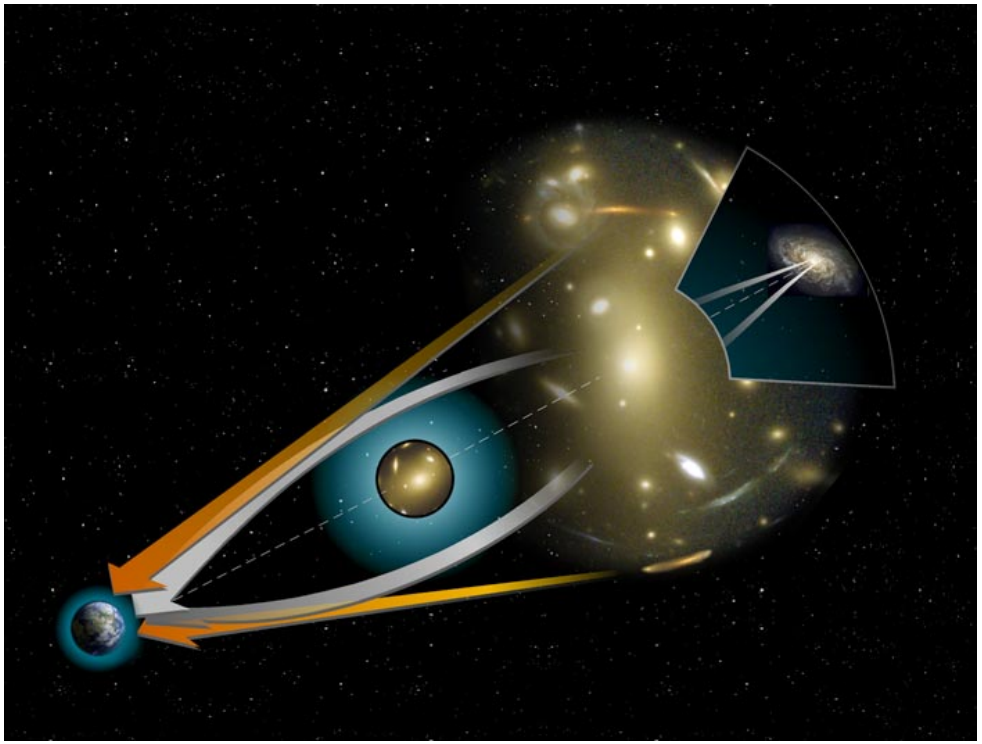
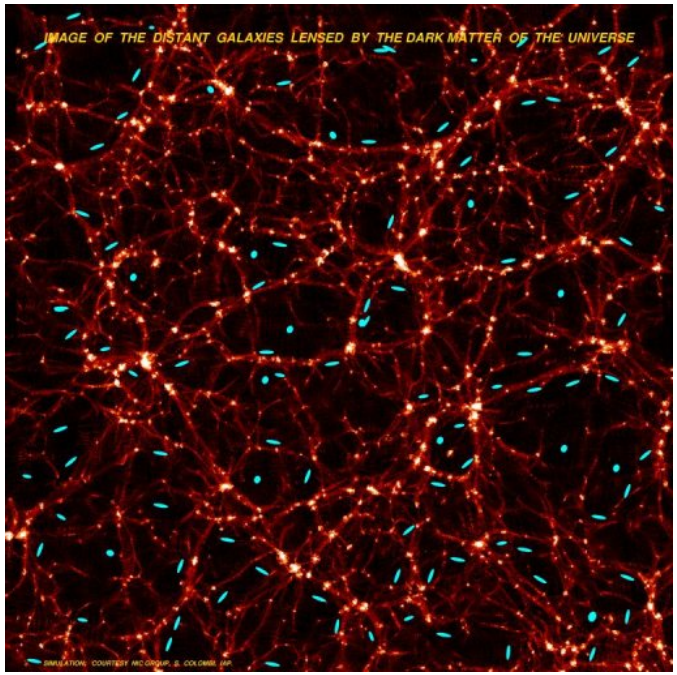
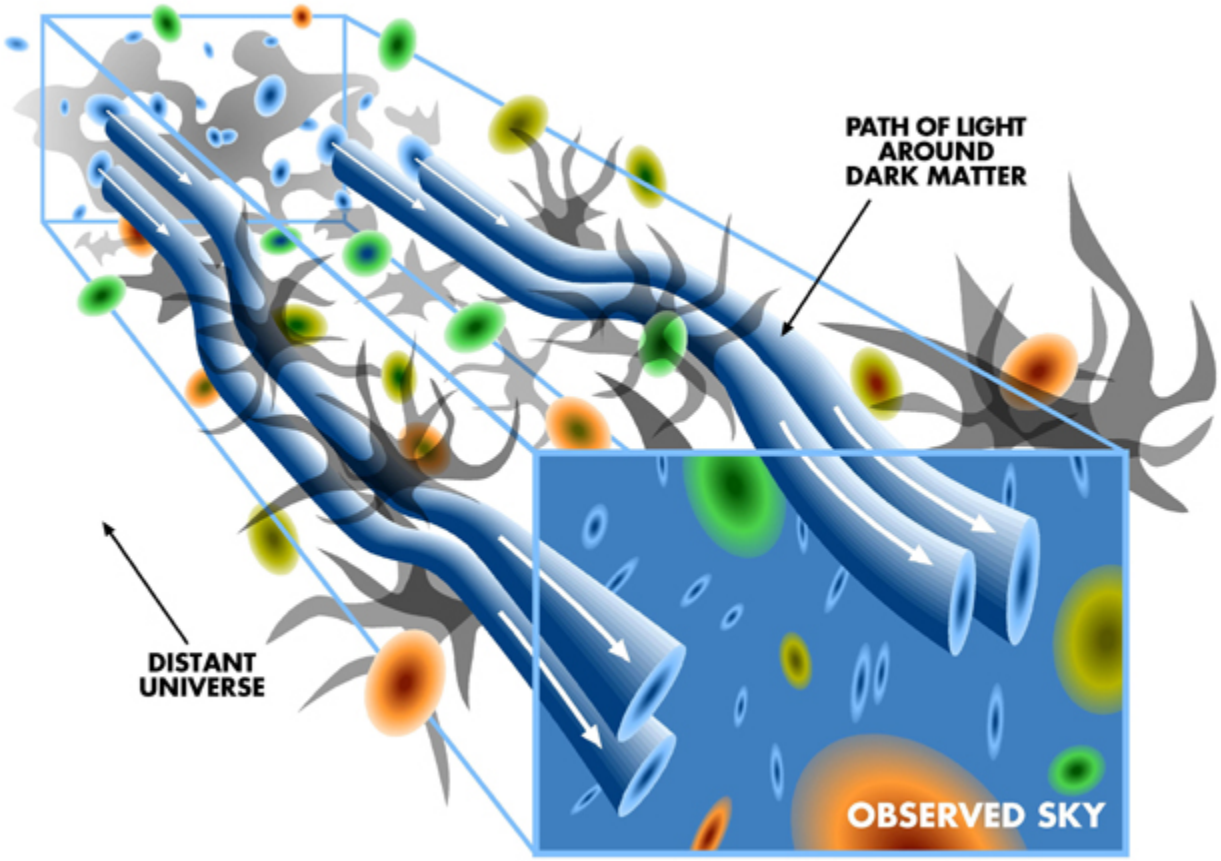
Sparsity and Compressed Sensing in 3D Weak Lensing



