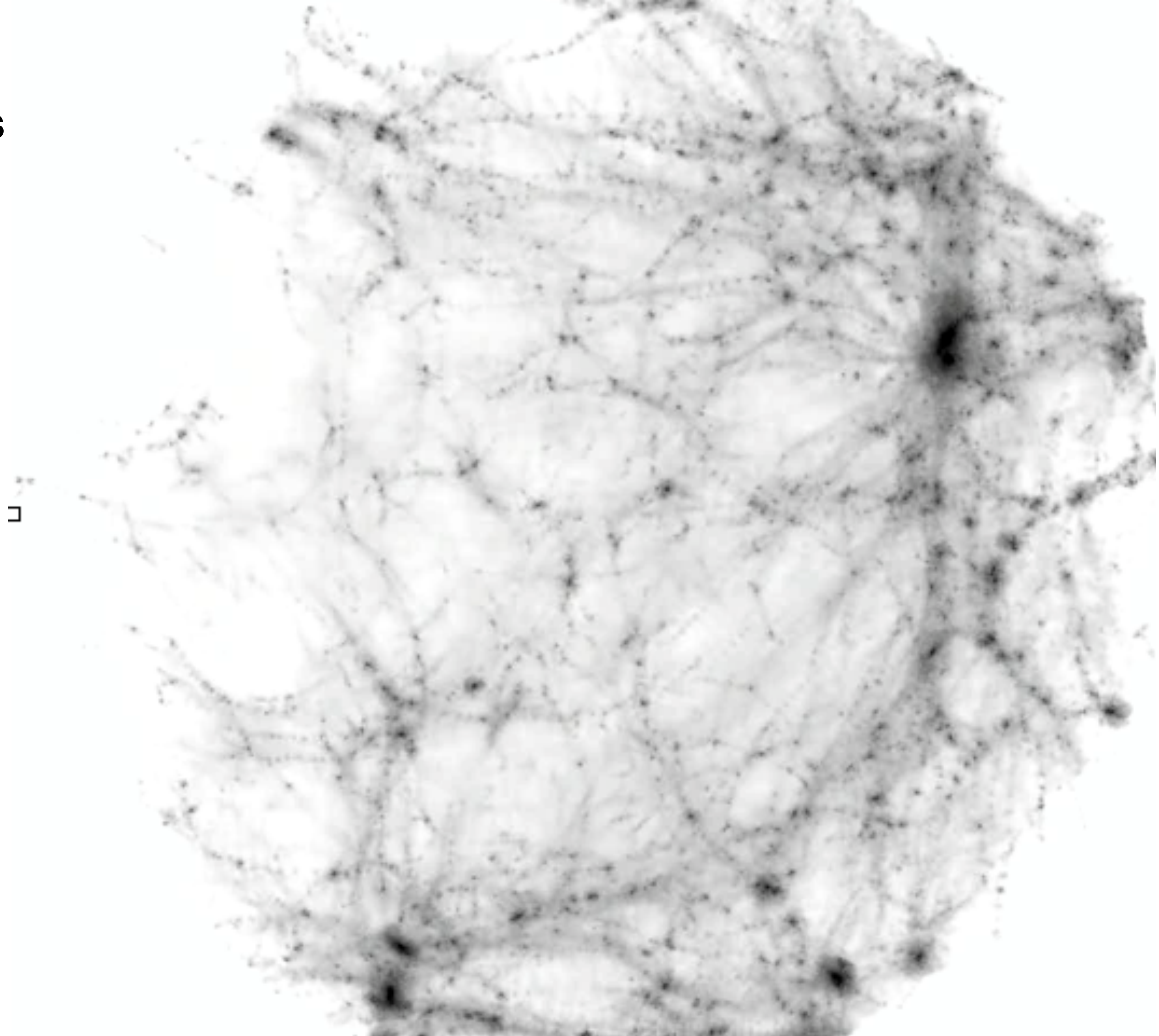
Cosmic shear full nulling: sorting out dynamics, geometry and systematics

