Cosmology with BigBOSS

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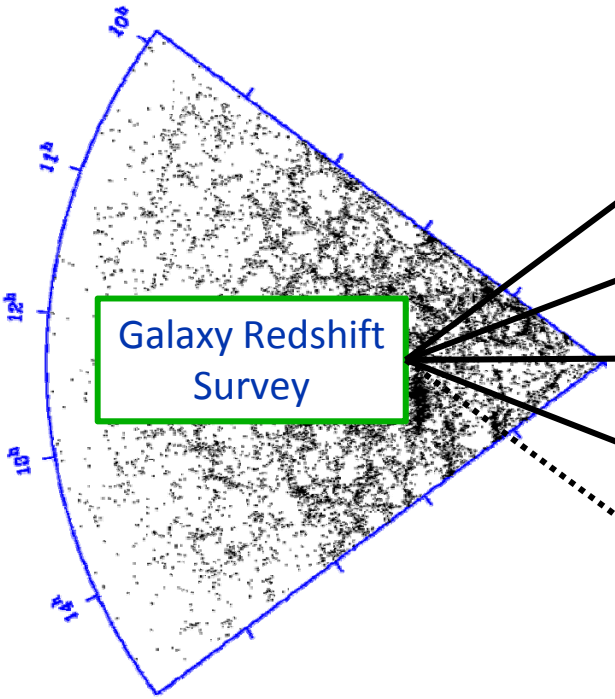
(Yale)

For the BigBOSS collaboration

Cosmology from galaxy surveys



Galaxy Redshift Survey

Comoving clustering → What are the constituents of matter? What is the physics of inflation? e.g. neutrino mass, primordial P(k)

Standard Ruler (BAO) → What is the expansion rate of the Universe? e.g. quintessence, Λ

Redshift-Space distortions → How does structure form within this background? e.g. modified gravity, GR

Understanding acceleration

Large-scale density → Is the Universe homogeneous on large scales? Copernican principle, Non-Gaussianity

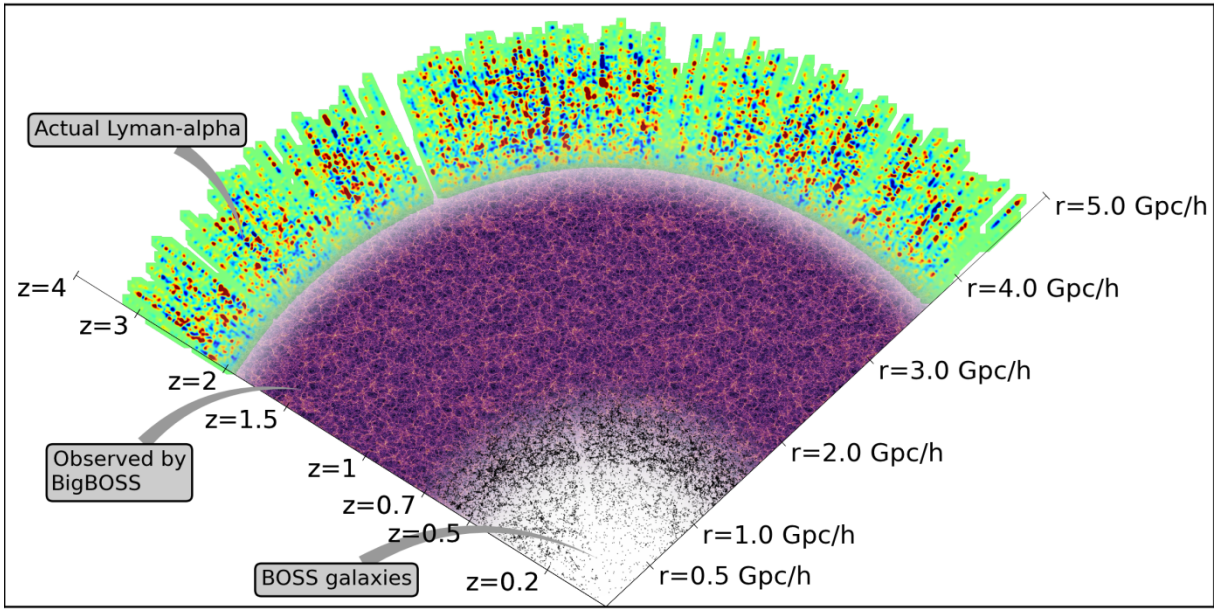
Spectral analysis → Other non-cosmology science e.g. galaxy formation & evolution

BigBOSS

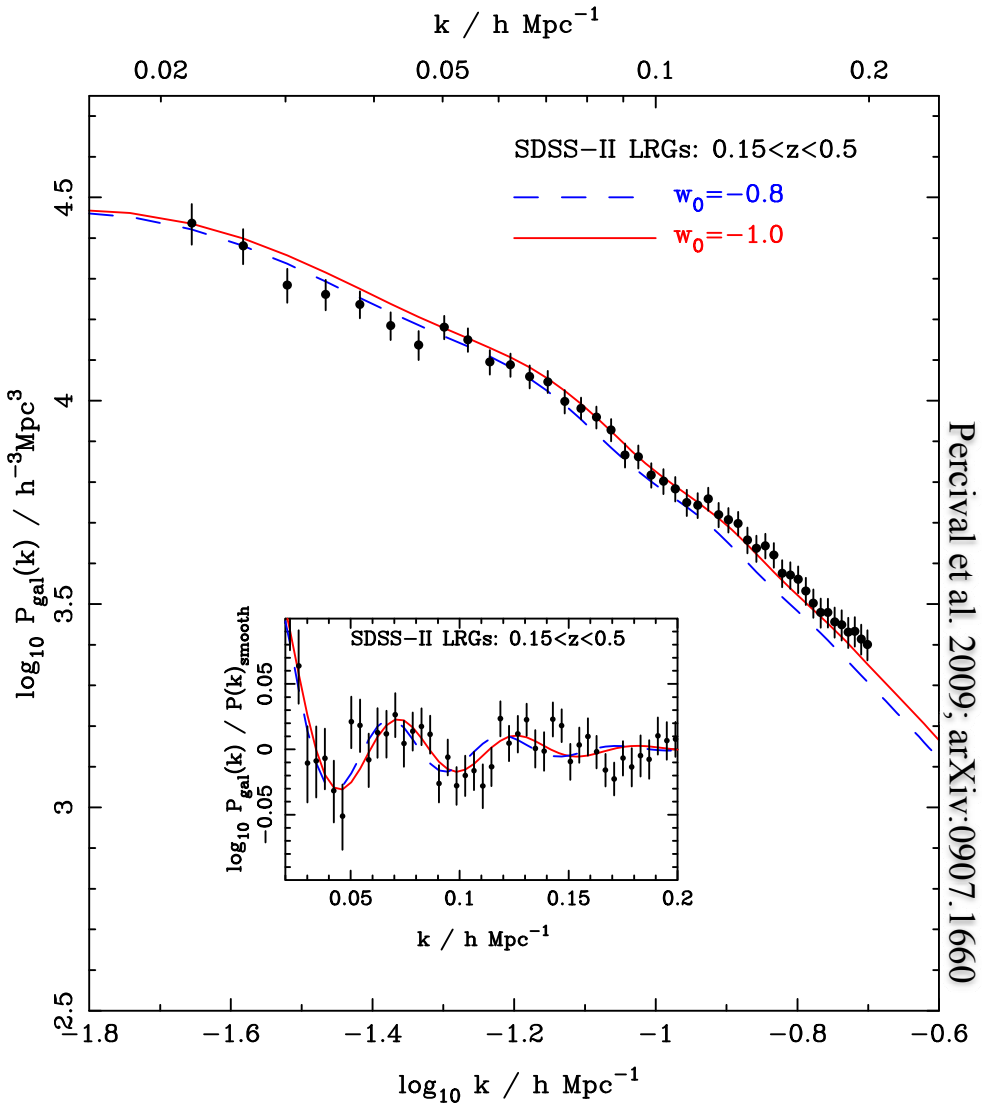
- **Is a Stage IV DE Survey**
  - Precise measurements of expansion using BAO
  - Precise measurements of growth using RSD
- **Probes inflation**
  - Primordial power spectrum
  - Non-gaussianities
- **Precise probe of contents of Universe**
  - Neutrino masses

