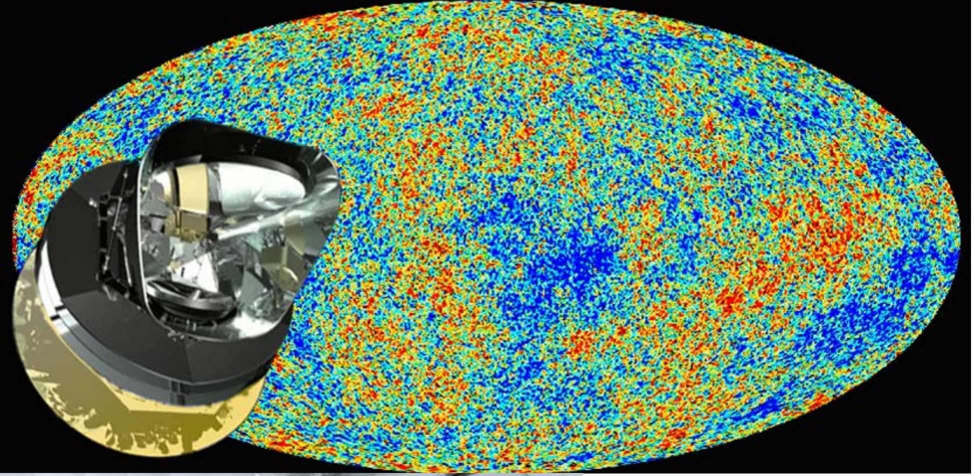
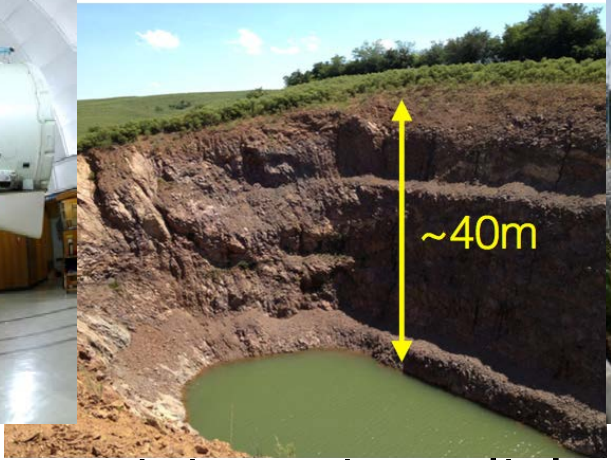




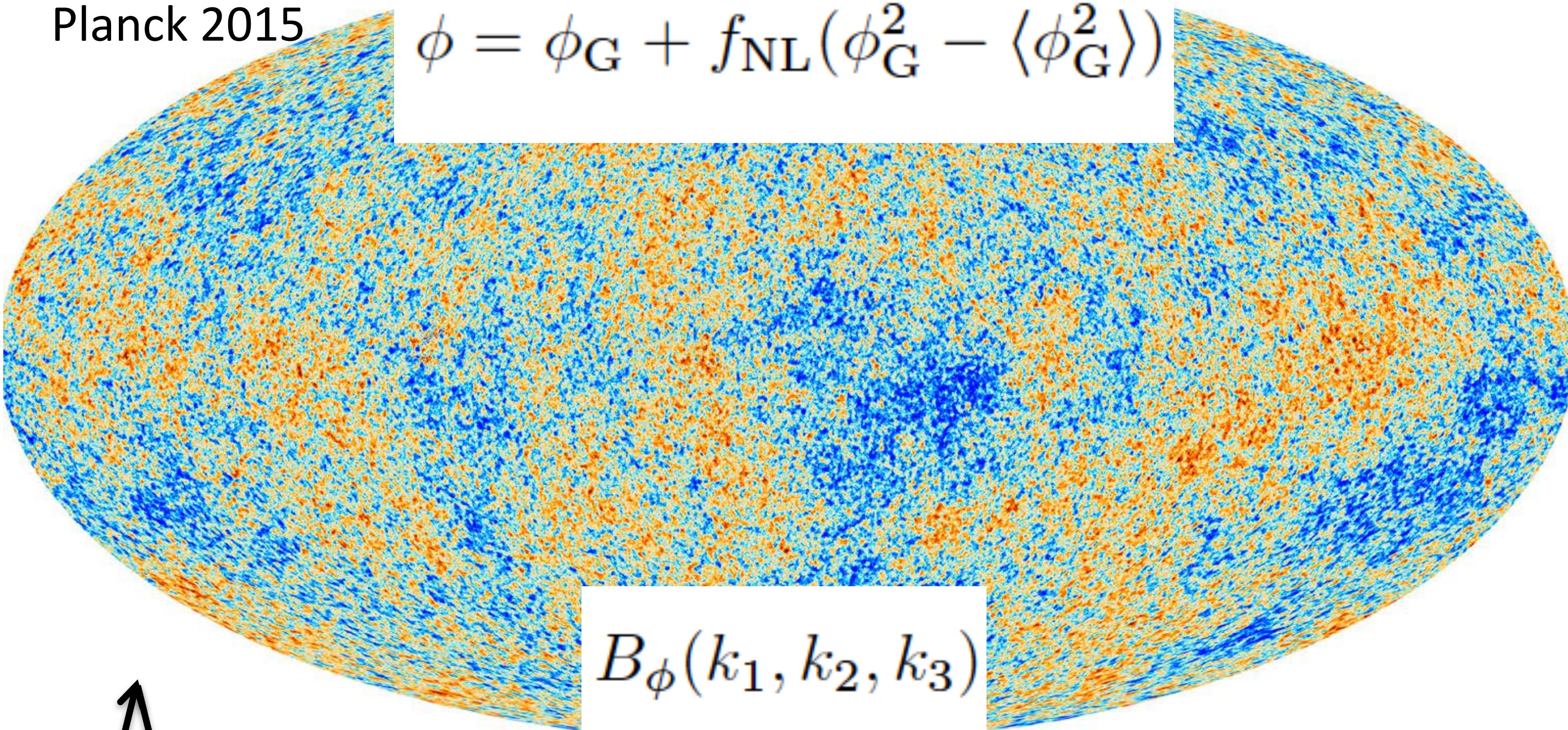
Constraining primordial non-Gaussianity with cosmiological observatoin

