Squeezing the bispectrum up to the non-linear regime

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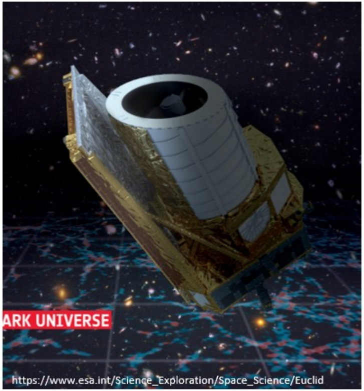
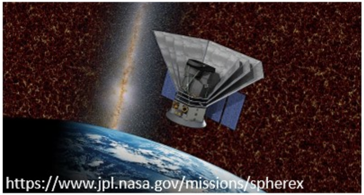
Newcastle University

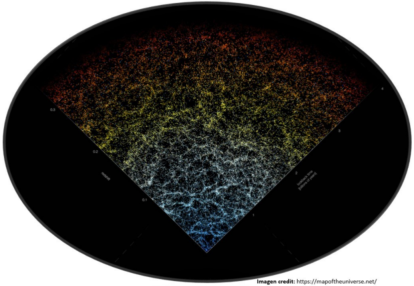
Future Cosmology
April 2023





We are in the era of precision cosmology

Extracting the maximum information from the observations is a challenge!



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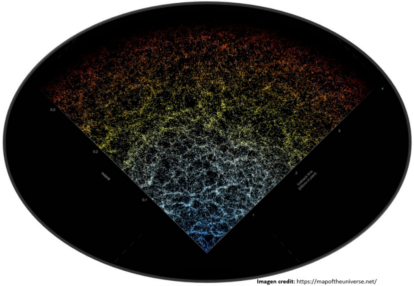
- We need models able to access the whole range of scales measured in the surveys.



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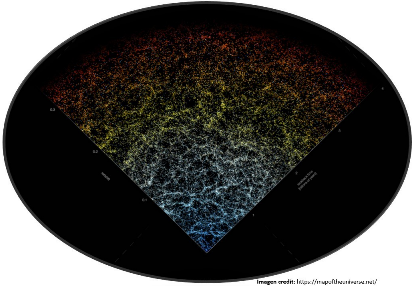

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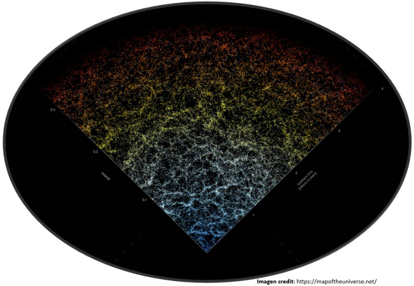
- SPT and EFTofLSS provide a good description of data up to $k \sim 0.2\mathrm{h/Mpc}$.



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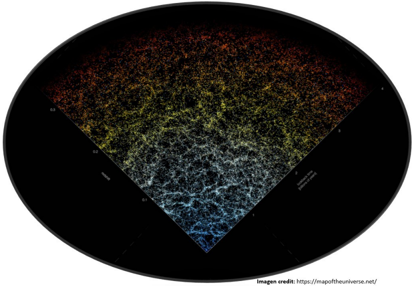

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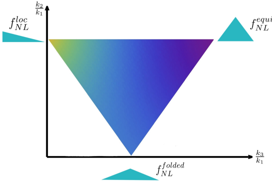
Squeezed bispectrum model valid at small scales.



$$\langle \delta(\boldsymbol{k}_1)\delta(\boldsymbol{k}_2)\delta(\boldsymbol{k}_3)\rangle = (2\pi)^3\delta_D(\boldsymbol{k}_1+\boldsymbol{k}_2+\boldsymbol{k}_3)B(\boldsymbol{k}_1,\boldsymbol{k}_2,\boldsymbol{k}_3)$$

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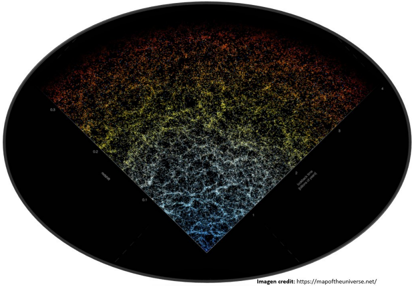

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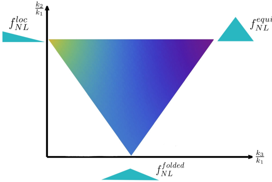

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Consistency Relation of LSS.

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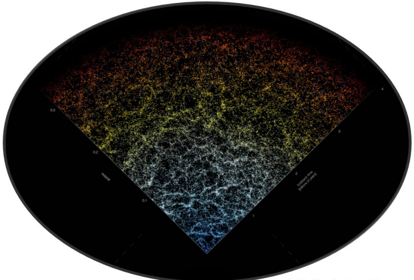

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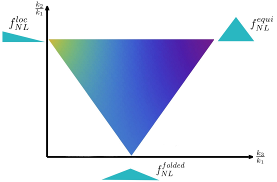

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Consistency Relation of LSS.

