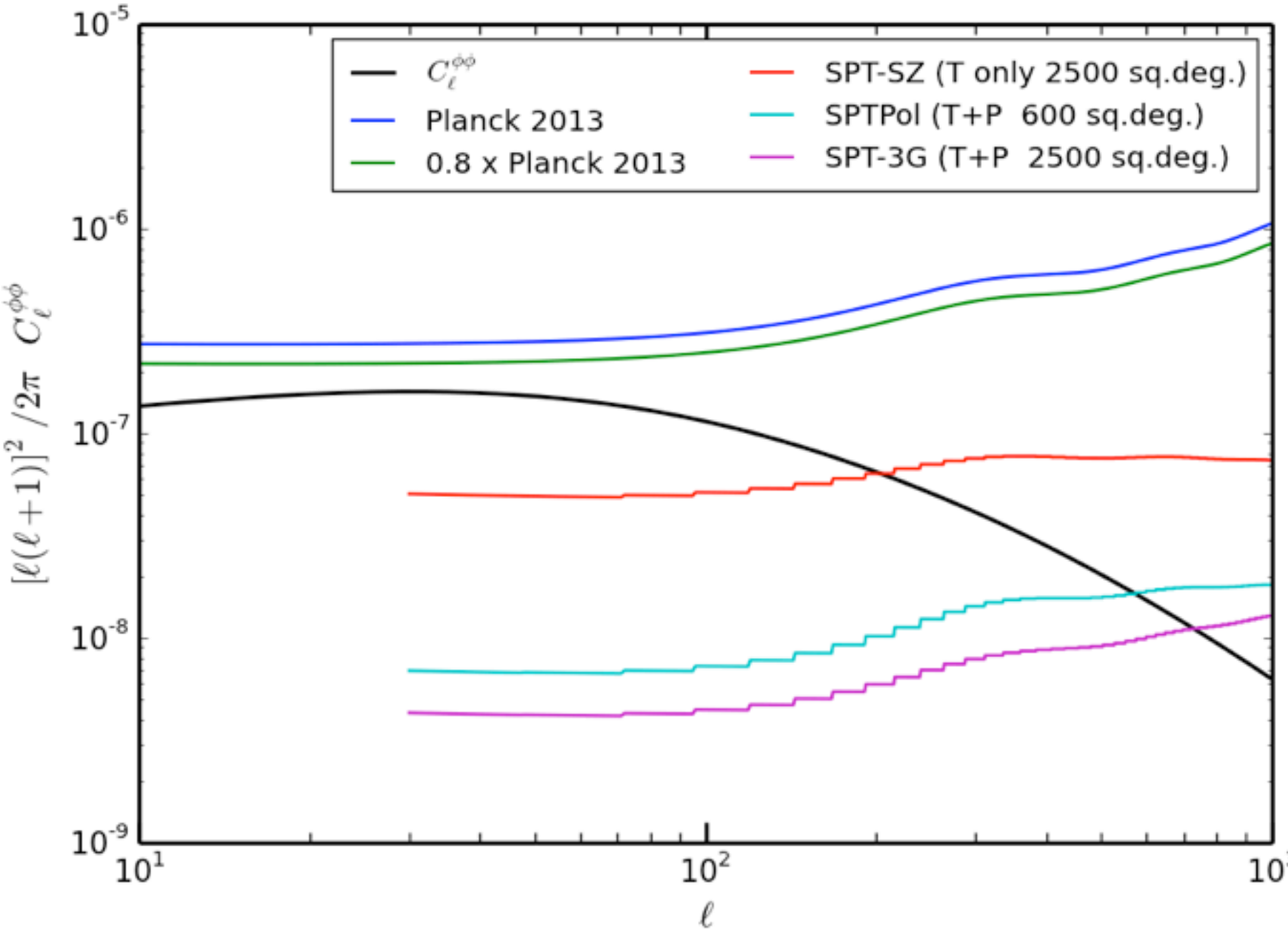




CMB lensing landscape in the coming years



2013

2014

Present (not fully public)

