TECHNION
Israel Institute
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The redshift space galaxy power spectrum

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1806.04015 (with Donghui Jeong and Fabian Schmidt)

$$\frac{2}{3\Omega_m \mathcal{H}^2}\partial_i\partial_j\Phi = K_{ij} + \frac{1}{3}\delta_{ij}\delta$$

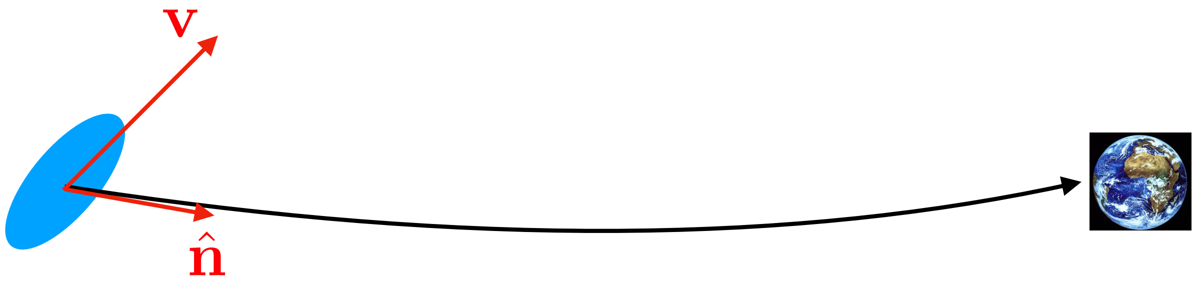
real space / rest frame:

$$\delta_g = b_1\delta + \frac{1}{2}b_2\delta^2 + b_{K^2}K^2 + \ldots$$
$$+ b_{\nabla^2\delta}\nabla^2\delta + \ldots$$
$$+ b_{\rm td}O_{\rm td} + \ldots$$
$$+ \text{stochastic terms}$$

redshift space:

