Magnification modelling

for DES Y6 galaxy clustering and galaxy-galaxy lensing cosmology

Elisa Legnani

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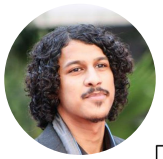
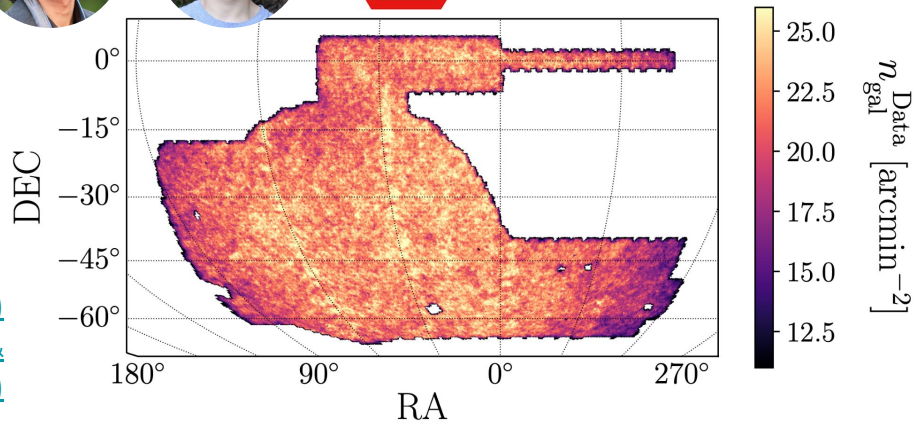
for DES Y6 galaxy clustering and galaxy-galaxy lensing cosmology

Elisa Legnani et al. (in prep)
Jack Elvin-Poole, Dhayaa Anbajagane, David-Sánchez Cid, Ramon Miquel, ... (DES Collaboration)





DES Y6 Gold catalog: Bechtol et al. (2025)
DES Y6 Synthetic Source Injection catalog: Anbajagane & Tabbutt, ..., EL et al. (2025)

Magnification modelling

Following DES Y3 Elvin-Poole & MacCrann et al. (2022)

Effects of magnification $\mu = \frac{1}{(1-\kappa)^2 - |\gamma|^2} \approx 1 + 2\kappa$

We are interested in the observed number density of objects $\delta_g^{\rm obs} = \delta_g^{\rm int} + \delta_g^{\rm mag}$

- change in observed area element
- change in selection probability of individual galaxies

} competing effects

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} competing effects

Galaxy overdensity due to convergence κ at a position $\hat{\boldsymbol{n}}$ on the sky

$$\delta_g^{\rm mag}(\hat{\boldsymbol{n}}) = \kappa(\hat{\boldsymbol{n}})[\underbrace{C_{\rm area}}_{=-2} + C_{\rm sample}]$$

Lens magnification modelling for 2x2pt cosmology

$$\delta_g^{\rm obs} = \delta_g^{\rm int} + \delta_g^{\rm mag}$$

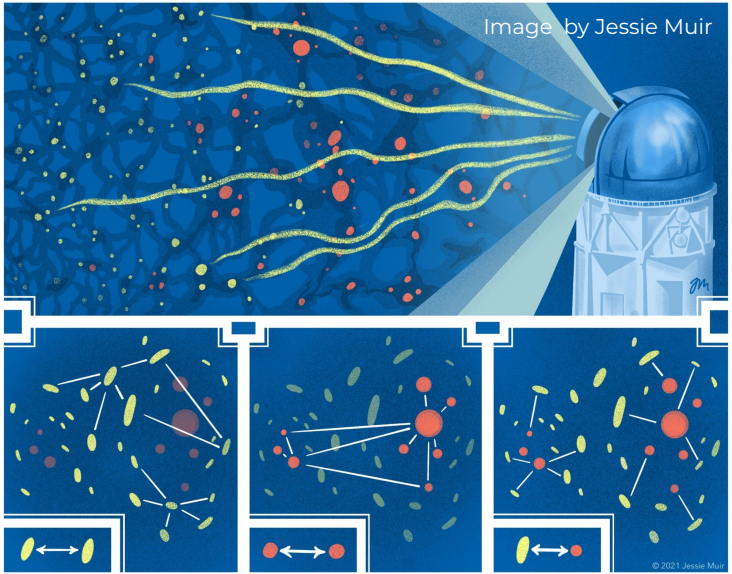
$$\delta_g^{\rm mag}(\hat{\boldsymbol{n}}) = \kappa(\hat{\boldsymbol{n}})[C_{\rm area} + C_{\rm sample}]$$
$$= -2$$

Galaxy clustering

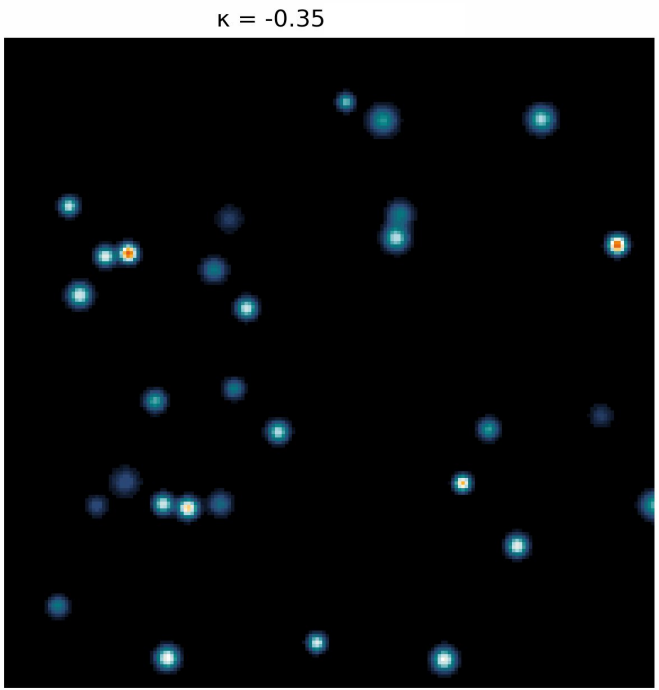
$$\langle \delta_g^{\rm obs} \delta_g^{\rm obs} \rangle = \langle \delta_g^{\rm int} \delta_g^{\rm int} \rangle + C^2 \langle \kappa\kappa \rangle + 2C \langle \delta_g^{\rm int} \kappa \rangle$$

