The integrated 3-point correlation function of projected density fields

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based on: ***Halder++ 2021 (arxiv:2102.10177), Halder & Barreira 2022 (arxiv:2201.05607)***, ***Halder++ (in prep.)***

Future Cosmology, Cargese

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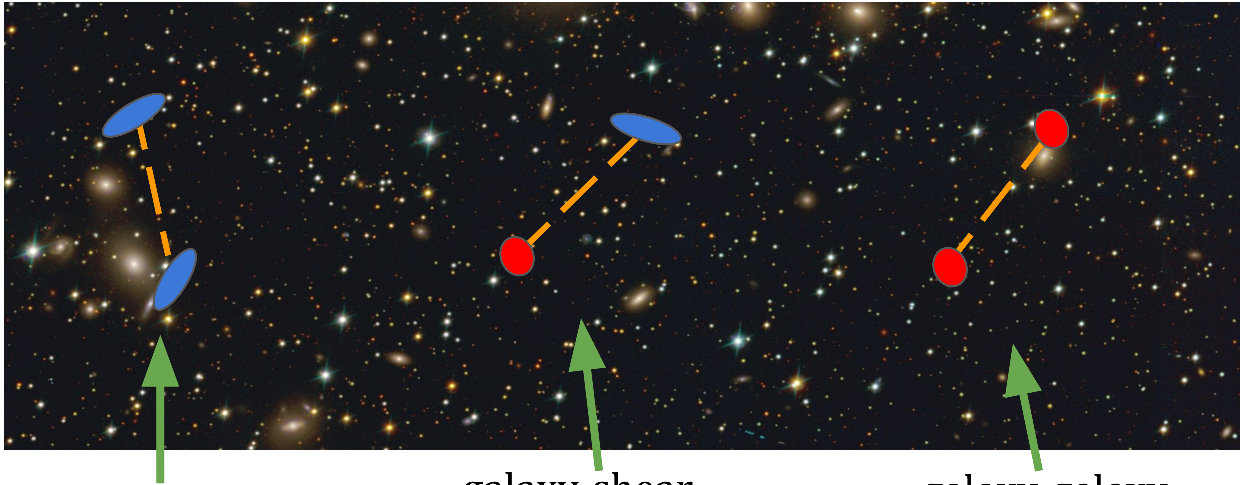
2-point correlations of projected galaxy & shear fields



Background source galaxy ellipticity

Foreground lens galaxy position

shear-shear 2PCF $\hat{\xi}_\pm(\alpha)$

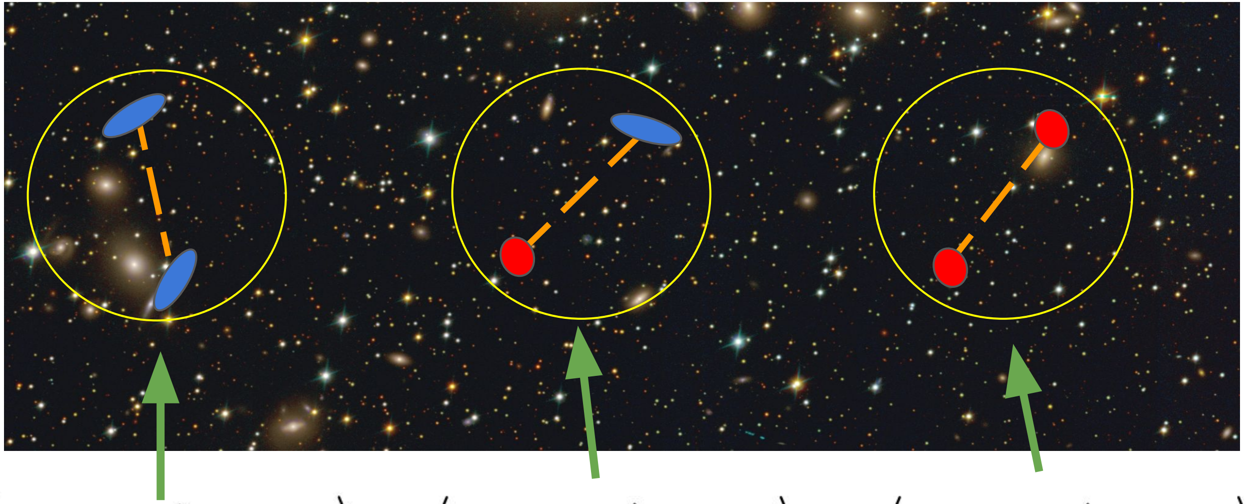
galaxy-shear 2PCF $\hat{\xi}_t(\alpha)$

galaxy-galaxy 2PCF $\hat{\xi}_g(\alpha)$

$\rightarrow$ Probes LOS projection of 3D **galaxy-matter power spectra** (depends on galaxy bias terms)

$\rightarrow$ But late-time density fields are non-Gaussian with information beyond 2-point correlations!

