MAGNIFICATION BIAS OF SMGS AS A PROBE OF DARK ENERGY EVOLUTION

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on behalf of

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ICTEA

III ICTEA RESEARCH DAYS | JUNE 2026

Universidad de Oviedo

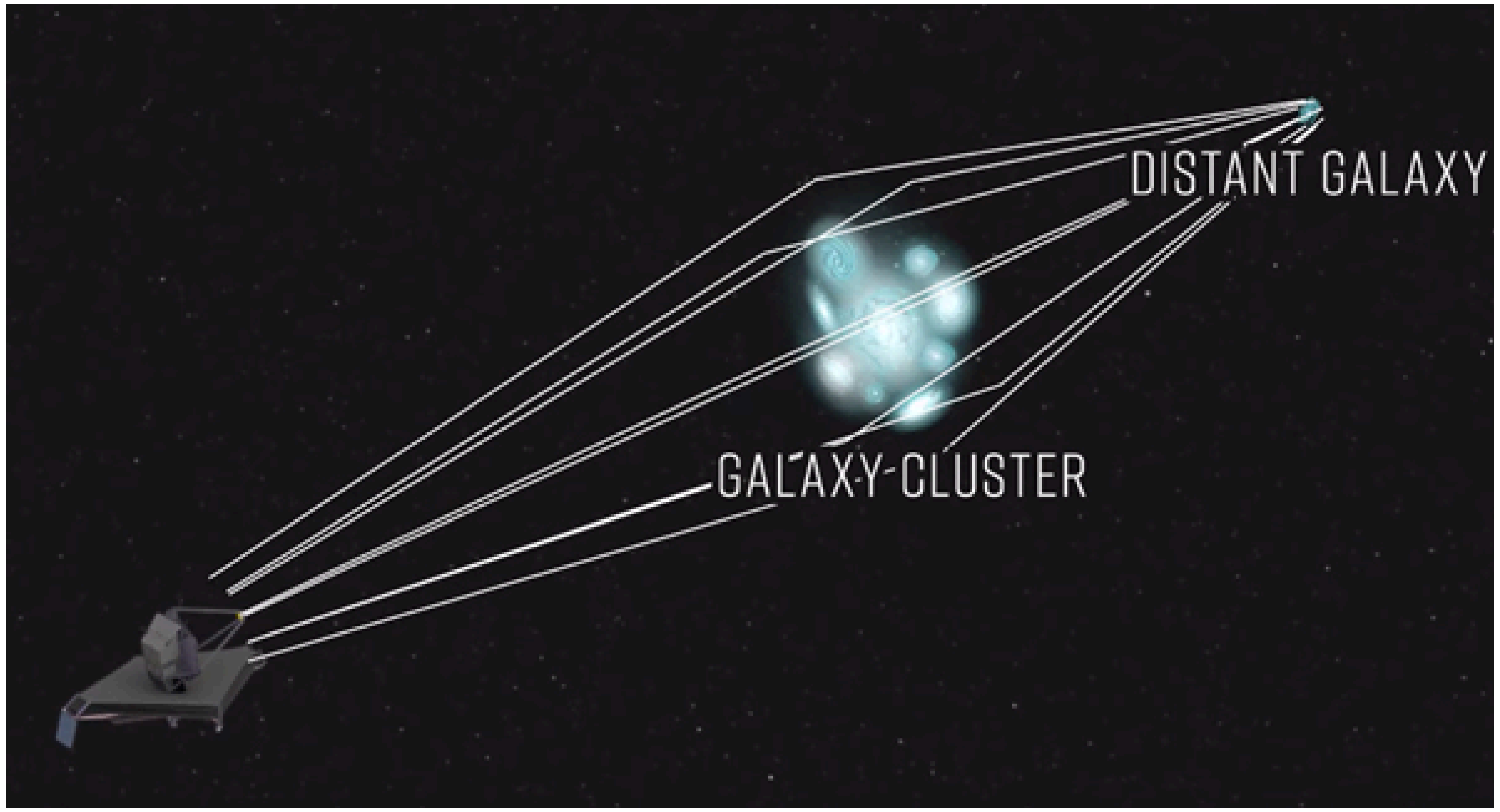
GRAVITATIONAL LENSING

Matter acts like a magnifying glass in space, deflecting light rays. Images of the background object will be magnified* and distorted.

