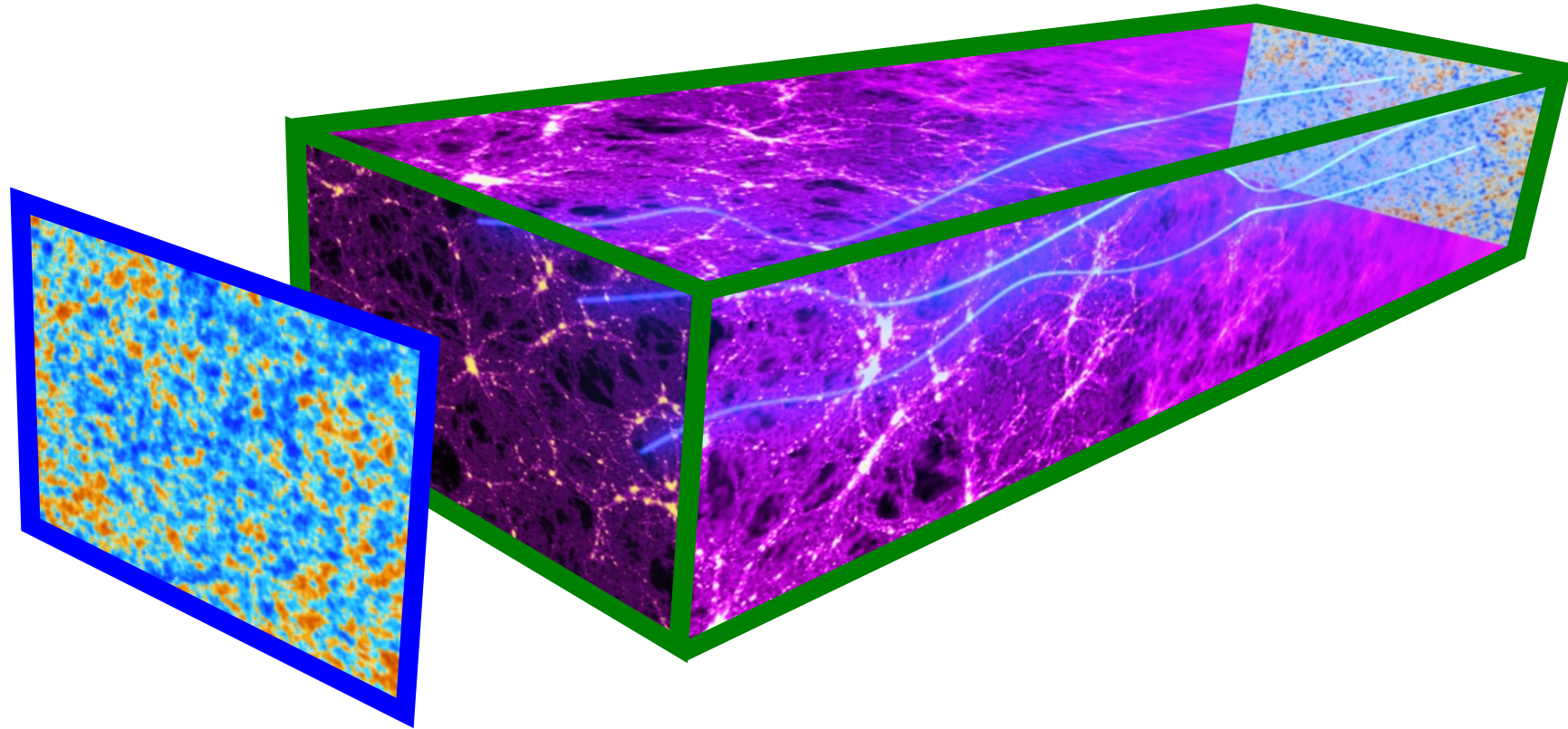


Mapping matter jointly with CMB lensing and Large Scale Structure

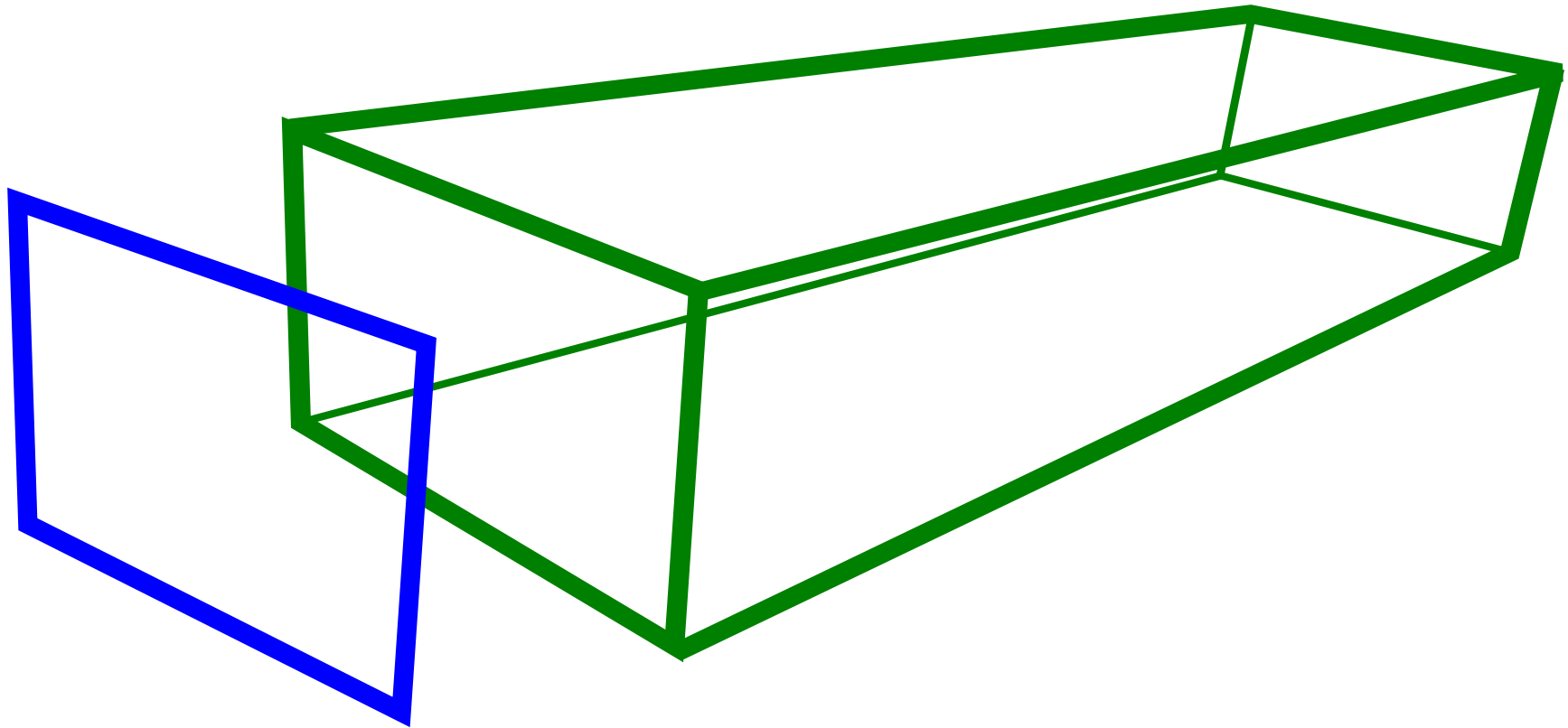


Kevin Huffenberger