BigBOSS is BIG

- SDSS covered ~ $2h^{-3}Gpc^3$
- BOSS is covering ~ $6h^{-3}Gpc^3$
- BigBOSS will cover ~ $50h^{-3}Gpc^3$
- unprecedented volume

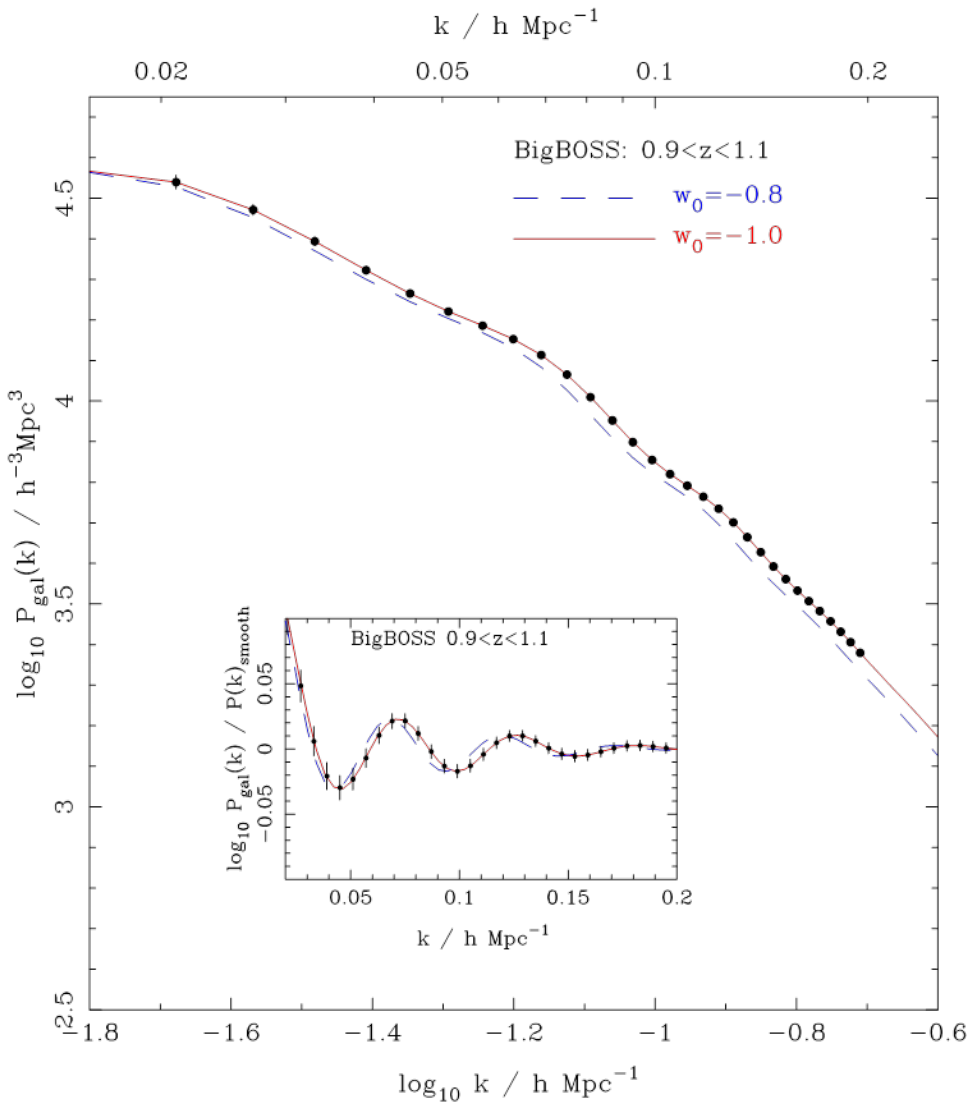


Current clustering power spectrum

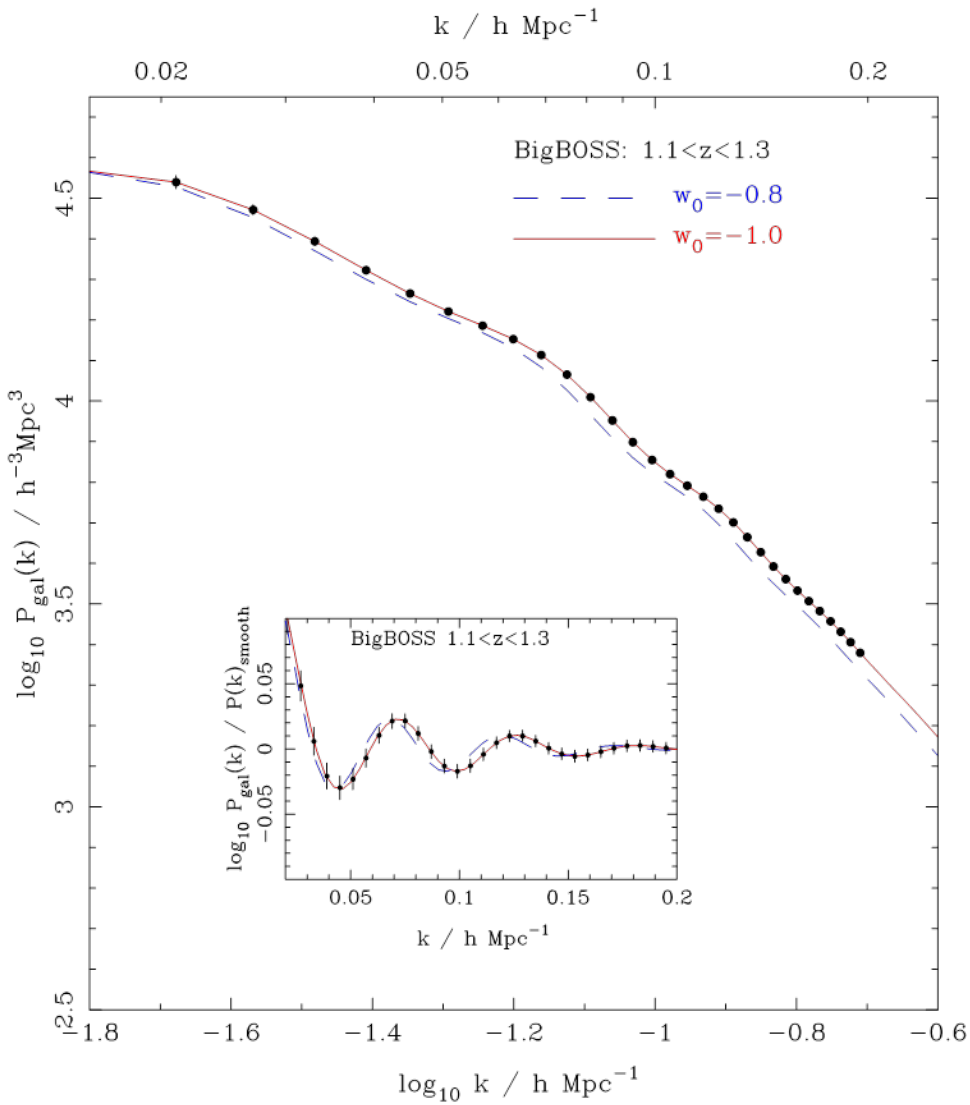


Percival et al. 2009; arXiv:0907.1660

The power of BigBOSS: 0.9<z<1.1



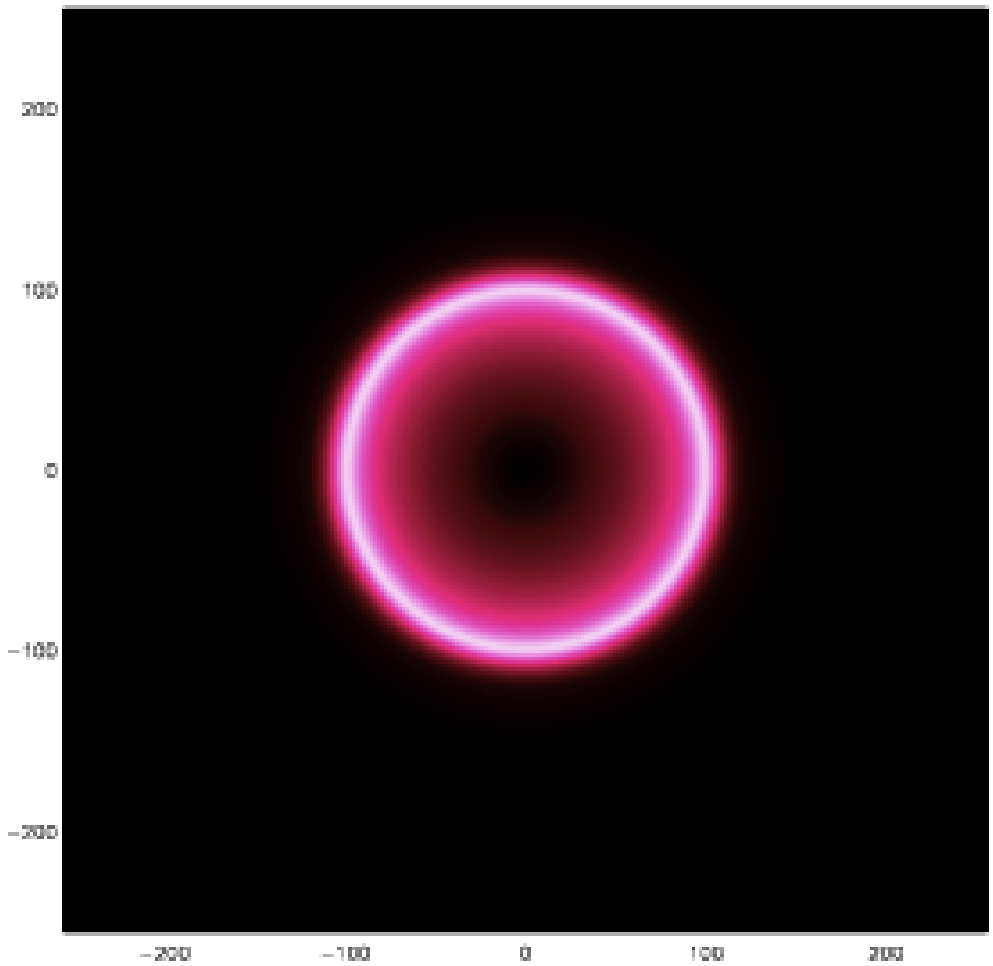
