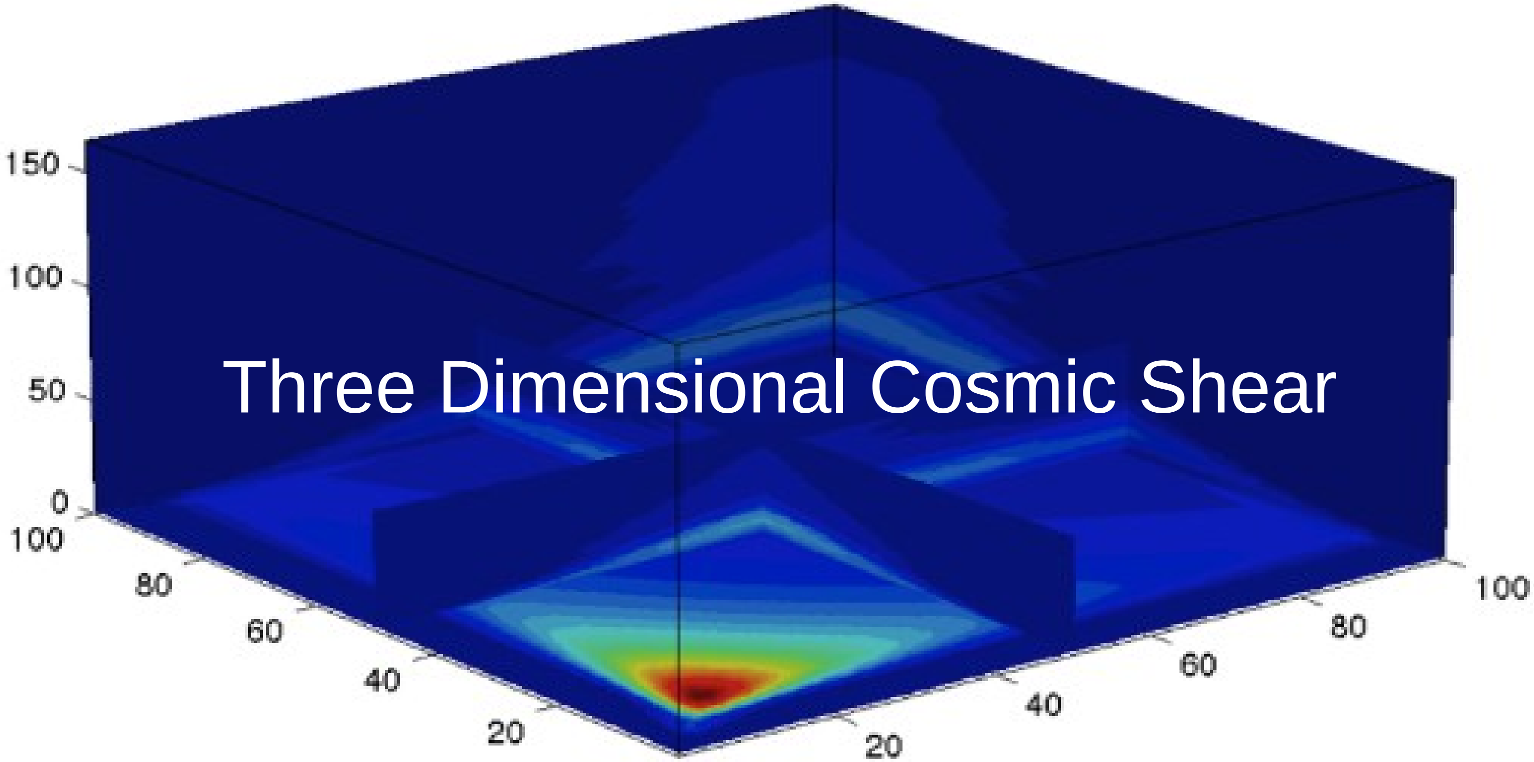
Three Dimensional Cosmic Shear



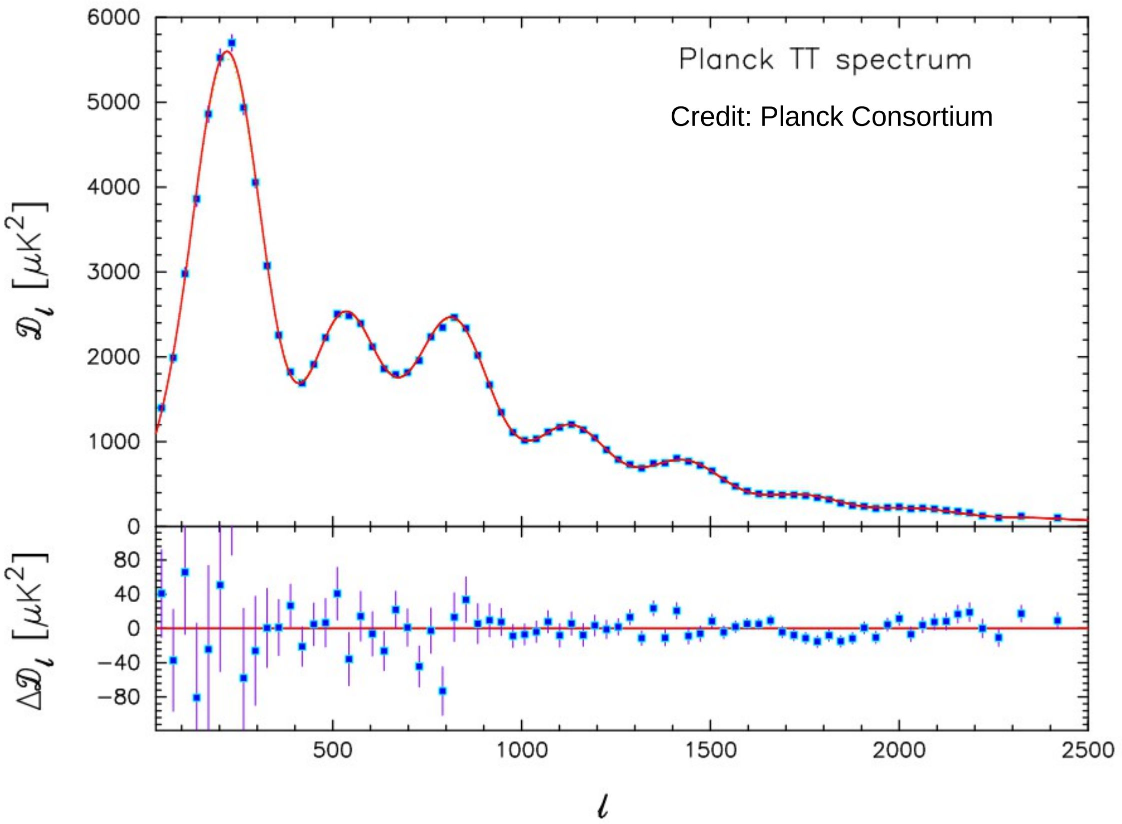
Tom Kitching MSSL/UCL

Alan Heavens ICIC/Imperial College

Alina Kiessling, Lance Miller, Dipak Munshi, Andy Taylor

CFHTLenS Collaboration

- For lensing we want equivalent of the CMB power spectrum



CMB is a 2D field

Shear is a 3D field

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Spherical Harmonics

- We want the 3D power spectrum for cosmic shear
  - So need to generalise spherical harmonics for spin-2 field
- Normal Fourier Transform

$$\hat{f}(\xi) = \int_{-\infty}^{\infty} f(x)\, e^{-2\pi i x \xi}\, dx,$$ for every real number ξ.

$$f(x) = \int_{-\infty}^{\infty} \hat{f}(\xi)\, e^{2\pi i x \xi}\, d\xi,$$ for every real number x.

Spherical/Bessel Harmonics

$$ {}_s f_{\ell m}(k) \equiv \sqrt{\frac{2}{\pi}} \int d^3\mathbf{r}\, {}_s f(\mathbf{r})\, k j_\ell(kr)\, {}_s Y_\ell^{m*}(\hat{\mathbf{n}}) $$

- Describes general transforms on a sphere for any spin-weight quantity
- For cosmic shear s=2
- Want to find the predicted covariance of this

$$ \hat{\gamma}_i(k, \boldsymbol{\ell}) = \sqrt{\frac{2}{\pi}} \sum_g \gamma_i^g j_\ell(k r_0^g) \mathrm{e}^{-i\boldsymbol{\ell}.\boldsymbol{\theta}^g} W(r_0^g) $$