It is a prediction of General Relativity

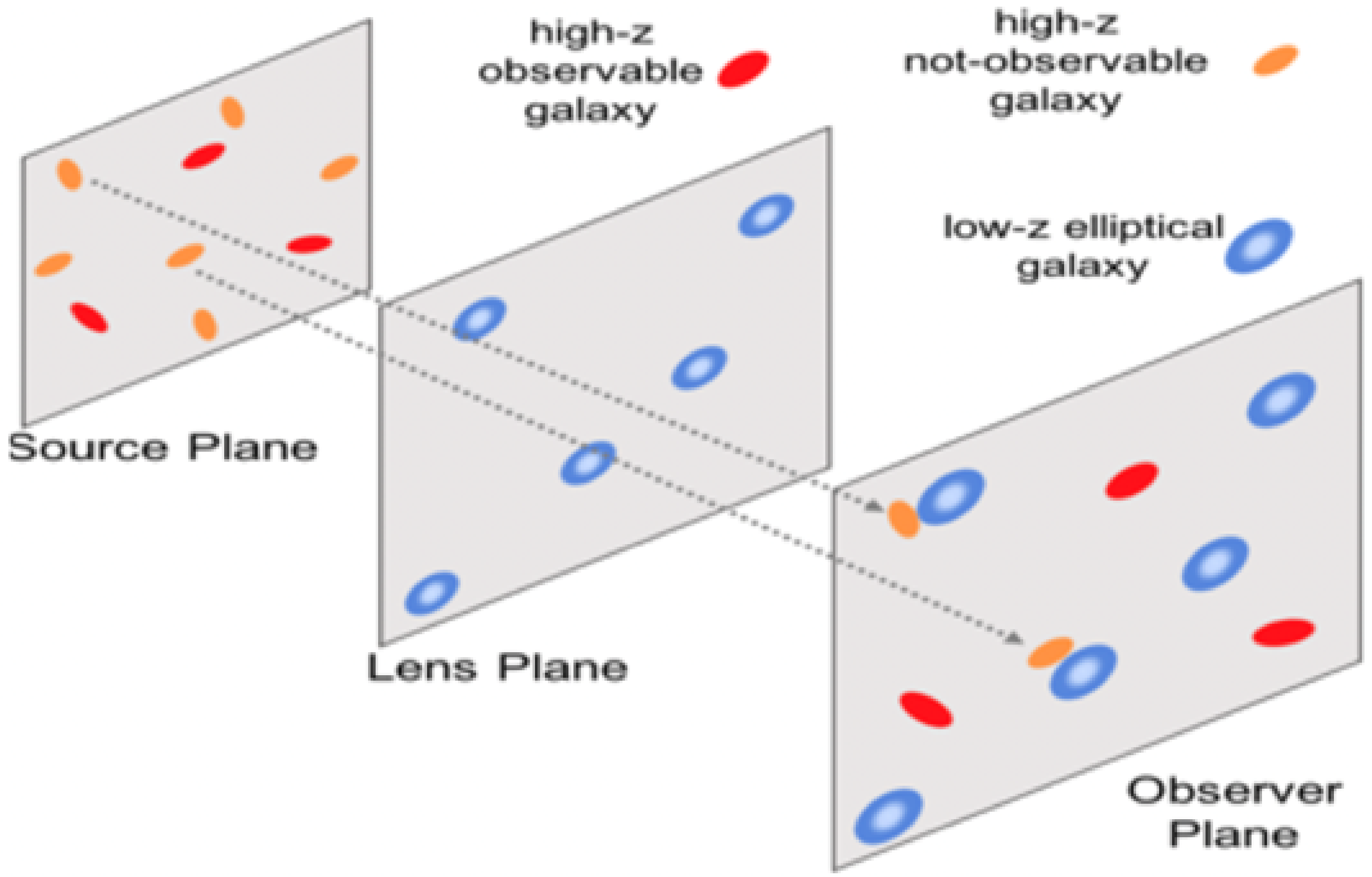
↓

cosmological tool



MAGNIFICATION BIAS

Weak lensing effect that increases the background source number counts around the lenses' positions.



