HETDEX & f_{NL}

Measuring **primordial non-Gaussianity** from HETDEX power spectrum

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One page introduction to f_{NL}

- f_{NL} = measure of primordial non-Gaussianity in curvature perturbation
- In “plain vanilla” models of inflation, initial perturbations are Gaussian.
  - “plain vanilla” = **slow roll**ing **single** scalar field with **canonical kinetic term** and was initially in the **Banch-Davies** vacuum
- If f_{NL} is NOT zero, inflation may be explained by “exotic” models.
  - “exotic models”
    - multi-field
    - non-canonical kinetic term (not $\frac{1}{2}mv^2$)
    - fast rolling inflation
    - departure from Banch-Davies vacuum
- For more information, see Komatsu, astro-ph/0206039 (Ph.D. Thesis)

Current status of measuring f_{NL}

- Mostly come from the higher order statistics of **CMB** anisotropy
  - higher order (n>3) "connected" correlation function is zero for Gaussian statistics.

- From CMB Bispectrum (Fourier transf. of three point correlation function)
  - $f_{NL} = 32 \pm 34$ (Creminelli et al. (2006) WMAP3)
  - $f_{NL} = 87 \pm 30$ (Yadav & Wandelt (2007) WMAP3)
  - $f_{NL} = 55 \pm 30$ (Komatsu et al. (2008) WMAP5)
  - $f_{NL} = 38 \pm 21$ (Smith et al. (2009) WMAP5)
  - f_{NL} = ?? ± 5 (??? et al. (2013) Planck!)

- By the way, f_{NL} here is referred as $f_{NL}^{(local)}$ elsewhere.

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

f_{NL} from large scale structure

- Three ways of measuring f_{NL} from large scale structure
  - Galaxy Bispectrum
  - Cluster mass function
  - Galaxy Power spectrum
    (through scale dependent large scale bias)

f_{NL} from HETDEX bispectrum

- Sefusatti & Komatsu (2007)

	V	n_g	z	k_{max}	b_1	b_2	Δb_1	Δb_2	Δb_1	Δb_2	$\Delta f_{NL}^{loc.}$	Δb_1	Δb_2	$\Delta f_{NL}^{eq.}$
SDSS	0.3	30		0.09	1.19	−0.10	0.270	0.151	0.309	0.151	255.5	0.450	0.421	1775
LRG	0.72	1	0.35	0.11	2.14	0.96	0.209	0.348	0.223	0.353	113.4	0.338	0.726	998
APO-LSS	3.8	4	0.35	0.11	1.69	0.21	0.069	0.068	0.071	0.069	34.9	0.108	0.160	386
WFMOS1	1.6	5	0.7	0.14	1.87	0.45	0.076	0.096	0.080	0.096	41.0	0.123	0.216	435
	2.4	5	1.1	0.18	2.16	1.00	0.047	0.081	0.048	0.081	23.1	0.076	0.175	266
	combined						…	…	…	…	20.1	…	…	227
ADEPT	45	1	1.25	0.20	2.97	3.44	0.020	0.063	0.021	0.063	6.1	0.031	0.111	73
	55	1	1.75	0.26	3.44	5.43	0.017	0.066	0.017	0.067	4.5	0.025	0.112	53
	combined						…	…	…	…	3.6	…	…	43
WFMOS2	0.5	5	2.55	0.38	3.27	4.64	0.058	0.220	0.060	0.223	25.7	0.094	0.406	256
	0.5	5	3.05	0.48	3.64	6.39	0.056	0.253	0.058	0.255	22.1	0.087	0.439	215
	combined						…	…	…	…	16.8		…	164
HETDEX	0.68	5	2.25	0.34	3.05	3.70	0.051	0.172	0.053	0.174	23.6	0.083	0.326	244
	0.69	5	2.75	0.42	3.42	5.32	0.049	0.199	0.050	0.201	20.0	0.077	0.357	202
	0.67	5	3.25	0.53	3.79	7.16	0.050	0.237	0.051	0.238	18.0	0.076	0.401	177
	0.64	5	3.75	0.65	4.14	9.20	0.053	0.291	0.054	0.292	17.1	0.079	0.469	163
	combined				…	…	…	…	…	…	9.6	…	…	95
CIP	1.26	50	4	0.71	3.16	4.12	0.010	0.036	0.010	0.037	4.7	0.016	0.066	51
	1.13	50	5	1.03	3.72	6.76	0.010	0.047	0.010	0.048	4.0	0.015	0.079	40
	1.02	50	6	1.46	4.26	9.90	0.011	0.066	0.012	0.066	3.8	0.016	0.102	36
	combined				…	…	…	…	…	…	2.4	…	…	24

f_{NL} and large scale bias I

- From non-Gaussian curvature perturbation to density field

$$\Phi(\boldsymbol{x}) = \phi(\boldsymbol{x}) + f_{NL}(\phi^2(\boldsymbol{x}) + \langle\phi^2\rangle)$$