MNRAS 2014, FB, Nishimichi, Taruya

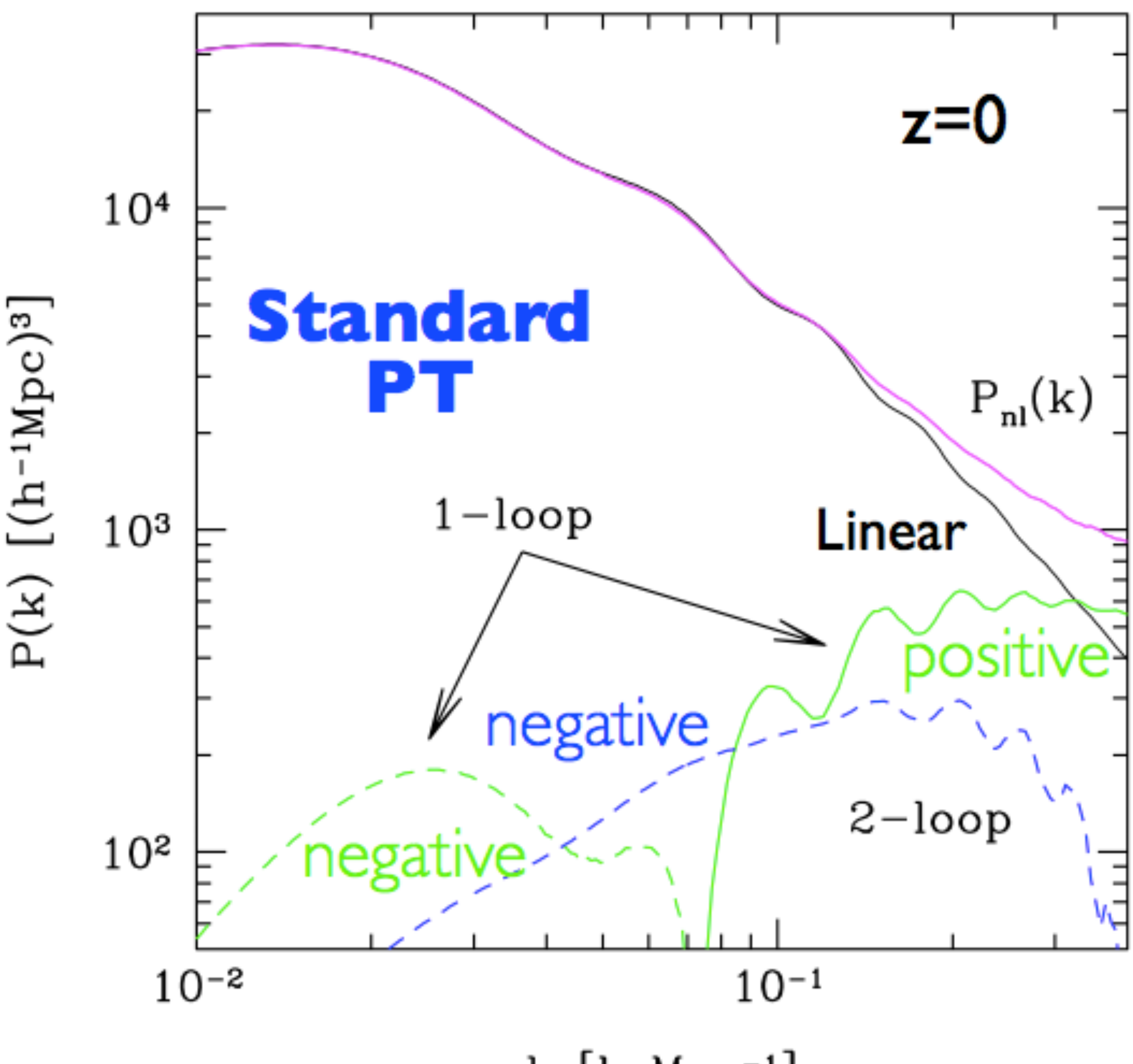
CEA IAP meeting 13 novembre 2015

Growth of structure in a self-gravitating dust fluid

LSS stats

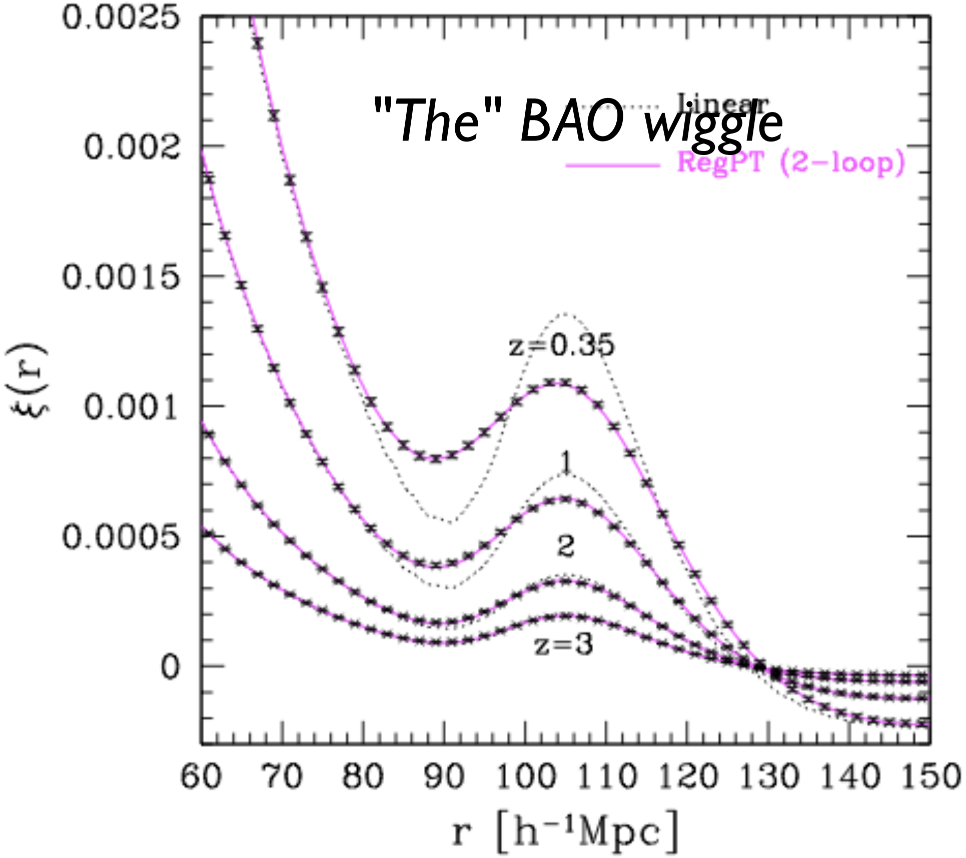


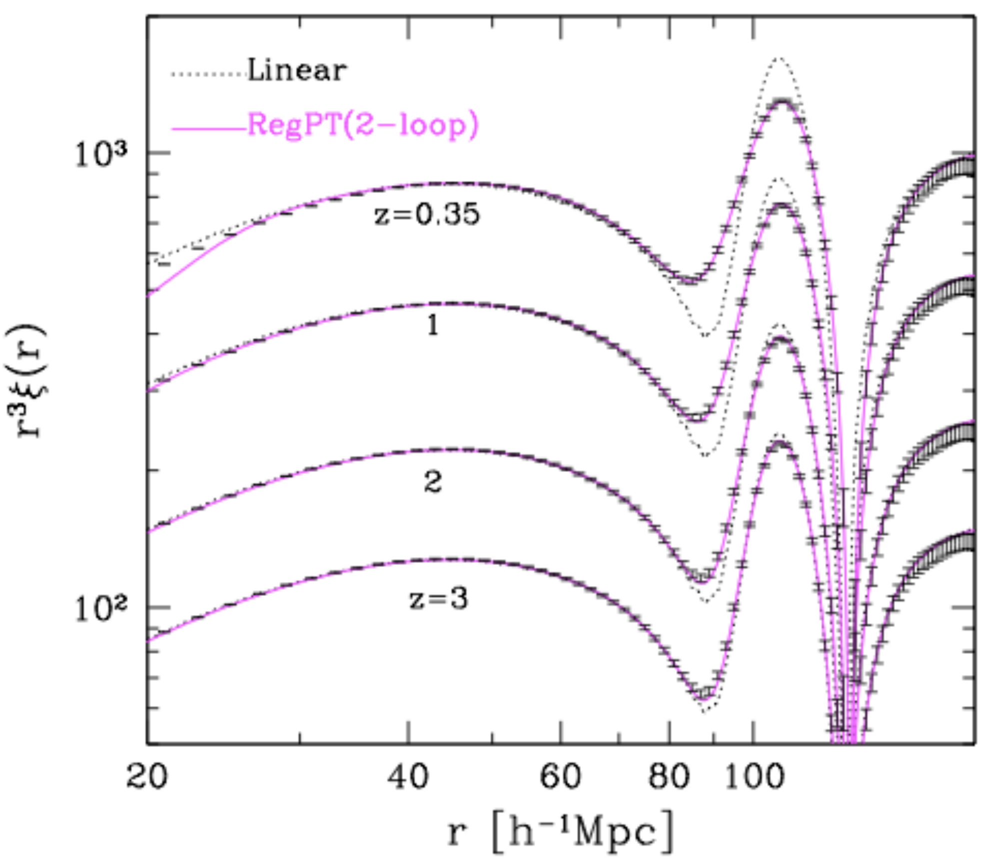
Reconstruction of the power spectrum: from sPT to Multi-point propagator reconstruction



Good performance of PT calculations (up to 2 loops)