Felipe Maldonado
Aditya Rotti



Overdensity

δ



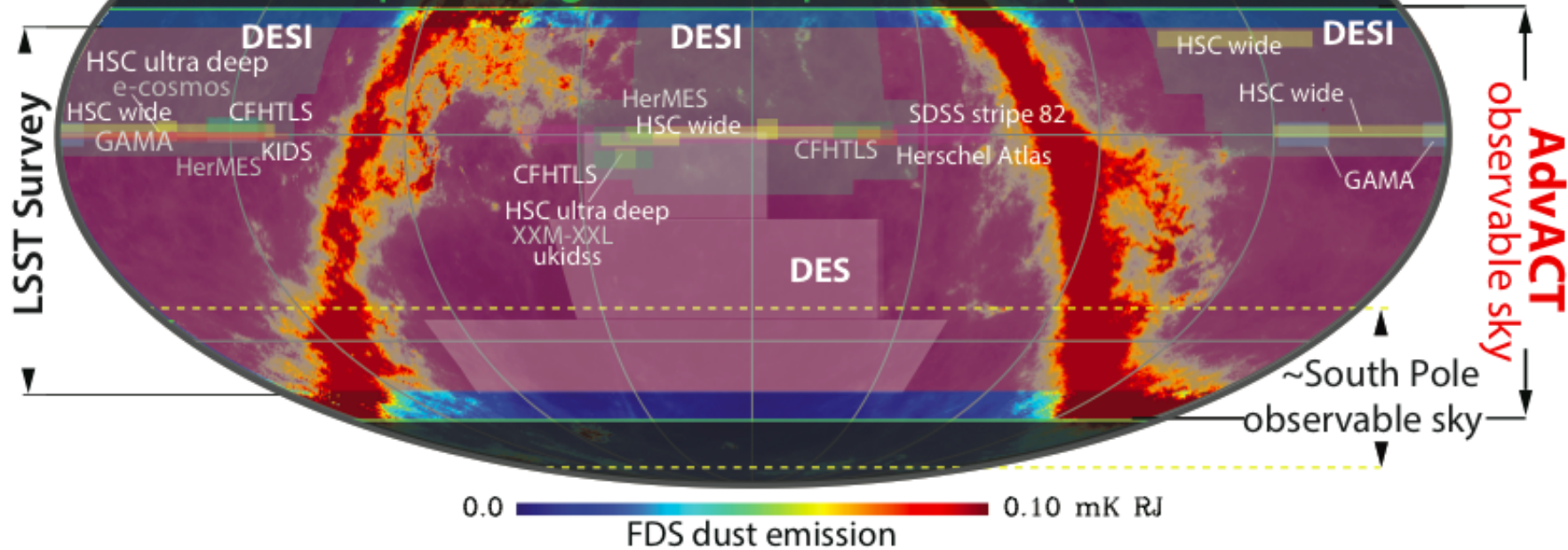
Convergence

κ

**How to combine
measurements?**

Advanced ACTPol Survey:

