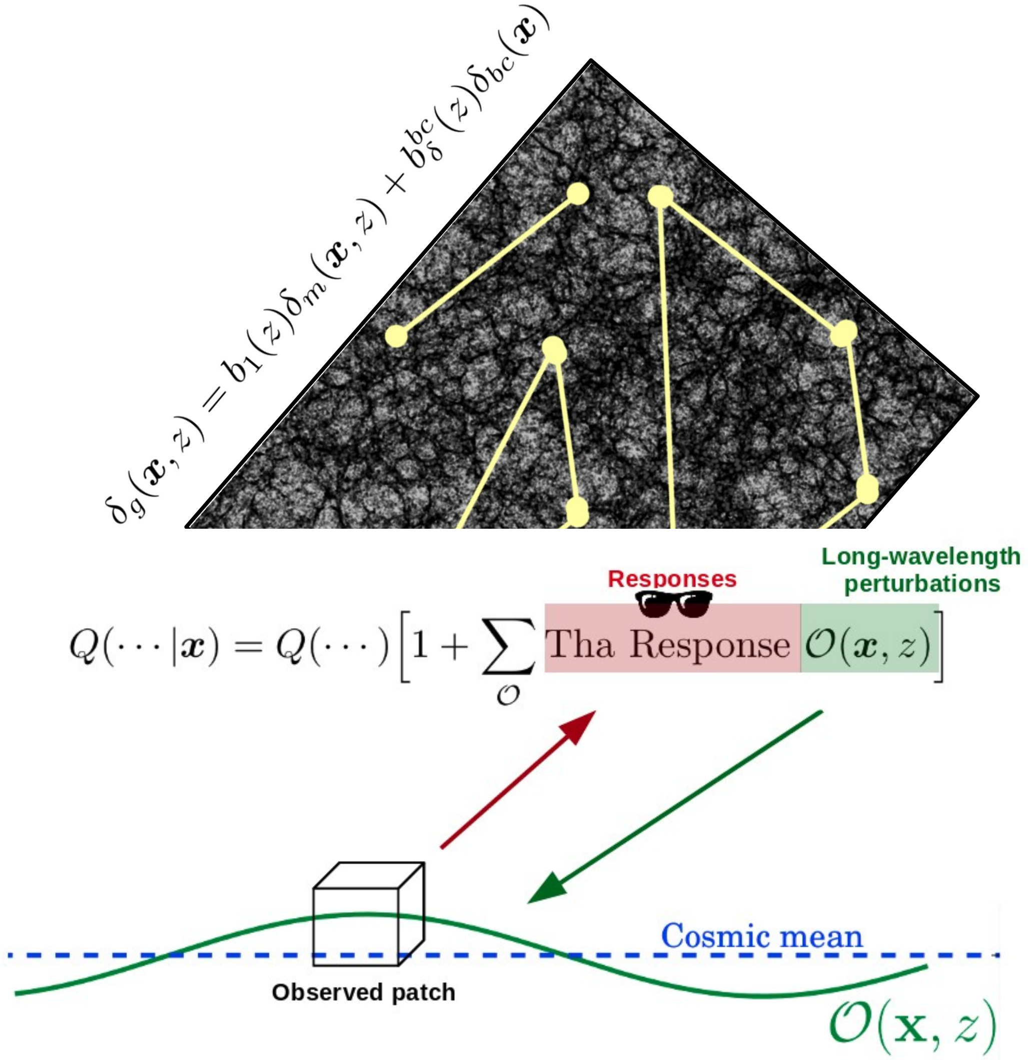
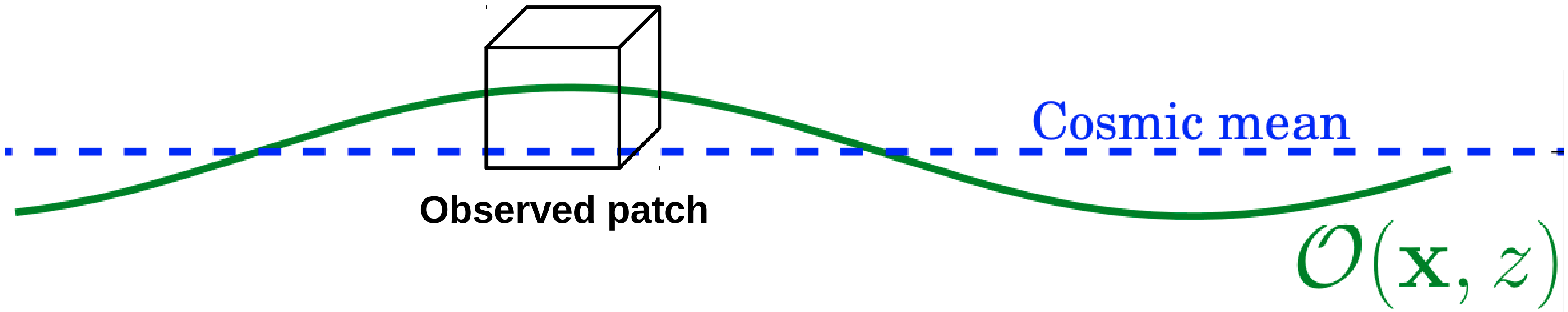
Baryonic effects on higher-order lensing statistics

Alexandre Barreira
(MPA)



Responses and Separate Universes

$$P_m(k, z|\boldsymbol{x}) = P_m(k, z)\left[1 + \sum_{\mathcal{O}} R_{\mathcal{O}}(k, z)\mathcal{O}(\boldsymbol{x}, z)\right]$$



Responses and Separate Universes

Local power spectrum

Global power spectrum

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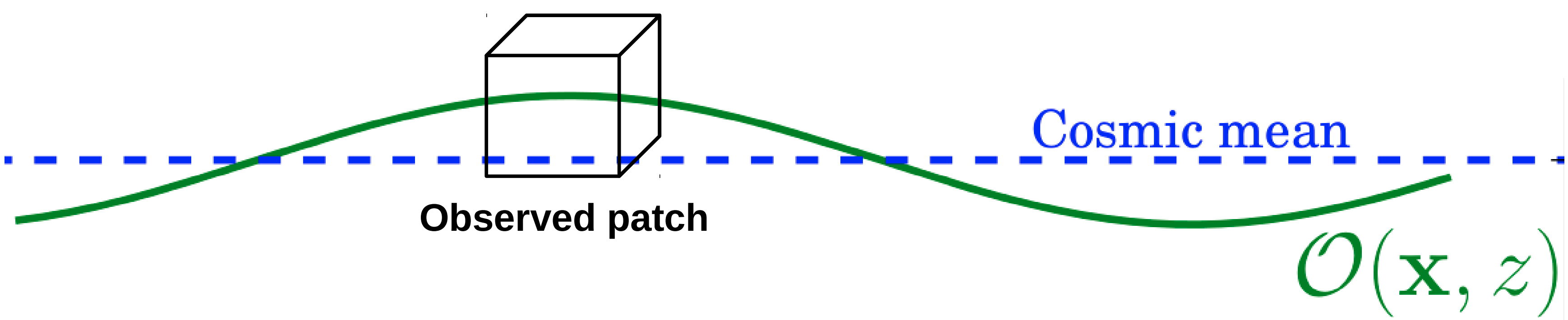

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Power spectrum responses

Long-wavelength perturbations

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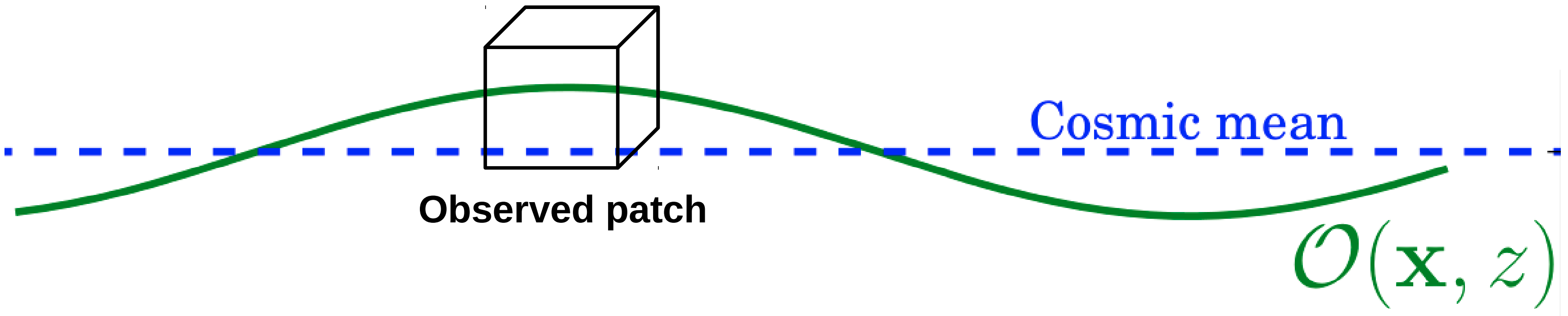