in real space

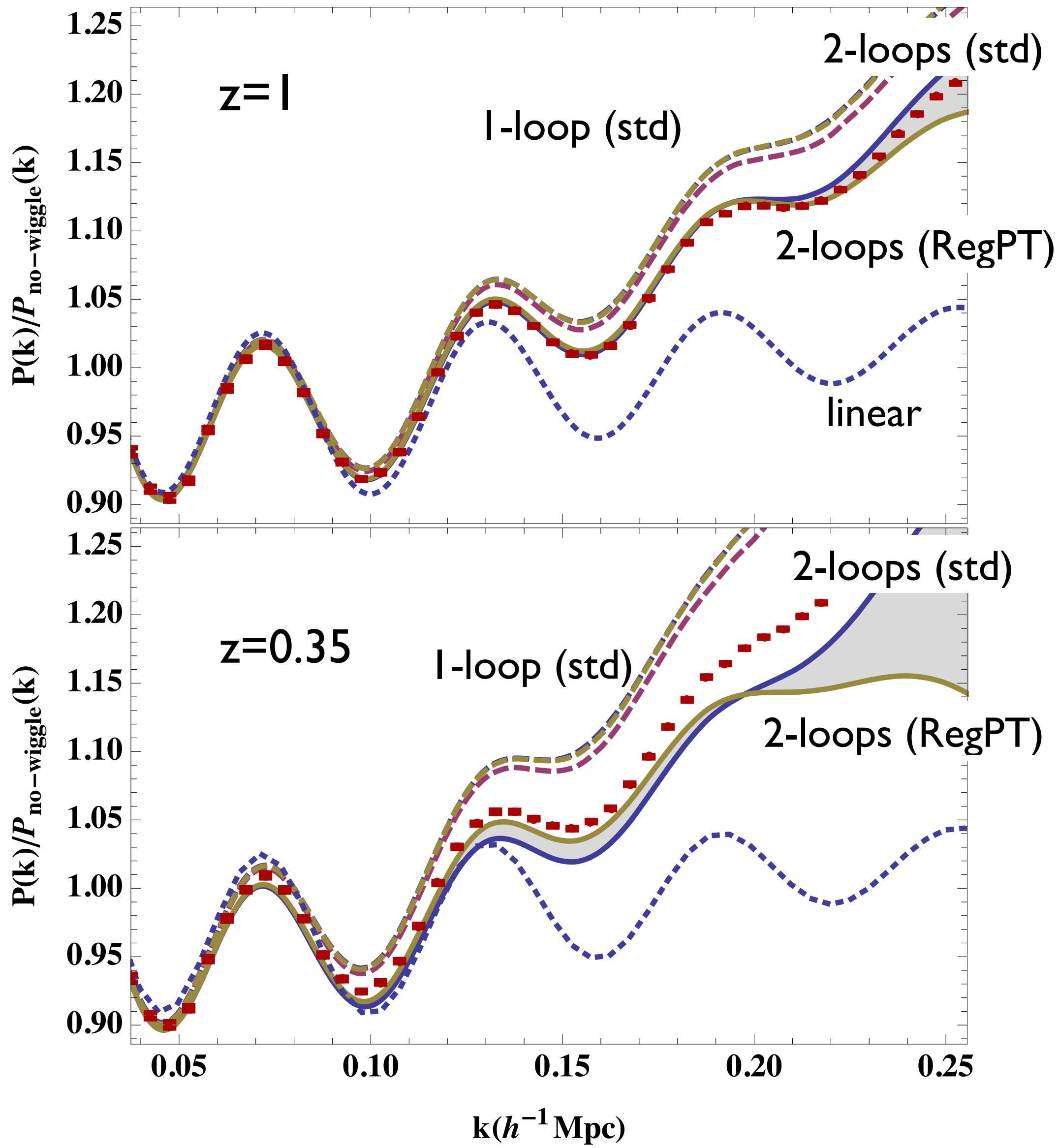




Power spectra up to 1-loop and 2-loop order

Taruya , FB, Nishimichi, Codis '12 Crocce, Scocimarro, FB, '12

1st computation of 2-loop order effects in Okamura,Taruya, Matsubara, '11



- Public codes for fast computations of power spectra at 2-loop order are now available.

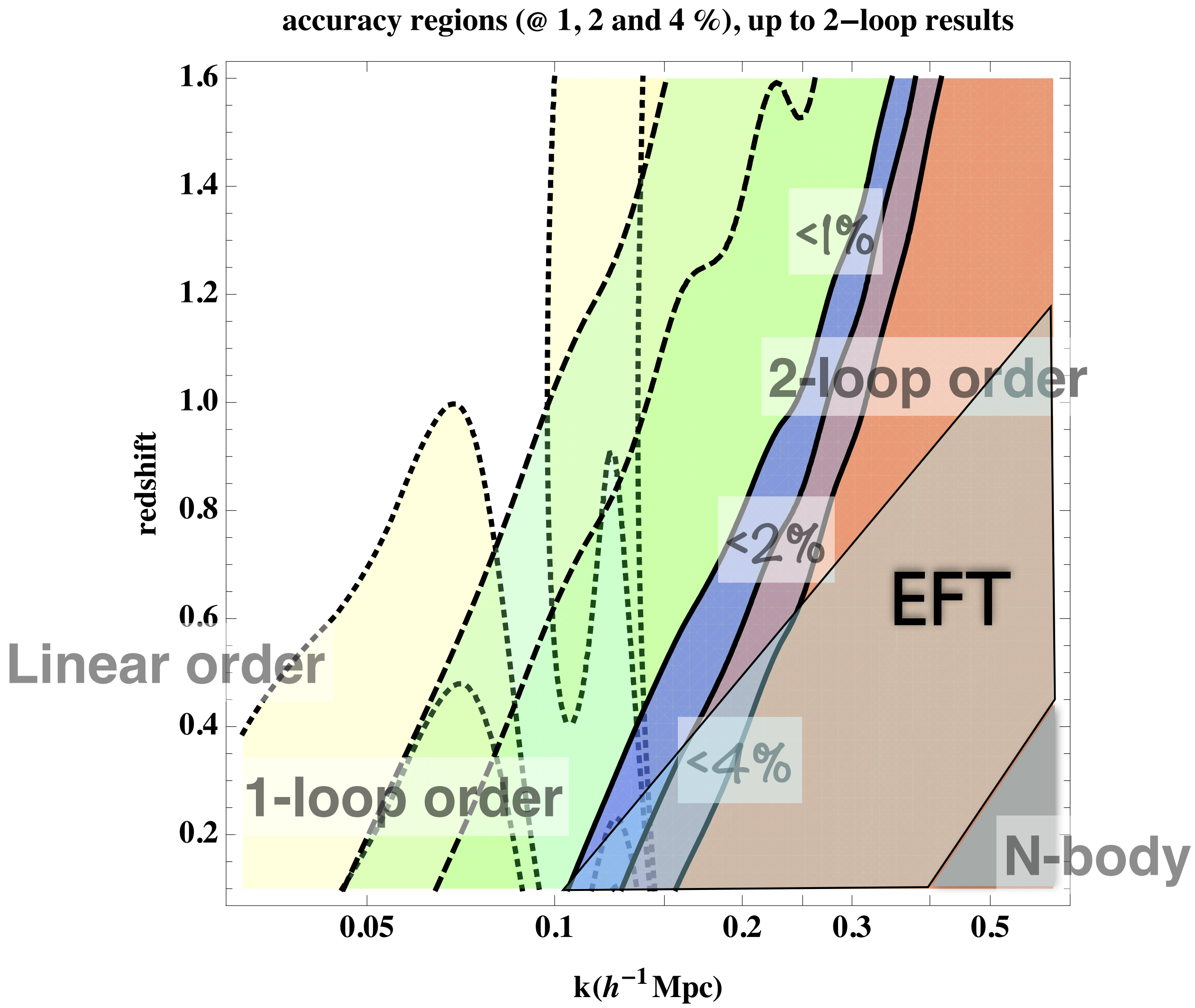
  http://maia.ice.cat/crocce/mptbreeze/

  http://www-utap.phys.s.u-tokyo.ac.jp/~ataruya/regpt_code.html

- Theoretical predictions are within 1% accuracy.

Charting PT in Fourier space

- Accuracy of linear and 1-loop results is obtained with a comparison with 2-loop results;
- Accuracy of 2-loop results is obtained with a comparisons with different prescriptions (that depart at 3-loop order)



- In the red region, improvement could be obtained from fits or Effective Theory approaches that should either be calibrated from N-body results or introduce free parameters.

The nulling

- the idea is to exploit nulling in order to avoid linear-nonlinear mixing in the projection effects.

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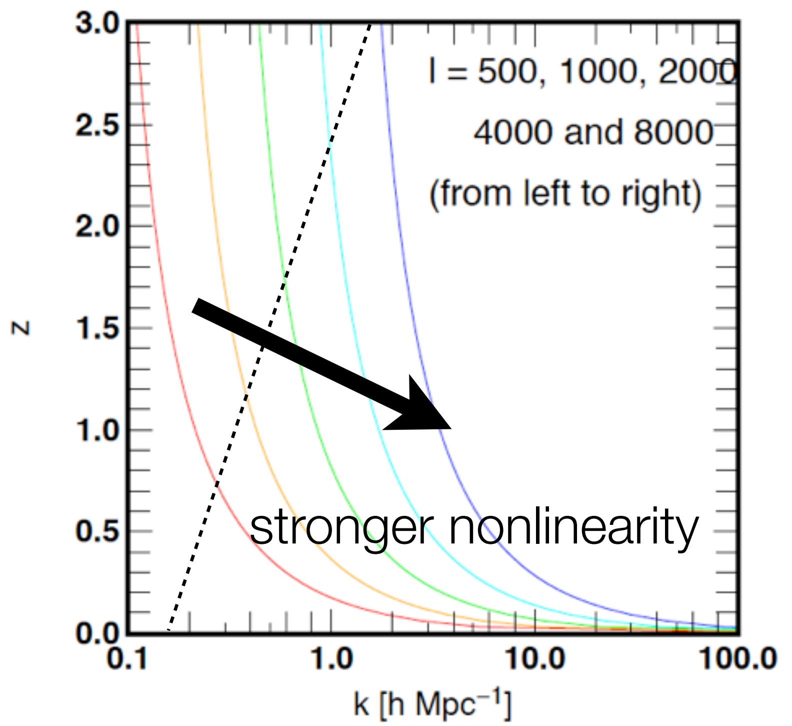
Mixture of information

$$P_\kappa(\ell) = \frac{9H_0^4\Omega_{\rm m}^2}{4c^4}\int_0^{\chi_{\rm h}} {\rm d}\chi \frac{g^2(\chi)}{a^2(\chi)} P_\delta\left(\frac{\ell}{f_K(\chi)}; z(\chi)\right),$$