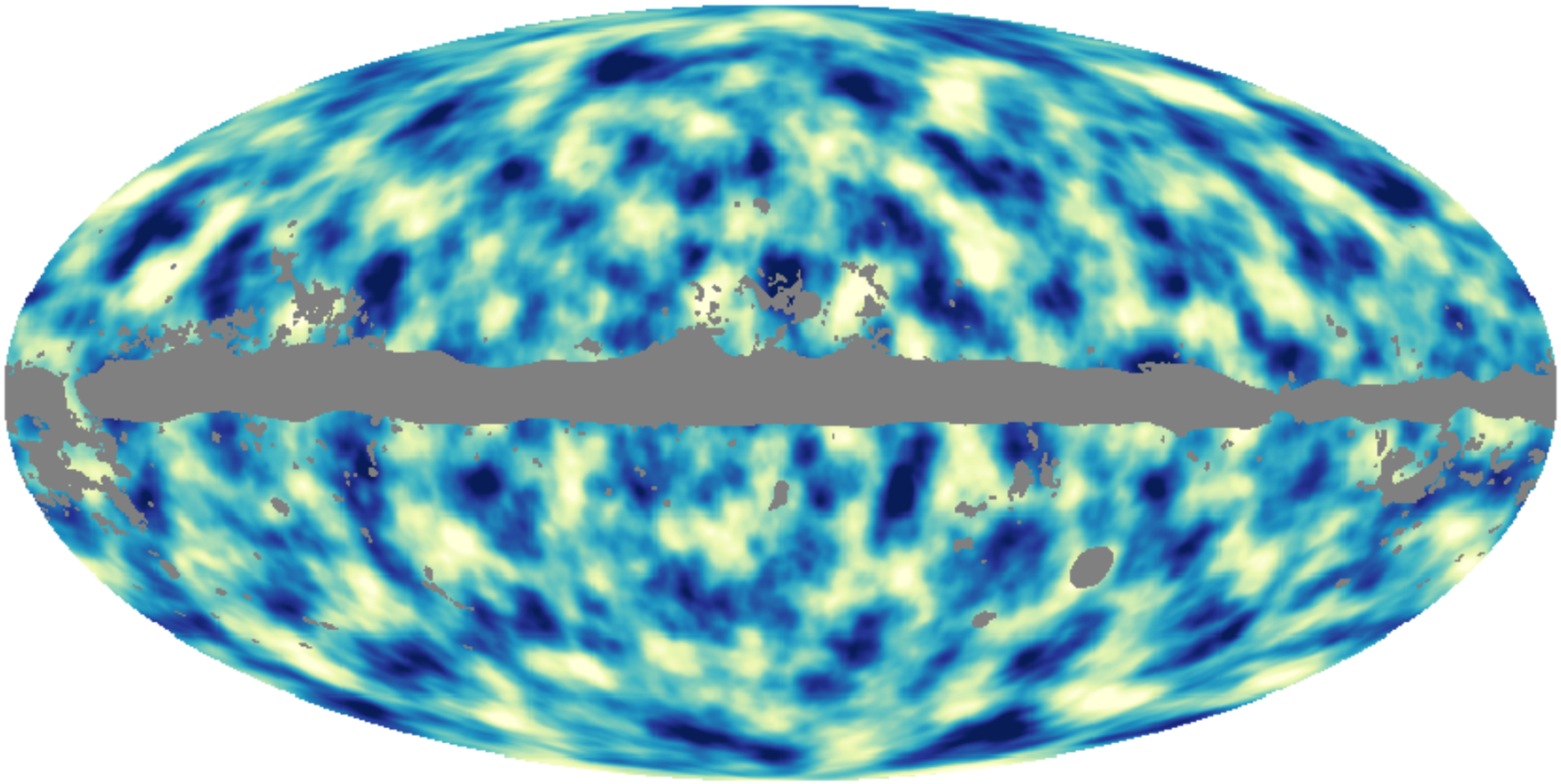
soon, data is here

2016?

SPT noise levels kindly provided by G. Simard & G. Holder (McGill Univ.)

+ ACT, ACTpol, Advanced ACT: similar timescale and properties as SPT surveys
+ Possible post-planck CMB mission ESA-M4, USA CMB-S4