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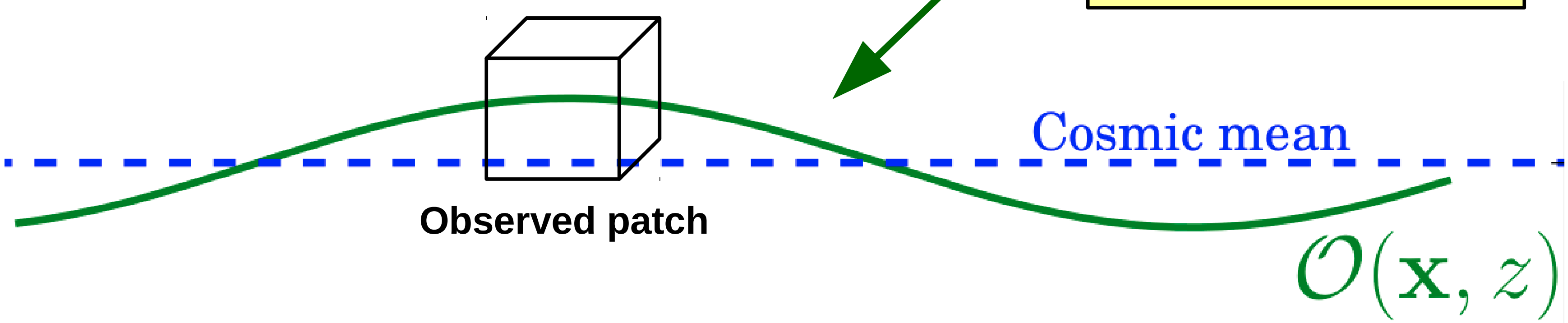
2. Compare with "normal" simulations

1. Induce these in simulations
(modify cosmology)



P(k) responses

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Response to overdensity

Li et al (1401.0385) ; Wagner et al (1409.6294)

Response to tidal field

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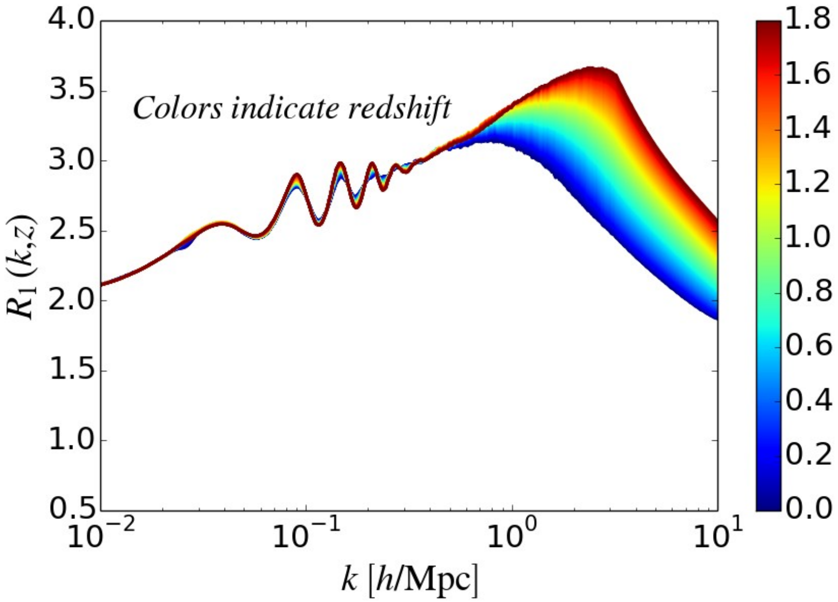

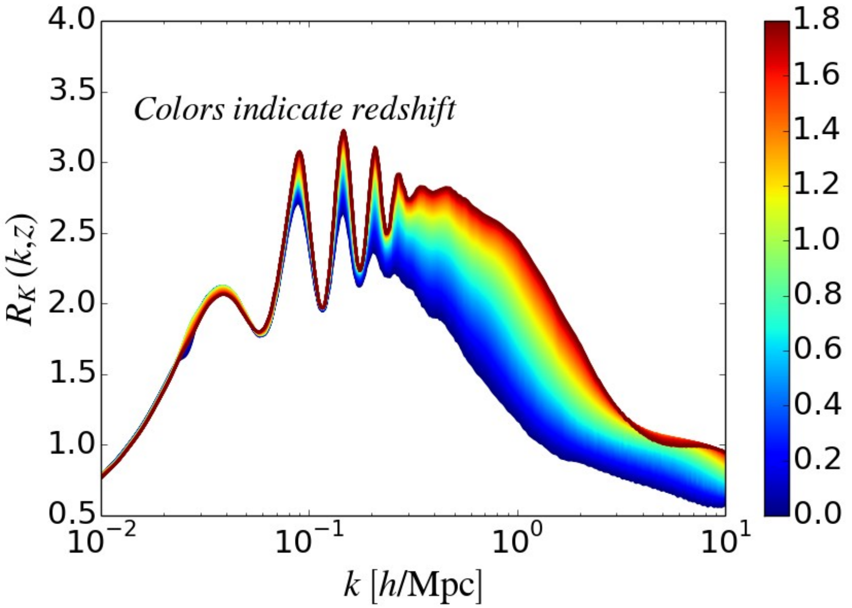

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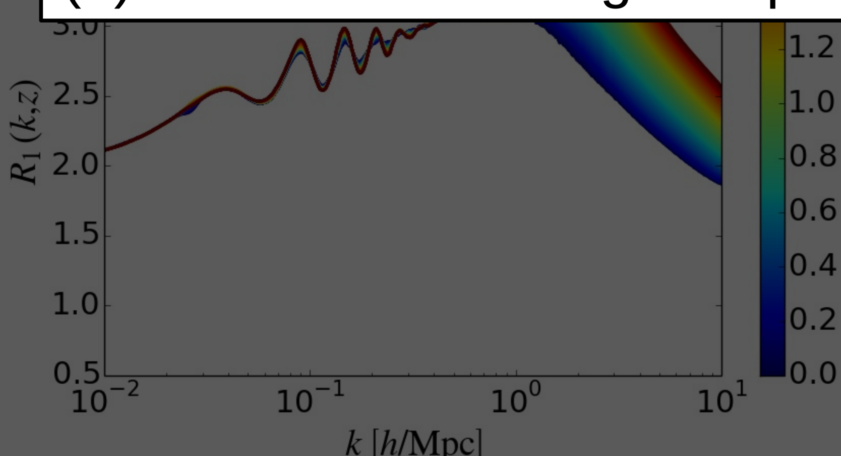
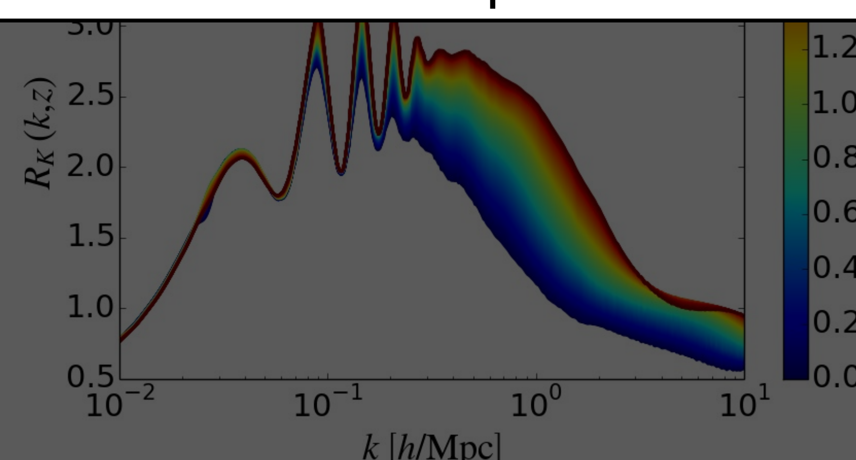
Separate Universe simulations have been gravity-only, ***<u>so add hydrodynamics and galaxy formation:</u>***

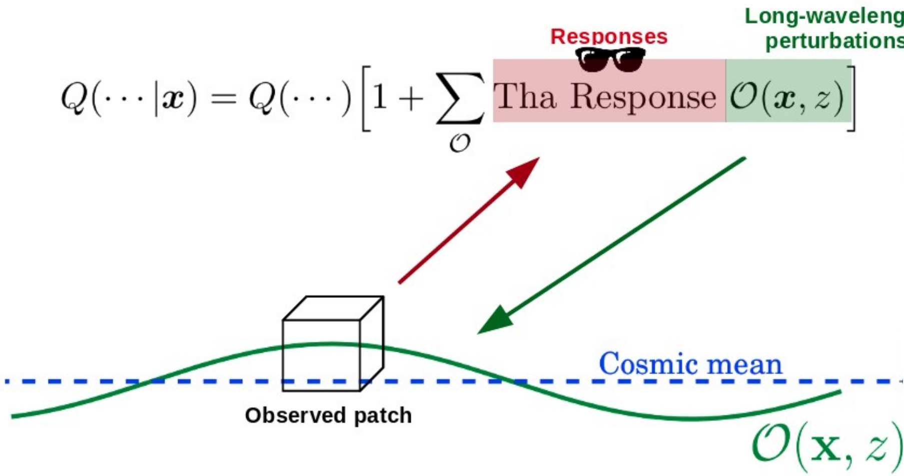
(1) Measure baryonic impact on gravity-only responses;

(2) Broadens the range of quantities we can measure the response of.