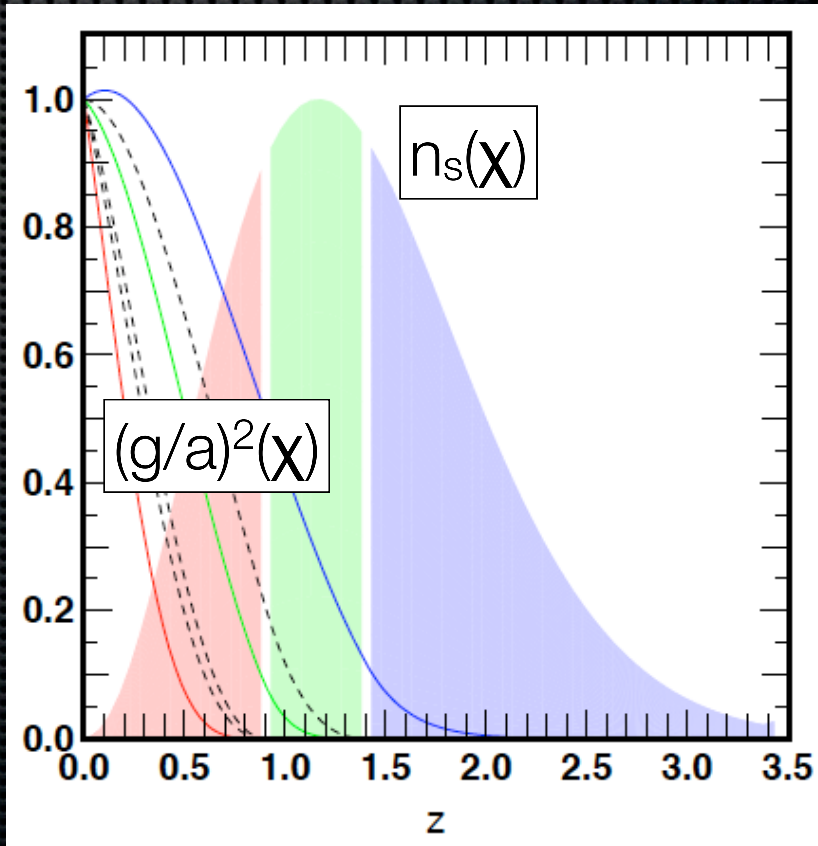
- Nonlinearity is more important on larger k at smaller z.
- Linear information at high z is contaminated by nonlinearity at low z.
- For any ℓ, nearby nonlinear structure always comes in to the angular power spectrum.



Tomography?

$$P_{\kappa}^{(ij)}(\ell) = \frac{9H_0^4\Omega_{\rm m}^2}{4c^4}\int_0^{\chi_{\rm h}} {\rm d}\chi \frac{g^{(i)}(\chi)g^{(j)}(\chi)}{a^2(\chi)} P_\delta\left(\frac{\ell}{f_{\rm K}(\chi)}; z(\chi)\right)$$

- More information is accessible by tomography.
  - can probe the structure growth at different times
- Lensing profiles overlap with each other.
- All are strongly affected by nearby structure.

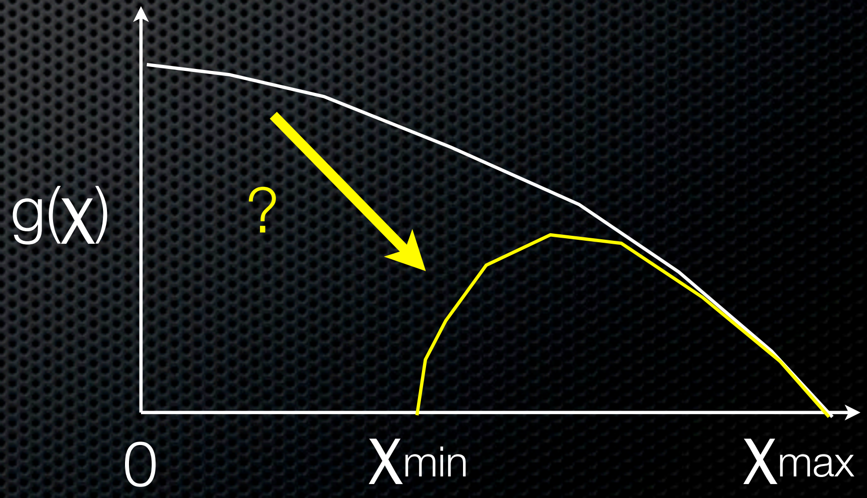


Cosmic shear full nulling

- Can we control the lensing response function as desired?
  - non-zero response only for a given interval of χ (or z)?
  - Let us introduce a weight function $w(\chi_s)$, which we can set arbitrarily.

condition

$$g(\chi) = \int_{\chi}^{\chi_h} d\chi_s w(\chi_s) n_s(\chi_s) \frac{f_K(\chi_s - \chi)}{f_K(\chi_s)} = 0, \quad (0 < \chi < \chi_{min}),$$



Cosmic shear full nulling (cont.)

- The condition for the *weighted* source number density, wn_s, can be rewritten as

$$\int \mathrm{d}\chi_{\mathrm{s}} w(\chi_{\mathrm{s}}) n_{\mathrm{s}}(\chi_{\mathrm{s}}) = 0, \quad + \quad \begin{cases} \displaystyle\int \mathrm{d}\chi_{\mathrm{s}} \frac{w(\chi_{\mathrm{s}}) n_{\mathrm{s}}(\chi_{\mathrm{s}})}{\tan(\sqrt{K}\chi_{\mathrm{s}})} = 0, & (K > 0), \\ \displaystyle\int \mathrm{d}\chi_{\mathrm{s}} \frac{w(\chi_{\mathrm{s}}) n_{\mathrm{s}}(\chi_{\mathrm{s}})}{\chi_{\mathrm{s}}} = 0, & (K = 0), \\ \displaystyle\int \mathrm{d}\chi_{\mathrm{s}} \frac{w(\chi_{\mathrm{s}}) n_{\mathrm{s}}(\chi_{\mathrm{s}})}{\tanh(\sqrt{-K}\chi_{\mathrm{s}})} = 0, & (K < 0). \end{cases}$$

- We can always find solutions when the sources have a distribution with a finite width!