The power of BigBOSS: 1.1<z<1.3



Two Approaches to Dark Energy

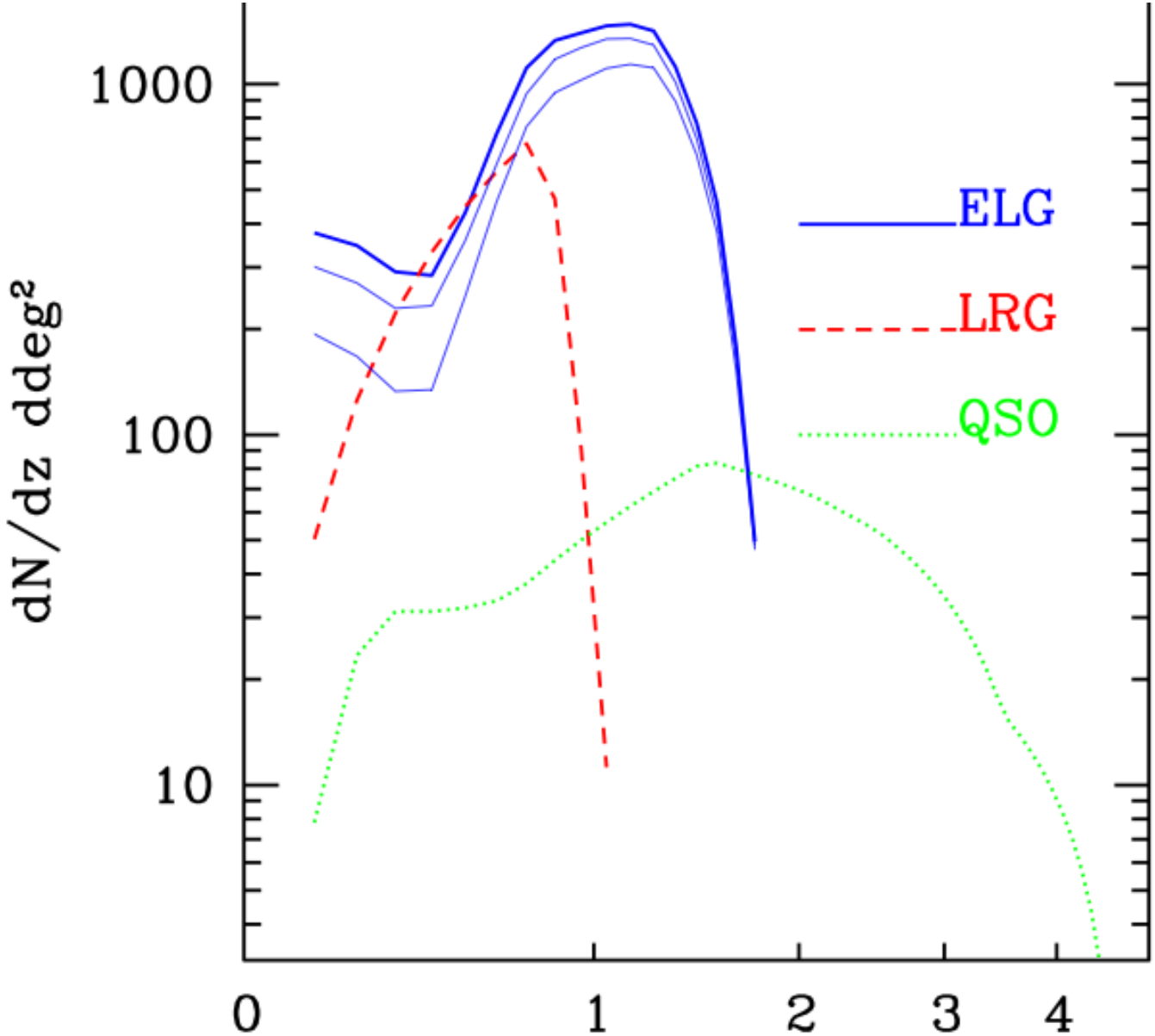
- **Theoretical**
  - A new energy component
  - Modifications to gravity on cosmological scales
- **Observational**
  - Geometry (Homogeneous)
  - Growth of structure (Inhomogeneous)
- **BigBOSS does *both* of these**
  - Baryon Acoustic Oscillations (Expansion)
  - Redshift Space Distortions (Growth)