The matter in the Universe as seen by Planck



The Planck Collaboration XVII, 2013

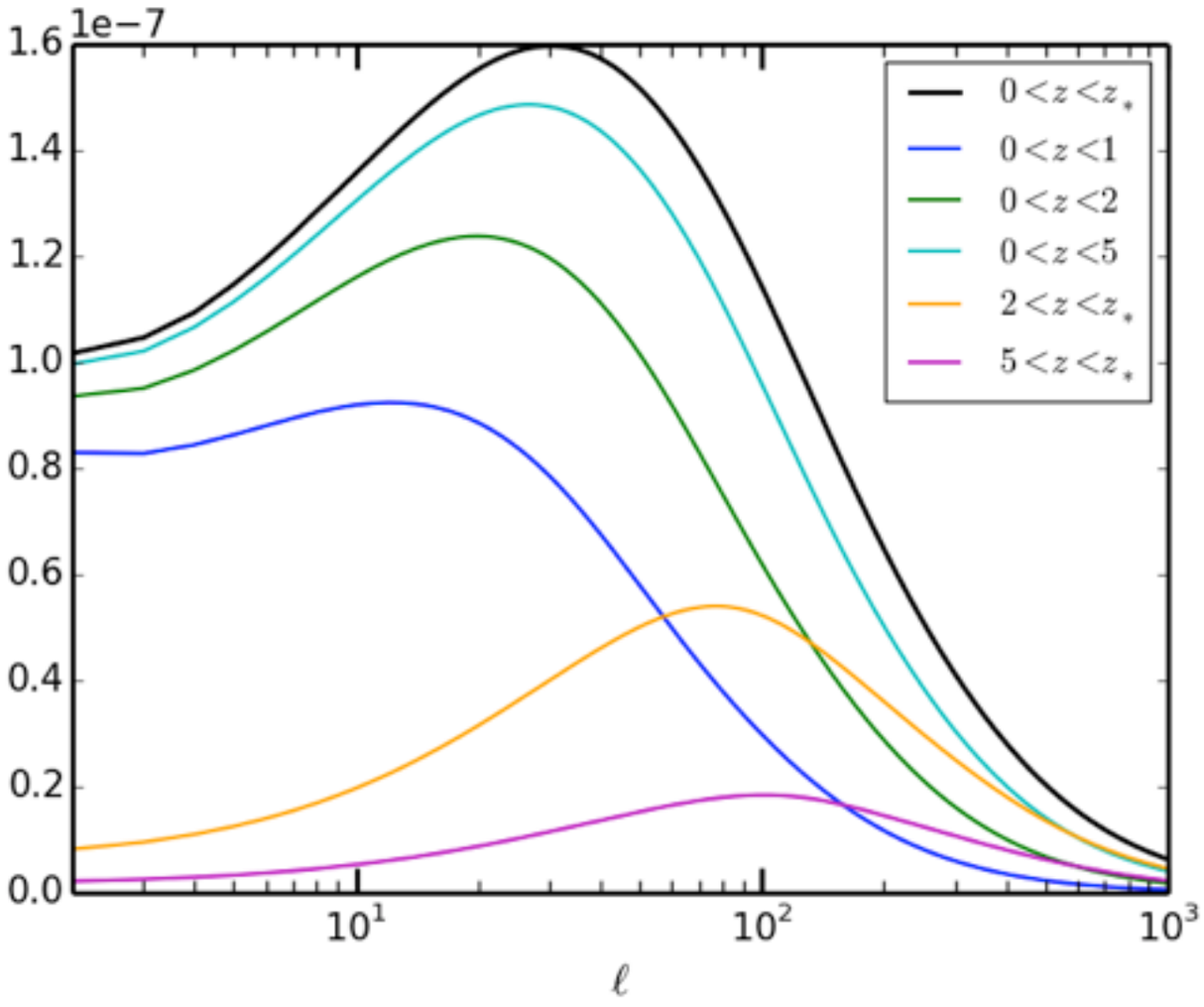
(noisy) Map of the matter distribution at z ~ 2