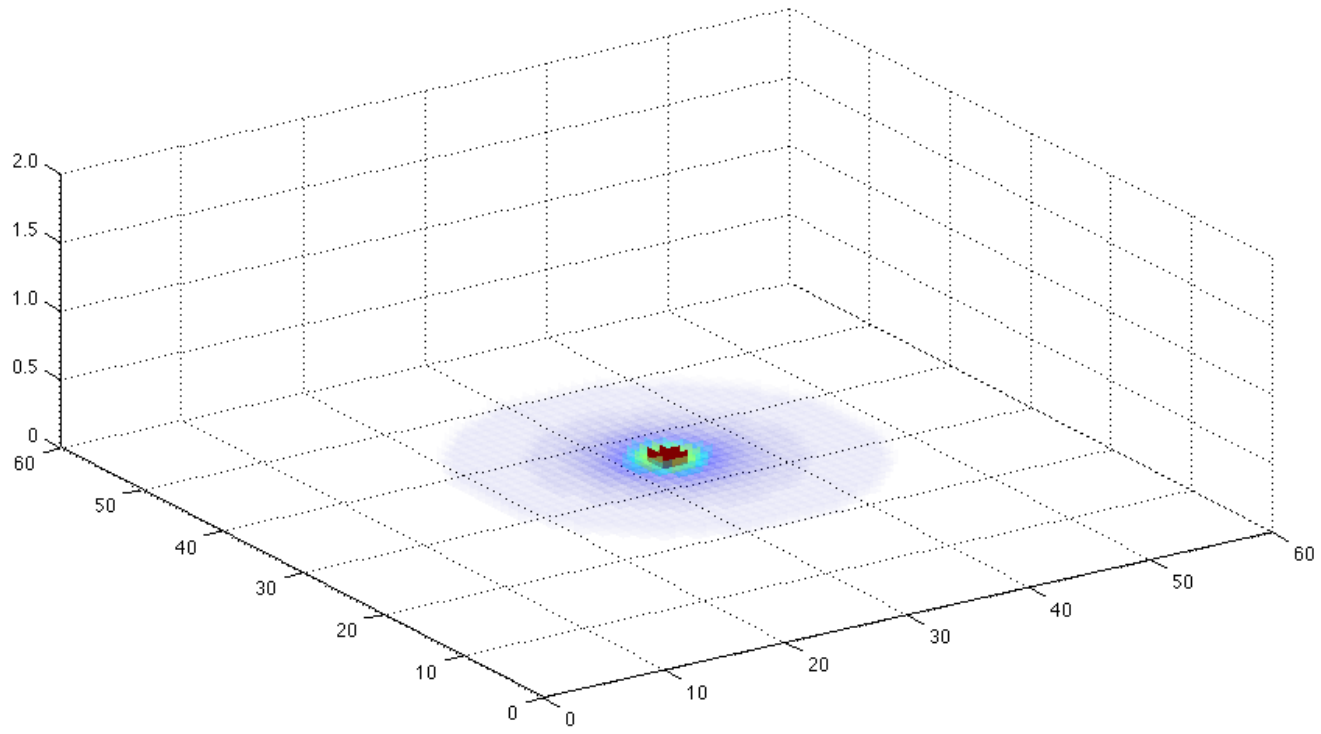


Adrienne Leonard,
Jean-Luc Starck, François-Xavier Dupé,
François Lanusse

Weak Gravitational Lensing



3D Map-making



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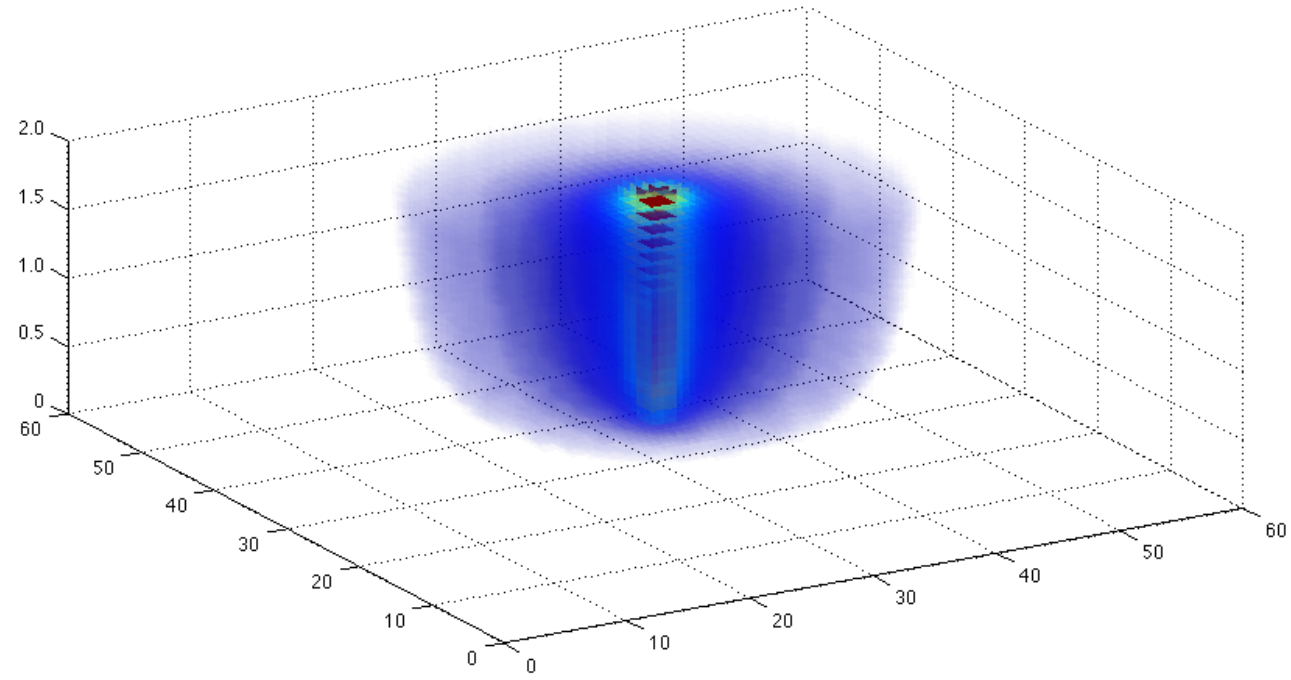
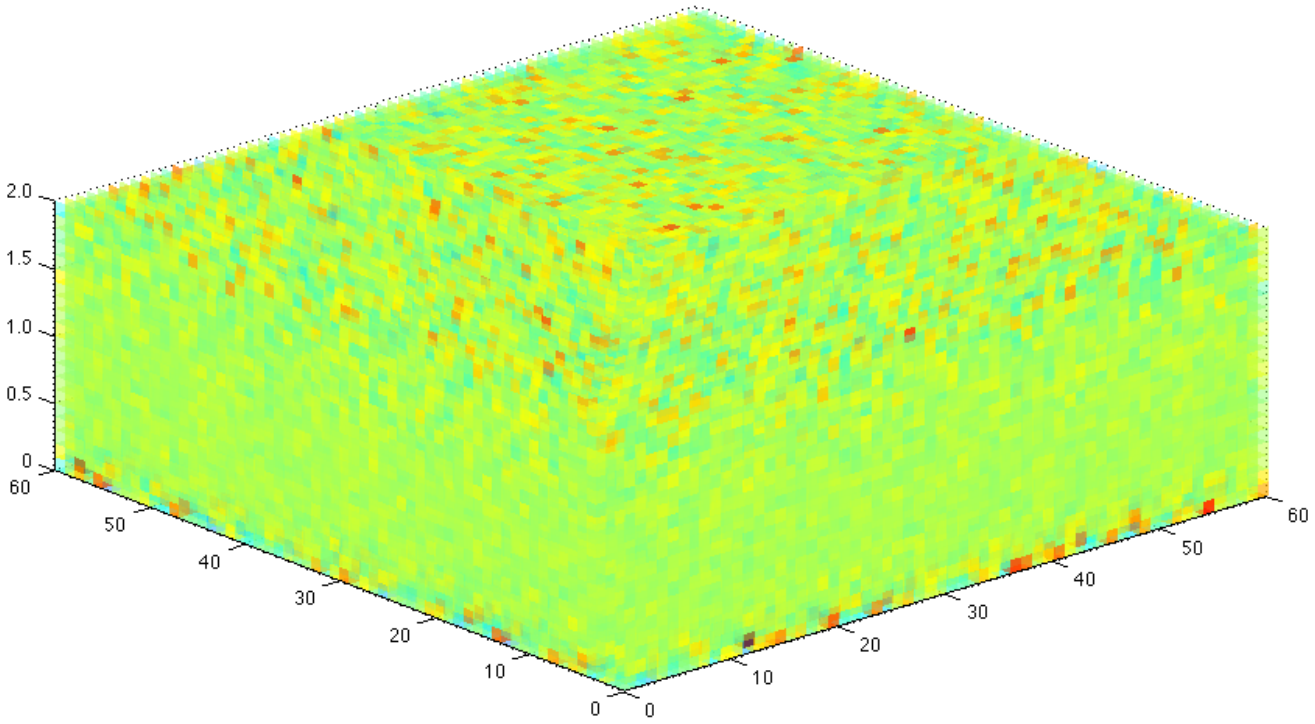
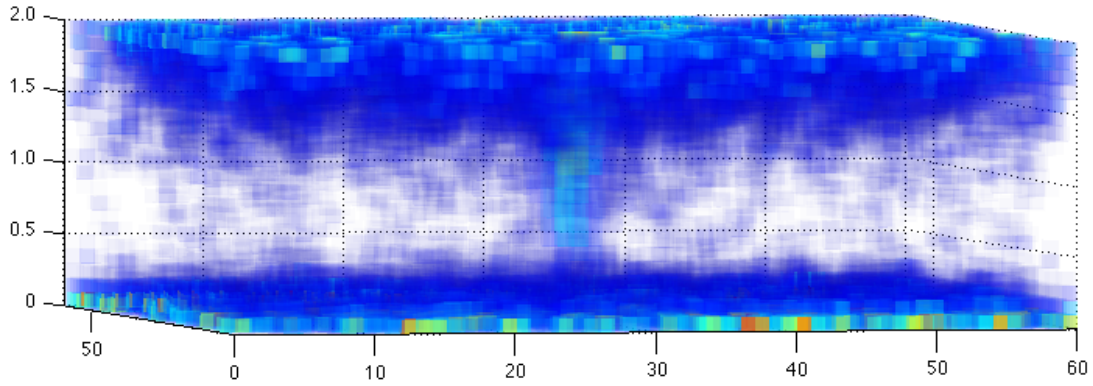