Integrated 3-point correlations of galaxy & shear



$\left\langle M_{\mathrm{ap}}(\boldsymbol{\theta}_C)\ \hat{\xi}_{\pm}(\alpha;\boldsymbol{\theta}_C)\right\rangle$ $\left\langle M_{\mathrm{ap}}(\boldsymbol{\theta}_C)\ \hat{\xi}_{t}(\alpha;\boldsymbol{\theta}_C)\right\rangle$ $\left\langle M_{\mathrm{ap}}(\boldsymbol{\theta}_C)\ \hat{\xi}_{g}(\alpha;\boldsymbol{\theta}_C)\right\rangle$

Position-dependent 2-pt correlations

$$\hat{\xi}_{\pm,t,g}(\alpha;\boldsymbol{\theta}_C)$$

1-pt aperture mass

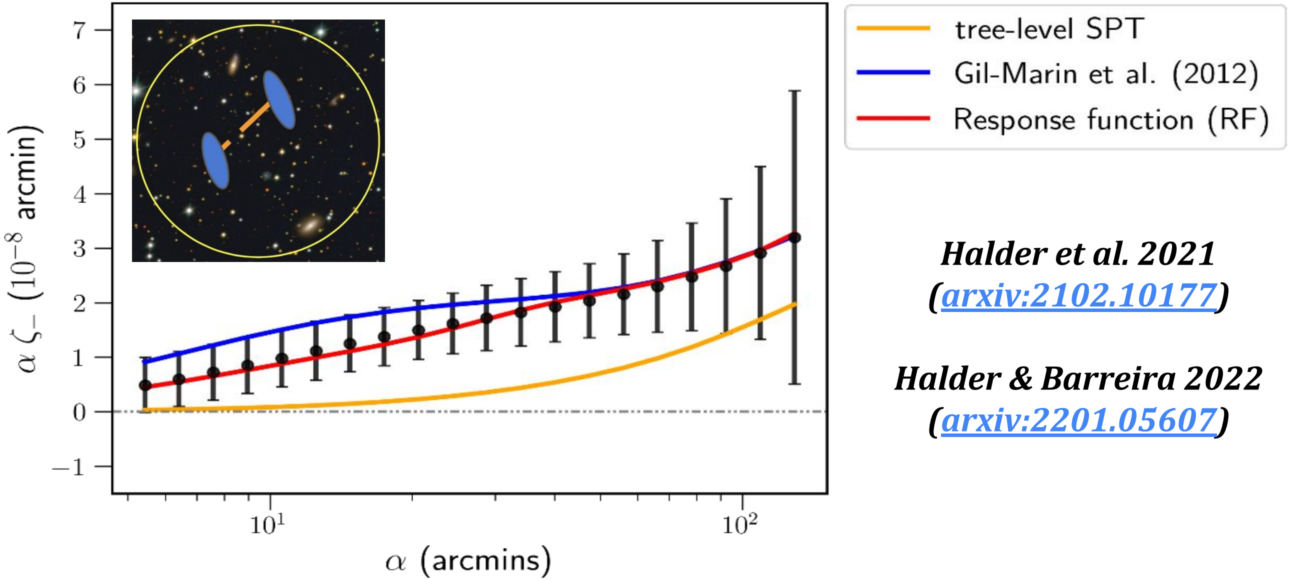
$$M_{\mathrm{ap}}(\boldsymbol{\theta}_C)$$

→ Directly observable higher-order statistics of projected galaxy density and cosmic shear fields

→ Probes LOS projection of 3D **galaxy-matter bispectra** (depends on galaxy bias terms)