Lensing potential power spectrum

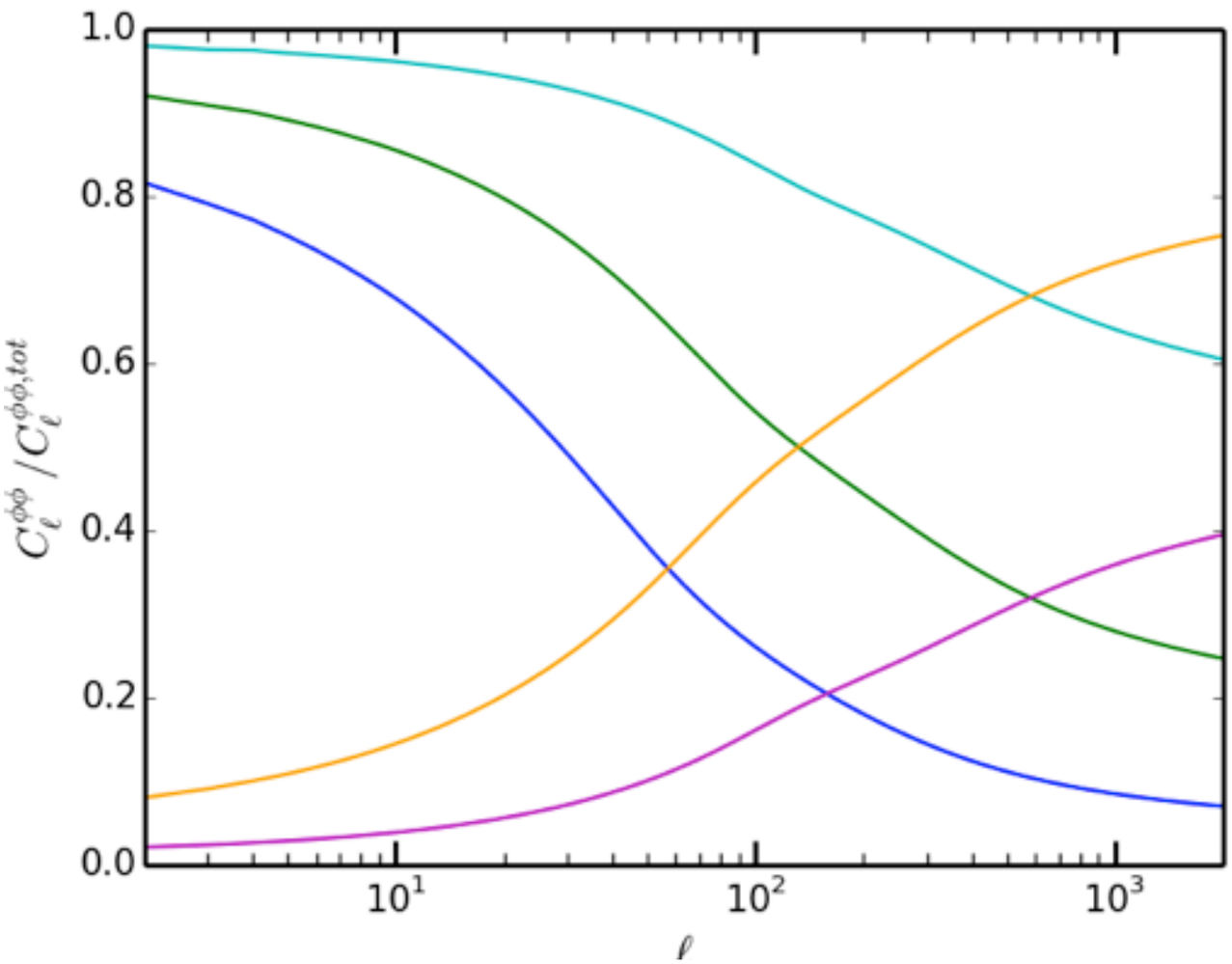
$$\phi(\hat{\mathbf{n}}) = -2\int d\eta \frac{\chi(\eta-\eta_{\rm rec})}{\chi(\eta_{\rm rec})\chi(\eta)}\Psi(\chi\hat{\mathbf{n}},\eta)$$

Contribution of LSS at different redshifts to the lensing potential power spectrum