Traces large scale (total) matter distribution.

Independent from shapes.

Complementary to other weak lensing observables.

CROSS-CORRELATION ON SMGS

Magnification bias induces a cross-correlation.

If samples do not overlap in redshift, it can be expressed as:

$$w_{fb}(\theta) \equiv \langle \underbrace{\delta n_f^c(\phi)}_{\text{clustering}} \underbrace{\delta n_b^\mu(\phi+\theta)}_{\text{amplification}} \rangle$$

⟷

It can be measured as pair-counts

$$\tilde{w}_{fb}(\theta) = \frac{\mathrm{D_f D_b}(\theta) - \mathrm{D_f R_b}(\theta) - \mathrm{D_b R_f}(\theta) + \mathrm{R_f R_b}(\theta)}{\mathrm{R_f R_b}(\theta)}$$

Landy & Szalay (1993); Herranz et al. (2001)

In the weak lensing regime:

$$\delta n_b^\mu(\theta) \approx 2(\beta - 1)\kappa(\theta)$$

$$\delta n_f^c(\phi) = \int dz \frac{dN_z}{dz} \delta_g(\chi(z)\theta, z)$$

Halo Model (Coorey and Sheth, 2002)

$$w_{fb}(\theta) \equiv w_{fb}(\theta; cosmology, HOD)$$