→ Analytically model using response approach and leading-order PT

Integrated shear 3PCF model comparison to lensing simulations



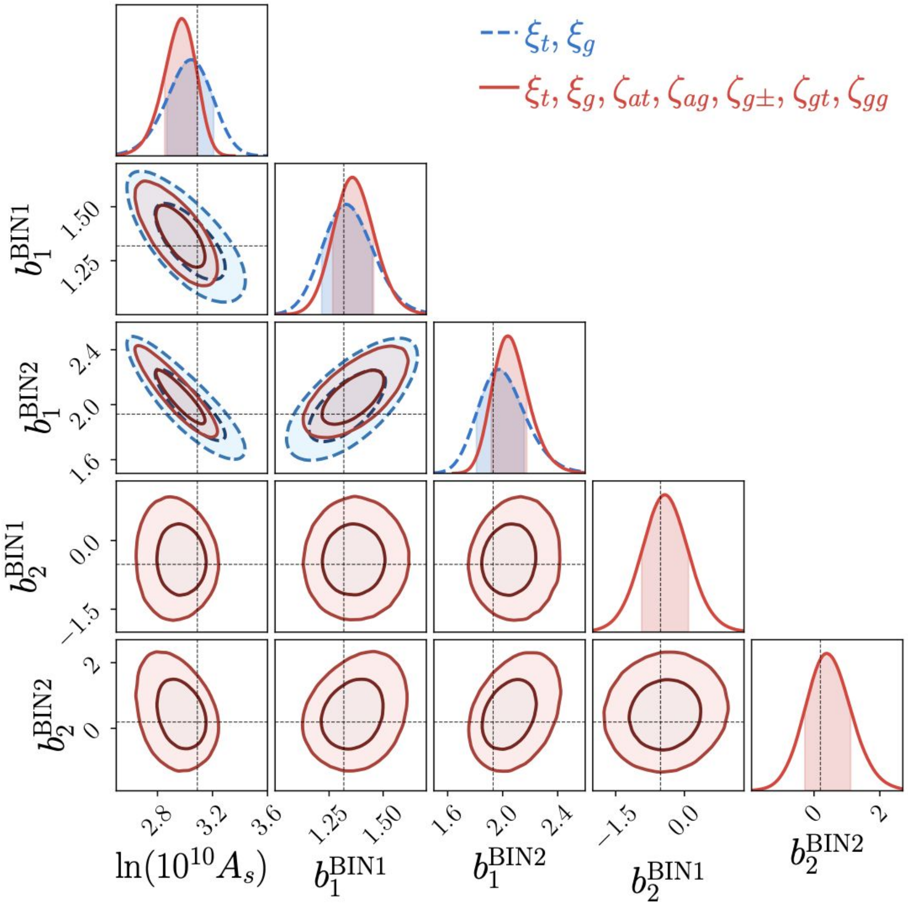
Halder et al. 2021
(arxiv:2102.10177)

Halder & Barreira 2022
(arxiv:2201.05607)

$$\zeta_{\pm}(\theta) = \left\langle M_{\rm ap}(\boldsymbol{\theta}_C)\ \hat{\xi}_{\pm}(\theta;\boldsymbol{\theta}_C)\right\rangle = \frac{1}{A(\theta)}\int \frac{\mathrm{d}\ell\ \ell}{2\pi}\ \mathcal{B}_{\pm}(\ell) J_{0/4}(\ell\theta)$$

- *Response function (RF)* **red curves** → excellent agreement to simulations (**black dots**)

Simulated DES-like MCMC with galaxy-shear 2PCFs and integrated 3PCF s



- Blue: galaxy-shear 2PCF only
  Red: galaxy-shear 2PCF & integrated 3PCF

- Relative improvement on parameters compared to 2PCF alone:

  ln(10^10 As), linear galaxy bias: **20-30%**

- Integrated 3PCF also allows to put constraints on quadratic bias parameters (leading-order SPT models)

Halder et al. (in prep.)

Summary

- Integrated 3PCFs are easy to measure higher-order lensing statistics!
- Calculate using perturbation-theory inspired models
- Potential to improve parameter constraints relative to 2PCF only analyses
- *Ongoing work:*

  - Application to DES cosmic shear data

Thank you!