Absolute spectrum



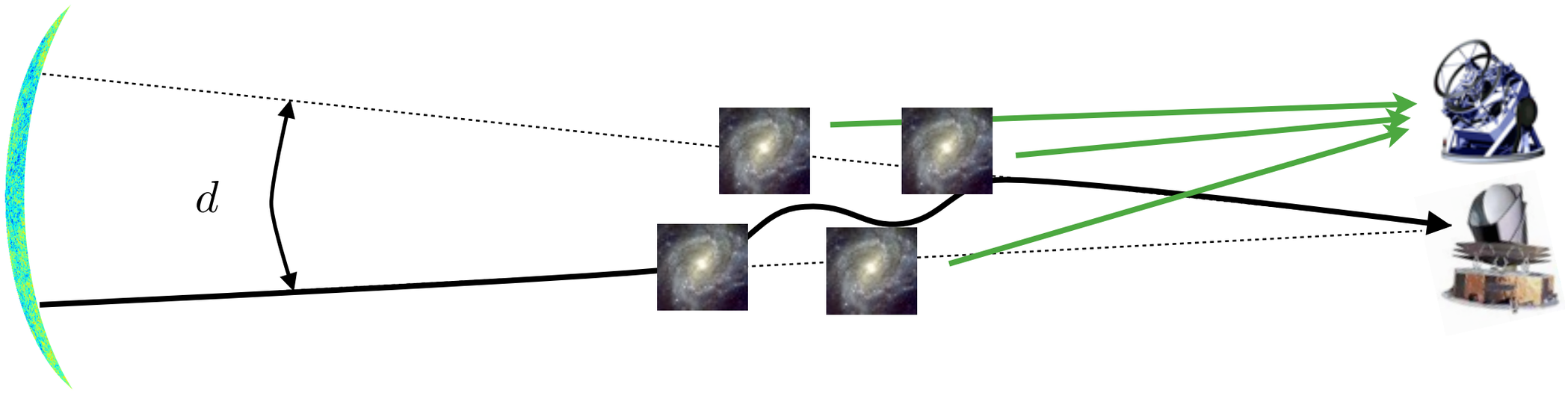
Ratio



The CMB lensing kernel is wide. Almost all redshift contribute

Cross-correlations

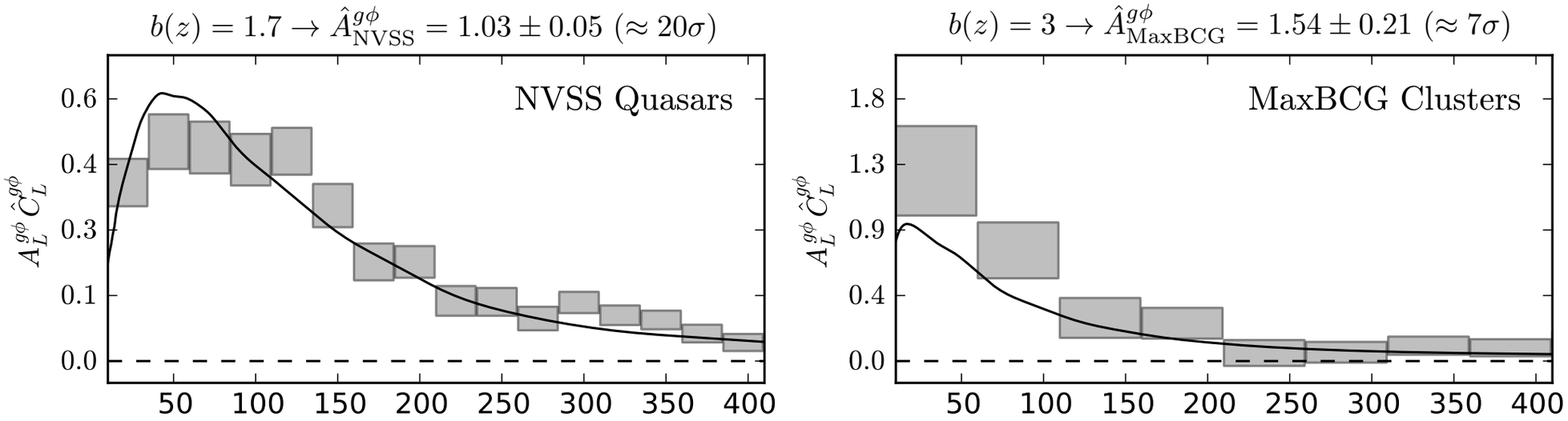
LSS that causes CMB lensing can be (directly) observed by LSST



- **Galaxies trace the matter distribution (biased!)**

- **CMB lensing by all the matter distribution**

CMB lensing - External tracers



The Planck Collaboration XVII, 2013

+ similar measurements from SPT, ACT, PolarBear

Cross-correlations

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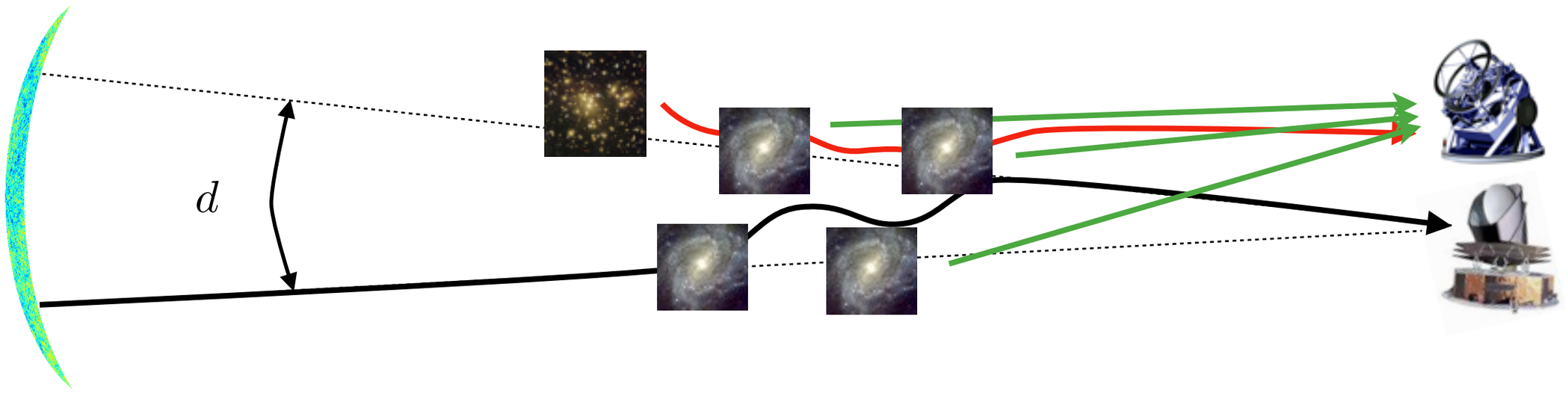