Yin-Zhe Ma

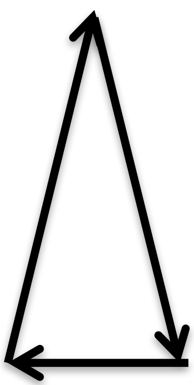
University of KwaZulu-Natal, South Africa

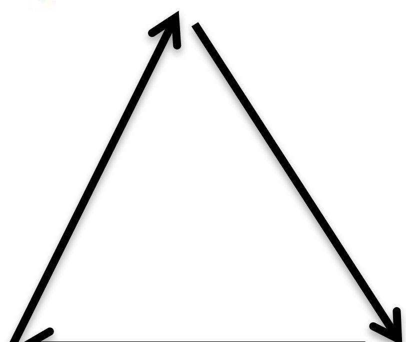
Planck 2015

$$\phi = \phi_{\rm G} + f_{\rm NL}(\phi_{\rm G}^2 - \langle \phi_{\rm G}^2 \rangle)$$



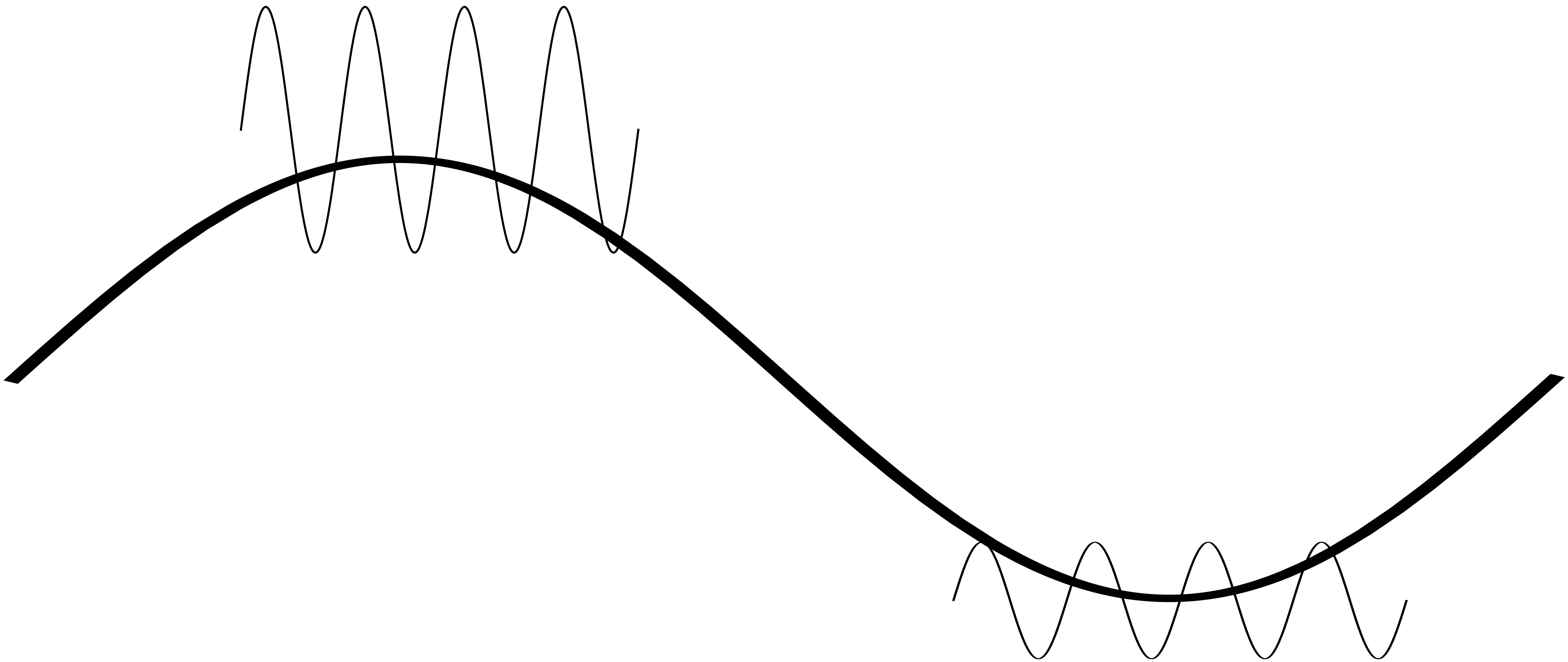
$$B_\phi(k_1, k_2, k_3)$$





Independent shape

$$f_{\rm NL}^{\rm local} = 0.8 \pm 5.0,\ f_{\rm NL}^{\rm equil} = -4 \pm 43 \text{ and } f_{\rm NL}^{\rm ortho} = -26 \pm 21$$



$$b_{\mathrm{E}} = b_{\mathrm{L}} + 1$$

See also Dalal et al. 2008

f_NL Constraint:

- Peculiar velocity field data
- (Future) 21-cm intensity mapping
- (Future) Multi-tracer technique

YZM, Douglas Scott, James E. Taylor, 2013, MNRAS
Yi-Chao Li and YZM, 2017, ArXiv: 1701.00221

