Lyman-alpha forest and Primordial Non-gaussianities (fnl)

with collaborators:
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Vincent Desjacques

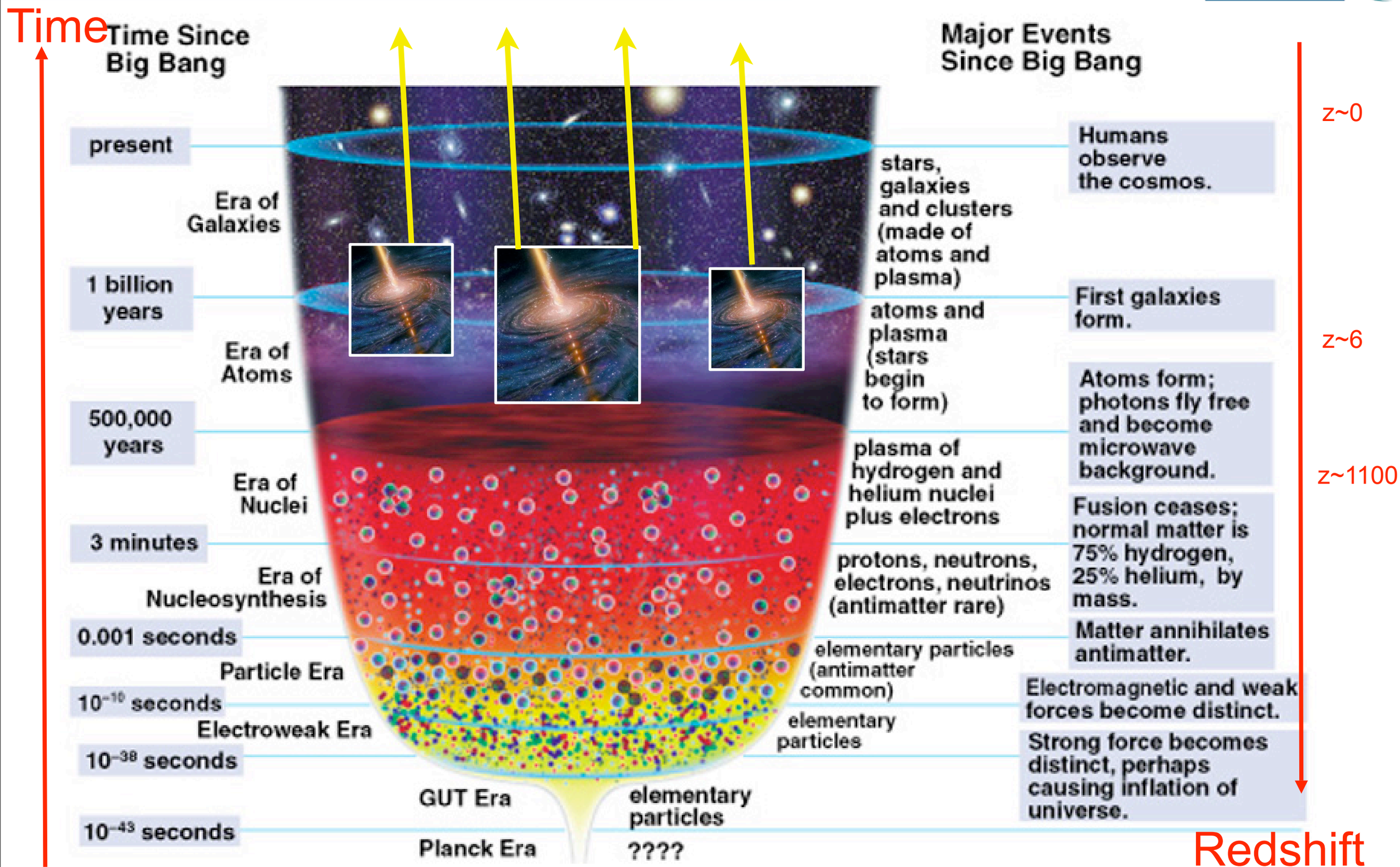
Shirley Ho
Lawrence Berkeley Lab

18 Sep 2009, Paris-Berkeley meeting

Outline

- What is fnl?
- What have we done with LSS and fnl?
- What can we do with Lya and fnl?
  - —Lya flux spectra with different non-gaussianities
  - —How about with redshift space distortions?
- Things to worry about:
  - —UV background fluctuations
  - —Continuum subtractions ...

Lyman Alpha Forest: what is it?



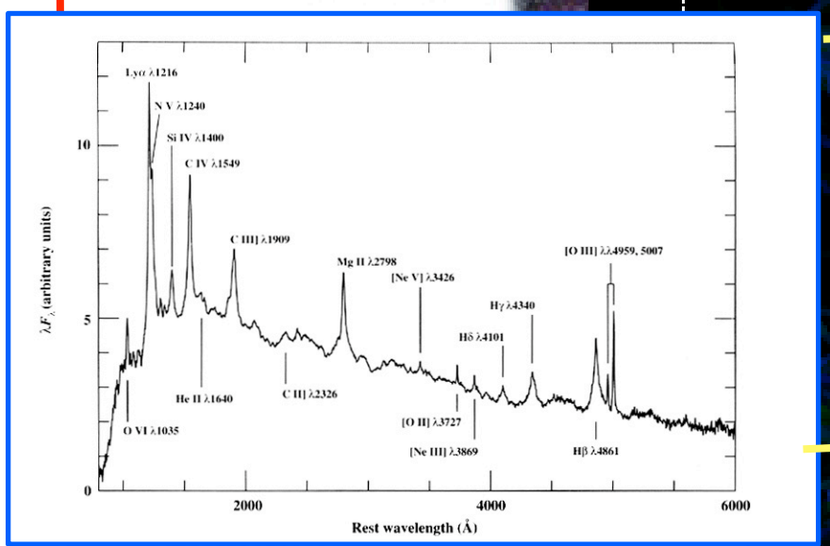
Lyman Alpha Forest: what is it?

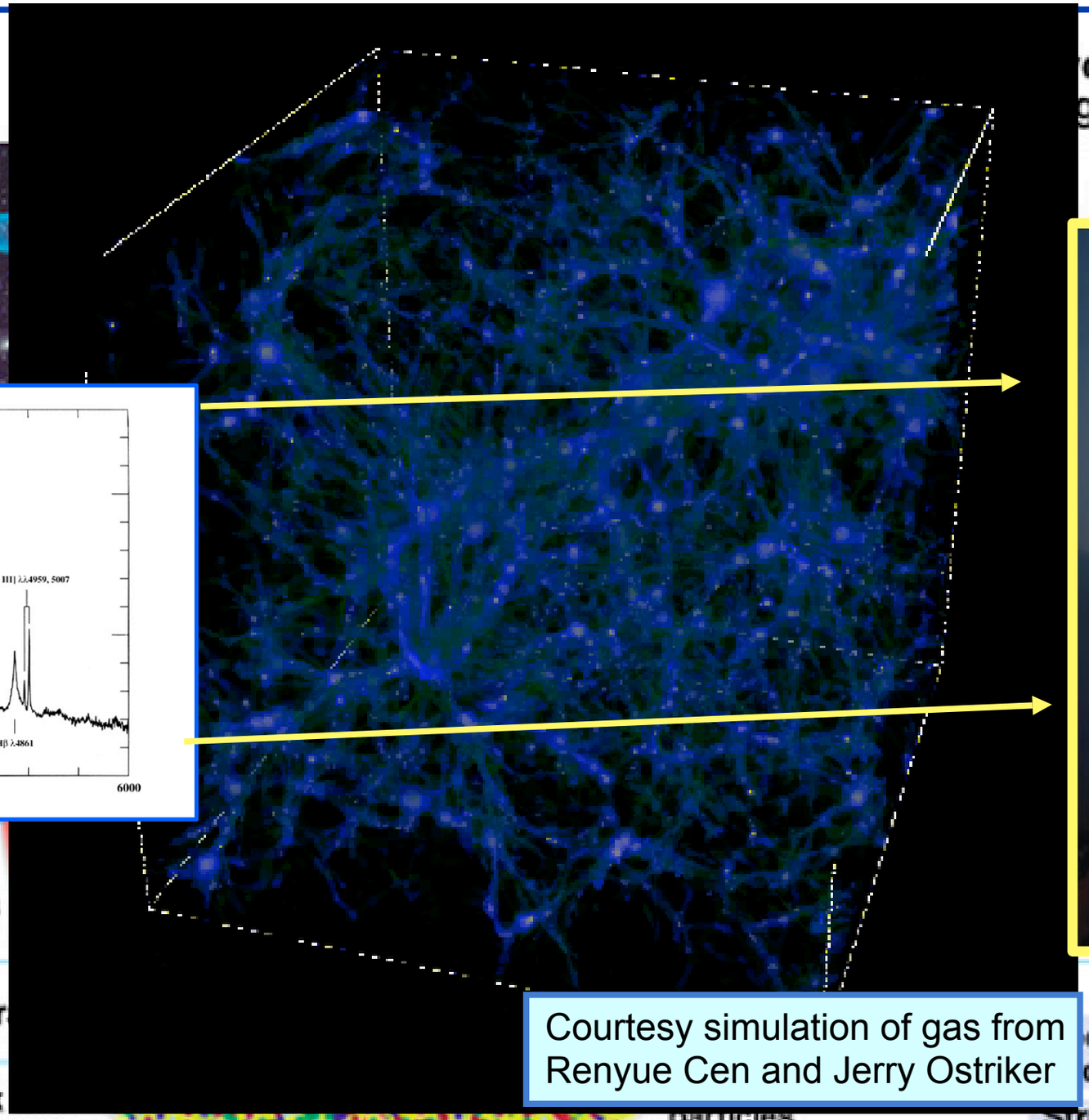
Time

Time Since Big Bang

present

Era of Galaxies





Courtesy simulation of gas from Renyue Cen and Jerry Ostriker

z~0

Era of Nucleosynthesis

0.001 seconds

Particle Er

10^{-10} seconds

Electroweak

10^{-38} seconds

GUT Era

elementary particles

10^{-43} seconds

Planck Era

????

antimatter.

ctromagnetic and weak ces become distinct.

Strong force becomes distinct, perhaps causing inflation of universe.

Redshift

Lyman Alpha Forest: what is it?

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Time Since Big Bang

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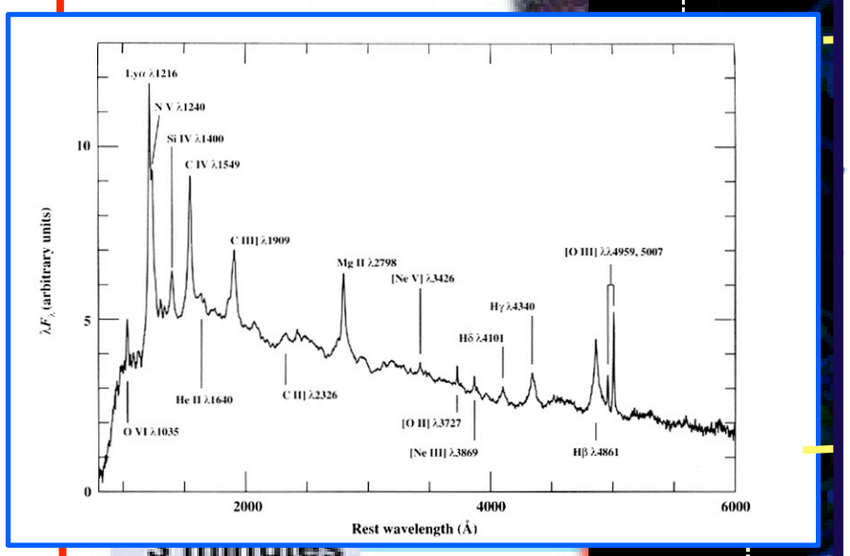
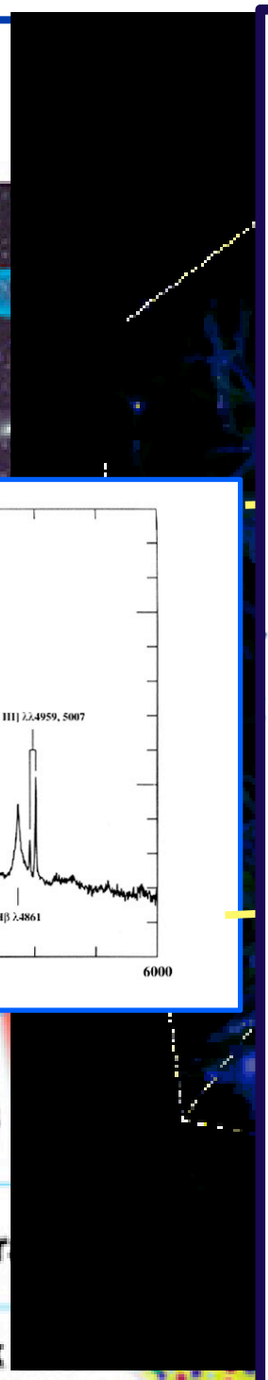




flux (amount of light)

emission

wavelength λ →

One absorbing cloud close by

flux (amount of light)

emission

absorption

wavelength λ →

Several absorbing clouds

flux (amount of light)

emission

absorption

wavelength λ →

ents

g Bang

z~0

Humans

antimatter.

