Characterization of the HOD redshift and magnitude evolution from magnification bias observations

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Introduction

Magnification bias arises when weak gravitational lensing by foreground mass structures alters the apparent number of background sources. This effect provides a powerful tool to probe both the galaxy–halo connection through Halo Occupation Distribution (HOD) models and to constrain key cosmological parameters.

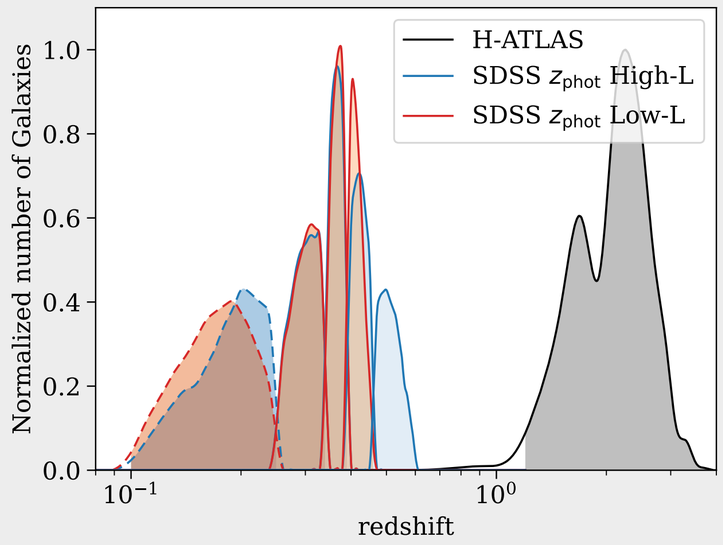
We investigate this effect as an alternative probe of the galaxy–halo connection across redshift and luminosity.

By comparing different HOD prescriptions, we aim to refine existing methodologies and strengthen the use of magnification bias as a cosmological probe.

Data

Foreground and background sources are selected from the 18th data release of the Sloan Digital Sky Survey (SDSS) and the *Herschel* Astrophysical Terahertz Large Area Survey (H-ATLAS), respectively (Fig. 1). These surveys reduce to a common area of ~ 360 deg^2, divided into three equatorial regions (G09, G12 and G15) and the north galactic pole (NGP) region.

- Background SMGs are selected at $1.2 < z < 4.0$ with $\geq 4\sigma$ detections at 250 μm and $\geq 3\sigma$ at 350 μm.
- Foreground lenses are divided into 4+1 redshift bins and two absolute magnitude bins to study luminosity-dependent galaxy evolution, spanning between $0.10 < z < 0.6$ and $-26.0 < M_r < -19.5$.



Redshift bins:
0. $0.10 < z < 0.25$
1. $0.25 < z < 0.34$
2. $0.34 < z < 0.39$
3. $0.39 < z < 0.46$
4. $0.46 < z < 0.60$

M_r bins:
1. $-26 < M_r < -22$
2. $-22 < M_r < -21$

Figure 1: Redshift distributions of the foreground and background samples.

Measurements

- Cross-correlation measurements are performed with the Landy & Szalay (1993) estimator, modified by Herranz (2001):

$$w_{\rm cross}(\theta) = \frac{D_f D_b - D_f R_b - D_b R_f + R_f R_b}{R_f R_b}$$

- Errors and full covariance are computed with Bootstrap resampling.
- Cross-correlation signal is interpreted within the halo model formalism, using Markov Chain Monte Carlo (MCMC) techniques under a flat ΛCDM cosmology to obtain posterior distributions of the HOD parameters.

HOD models

The average number of galaxies that populate an halo can be written as the sum of central and satellite components: $\langle N_g \rangle_M = \langle N_{\rm cen} \rangle_M + \langle N_{\rm sat} \rangle_M$.

- Zheng et al. (2005) 3-parameter model:

$$\langle N_g \rangle_M = \left[1 + \left(\frac{M}{M_1}\right)^{\alpha}\right] \Theta(M - M_{\rm min}),$$

where $M_{\rm min}$ is the mean minimum mass a halo needs to host one galaxy above the specified luminosity threshold, M_1 is the mean halo mass at which there is exactly one satellite, and α is the logarithmic slope of the satellite occupation number.

- Gonzalez-Perez et al. (2018) Gaussian 6-parameter model:

$$\langle N_g \rangle_M = \frac{A_c}{\sqrt{2\pi}\sigma_g} \exp\left[-\frac{(\log M - M_g)^2}{2\sigma_g^2}\right] + \left(\frac{M - M_0}{M_1}\right)^{\alpha}$$

