FERMILAB-SLIDES-23-390-STUDENT

Weak Gravitational Lensing of Low Surface Brightness Galaxies in the Dark Energy Year 3 Catalog

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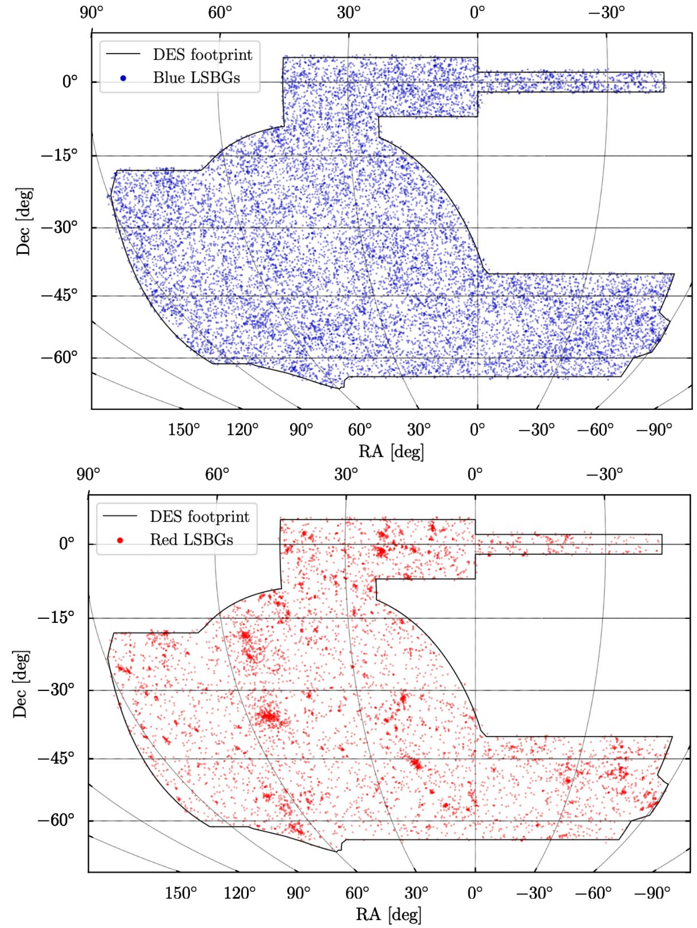
Introduction

Low Surface Brightness Galaxies

- Low surface brightness galaxies (LSBGs) are faint, diffuse, dark matter dominated galaxies
- They contribute little to the observable universe's stellar mass density, but may account for a large fraction (30%-60%) of the total number density of galaxies
- LSBGs play a critical role to understanding galaxy evolution, but direct observation is challenging

Collection of red *(g-i>0.6)* LSBG images from *Tanoglidis et al. (2021).*

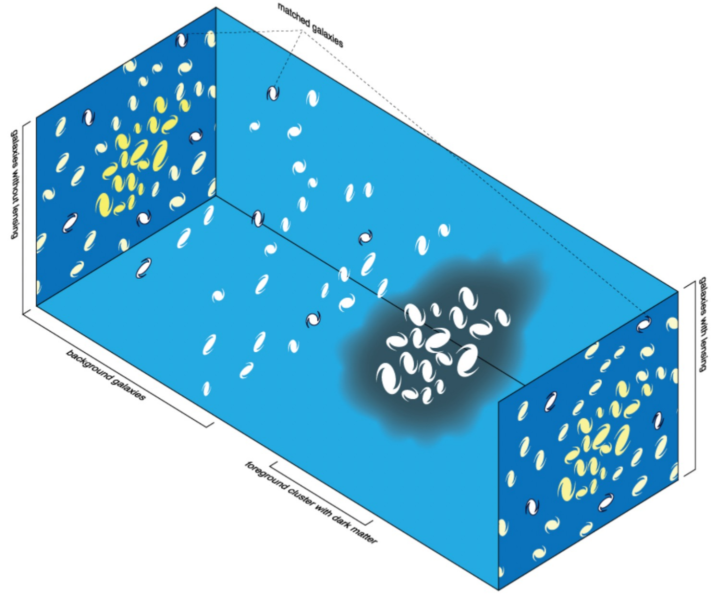


Spatial distribution of red and blue LSBGs against the Dark Energy Survey Y3 footprint, from *Tanoglidis et al. (2021)*. Note the clustered behavior of the red sample.