ctromagnetic and weak

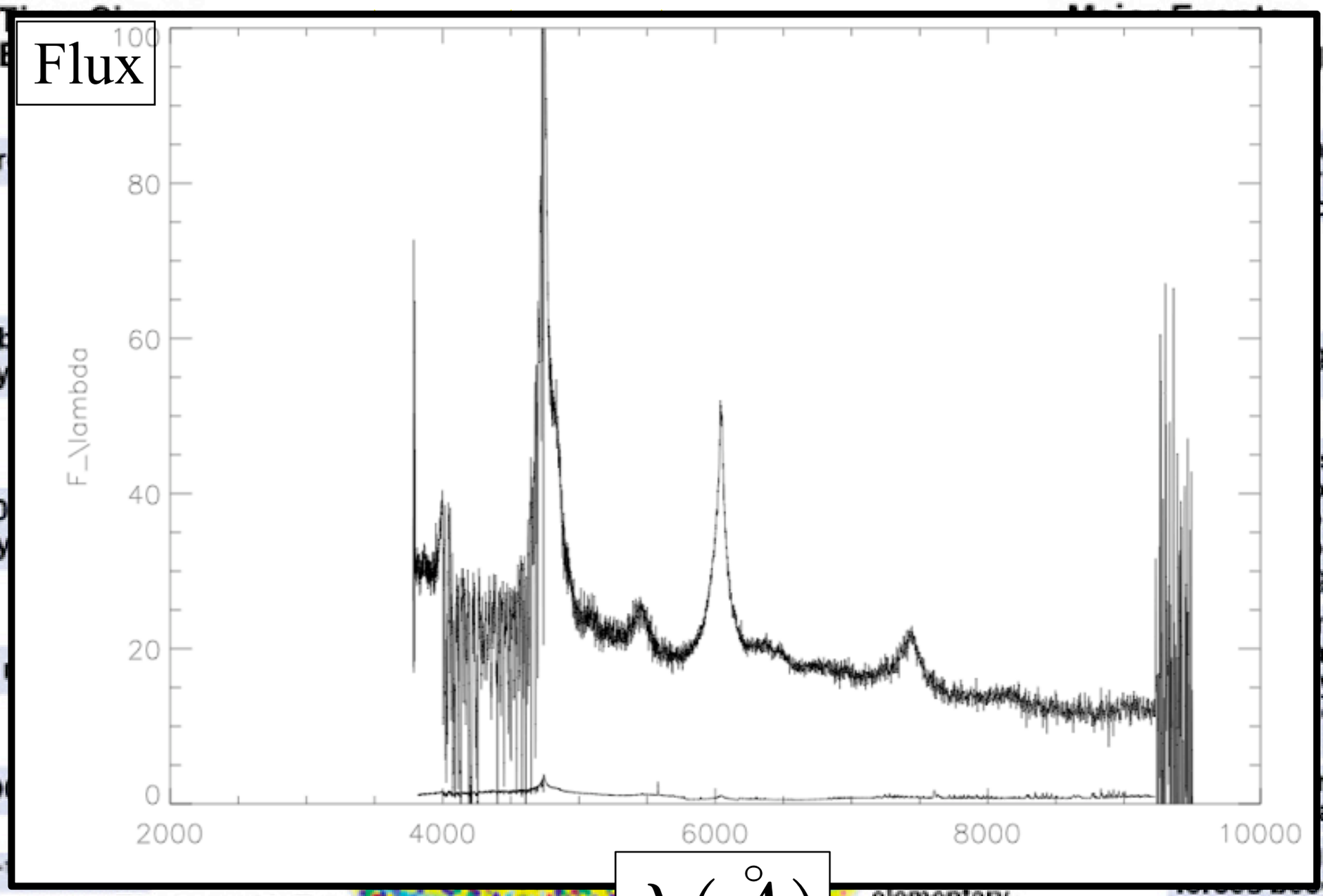
ces become distinct.

Strong force becomes distinct, perhaps

Courtesy image from Joanne Cohn's website

Redshift

Lyman Alpha Forest: what is it?



Time

z~0

z~6

z~1100

Redshift

Electroweak Era

10^{-38} seconds

GUT Era

10^{-43} seconds

Planck Era

????

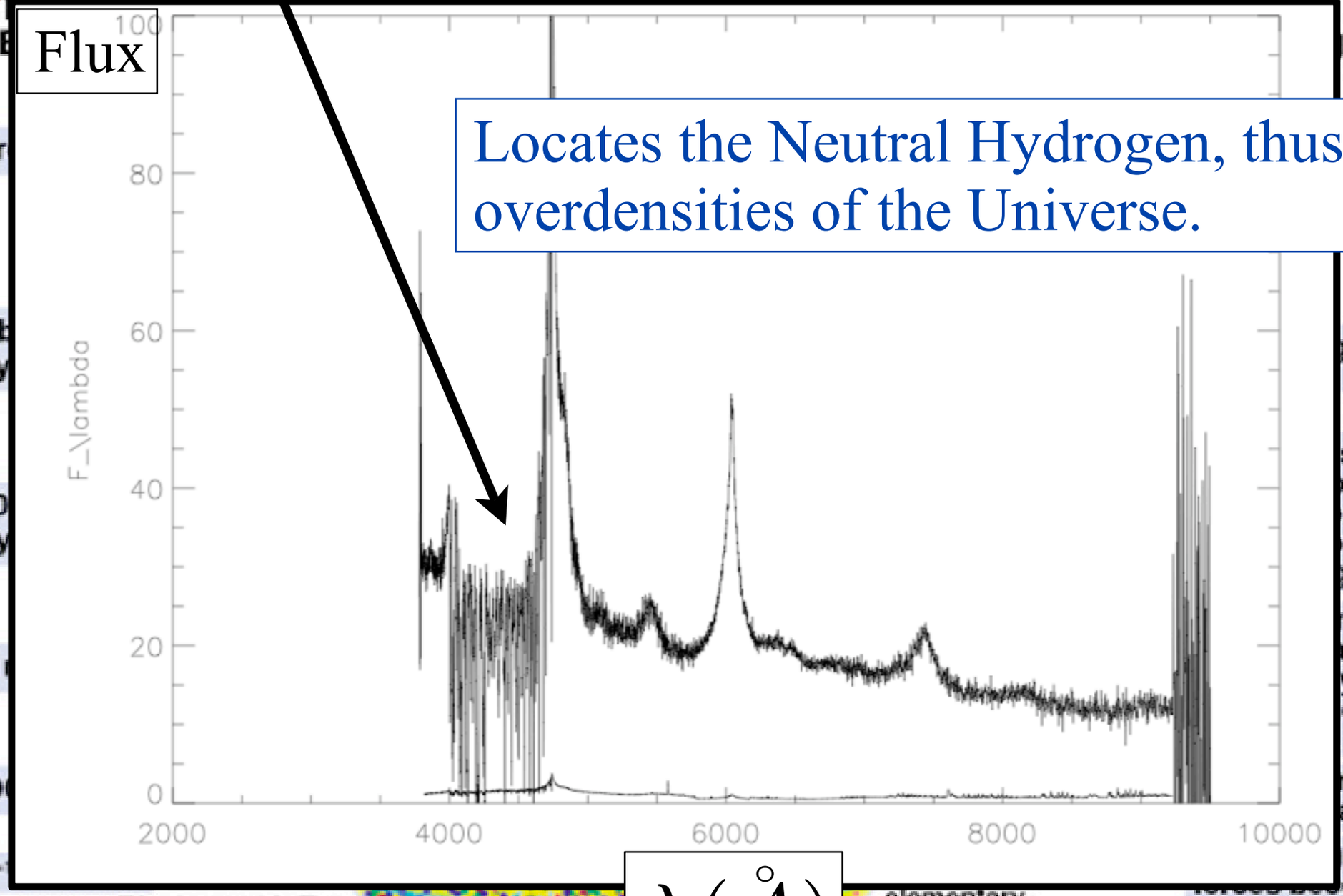
elementary particles

elementary particles

Strong force becomes distinct, perhaps causing inflation of universe.

Lyman Alpha Forest: what is it?

Time



Locates the Neutral Hydrogen, thus overdensities of the Universe.

z~0

z~6

z~1100

Redshift

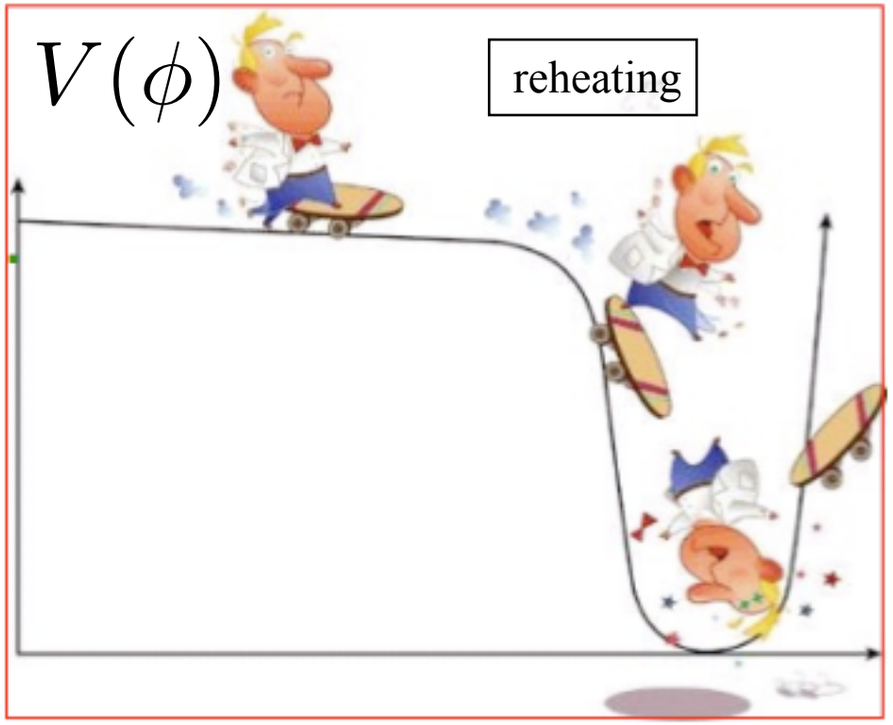
What is fnl?

—Non-gaussianities in Early Universe

parameterize how much non-linear corrections are there to the potential

$$\Phi = \phi + f_{NL}\phi^2$$

Primordial potential (assumed to be gaussian random field)



← Inflation →

What is fnl?

—Non-gaussianities in Early Universe

parameterize how much non-linear corrections are there to the potential

$$\Phi = \phi + f_{NL}\phi^2$$

Primordial potential (assumed to be gaussian random field)

Non-Gaussianity from Inflation

f_{NL} ~ 0.05 canonical inflation (single field, couple of derivatives)

(Maldacena 2003, Acquaviva etal 2003)

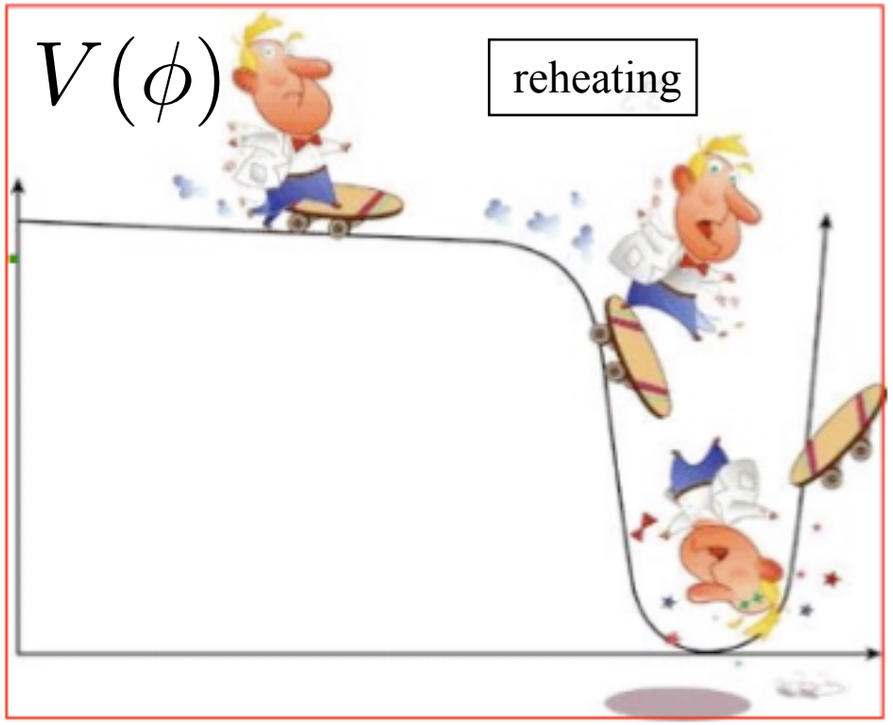
f_{NL} ~ 0.1--100 higher order derivatives

DBI inflation (Alishahiha, Silverstein and Tong 2004)

UV cutoff (Craminelli and Cosmol, 2003)