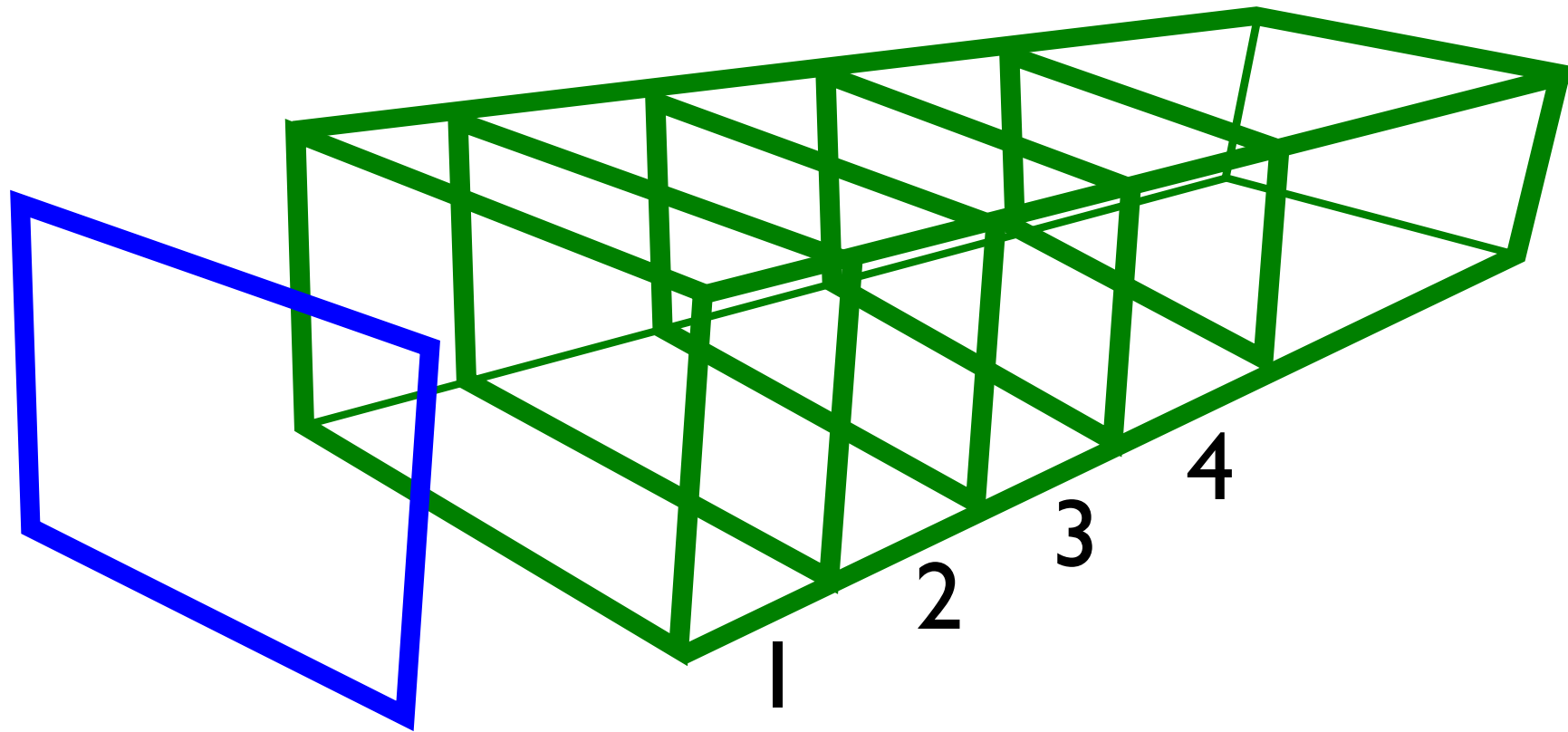
20,000 square degrees, complete overlap with LSST



