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UNIVERSE+ Online Seminar

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“Wilson-Polchinski renormalization group for large-scale structure”

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Wilson-Polchinski RG for LSS

Based on: arXiv: 2307.15031
2404.16929

Henrique Rubira & FS

Gal. formation:

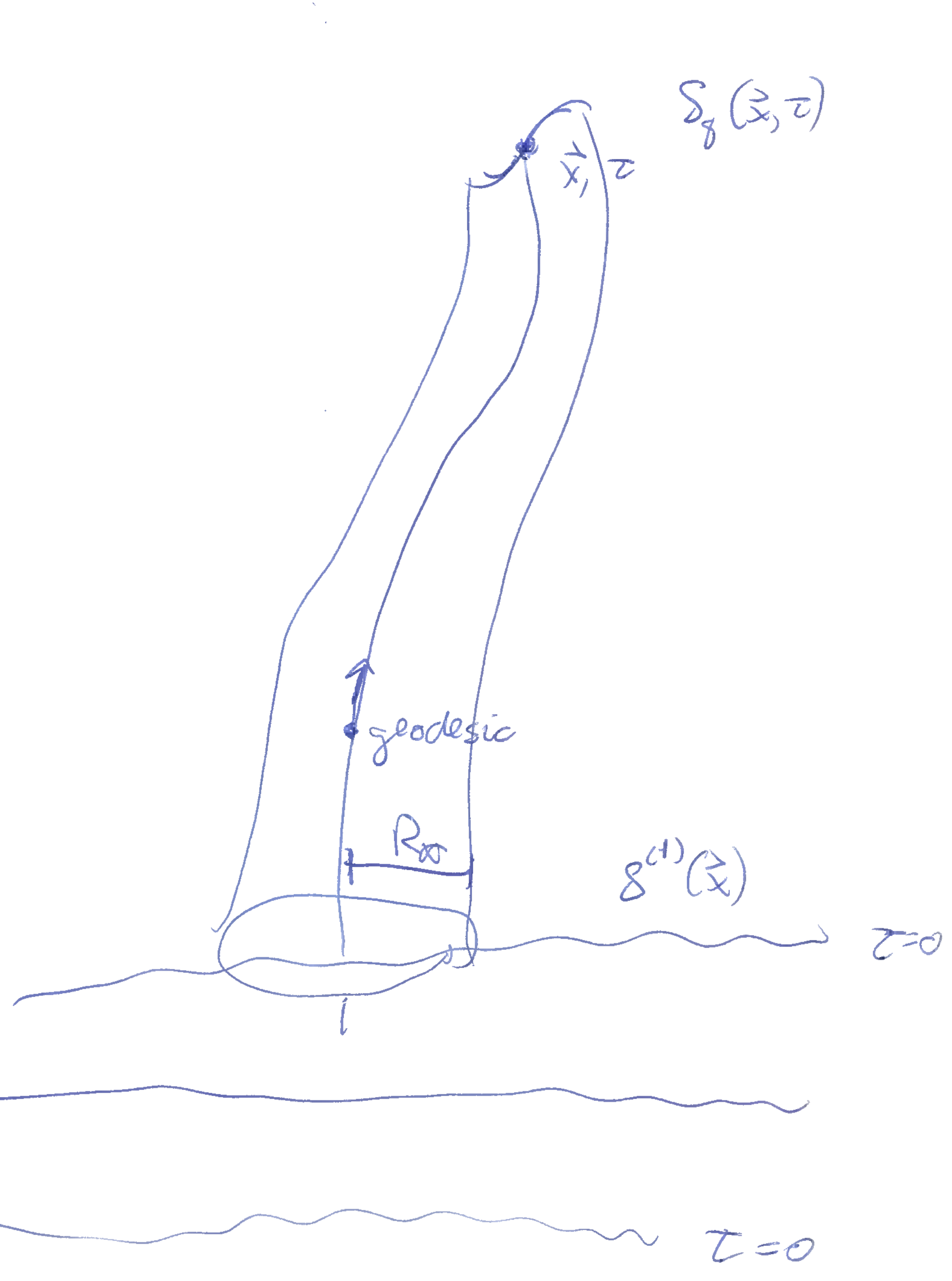
- spatially local
- equivalence principle

⤳ closed (at fixed order in PT) of grav. Observables $O[\vec{x}, \tau]$

$\Uparrow$

solutions to EFT of LSS e.o.m.

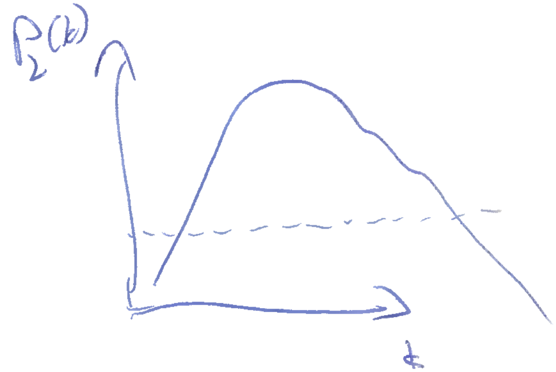
$$\{O\} \supset \delta, \left(\frac{\partial_i \partial_j}{\nabla^2}\delta\right)^2, \cancel{\frac{1}{\nabla^2}\delta}$$



Gal. density field $\delta_g(\vec{x}, \tau) = \dfrac{n_g(\vec{x},\tau)}{\bar{n}_g(\tau)} - 1$ 1st order in PT