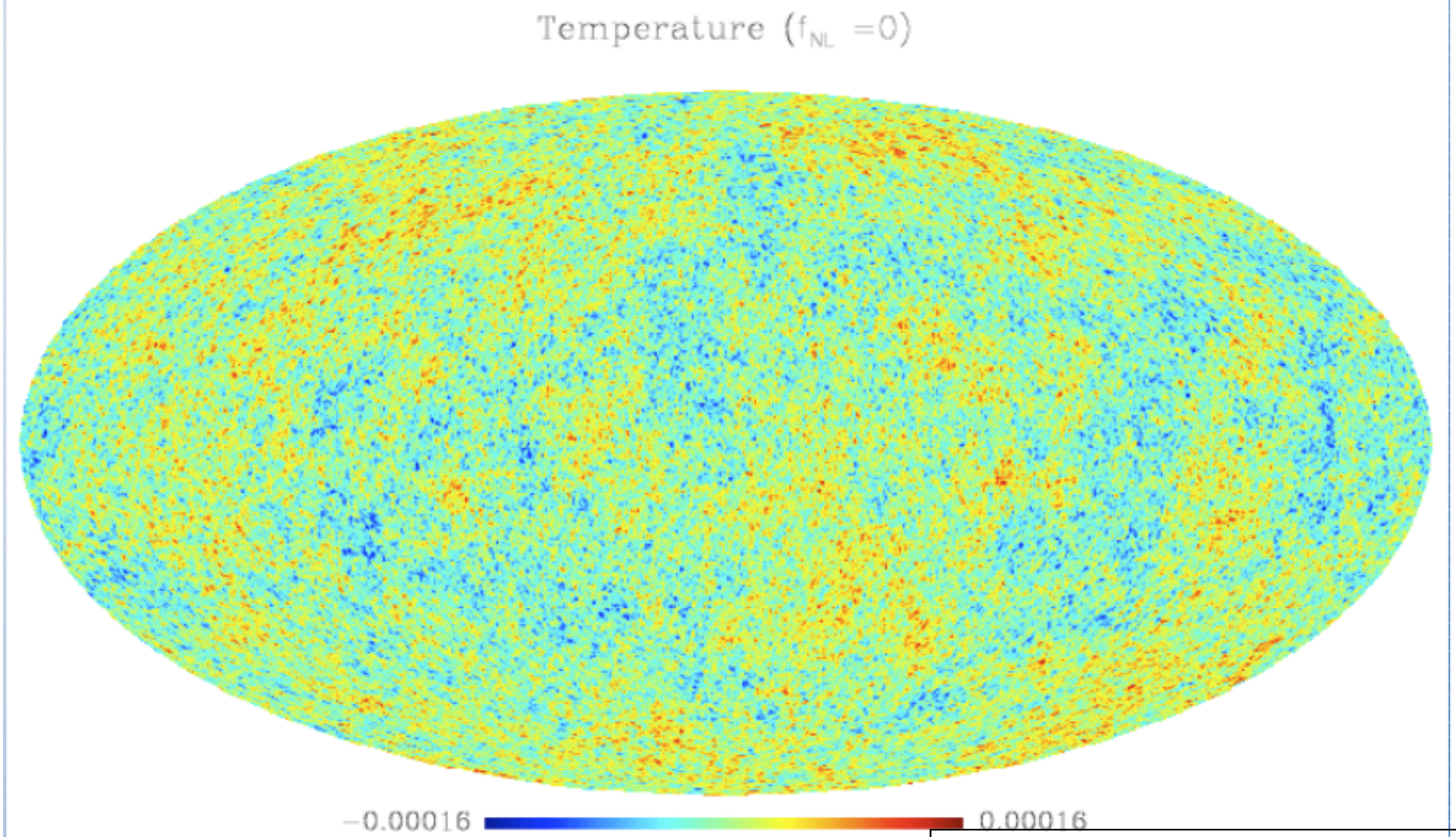
f_{NL} >10 curvaton models (Lyth, Ungarelli and Wands, 2003)

f_{NL} ~100 ghost inflation (Arkani-Hamed et al., Cosmol, 2004)