PREVIOUS AND CURRENT WORK

Revisiting Bonavera+21 with the refined pipeline from Cueli+24

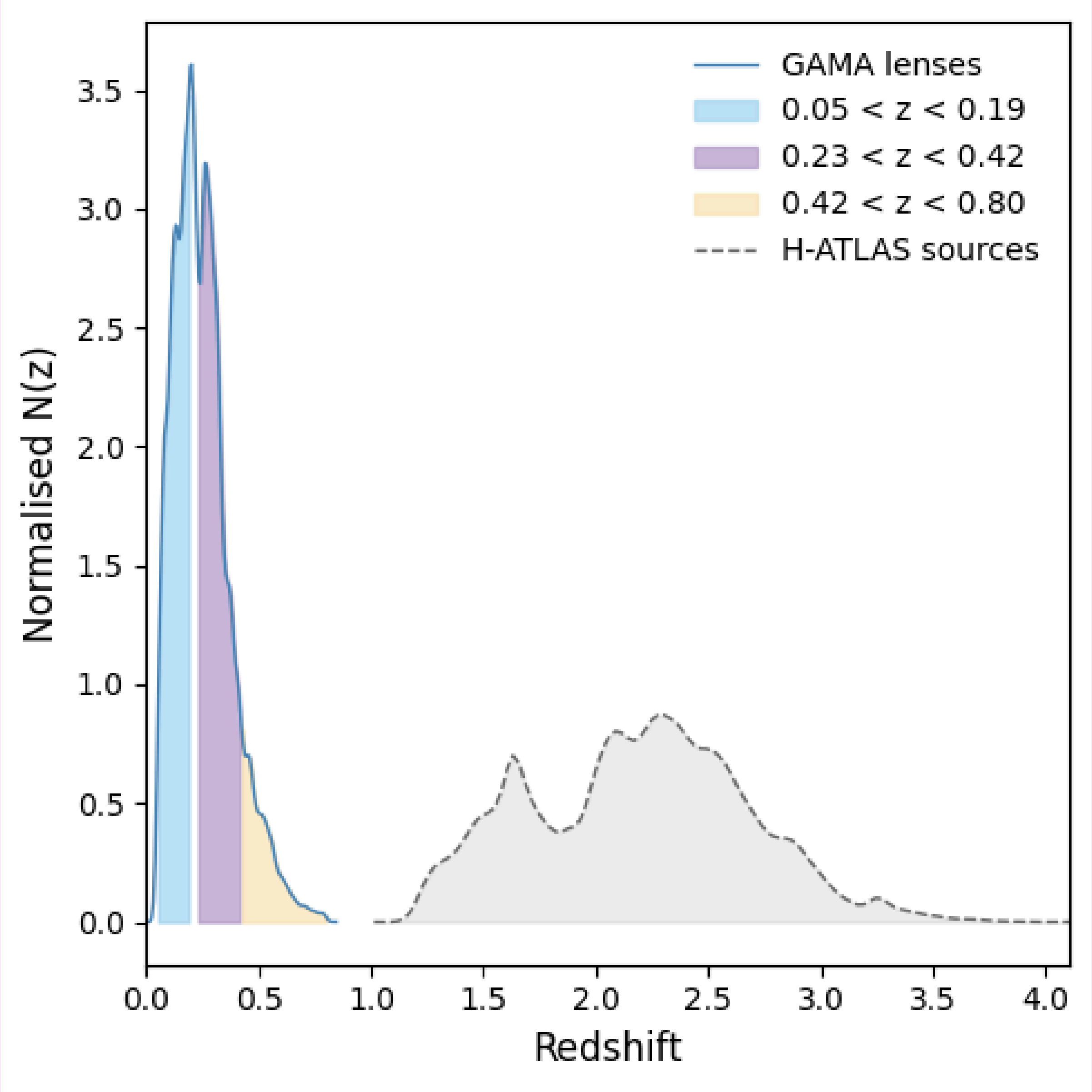
2021	2024	2025-26
Bonavera+21	**Cueli+24, Bonavera+24**	**Current work**
CCF + cosmology on 4 bins	CCF + cosmology on single & 4 bins	CCF + cosmology on 3 bins
Models: LCDM, wCDM, w0waCDM	Only LCDM	Covariance estimator from Cue24
Wide or no constraints on DE parameters	Improved model, better constraints	(Pending) improved random catalogue

DATA AND TOMOGRAPHIC BINS

Three foreground redshift bins are cross-correlated with the same high-redshift H-ATLAS source sample.

Catalogue	Role	Sky regions	Objects	Area
GAMA II	Foreground lenses	G09, G12, G15, SGP	184 167	207 $\deg^2$
H-ATLAS	Background SMGs	G09, G12, G15, SGP	36 096	207 $\deg^2$

Bin	Redshift range	Objects
Bin 1	$0.05 < z < 0.19$	76 573
Bin 2	$0.23 < z < 0.42$	85 789
Bin 3	$0.42 < z < 0.80$	21 805