Posterior Redshift Probabilities

$$C_\ell^{3D}(k_1,k_2) = \mathcal{A}^2 \int \mathrm{d}r_g r_g^2 n(r_g) j_\ell(k_1 r_g) \int \mathrm{d}r_h r_h^2 n(r_h) j_\ell(k_2 r_h) \int \mathrm{d}r' \bar{p}(r'|r_g) \int \mathrm{d}r'' \bar{p}(r''|r_h)$$
$$\int \mathrm{d}\tilde{r}' \int \mathrm{d}\tilde{r}'' \frac{F_K(r',\tilde{r}')}{a(\tilde{r})'} \frac{F_K(r'',\tilde{r}'')}{a(\tilde{r}'')} \int \frac{\mathrm{d}k'}{k'^2} j_\ell(k'\tilde{r}') j_\ell(k'\tilde{r}'') P^{1/2}(k';\tilde{r}') P^{1/2}(k';\tilde{r}'')$$

Large Scale Structure

Geometry

Heavens, 2003
Heavens, Kitching, Taylor, 2006
Kitching, Heavens, Miller, 2012

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Posterior Redshift Probabilities

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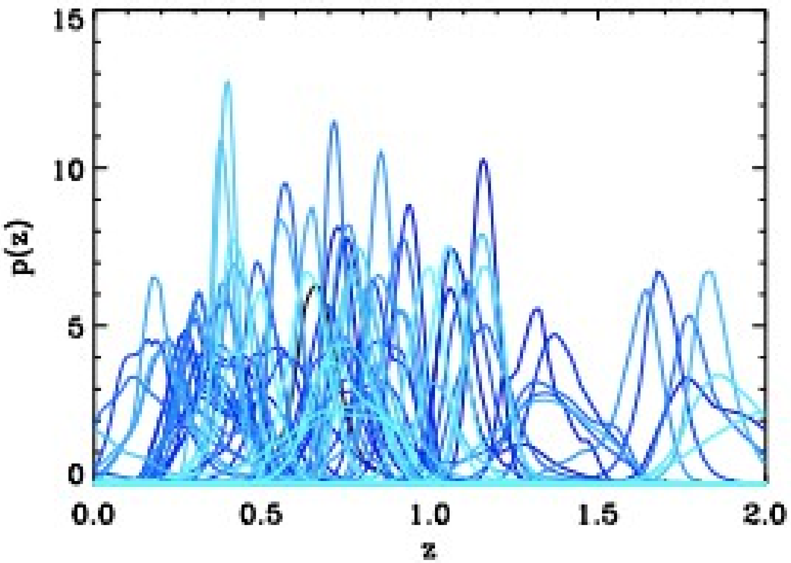
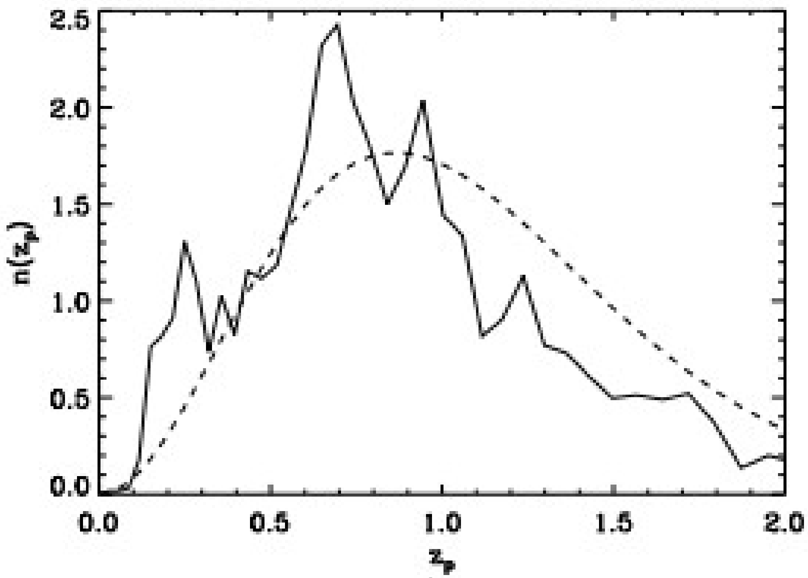
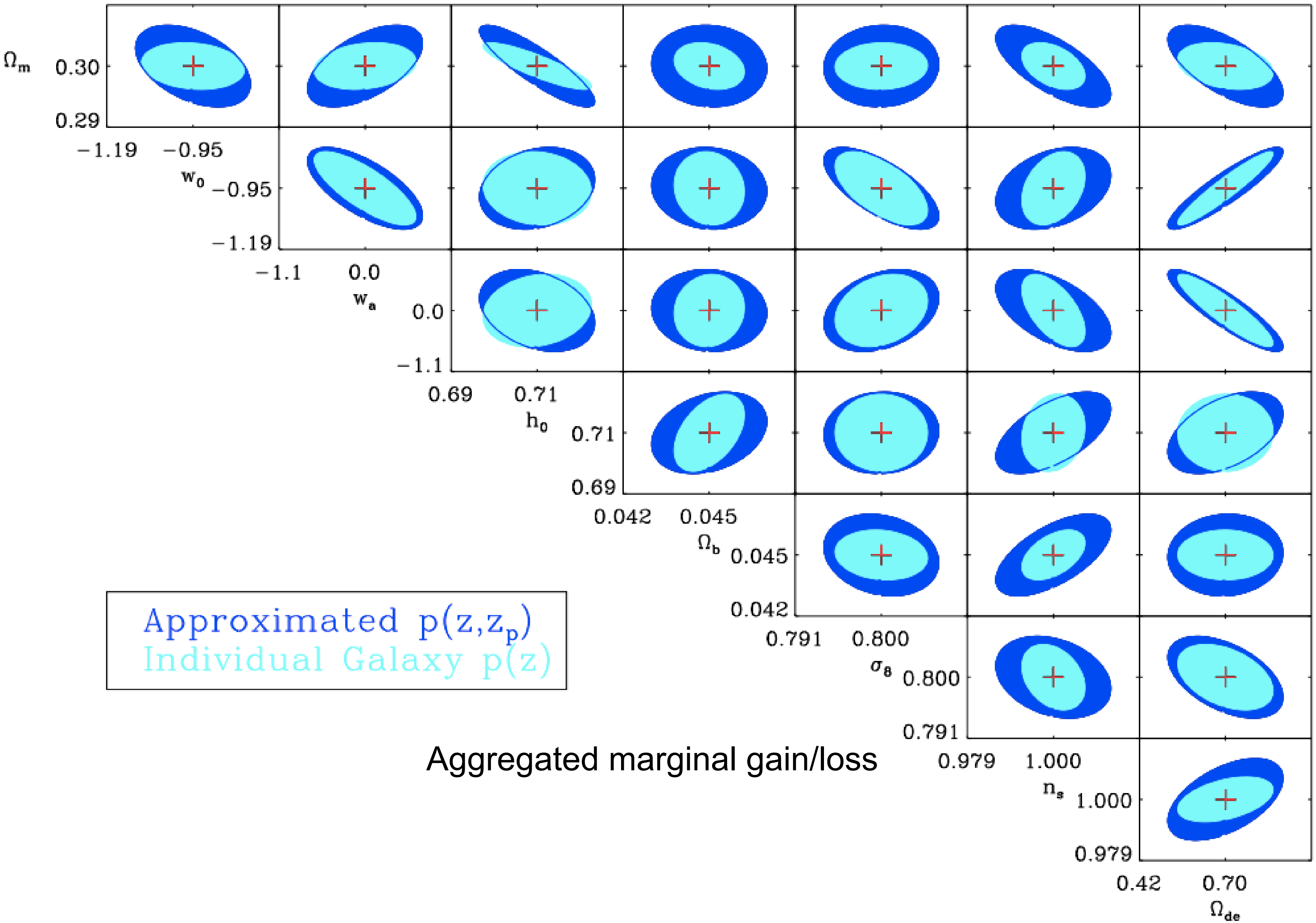




Simulated p(z) for Euclid-like survey (from Bordoloi et al., 2009)



Aggregated marginal gain/loss

Kitching, Heavens, Miller, 2012

Posterior Redshift Probabilities

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Large Scale Structure

Geometry

More Approximations

Heavens, 2003
Heavens, Kitching, Taylor, 2006
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`Tomography'

- An approximation to the 3D power

  (Kitching, Heavens, Miller, 2012)