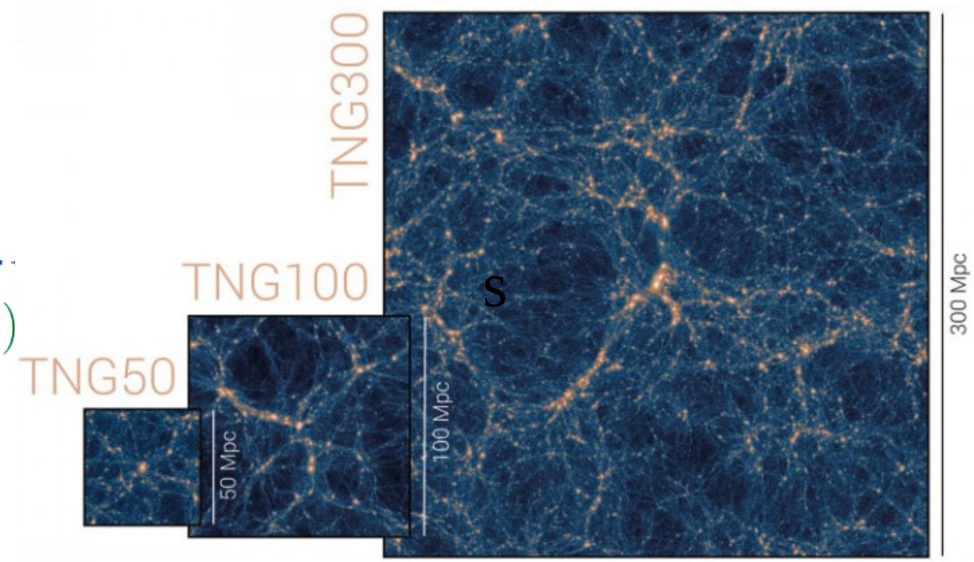




Separate Universe with IllustrisTNG



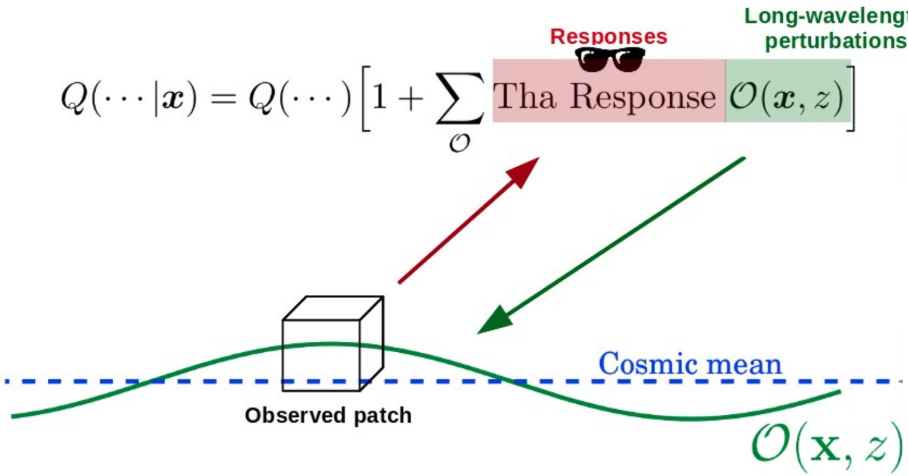
Pillepich+(2017); Weinberger+ (2017)
http://www.tng-project.org



1) ***Baryon effects on P(k) responses and lensing N-point functions***
Barreira, Nelson, Pillepich, Springel, Schmidt, Pakmor, Hernquist, Volgelsberger – 1904.02070

2) ***Baryon-CDM isocurvature galaxy bias***
Barreira, Cabass, Nelson, Schmidt – 1907.04317

Separate Universe with IllustrisTNG



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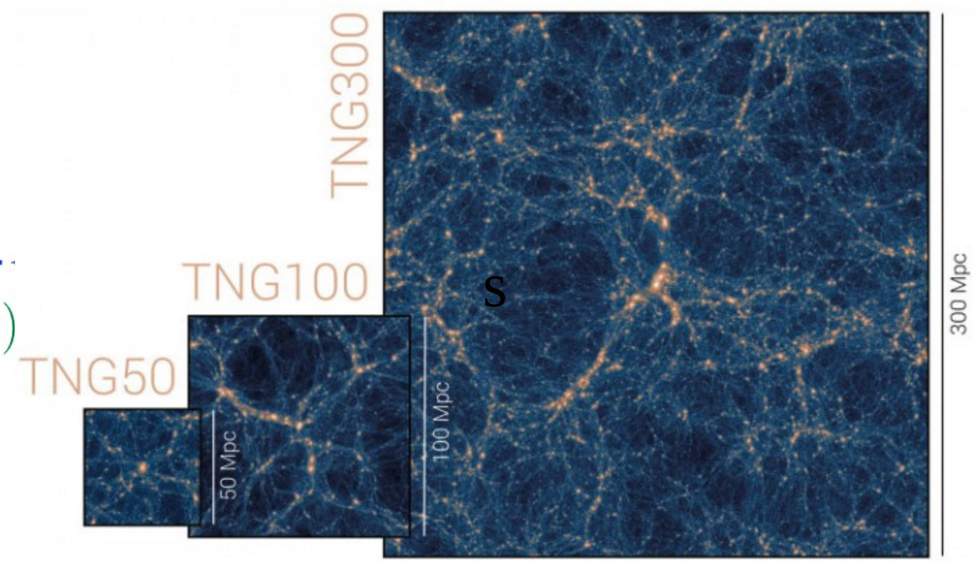

1) ***Baryon effects on P(k) responses and lensing N-point functions***
Barreira, Nelson, Pillepich, Springel, Schmidt, Pakmor, Hernquist, Volgelsberger – 1904.02070

This talk!

2) ***Baryon-CDM isocurvature galaxy bias***
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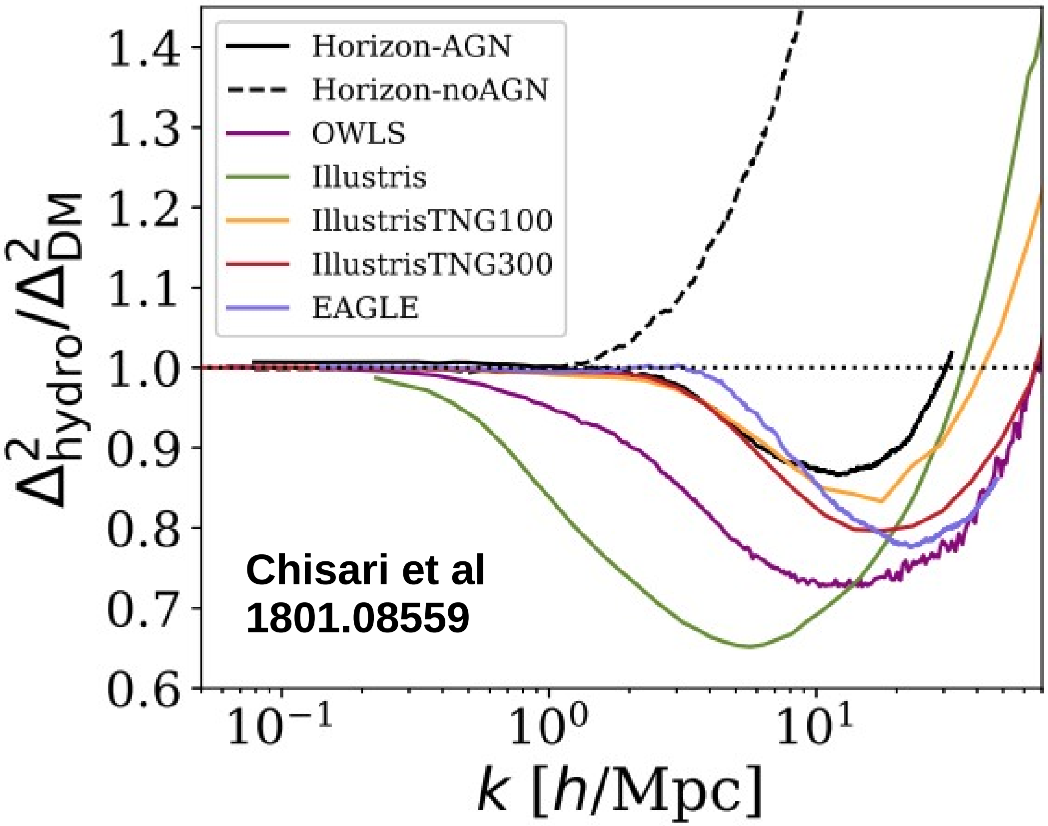
Responses and N-point functions

