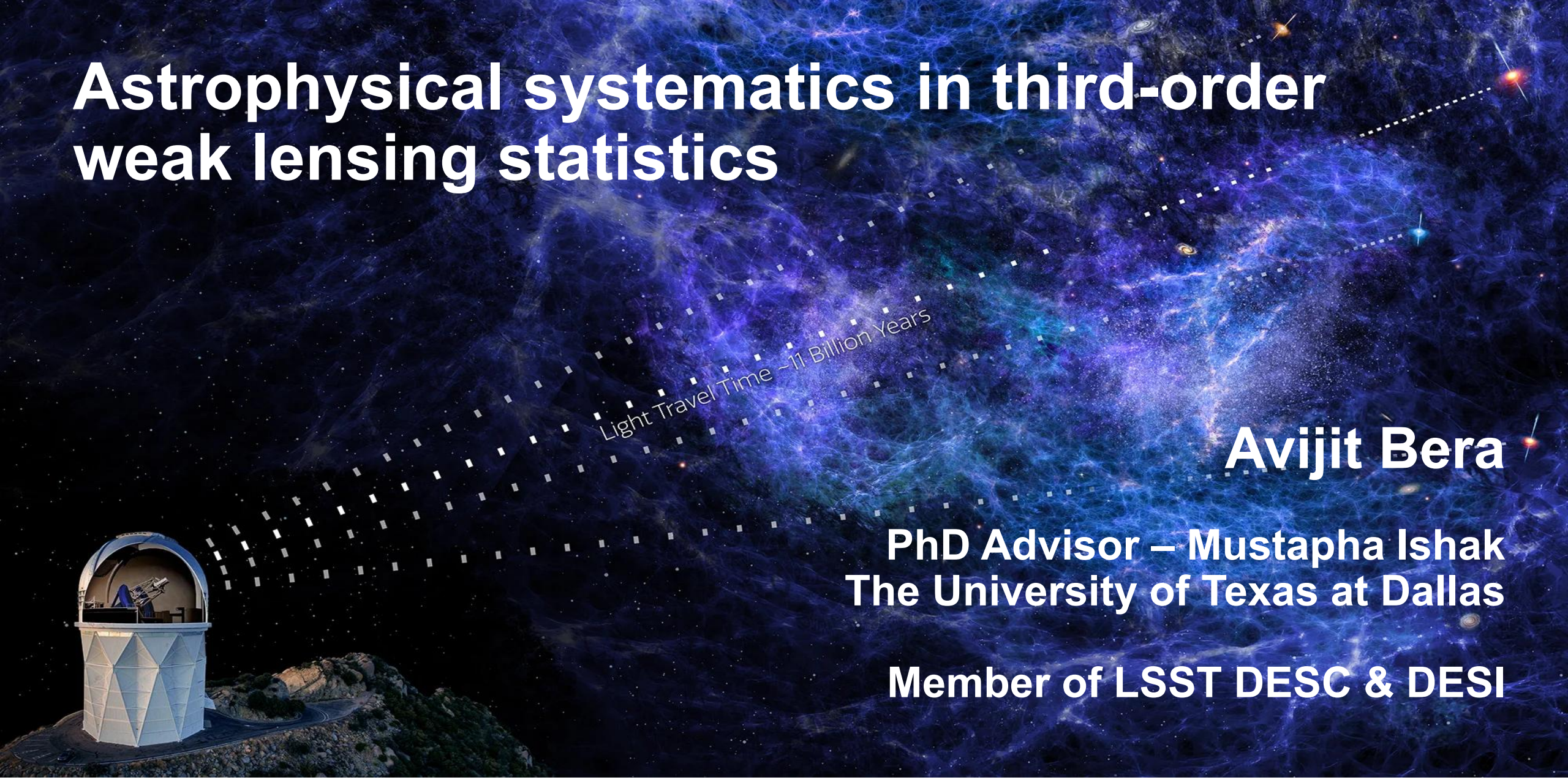
Astrophysical systematics in third-order weak lensing statistics



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Quantifying the impact of baryons on the weak lensing 3x2 & 4x3 point correlation functions using HACC simulation