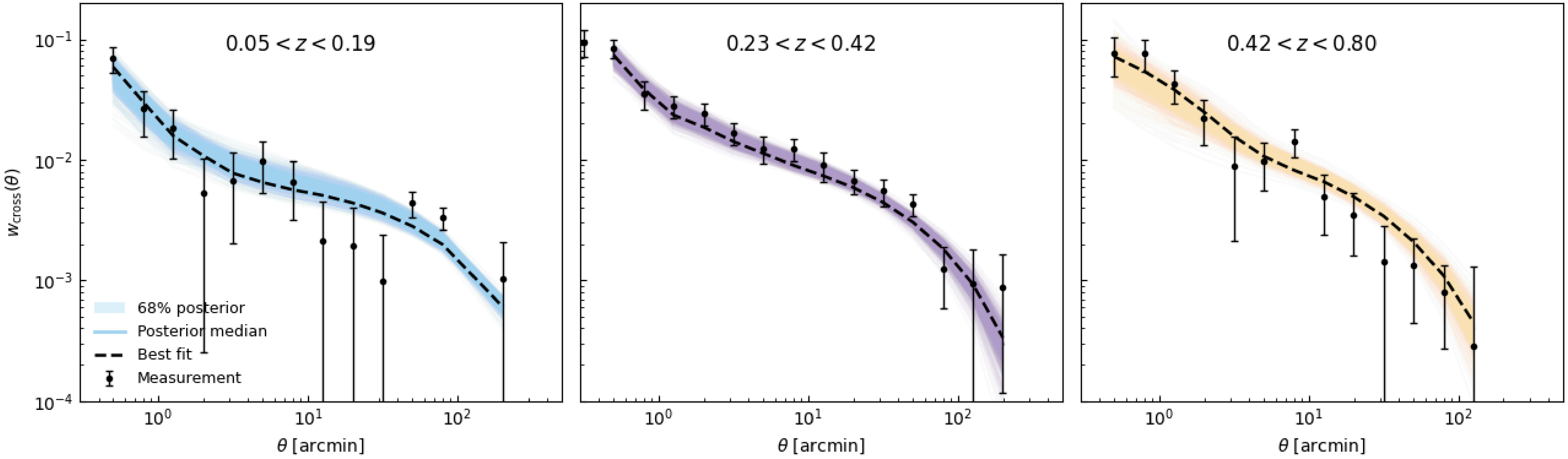
MEASUREMENTS

- We measure the pair counts between galaxies in foreground and background catalogues and compare it with a random
- We build a theoretical model for the CCF that has 3x3 HOD+4-6 COSMO free parameters
- Using MCMC we explore constraints for the parameters and check constraints on DE evolution models