- Approximations
  - Limber Approximation (lossy)
    - replaces Bessels with Dirac delta functions

$$C_\ell^{3D,\mathrm{Limber}}(k_1,k_2) = \frac{9\Omega_m^2 H^4}{4c^2}\int \mathrm{d}r \frac{P(\ell/r;r)}{a^2(r)}\frac{\mathcal{W}(r_1,r)\mathcal{W}(r_2,r)}{r^2}$$

  - Transform to Real space (benign)
  - Discretisation in redshift space (lossy)

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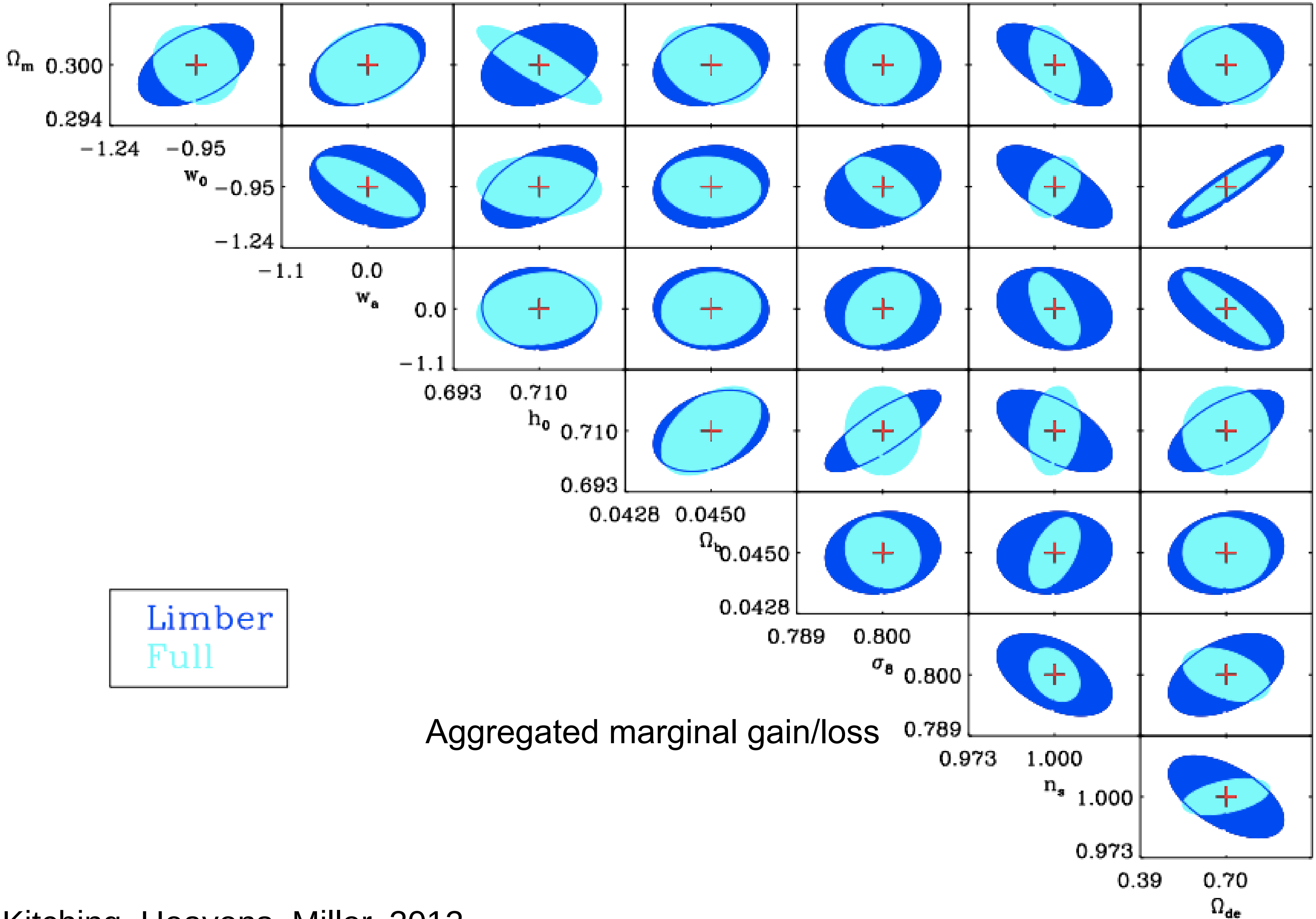