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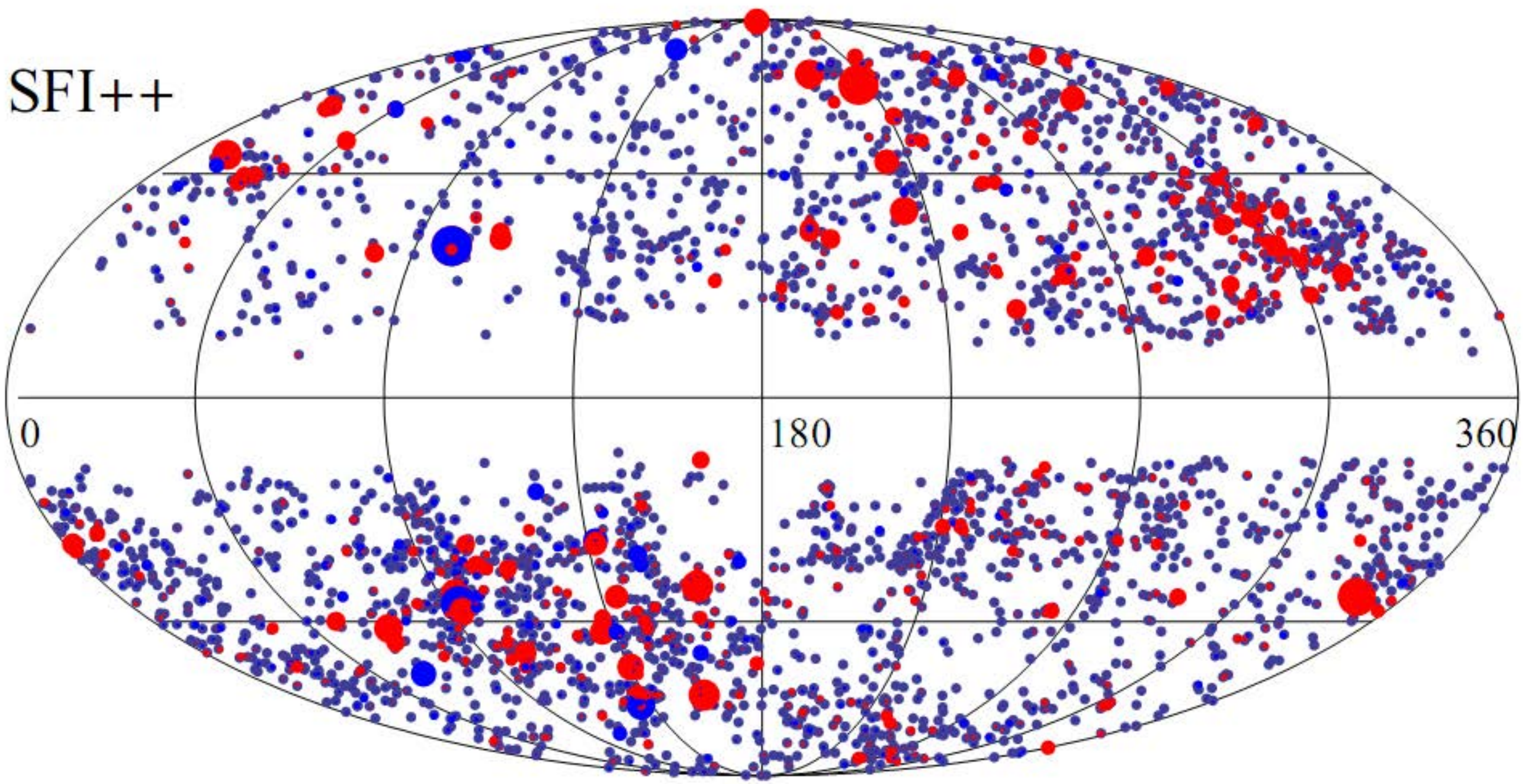


$$cz = H_0 r + v$$

Linear perturbation theory: (Peebles 1971)

Linear bias factor:

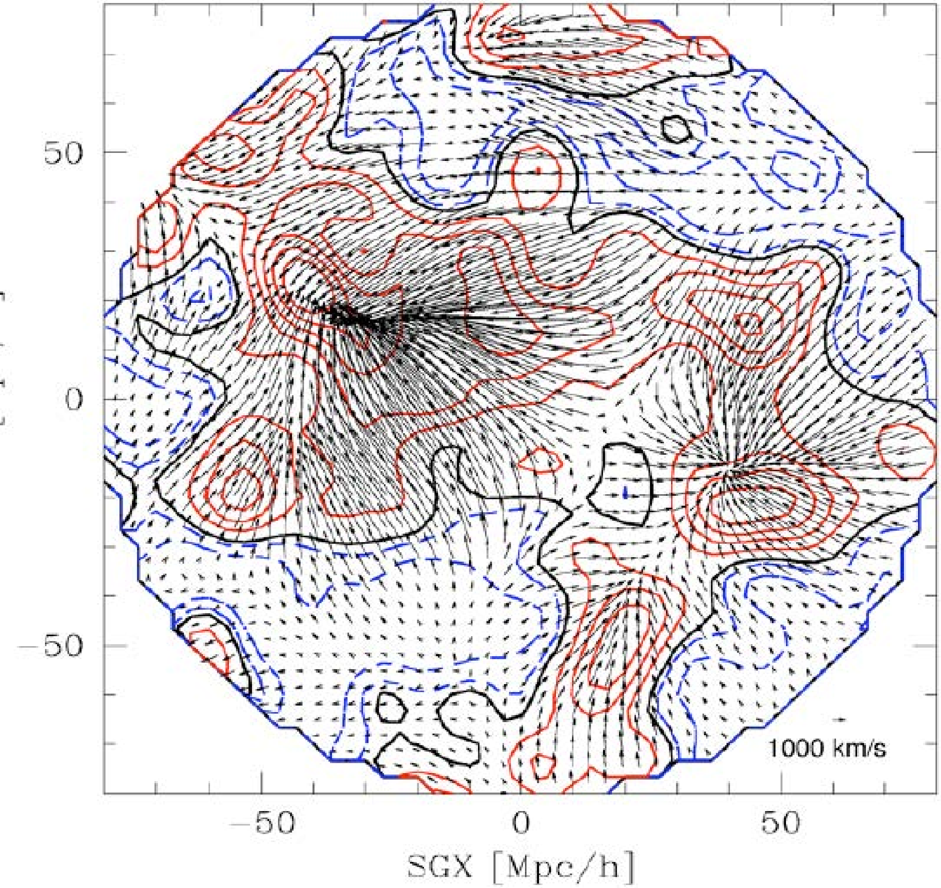
$$\vec{v}_{\rm g}(\vec{x}) = \frac{H_0 f_0}{4\pi}\int d^3\vec{x}'\,\delta_{\rm m}(\vec{x}',t)\frac{(\vec{x}'-\vec{x})}{|\vec{x}'-\vec{x}|^3}$$

$$\delta_{\rm g} = b\delta_{\rm m} \qquad\qquad f \equiv \frac{a}{D_1}\frac{dD_1}{da}$$

$$\vec{v}_{\rm g}(\vec{x}) = \frac{H_0 \beta}{4\pi}\int d^3\vec{x}'\,\delta_{\rm g}(\vec{x}',t)\frac{(\vec{x}'-\vec{x})}{|\vec{x}'-\vec{x}|^3}$$