A Standard Ruler

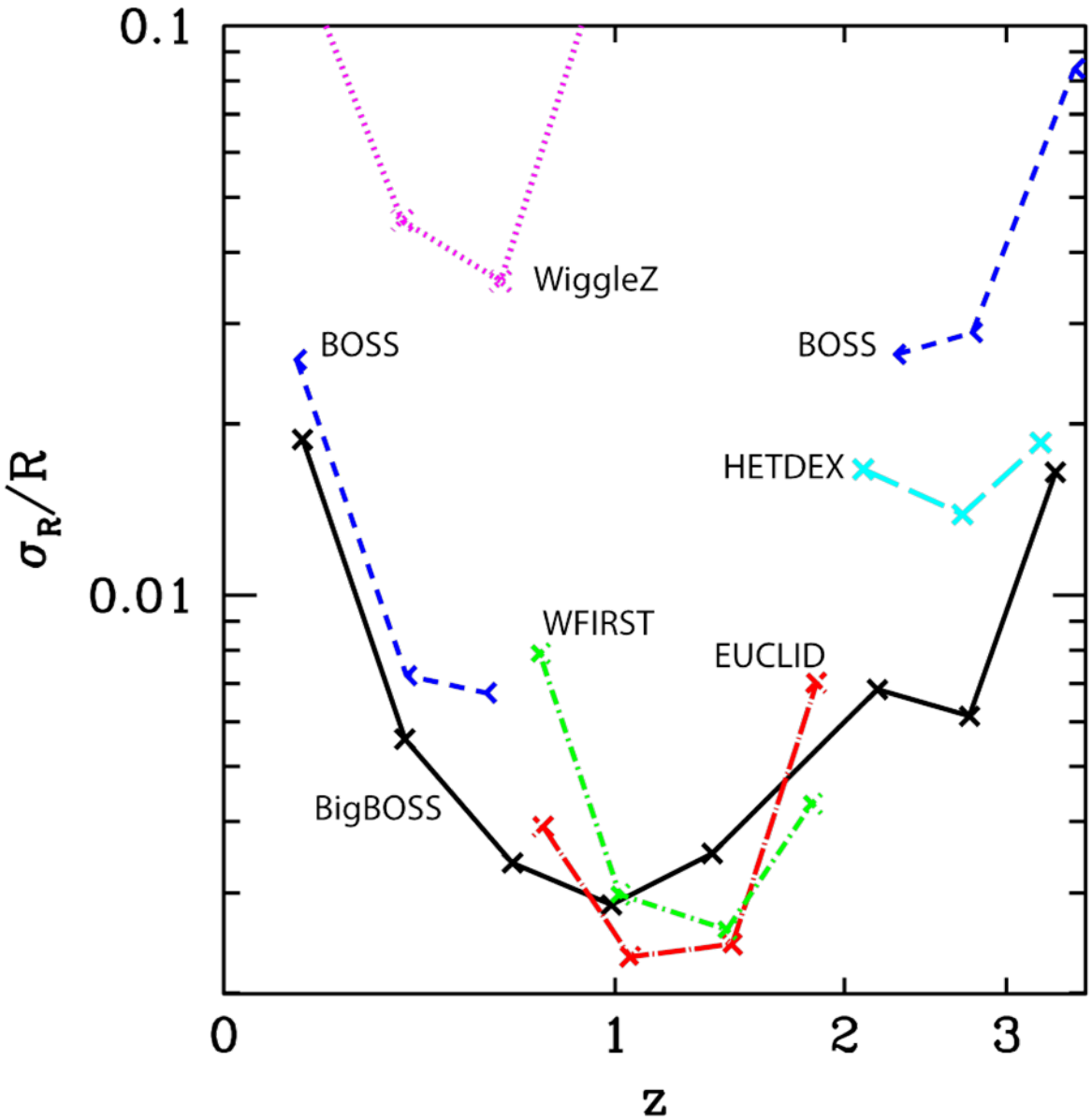


- Standard rulers analogous to standard candles
- Sound waves frozen in the Early Universe
- Characteristic scale ~ sound horizon
- 100 Mpc/h for concordance cosmologies
- Scale imprinted on density fluctuations
- Constrained by the CMB

BigBOSS tracers



Distance constraints



- Isotropic dilation factor
- BigBOSS has < 1% distance errors over the widest redshift range
- Probe the expansion history over the widest redshift range

The impact of BigBOSS : FoM

	no BOSS	BOSS	BigBOSS 100%
no Lyman-α	0	11	125
+BAO III	12	34	132
+SNIII	27	49	163
+WLIII	43	83	201