Aggregated marginal gain/loss

Kitching, Heavens, Miller, 2012

Posterior Redshift Probabilities

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Large Scale Structure

Geometry

Scales, Scales, Scales
- Allows for a clean cut in k-space

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Heavens, Kitching, Taylor, 2006
Kitching, Heavens, Miller, 2012

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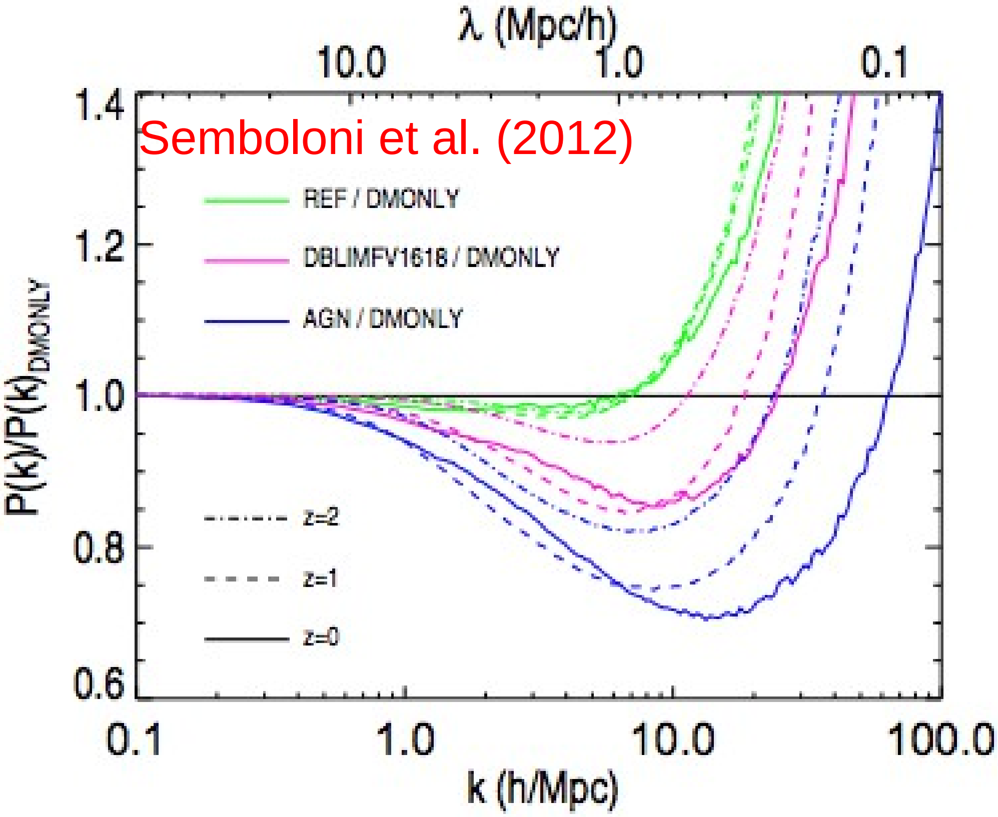
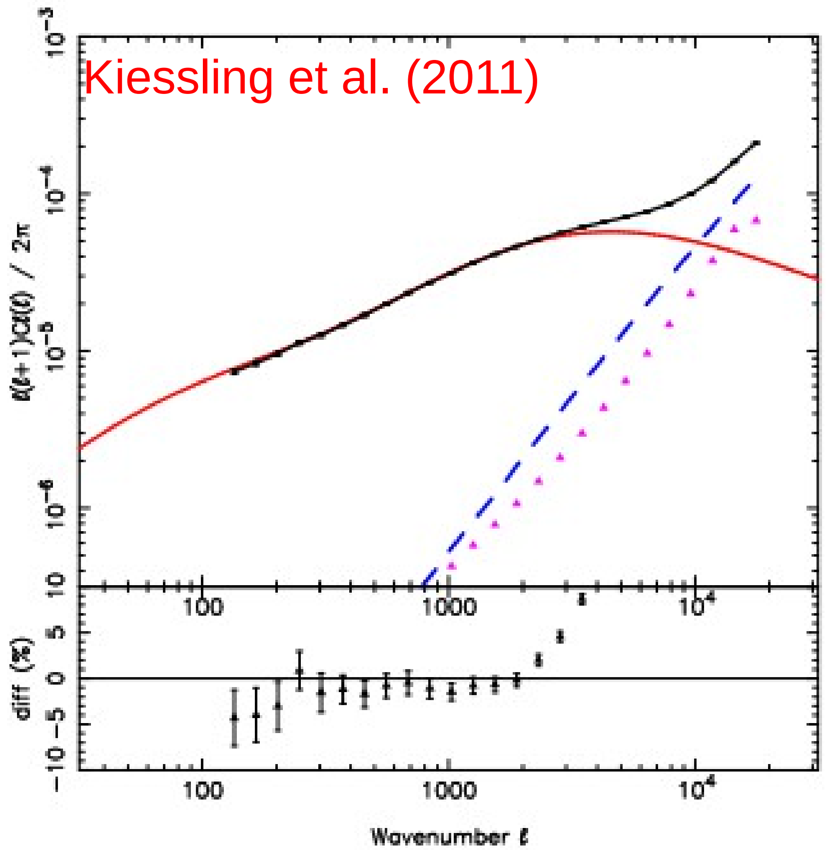
It is *crucial* that we cleanly separate scales