Galaxy-galaxy lensing

$$\langle \delta_g^{\rm obs} \gamma \rangle = \langle \delta_g^{\rm int} \gamma \rangle + C \langle \kappa\gamma \rangle = \langle \delta_g^{\rm int} \gamma \rangle + C \langle \kappa\kappa \rangle$$



Magnification modelling



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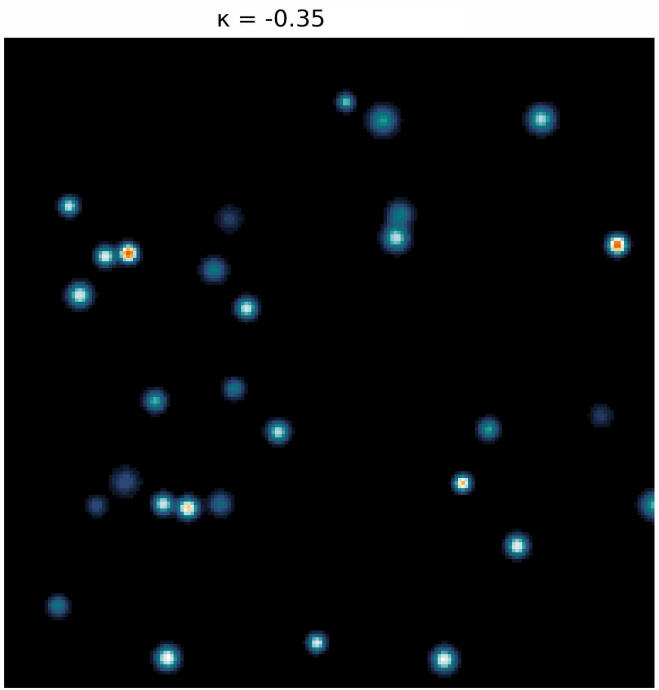
Magnification modelling



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If the galaxy selection function is a cut in magnitude

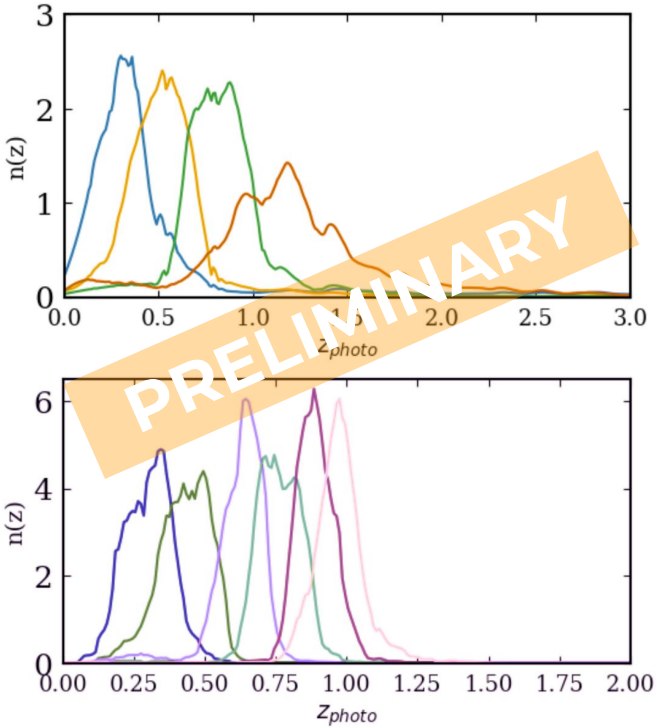
$$\delta_{g,\rm mag}(\hat{\boldsymbol{n}}) = \kappa(\hat{\boldsymbol{n}})\, 2[\alpha\,(m_{\rm cut}) - 1]$$

where $\alpha(m_{\rm cut}) = 2.5\, \dfrac{\rm d}{{\rm d}m} \log_{10} N_\mu(m)\Big|_{m=m_{\rm cut}}$

but DES galaxy samples are a complex selection of flux, color, position and shape

DES Y6 Galaxy samples

Complex selection of flux, color, position and shape



Metadetect source sample
~ 150 million galaxies
more sources, reduced shear bias wrt Y3

Yamamoto et al. (2025)

MagLim++ lens sample
~ 10 million galaxies
Improved selection and masking wrt Y3

$$17.5 < m_i < 18 + 4z$$

Wyverdyck et al. (in prep)
Rodríguez-Monroy et al. (in prep)

$$\delta_g^{\rm obs} = \delta_g^{\rm int} + \delta_g^{\rm mag}$$

$$\delta_g^{\rm mag}(\hat{\boldsymbol{n}}) = \kappa(\hat{\boldsymbol{n}})[\underbrace{C_{\rm area}}_{=-2} + C_{\rm sample}]$$