Position-dependent 2PCF intuitively and modelling of integrated 3PCF

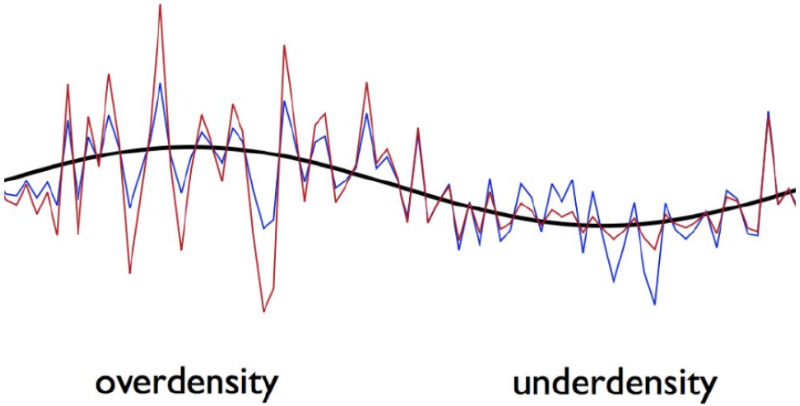
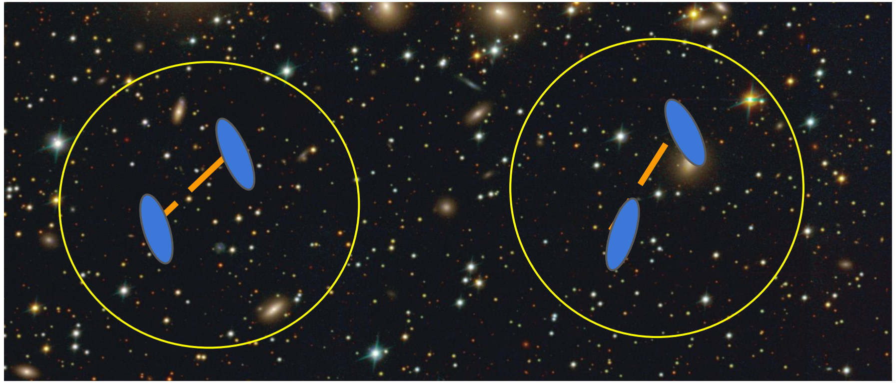


Image credit: *E. Komatsu*

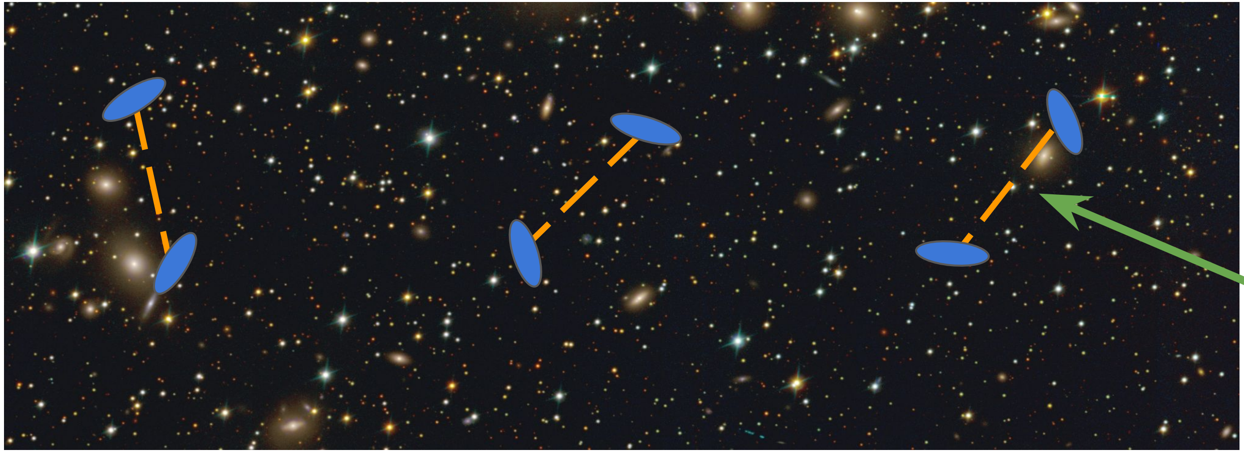


Accurately modelled using the ***'response approach'*** to perturbation theory

***Halder & Barreira 2022* (*arxiv:2201.05607*)**

***Barreira & Schmidt 2017* (*arxiv:1703.09212*)**

Cosmic shear 2-point correlation functions (2PCFs)