Particularly Important for modified gravity and neutrino physics

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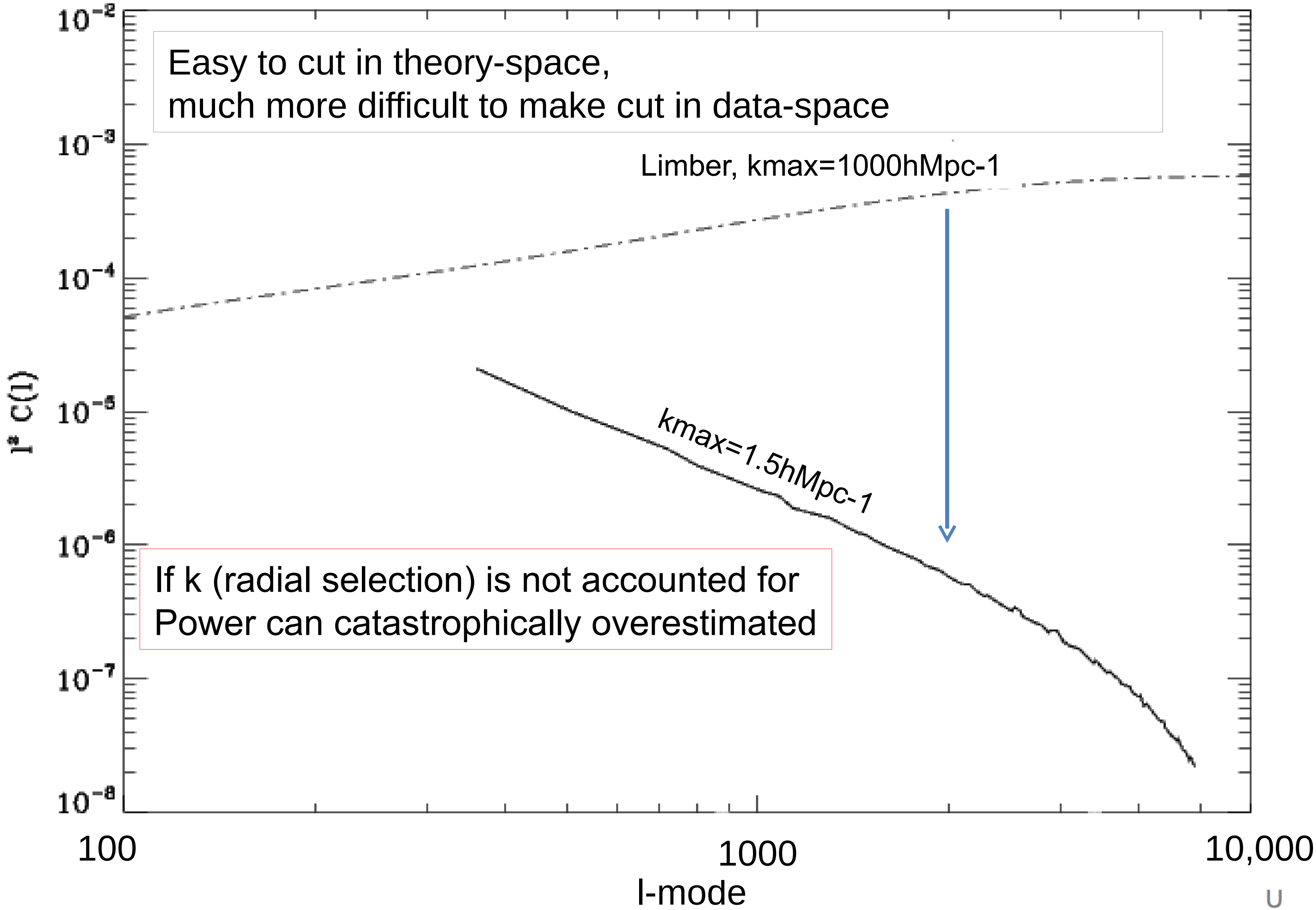