- Galaxies trace the matter distribution (biased!)
- Weak lensing of background galaxy by foreground matter distribution
- CMB lensing by all the matter distribution

Cross-correlations

$$C_\ell^{XY} \sim \int_0^{\chi_*} d\chi w^X(\chi) w^Y(\chi) P(\ell/\chi, \chi)$$

Angular power spectrum of the cross-correlation

Matter power spectrum

$$w^l(\chi) \propto \Omega_m H_0^2 \frac{\chi_* - \chi}{\chi_*} \frac{\chi}{a}$$

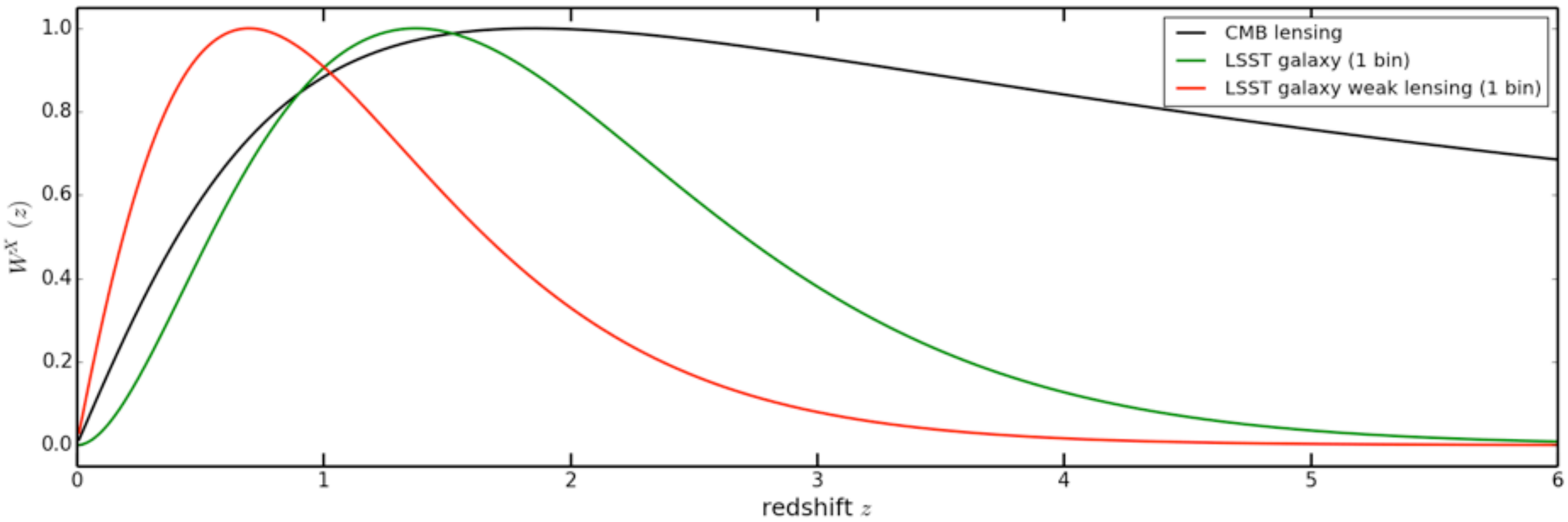
CMB lensing

$$w^g(\chi) \propto b \frac{dN}{d\chi}$$

Galaxy distribution

$$w^s(\chi) \propto H_0^2 \Omega_m \frac{\chi}{a} \int_\chi^{\chi_*} d\chi' \frac{dN}{d\chi'} \frac{\chi' - \chi}{\chi'}$$