$$\hat{\xi}_{\pm}(\theta)$$

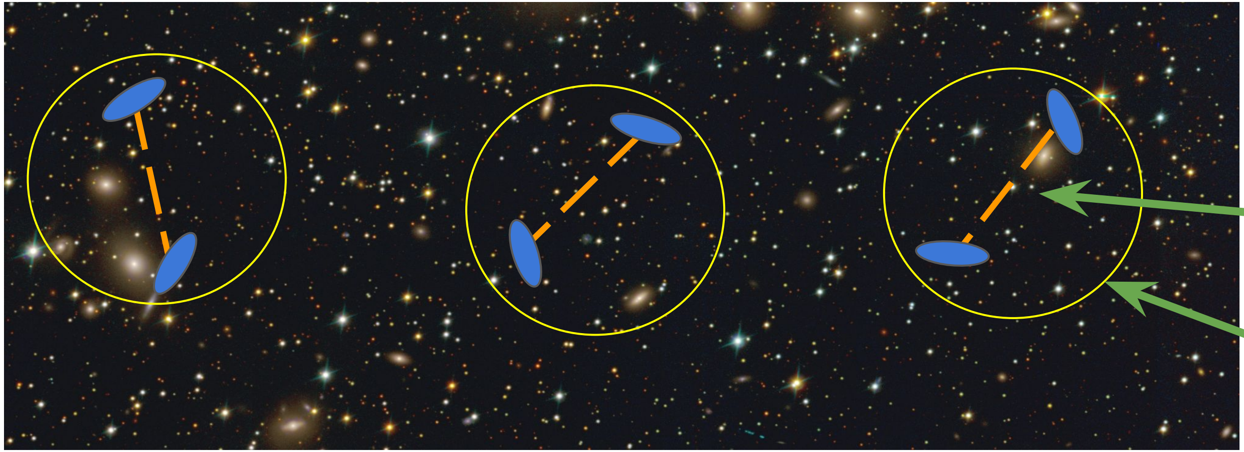
Shear 2-point correlation functions

$$\xi_{\pm}(\theta) = \int \frac{\mathrm{d}\ell\ \ell}{2\pi} J_{0/4}(\ell\theta) \int \mathrm{d}\chi \frac{q_{\kappa}^{2}(\chi)}{\chi^{2}}\ P_{m}^{3\mathrm{D}}(\ell/\chi, \chi)$$

→ Probes the line-of-sight projection of the **3D matter power spectrum**

→ But cosmic shear is a non-Gaussian field with information beyond 2-point correlations!

Integrated shear 3-point correlation functions



Position-dependent shear 2-pt correlation in aperture

$$\hat{\xi}_{\pm}(\theta; \boldsymbol{\theta_C})$$

1-pt aperture mass

$$M_{\rm ap}(\boldsymbol{\theta_C})$$

Weighted tangential shear inside aperture

$$\zeta_{\pm}(\theta) = \left\langle M_{\rm ap}(\boldsymbol{\theta}_C)\ \hat{\xi}_{\pm}(\theta; \boldsymbol{\theta}_C) \right\rangle = \frac{1}{A(\theta)} \int \frac{\mathrm{d}\ell\ \ell}{2\pi} \mathcal{B}_{\pm}(\ell) J_{0/4}(\ell\theta)$$

→ Probes the line-of-sight projection of the **3D matter bispectrum** in ***'squeezed configurations'***

→ **Directly observable higher-order statistic** of the cosmic shear field! Easy to measure!

Halder et al. 2021 (arxiv:2102.10177)

Modelling the integrated shear 3-point correlation function

$$\zeta_{\pm}(\alpha) = \left\langle \hat{M}_{\rm ap}(\boldsymbol{\theta}_C)\, \hat{\xi}_{\pm}(\alpha; \boldsymbol{\theta}_C) \right\rangle$$
$$= \frac{1}{A_{\rm 2pt}(\alpha)} \int \frac{\mathrm{d}\ell\, \ell}{2\pi}\, \mathcal{B}_{\pm}(\ell) J_{0/4}(\ell\alpha)$$

$$\mathcal{B}_{\pm}(\ell) = \int \mathrm{d}\chi\, \frac{q_\kappa^3(\chi)}{\chi^4} \int_{\boldsymbol{\ell}_1} \int_{\boldsymbol{\ell}_2} B_\delta^{\rm 3D}\left(\frac{\boldsymbol{\ell}_1}{\chi}, \frac{\boldsymbol{\ell}_2}{\chi}, \frac{-\boldsymbol{\ell}_{12}}{\chi}; \chi\right) e^{2i(\phi_{\boldsymbol{\ell}_2} \mp \phi_{-\boldsymbol{\ell}_{12}})} U(\boldsymbol{\ell}_1) W(\boldsymbol{\ell}_2 + \boldsymbol{\ell}) W(-\boldsymbol{\ell}_{12} - \boldsymbol{\ell})$$

