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Effective theory of LSS with primordial non-Gaussianity

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Message:

In the presence of primordial non-Gaussianity, the matter equations of motion require new terms.

This talk:

Theoretical motivation

Evolution of matter

Smoothing:

$$O_l \equiv [O]_\Lambda(x,t) \equiv \int \mathrm{d}x' W_\Lambda(x-x')O(x',t)$$

Equations of motion:

$$\begin{cases} \partial_\tau \delta_l + \partial_i[(1+\delta_l)v_l^i] = 0; \quad v_l^i \equiv [\rho v^i]_\Lambda/[\rho]_\Lambda \\ \partial_\tau v_l^i + \mathcal{H}v_l^i + v_l^j \partial_j v_l^i = -\partial_i \phi_l - \frac{1}{\rho_l}\partial_i[\tau^{ij}]_\Lambda \end{cases}$$

Baumann, Nicolis, Senatore, Zaldarriaga 2010
Carrasco, Hertzberg, Senatore 2012
Mercolli, Pajer 2013

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The stress tensor

$$\tau^{ij} = \frac{1}{8\pi G a^2}\left[2\partial^i\phi_s\partial^j\phi_s - \delta^{ij}(\partial_k\phi_s)^2\right]_\Lambda + \left[\rho v_s^i v_s^j\right]_\Lambda + \left[\rho\sigma_s^{ij}\right]_\Lambda$$

Pietroni, Magnano, Saviano, Viel 2011

- Depends on short scales
- We can treat its effect on large scales perturbatively
- Space-time dependence unknown

Pueblas, Scoccimarro 2008
Peebles 1980

- However, we care about <u>statistics:</u>

$$\langle\tau^{ij}\rangle_s = p(\tau)\delta^{ij}, \quad \langle\tau^{ij}\delta\rangle_s = ?, \quad \langle\tau^{ij}(x,\tau)\tau^{kl}(x',\tau)\rangle_s = \text{ local}, \ \ldots$$

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Correlation type 1

'Gravitationally induced': local in space, non-local in time

$$\tau^{ij}(x,\tau) \supset \int c^{ij}(x_{fl},\tau',\tau)\delta(x_{fl},\tau') + \ldots$$

Carrasco, Foreman, Green, Senatore 2013
Baldauf, Mercolli, Mirbabayi, Pajer 2014
Mirbabayi, Schmidt, Zaldarriaga 2014
Bertolini, Schutz, Solon Zurek 2016

Constrained by symmetries!

$$\langle c^{ij}(x,\tau',\tau)\rangle_s = c(\tau',\tau)\delta^{ij}, \quad \langle c^{ij}(x,\tau',\tau)c^{kl}(x',\tau',\tau)\rangle_s = \text{ local, } \ldots$$

This leads to EFT of LSS for Gaussian initial conditions

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Correlation type 2: 'memory' of i.c.

Question: given

$$\boxed{\langle \hat{O}_s(q, \tau_{in}) \delta_l(q', \tau_{in}) \rangle \neq 0}$$

What can we say about

$$\boxed{\langle \tau^{ij}(x, \tau) \delta_l(x', \tau) \rangle}$$

Note: the stress tensor is an unknown, 'local' function of i.c.

$$\boxed{\tau^{ij}(x, \tau) = \mathcal{F}[\hat{O}_s(q, \tau_{in}), \ldots]}$$

Initial correlation

To first order in non-Gaussianity, the long scale dependence is determined by the primordial bispectrum:

$$\langle \tau^{ij}(x,\tau)\delta_l(x',\tau)\rangle \sim \langle \varphi_s^2(q,\tau_{in})\delta_l(q',\tau_{in})\rangle$$

Ansatz: (assumes separability)

$$B_\varphi(k,p,|\mathbf{k}-\mathbf{p}|)_{p\ll k} = 4P_\varphi(k)P_\varphi(p)\sum_{L,i} a_{L,i}\left(\frac{k}{p}\right)^{\Delta_i} P_L(\hat{\mathbf{k}}\cdot\hat{\mathbf{p}})$$

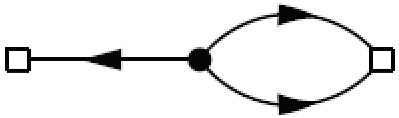
Long scale dependence

$$\int_{\mathbf{r}} e^{-i\mathbf{k}\cdot\mathbf{r}}\langle \varphi_s^2(x,\tau)\delta_l(x+r,\tau)\rangle \sim k^2 T(k) P_\varphi(k) k^{\Delta}\mathcal{P}^{ij..}(\hat{\mathbf{k}})$$

Late-time correlation

Assume short modes are perturbative. Power spectrum contains:

$$P_{12}(k) \; = $$



$$= \int_p F_2(\boldsymbol{p}, \boldsymbol{k}-\boldsymbol{p}) B_{111}(k, p, |\boldsymbol{k}-\boldsymbol{p}|) \; + \; \text{perm}$$

Bernardeau, Colombi, Gaztanaga, Scoccimarro 2002

Contribution from short modes:

$$P_{12}^{div}(k) = k^2 k^2 T(k) P_{\varphi}(k) k^{\Delta} \mathcal{P}^{ij..}(\hat{\mathbf{k}}) \int_{|\mathbf{p}|>\Lambda} f_{ij..}(\mathbf{p})$$

Long scale dependence is the same!

New terms in the stress tensor

Introduce ‘bookkeeper’ in the stress tensor.

$$\psi^{ij..}(q,\tau_{in}) = \int_{\mathbf{k}} e^{i\mathbf{k}\cdot\mathbf{r}}\varphi(k)k^{\Delta}\mathcal{P}^{ij..}(\hat{\mathbf{k}})$$

This new, non-dynamical field can be added to all terms in the original stress tensor expansion:

$$\tau^{ij}(x,\tau) \supset \tilde{c}^{ij}(q,\tau_{in},\tau)\psi(q,\tau_{in}) + \ldots$$

Conclusions:

- Consistent PT in the presence of PNG requires new terms in equations of motion.

Further work:

- Relevance for matter predictions?
- Relevance in biasing? *Angulo, Fasiello, Senatore, Vlah 2015*
  Assassi, Baumann, Schmidt 2015

Thanks!