Weak lensing on galaxies



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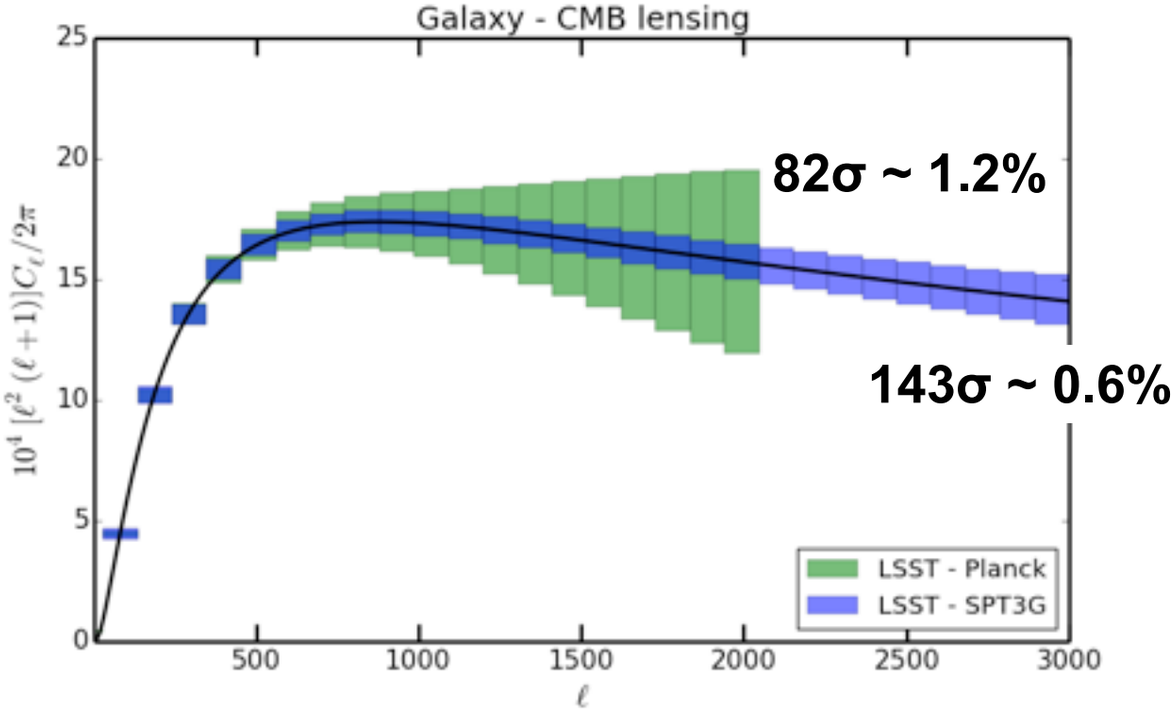

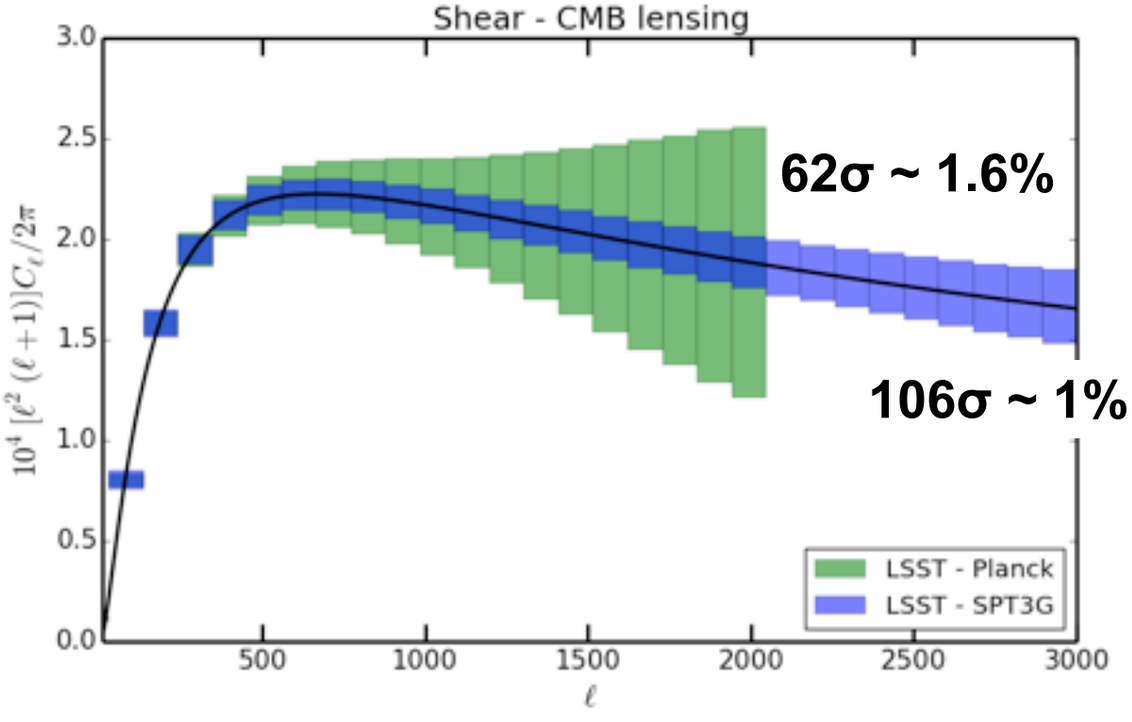

Similar measurements are underway within the Dark Energy Survey (DES)