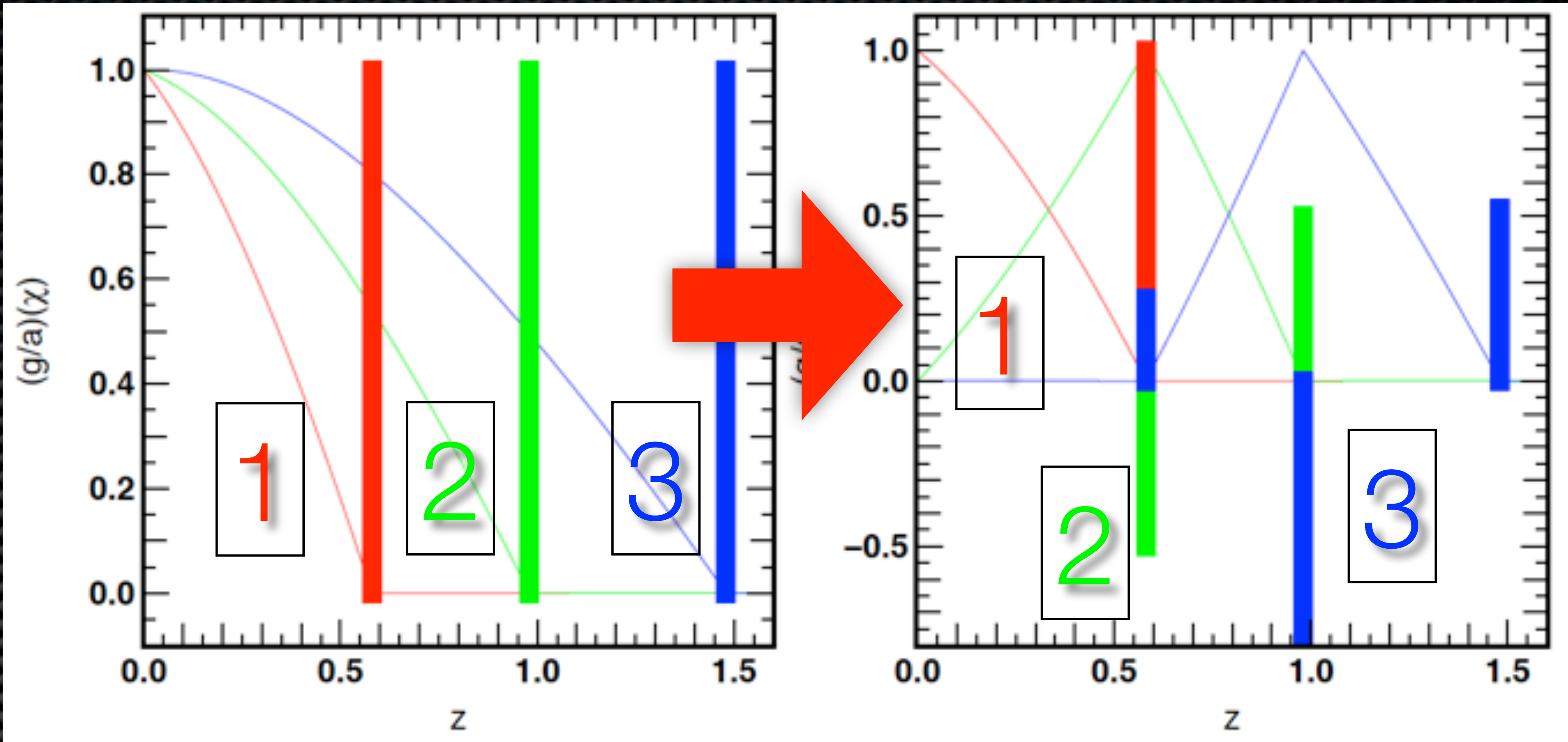
Demonstration:
discrete source distribution

$$
\begin{aligned}
(wn_s)_1 &= \quad \chi_1(\chi_3 - \chi_2), \\
(wn_s)_2 &= -\ \chi_2(\chi_3 - \chi_1), \\
(wn_s)_3 &= \quad \chi_3(\chi_2 - \chi_1),
\end{aligned}
$$

(K=0)

- One can always find a solution with 3 distinct source redshifts @ $z = z_1$, z_2 & z_3 ($z_1 < z_2 < z_3$).

$$
\begin{pmatrix} \tilde{\kappa}_1 \\ \tilde{\kappa}_2 \\ \tilde{\kappa}_3 \end{pmatrix} = \begin{pmatrix} 1 & 0 & 0 \\ -1 & 1 & 0 \\ (wn_s)_1 & (wn_s)_2 & (wn_s)_3 \end{pmatrix} \begin{pmatrix} \kappa_1 \\ \kappa_2 \\ \kappa_3 \end{pmatrix}
$$

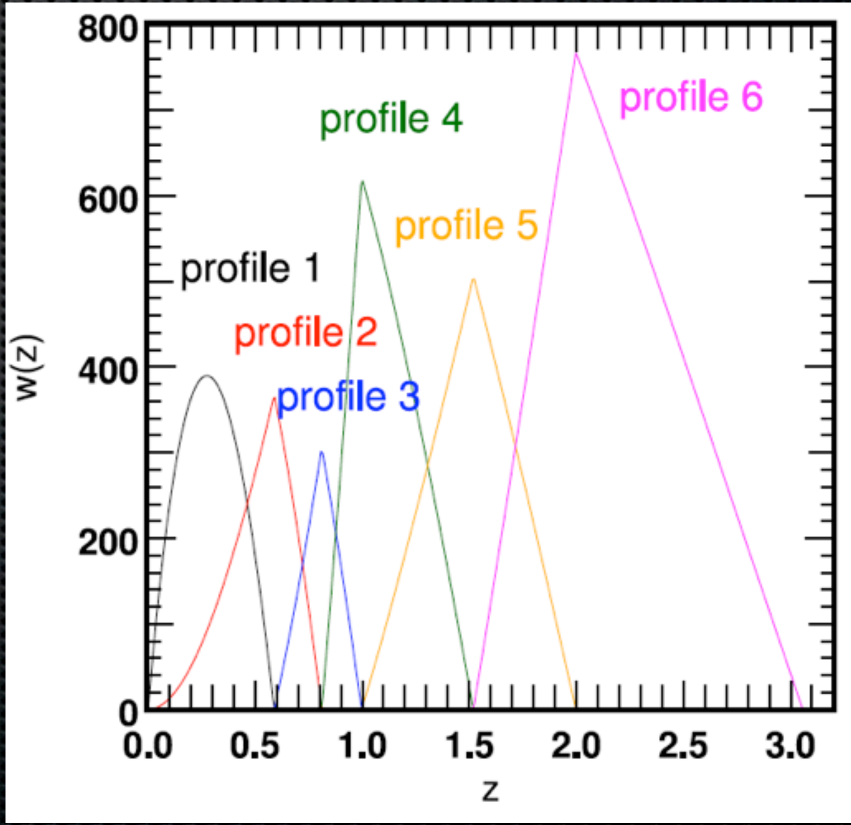


Demonstration: discrete source distribution

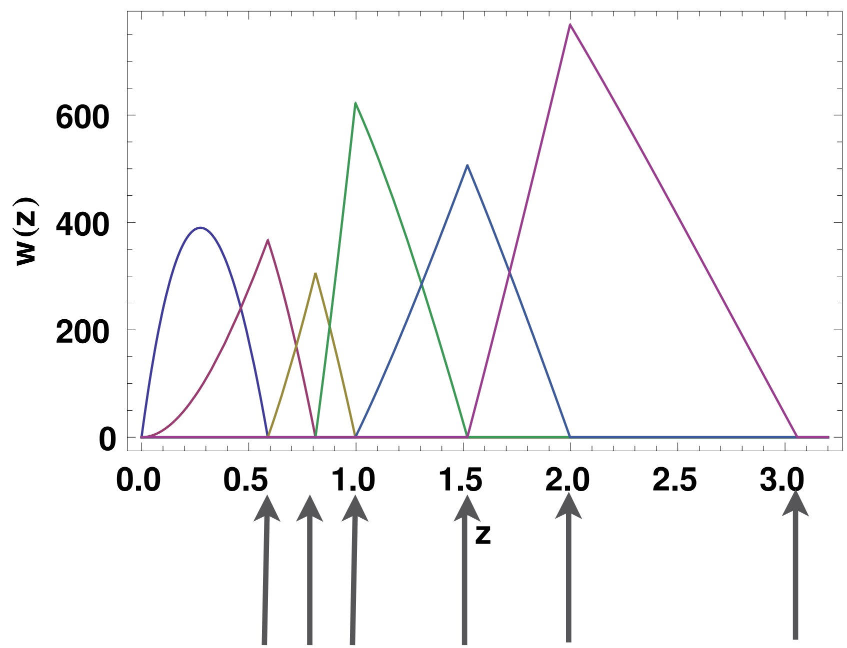
- We can play the same game with more source planes...