<u>A motivation:</u> *we are now getting to know how 2pt functions depend on baryons; <u>what's the baryonic dependence of higher-order statistics?</u>*



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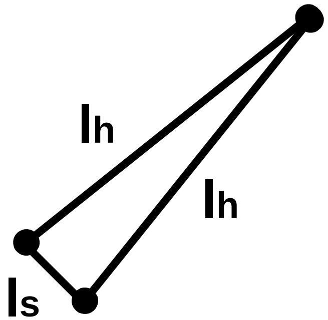

→ ***<u>Example 1</u> : Lensing squeezed bispectrum (l_h >> l_s)***

$$B_\kappa(\ell_h,\ell_h,\ell_s) = \int \mathrm{d}\chi \frac{g(\chi)^3}{\chi^4}\left[R_1(\ell_h/\chi) - \frac{1}{6}R_K(\ell_h/\chi)\right]P_m(\ell_h/\chi)P_m(\ell_s/\chi)$$

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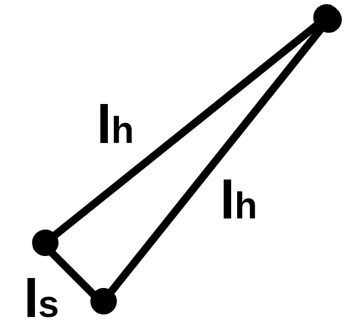

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Responses

Responses and N-point functions

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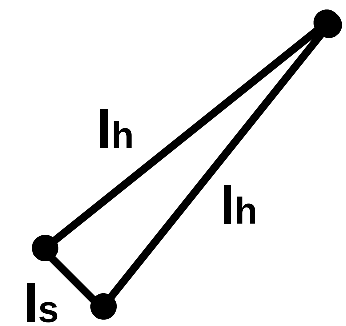

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→ ***<u>Example 2</u> :Lensing super-sample covariance term (4pt function)***
(dominant non-Gaussian piece for Euclid/LSST)

$$\begin{aligned} \mathrm{Cov}_\kappa^{\mathrm{SSC}}(\ell_1, \ell_2) &= \frac{1}{\Omega_W^2} \int \mathrm{d}\chi \frac{g(\chi)^4}{\chi^6} \int \mathrm{d}^2\boldsymbol{\ell} |\tilde{W}(\boldsymbol{\ell})|^2 P_m(\ell/\chi) \\ &\times \Big[\underbrace{\boxed{R_1(\ell_1/\chi) - \frac{1}{6} R_K(\ell_1/\chi)}}_{\text{Responses}} \Big] P_m(\ell_1/\chi) \Big[\underbrace{\boxed{R_1(\ell_2/\chi) - \frac{1}{6} R_K(\ell_2/\chi)}}_{\text{Responses}} \Big] P_m(\ell_2/\chi) \end{aligned}$$

P(k) response decomposition

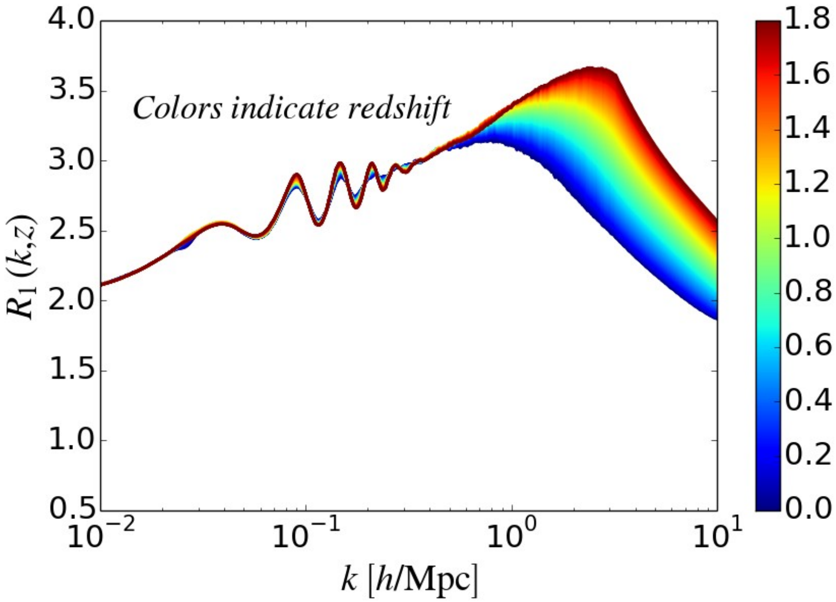
$$P_m(k|\boldsymbol{x}) = P_m(k)\left[1 + R_1(k)\delta(\boldsymbol{x}) + R_K(k)\hat{k}^i\hat{k}^j K_{ij}(\boldsymbol{x})\right]$$

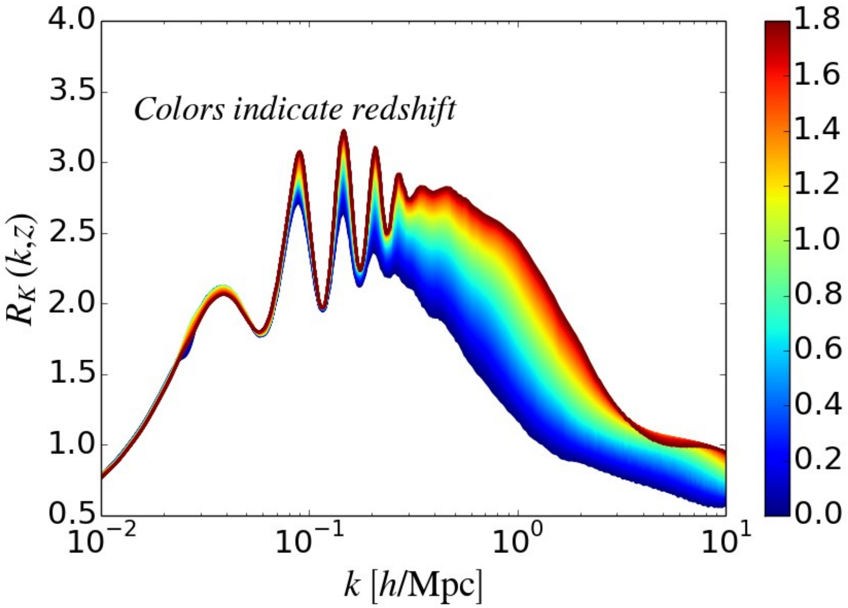
Response to overdensity

Li et al (1401.0385) ; Wagner et al (1409.6294)

Response to tidal field

Schmidt et al (1803.03274)





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$$\boxed{R_1(k) = 1 - \frac{1}{3}\frac{\mathrm{dln}P_m(k)}{\mathrm{dln}k} + G_1(k)}$$

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$$\boxed{R_K(k) = -\frac{\mathrm{dln}P_m(k)}{\mathrm{dln}k} + G_K(k)}$$

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Growth-only piece
(Sep. Uni. needed)

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Results

TNG300-2 box : L = 205Mpc/h, Np = 1250^3

Name	Ω_{m0}	Ω_{b0}	$\Omega_{\Lambda 0}$	h	$L_{\rm box}\ [\frac{\rm Mpc}{h}]$
Fiducial	0.3089	0.0486	0.6911	0.6774	205
SepHigh	0.3194	0.0502	0.7146	0.6662	201.608
SepLow	0.2991	0.0471	0.6691	0.6884	208.337

5% overdensity (SepHigh)

5% underdensity (SepLow)

$$G_1(k) = \frac{1}{\delta_L}\left[\frac{P_m^{\rm Sep.Uni.}(k)}{P_m^{\rm Fiducial}(k)} - 1\right]$$

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SepLow	0.2991	0.0471	0.6691	0.6884	208.337