Galaxy distribution, density and shape noise from LSST science book

Cross-correlations

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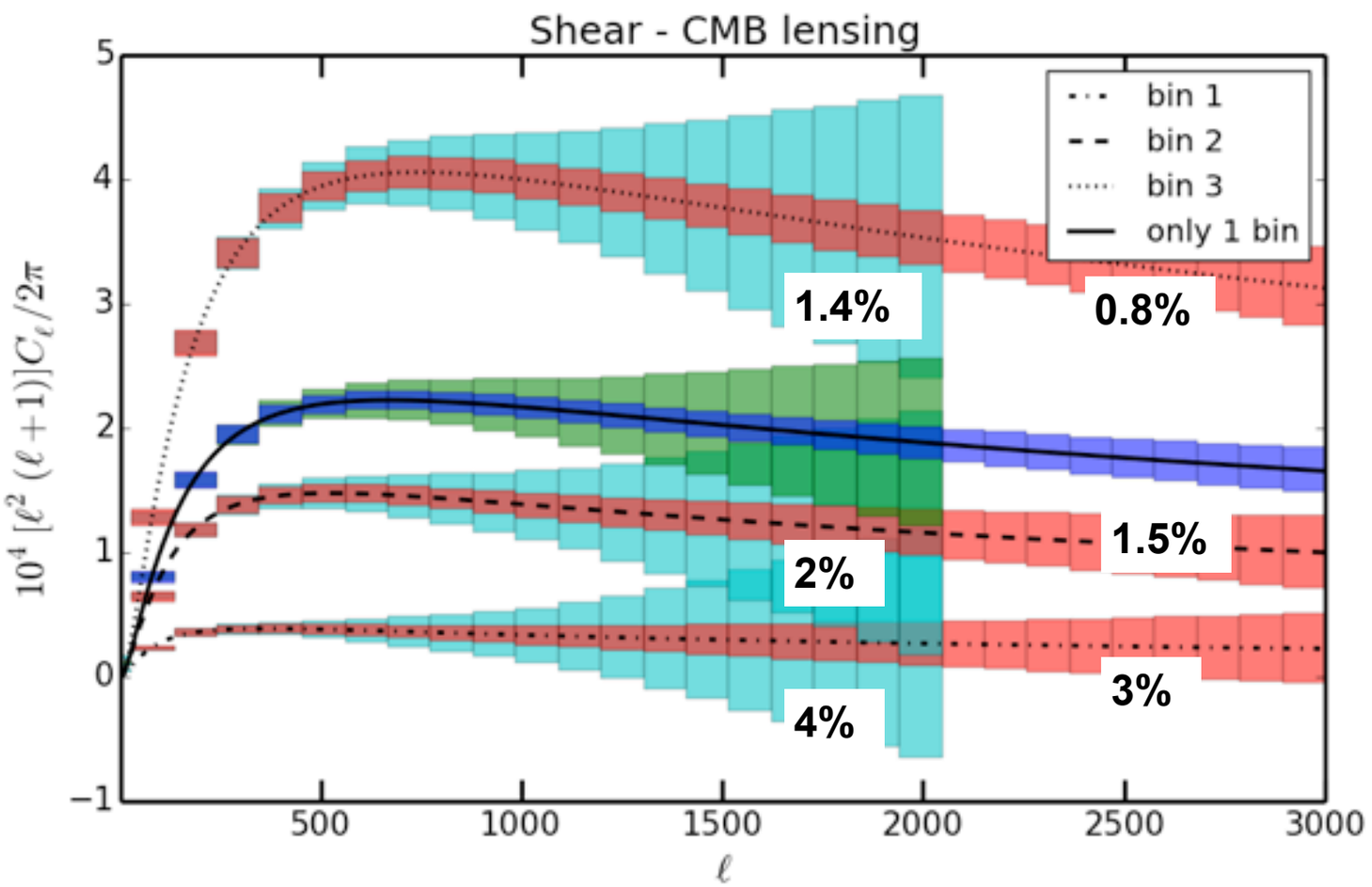
Weak lensing on galaxies



CMB lensing bring new LSS observation, with CMB data

These cross-correlation contain huge statistical power

Next steps: include CMB lensing in FoM calculations

Conclusions

CMB & LSS
2 complementary probes

- Arcminute scale CMB experiments provides additional information on the Large-Scale Structure of the Universe: CMB lensing, SZ effect
- Full-sky CMB & LSS data needed for ISW (not mentioned here)

CMB lensing

- CMB lensing can be considered as a new probe of the matter distribution
- Different systematics, bias free, no observational effects (source distribution)
- Hardly mentioned in LSST Science Book (i.e. detailed forecasts needed)

Item for discussions

- Other LSS probes from CMB: SZ, ISW
- CMB data around 2025