Response functions approach.

Large-scale structure consistency relations

Large-scale structure consistency relations

$$\langle \delta_{\boldsymbol{q}} \delta_{\boldsymbol{k}_1} \cdots \delta_{\boldsymbol{k}_n} \rangle'_{q \to 0} = -P_{\delta_L}(q, \tau) \sum_{a=1}^{n} \frac{D_+(\tau_a)}{D_+(\tau)} \frac{\boldsymbol{q} \cdot \boldsymbol{k}_a}{q^2} \langle \delta_{\boldsymbol{k}_1} \cdots \delta_{\boldsymbol{k}_n} \rangle'$$

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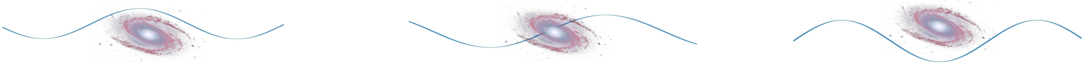

M.Peloso,M.Pietron(2013), A.Kehagias,A.Riotto(2013), P. Creminelli,J.Norena,M. Simonovic,F.Vernizzi(2013)

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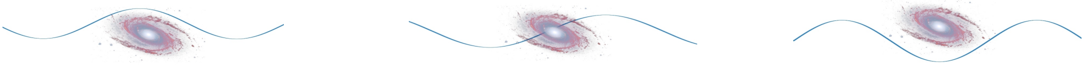
The LSS consistency relations are a consequence of the ***Equivalence principle!***



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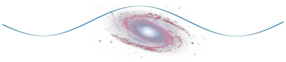
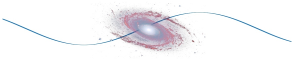
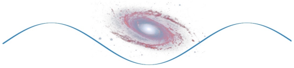
The LSS consistency relations are a consequence of the ***Equivalence principle!***

Are valid at any order in perturbations theory.







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Power spectrum response function

A Barreira, F Schmidt (2017)

P Valageas (2013)

Power spectrum response function

Effect of long wavelength perturbations on small scales n-point correlation functions.

A Barreira, F Schmidt (2017)

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Power spectrum response function

Effect of long wavelength perturbations on small scales n-point correlation functions.

The effect on the small scale power spectrum determines the squeezed limit of $(n + 2)$*-point correlation functions*

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The effect on the small scale power spectrum determines the squeezed limit of $(n+2)$-point correlation functions

The bispectrum in the squeezed limit is well described by the response of the small scale power spectrum to the presence of a long wavelength perturbation.

$$\lim_{q \to 0} B(\boldsymbol{k}, \boldsymbol{k}', \boldsymbol{q}) = \mathcal{R}_1(k, \mu_{\boldsymbol{k},\boldsymbol{q}}) P_m(k) P_L(q)$$

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- "Bias-like" expansion in terms of local gravitational observables.

$$\frac{P_m(\boldsymbol{k}|\boldsymbol{x})}{P_m(k)} - 1 = \sum_{\mathcal{O}} R_{\mathcal{O}}(k) \left(\hat{k}^i \hat{k}^j \cdots\right) \mathcal{O}_{ij\cdots}(\boldsymbol{x})$$

A Barreira, F Schmidt (2017)

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Response function expansion at the field level.

Response of the matter density at small scales to the change of the long wavelenght gravitational potencial

1. Rotational invariance

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Squeezed Bispectrum

$$\lim_{q\to 0}\langle\delta(\boldsymbol{q})\delta(\boldsymbol{k}_1)\delta(\boldsymbol{k}_2)\rangle' = P_m(q)P_m(k_1)\left[\frac{\boldsymbol{k}_1.\boldsymbol{q}}{q^2} + R_1(k_1) + R_\theta(k_1)(\hat{k}_1.\hat{q})^2\right] + (1\leftrightarrow 2)$$

$$R_i(k) = \frac{\langle\delta(\boldsymbol{k})\Delta_i(-\boldsymbol{k})\rangle'}{P_m(k)}$$

Response coeficcients from perturbation theory

M Biagetti,J Calles, L Castiblanco,K Gonzalez,J Noreña. (2022)

Response coeficcients from perturbation theory

Tree level bispectrum

$$\delta(\boldsymbol{k})|_{\Phi_L} = \delta_\ell(\boldsymbol{k}) + 2F_2(\boldsymbol{q}, \boldsymbol{k}-\boldsymbol{q})\delta_\ell(\boldsymbol{q})\delta_\ell(\boldsymbol{k}-\boldsymbol{q}) + \mathcal{O}(\delta_\ell^3, q/k\delta_\ell(q)\delta_\ell(k))$$

Isotropic response: $\Delta_1(\boldsymbol{k}) = \frac{10}{7}\delta_\ell(\boldsymbol{k}))$

Angular response: $\Delta(\boldsymbol{k}) = \frac{4}{7}\delta_\ell(\boldsymbol{k}$