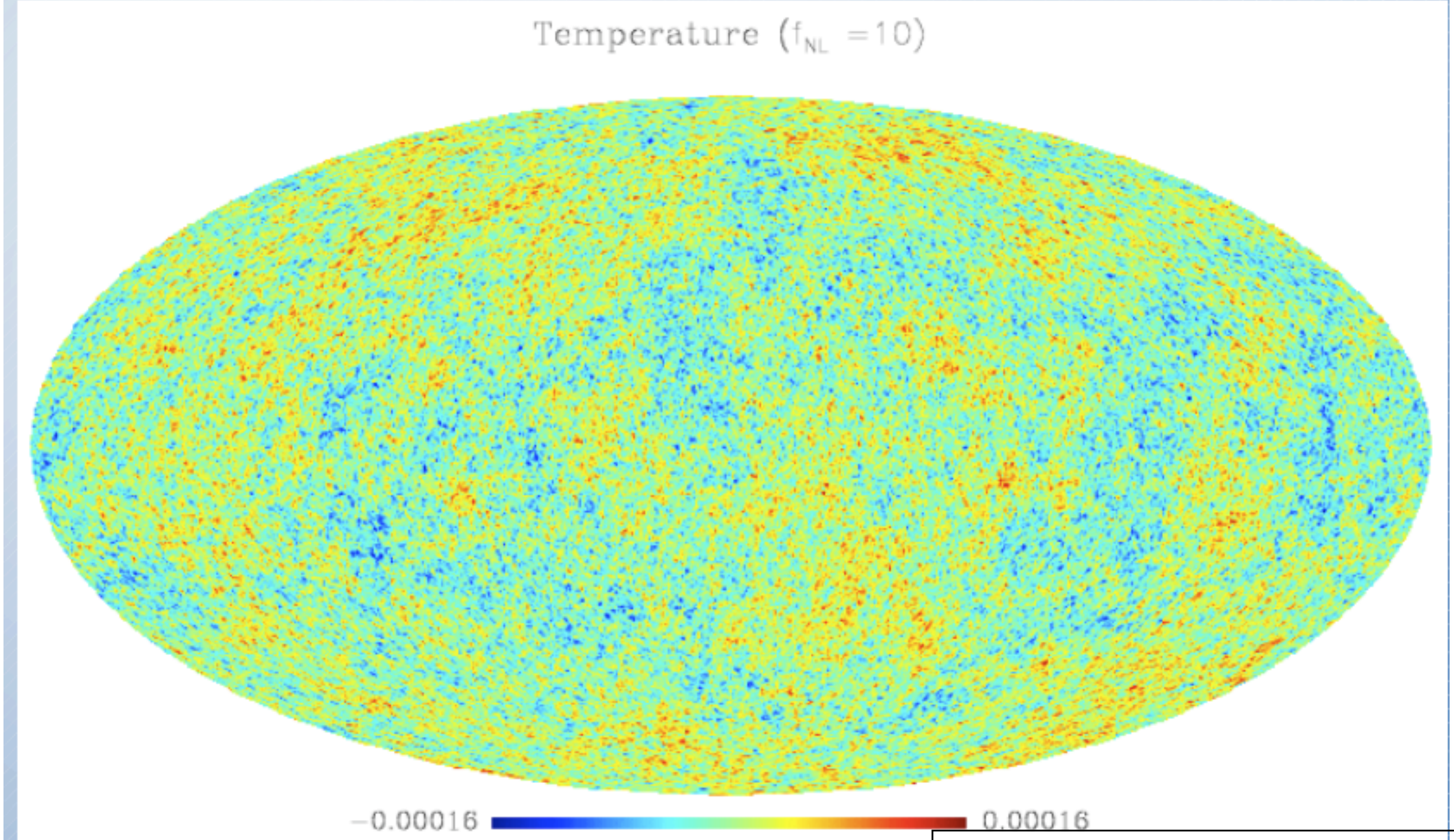
Inflation

$f_{NL}=0$



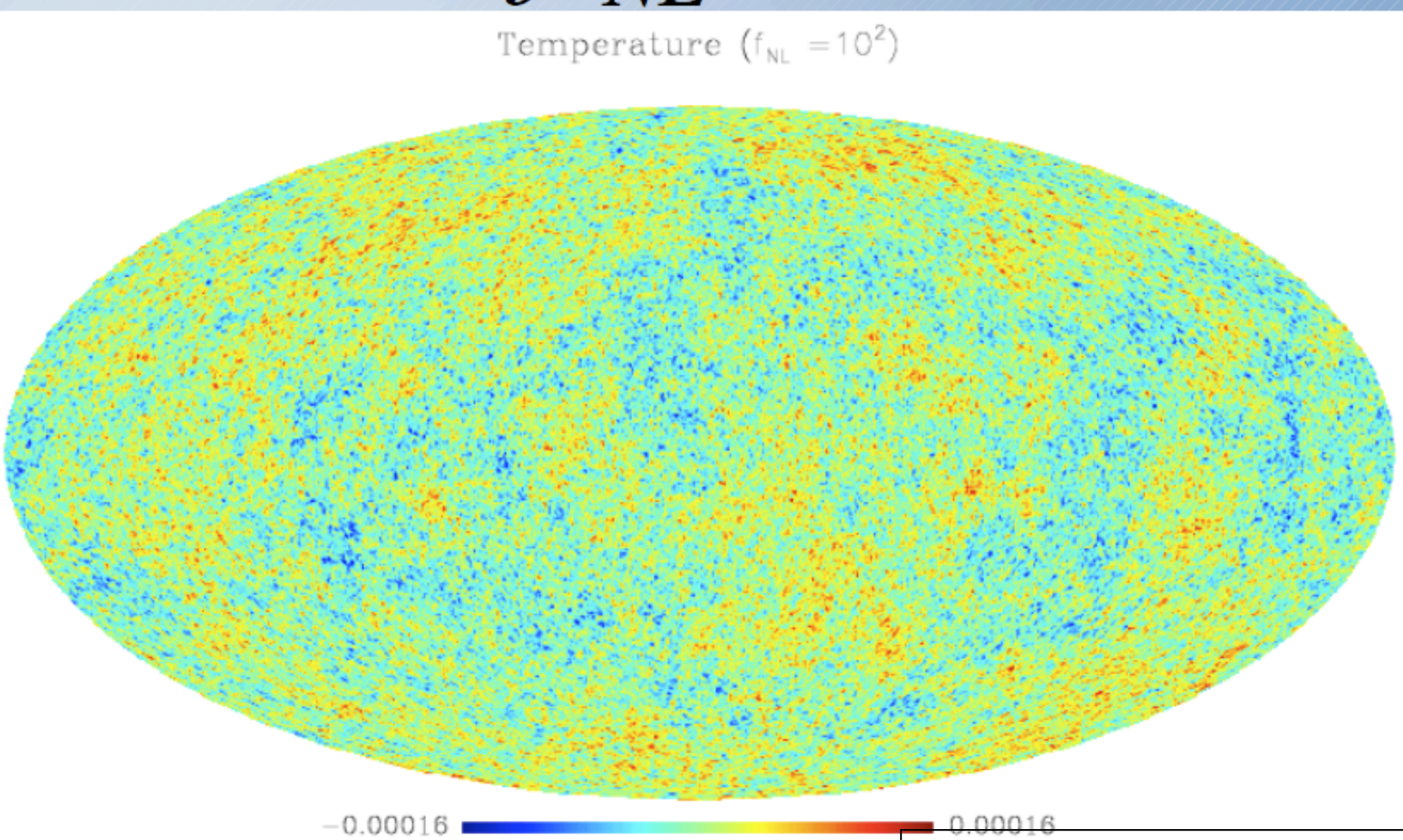
Stolen from Ben Wandelt

$f_{NL} = 10^1$



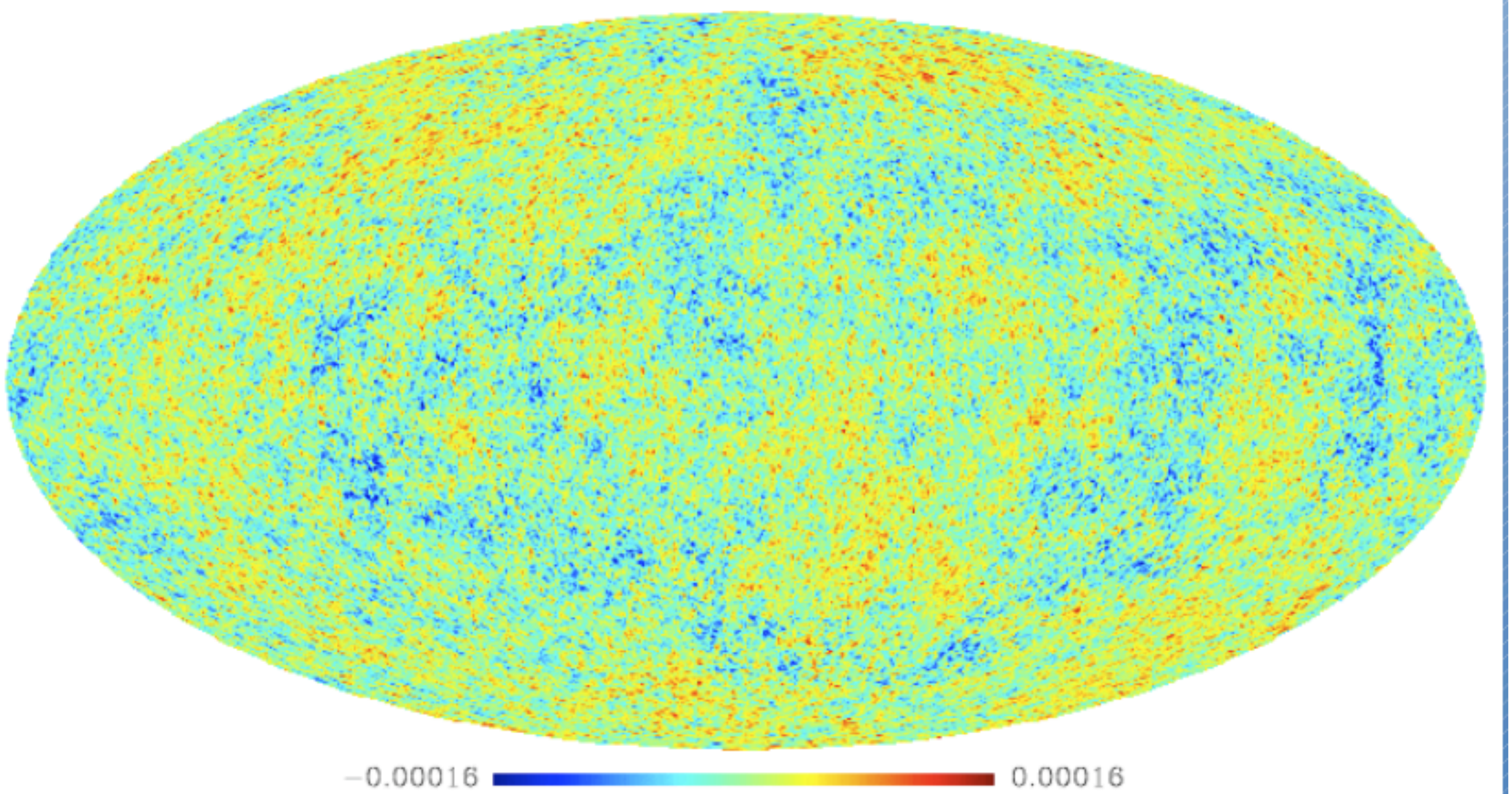
Stolen from Ben Wandelt

$f_{NL} = 10^2$



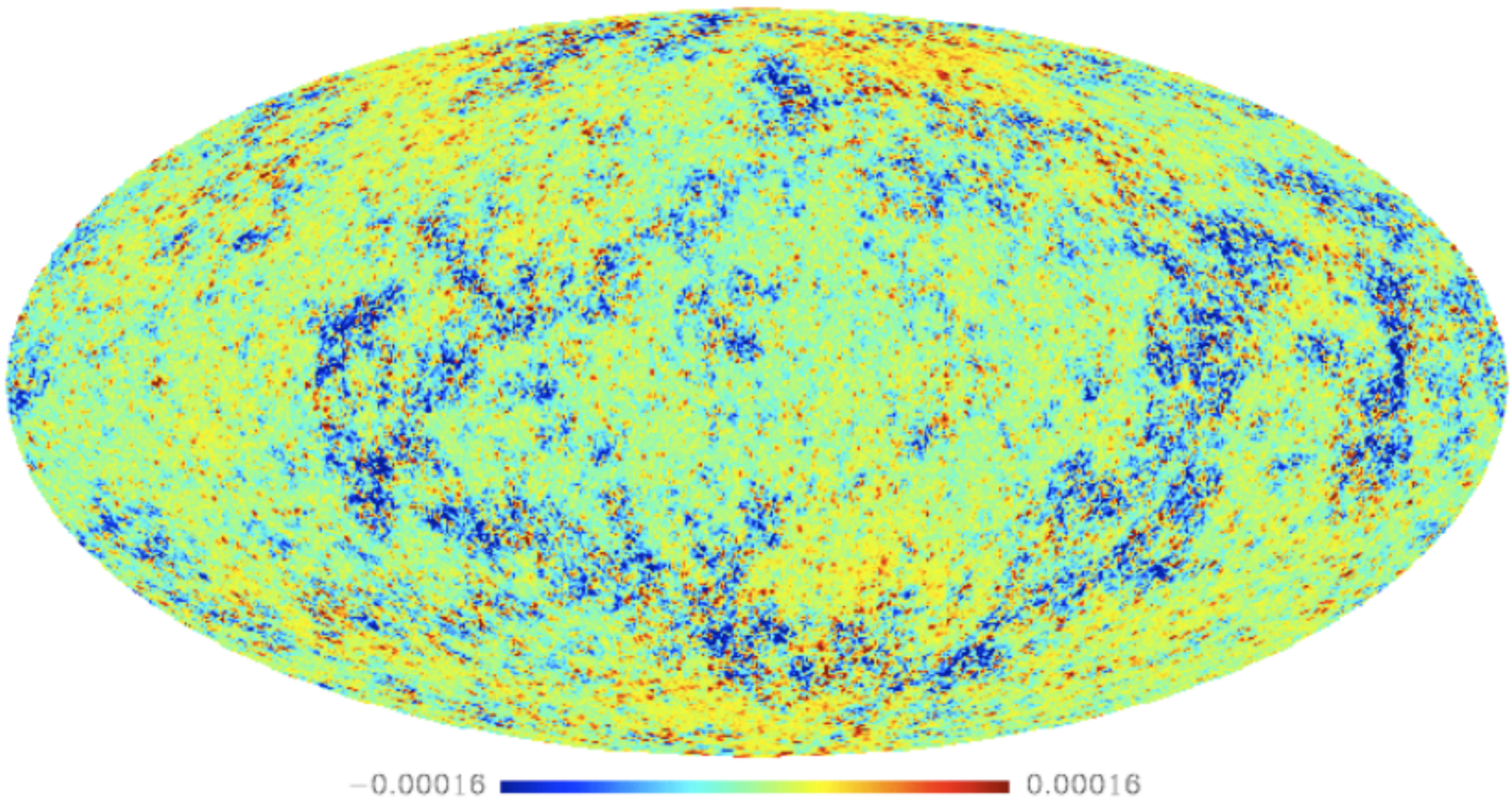
Stolen from Ben Wandelt

$f_{NL} = 10^3$



Stolen from Ben Wandelt

$f_{NL} = 10^4$



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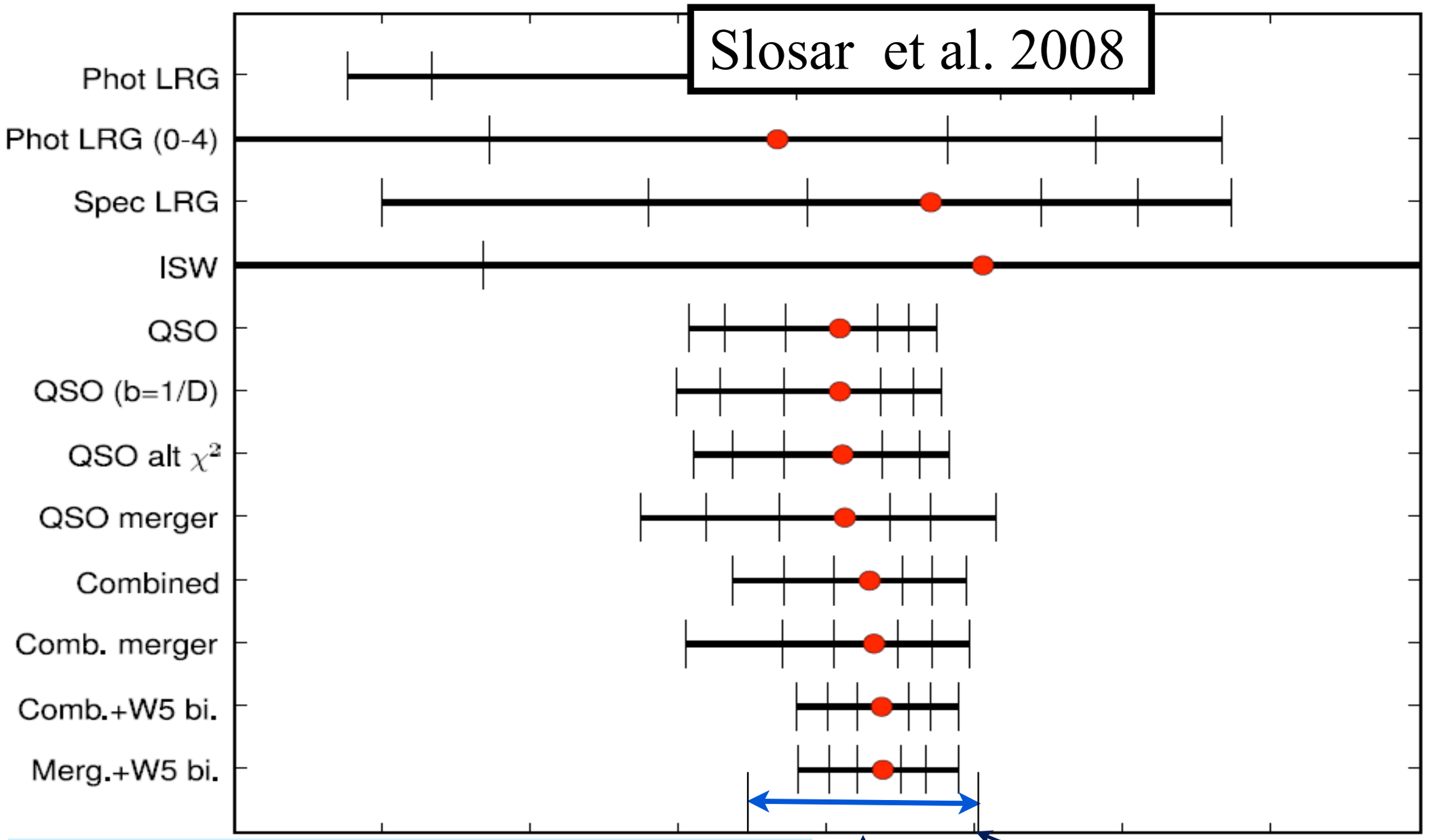
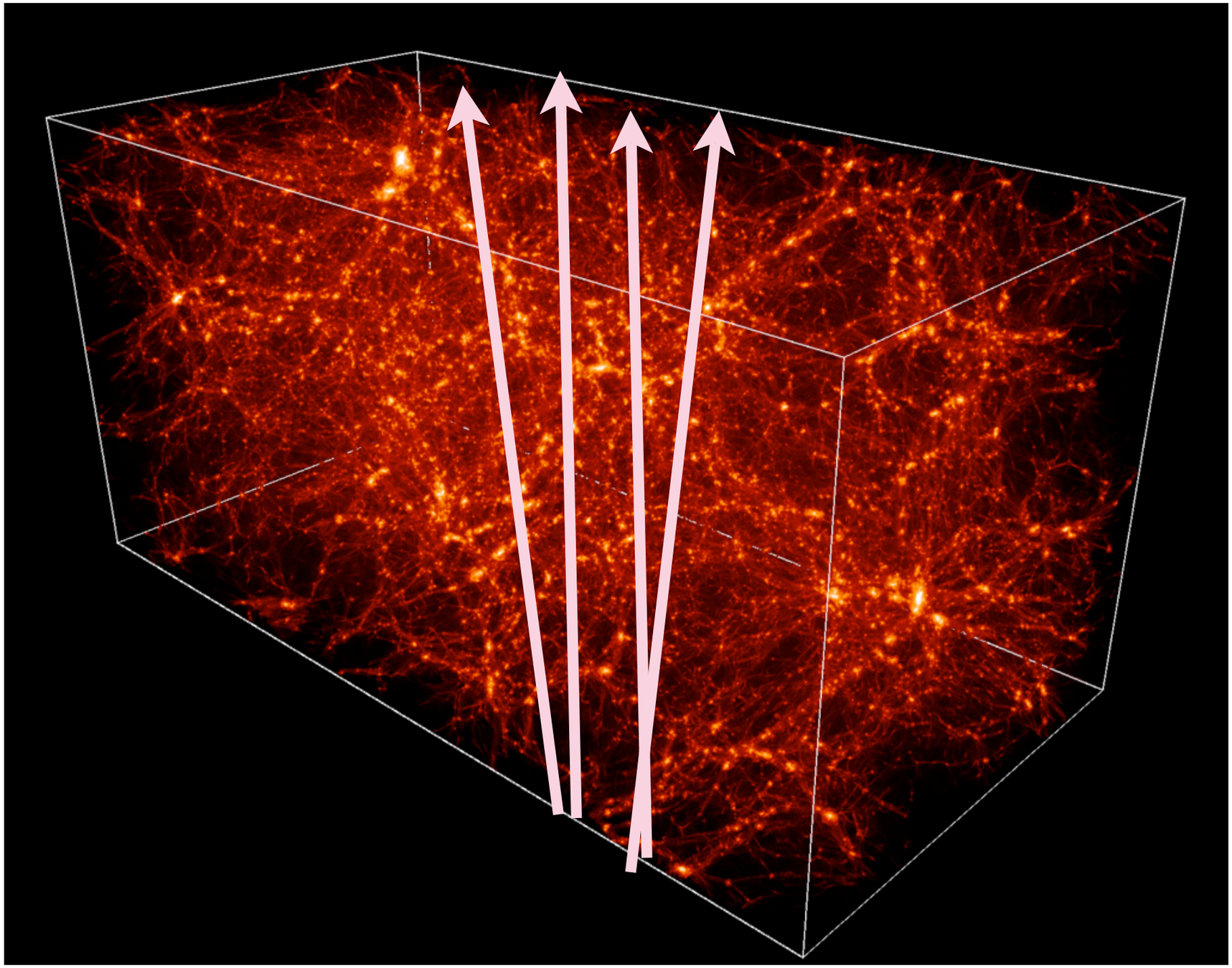
What have we done with LSS and fnl?
—Non-gaussianities in Early Universe