Fractional change in number of selected galaxies in response to a small convergence $\delta\kappa$

$$C_{\rm sample} = \frac{N(\delta\kappa) - N(0)}{N(0)\delta\kappa}$$

$$\delta_g^{\rm obs} = \delta_g^{\rm int} + \delta_g^{\rm mag}$$
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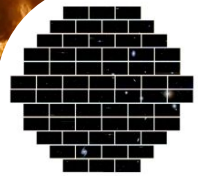
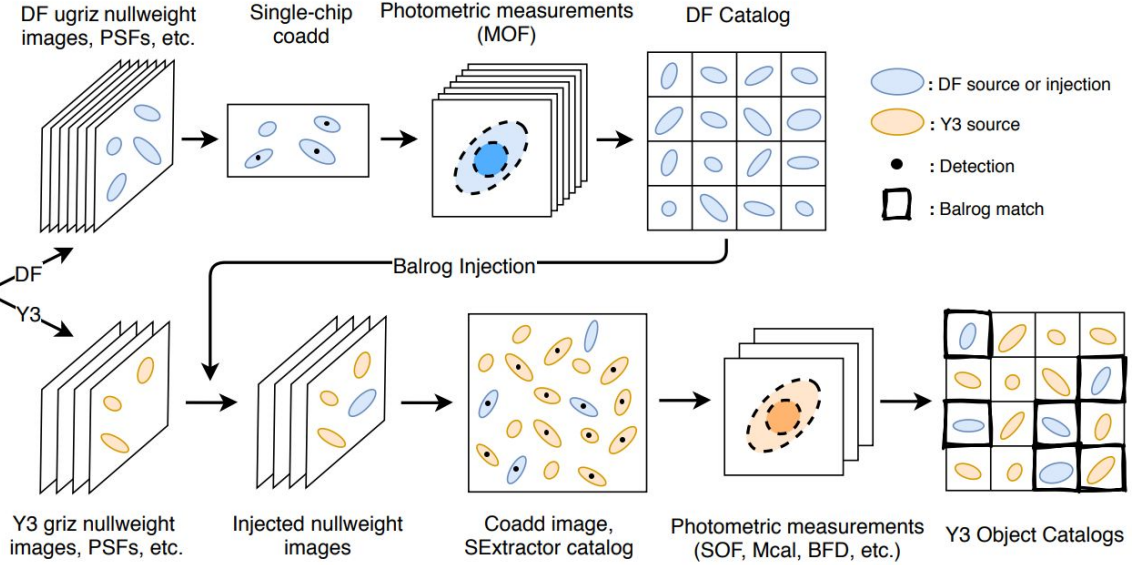
Fractional change in number of selected galaxies in response to a small convergence $\delta\kappa$

$$C_{\rm sample} = \frac{N(\delta\kappa) - N(0)}{N(0)\delta\kappa} \qquad \delta\mu = 1.02\ (\delta\kappa \sim 0.01)$$

DES Y6 Synthetic Source Injection: Balrog





Goal: characterize the survey transfer function

+ Used to estimate photometric redshift distributions

Anbajagane & Tabbutt, ..., EL et al. (2025)

$$\delta_g^{\rm obs} = \delta_g^{\rm int} + \delta_g^{\rm mag}$$

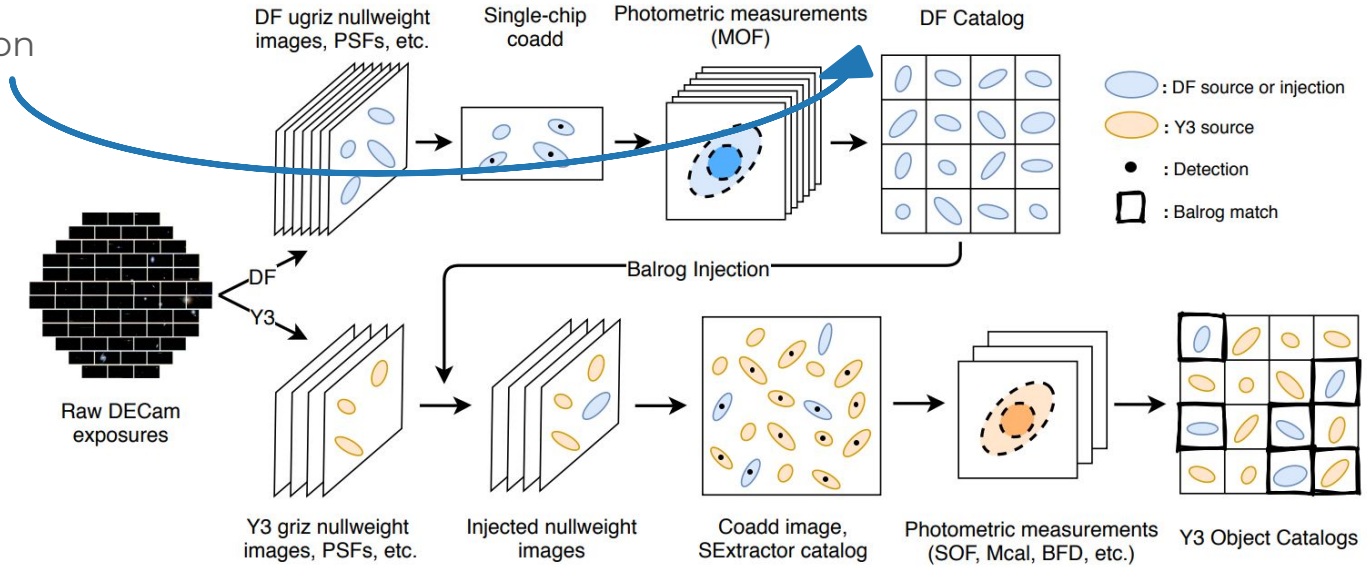
$$\delta_g^{\rm mag}(\hat{\boldsymbol{n}}) = \kappa(\hat{\boldsymbol{n}})[C_{\rm area} + C_{\rm sample}]$$
$$= -2$$

Estimated as fractional change in detections between magnified and unmagnified runs

$$C_{\rm sample} = \frac{N(\delta\kappa) - N(0)}{N(0)\delta\kappa} \qquad \delta\mu = 1.02\ (\delta\kappa \sim 0.01)$$