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One loop bispectrum

$$\lim_{q\to 0}\langle\delta(\boldsymbol{q})\delta(\boldsymbol{k}_1)\delta(\boldsymbol{k}_2)\rangle' = B_{211} + B^{I}_{321} + B^{II}_{321} + B_{411}$$

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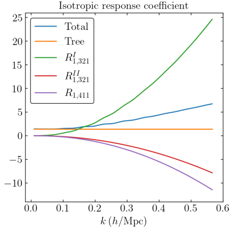
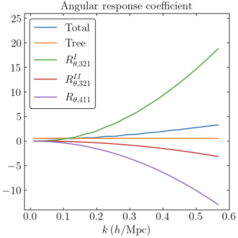


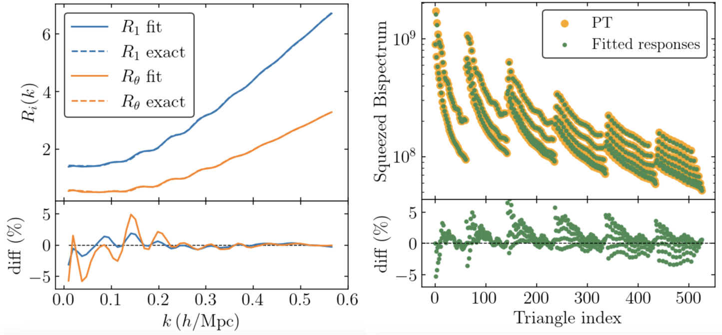


Fitting function

$$R_1(k) = \frac{10}{7} + \sum_{n=1} S_n^1 k^n + \left(\sum_{m=0} O_m^1 k^m \right) P_{\rm nw}(k) e^{-\Sigma^2 k^2} \sin(\omega k + \phi)$$

$$R_s(k) = \frac{4}{7} + \sum_{n=1} S_n^\theta k^n + \left(\sum_{m=0} O_m^\theta k^m \right) P_{\rm nw}(k) e^{-\Sigma^2 k^2} \sin(\omega k + \phi)$$

Zvonimir Vlaha, Uros Seljak, Man Yat Chu ,Yu Feng (2016)



$q \sim (0.009, 0.057)$h/Mpc

$k \sim (0.094, 0.565)$h/Mpc

M Biagetti,J Calles, L Castiblanco,K Gonzalez,J Noreña. (2022)

Comparison with simulations **in the deep non-linear regime**

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  M.Biagetti, L.C, J.Noreña, E. Sefusatti (2021)

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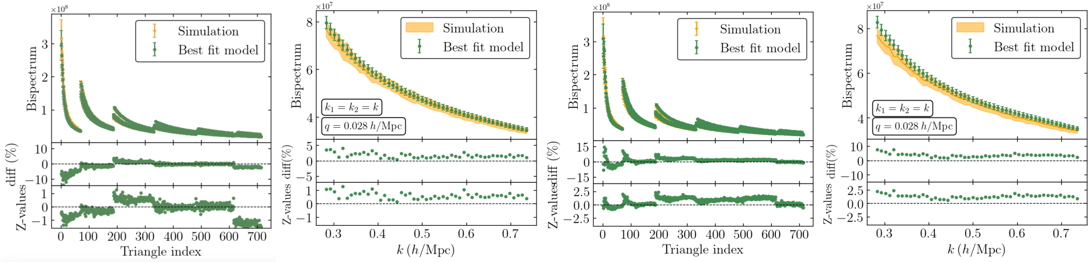

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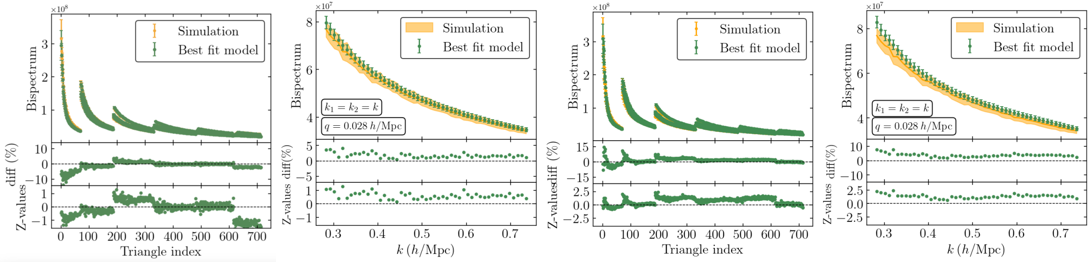

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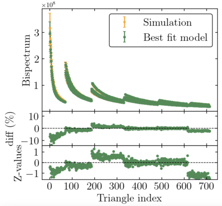

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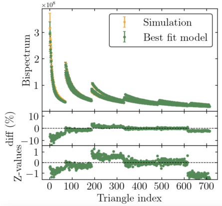

- The model can be extended to describe the squeezed galaxy bispectrum in redshift space.


Thank you