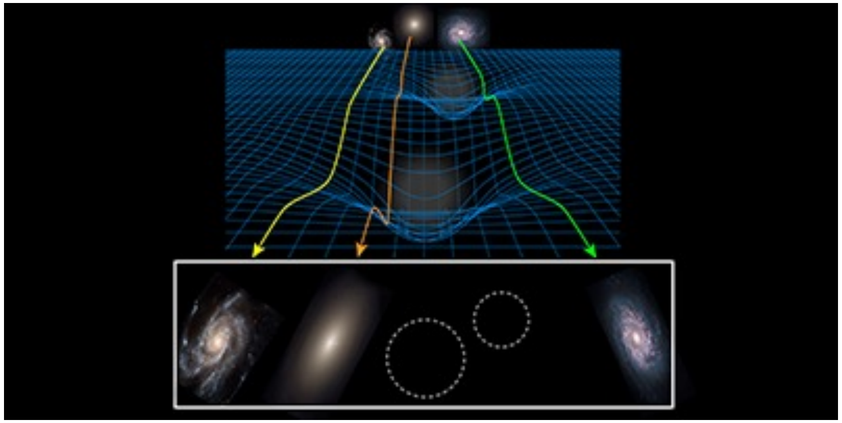
Conducting Measurements

Weak Lensing

- Weak lensing probes both the baryonic and dark matter content of astronomical objects
- Light from a background object passes by the gravitational potential well of a foreground mass, creating a distorted image.
- We measure this distortion- the tangential shear- by cross-correlating the positions of background (source) galaxies with the positions of foreground (lens) galaxies.
- This project represents the first example of an attempted constraint on the mass of LSBGs using weak lensing

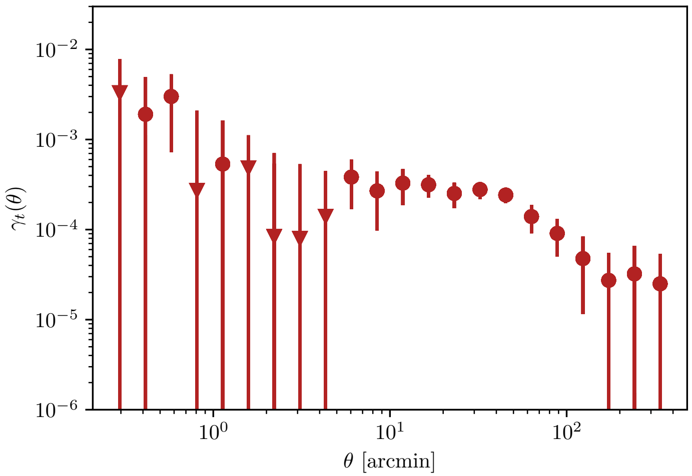


Visualization of weak lensing: the 3-D galaxy distribution becomes a 2-D projection image that is warped by the foreground mass