DES Y6 Synthetic Source Injection: Balrog

Apply 2% magnification to each galaxy image before injection



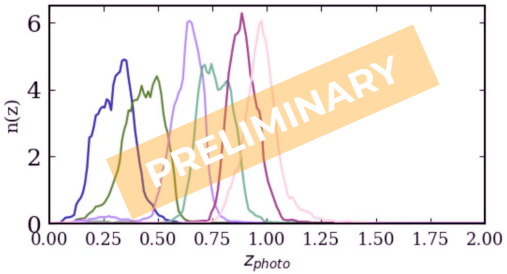
Anbajagane & Tabbutt, ..., EL et al. (2025)

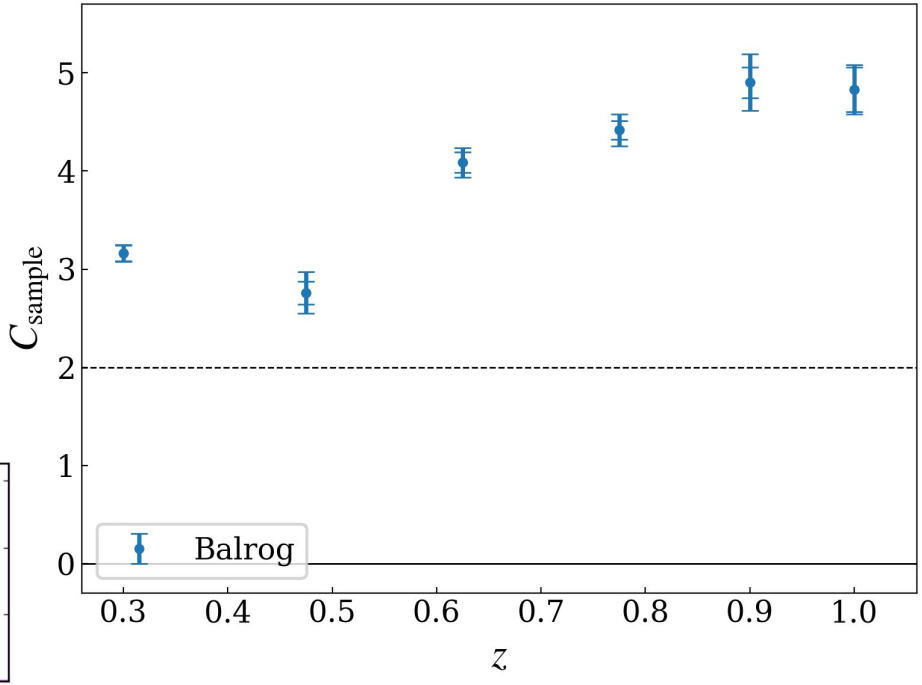
DES Y6 Lens magnification coefficients

Fractional change in detections between magnified and unmagnified runs

$$C_{\text{sample}} = \frac{N(\delta\kappa) - N(0)}{N(0)\delta\kappa}$$

Balrog by applying constant magnification to images





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Fractional change in detections between magnified and unmagnified runs

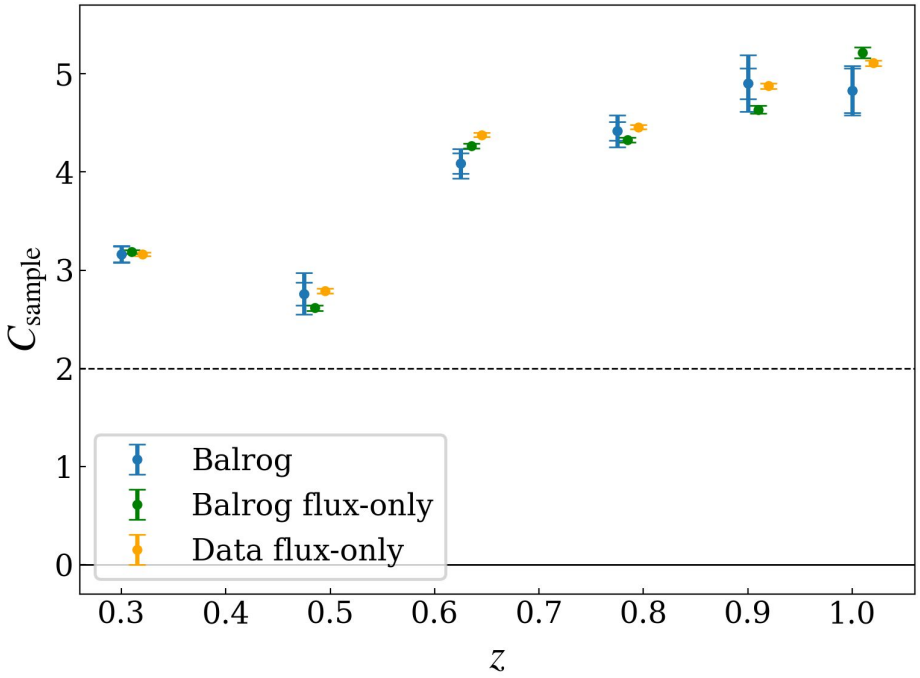
$$C_{\text{sample}} = \frac{N(\delta\kappa) - N(0)}{N(0)\delta\kappa}$$