Dark matter only (dmo) N-body simulations –
- Provide accurate predictions for collisionless structure formation
- Assume that baryons do not affect the large-scale structure formation processes

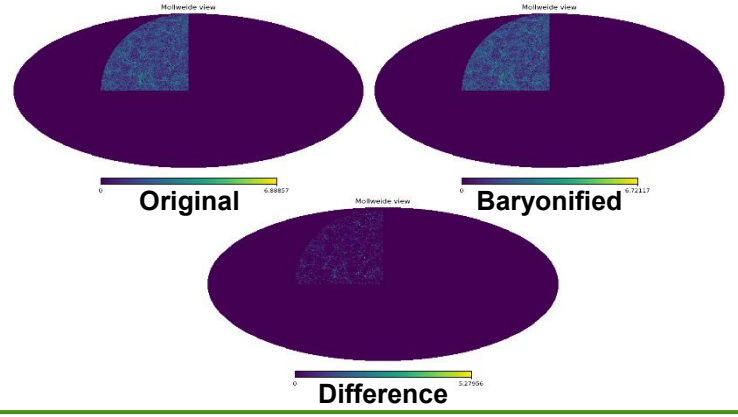
How do baryons impact matter clustering at cosmological scales –
- AGN feedback
- Star formation

Hydro simulation –
- Provide accurate description of baryonic physics
- Computationally expensive

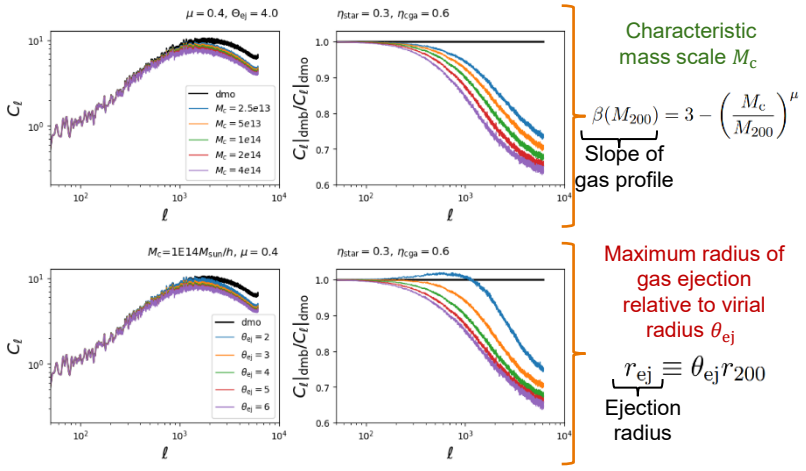
Baryonic Correction Model (BCM) –
- Modifies the density field of DM only simulations by mimicking the effects of baryons
- Assumes halos are made of 3 components – Gas, Stars & DM

In this work, we present –
1. 9 baryonified high-resolution (nside=8192) simulations, varying the two most sensitive parameters (M_c, θ_{ej})
2. Convergence maps are created by ray-tracing (using pollux) the baryonified shells
3. Galaxy calalogs are created using the SRD Y1 setup for the LSST DESC
4. Demonstrated the impact of baryonic feedback on all 2-point and 3-point weak lensing correlations