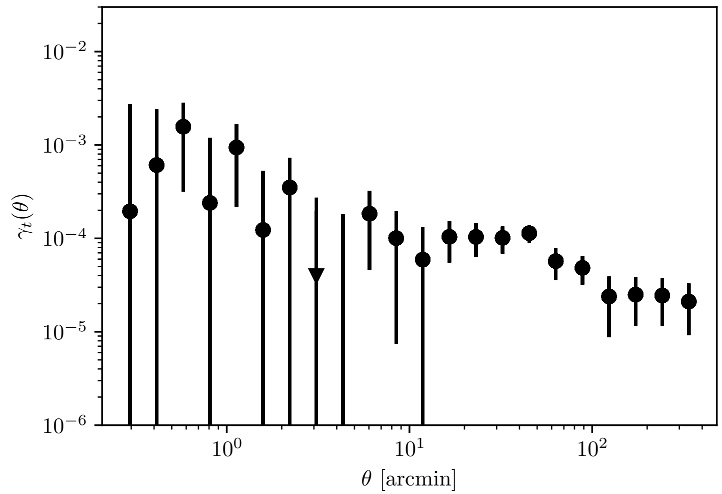


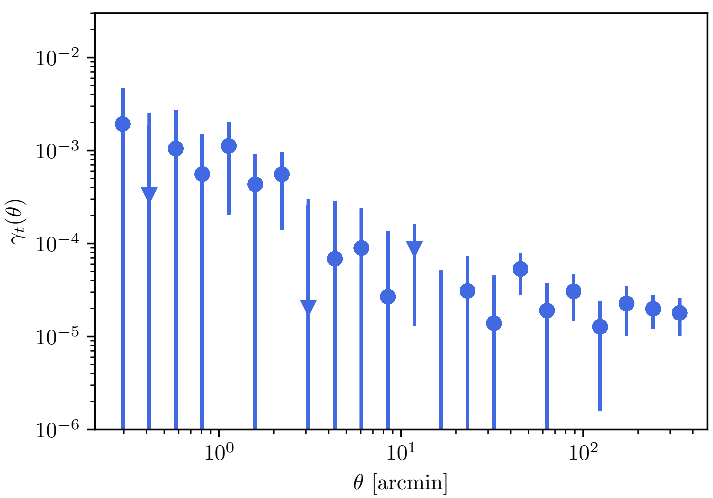
Visualization of the impact of shear on image quality, from APS; galaxy images from STScI/AURA, NASA, ESA, and the Hubble Heritage Team

Tangential Shear Measurements



Tangential shear measurements for the red, blue, and total LSBG sample across angular scales of 0.25-400 arcmin. The triangles indicate negative shear measurements. The errorbars are derived from the jackknife covariance





	χ^2_{null}/ν	S/N
Total Sample	50.09/22	5.30
Red	66.42/22	6.67
Blue	26.70/22	2.17

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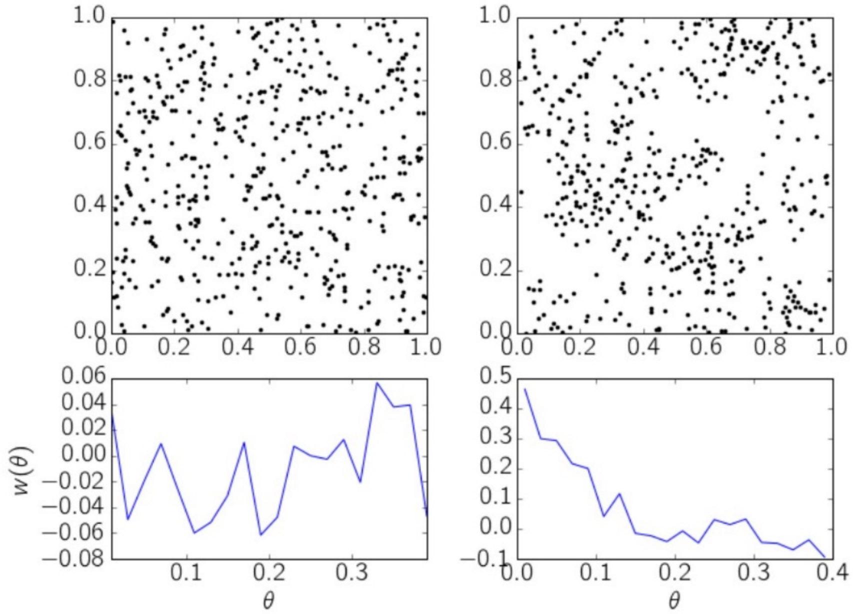
Conducting Measurements