$$\beta = \frac{f_0}{b} = \frac{f_0}{(\sigma_8^{gal}/\sigma_8)}$$

$$\beta\sigma_8^{gal} = f_0\sigma_8$$

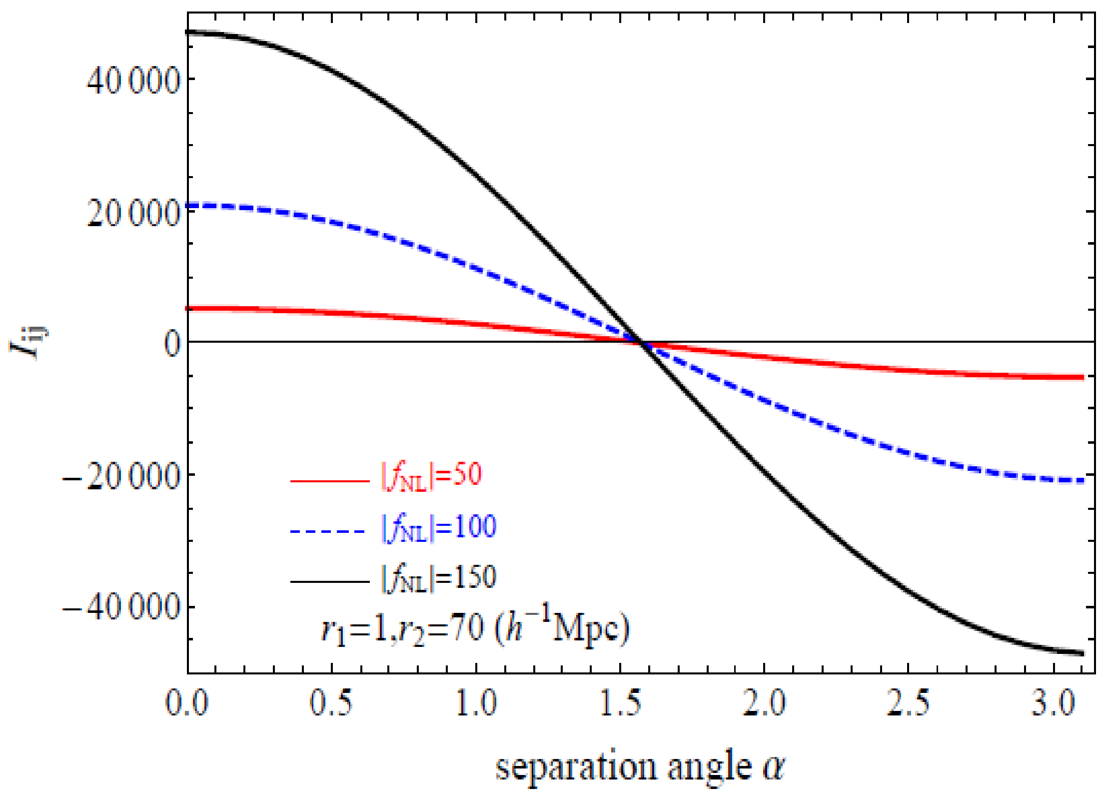


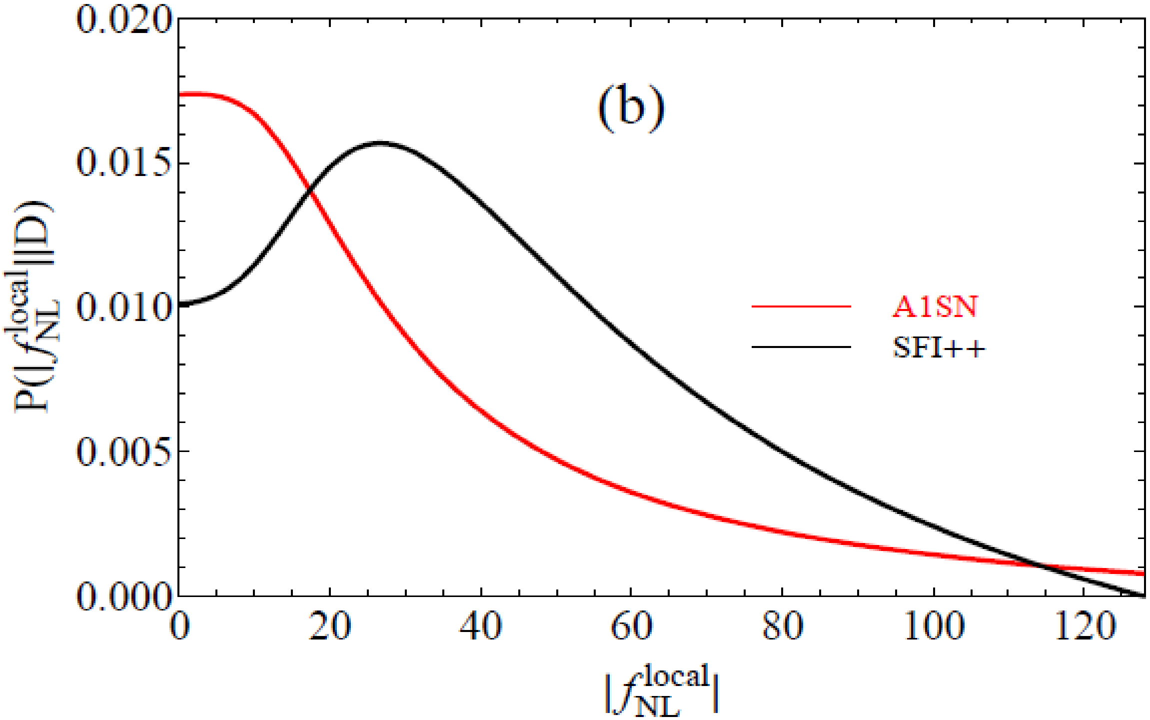
$$\mathbf{v}(\mathbf{r}) = \frac{H_0\beta}{4\pi}\int d^3\mathbf{r}'\delta_g(\mathbf{r}')\frac{\mathbf{r}'-\mathbf{r}}{|\mathbf{r}'-\mathbf{r}|^3} - \frac{iH_0(f/b)}{(2\pi)^3}\int d^3\mathbf{k}(\Delta b(k))\delta_m(\mathbf{k})\frac{\mathbf{k}}{k^2}\exp(i\mathbf{k}\cdot\mathbf{r})$$

Dalal 2008:

$$\Delta b(k) = (b-1)f_{NL}^{local}A(k) \qquad A(k) = \frac{3\delta_c(z)\Omega_m h^2}{k^2T(k)}\left(\frac{H_0}{c}\right)^2$$

The extra term in the V(r) caused by non-Gaussianity will add more spatial correlation in the covariance matrix.