Current BAO + SN + CMB FoM : 10

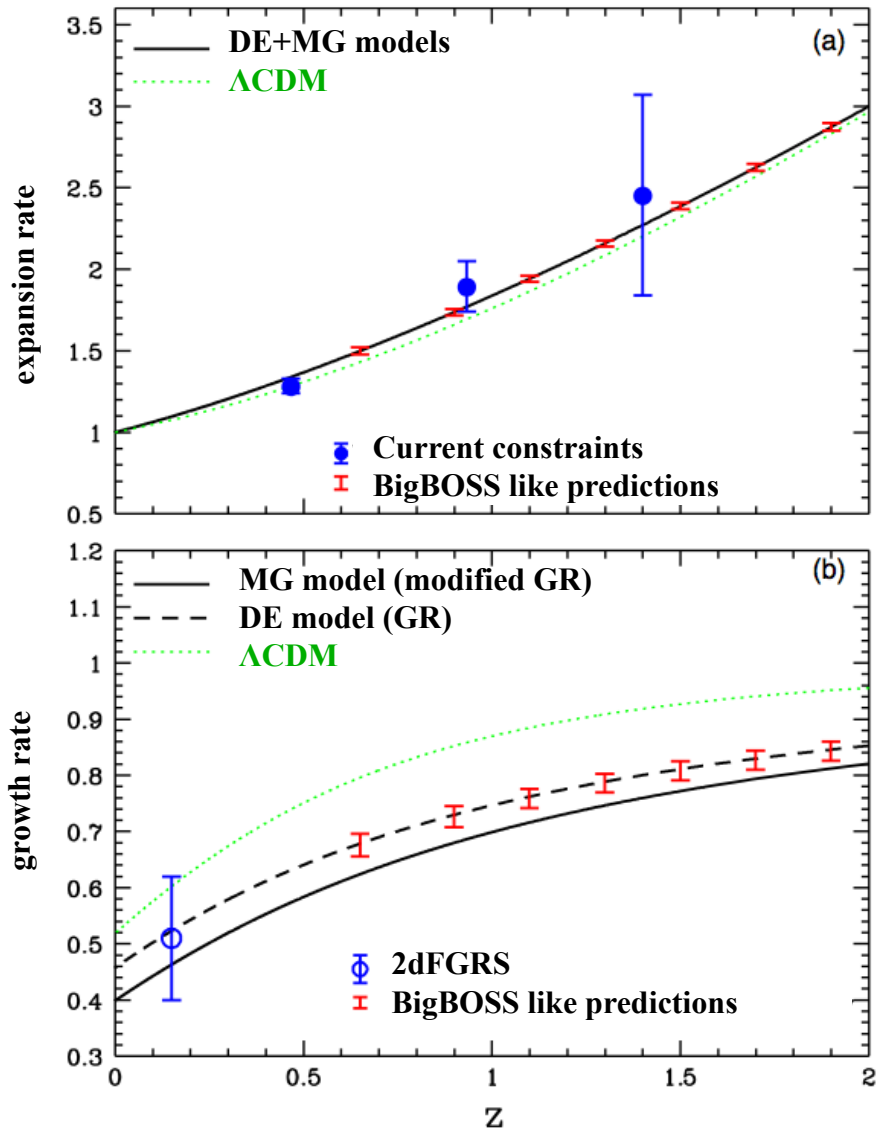
BigBOSS is a Stage IV experiment

	BOSS + WFIRST	BOSS + Euclid	BigBOSS
–	122	140	125
+BAO III	126	145	132
+SNIII	163	183	163

For BAO only, assuming Planck prior and H0
Assumes 14K sq.deg

BigBOSS is competitive with space missions

Complementarity of growth & expansion



Wang 2008: JCAP, 05, 21

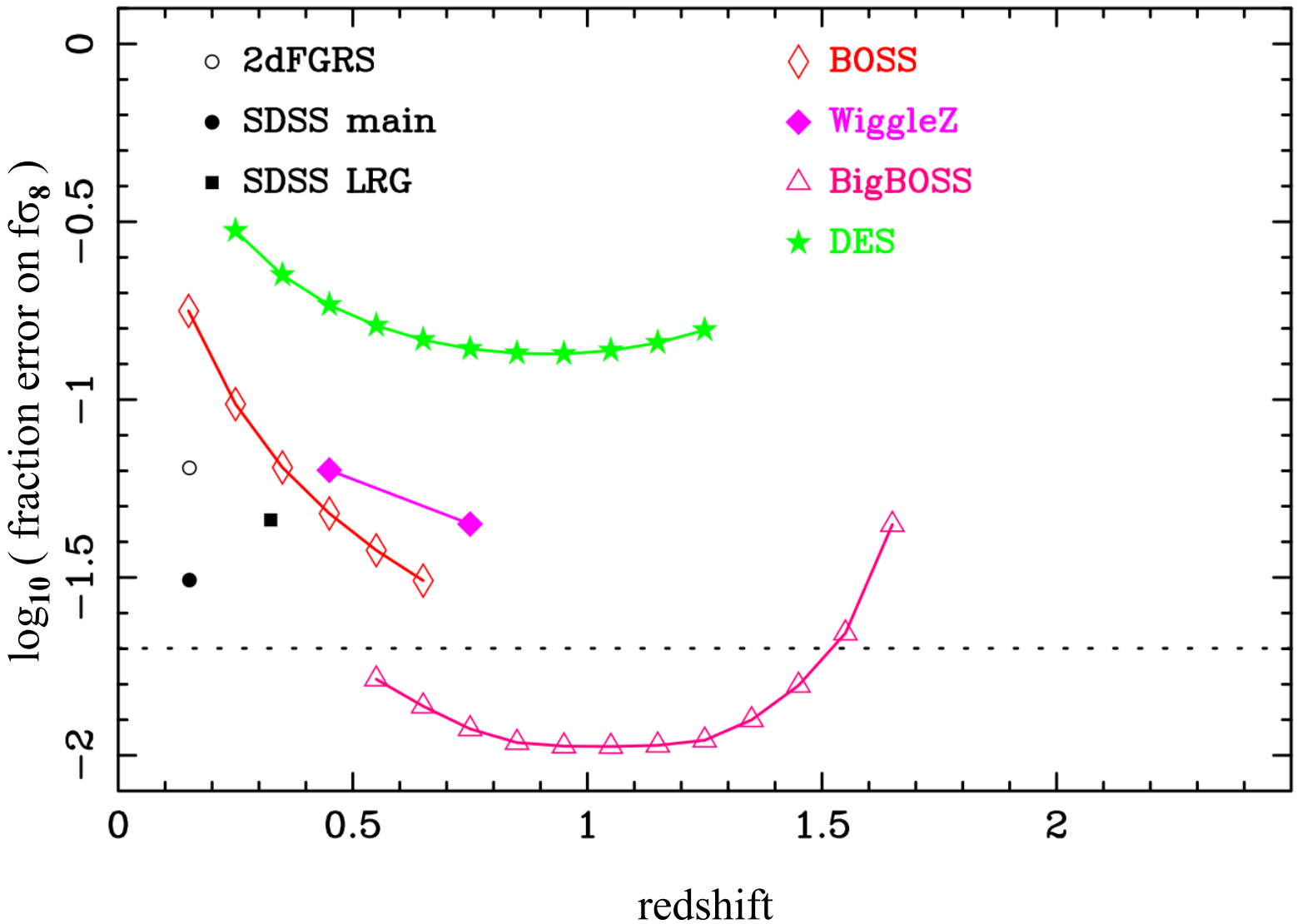