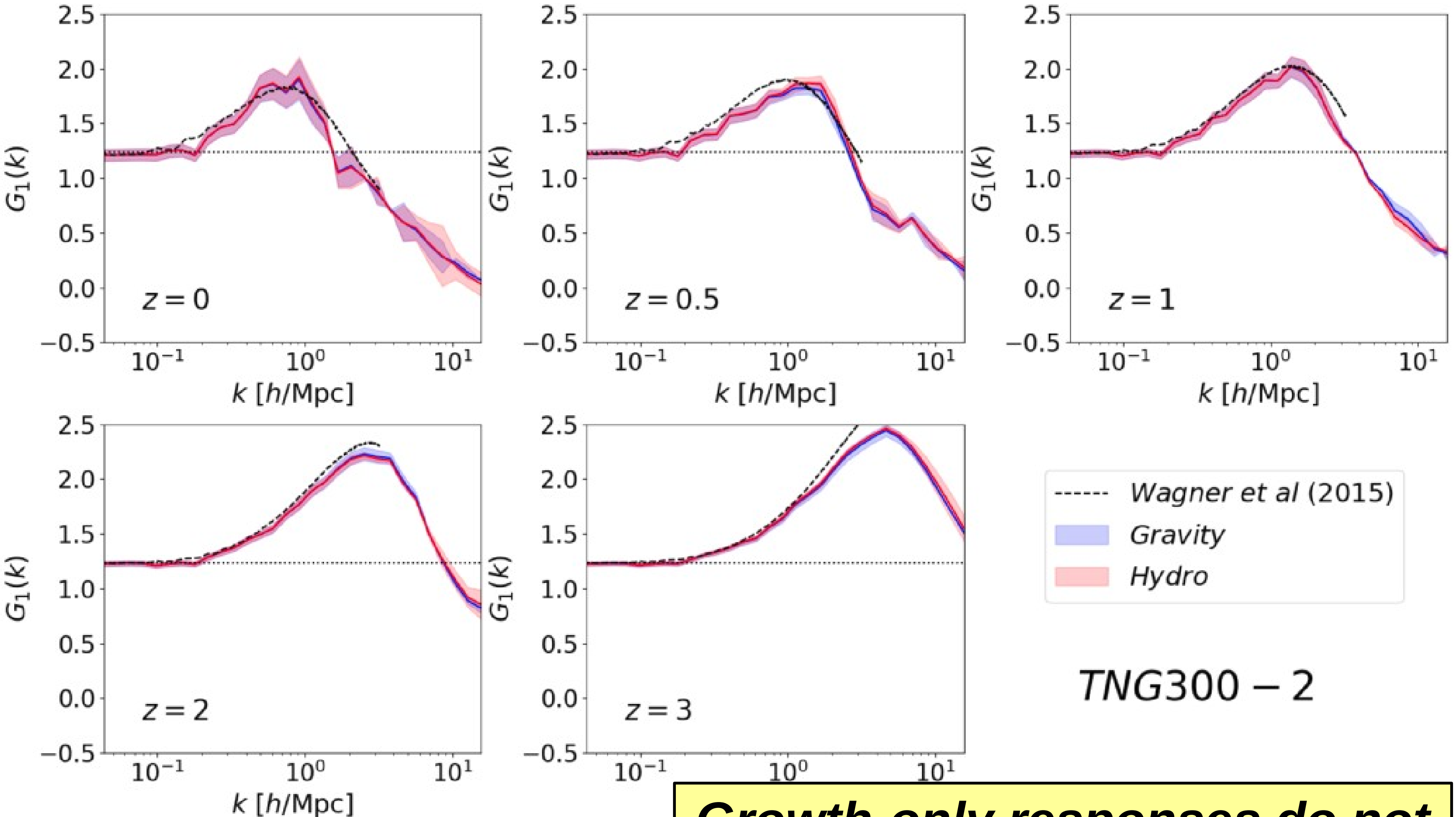
5% overd[illegible]

5% underdensity

"Subgrid" TNG model parameters kept fixed.

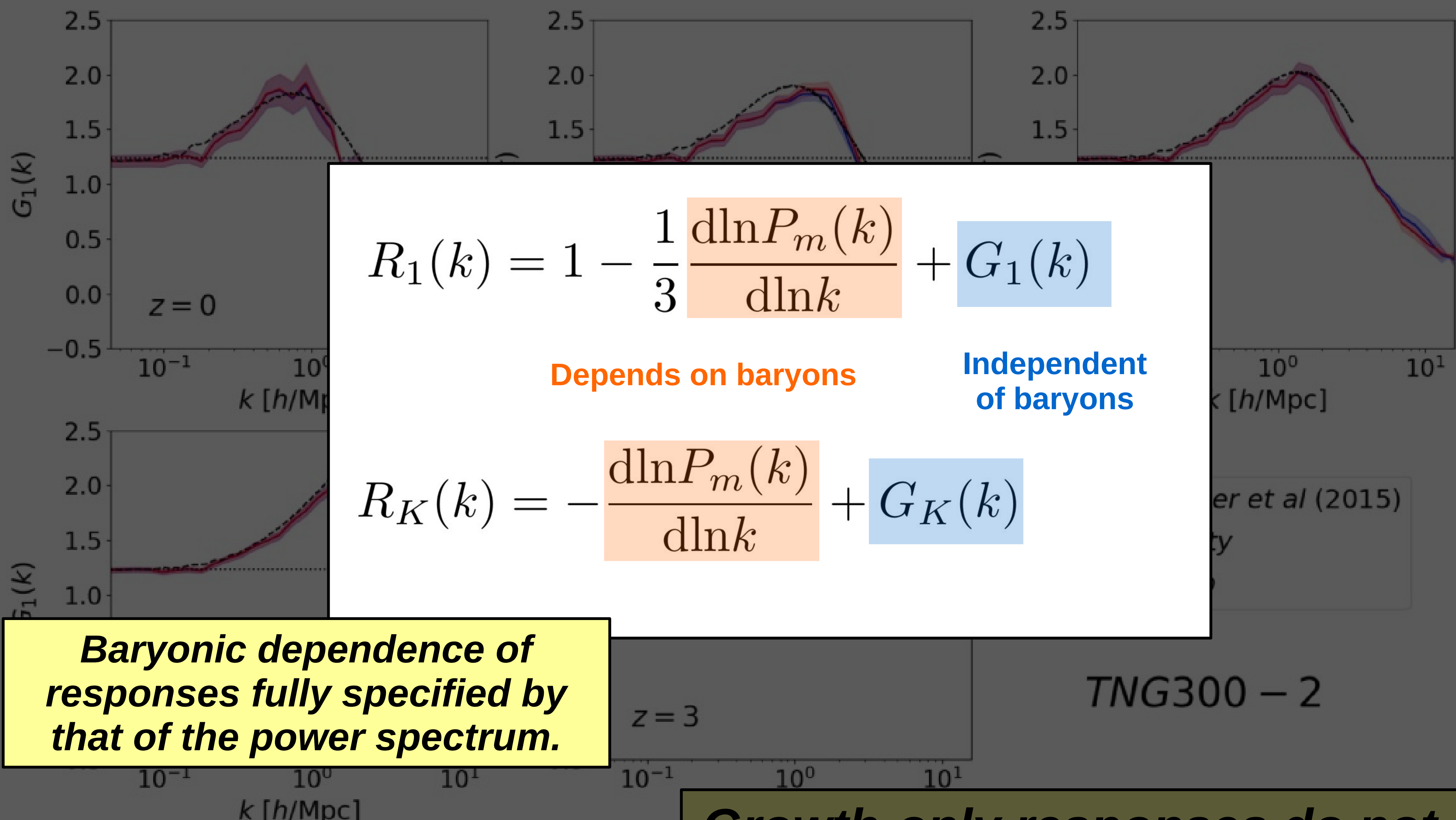
$$G_1(k) = \frac{1}{\delta_L}\left[\frac{P_m^{\mathrm{Sep.Uni.}}(k)}{P_m^{\mathrm{Fiducial}}(k)} - 1\right]$$

Results: total matter responses



Growth-only responses do not depend on baryonic effects !