Data set	Model	β value	$\left\|f_{\rm NL}^{\rm local}\right\|$ value	$-\log L_{\rm min}$
A1SN	β- $f_{\rm NL}^{\rm local}$	$0.53^{+0.15}_{-0.04}$	0.0 ± 25.7	681.7
	β-only	$0.65^{+0.07}_{-0.06}$		681.7
SFI++	β- $f_{\rm NL}^{\rm local}$	$0.49^{+0.03}_{-0.05}$	26.6 ± 33.0	14159.1
	β-only	$0.49^{+0.04}_{-0.03}$		14159.1

Comparing with others:

(i) Radio sources from the NRAO VLA Sky Survey (NVSS), the quasar and MegaZ-LRG (DR7) catalogues of the SDSS, and the SDSS LRG redshift survey (Xia et al.(2011) found):

$$f_{\rm NL}^{\rm local} = 48 \pm 20 \ (1\sigma{\rm CL}). \tag{8}$$

(ii) Photometric SDSS data (Nikoloudakis et al. (2013)):

$$f_{\rm NL}^{\rm local} < 120 \ (84\%). \tag{9}$$

(iii) SDSS-III (BOSS) DR9 (Ross et al. (2013)):

$$-45 < f_{\rm NL}^{\rm local} < 195 \ (2\sigma{\rm CL}). \tag{10}$$

(iv) *Planck* CMB (2013):

$$-45 < f_{\rm NL}^{\rm local} = 2.7 \pm 5.8 \ (1\sigma{\rm CL}). \tag{11}$$

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No time to mention foreground analysis, see Richard Shaw's talk.

Bias

$$b_{\mathrm{HI}}^{\mathrm{NG}}(z,k) = b_{\mathrm{HI}}(z) + \Delta b_{\mathrm{HI}}(z,k)$$

$$\Delta b_{\mathrm{HI}}(z,k) = \frac{1}{\rho_{\mathrm{HI}}(z)} \int_{M_{\mathrm{min}}}^{M_{\mathrm{max}}} \mathrm{d}M$$

$$b_{\mathrm{HI}} \qquad \times \frac{\mathrm{d}n}{\mathrm{d}M}(M,z) M_{\mathrm{HI}}(M) \Delta b(M,z,k) \quad M, z),$$

$$\Delta b^{\mathrm{MV}}(M,z,k) = 2 f_{\mathrm{NL}} \left(\frac{\delta_{\mathrm{c}}^2(z)}{\sigma_R^2} \right) \frac{\mathcal{F}(k)}{\mathcal{M}_R(k)}$$

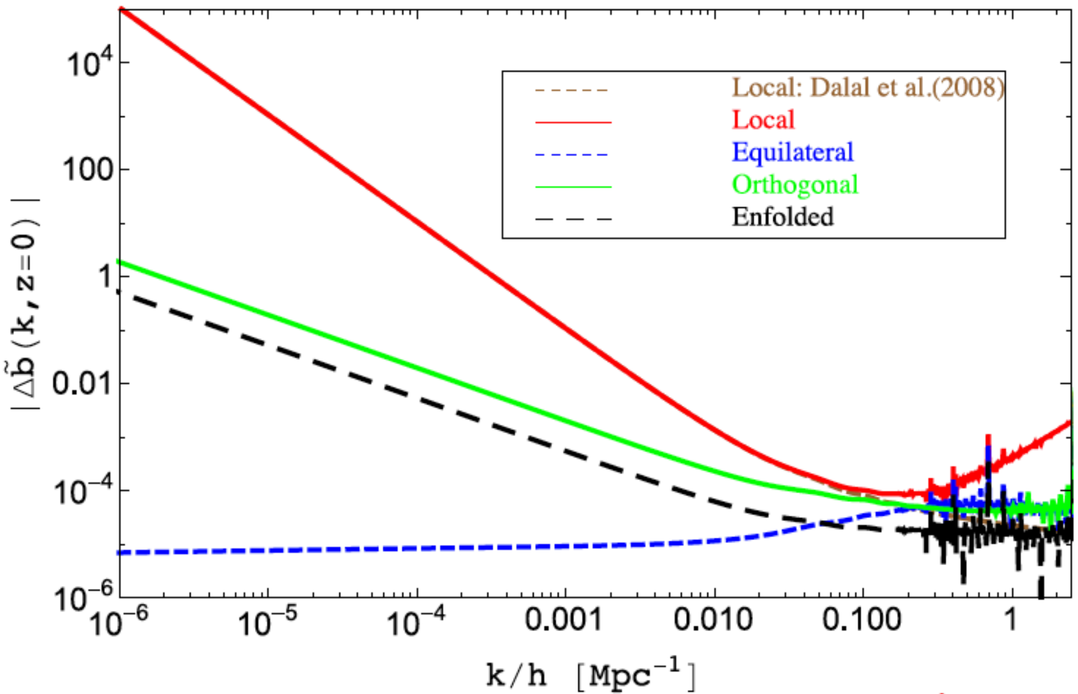
$$\mathcal{F}(k) = \frac{1}{16\pi^2 \sigma_R^2} \int \mathrm{d}k_1 k_1^2 \mathcal{M}_R(k_1)$$

$$\times \int_{-1}^{1} \mathrm{d}\mu \mathcal{M}_R(k_2) \frac{B_\phi(k_1,k_2,k)}{P_\phi(k)}$$