Balrog by applying constant magnification to images → Fiducial

Data & Balrog flux-only by adding a constant offset to the measured magnitudes

$$\Delta m = -2.5 \log_{10}(1 + 2\delta\kappa)$$

→ not accounting for all the selection effects

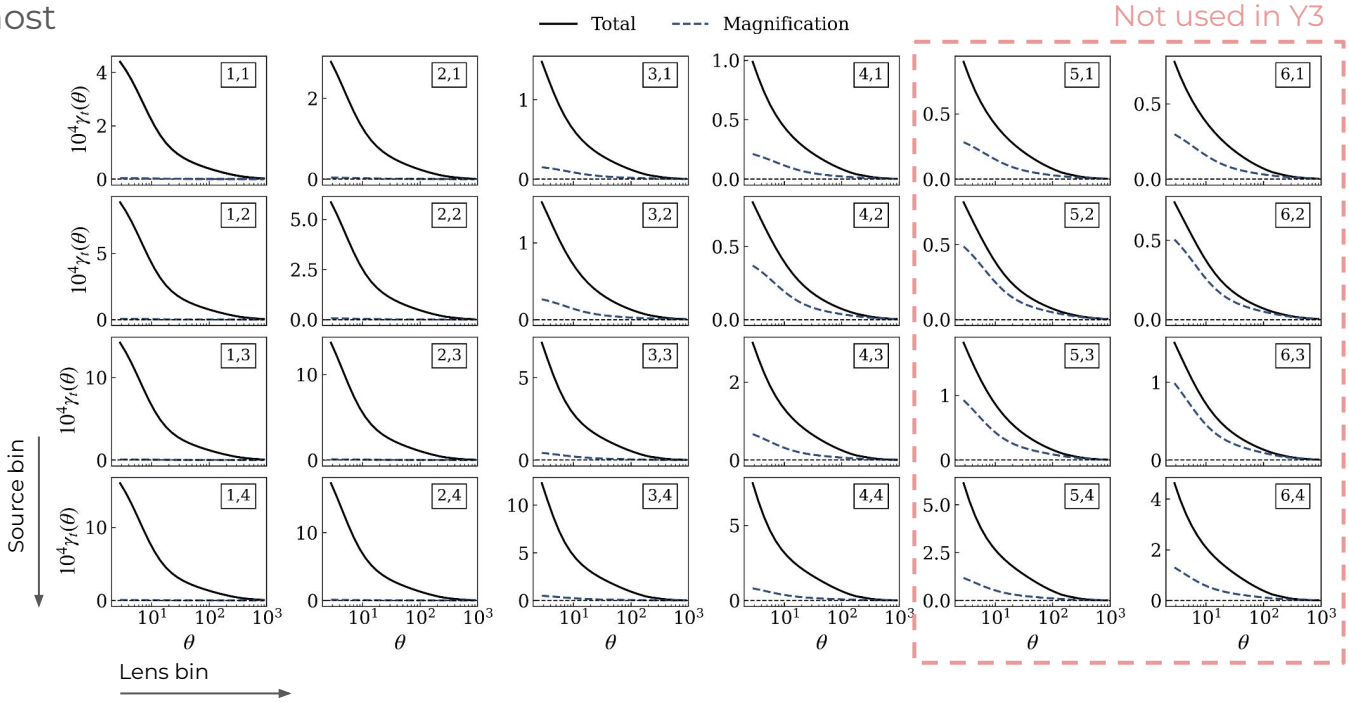


Impact of lens magnification on galaxy-galaxy lensing

Simulated data vector, with magnification contribution (assuming fiducial coefficients)

Magnification has the most significant impact on high-z source bins around high-z lens bins

Note: most of the S/N comes from the three lowest-z lens bins



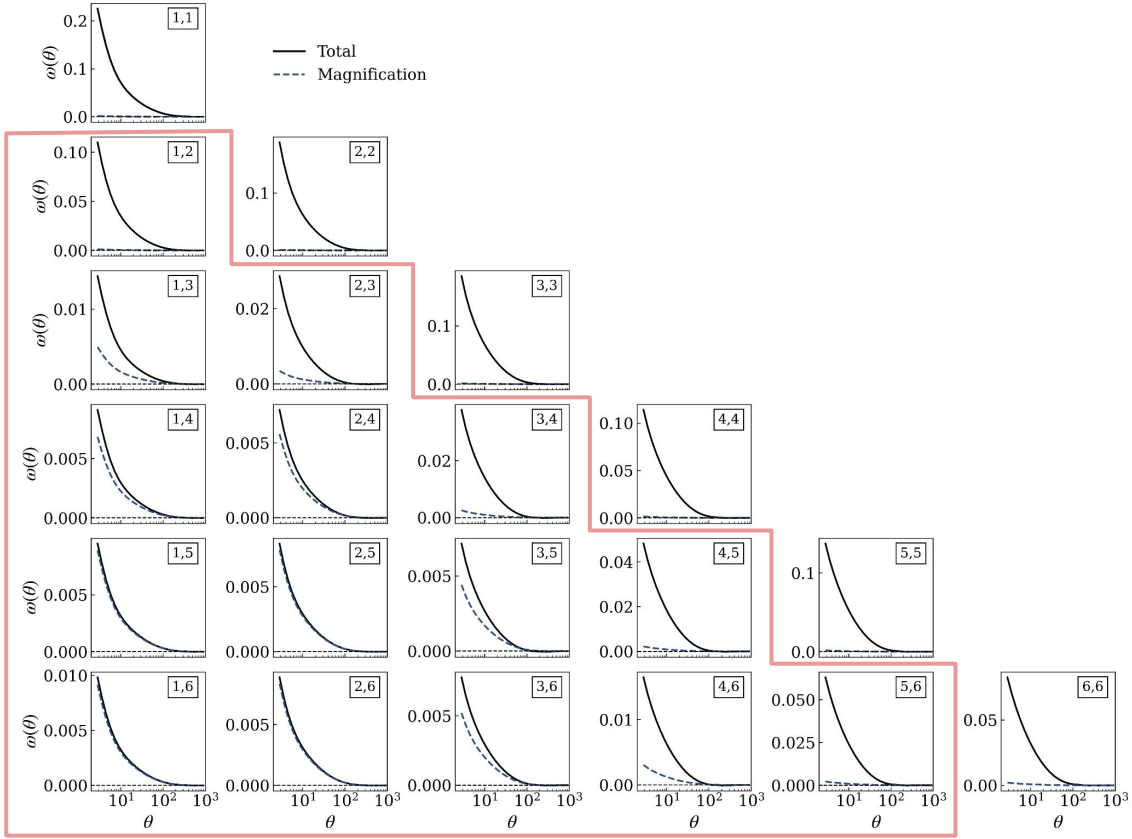
Impact of lens magnification on galaxy clustering