LCDM | wCDM | wowaCDM

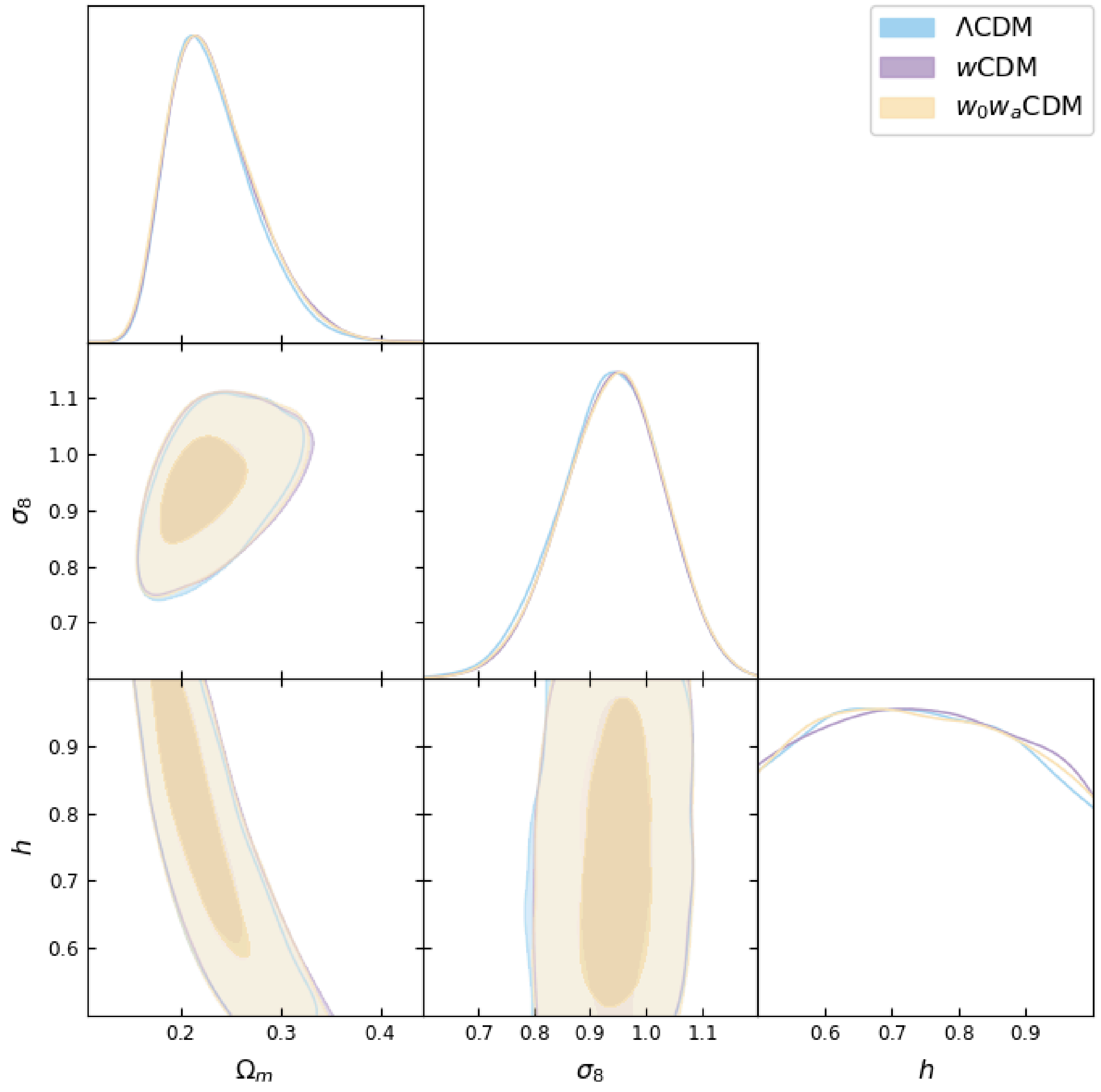
RESULTS:CROSS-CORRELATION

Cross-correlation measurements are compatible with magnification bias in LCDM cosmology.