S. Matarrese and L. Verde, 2008

N. Dalal, et al., 2008

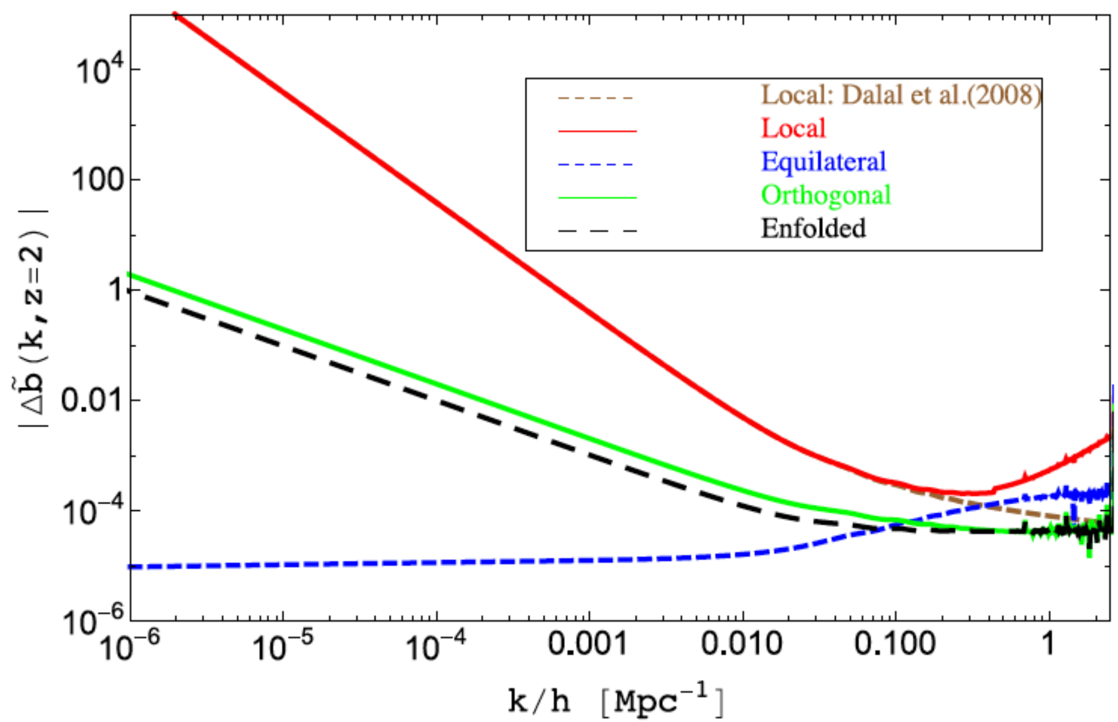
Y.-C. Li and YZM, 2017, ArXiv: 1701.00221

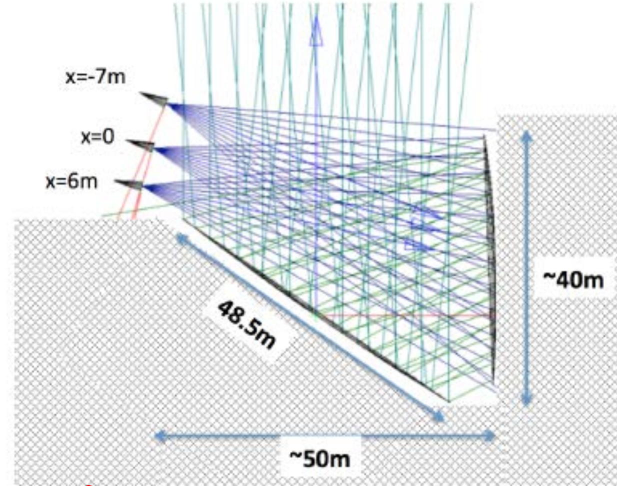


Yi-Chao Li and YZM, 2017, ArXiv: 1701.00221

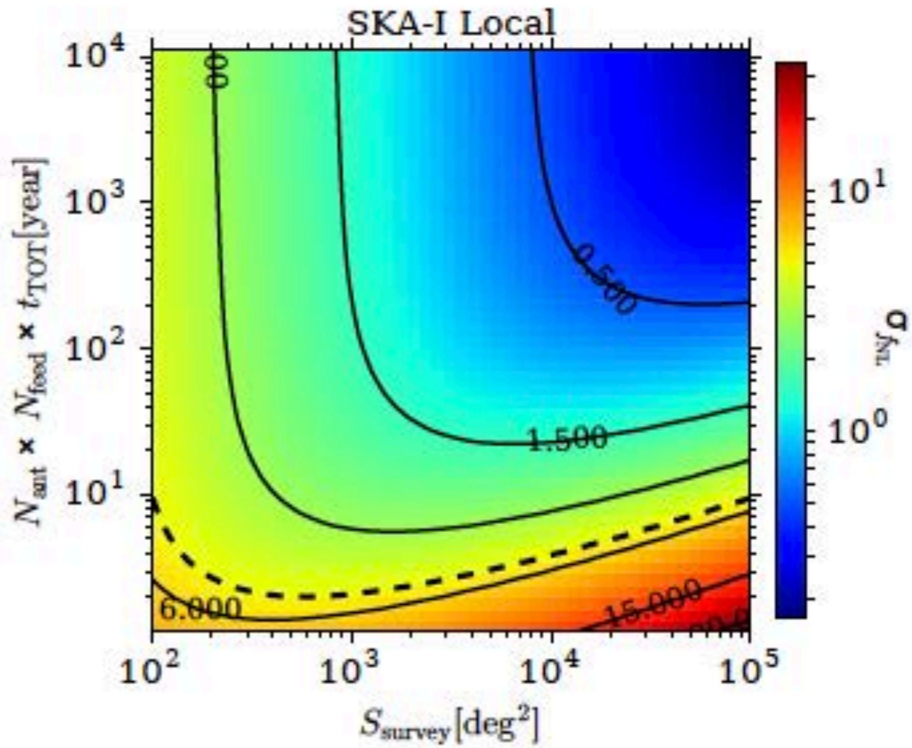
C. Fedeli et al., 2011, MNRAS

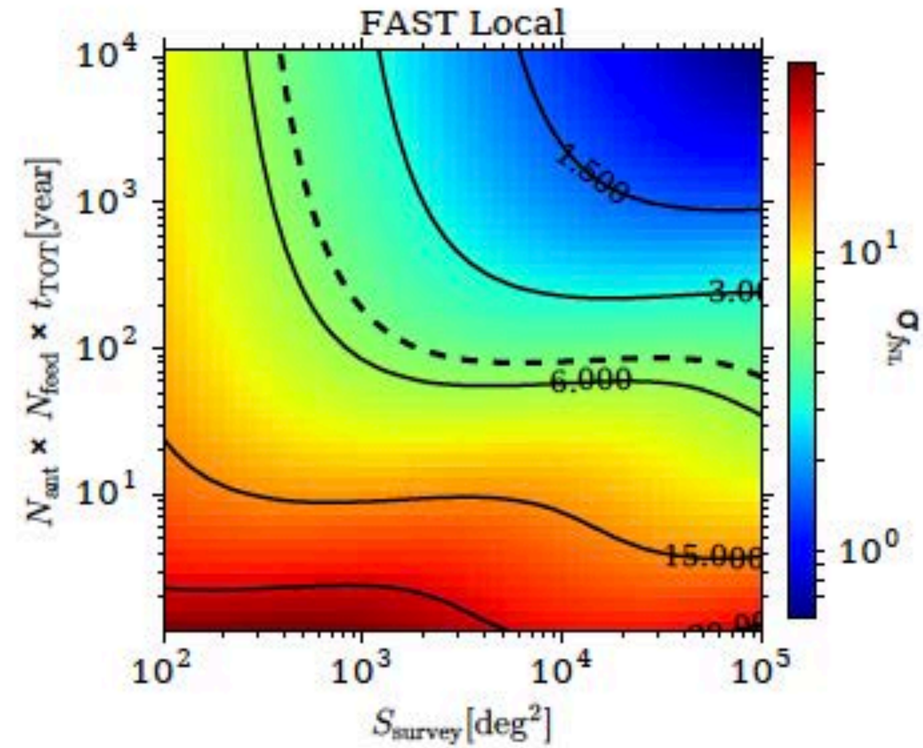
$$\Delta b(\mathrm{Local}) \sim k^{-2}$$
$$\Delta b(\mathrm{Equilateral}) \sim \mathrm{const}$$
$$\Delta b(\mathrm{Enfolded}) \sim k^{-1}$$
$$\Delta b(\mathrm{Orthogonal}) \sim k^{-1}.$$