Magnification has a small contribution on autocorrelations

→ Magnification has a limited impact on the fiducial DES Y6 analysis

DES Y6 Modelling strategy:
Sánchez-Cid, Ferté, Blazek et al. (in prep)

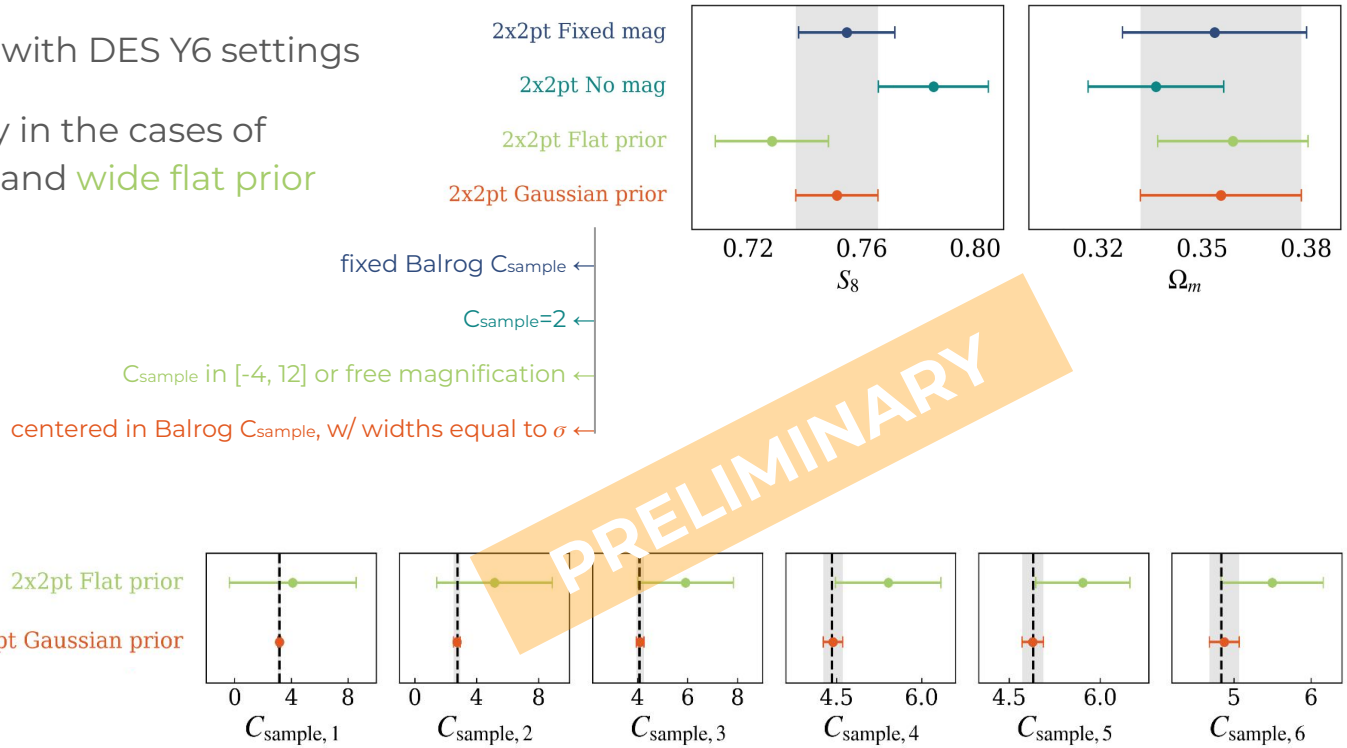
Not used in the fiducial analysis



Impact of lens magnification on 2x2pt cosmology

2x2pt ΛCDM chains with DES Y6 settings

- Biased cosmology in the cases of no magnification and wide flat prior



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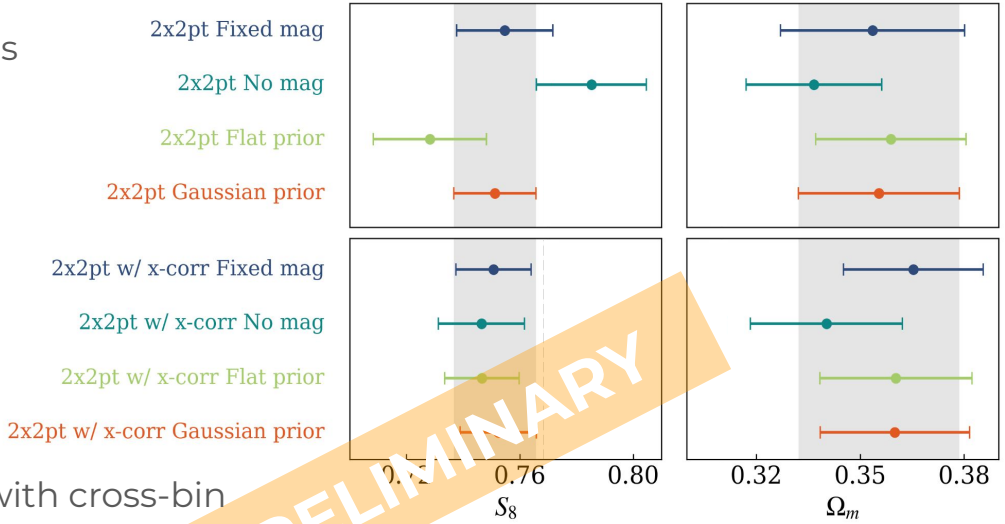