Results

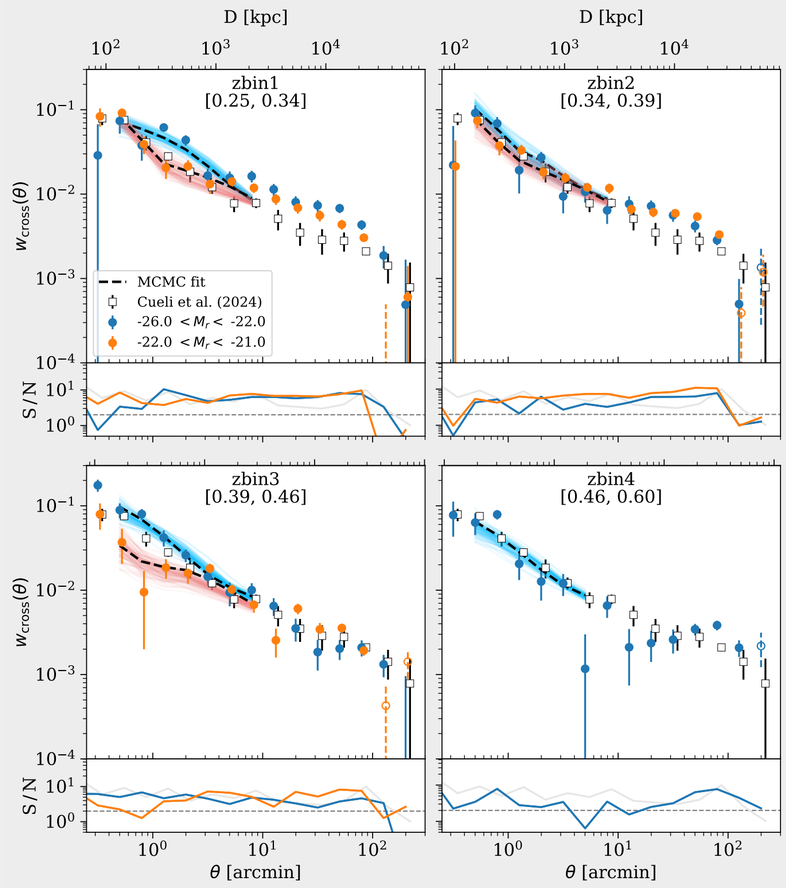


Figure 2: Cross-correlation signal for each redshift and magnitude bin. Sampled models from the Gaussian HOD are shown in the corresponding colors, along with the best-fit model.

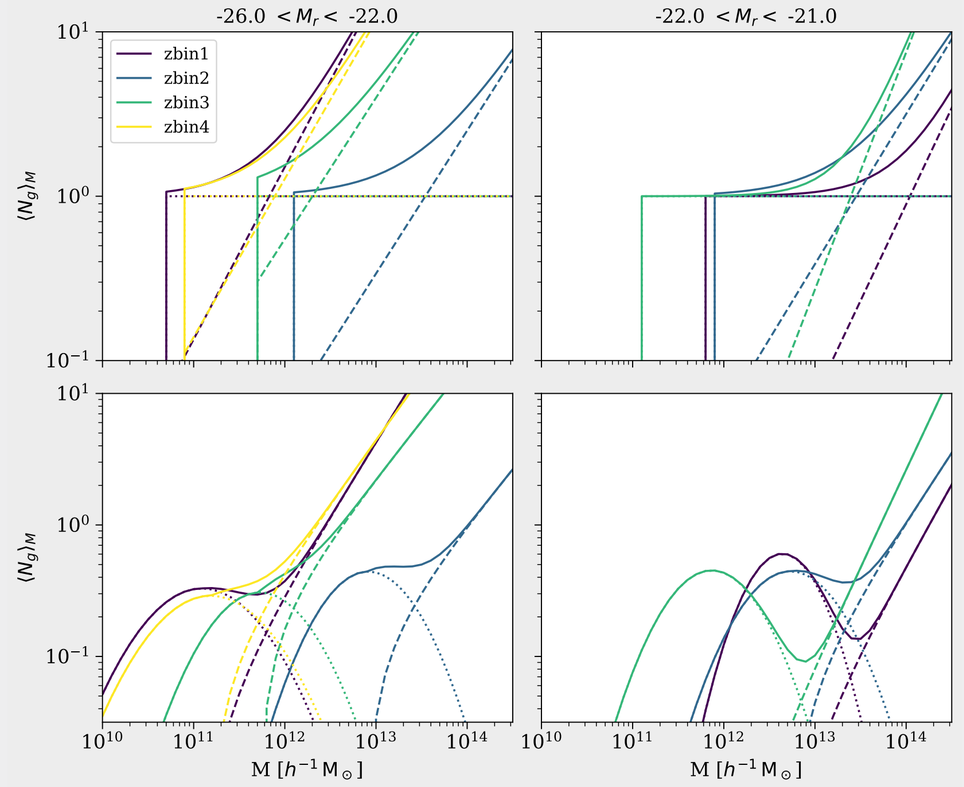


Figure 3: HOD models derived from MCMC analysis. Top panels correspond to the 3-parameter model, and bottom panels to the 6-parameter one, for the two luminosity bins.

Conclusions

- Consistent strength of the lensing cross-correlation signal between high- and low-luminosity galaxies.
- Improved HOD reconstruction in magnification bias analyses compared to previous studies.
- Expected evolution of most HOD parameters, except in the first redshift bin, likely due to its lower lensing probability.

Further work

- Use improved HOD models to better constrain cosmological parameters.
- Compare results with the auto-correlation function and perform a joint analysis of auto- and cross-correlations.

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