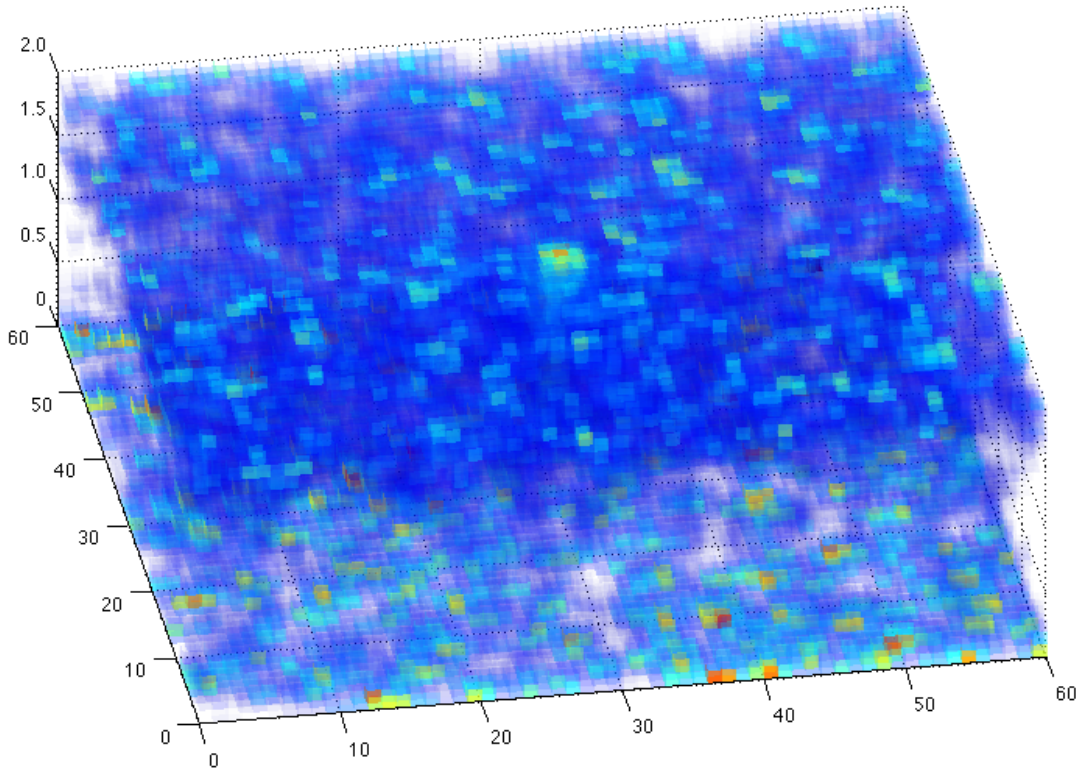
3D Map-making



3D Map-making



3D Map-making



3D reconstructions: Linear approach

$$\kappa = Q\delta + n \qquad \gamma = \mathbf{R}\delta + n$$

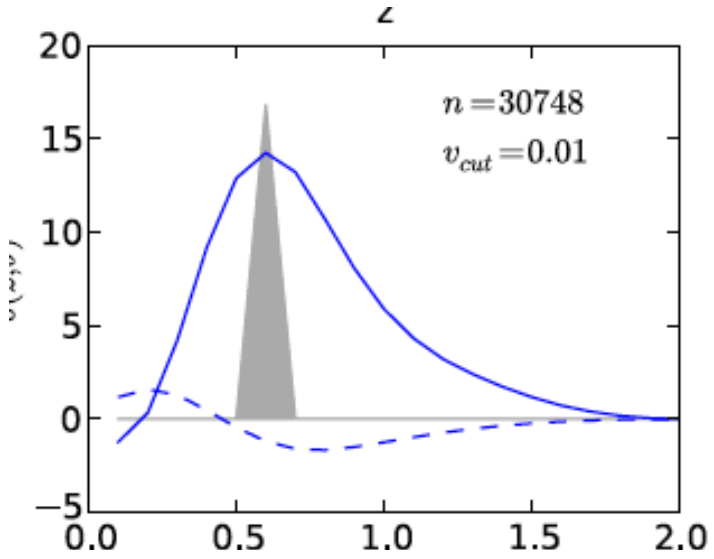
- Assume uncorrelated Gaussian noise*
- Linear methods
  - Wiener/inverse variance filter (Simon et al., 2009)

$$\hat{\boldsymbol{s}}_{MV} = [\alpha \mathbf{1} + \mathbf{S}\mathbf{R}^{\dagger}\boldsymbol{\Sigma}^{-1}\mathbf{R}]^{-1}\mathbf{S}\mathbf{R}^{\dagger}\boldsymbol{\Sigma}^{-1}\boldsymbol{d} \ .$$

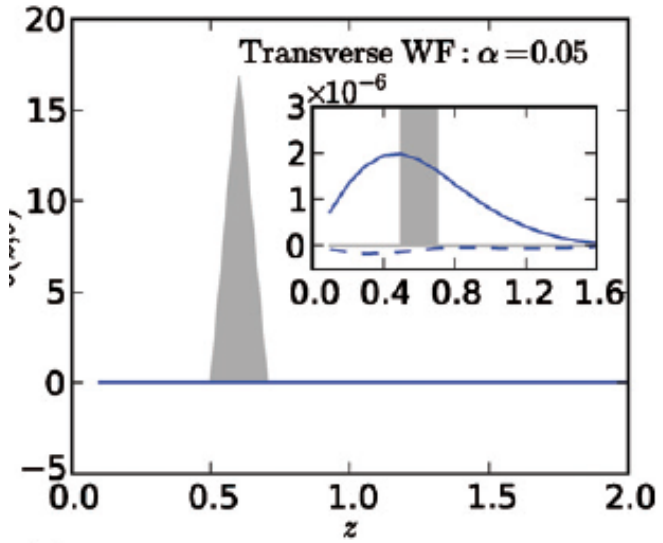
  - SVD decomposition & thresholding (VanderPlas et al., 2011)