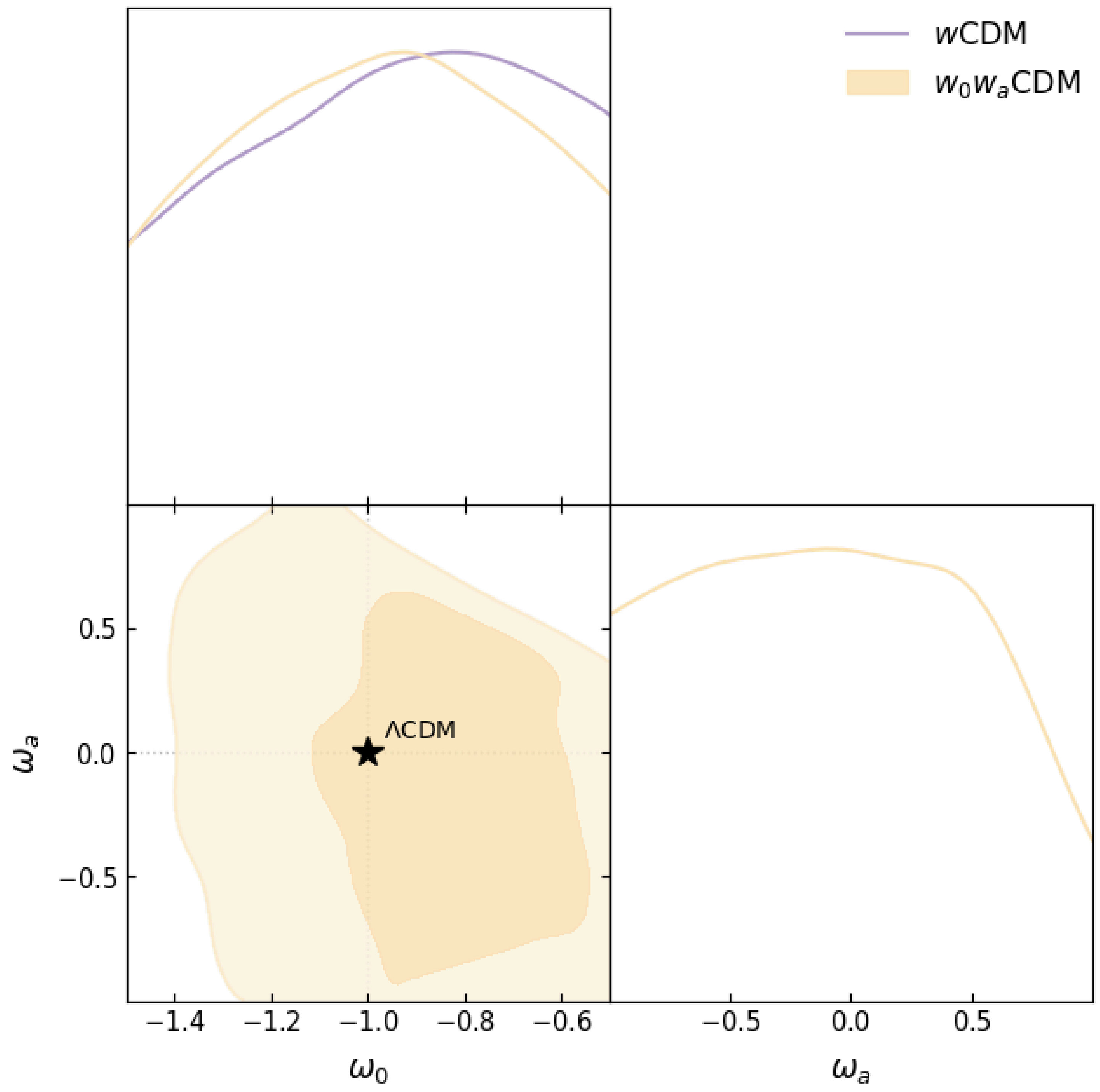
RESULTS: COSMOLOGY

Constraints on Ωm , σ8 and h remain stable when extending the cosmological model from ΛCDM to wCDM and wowaCDM.



Model	Ω_m	σ_8	h
ΛCDM	0.233 ± 0.043	0.937 ± 0.093	unconstrained
wCDM	0.235 ± 0.045	0.941 ± 0.091	unconstrained
w_0w_aCDM	0.234 ± 0.044	0.941 ± 0.091	unconstrained

RESULTS: DE EVOLUTION



No evidence for departures from ΛCDM is found.

The (w0,wa) constraints remain fully consistent with a cosmological constant and are significantly tighter than those of Bonavera et al. (2021).

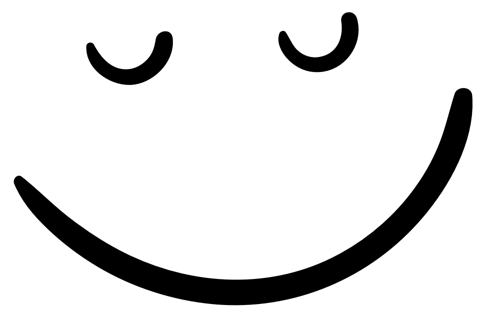
Analysis	w_0	w_a
Bonavera+21	$-1.09^{+0.43}_{-0.63}$	$-0.19^{+1.67}_{-1.69}$
This work	-0.99 ± 0.27	-0.06 ± 0.54

Both results are compatible with ΛCDM: $(w_0, w_a) = (-1, 0)$.

CONCLUSIONS

- We obtain robust tomographic constraints on ΛCDM, wCDM and w0waCDM using magnification bias, finding no evidence for departures from ΛCDM.
- Ongoing work focuses on reducing observational systematics through KDE-based random catalogues and improved covariance estimation.
- Current analyses are limited by the size of existing sub-mm catalogues. Future surveys such as AtLAST will provide the statistics needed to fully exploit magnification bias as a cosmological probe.

THANK YOU FOR YOUR ATTENTION!