Redshift-Space Distortions

When we measure the position of a galaxy, we measure its position in redshift-space; this differs from the real-space because of its peculiar velocity:

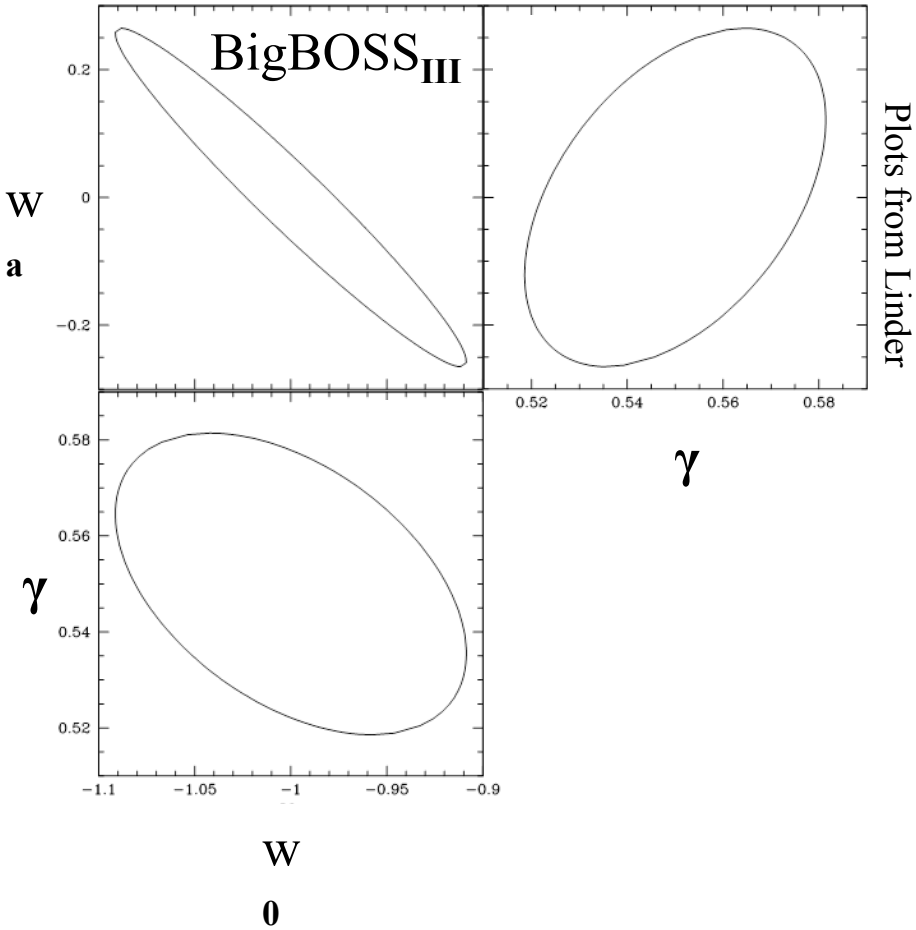
$$\vec{s}(r) = \vec{r} - v_r(r)\frac{\vec{r}}{r}$$

Where **s** and **r** are positions in redshift- and real-space and v_r is the peculiar velocity in the radial direction