Results: total matter responses



$$R_1(k) = 1 - \frac{1}{3}\frac{\mathrm{dln}P_m(k)}{\mathrm{dln}k} + G_1(k)$$

Depends on baryons

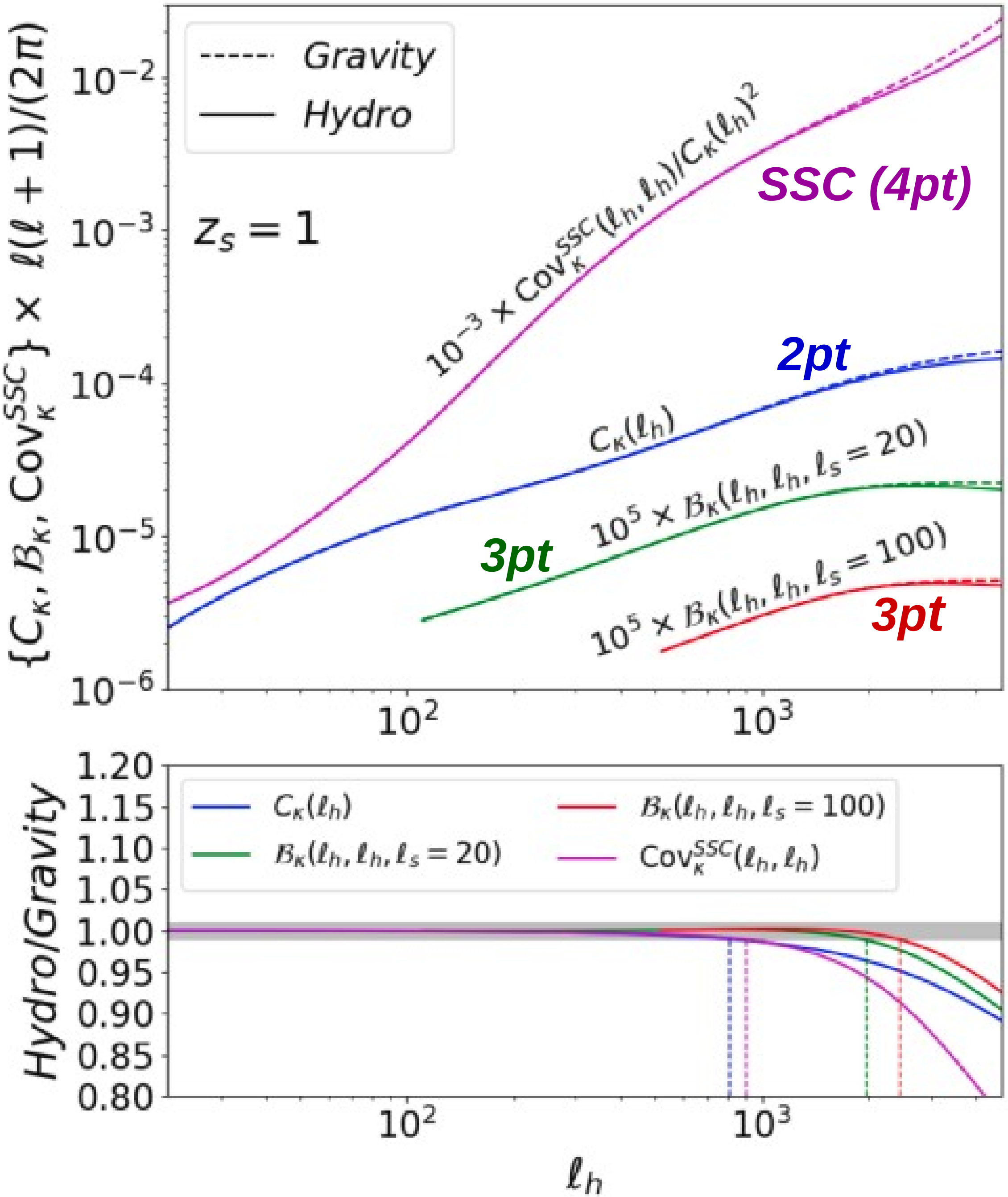
Independent of baryons

$$R_K(k) = -\frac{\mathrm{dln}P_m(k)}{\mathrm{dln}k} + G_K(k)$$

Baryonic dependence of responses fully specified by that of the power spectrum.

Growth-only responses do not depend on baryonic effects !

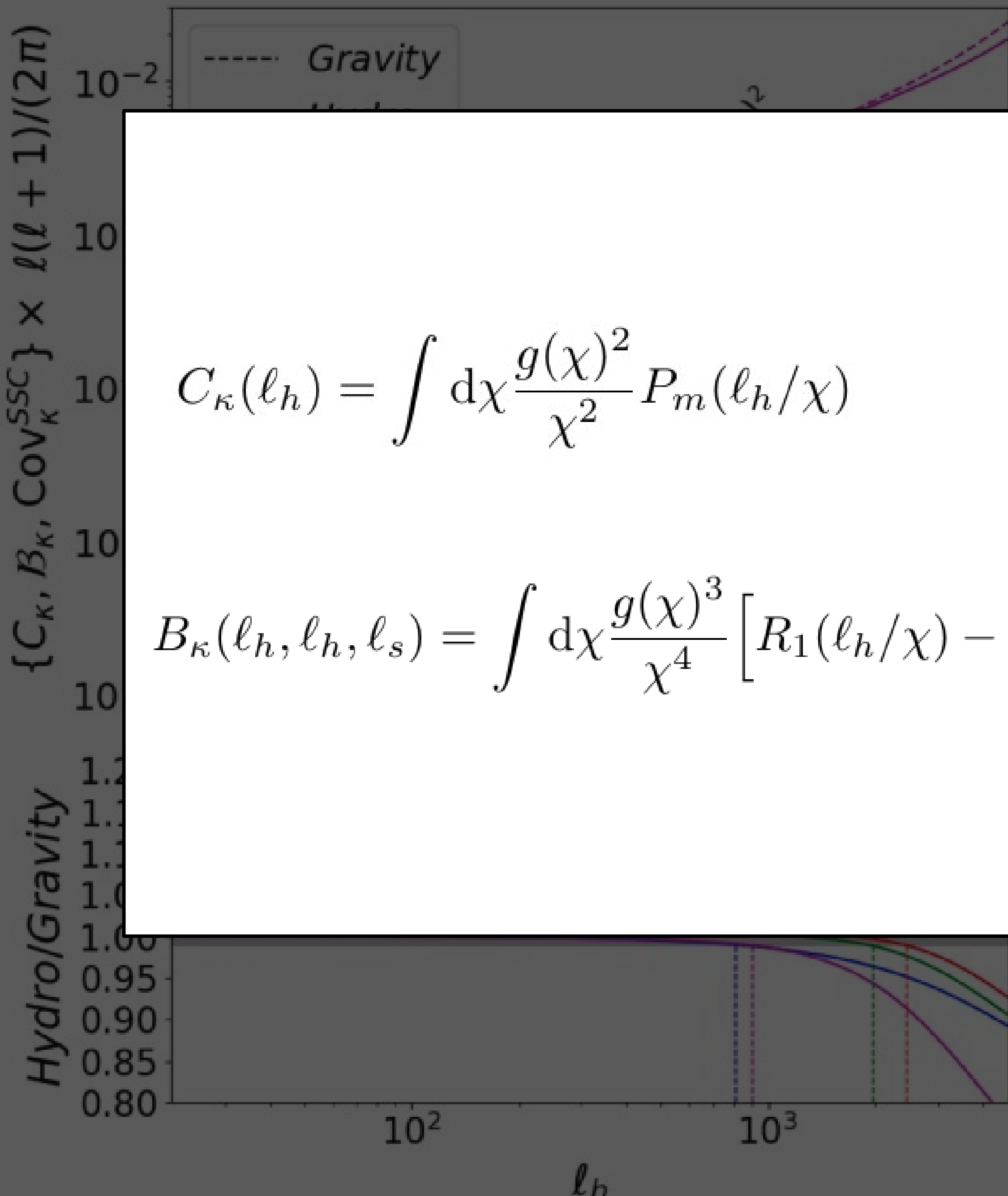
Baryonic impact on lensing statistics



Baryons have slightly varying impact on different N-point functions.