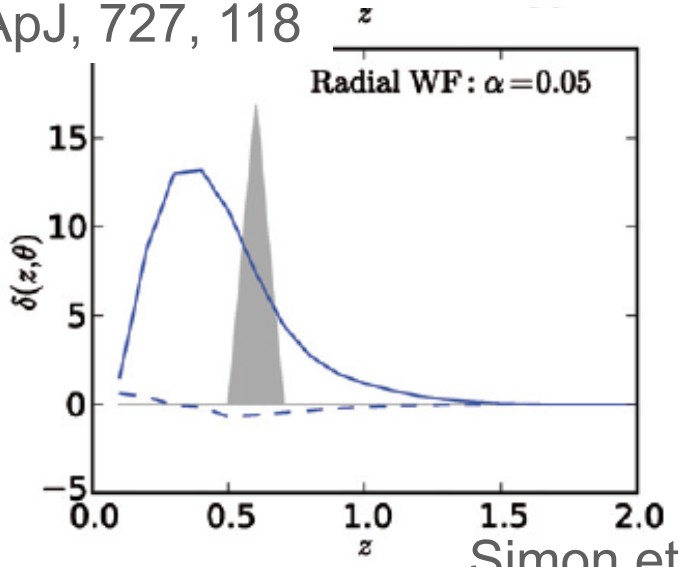
$$\hat{\boldsymbol{s}}_{IV} = \mathbf{V}\boldsymbol{\Lambda}^{-1}\mathbf{U}^{\dagger}\boldsymbol{\Sigma}^{-1/2}\boldsymbol{d} \ ,$$