**Typical: make slices
and cross-correlate**

Overdensity

δ

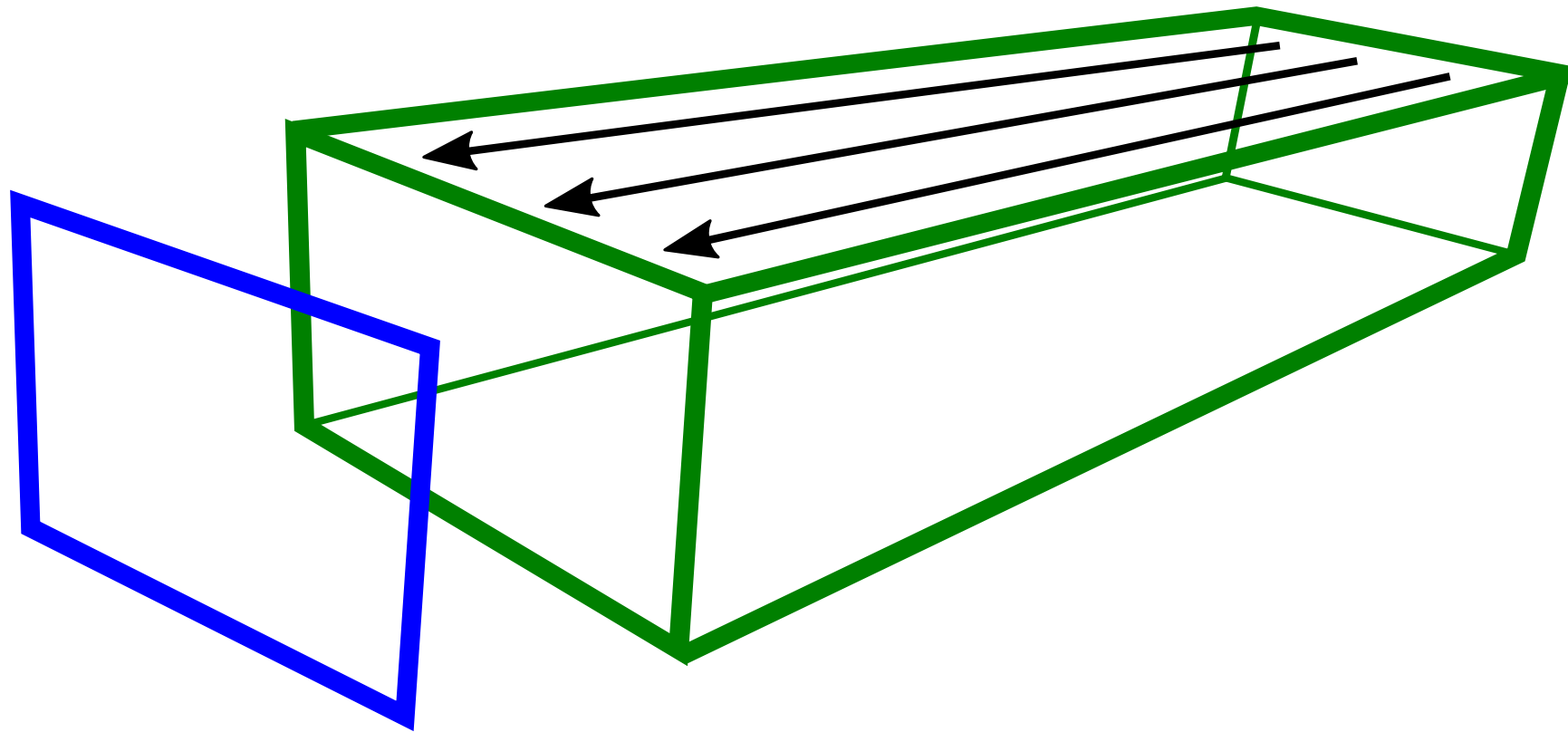


Convergence

\mathcal{K}

Y2: Ross Cawthon

Allison+ 2015; Planck+ 2014, 2015; Ade+ 2014; van Engelen+ 2014; Hanson+ 2013; Holder+ 2013; ...



$\kappa(\mathbf{n}) = \int dr F(r) \delta(r, \mathbf{n})$ is linear operation

Matrix interpretation

Simon (2013);
Simon, Taylor,
Hartlap (2009)

$$d = R \delta + n$$