***Can be used to break degeneracies with baryonic effects** (Semboloni+ 1210.7303)*

Baryonic impact on lensing statistics



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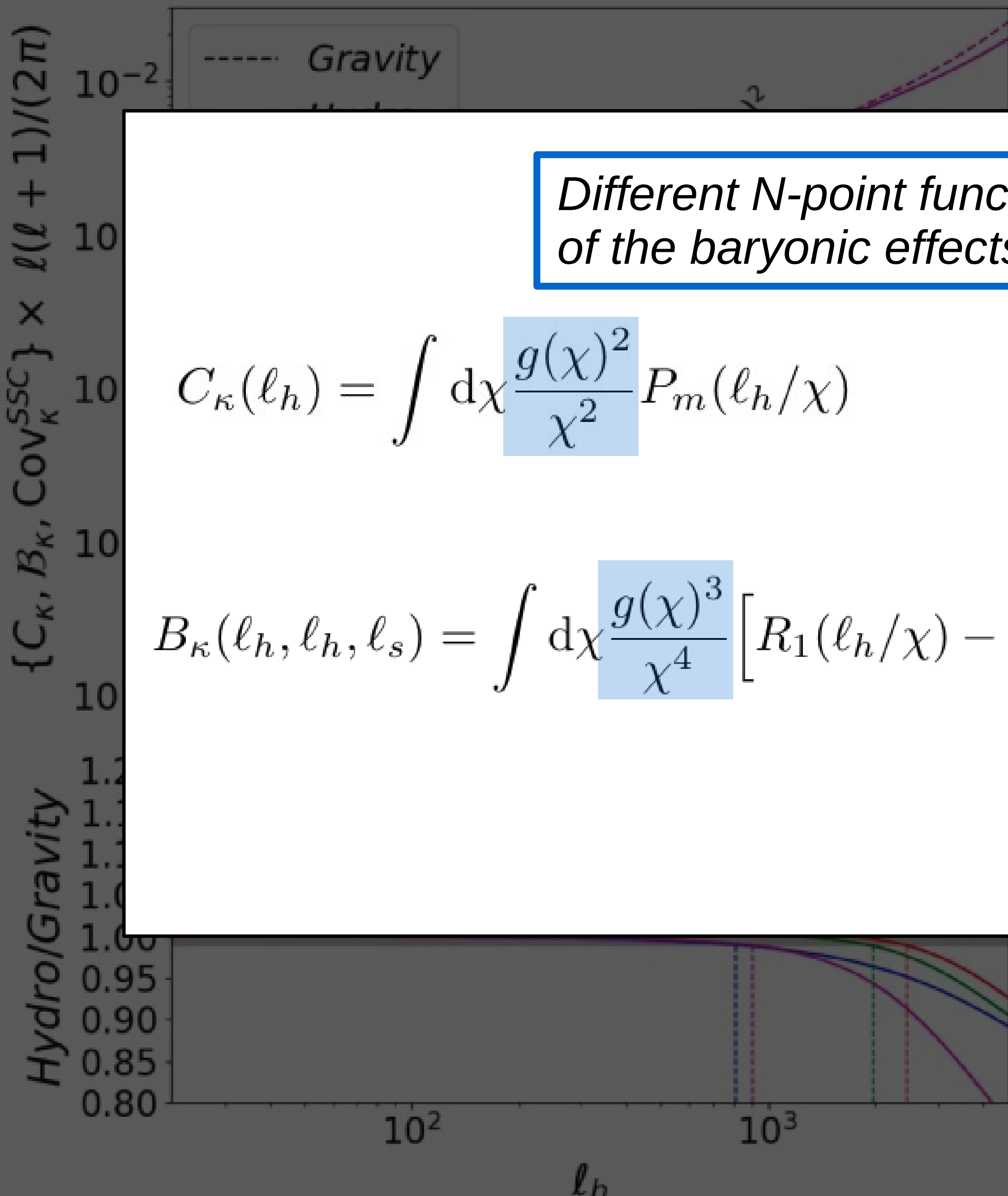

Different N-point functions weight time-dependence of the baryonic effects differently.

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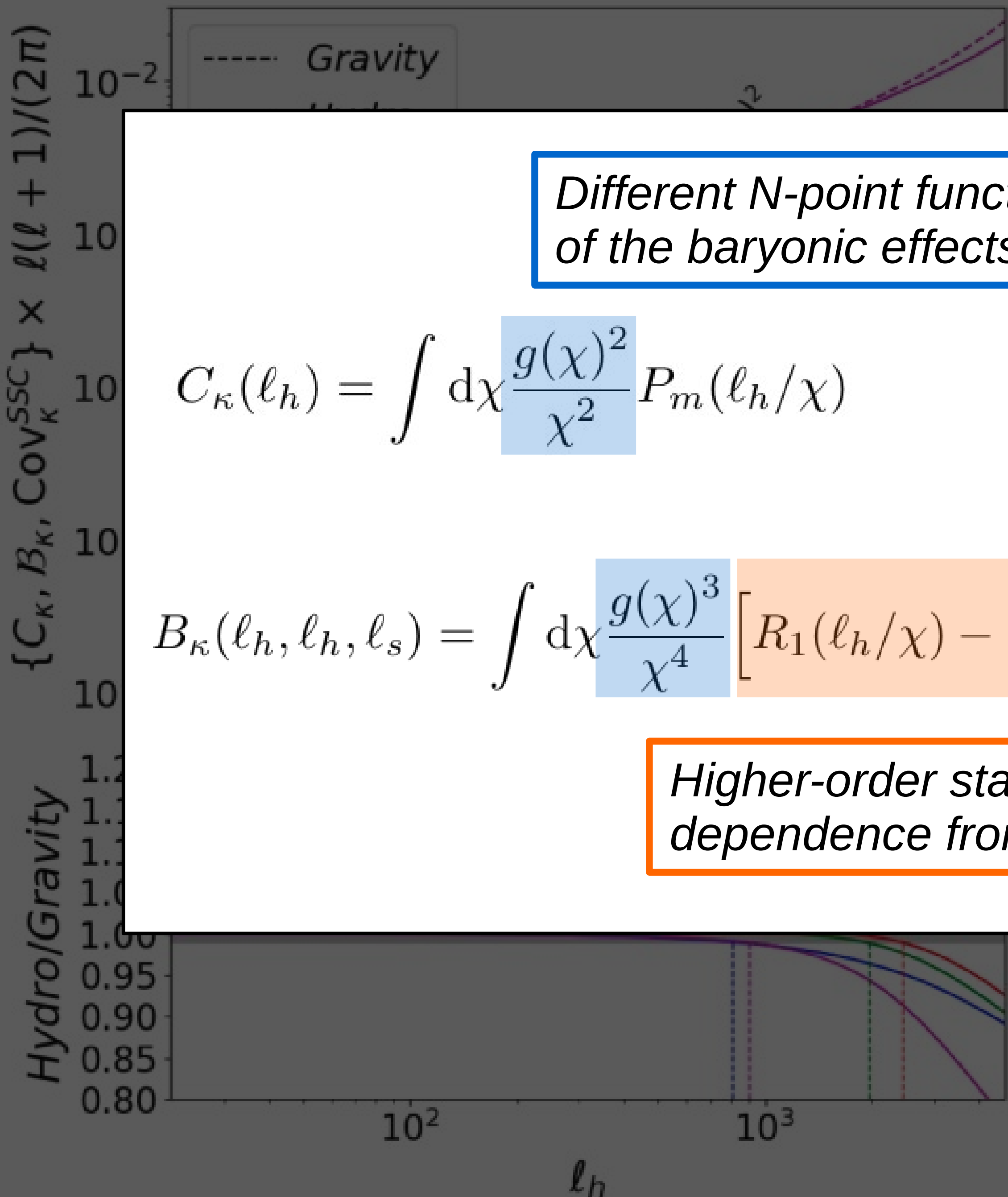

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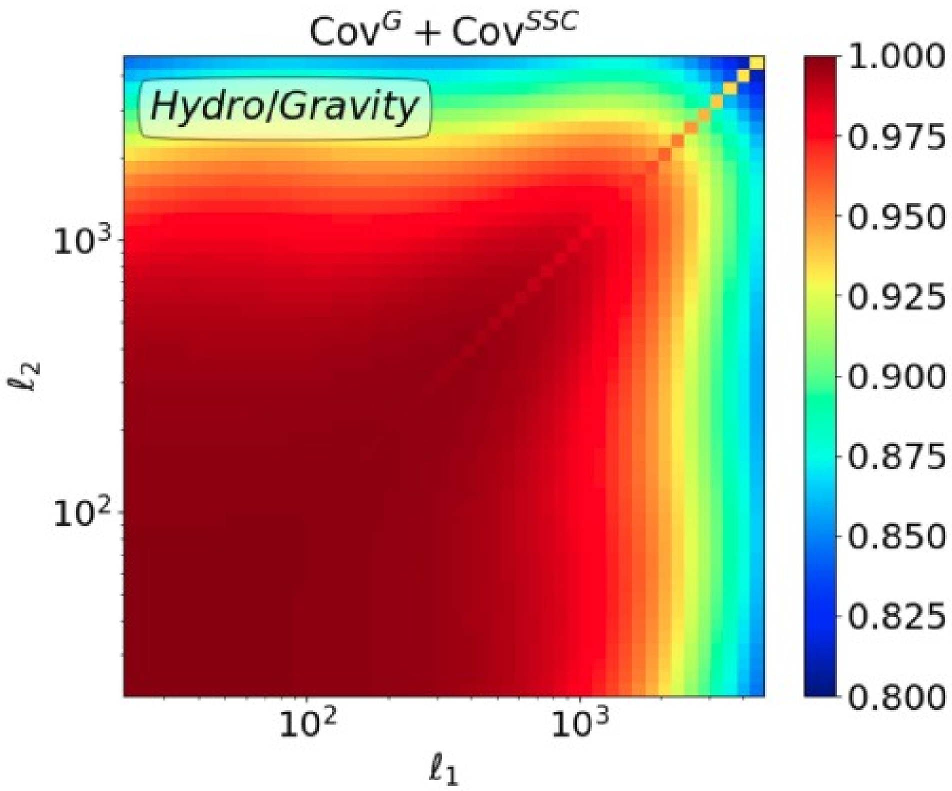
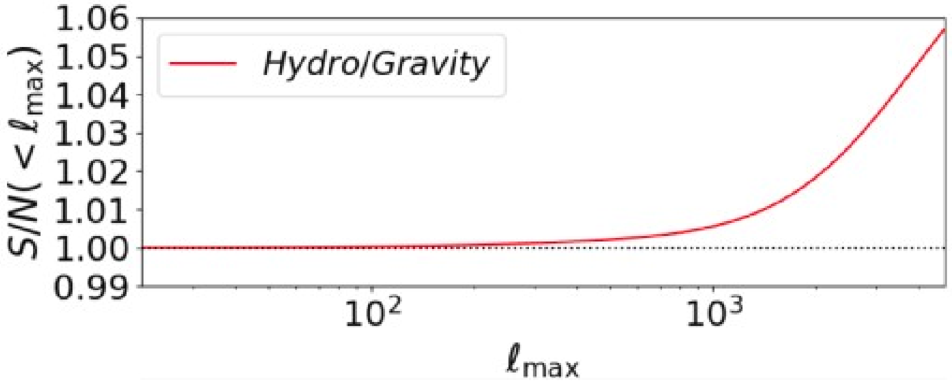
Higher-order statistics include also additional dependence from the responses.