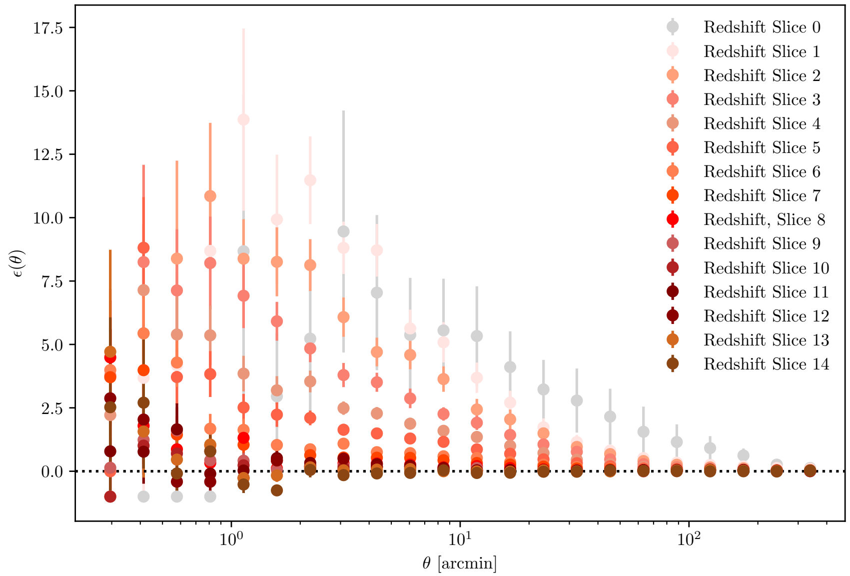
Two-Point Correlation Measurements

- The two-point correlation function describes the likelihood of finding a pair of objects at a given separation compared to a random distribution
- In the context of galaxy-galaxy lensing, the two-point correlation is linked to the relationship between the positions of lens galaxies and the distribution of dark matter.
- We use the two-point correlation signal to cross-correlate the LSBG lens sample with the 2MPZ photometric redshift catalog and estimate the redshift distribution of the LSBG sample.



Visualization of the relationship between clustering and the two-point correlation function

Redshift Distribution

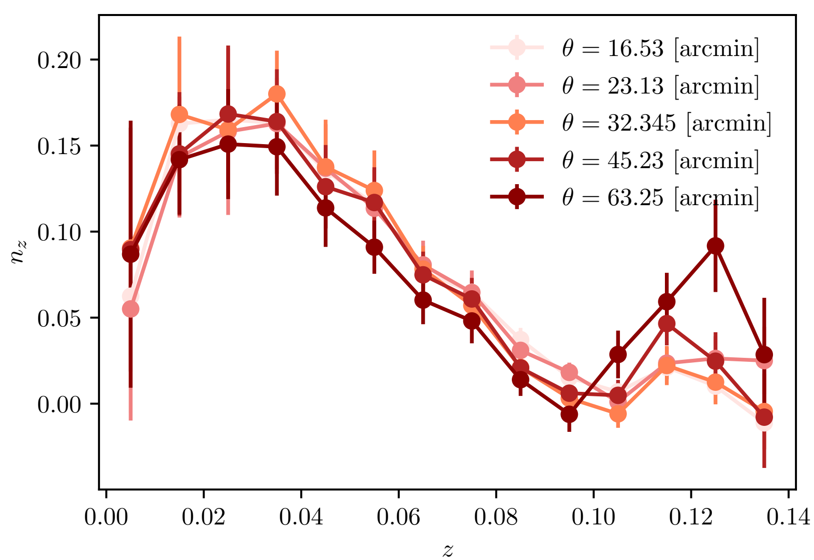


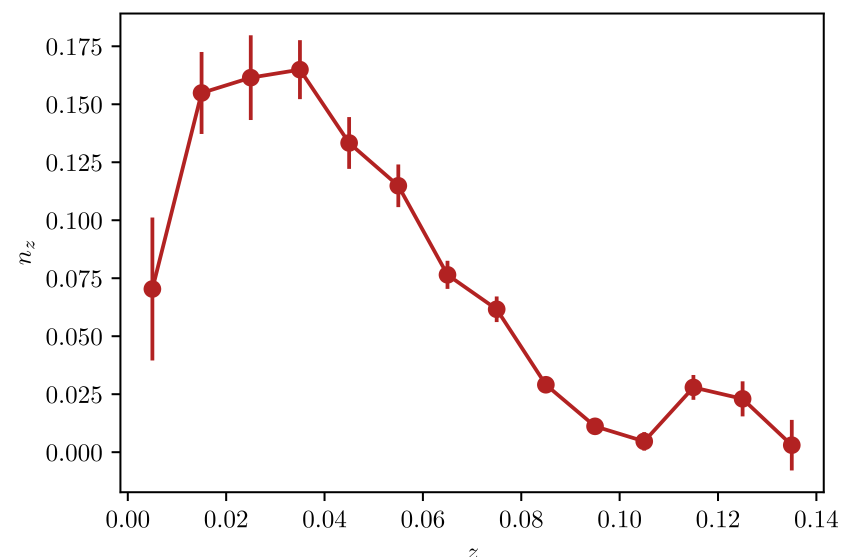
$$w_{ur}(\theta) = \frac{D_u D_r(\theta)}{D_u R_r(\theta)} - 1$$