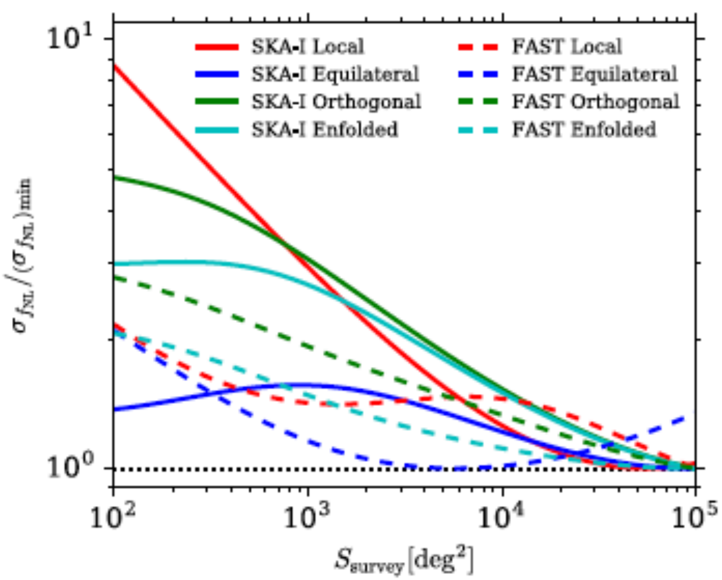
	FAST	SKA-I	BINGO
$\nu_{\rm min}$[MHz]	1050	350	960
$\nu_{\rm max}$[MHz]	1350	1050	1260
$\Delta\nu$[MHz]	10	10	10
$n_\nu(n_z)$	30	70	30
$D_{\rm dish}$[m]	300	15	25
$N_{\rm ant}\times N_{\rm feed}$	1×19	190×1	1×60
$t_{\rm TOT}$[yr]	1	1	1
$T_{\rm rec}$[K]	25	28	50
$S_{\rm survey}$[deg^2]	<24000	<25000	2500