Baryonic impact on lensing covariance

Baryons reduce the covariance.



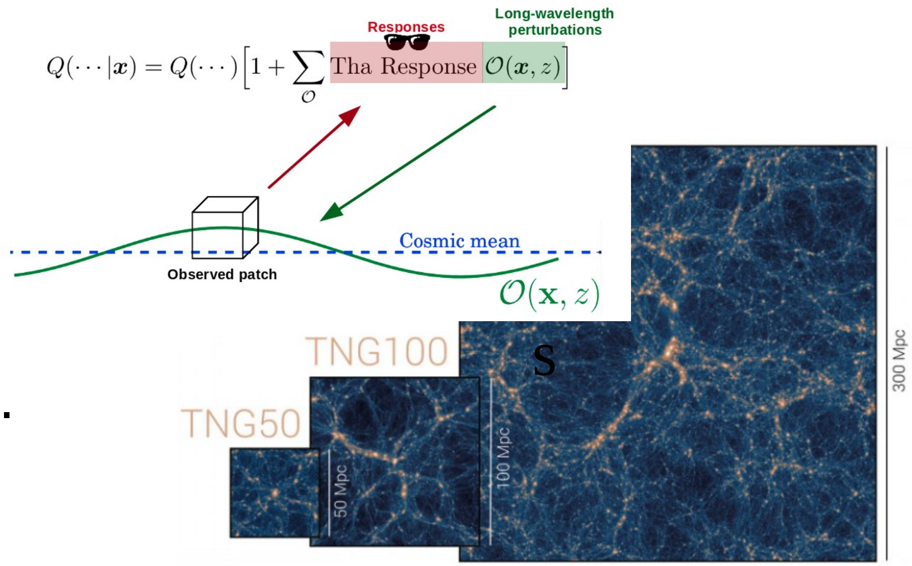
Ignoring baryons is therefore conservative on errors bars!



Negligible impact also on the goodness-of-fit.

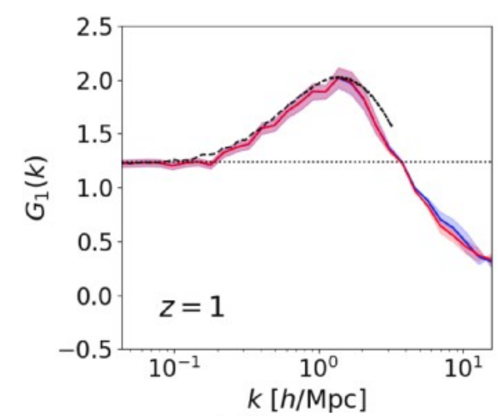
Summary

Hydrodynamical Separate Universe Simulations



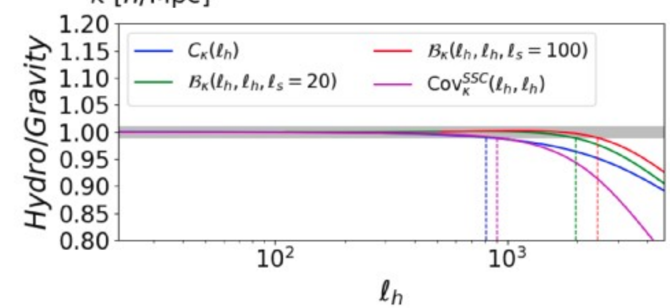
- Baryonic impact on responses;
- More observables to measure the response of.

Baryonic impact on P(k) responses and N-point functions



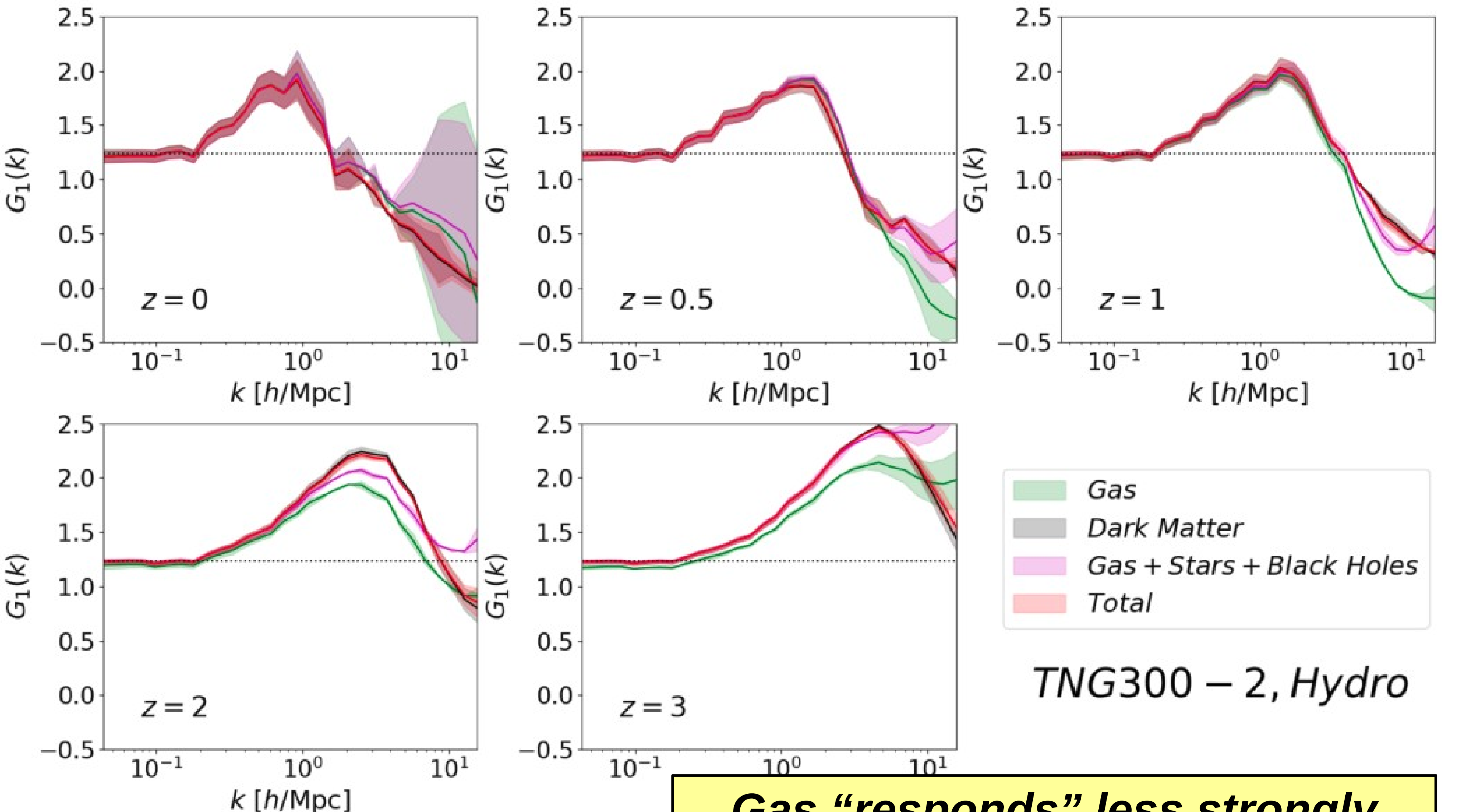
- P(k) specifies baryonic dependence of its
- responses.

- Different N-point functions are affected differently; effects on lensing covariances exist, but not large.



Extra stuff

Results: component responses



Gas "responds" less strongly because it is not conserved .

Results: dlnP(k)/dlnk dependence