$\hookrightarrow$ drop

$$\delta^{(1)}(\vec{k}) \sim \mathcal{N}(0, P_L(k))$$



$$Z_{\delta^{(1)}}[J] = \int \mathcal{D}\delta^{(1)} \exp\left[-\frac{1}{2}\int_k \frac{|\delta^{(1)}(\vec{k})|^2}{P_L(k)} + \int_k \vec{J}(\vec{k}) \cdot \delta^{(1)}(-\vec{k})\right] \times \mathcal{N}$$

$\rightsquigarrow$ galaxies:

$$Z[J] = \mathcal{N} \int \mathcal{D}\delta^{(1)} \exp\left[-\frac{1}{2}\int_k \frac{|\delta^{(1)}(\vec{k})|^2}{P_L(k)} + \int_k J(-\vec{k}) \left\{ \sum_O b_O\, O[\delta^{(1)}](\vec{k}) \right\} + \frac{1}{2} \cdot P_\varepsilon \int_k |J(\vec{k})|^2 \right]$$

Gal. power spectrum:

$$\frac{\mathcal{D}}{\mathcal{D}J(\vec{k})} \frac{\mathcal{D}}{\mathcal{D}J(\vec{k})} Z[J]\Big|_{J=0} = \sum_{O,O'} b_O b_{O'} \left\langle O[\delta^{(1)}](\vec{k})\, O'[\delta^{(1)}](-\vec{k}) \right\rangle_{\delta^{(1)}} \quad \text{"det."}$$

$$+ P_\varepsilon \quad \text{"stoch."}$$

Full EFT part. fct. for galaxies:

$$Z[J] = \mathcal{N} \int \mathcal{D}\delta^{(1)} \exp\left[-\frac{1}{2} \int_k \frac{|\delta^{(1)}(\vec{k})|^2}{P_L(k)} + S_{eff}[\delta^{(1)}, J] \right]$$

$$S_{eff}[\delta^{(1)}, J] = \sum_{m=1}^{\infty} \sum_{O, \mathbb{1}} \frac{C_O^{(m)}}{m!} \int_x J^m(\vec{x})\, O[\delta^{(1)}](\vec{x})$$

$\rightsquigarrow$ derive 2-pt, 3-pt functions

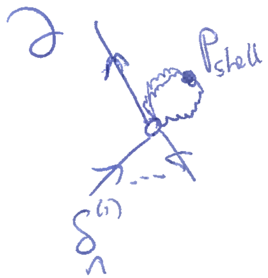
$$\langle \delta_g \, \delta_g \, \delta_g \rangle = \langle O \; O' \; O'' \rangle$$
$$+ \, C^{(2)} \langle O \; O' \rangle$$
$$+ \, C_{\mathbb{1}}^{(3)}$$

Wilson-Polchinski RG

$\delta^{(1)} \to \delta^{(1)}_\Lambda \rightsquigarrow C_O^{(m)}(\Lambda)$

$\Lambda \leftarrow \Lambda' = \Lambda + \lambda$ (λ infinitesimal) $\Rightarrow$ $\delta^{(1)}_{\Lambda'} = \delta^{(1)}_\Lambda + \delta_{shell}$

$$Z[J] = \int \mathcal{D}\delta_\Lambda^{(1)}\, P[\delta_\Lambda^{(1)}] \boxed{\int \mathcal{D}\delta_{\text{shell}}\, P[\delta_{\text{shell}}]\, \exp\left[S_{\text{eff}}\left[J, \delta_\Lambda^{(1)} + \delta_{\text{shell}}^{(1)}\right]\right]}$$



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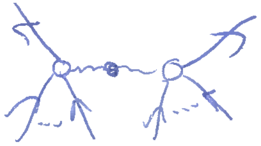


bias renormalization

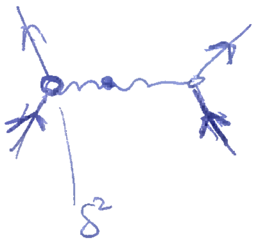
$\rightarrow$ stoch. term

$$\rightsquigarrow \frac{d}{d\Lambda} b_O^\Lambda = - \frac{d\sigma_\Lambda^2}{d\Lambda^2} \sum_{O'} c_{OO'}\, b_{O'}^\Lambda$$

(1st paper)

$$\sigma_\Lambda = \langle (\delta_\Lambda^{(1)})^2 \rangle = \int_0^\Lambda \frac{d^3k}{(2\pi)^3} P_L(k)$$

Renormalizing stoch. contr.s

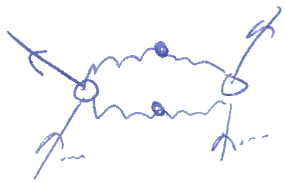


$$\sim \int_x \gamma(\vec x)\,\delta_\Lambda^{(1)}(\vec x)\int_{x'} \gamma(\vec x')\,\delta_\Lambda^{(1)}(\vec x')\;\xi_{shell}(\vec x-\vec x') \sim 1/\Lambda$$

$\rightsquigarrow$ local approx:

- "thin shell" $\Rightarrow$ ~~exactly 2 instances~~ 1 loop in ξ_{shell} sufficient

already discussed



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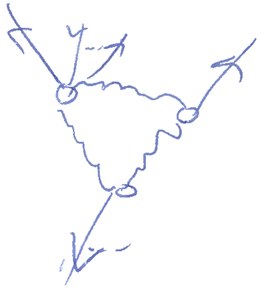

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$\downarrow$

simplest example

$$\approx \gamma^2(\vec x)\int_{k\in shell}[P_2(k)]^2 = \gamma^2(\vec x)\,P_2(\Lambda)\,\frac{d\sigma_\Lambda^2}{d\Lambda}$$

$\Rightarrow$ closed RGE $\frac{d}{d\Lambda} C_O^{(m)} = \dots \; C_{O_1}^{(i_1)} \cdots C_{O_p}^{(i_p)}$ (2nd paper)