BigBOSS RSD predictions



BigBOSS constraints on w_0, w_a, γ



- **Gravitational growth index γ tests gravity separately from expansion history**

$$f(z)\sigma_8(z) \propto \Omega_m^\gamma \exp\left[\int \Omega_m^\gamma \, d\log a\right]$$

- **$\gamma = 0.55$, GR**
- **$\gamma \neq 0.55$, major discovery!**
- **BigBOSS measures $\gamma \pm 0.02$**
- **BigBOSS data has little degeneracy with expansion rate**
- **correlation $|r|<0.46$ with w_0, w_a.**

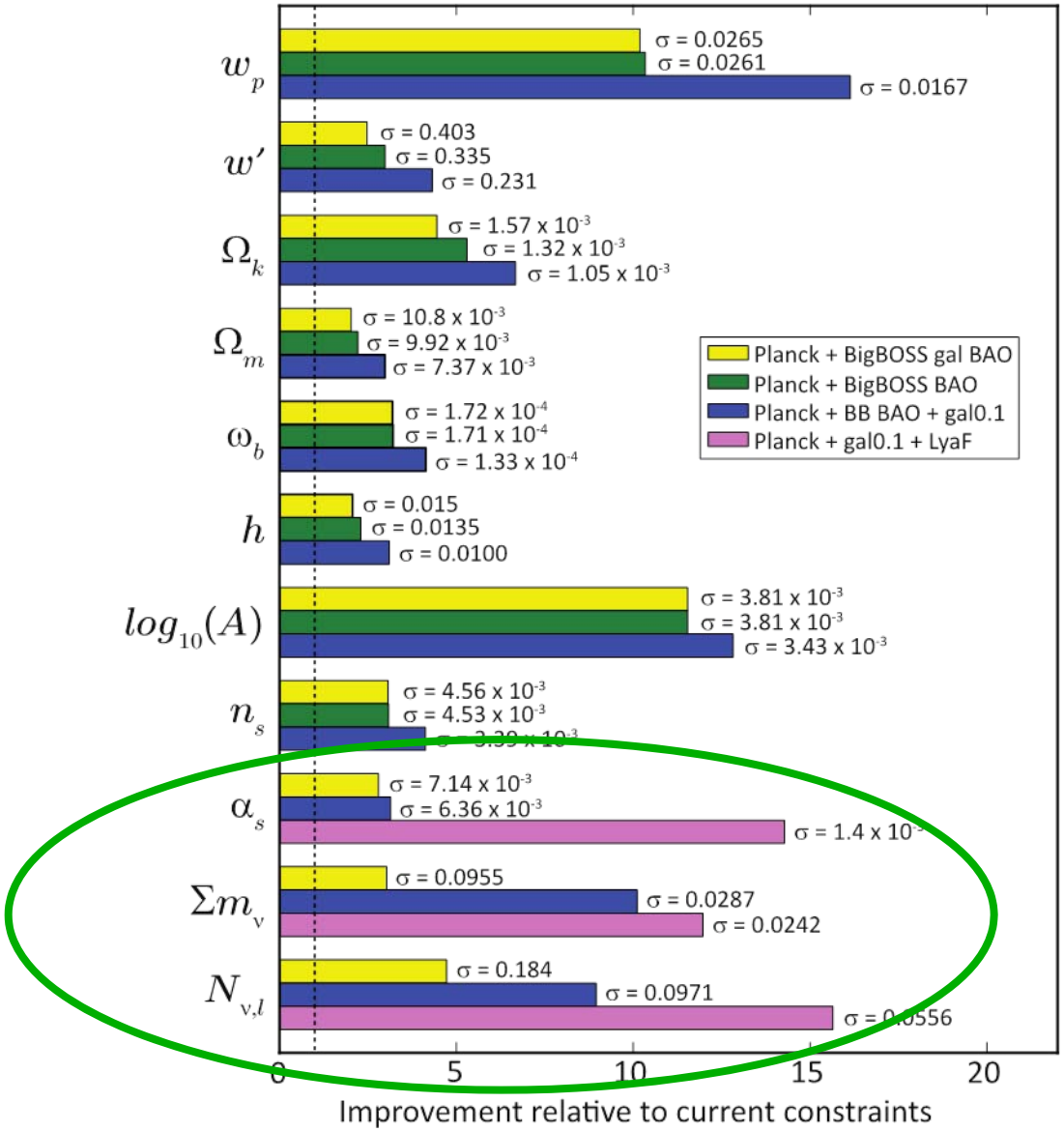
Broad-band power for DE

Broad-band power spectrum offers strong potential for dark energy measurements beyond those from BAO only

(fits include all P(k) information, including RSD)

	FoM
BigBOSS BAO	125
+BAO III	132
+SN III	163
BigBOSS P(k), k_{max}= 0.15 $hMpc^{-1}$	430
+BAO III	437
+SN III	466
BigBOSS P(k), k_{max}= 0.30 $hMpc^{-1}$	661
+BAO III	667
+SN III	691

Inflation & Neutrino mass measurements



from bigboss.lbl.gov/docs/BigBOSS_NOAO_public.pdf

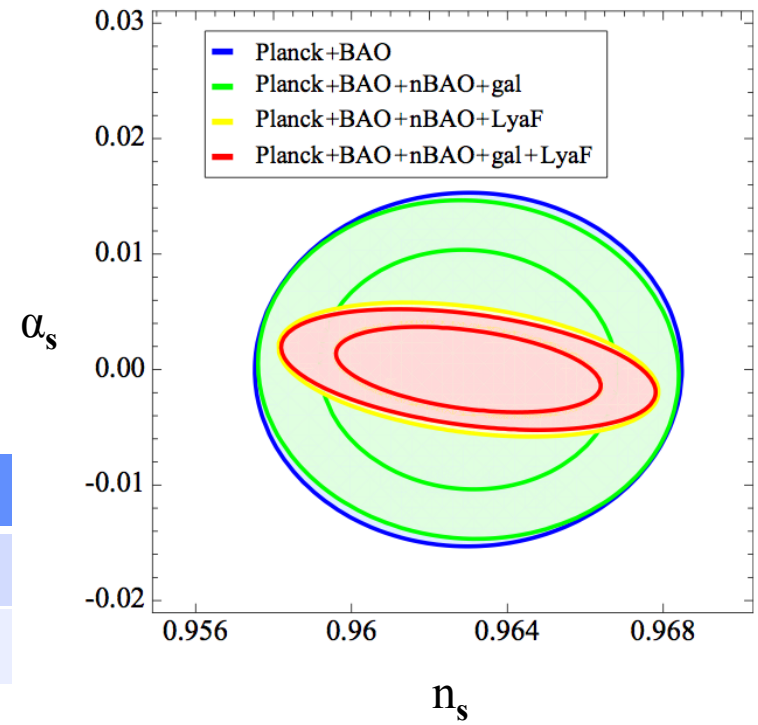
Constraints on inflation models

- **Arguments based on the near scale-invariance of inflation mean the standard assumption is a primordial power-law spectrum**

$$
\begin{aligned}
P_{\rm p}(k) &= P_{\rm p}(k_0)^{n_s(k_0)+\frac{1}{2}\alpha_s \ln(k/k_0)} \\
n_s(k) &= \frac{d\ln P_{\rm p}}{d\ln k} \\
\alpha_s &= \left.\frac{dn_s}{d\ln k}\right|_{k_0}
\end{aligned}
$$