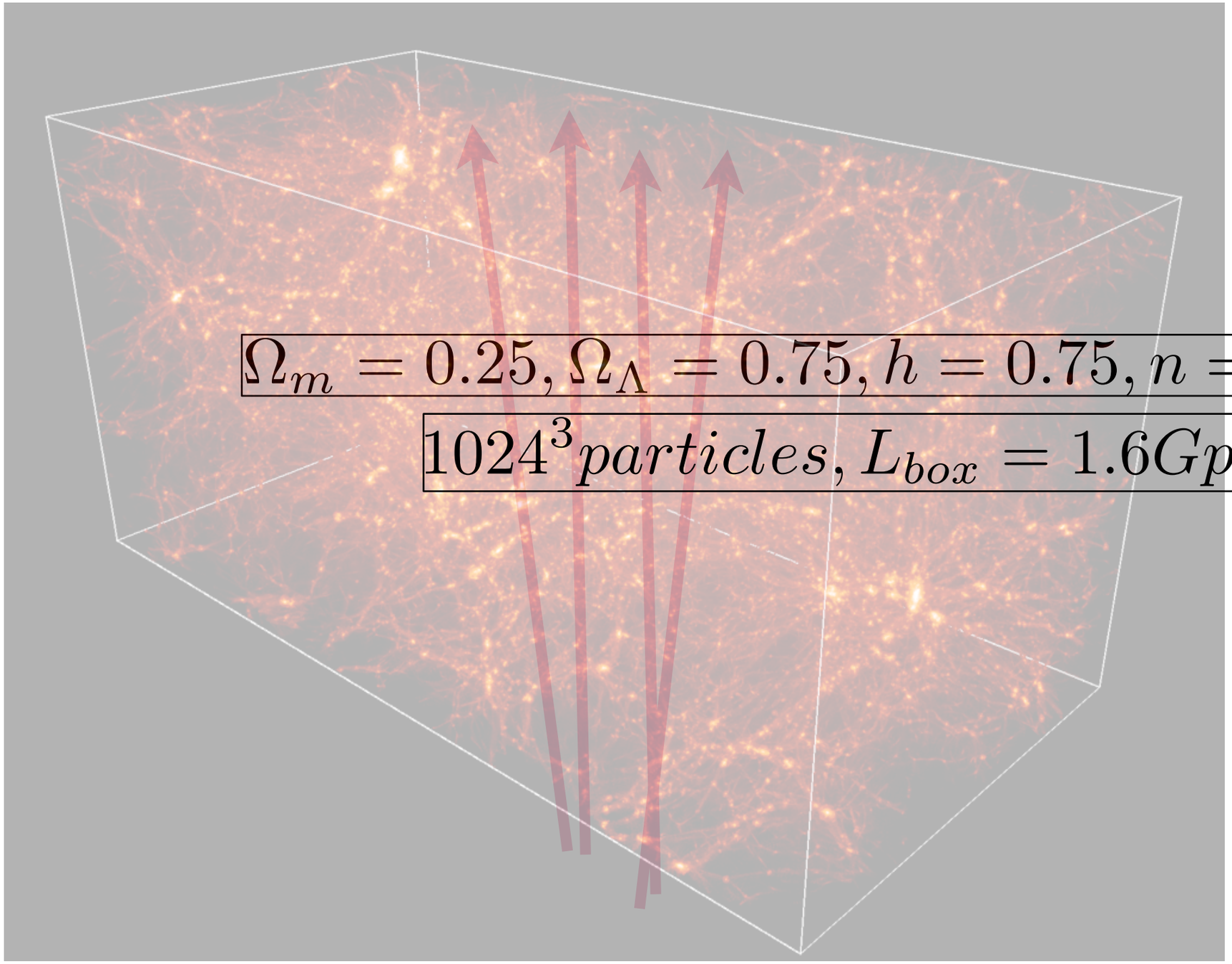


Best current CMB measurement

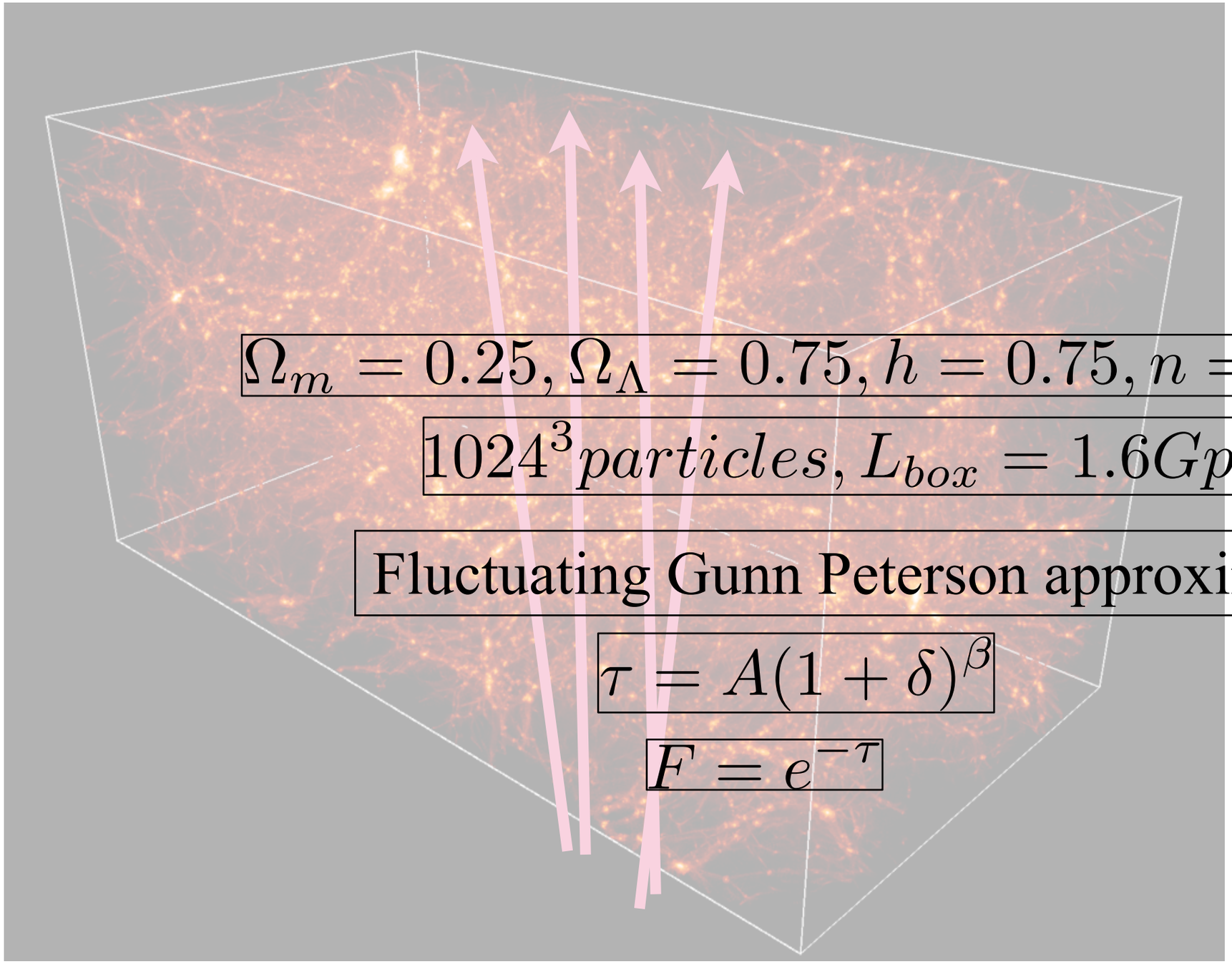
Lyman Alpha Forest: what can it do?



Lyman Alpha Forest: what can it do?



Lyman Alpha Forest: what can it do?