Results with Linear Methods



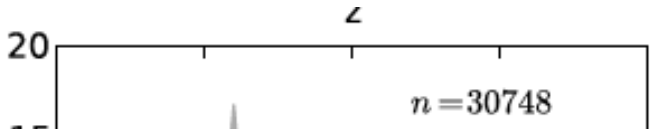
Vanderplas et al. 2011, ApJ, 727, 118

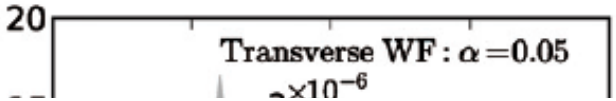




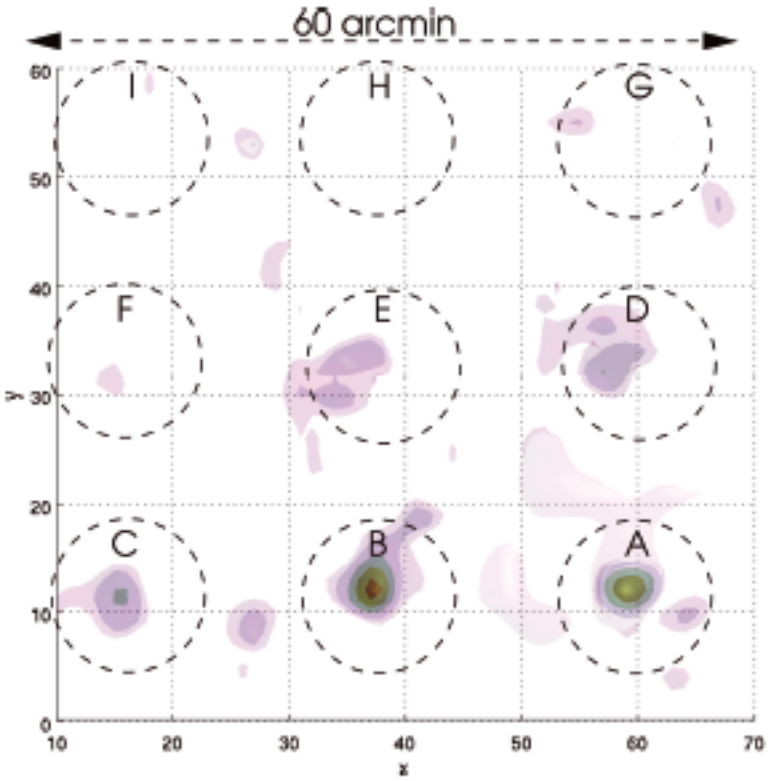
Simon et al. 2009, MNRAS, 399, 48

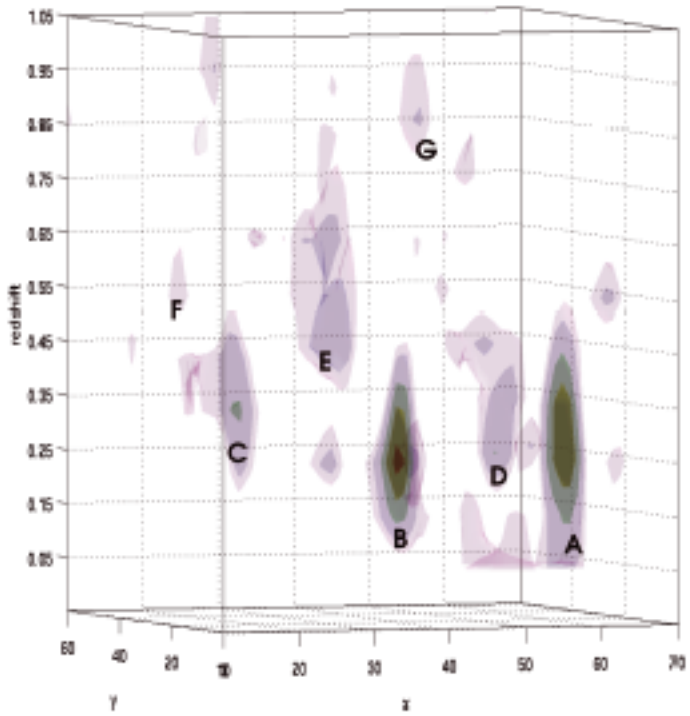
Results with Linear Methods

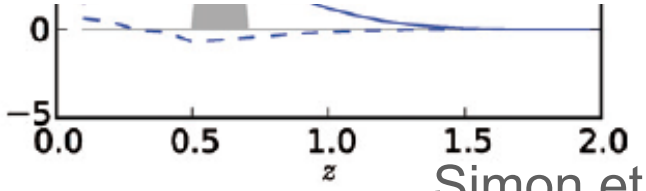




Van







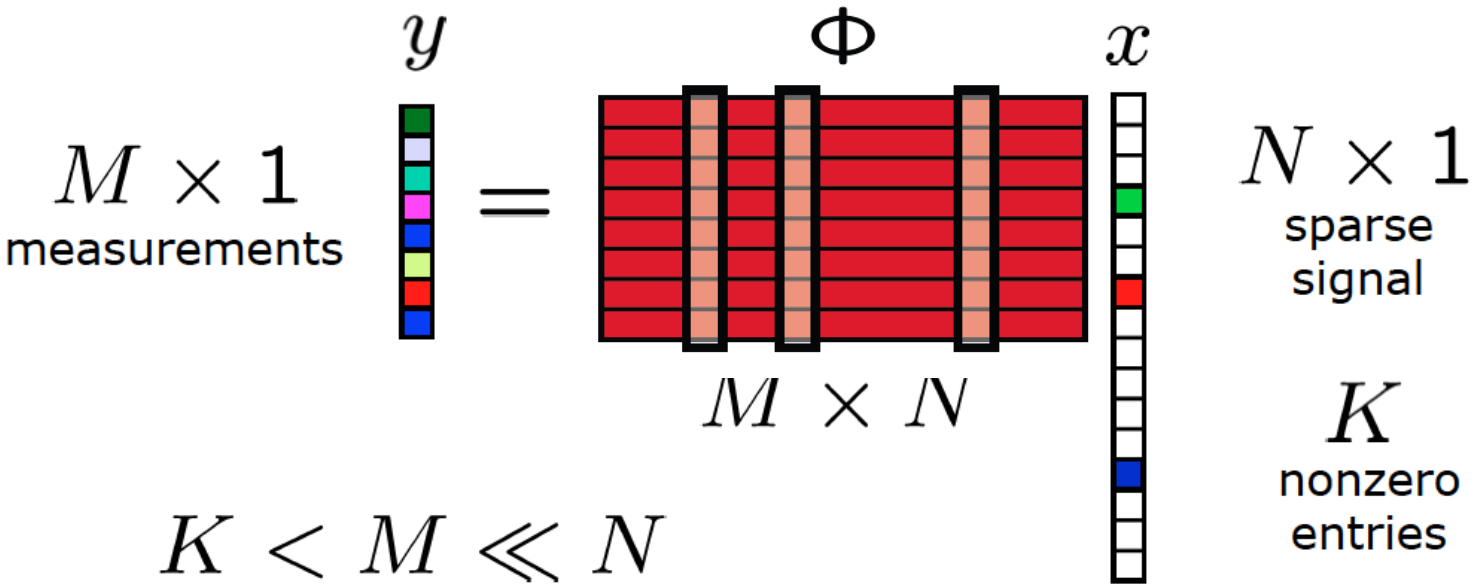
Simon et al. 2009, MNRAS, 399, 48

What is Compressed Sensing?

In compressed sensing, we seek to reduce the dimensionality of our data, without loss of information:

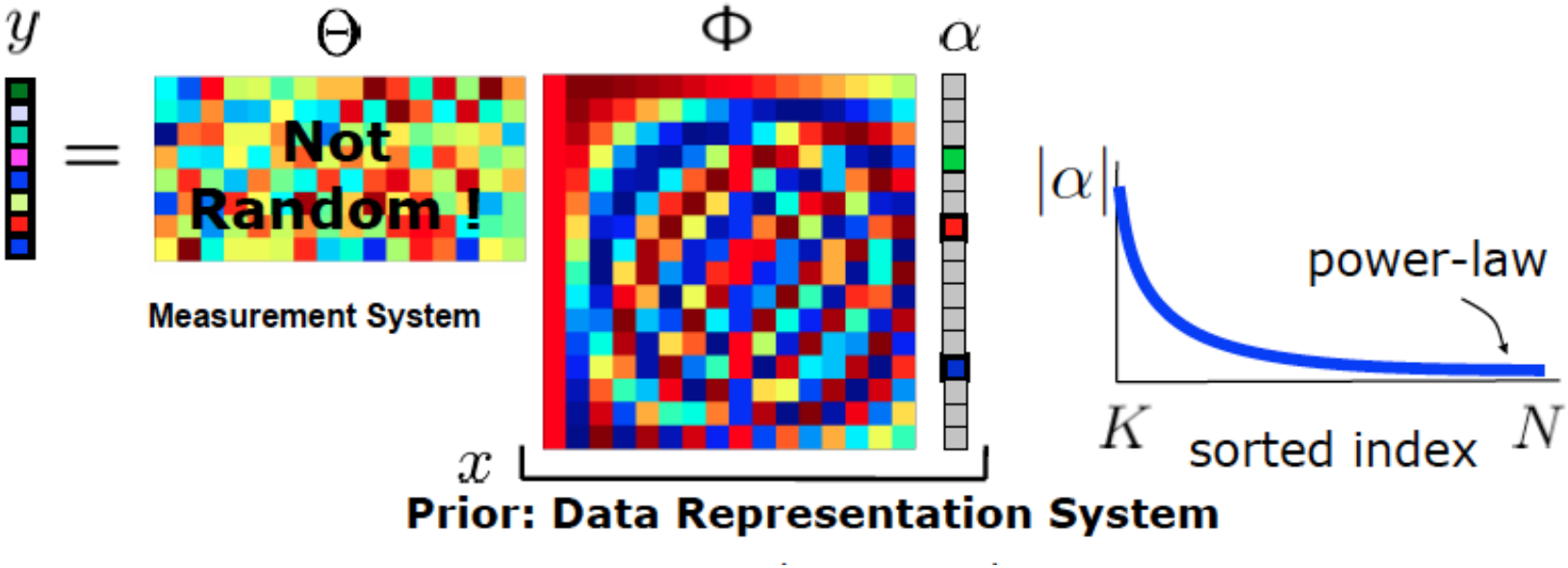
Sensing operator is not full rank – general loss of information

BUT, if signal is sparse….

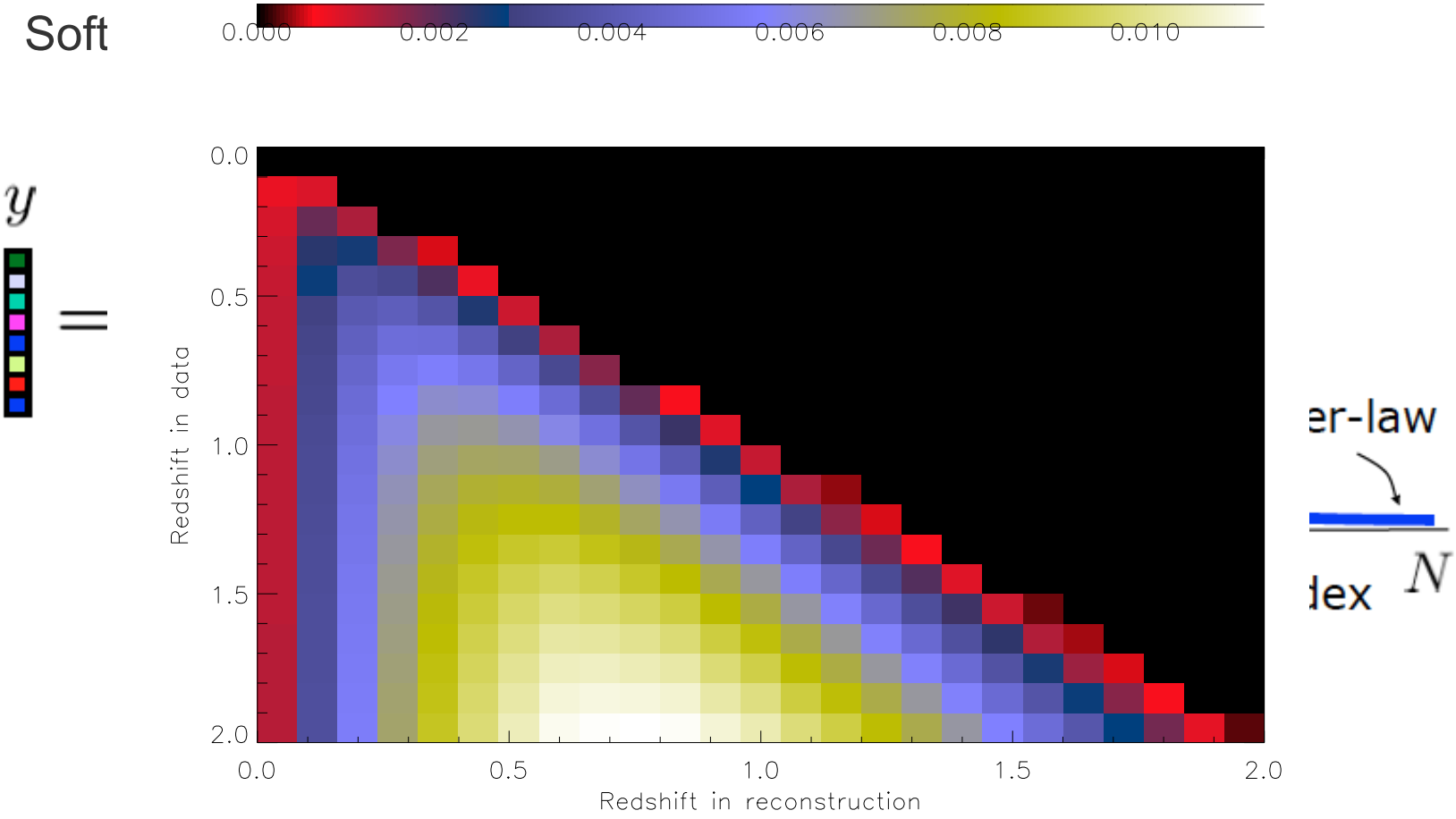


How can we relate CS to lensing?