$$\begin{pmatrix} n_{\text{gal}} \\ \kappa_{\text{obs}} \end{pmatrix} = \begin{pmatrix} \text{bias,} \\ \text{window} \\ \text{lensing} \\ \text{kernel} \end{pmatrix} \delta + \begin{pmatrix} \text{Poisson} \\ \text{noise} \\ \text{lensing} \\ \text{noise} \end{pmatrix}$$

Matrix solutions

Weiner filter minimizes reconstruction errors

$$(S^{-1} + R^{\dagger} N^{-1} R) \tilde{\delta} = R^{\dagger} N^{-1} d$$

(today)

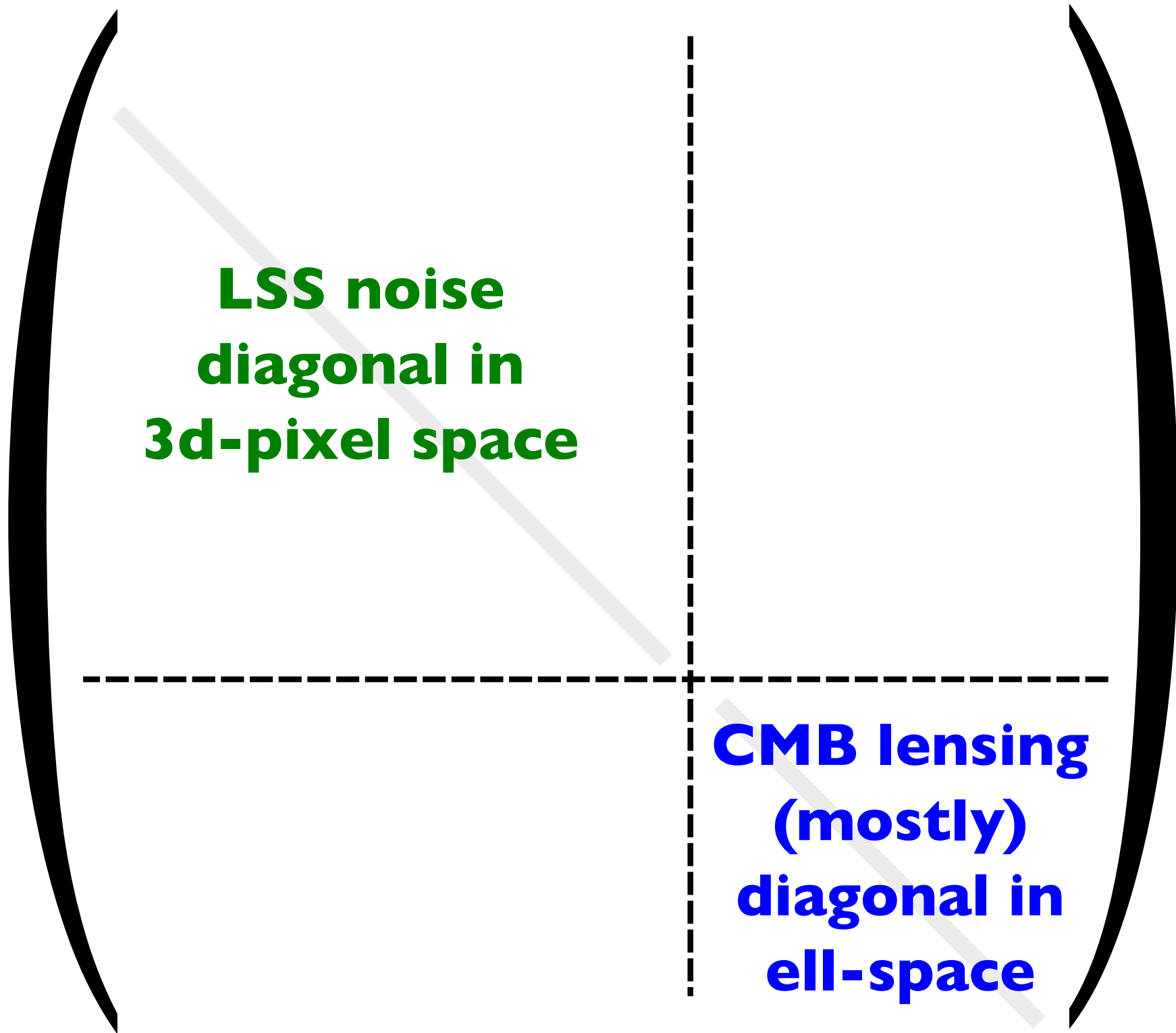
Mapmaking equation minimizes χ^2 wrt noise