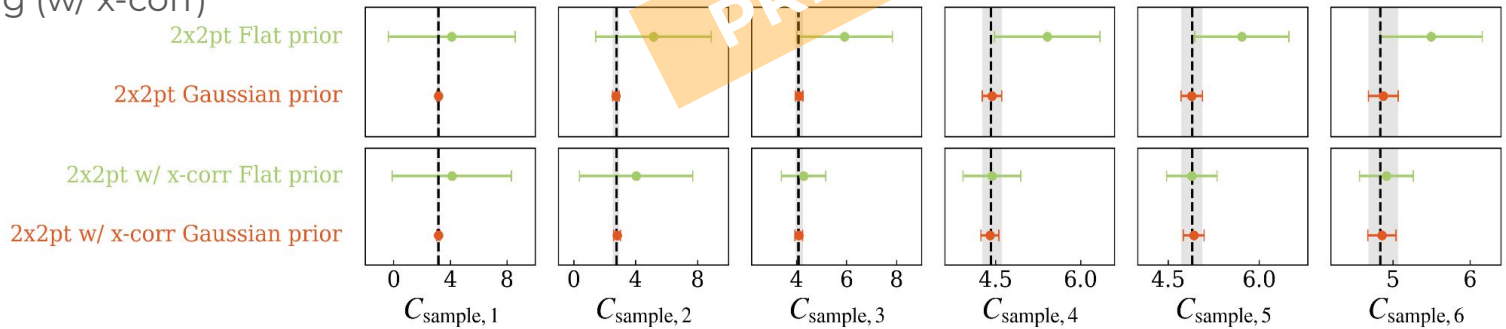


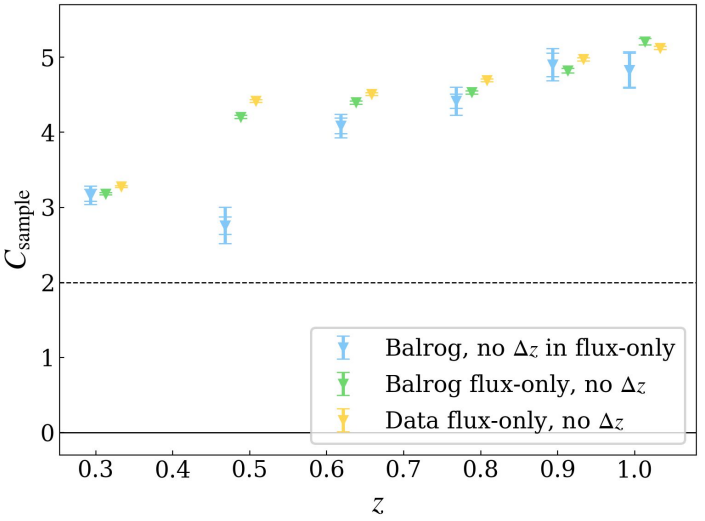
PRELIMINARY

- Improved magnification constraints with cross-bin clustering (w/ x-corr)



Magnification modelling from DES Y3 to Y6

- Balrog reweighted to match data properties



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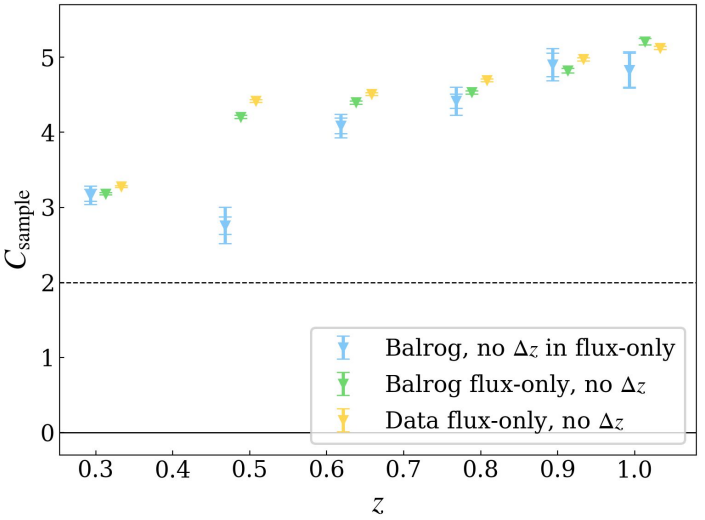
- Add a constant offset to the measured magnitudes

$$\Delta m = -2.5 \log_{10}(1 + 2\delta\kappa)$$



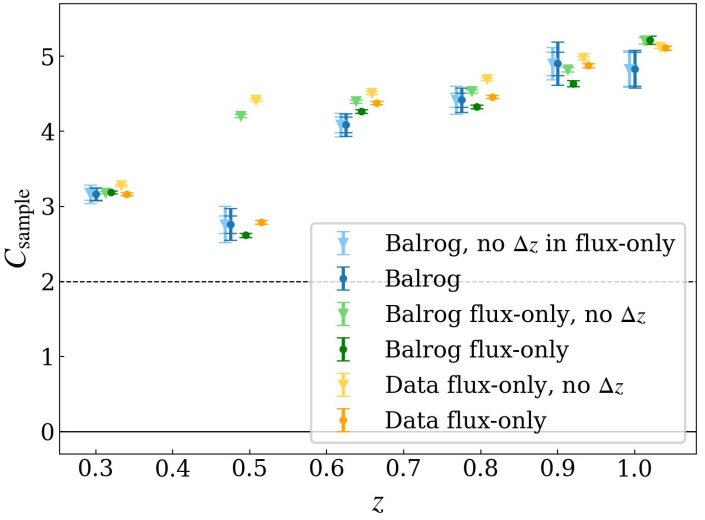
Magnification modelling from DES Y3 to Y6