$$n_u(z_i) \propto \frac{w_{ur}(z_i)}{b_r(z_i) w_{DM}(z_i)}$$

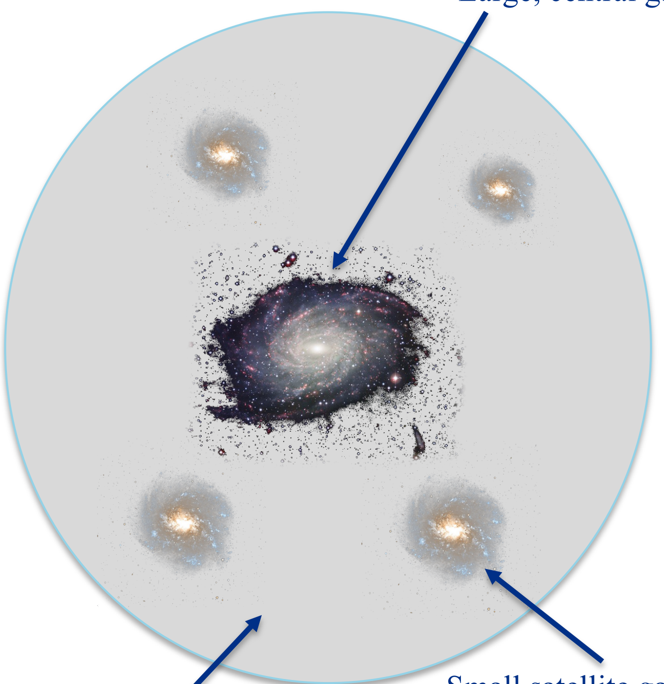
$$b_r(z_i) \approx \sqrt{\frac{w_{rr}(z_i)}{w_{DM}(z_i)}}$$

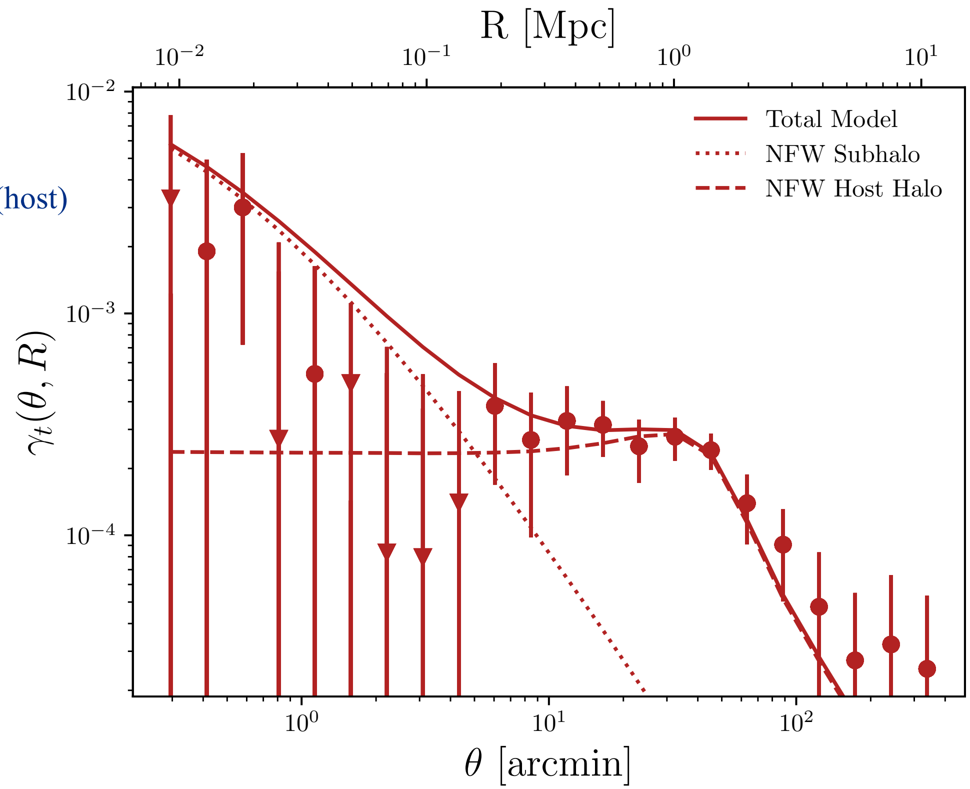
- Upper left: Two-point correlation measurements between the 2MPZ catalog and the red LSBG sample, in 14 redshift slices from 0.0 to 0.14
- Lower left: Approximated redshift distribution over thin redshift slices, derived from the two-point correlation, the galaxy bias, and the dark matter clustering function, for five sets of angular scales
- Lower right: Redshift distribution averaged over sets of angular scales