Taking Laplacian

$$\nabla^2\Phi = \nabla^2\phi + 2f_{NL}\left[\phi\nabla^2\phi + |\nabla\phi|^2\right]$$

grad(φ)=0 at the potential peak

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

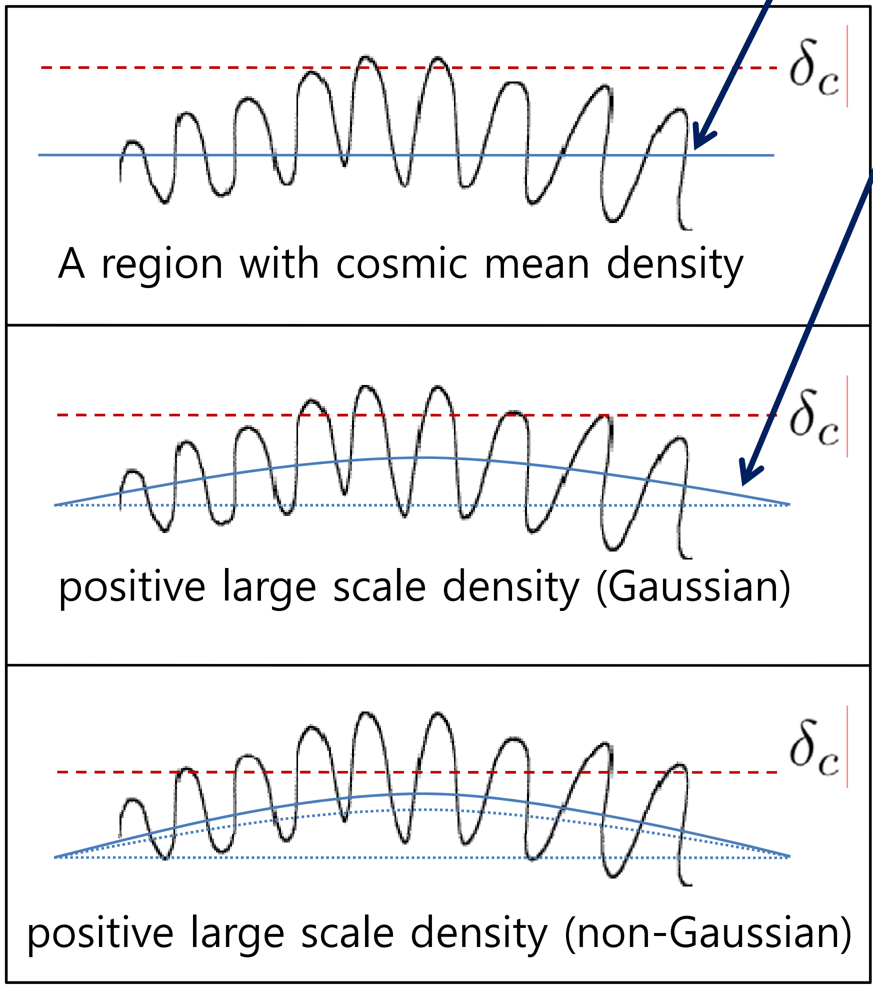
Poisson equation Laplacian(φ)∝δρ=δ<ρ>

$$\boxed{\delta_{NG} \simeq \delta(1 + 2f_{NL}\phi_p)}$$

Dadal et al.(2008); Matarrese&Verde(2008); Carmelita et al.(2008); Afshordi&Tolly(2008); Slosar et al.(2008);

f_{NL} and large scale bias II

- Heuristic understanding with peak background split method



- For **Gaussian case**, background density field provide an offset to the peaks, and <u>peak density contrast proportional to the large scale density contrast</u>. (linear bias)