$$\Omega_m = 0.25, \Omega_\Lambda = 0.75, h = 0.75, n = 0.97, \sigma_8 = 0.8$$

$$1024^3 particles, L_{box} = 1.6 Gpc/h$$

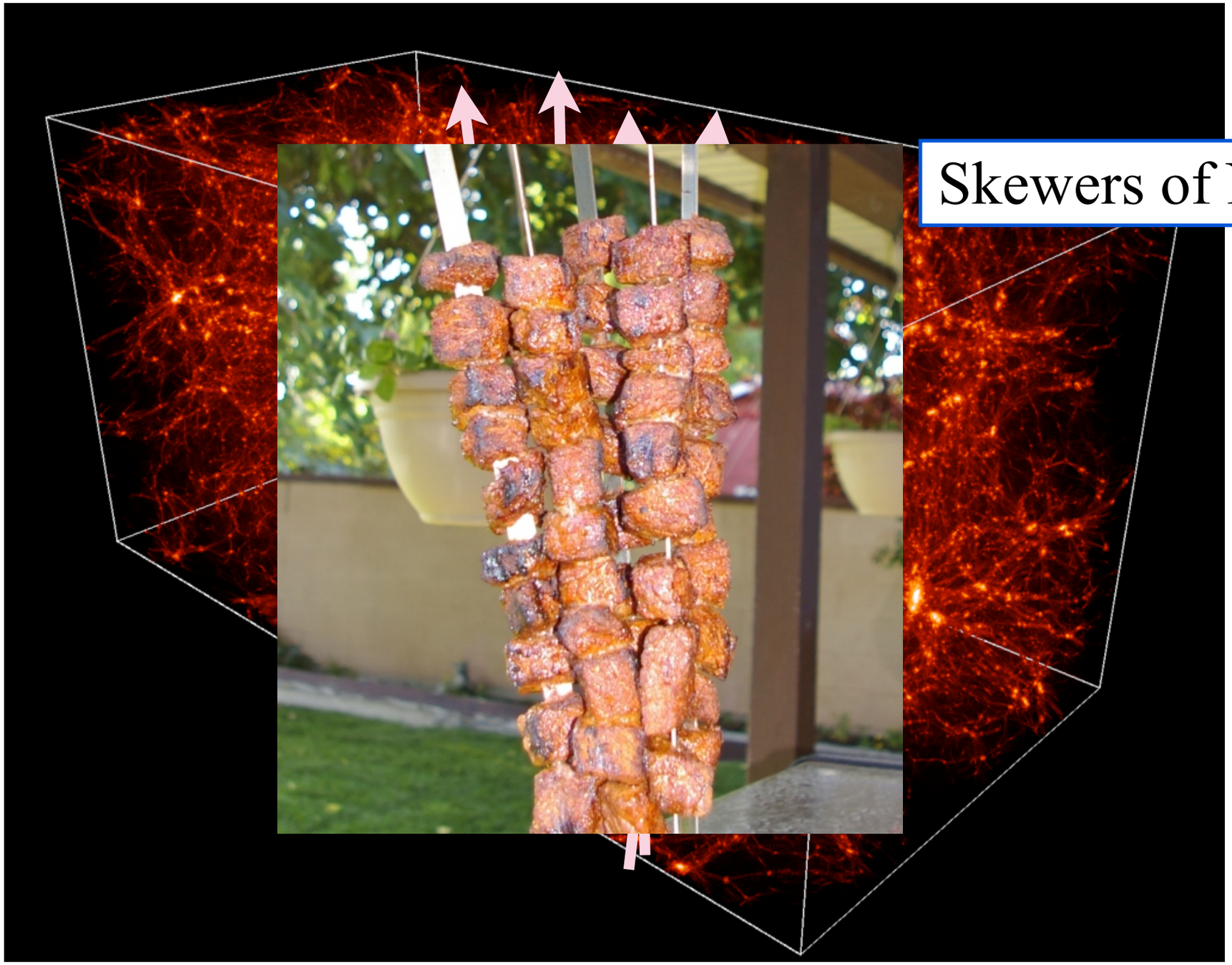
Fluctuating Gunn Peterson approximation

$$\tau = A(1+\delta)^\beta$$

$$F = e^{-\tau}$$

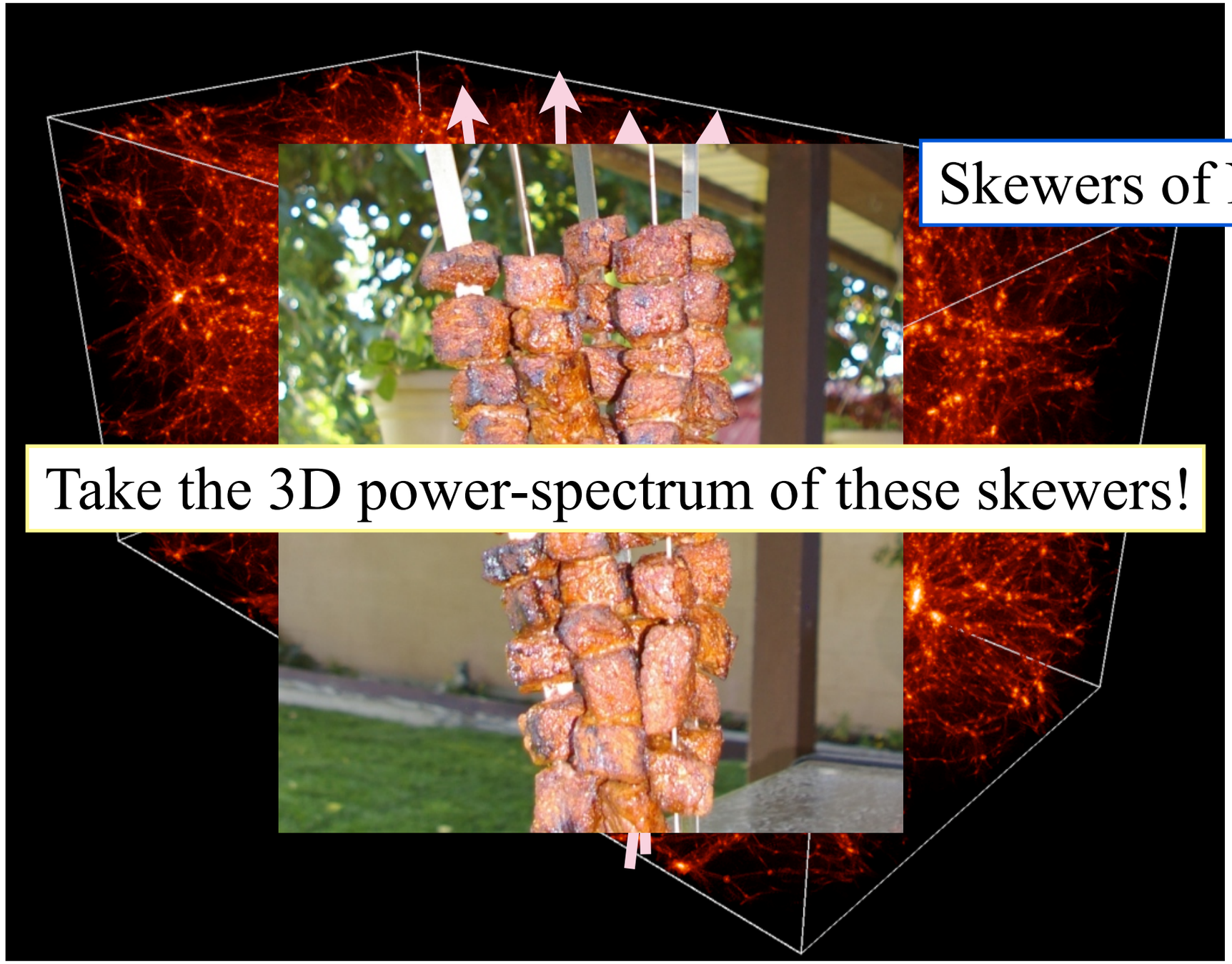
Lyman Alpha Forest: what can it do?

- **Primordial Non-gaussianities via Lyman alpha forest**



Skewers of Neutral Hydrogen

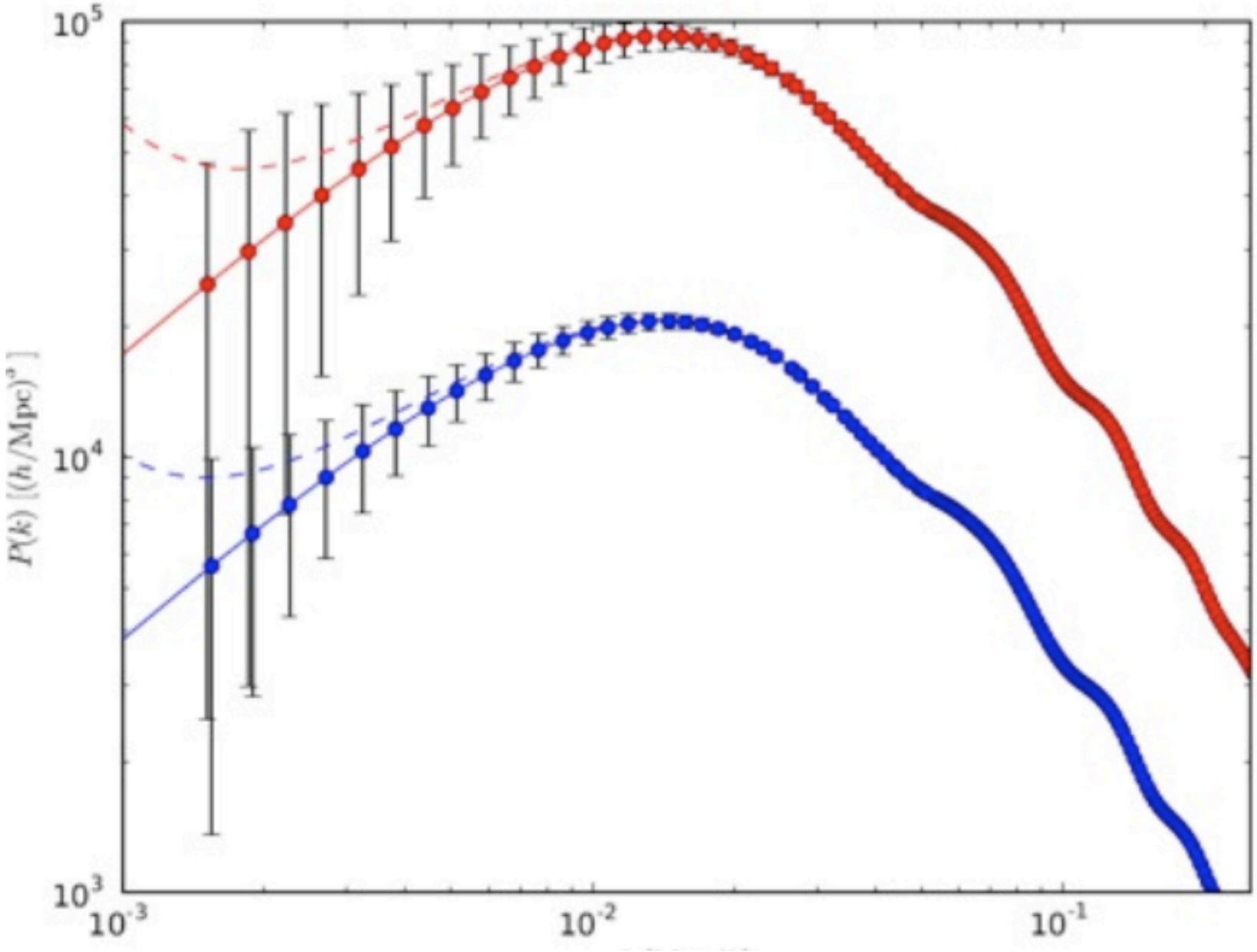
Lyman Alpha Forest: what can it do?



Skewers of Neutral Hydrogen

Take the 3D power-spectrum of these skewers!

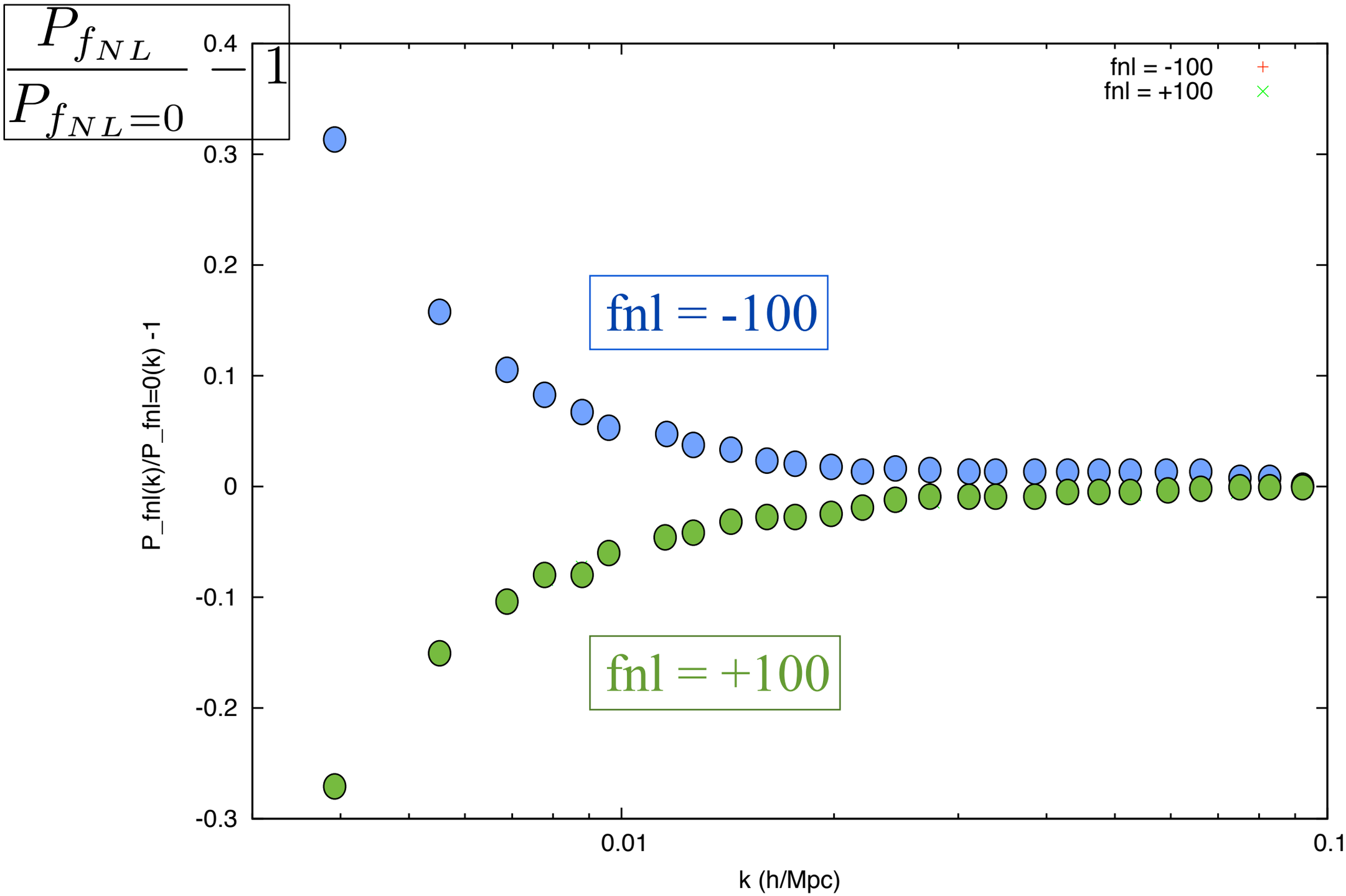
P(k) (Mpc/h)^3



k (h/Mpc)

Courtesy slide from Anze Slosar

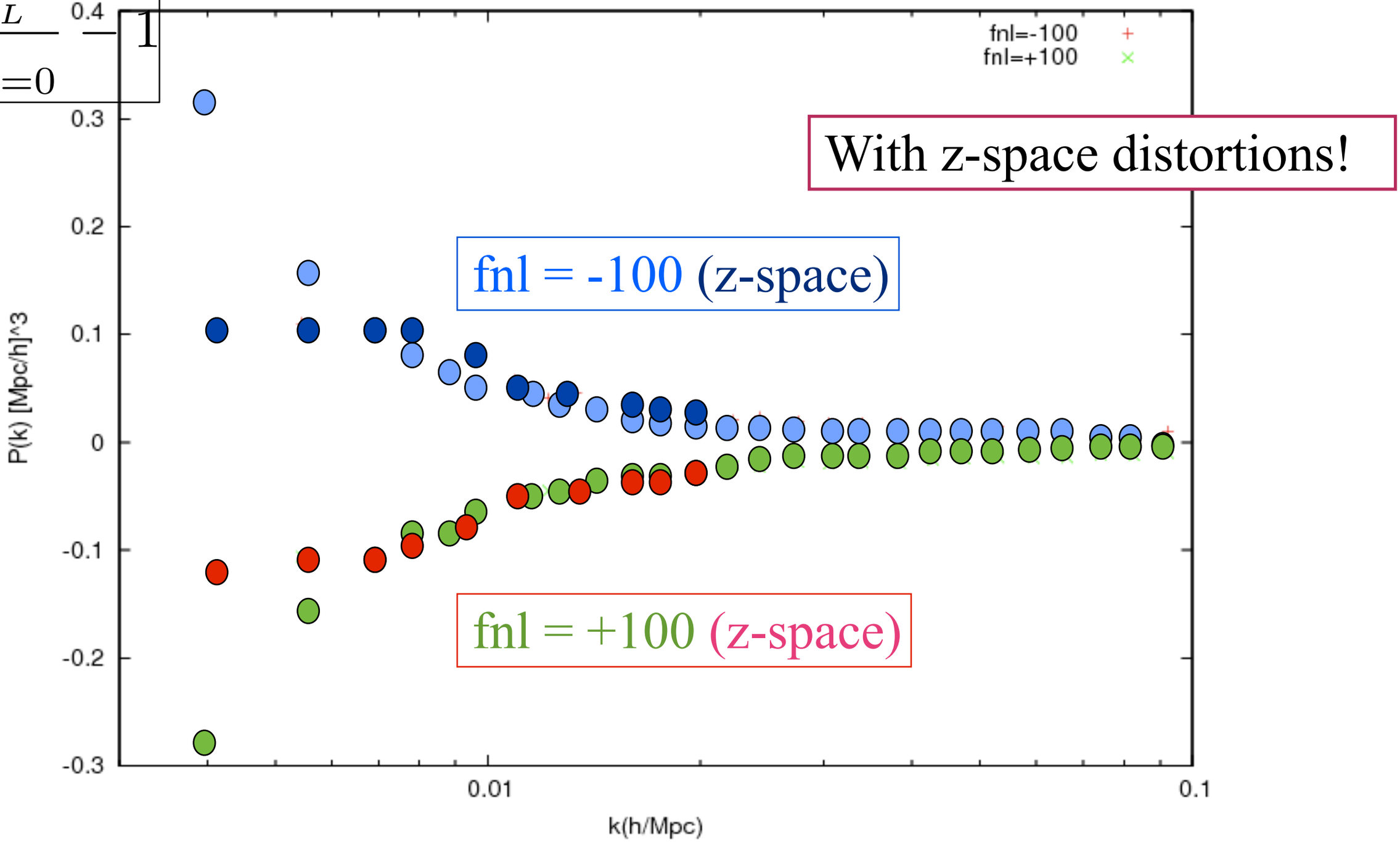
What can we do with Lya and fnl?