$$\tilde{\kappa}_i = \sum_j \mathcal{W}_{ij} \kappa_j,$$

$$\mathcal{W}_{ij} = \begin{bmatrix} 1 & 0 & 0 & 0 & 0 & 0 \\ -1 & 1 & 0 & 0 & 0 & 0 \\ n_{132} & n_{213} & n_{321} & 0 & 0 & 0 \\ 0 & n_{243} & n_{324} & n_{432} & 0 & 0 \\ 0 & 0 & n_{354} & n_{435} & n_{543} & 0 \\ 0 & 0 & 0 & n_{465} & n_{546} & n_{654} \end{bmatrix}$$



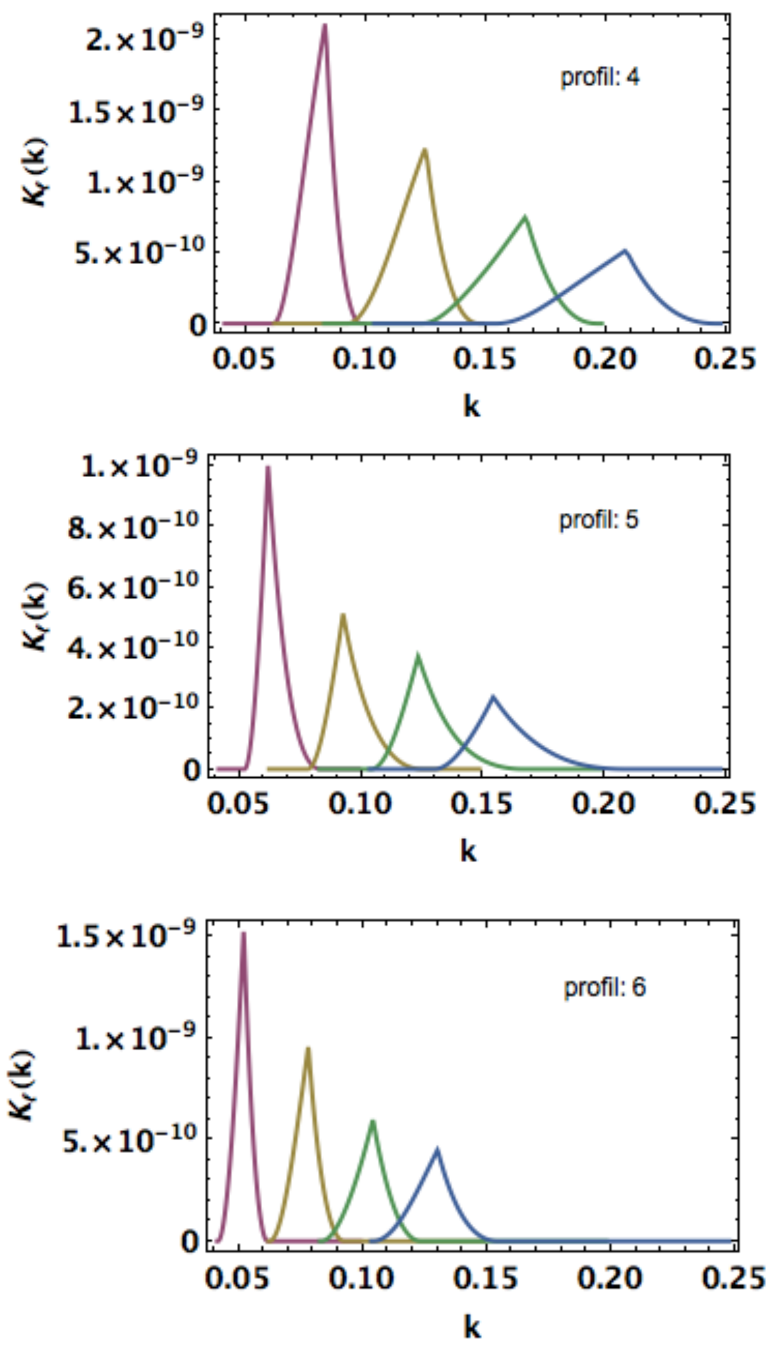
Nulling: it is possible to choose the weights so that the lens distributions have finite ranges in z.



the available source planes

From the simulation of Sato et al.: 6 source planes from which one can build 6 lens distributions shown here.

k contributions for l: 200, 300, 400, 500



- The bin auto-correlations

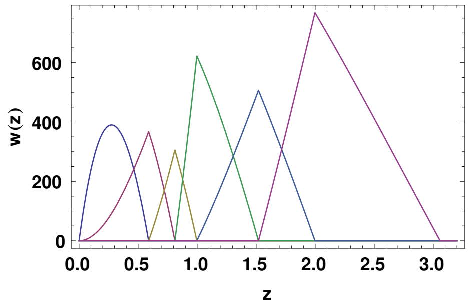
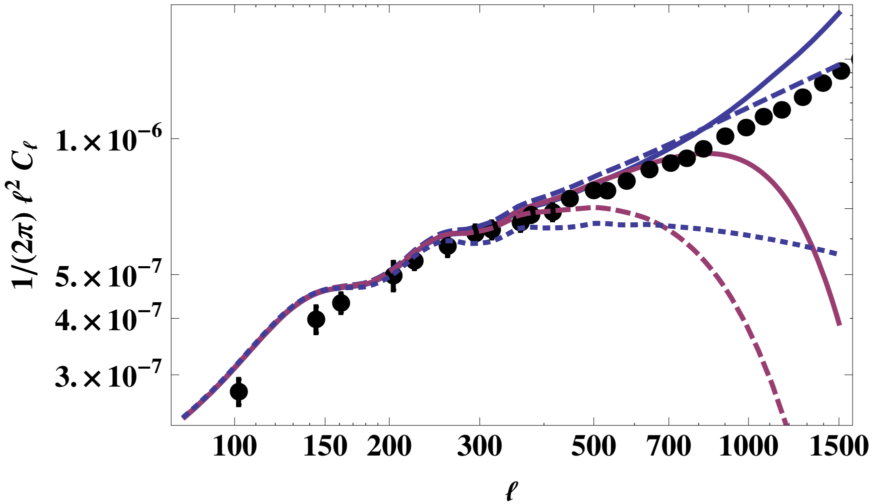
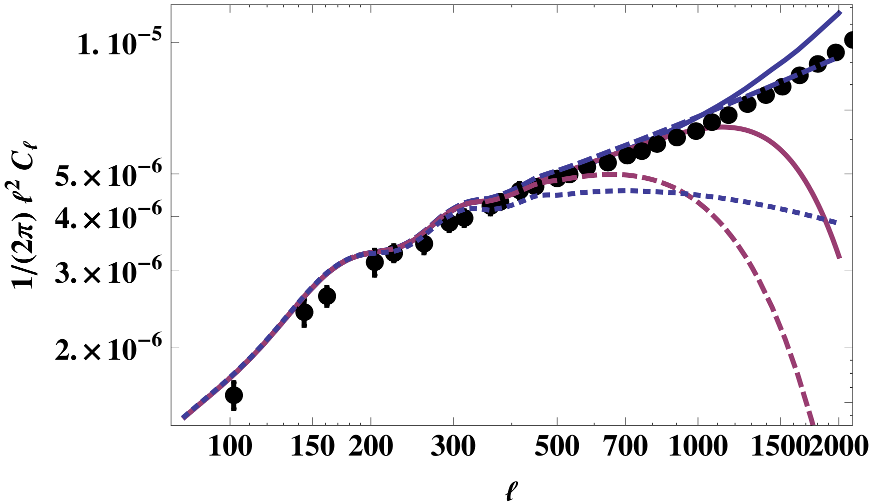
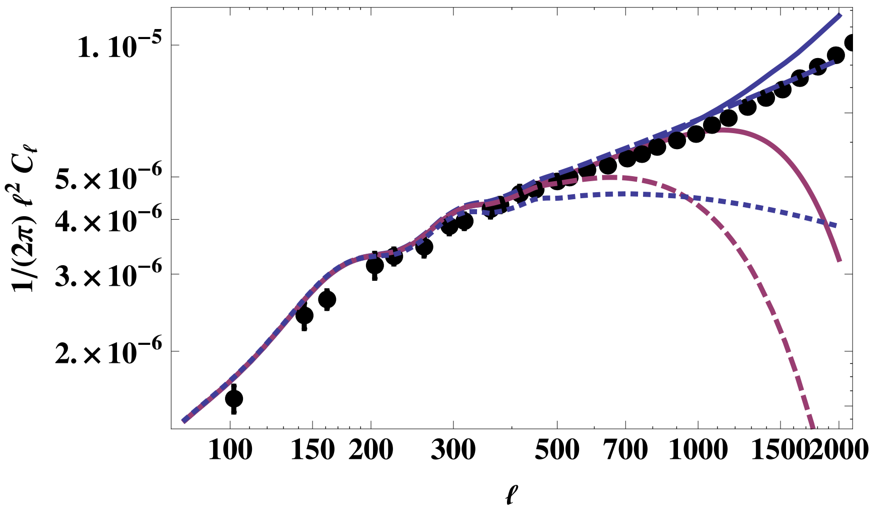
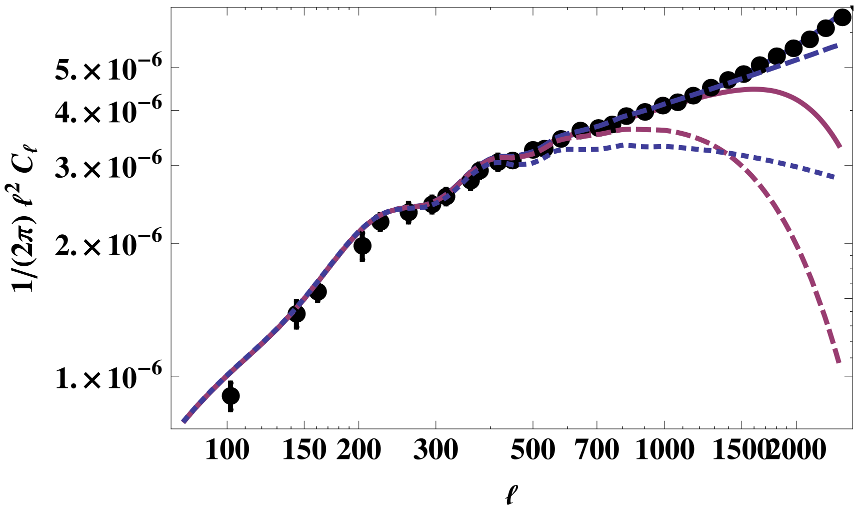