$$(R^{\dagger} N^{-1} R) \tilde{\delta} = R^{\dagger} N^{-1} d$$

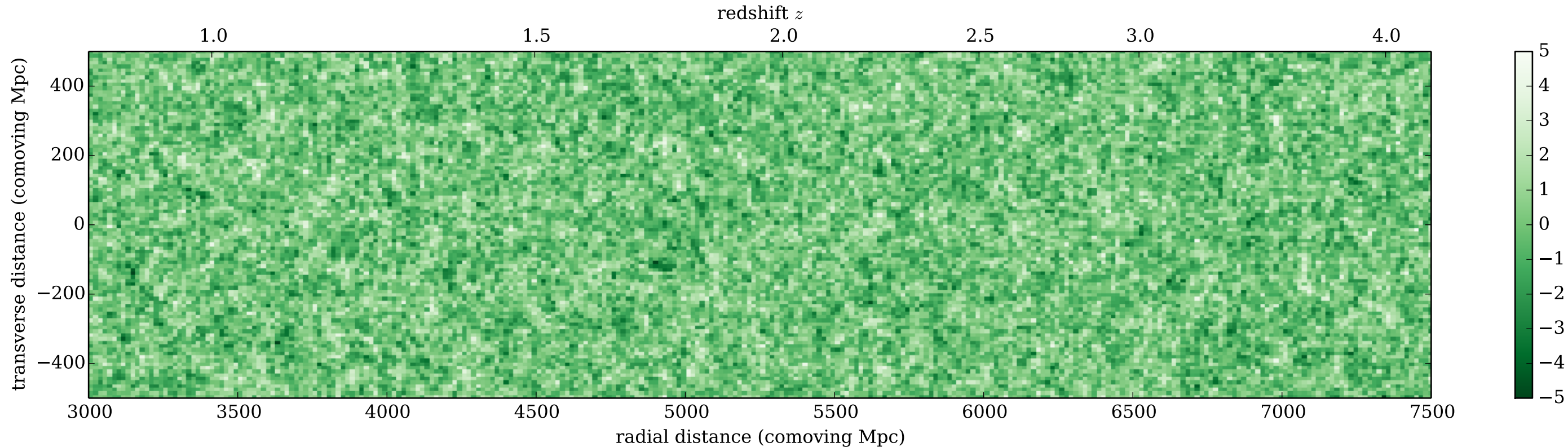
$N =$

**LSS noise
diagonal in
3d-pixel space**

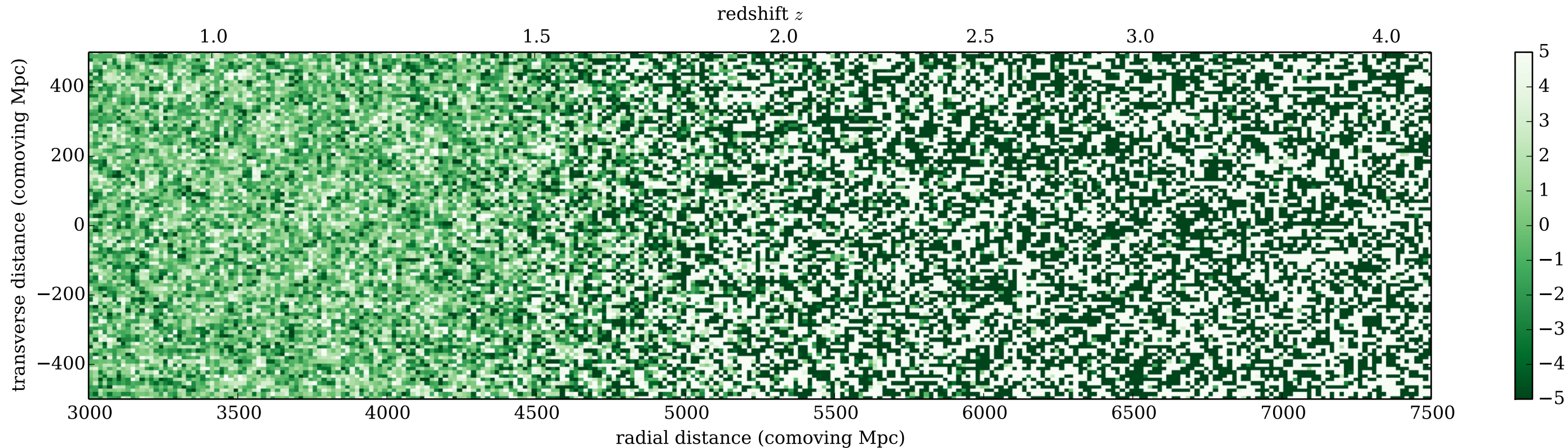
**CMB lensing
(mostly)
diagonal in
ell-space**