Modeling





Comparison between red LSBG tangential shear measurements and the model across both physical and angular scales

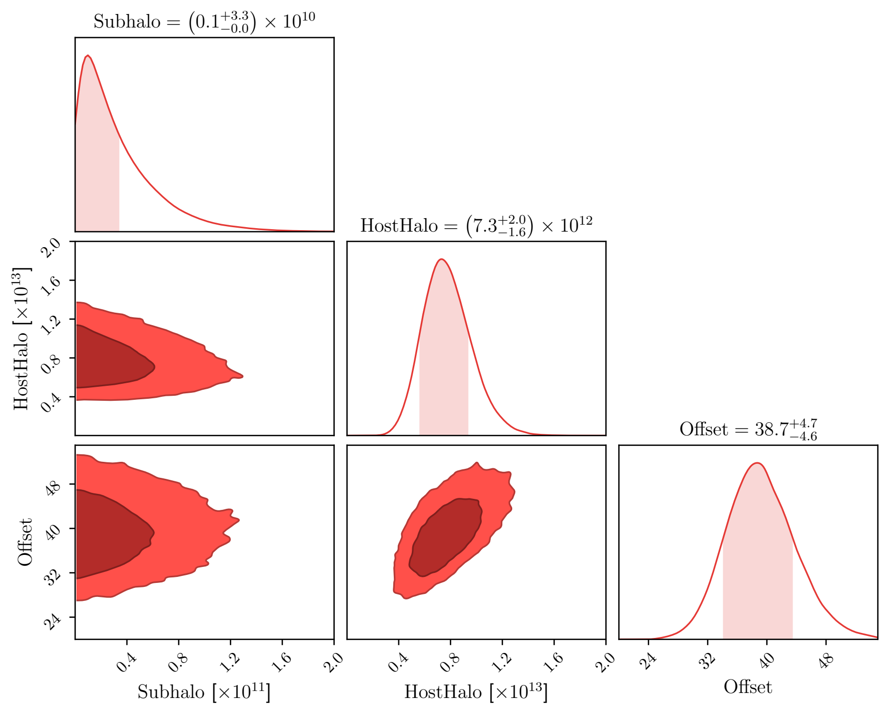
$$\gamma_{t,i,j}(R) = \frac{\Delta\Sigma_i(R)}{\Sigma_{crit}(z_{L,i}, z_{S,j})}$$

$$\gamma_{t,sub,pop}(R) = \int \gamma_{t,i,j}(R) \times N(z_L)\, dz_L$$

$$\gamma_{t,host,pop}(R, R_{off}) = \int\int \gamma_{t,i,j}(R, R_{off}) \times N(R_{off}) \times N(z_L)\, dR_{off}\, dz_L$$