Ho, Slosar, Seljak & Desjacques (in prep)

What can we do with Lya and fnl?

$$\frac{P_{f_{NL}}}{P_{f_{NL}=0}} - 1$$



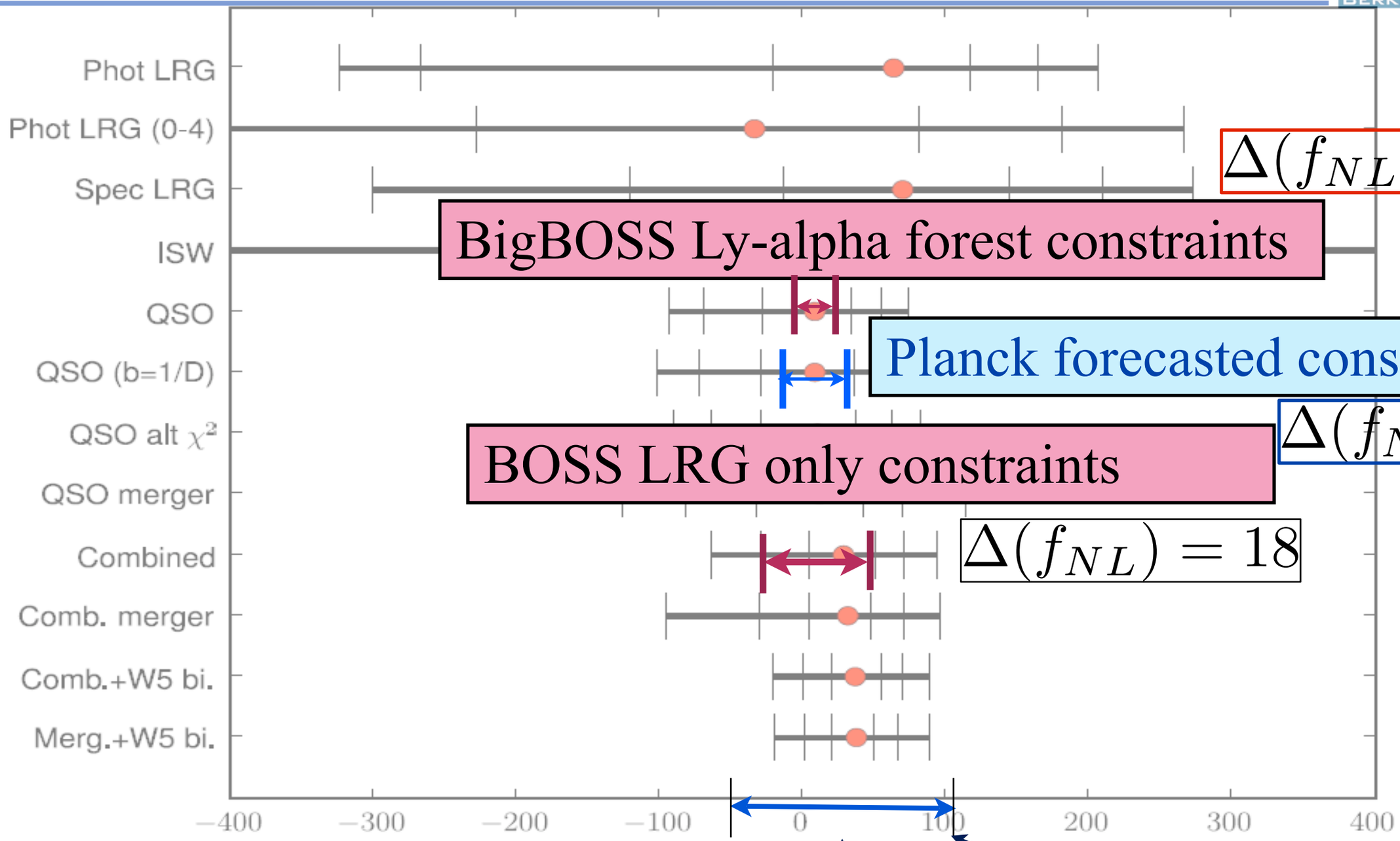
With z-space distortions!

fnl = -100 (z-space)

fnl = +100 (z-space)

Ho, Slosar, Seljak & Desjacques (in prep)

What can we do with Lya and fnl?
—Non-gaussianities in Early Universe



Best current CMB measurement

Ho, Slosar, Seljak & Desjacques (in prep)

canonical inflation

curvaton models, DBI inflation

ghost inflation

Other things we should worry about:

- UV background fluctuations
- continuum subtractions
- others?

- There maybe easy solutions:
  - —Using multiple tracers!
  - —Quasars, LRGs, Lyman-alpha forest (but in different ways)

Lyman Alpha Forest: what else can it do?

- **Dark Energy via Baryon Acoustic Oscillations**

—the correlation function:

$$\xi_f(r) = < \delta_f(\hat{x})\delta_f(\hat{x}+\hat{r}) >$$

Lyman Alpha Forest: what can it do?

- **Dark Energy via Baryon Acoustic Oscillations**

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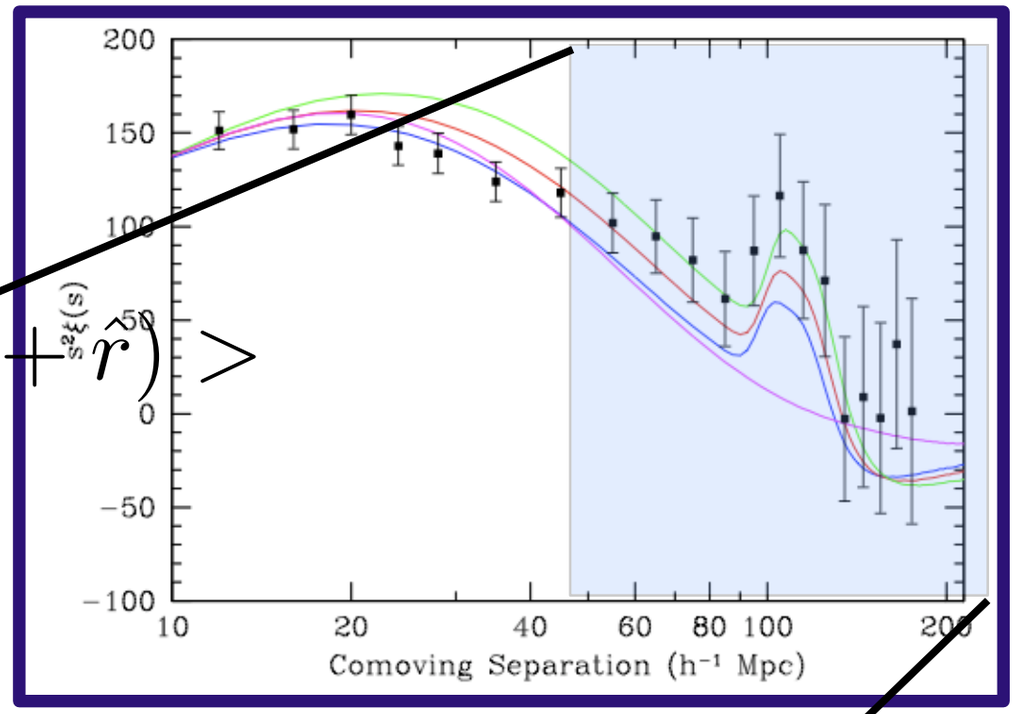
$$\xi_f(r) = < \delta_f(\hat{x}) \delta_f(\hat{x} + \hat{r}) >$$



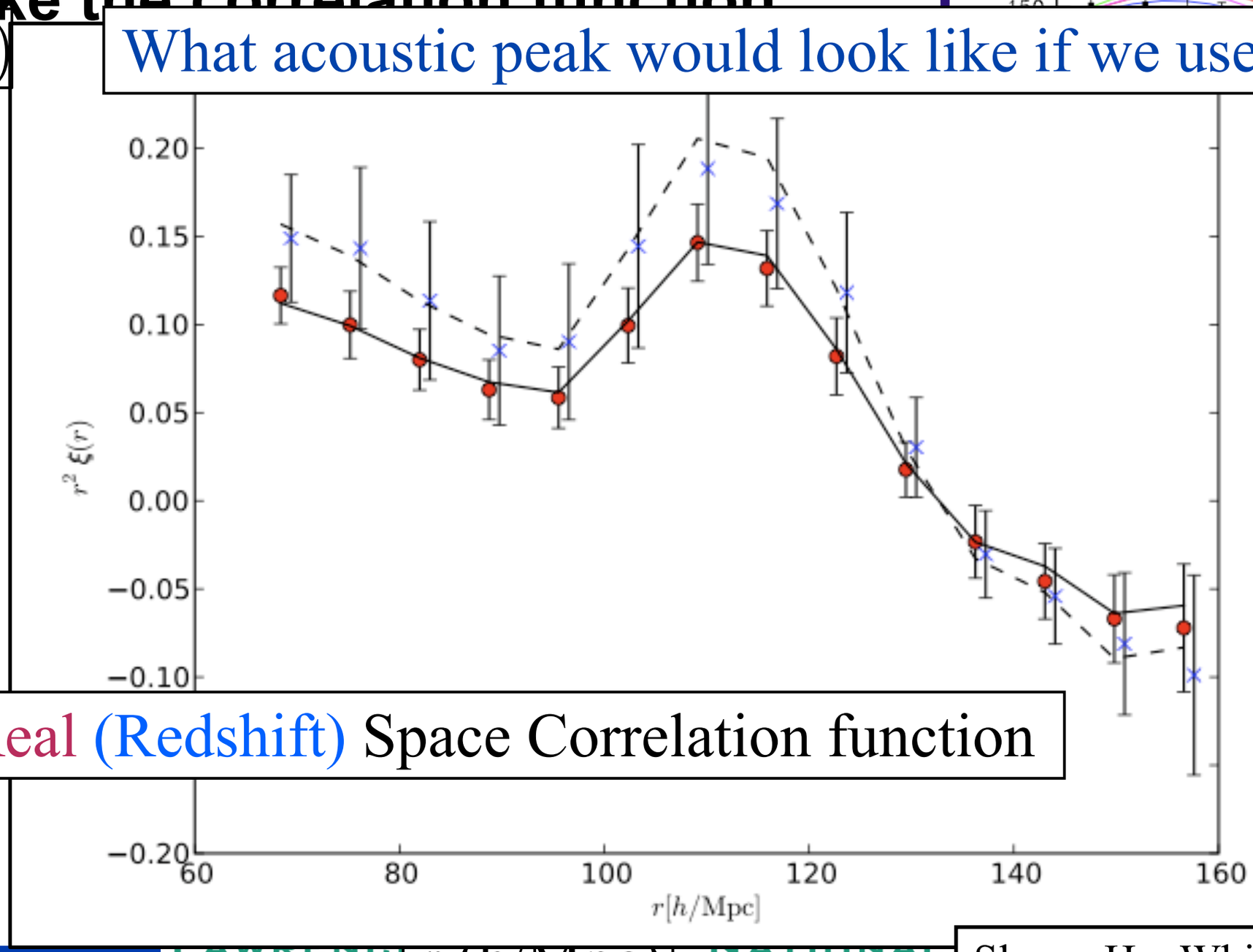
Lyman Alpha Forest: what can it do?

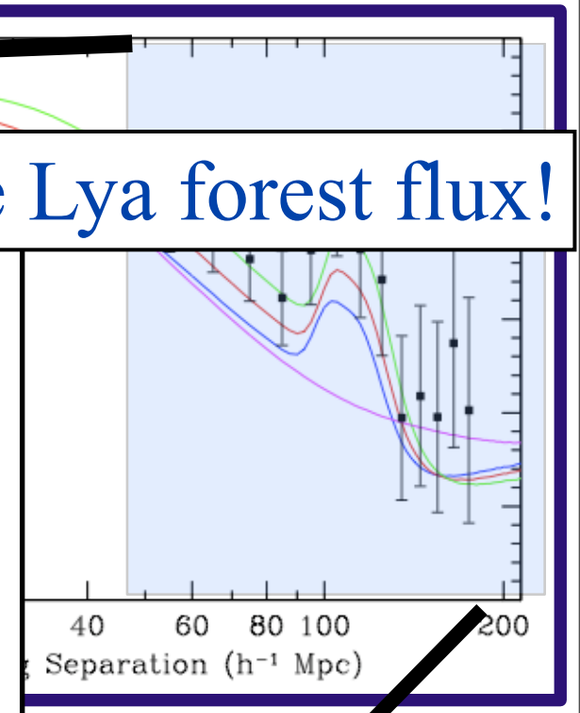
- **Dark Energy via Baryon Acoustic Oscillations**

take the correlation function:

$r^2\xi(r)$

What acoustic peak would look like if we use Lya forest flux!