THEORETICAL MODEL

MagBias:

$$n_0(>S,z) = AS^{-\beta}$$

$$n(>S,z;\vec{\theta}) = \frac{1}{\mu(\vec{\theta})} n_0\left(>\frac{S}{\mu(\vec{\theta})}, z\right) \qquad \frac{n(>S,z;\vec{\theta})}{n_0(>S,z)} = \mu^{\beta-1}(\vec{\theta})$$

Cross-correlation function:

$$w_{fb} = 2(\beta-1)\int_0^{z_s} \frac{dz}{\chi^2(z)} \frac{dN_f}{dz} W^{lens}(z) \int_0^{\infty} \frac{ldl}{2\pi} P_{gal-dm}(l/\chi^2(z), z) J_0(l\theta),$$

where

$$W^{lens}(z) = \frac{3}{2}\frac{H_0^2}{c^2}E^2(z)\int_z^{z_s} dz' \frac{\chi(z)\chi(z'-z)}{\chi(z')}\frac{dN_b}{dz'}$$

Halo Model:

$$P_{\text{g-dm}}(k,z) = P^{1h}_{\text{g-dm}}(k,z) + P^{2h}_{\text{g-dm}}(k,z)$$ Cooray & Sheth (2002)

$$P^{1h}_{\text{g-dm}}(k,z) = \int_0^{\infty} dM\, M \frac{n(M,z)}{\bar{\rho}(z)} \frac{\langle N_g \rangle_M}{\bar{n}_g(z)} |u_{\text{dm}}(k,z|M)||u_g(k,z|M)|^{p-1}$$

$$P^{2h}_{\text{g-dm}}(k,z) = P^{\text{lin}}_{\text{mm}}(k,z)\left[\int_0^{\infty} dM\, M \frac{n(M,z)}{\bar{\rho}(z)} b_1(M,z) u_{\text{dm}}(k,z|M)\right] \cdot \left[\int_0^{\infty} dM\, n(M,z) b_1(M,z) \frac{\langle N_g \rangle_M}{\bar{n}_g(z)} u_g(k,z|M)\right]$$

HOD Model:

$$N_{\text{cen}}(M_h) = \begin{cases} 0 & \text{if } M_h < M_{\min} \\ 1 & \text{otherwise} \end{cases} \qquad N_{\text{sat}}(M_h) = N_{\text{cen}}(M_h) \cdot \left(\frac{M_h}{M_1}\right)^{\alpha_{\text{sat}}}$$

DE Model:

$$\omega(z) = \omega_0 + \omega_a \frac{z}{1+z}$$

$$E(z) \equiv \sqrt{\Omega_M(1+z)^3 + \Omega_{\text{DE}} f(z)},$$

$$f(z) = (1+z)^{3(1+\omega_0+\omega_a)} e^{-3\omega_a \frac{z}{1+z}}$$

MEASUREMENTS

Cross-correlation estimator

Measures the excess probability wrt random at a given angular separation (pair counts).

$$\tilde{w}_{fb}(\theta) = \frac{\mathrm{D_f D_b}(\theta) - \mathrm{D_f R_b}(\theta) - \mathrm{D_b R_f}(\theta) + \mathrm{R_f R_b}(\theta)}{\mathrm{R_f R_b}(\theta)}$$

Landy & Szalay (1993); Herranz et al. (2001).

MCMC

Constraints on HOD and cosmological parameters were obtained via MCMC.

Astro		Cosmo	
Parameter	Prior	Parameter	Prior
$\log M_{min}$	$\mathcal{U}[10.0 - 16.0]$	Ω_m	$\mathcal{U}[0.1 - 0.8]$
$\log M_1$	$\mathcal{U}[10.0 - 16.0]$	σ_8	$\mathcal{U}[0.6 - 1.2]$
α	$\mathcal{U}[0.5 - 1.5]$	h	$\mathcal{U}[0.5 - 1.0]$
β	$\mathcal{N}[2.9, 0.2]$		