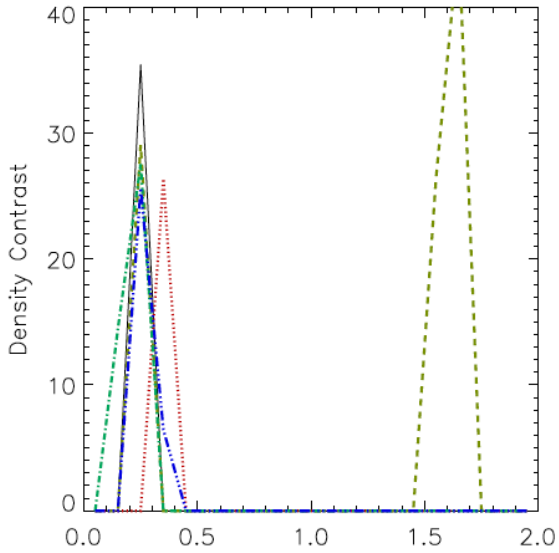
Soft compressed sensing definition

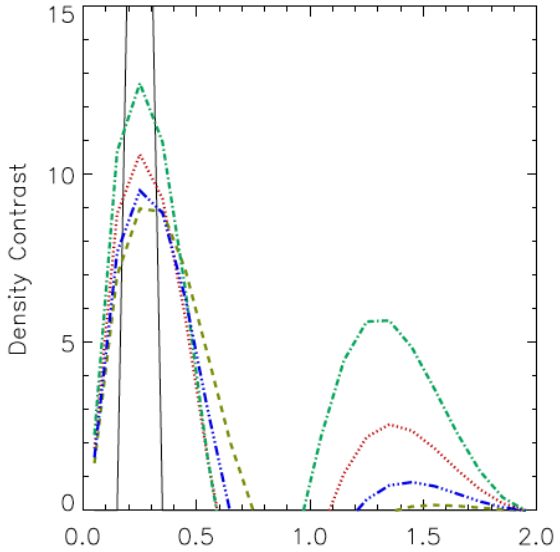


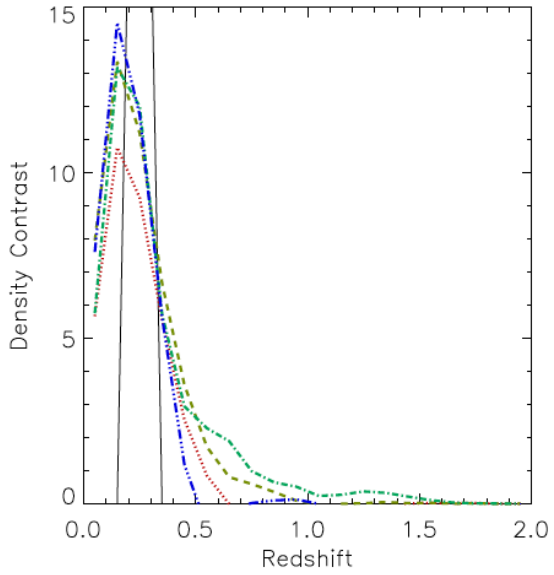
How can we relate CS to lensing?