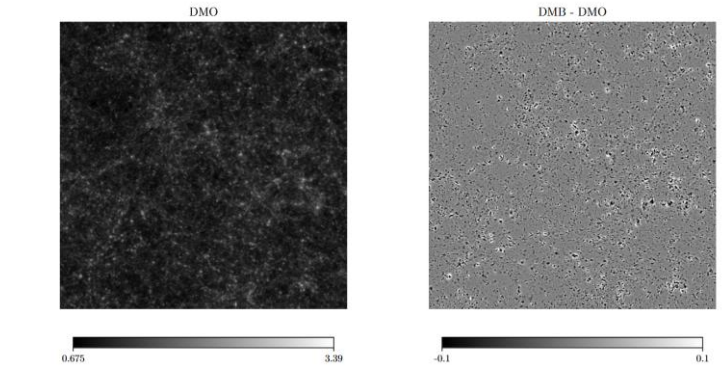
Baryonifying HACC simulation



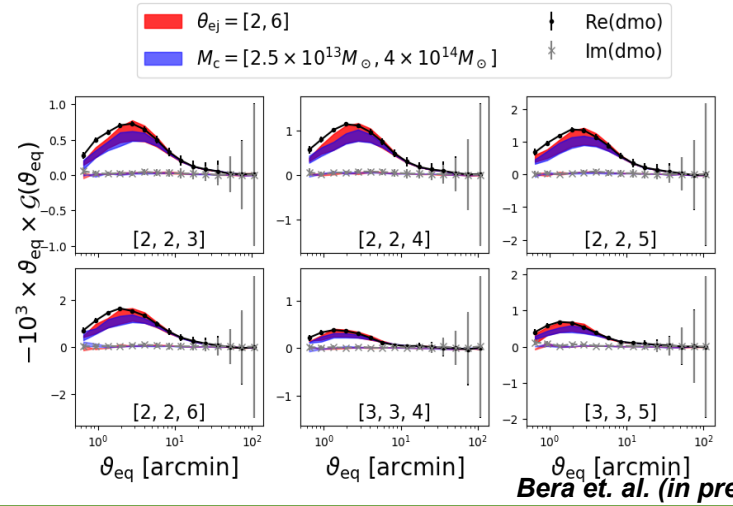
Quantifying the impact of gas parameters



Cartesian projection of the convergence field



Impact of baryons on galaxy-galaxy-shear correlation



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Detection techniques of three-point intrinsic alignment correlations using DESI & external photometric survey

Intrinsic alignment (IA) of galaxies –

- During the formation and evolution processes, tidal fields associated with the large-scale structure and processes like galaxy mergers have a significant impact on aligning galaxies with their local environment.
- These processes directly influence the shape, orientation and rotational properties of the galaxies
- Dominant contamination to cosmic shear

The observed shape of a galaxy – $\varepsilon^{\rm obs} = \varepsilon^{\rm G} + \varepsilon^{\rm I}$

$\varepsilon^{\rm I}, \varepsilon^{\rm G}$ are the Intrinsic shape and gravitational shear

2-point correlations –

- Shape-shape – $\xi_{\pm}^{\rm obs}(\vartheta) = \xi_{\pm}^{\rm GG}(\vartheta) + \xi_{\pm}^{\rm GI}(\vartheta) + \xi_{\pm}^{\rm IG}(\vartheta) + \xi_{\pm}^{\rm II}(\vartheta)$
- Position-shape – $\gamma_{\rm t}^{\rm obs} \equiv \gamma_{\rm t}^{\rm gG} + \gamma_{\rm t}^{\rm gI}$

3-point correlations –

- Shape-shape-shape – $\Gamma_{(\alpha)}^{\rm obs}(\vartheta_1,\vartheta_2,\vartheta_3) = \Gamma_{(\alpha)}^{\rm GGG}(\vartheta_1,\vartheta_2,\vartheta_3) + \left(\Gamma_{(\alpha)}^{\rm IGG}(\vartheta_1,\vartheta_2,\vartheta_3) + 2\ \text{comb.}\right) + \left(\Gamma_{(\alpha)}^{\rm IIG}(\vartheta_1,\vartheta_2,\vartheta_3) + 2\ \text{comb.}\right) + \Gamma_{(\alpha)}^{\rm III}(\vartheta_1,\vartheta_2,\vartheta_3)$
- Position-shape-shape – $\mathrm{G}_{\pm}^{\rm obs}(\vartheta_1,\vartheta_2,\vartheta_3) = \mathrm{G}_{\pm}^{\rm gGG}(\vartheta_1,\vartheta_2,\vartheta_3) + \left(\mathrm{G}_{\pm}^{\rm gIG}(\vartheta_1,\vartheta_2,\vartheta_3) + 1\ \text{comb.}\right) + \mathrm{G}_{\pm}^{\rm gII}(\vartheta_1,\vartheta_2,\vartheta_3)$
- Position-position-shape – $G^{\rm obs}(\vartheta_1,\vartheta_2,\vartheta_3) = G^{\rm ggG}(\vartheta_1,\vartheta_2,\vartheta_3) + G^{\rm ggI}(\vartheta_1,\vartheta_2,\vartheta_3)$