FIG. 4: Adopted lens distribution for the available redshift source planes

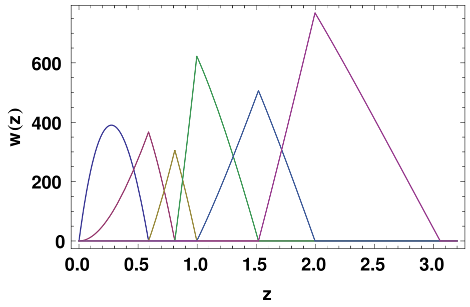








- The bin cross-correlations



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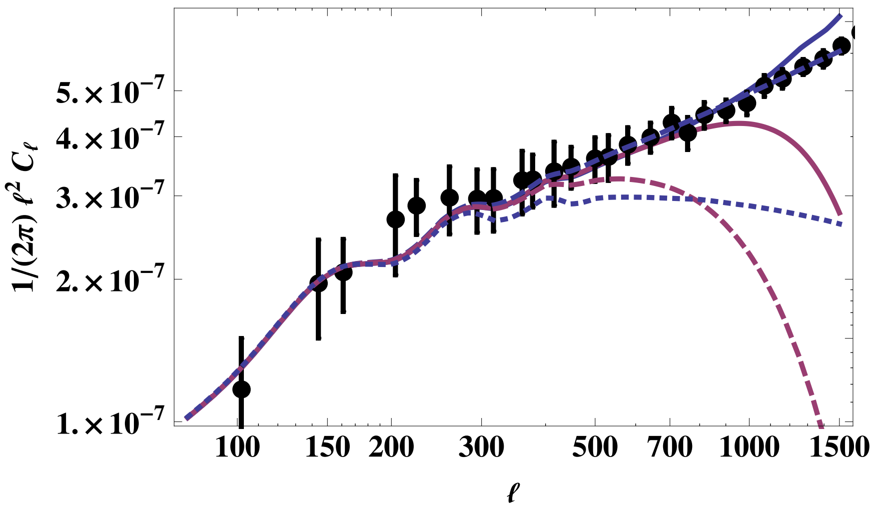
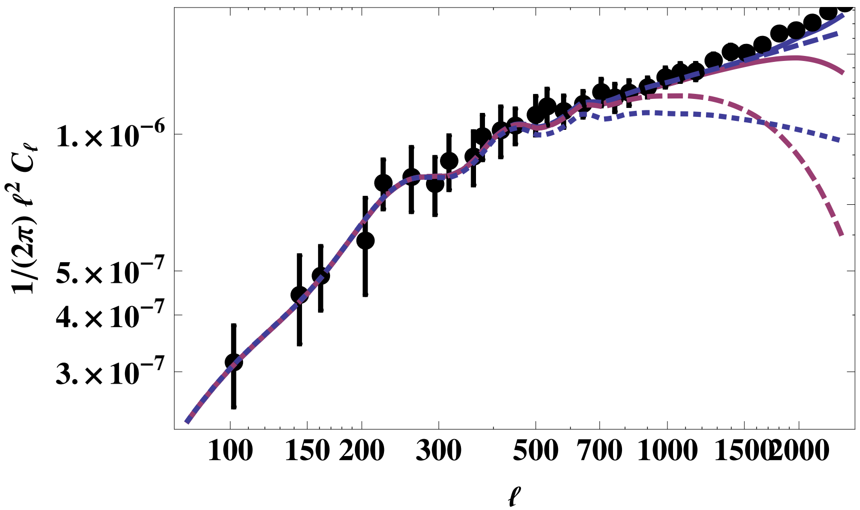
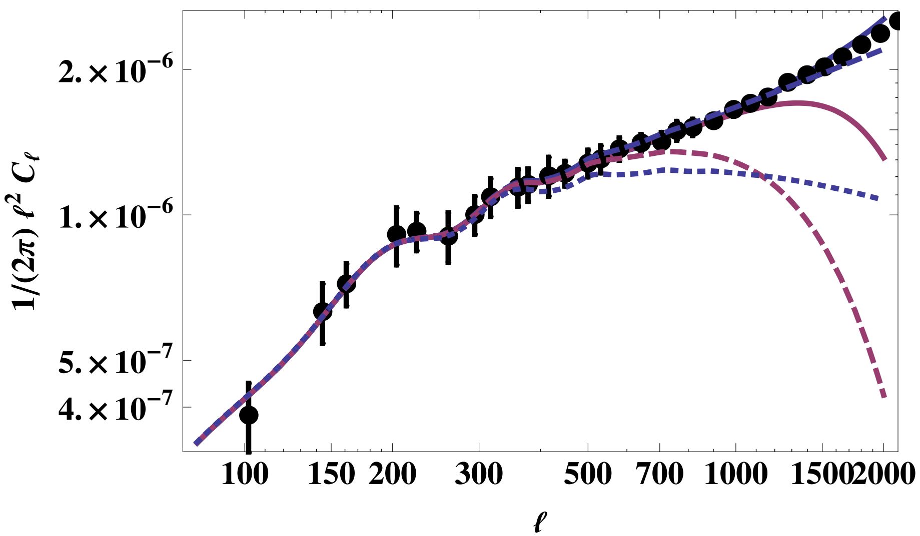