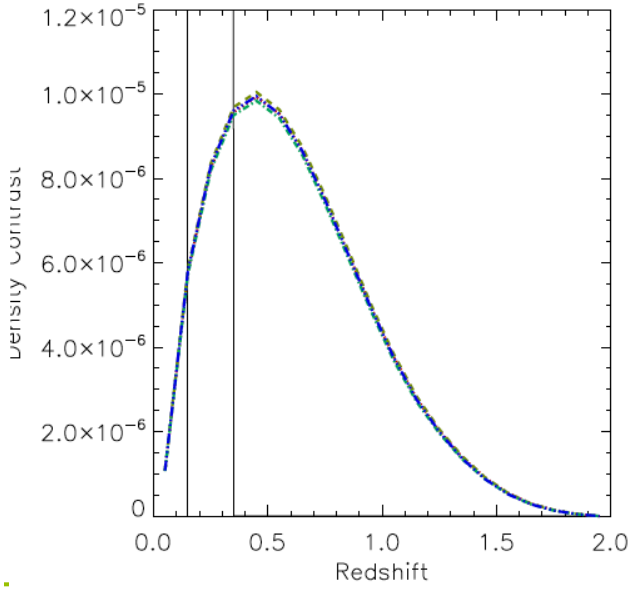


Results – Comparison with Linear Methods



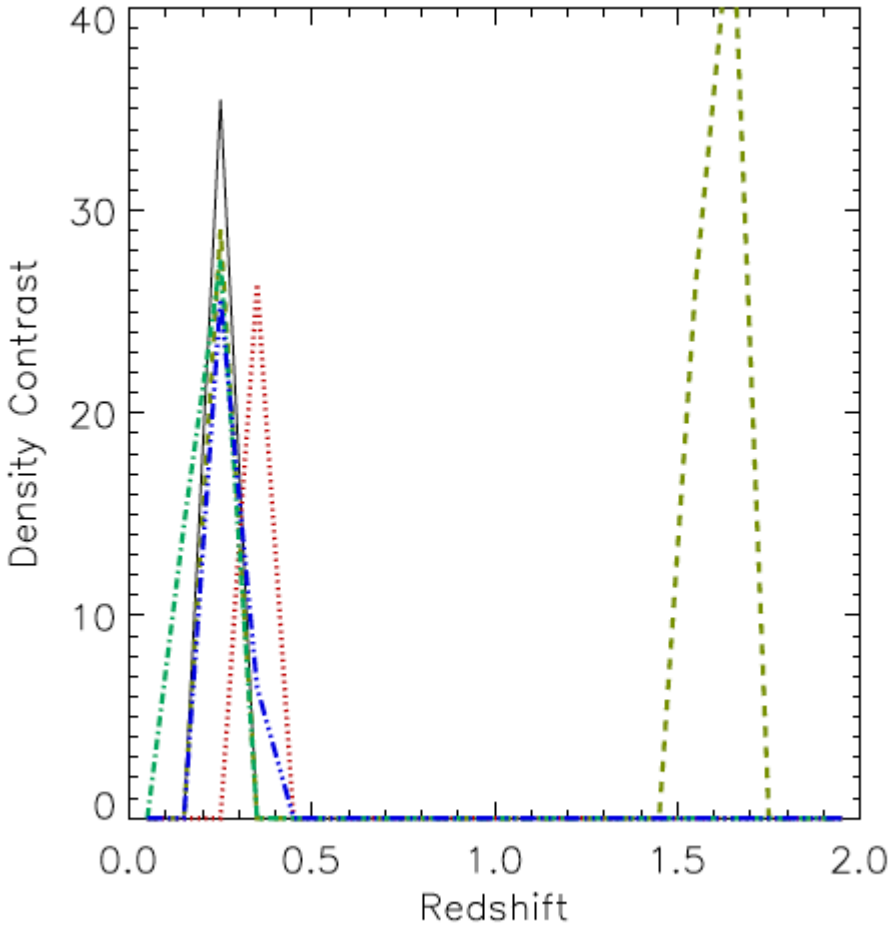




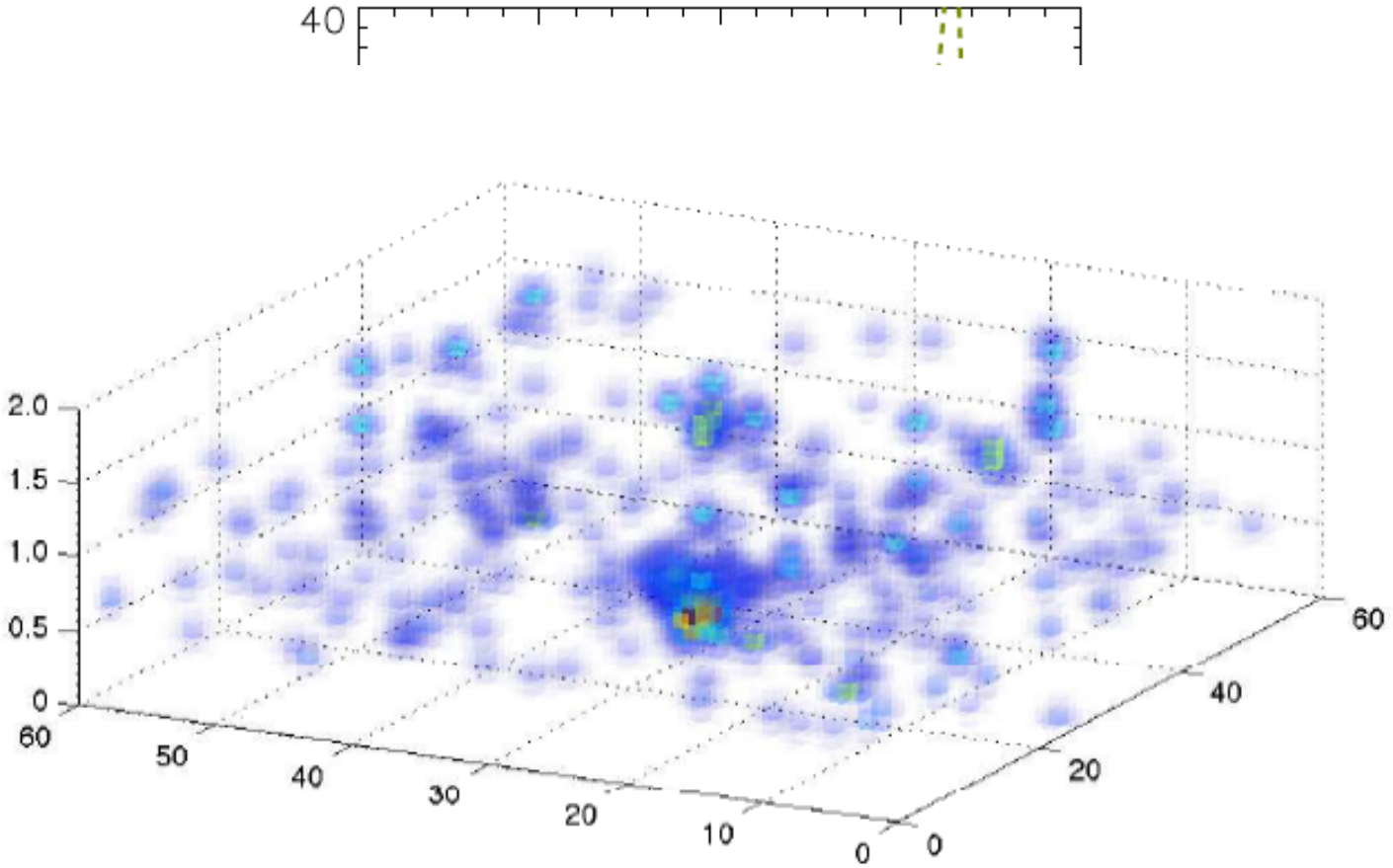


Leonard et al. 2012, A&A, 539, A85

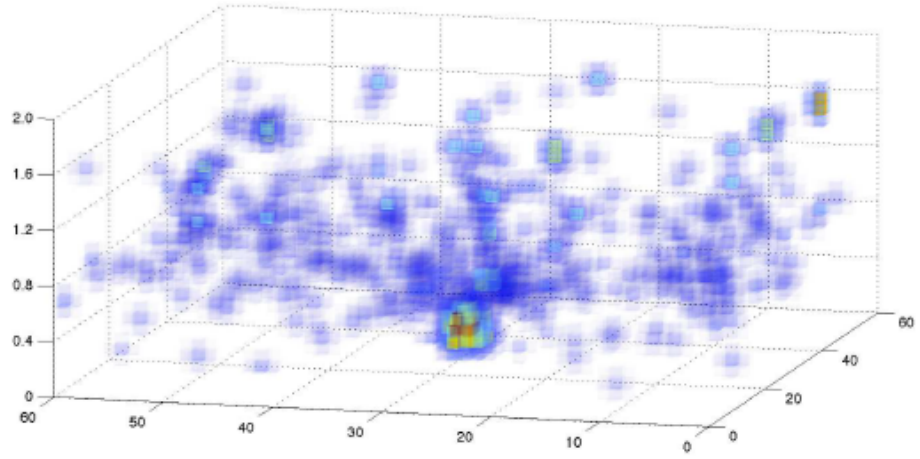
Our Method



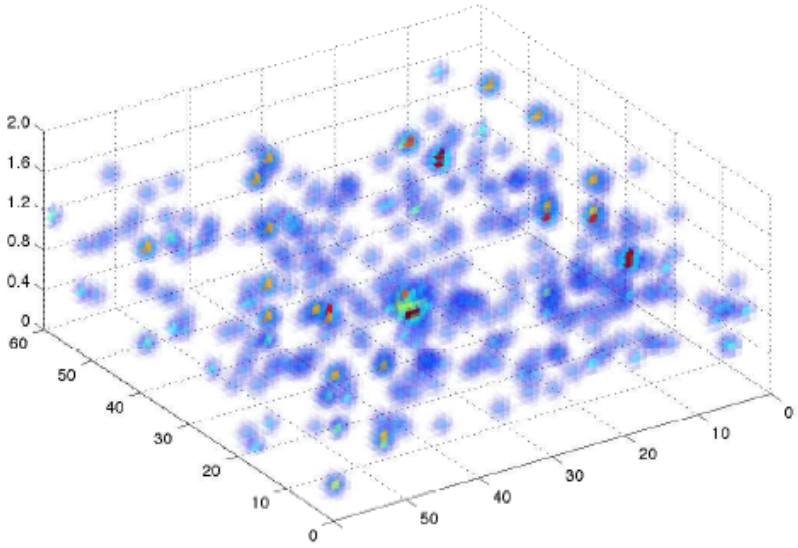
Our Method



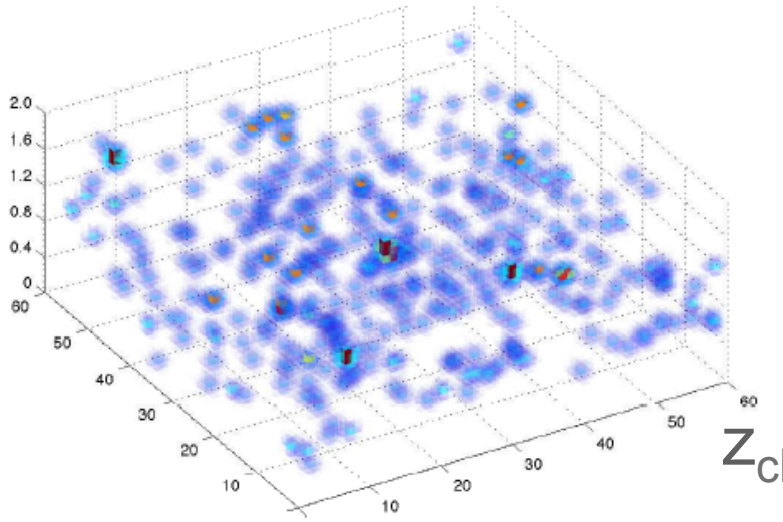
Our Method (II)