- **BigBOSS ly-α + gal P(k) is particularly strong when constraining α_s**

	σn_s	$\sigma \alpha_s$
Planck + BigBOSS BAO	0.0026	0.0071
+ P(k), k_{max}= 0.1 hMpc^{-1}	0.0022	0.0024

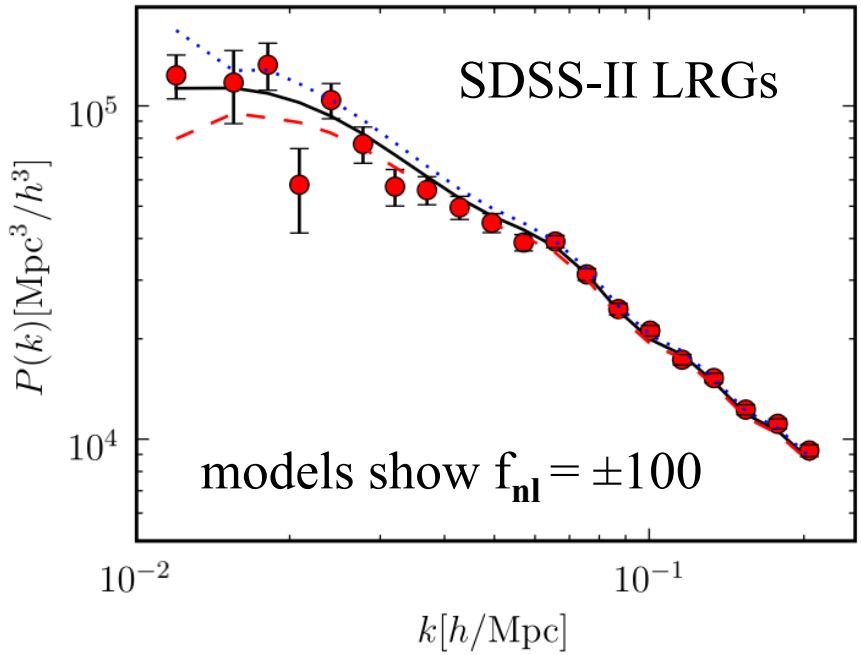


f_{nl} measurements

- Some models of inflation predict a non-Gaussian contribution to the potential, which is commonly parameterised by

$$\Phi = \phi + f_{nl}\left(\phi^2 - \langle\phi^2\rangle\right)$$

- This extra term has the effect of producing a large-scale, scale-dependent bias
- Using this effect BigBOSS will measure $f_{nl} \sim 5$, based on predicted statistical errors

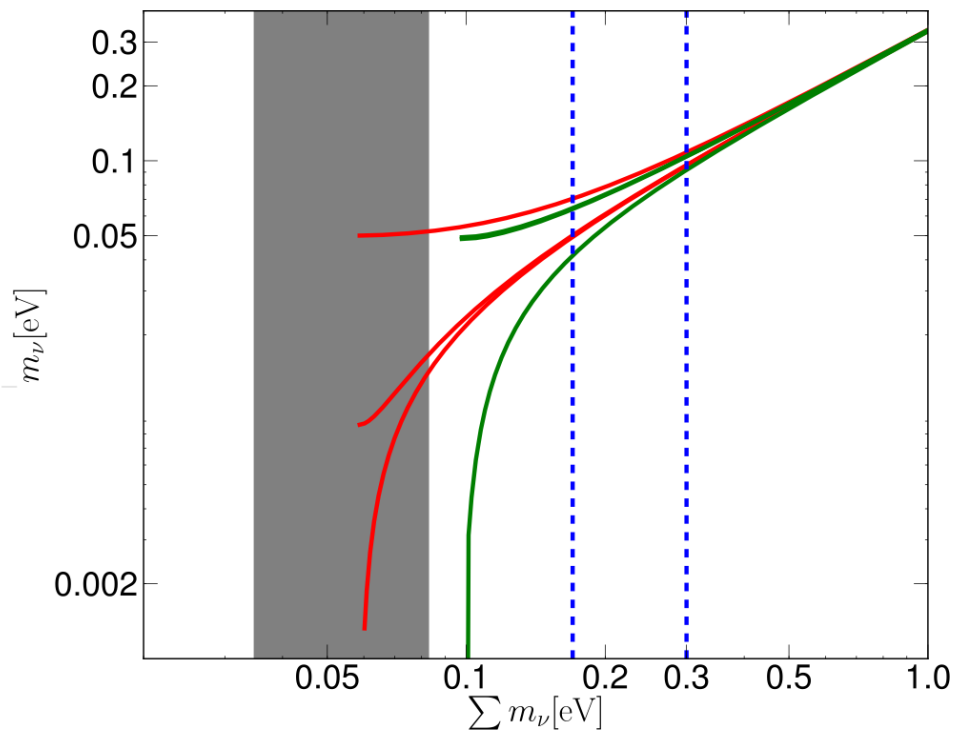


Neutrino mass measurements

- From KamLAND we know that at least one neutrino species has a particle mass 0.05eV
- In combination, galaxy and Ly-alpha power spectra will give a detection of a non-null sum of neutrino masses

$$\sum m_\nu = 0.05 \pm 0.020$$

- will give a 98% detection
- will rule out an inverted hierarchy if lowest mass negligible



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  - **Non-gaussianities**
- **Precise probe of contents of Universe**
  - **Neutrino masses**
- **Things we haven't even thought of!**
- **BigBOSS will be an unprecedented cosmological resource!**