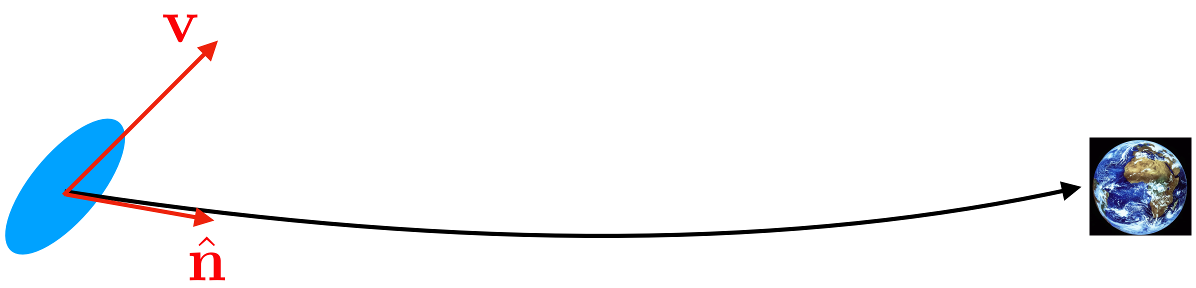
selection effects

projection effects $\supset$ RSD



$$u_{\parallel} \equiv \frac{1}{\mathcal{H}} \hat{n}^i v_i$$

$$\partial_{\parallel} \equiv \hat{n}^i \partial_i$$

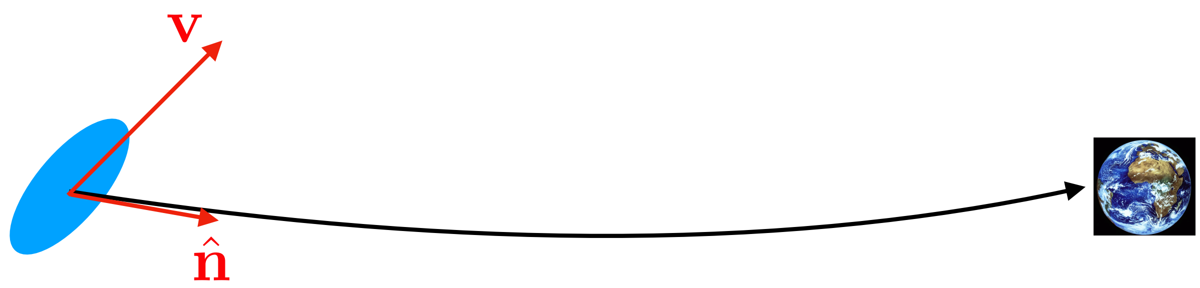


$$u_\parallel \equiv \frac{1}{\mathcal{H}}\hat{n}^i v_i$$

$$\partial_\parallel \equiv \hat{n}^i \partial_i$$

$$\text{selection effects} \quad \supset \quad \begin{aligned} & \partial_\parallel^2 \Phi \propto \eta \\ & \eta\delta \\ & \hat{n}^i\hat{n}^j K_{il}K_{lj} \equiv (KK)_\parallel \\ & \nabla^2\eta \\ & \text{etc.} \end{aligned}$$

$$\eta \equiv \partial_\parallel u_\parallel$$



$$u_{\parallel} \equiv \frac{1}{\mathcal{H}} \hat{n}^i v_i$$

$$\partial_{\parallel} \equiv \hat{n}^i \partial_i$$

$$\left[1 + \delta_{g,s}(\mathbf{x}_s)\right] d^3 x_s = \left[1 + \delta_g(\mathbf{x})\right] d^3 x$$

$$\mathbf{x}_s = \mathbf{x} + u_{\parallel} \hat{\mathbf{n}}$$

$$\delta_{g,s} = \delta_g + \sum_{n=1}^{\infty} \frac{(-1)^n}{n!} \partial_{\parallel}^n \left[u_{\parallel}^n (1 + \delta_g) \right]$$

$$\supset \frac{1 + \delta_g}{1 + \eta} - 1 = \delta_g - \eta - \delta_g \eta + \eta^2 + \dots$$

$$\eta \equiv \partial_{\parallel} u_{\parallel}$$

$$u_\parallel \equiv \frac{1}{\mathcal{H}}\hat{n}^i v_i$$

$$\partial_\parallel \equiv \hat{n}^i \partial_i$$

$$\mathbf{v}_g = \mathbf{v} + \beta_{\nabla^2\mathbf{v}}\nabla^2\mathbf{v} + \beta_{\partial_\parallel^2\mathbf{v}}\partial_\parallel^2\mathbf{v} + \text{stochastic terms}$$

$$\eta_g = \eta + \beta_{\nabla^2\mathbf{v}}\nabla^2\eta + \beta_{\partial_\parallel^2\mathbf{v}}\partial_\parallel^2\eta + \text{stochastic terms}$$

$$u_{\parallel} \equiv \frac{1}{\mathcal{H}} \hat{n}^i v_i$$

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$$\eta_g = \eta + \beta_{\nabla^2 \mathbf{v}} \nabla^2 \eta + \beta_{\partial_{\parallel}^2 \mathbf{v}} \partial_{\parallel}^2 \eta + \text{stochastic terms}$$

RSD $\supset$ $\partial_{\parallel} u_{\parallel} = \eta$

$\eta\delta$

~~$\hat{n}^i \hat{n}^j K_{il} K_{lj} = (KK)_{\parallel}$~~

$\nabla^2 \eta$

$u_{\parallel} \partial_{\parallel} \delta$

etc.