In this work, we present detection techniques for 3 third-order IA correlations

- galaxy density-galaxy density-intrinsic ellipticity (ggI),
- galaxy density-intrinsic ellipticity-intrinsic ellipticity (gII),
- Intrinsic ellipticity-intrinsic ellipticity-intrinsic ellipticity (III)

Selection criteria for triplets of galaxies –

- Accept if lens pair is at high redshift compared to the source galaxy ($Z_{\rm G} < Z_{\rm g1}, Z_{\rm g2}$)
- Discard otherwise ($Z_{\rm G} > Z_{\rm g1}, Z_{\rm g2}$)

Estimators

- Observed correlation with selection

$$\boldsymbol{G^{\rm obs}}\Big|_{\rm s} = \frac{\Sigma_{ijk}\, w_i w_j w_k\, \varepsilon_k^{\rm obs}}{\Sigma_{ijk}\, w_i w_j w_k}\Big|_{z_k<z_i,\, z_j}$$

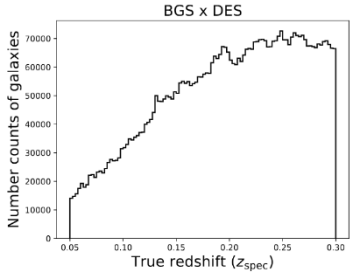
- True correlation $\boldsymbol{G^{\rm ggI}} = \frac{\Sigma_{ijk}\, w_i w_j w_k\, \varepsilon_k^{\rm I}}{\Sigma_{ijk}\, w_i w_j w_k}$

We propose these estimators are equivalent - $\boldsymbol{G^{\rm obs}}|_{\rm s} \approx \boldsymbol{G^{\rm ggI}}$

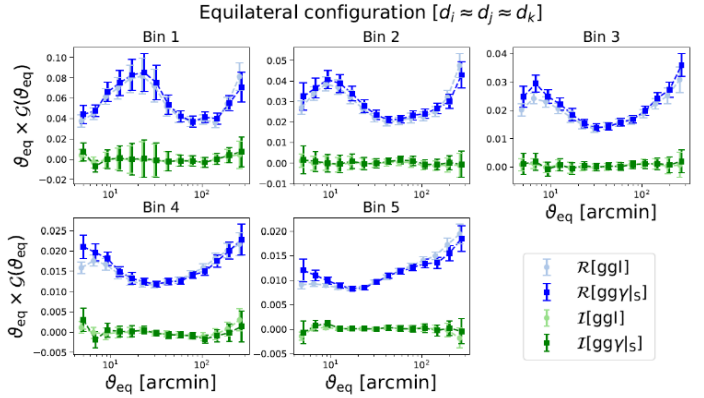
Galaxy catalog from Buzzard

Bin	Redshift range	No. of galaxies
1	0.05-0.10	446,561
2	0.10-0.15	840,681
3	0.15-0.20	1,170,552
4	0.20-0.25	1,335,203
5	0.25-0.30	1,375,725

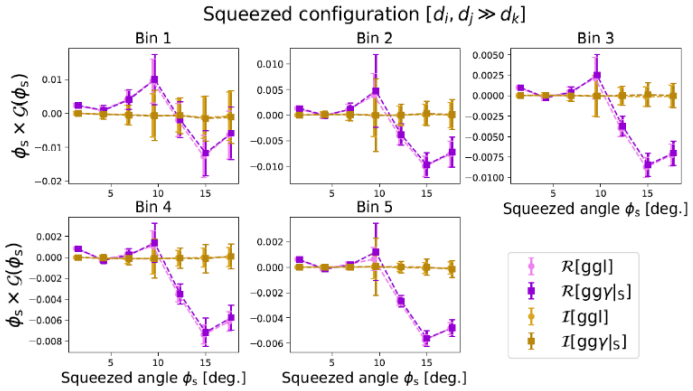
Table 1: Binning of DES × BGS galaxies in thin redshift bins of width 0.05.



Validation of the detection technique



(a) The ggI correlations for equilateral configuration are shown. The blue and green curves correspond to the real and imaginary components.



(b) The ggI correlations for squeezed configuration are shown. The violet and goldenrod curves correspond to the real and imaginary components.

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