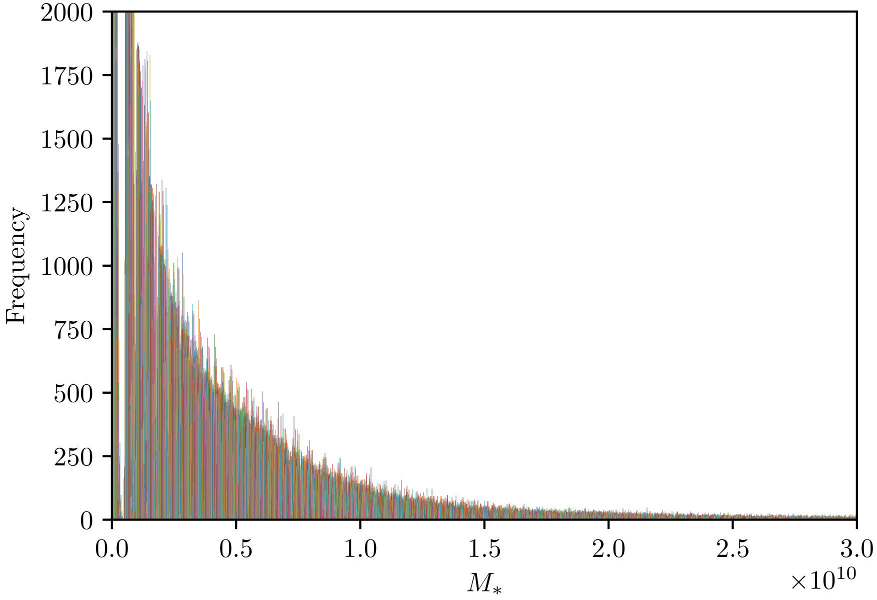
$$\gamma_t(R) = \gamma_{t,sub}(R) + \gamma_{t,host}(R, R_{off})$$

Model Posteriors

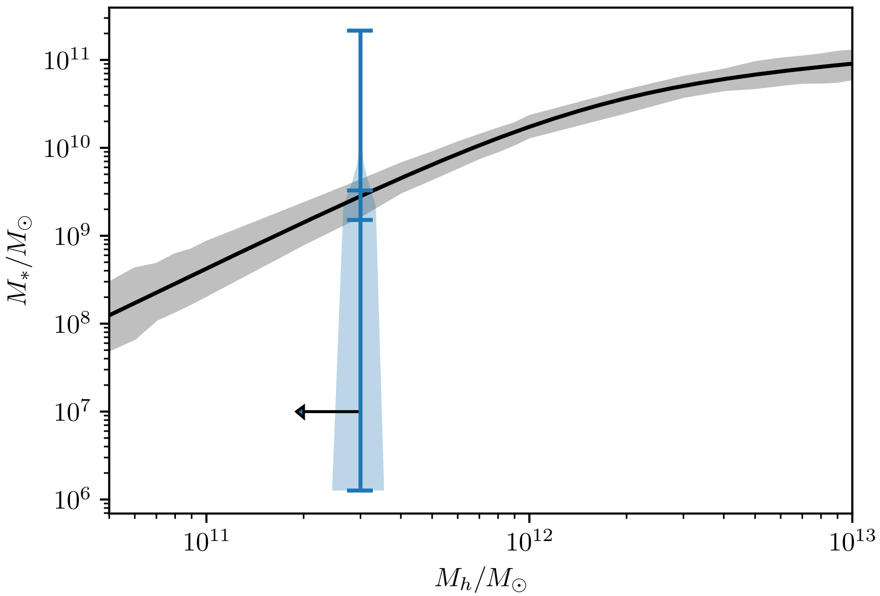


Red LSBGs	Priors	Posteriors
Subhalo Mass	$U(10^7 M_\odot < M_{sub} < 10^{12} M_\odot)$	$M_{sub} < 3\times10^{11}\ M_\odot$
Host Halo Mass	$U(10^{10} M_\odot < M_{host} < 10^{15} M_\odot)$	$7.3^{+2.0}_{-1.6}\times10^{12} M_\odot$
Offset	$U(25' < \mu < 55')$	$38.7^{+4.7}_{-4.6}{}'$

Stellar-to-Halo Mass Relation



Stellar mass distribution derived from photometry for *g-i* and *g-r* color bands and *g, r,* and *i* magnitudes



Full stellar mass distribution at upper subhalo mass limit (blue plot) compared to the parameterized stellar-to-halo mass relation from *Moster et al. (2010)* (gray shaded line)