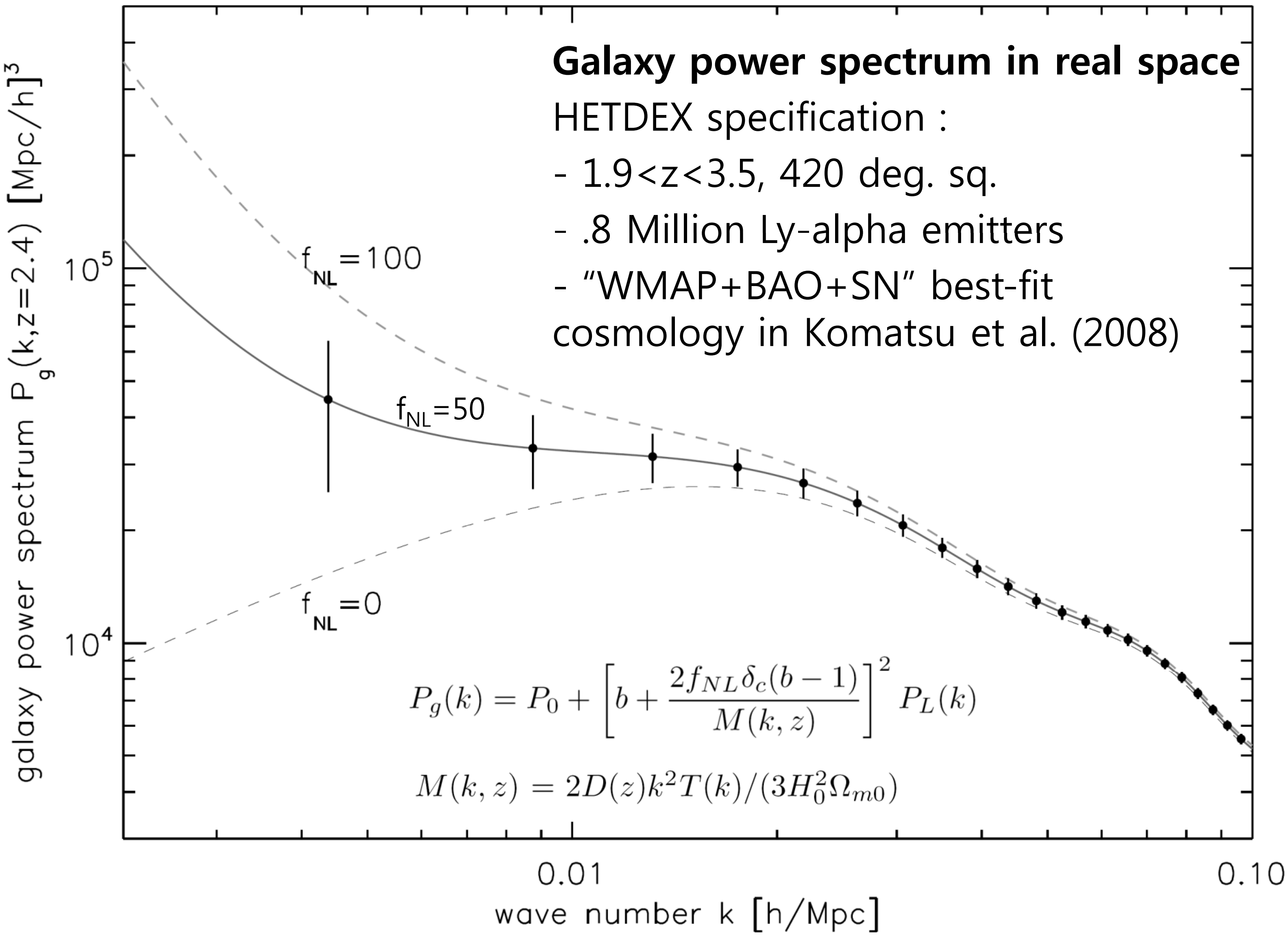
- For **non-Gaussian case**, on top of the large scale density contrast, <u>large scale curvature perturbation provide yet further offset to the peak</u>!

$$\delta_{NG} \simeq \delta(1 + 2f_{NL}\phi_p)$$

scale dependent!

$$\delta_h = b_L(\delta + 2f_{NL}\phi_p\delta_c)$$

HETDEX P(k) with f_{NL}



Result from Fisher matrix

- Fisher matrix for the redshift space power spectrum (Kaiser effect)

$$P_g(k,\mu) = P_0 + \left[b + \frac{2 f_{NL} \delta_c (b-1)}{M(k,z)} + f\mu^2 \right]^2 P_L(k)$$

- marginalized errors on f_{NL} (fiducial f_{NL} =50)

marginalized parameters	1σ error on f_{NL}
None	**10.34**
P_0	12.56
b	15.06
n_s	13.03
α_s	19.91
σ_8	14.75
f	11.90

marginalized parameters	1σ error on f_{NL}
b, σ_8	15.23
P_0,b	17.17
P_0,b,n_s	23.81
P_0,b,n_s,σ_8	24.06
P_0,b,n_s,σ_8,f	24.07
P_0,n_s, α_s,σ_8,f	50.21
P_0,b, n_s, α_s,σ_8	**52.63**

Conclusion

- Measuring primordial non-Gaussianity (f_{NL}) is very interesting because we can distinguish between "plain vanilla" and "exotic" inflation models.
- Current measurement of f_{NL} mainly comes from CMB bispectrum.
- There are many ways that we measure f_{NL} from large scale structure.
- For **HETDEX**, we can measure f_{NL} by using both bispectrum and large scale power spectrum. <u>Those two measurements are independent!!</u>