$z_{cl} = 0.2$

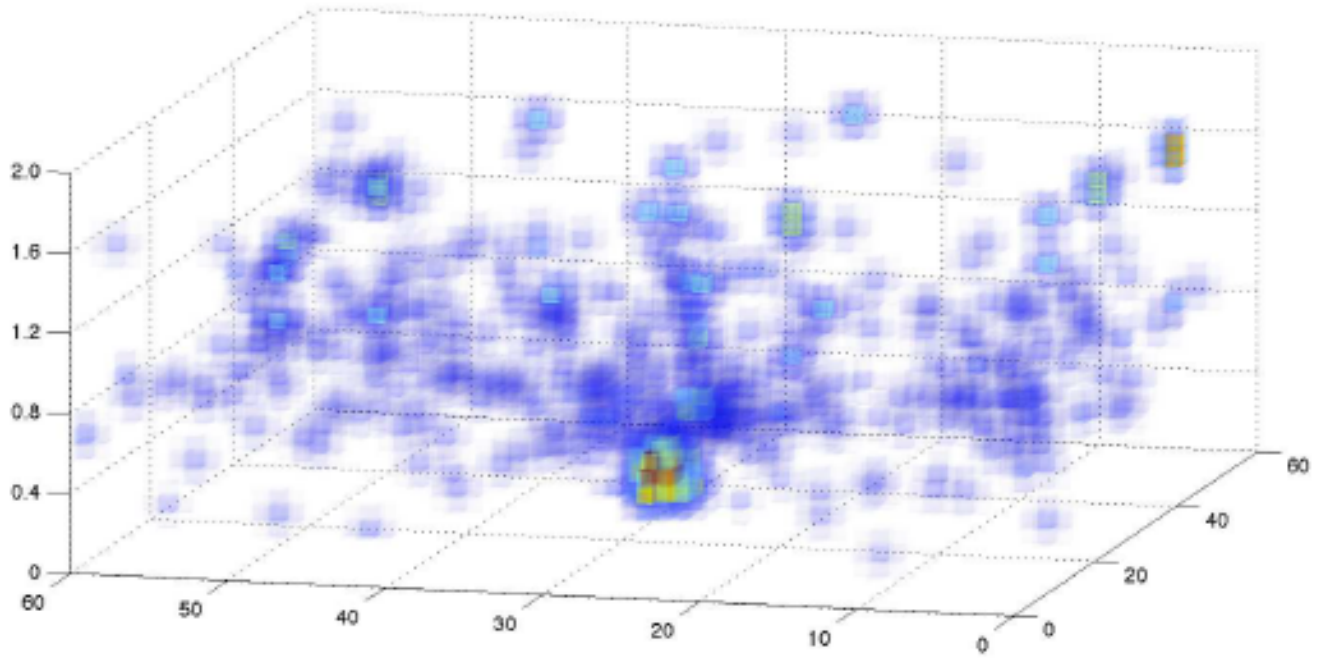


$z_{cl} = 0.6$

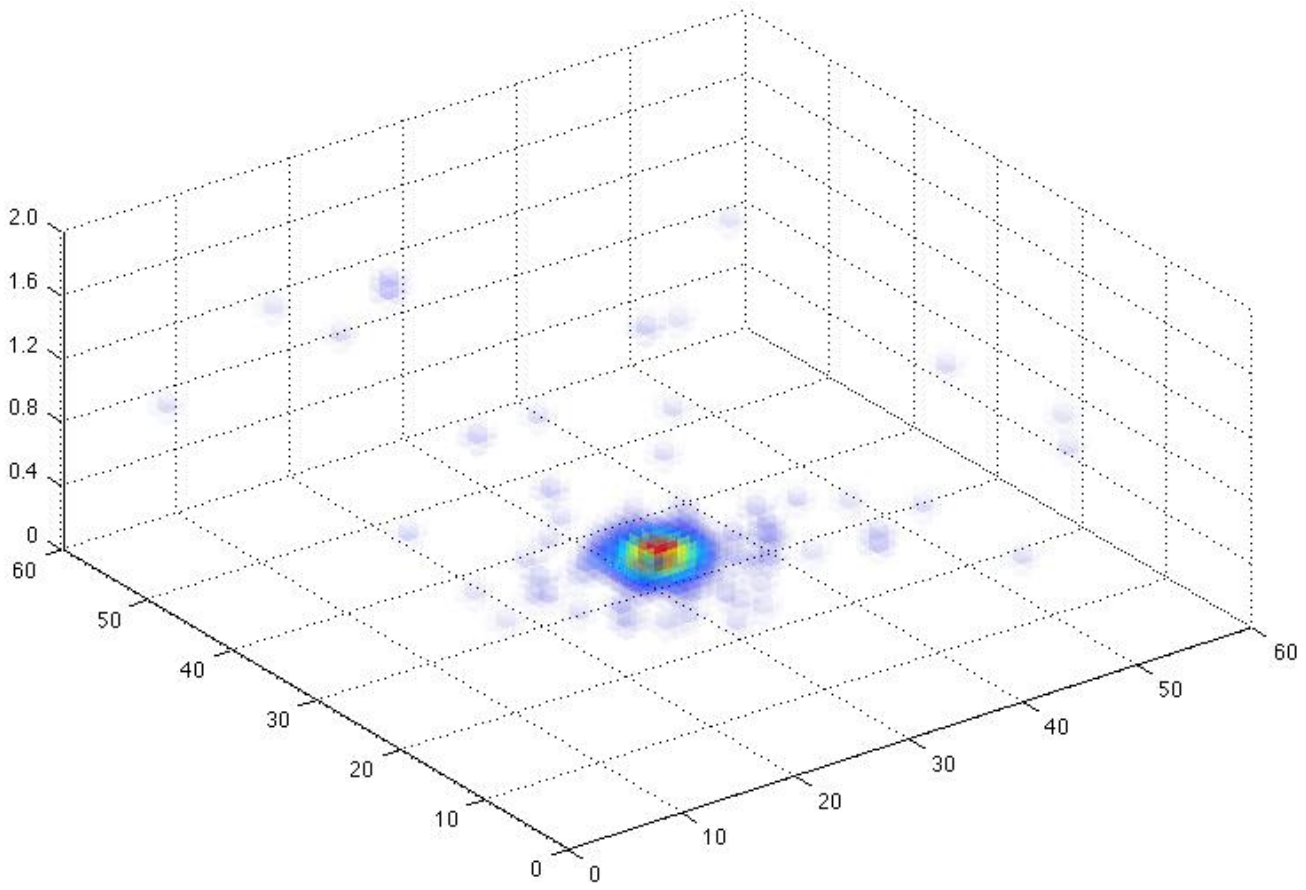


$z_{cl} = 1.0$

Work in Progress: 3D implementation



Work in Progress: 3D implementation



Summary

- 3D lensing is a very noisy, ill-posed inverse problem
- Linear methods use weak priors, and suffer from 4 main drawbacks:
  - Redshift bias
  - Smearing
  - Damping
  - Resolution limited by data
- CS approach allows us to improve on all four points
- We show increased sensitivity to high-redshift structure and complex LOS structures
- False detections seen in 1D implementation, but on pixel scales
- 3D algorithm (when complete) will reduce these errors significantly
- Inclusion of other sources of noise required for full application