A nulling approach, continuous limit

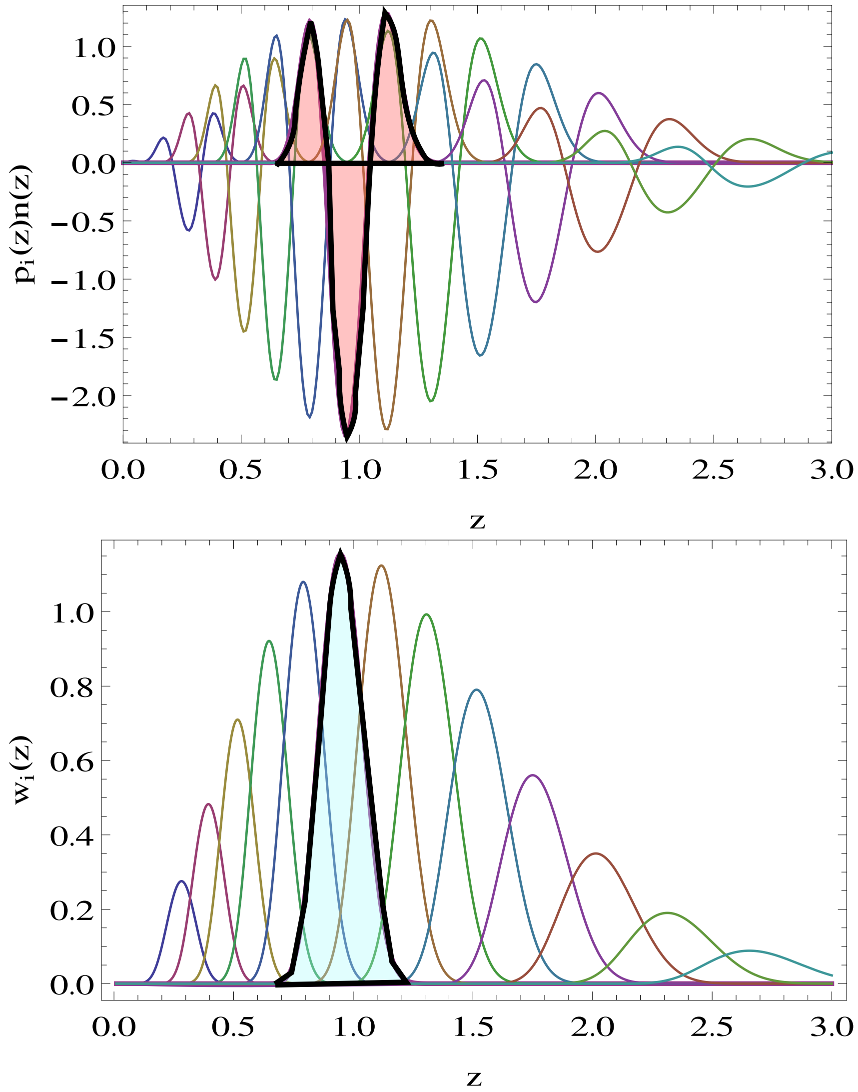
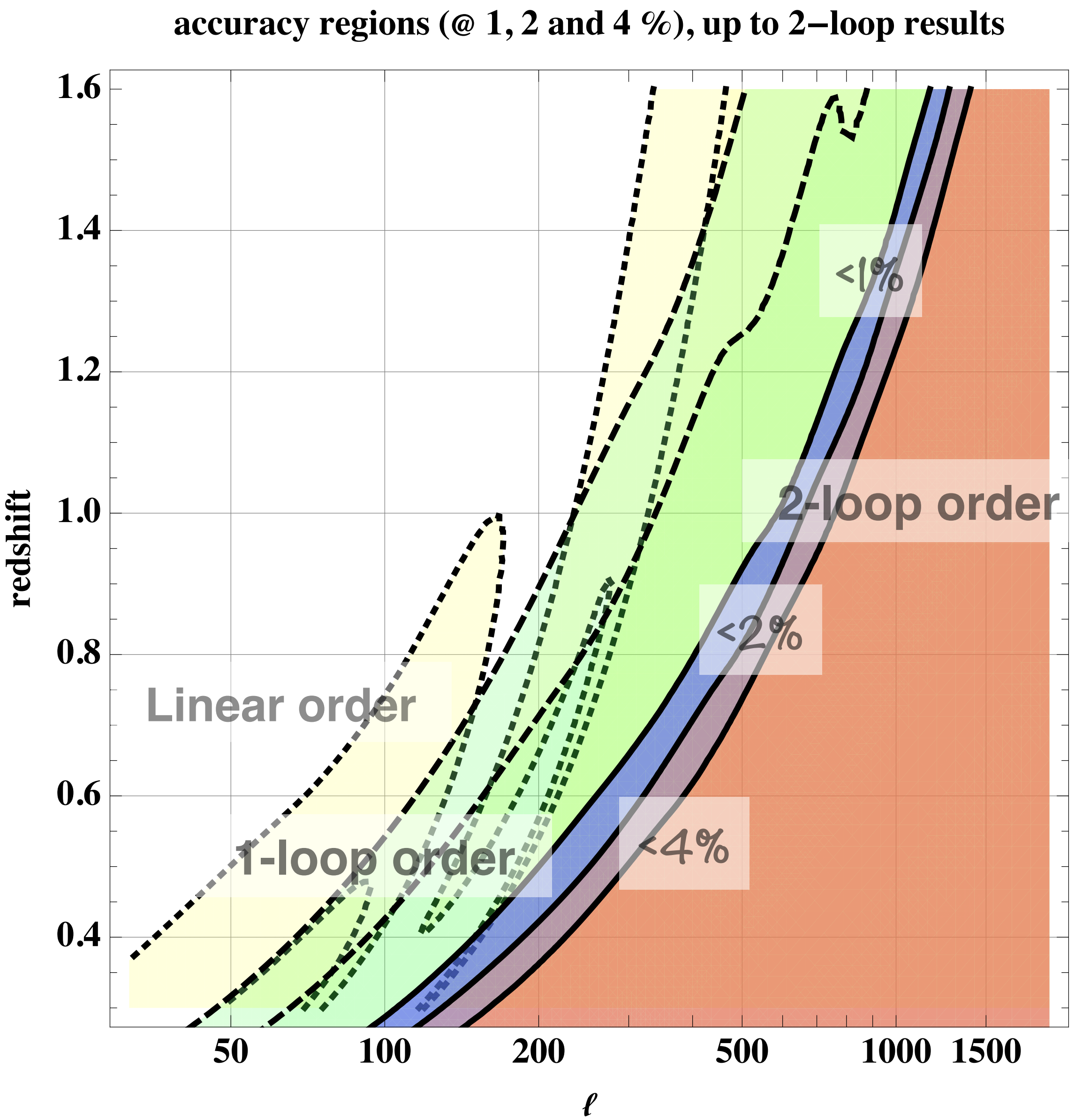


Figure 7. The adopted profiles in redshifts for the sources (top panel) and the resulting profiles for the lens distribution (bottom panel) for the fiducial cosmological model. The profiles for the sources have been obtained from the form (26) after they are convolved with a kernel that mimic the photometric redshifts error distribution.

Charting PT

- To get insights into the development of gravitational instabilities;
- To test/complement N-body simulations;
- Provide predictions from first principles in a large variety of models, and for a large numbers of parameters.

Charting PT in harmonic space (for cosmic shear observations)



Conclusions

There has been a lot of developments beyond mere recipes for the constructions of power spectra beyond linear regime.

The goal is to obtain **controllable** predictions from **first principles**.

These results are directly applicable to cosmic shear observations taking advantage of the nulling construction.