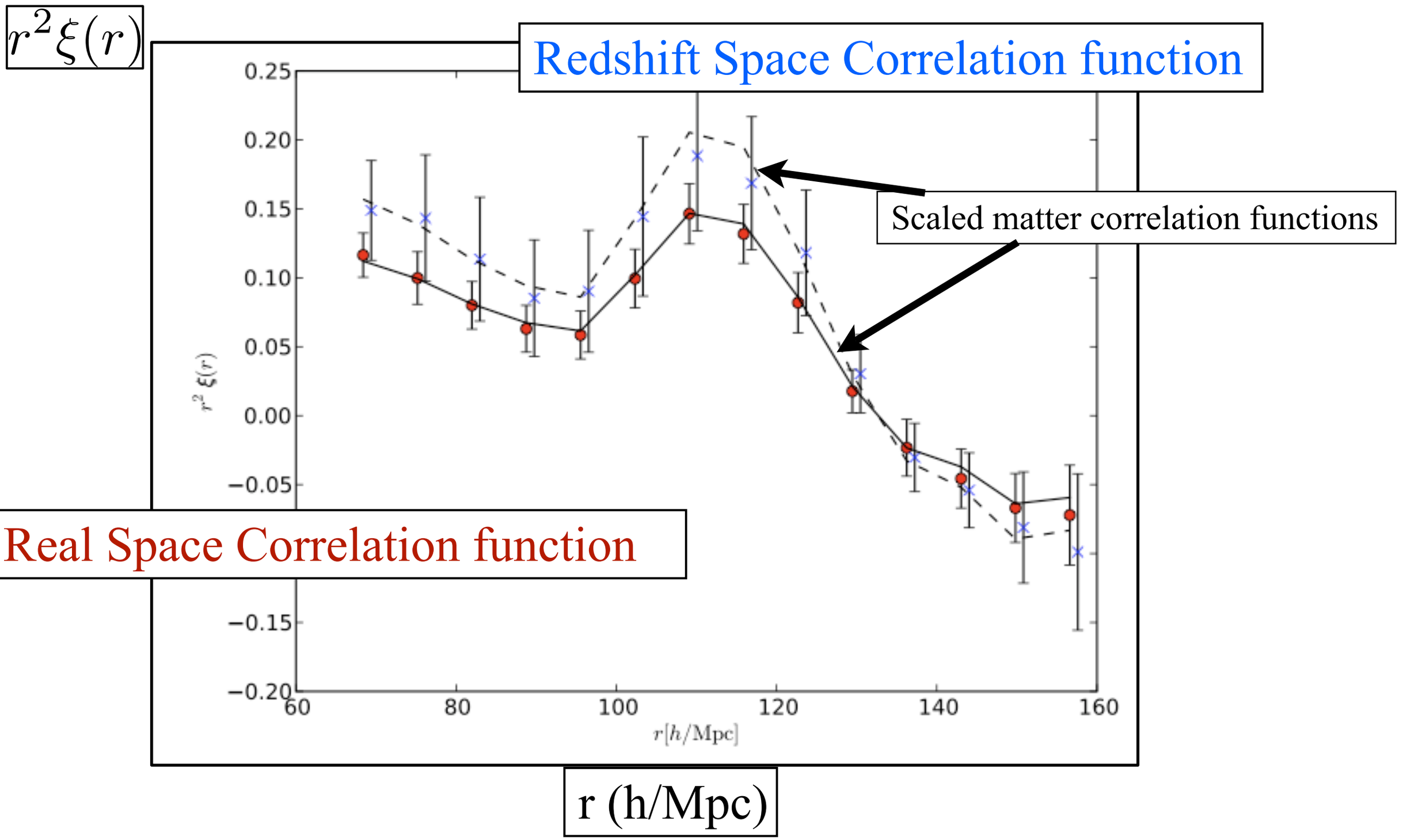


Flux Real (Redshift) Space Correlation function

r (h/Mpc)

Slosar, Ho, White & Louis (2009)

Lyman Alpha Forest: what can it do?



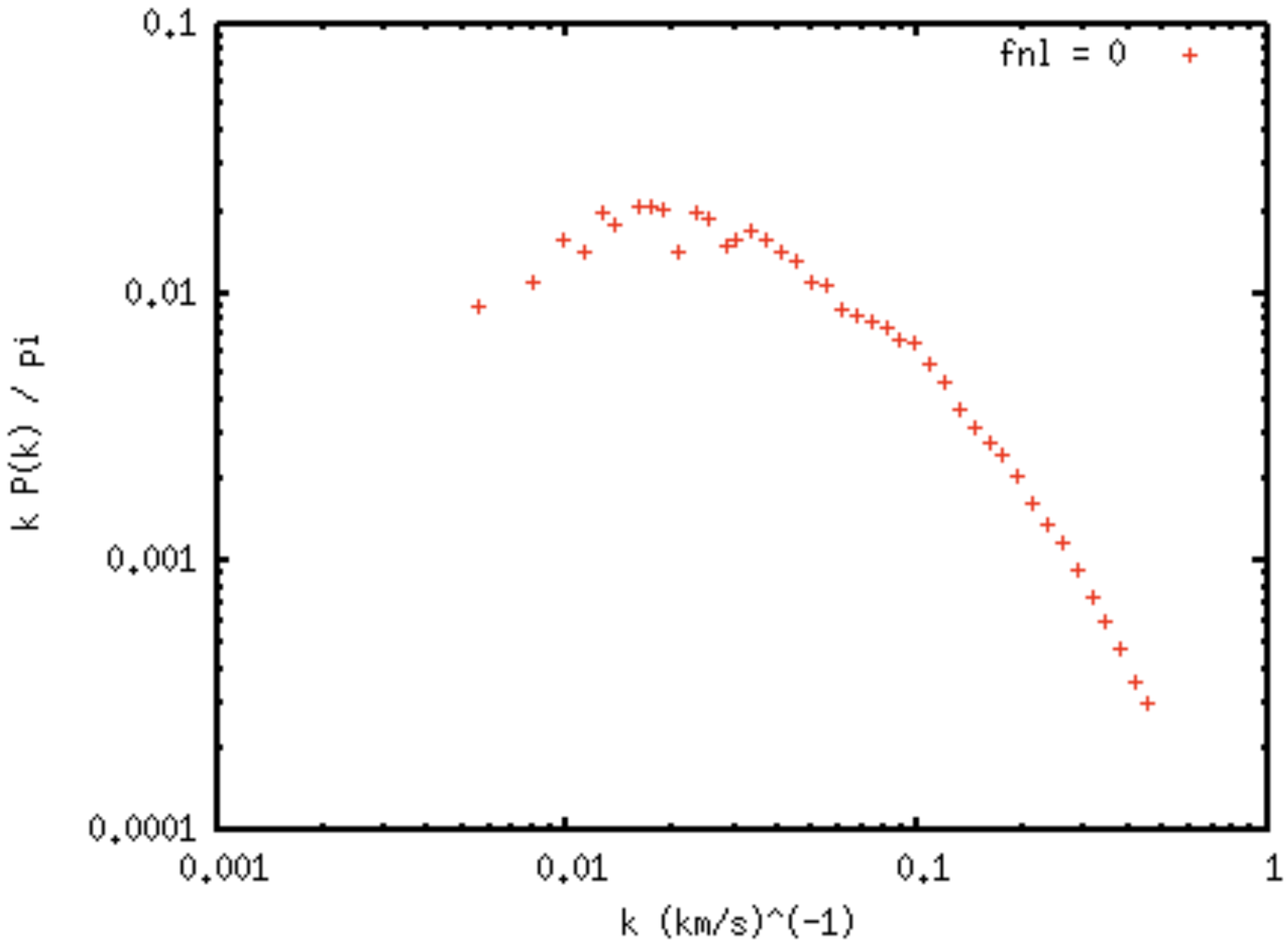
Slosar, Ho, White & Louis (2009)

Conclusions

- We can probe early universe with Lya forest!
- z-space distortions? not a problem!
- Other things Lya forest can do?
  - —BAO -> Dark energy at high-z
  - —neutrino mass constraints (small scale P(k))
  - —IGM physics...
- We need to worry about systematics such as:
  - —UV background fluctuations
  - —continuum fluctuations, etc

Checking my Lya-P(k)

$$kP(k)/\pi$$

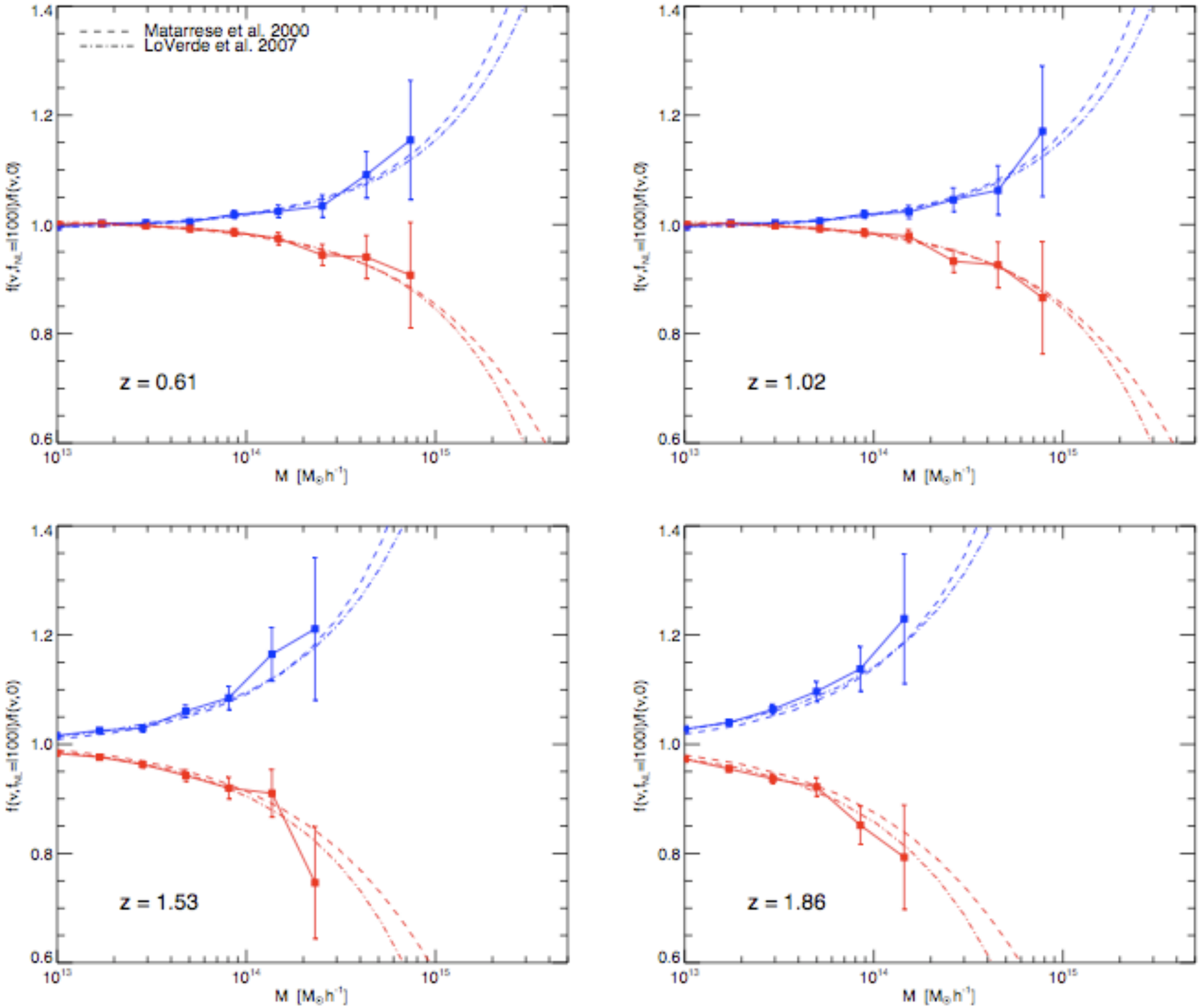


What does fnl do?

Data/method	Measurements $f_{\rm NL}, 1-2\sigma$ errors	reference
Photo LRG–bias	$84^{+54+85}_{-101-331}$	Slosar et al. 2008
Spectro LRG–bias	$93^{+74+139}_{-83-191}$	Slosar et al. 2008
QSO - bias	11^{+26+47}_{-37-77}	Slosar et al. 2008
combined	37^{+23+42}_{-26-57}	Slosar et al. 2008
NVSS–ISW	$140^{+647+755}_{-337-1157}$	Slosar et al. 2008
NVSS–ISW	272 ± 127 (2-σ)	Afshordi&Tolley 2008

Data/method	Forecasts $\Delta f_{\rm NL}(1-\sigma)$	reference
BOSS–bias	18	Carbone et al 2008
ADEPT/Euclid–bias	1.5	Carbone et al. 2008
PANNStarrs–bias	3.5	Carbone et al. 2008
LSST–bias	0.7	Carbone et al. 2008
LSST-ISW	10.	Afshordi&Tolley 2008

What does fnl do?



What about z-space distortions?

P(k) [Mpc/h]^3