RSD + selection effects:

$$\delta_g = b_1\delta + \frac{1}{2}b_2\delta^2 + b_{K^2}K^2 + \dots$$

$$+ b_{\nabla^2\delta}\nabla^2\delta + \dots$$

$$+ b_{\rm td}O_{\rm td} + \dots$$

$$+ \text{stochastic terms}$$

$$+ b_\eta\eta + b_{\eta\delta}\eta\delta + b_{\eta^2}\eta^2 + \dots$$

$$+ b_{(KK)_\parallel}(KK)_\parallel + \dots$$

$$+ b_\eta\left(\beta_{\nabla^2\mathbf{v}}\nabla^2\eta + \beta_{\partial_\parallel^2\mathbf{v}}\partial_\parallel^2\eta\right) + \dots$$

$$- b_1 u_\parallel\partial_\parallel\delta + \dots$$

RSD, no selection effects:

$$\delta_g = b_1\delta + \frac{1}{2}b_2\delta^2 + b_{K^2}K^2 + \ldots$$

$$+ b_{\nabla^2\delta}\nabla^2\delta + \ldots$$

$$+ b_{\rm td}O_{\rm td} + \ldots$$

$$+ \text{stochastic terms}$$

$$-\ \eta\ \ -b_1\,\eta\delta\qquad +\eta^2 + \ldots$$

$$-\ \left(\beta_{\nabla^2\mathbf{v}}\nabla^2\eta + \beta_{\partial_\parallel^2\mathbf{v}}\partial_\parallel^2\eta\right) + \ldots$$

$$- b_1 u_\parallel \partial_\parallel \delta + \ldots$$

Redshift space galaxy power spectrum at NLO:

$$\epsilon_{\rm loop} \propto \left(\frac{k}{k_{\rm NL}}\right)^{3+n} \sim \left(\frac{k}{k_{\rm NL}}\right)^{1-1.5}$$

$$\epsilon_{\rm deriv} \propto k^2 R_g^2 \sim k^2 R_M^2$$

shot noise amplitudes

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shot noise amplitudes

+ redshift-space galaxy bispectrum at LO:

- *3 additional stochastic amplitudes*
- *All the contributions have distinct shapes (also .w.r.t. line of sight)*

NLO galaxy power spectrum + LO galaxy bispectrum

RSD + selection effects:

5	galaxy bias parameters
5	stochastic amplitudes
9	selection parameters
2	deterministic velocity bias parameters
1	stochastic velocity bias amplitude
22	

RSD, no selection effects:

5	galaxy bias parameters
4	stochastic amplitudes
1	deterministic velocity bias parameters
1	stochastic velocity bias amplitude
11	

All this is perfectly consistent with the streaming model, e.g.

$$P^{\rm LO}_{gg,s}(k,\mu) = \left(1 - f^2k^2\mu^2\sigma_v^2\right)P^{\rm LO}_{gg}(k) + ifk\mu u_{g12}(\mathbf{k}) - \frac{1}{2}f^2k^2\mu^2\sigma^2_{g12}(\mathbf{k})$$

All this is perfectly consistent with the streaming model, e.g.

$$P_{gg,s}^{\rm LO}(k,\mu) = \left(1 - f^2 k^2 \mu^2 \sigma_v^2\right) P_{gg}^{\rm LO}(k) + i f k \mu u_{g12}(\mathbf{k}) - \frac{1}{2} f^2 k^2 \mu^2 \sigma_{g12}^2(\mathbf{k})$$

The redshift-space power spectrum is

$$P_s(k_\parallel, \mathbf{k}_\perp) = \int d^2\mathbf{r}_\perp e^{-i\mathbf{k}_\perp \cdot \mathbf{r}_\perp} \int dr_\parallel e^{-ik_\parallel r_\parallel}\, \xi(r)\, \mathcal{M}(ik_\parallel f, \mathbf{r}) + \frac{1}{\bar{n}}$$

i.e. the constant shot noise piece does not depend on mu:

$$P_s(k_\parallel, \mathbf{k}_\perp) \stackrel{k\to 0}{=} \int d^3r\, \xi(r) + \frac{1}{\bar{n}} \equiv P_\epsilon$$

$$P_{gg,s}^{\mathrm{LO+NLO}}(k,\mu) = P_{gg,s}^{\mathrm{l+hd}} + P_{gg,s}^{2-2}(k,\mu) + 2P_{gg,s}^{1-3}(k,\mu)$$

23 "2 – 2" loop integrals

5 "1 – 3" loop integrals