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Posterior Redshift Probabilities

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Large Scale Structure

Geometry

Where were we? What do we want to achieve?

Heavens, 2003
Heavens, Kitching, Taylor, 2006
Kitching, Heavens, Miller, 2012

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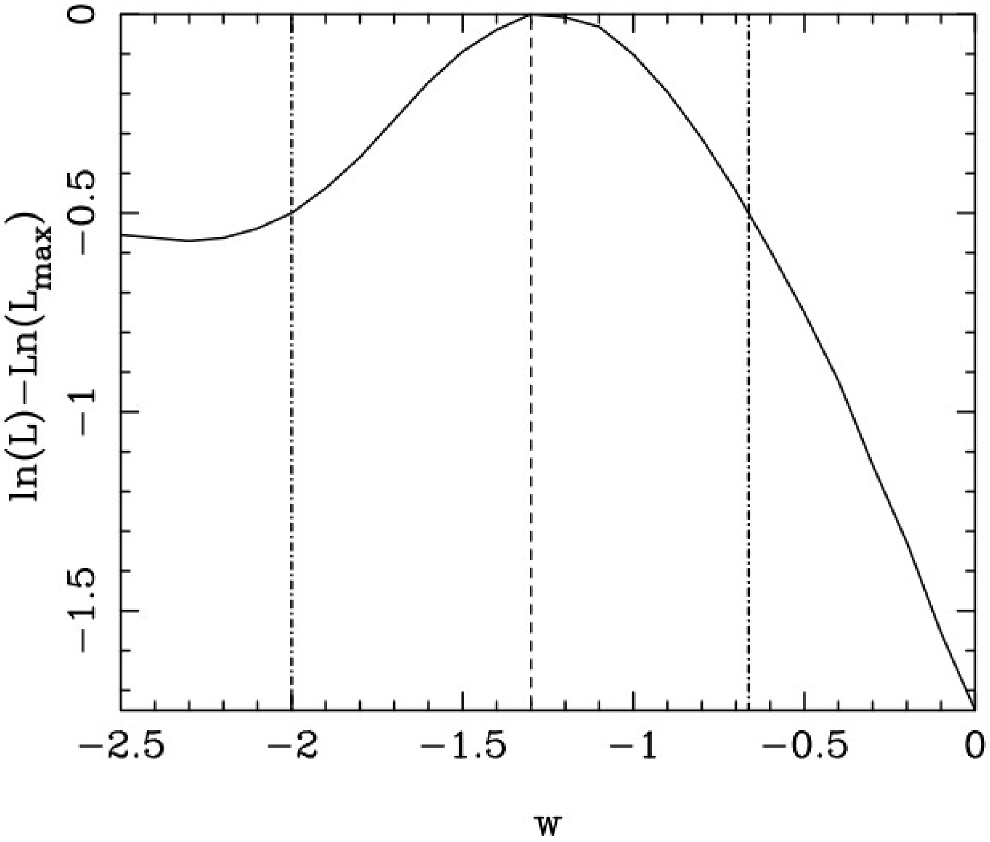
Where ~~are~~ were we?



COMBO-17 Proof of Concept
1.5 square degrees

Conditional Constraint on dark energy

Kitching et al. (2007)

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Slides Abridged , see Kitching et al. (2013) for more information

Conclusions

- 3D cosmic shear has potential to constrain
    - Post-Planck cosmological parameters
  - New likelihood code available *3Dfast*
    - Verified on n-body simulations
    - Applied to CFHTLenS
- It is important to understand the *aggregated effect of marginal gains* (or losses)