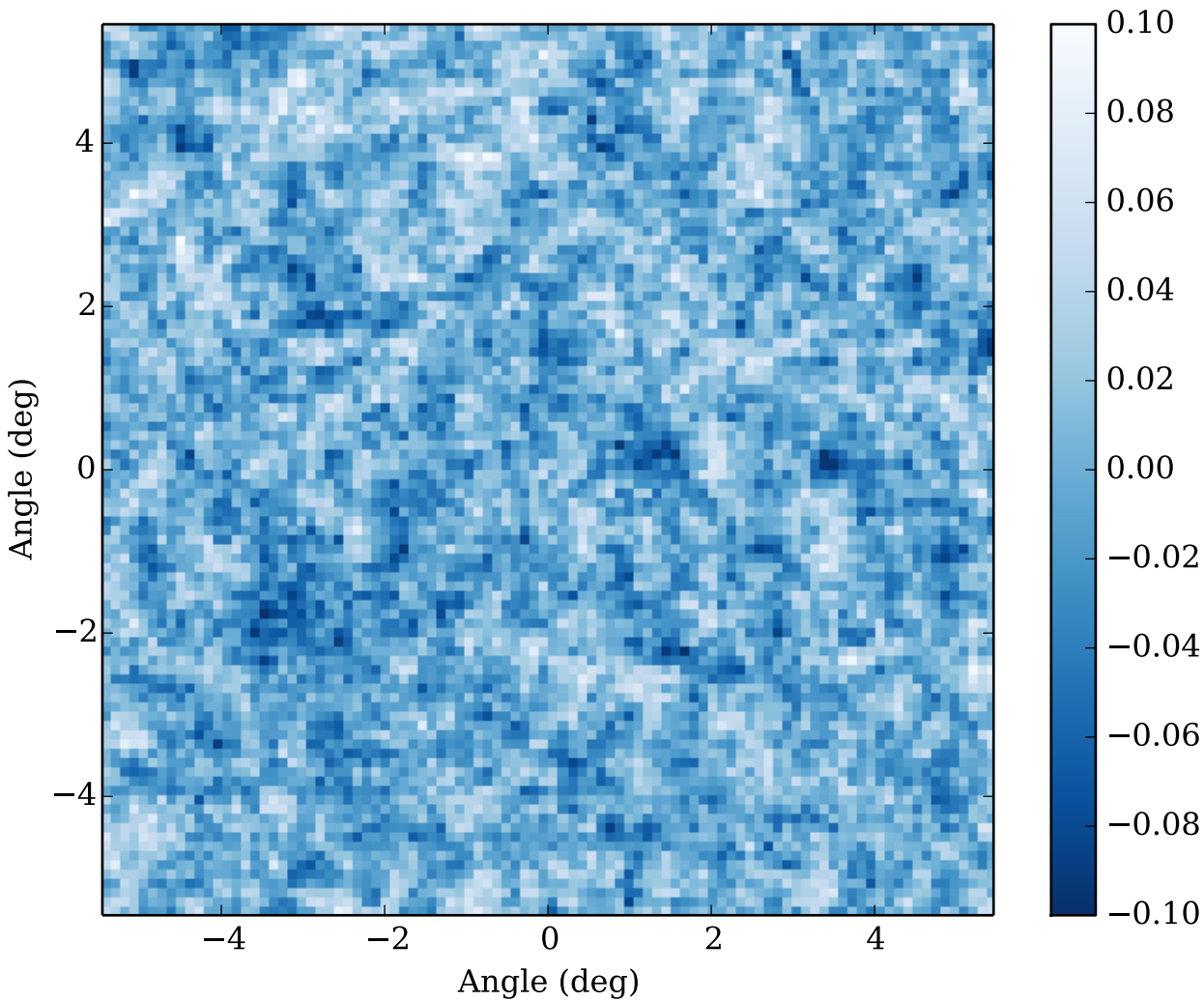
Overdensity $\delta(\mathbf{x})$



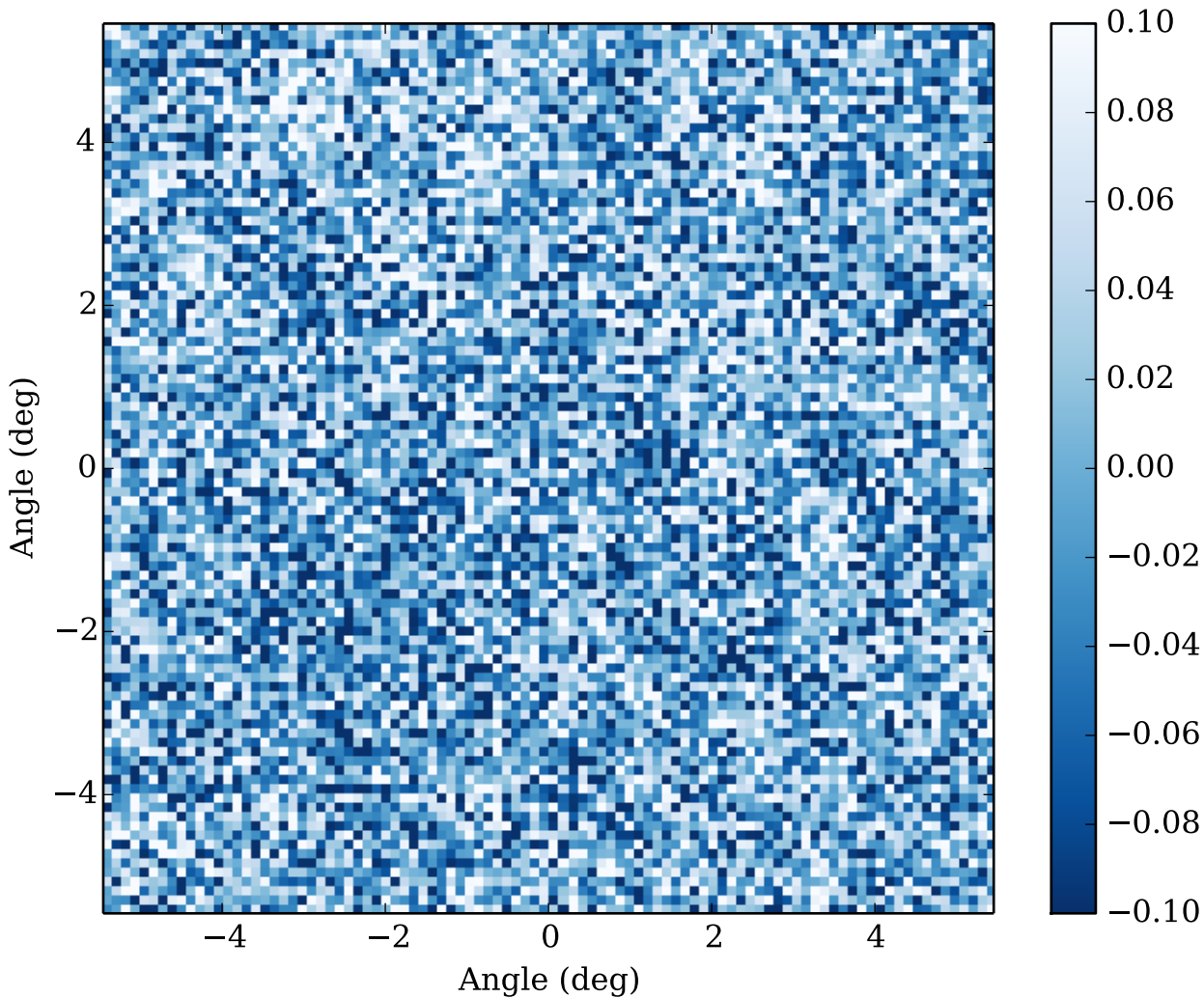
Simulated noisy observation: $d_{\text{LSS}} = \delta + n_{\text{LSS}}$



Sim. CMB lensing $\kappa(\mathbf{n})$



Sim. CMB lensing obs. $d_\kappa = \kappa + n_\kappa$



Matrix solution: practicalities

Modest resolution tests: $96 \times 96 \times 288$; ~ 100 sq deg.