- Balrog reweighted to match data properties
- Add a constant offset to the measured magnitudes

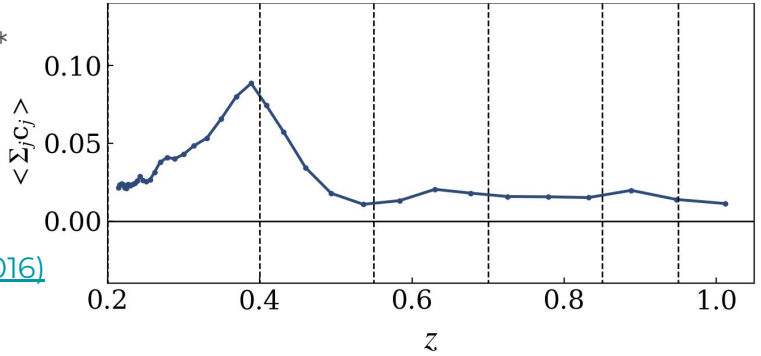
$$\Delta m = -2.5 \log_{10}(1 + 2\delta\kappa)$$

and also to the redshift estimates used for selection

$$\Delta z = \sum_j c_j \, \Delta m_j$$



→ For MagLim++ it is safe to use approximate method *

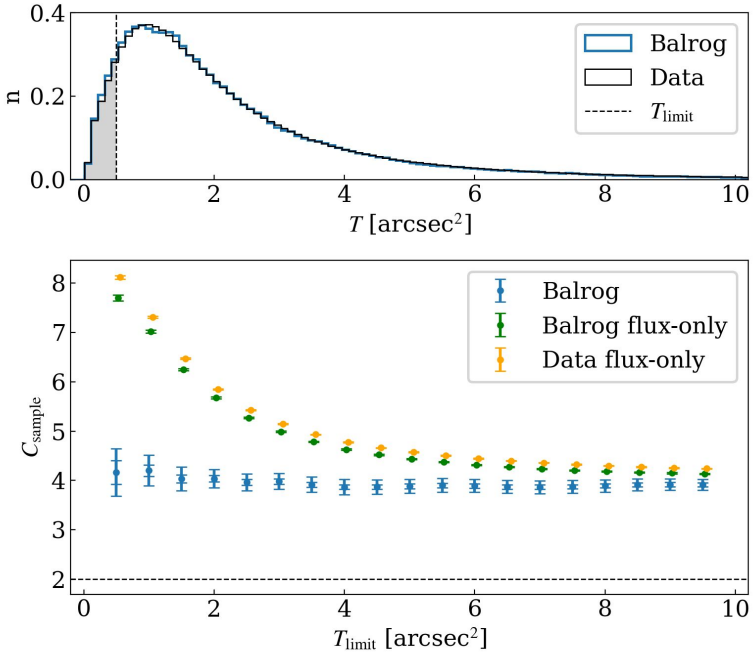


DNF photo-zs: De Vicente et al. (2016)

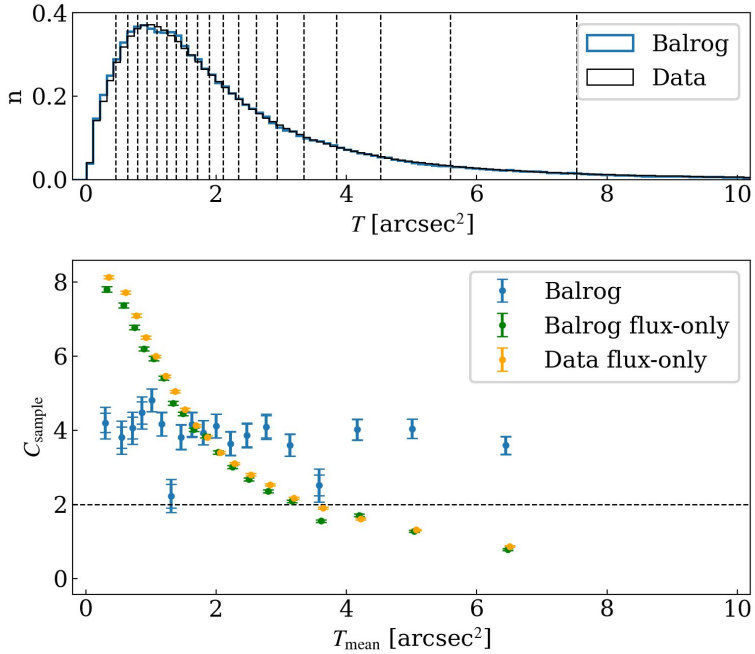
Magnification coefficients with changing selection

* Magnification with size selection

Size-limited sample



Size-binned sample



Conclusions

- Lens magnification bias needs to be modelled in LSS analyses
  Ignoring it leads to biased cosmological inference
- Selection effects are complex
  Flux and size cuts respond to lensing - not trivial to correct analytically
- Synthetic Source Injection is essential
  Accurately captures selection response to magnification
- Cross-bin clustering helps
  Strongly constrains magnification terms → allows broader priors

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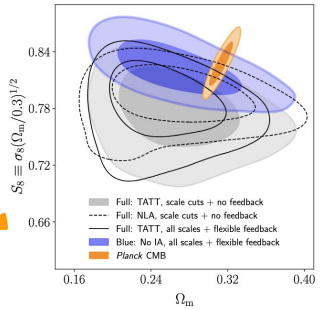
Galaxy splits analyses
See DES Y3 Blue shear:
McCullough, Amon, EL, Gruen et al. (2024)



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Stay tuned for DES Y6 results