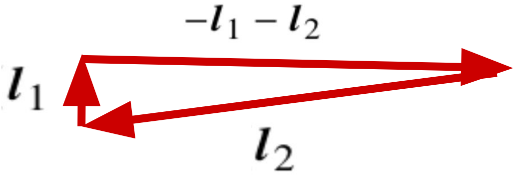
Line-of-sight projection

3D matter bispectrum

Window functions

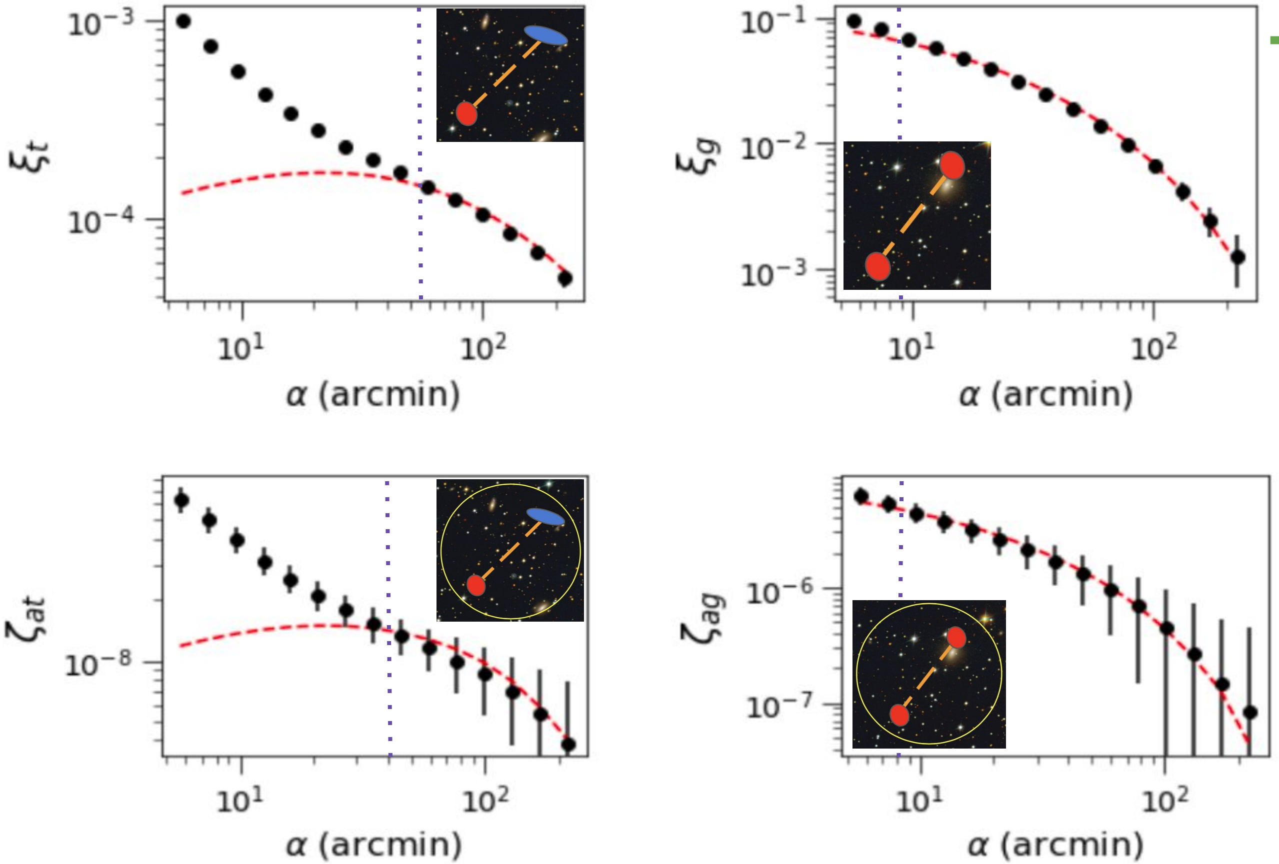
→ For large **l** values (*small scales*), the window functions mainly probe **squeezed** configurations of the bispectrum

→ Use **Response functions** to model the squeezed bispectrum configurations



Halder & Barreira 2022 (arxiv:2201.05607)

Galaxy-shear 2PCF and integrated 3PCF model comparison to simulations



2PCFs involving the galaxy field

- **Black data points**: Measurements from simulations
- **Dashed red curves**: Leading order perturbation theory models with *galaxy bias*

Integrated 3PCFs involving the galaxy field

Halder et al. (in prep.)

1D Fisher Forecasts of 2PCF vs joint 2PCF and integrated 3PCF