"Isometric" approximation for lines of sight

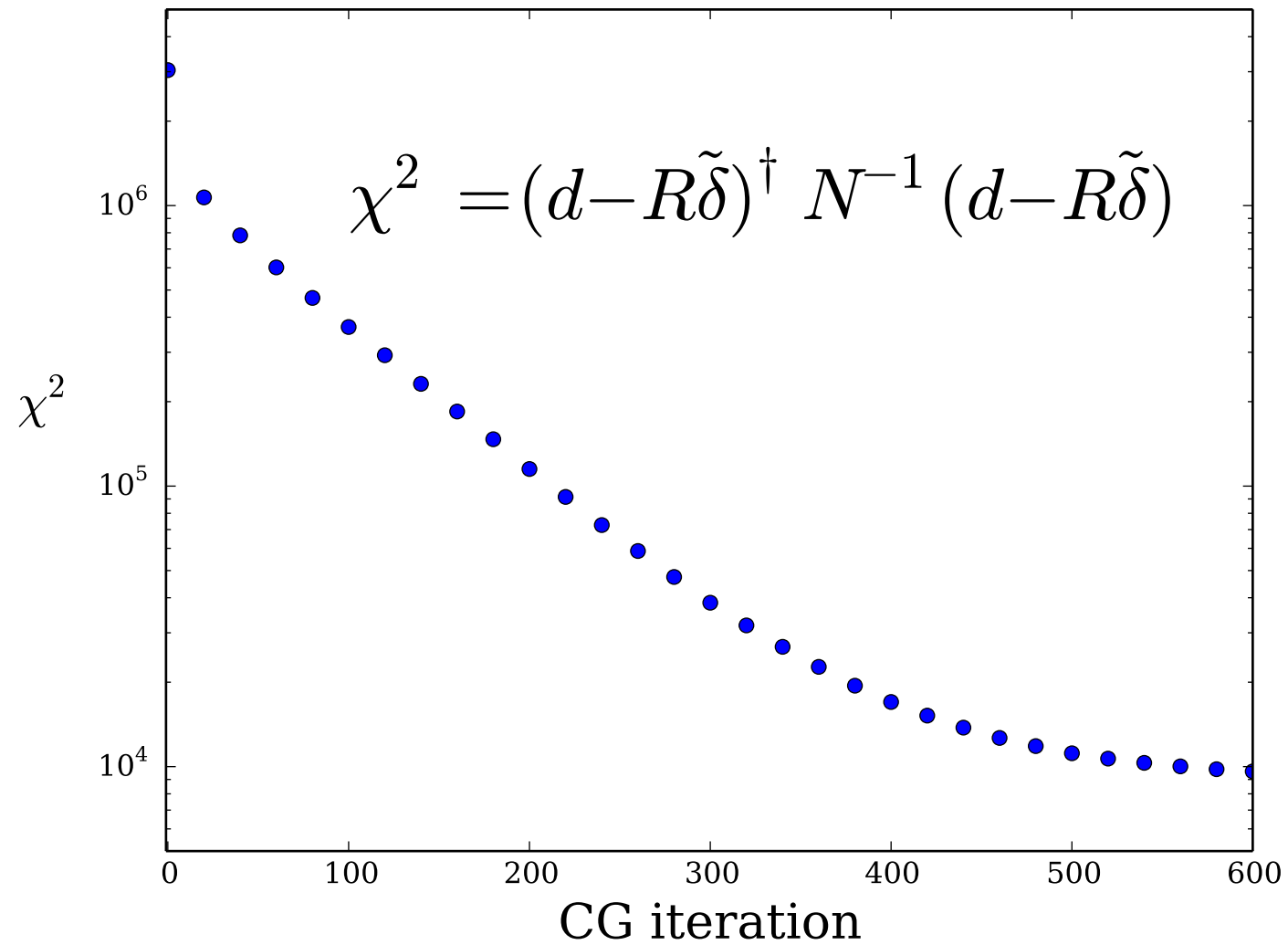
Conjugate gradient descent method:
 ~ 0.1 s / iteration on desktop

Convergence in 100s of iterations w/out preconditioner

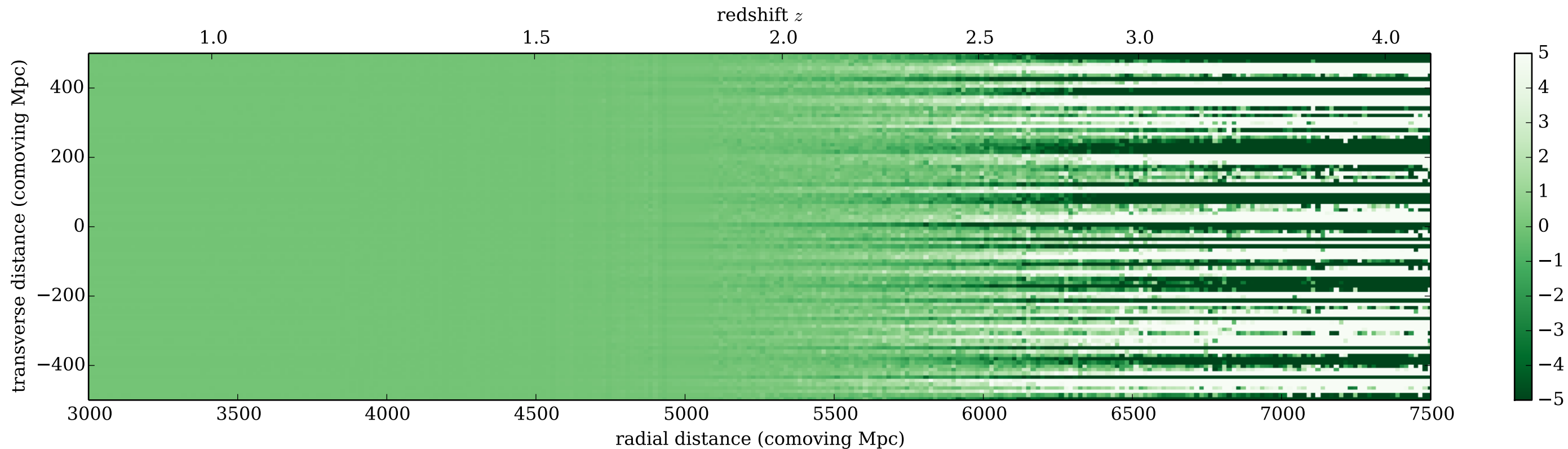
Does it work?

Yes*

Minimizing χ^2



Impact of mapmaking equation: $d_{\text{LSS}} - \tilde{\delta}$



Summary

Demonstrated "optimal" method for incorporating lensing information into 3d matter map.

Next steps: more careful evaluation of S/N for realistic surveys; application to systematics; Wiener filter.

Method is **extensible**: cosmic shear, large scale peculiar velocities, anything linear.

BACKUP

Convergence power spectrum