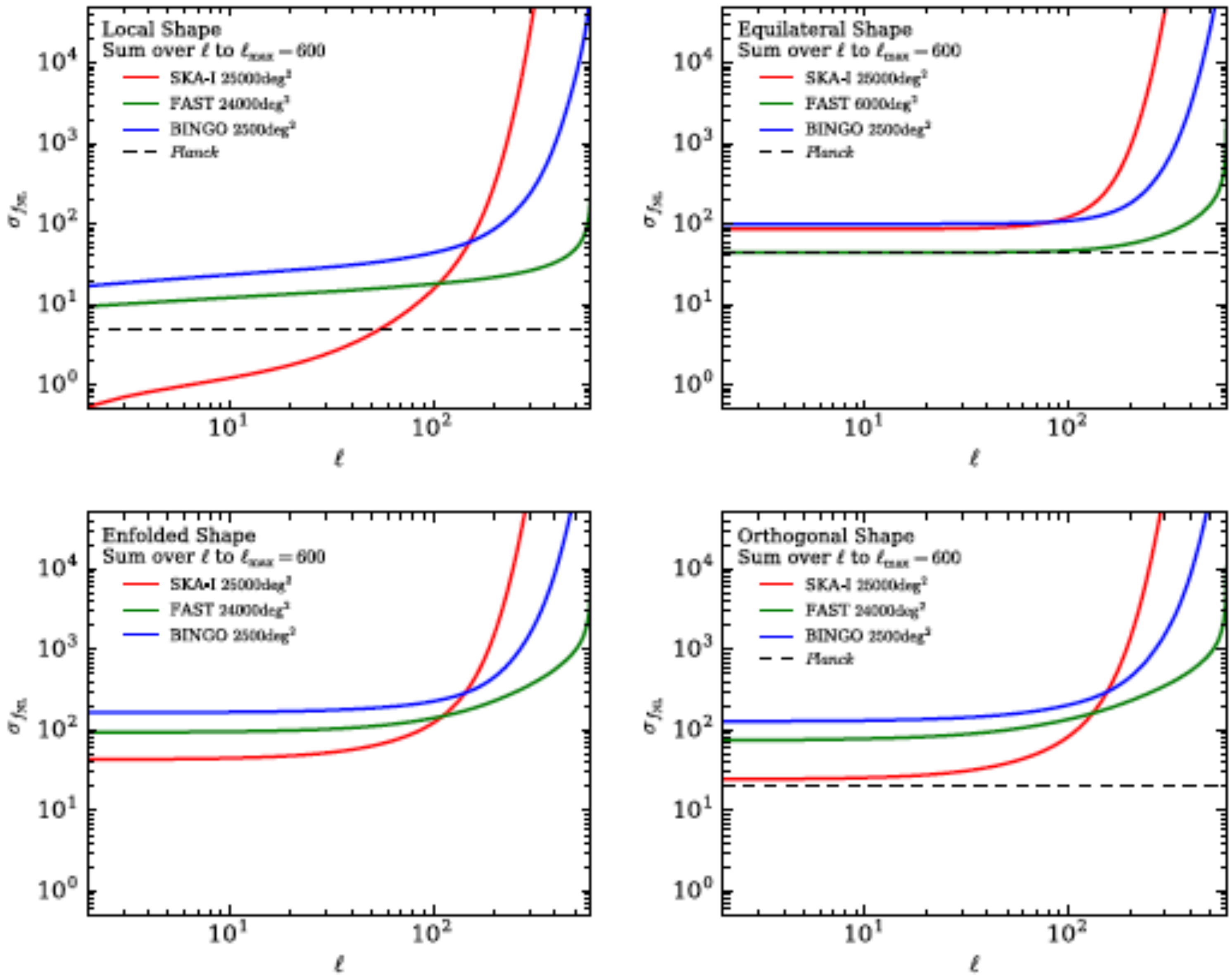




Yi-Chao Li and YZM, 2017, ArXiv: 1701.00221

S. Camera, M. G. Santos, P. G. Ferreira, and L. Ferramacho, 2013, PRL





Yi-Chao Li and YZM, 2017,
ArXiv: 1701.00221

	Planck 2015	Current Configuration			Extentions		
		FAST	SKA-I	BINGO	SKA-I 2yr[†]	FAST 2yr[††]	FAST low[‡]
Local	5	9.5	**0.54**	17	**0.43**	7.4	**1.6**
Equilateral	43	44	86	100	66	**32**	53
Orthogonal	21	75	25	128	**20**	59	39
Enfolded	–	94	43	164	36	70	64

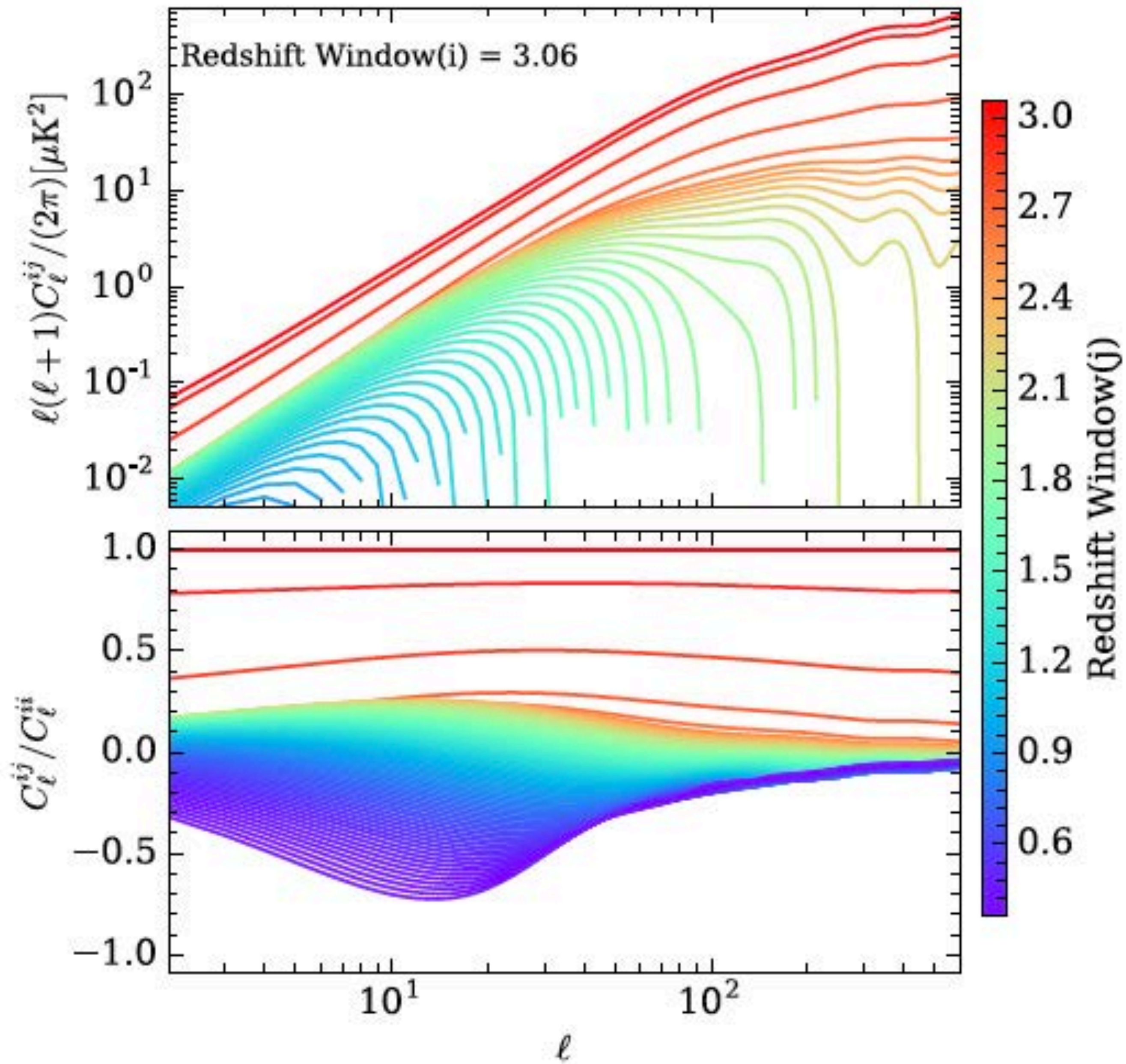
† SKA-I with two-year observation; †† FAST with two-year observation; ‡ FAST with low frequencies range from 350MHz to 1050MHz

Extended to 2-years, extended to 250 MHz receivers

Y.-C. Li and YZM, 2016, 1701.00221

Conclusion

- Understanding the primordial fluctuation is a crucial way of understanding the initial condition of the Universe
- Besides the CMB measurement on bispectrum, the measurement from cosmic peculiar velocity field, and 21-cm intensity mapping can provide complementary constraints on f_NL.
- By using the extra correlation between residual velocity on different directions, we can constrain the local shape of f_NL to be less than 25.7 at 1-sigma CL.
- We forecasted that the future constraints on f_NL from single-dish intensity mapping method on large scales can be comparable with Planck satellite, provides a complementary method to access primordial non-Gaussianity.
- Complimentary method (e.g. Multi-tracer) has also been developed to overcome the cosmic variance problem, improving precision of f_NL measurements.



Redshift Window(i) = 3.06
$\ell(\ell+1)C_\ell^{ij}/(2\pi)[\mu K^2]$
10^2
10^1
10^0
10^{-1}
10^{-2}
1.0
0.5
0.0
−0.5
−1.0
C_ℓ^{ij}/C_ℓ^{ii}
10^1
10^2
ℓ
Redshift Window(j)
3.0
2.7
2.4
2.1
1.8
1.5
1.2
0.9
0.6