References

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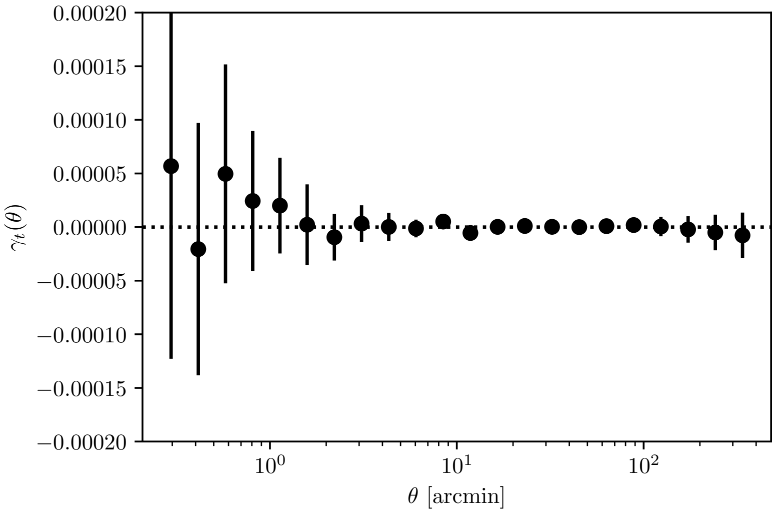
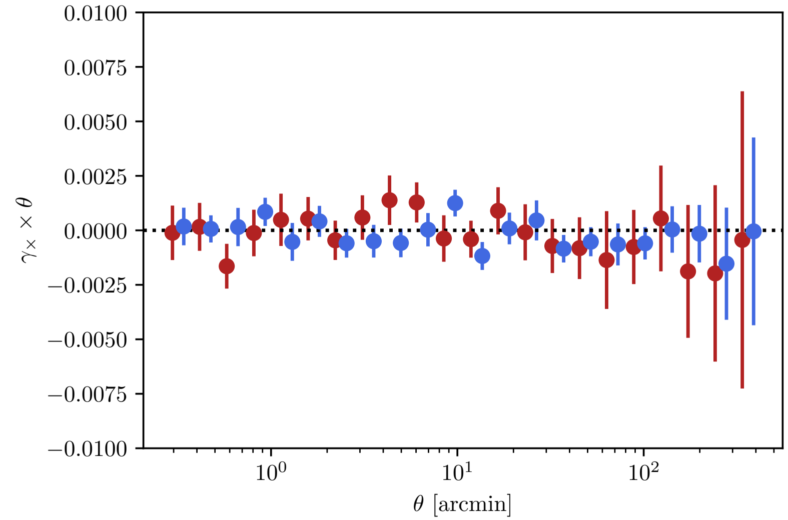
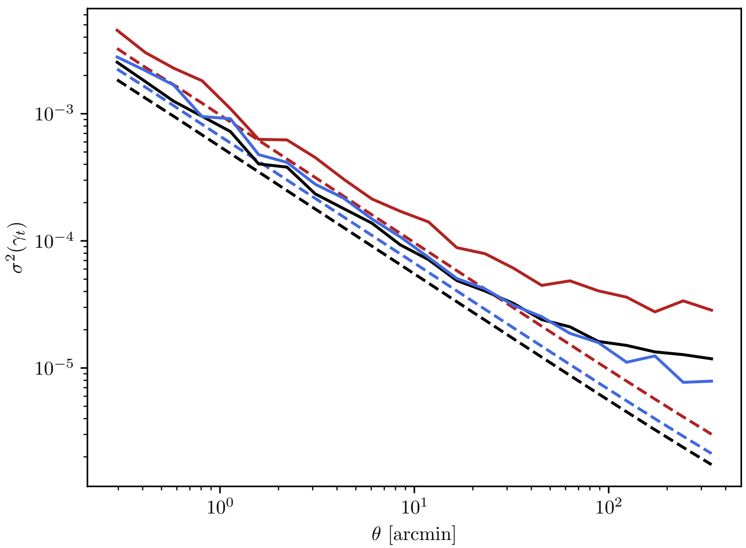
Systematics







- Upper left: Tangential shear around the random point sample in 22 angular bins. All shape catalog redshift bins are combined. The shear measurements do not produce a significant signal.
- Lower left: Comparison between shape noise and jackknife covariance diagonals for the red, blue, and total sample of galaxies over angular scales. The shape noise represents the combined uncertainty associated with the intrinsic ellipticity of the source galaxies and the shot noise from the Poisson statistic. The jackknife covariance appears to dominate at all scales. The color of each line represents the sample, with blue associated with blue LSBGs, red with red LSBGs, and black with the total sample.
- Upper right: Measurement of the γ_x term for the red and blue LSBG samples. Note that the blue sample positions are offset to improve visibility. We find this term to be consistent with zero.