Cosmology meets Astrophysics: the lensing-is-low problem

Cosmology from Home 2023

Jonás Chaves-Montero

jchaves@ifae.es

Monthly Notices
of the
ROYAL ASTRONOMICAL SOCIETY

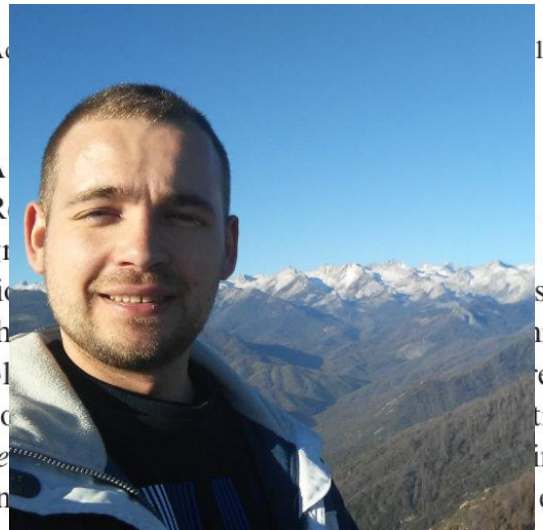
MNRAS **521,** 937–951 (2023)
Advance Access publication 2023 February 6

https://doi.org/10.1093/mnras/stad243

The galaxy formation origin of the *lensing is low* problem

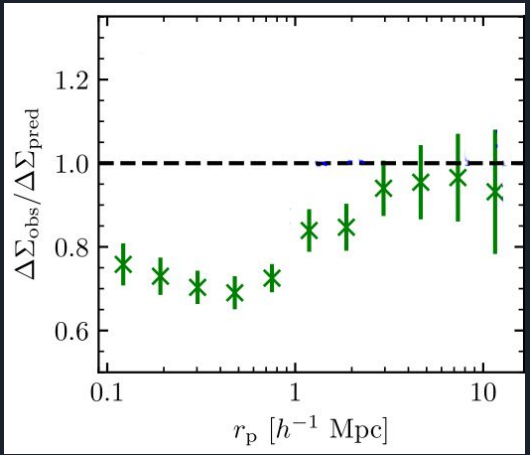
Jonás Chaves-Montero [1,2★] Raul E. Angulo [1] and Sergio Contreras [1]

[1] *Donostia International Physics Centre, Paseo Manuel de Lardizabal 4, 20018 Donostia-San Sebastian, Spain*
[2] *Institut de Física d'Altes Energies, The Barcelona Institute of Science and Technology, Campus UAB, E-08193 Bellaterra (Barcelona), Spain*

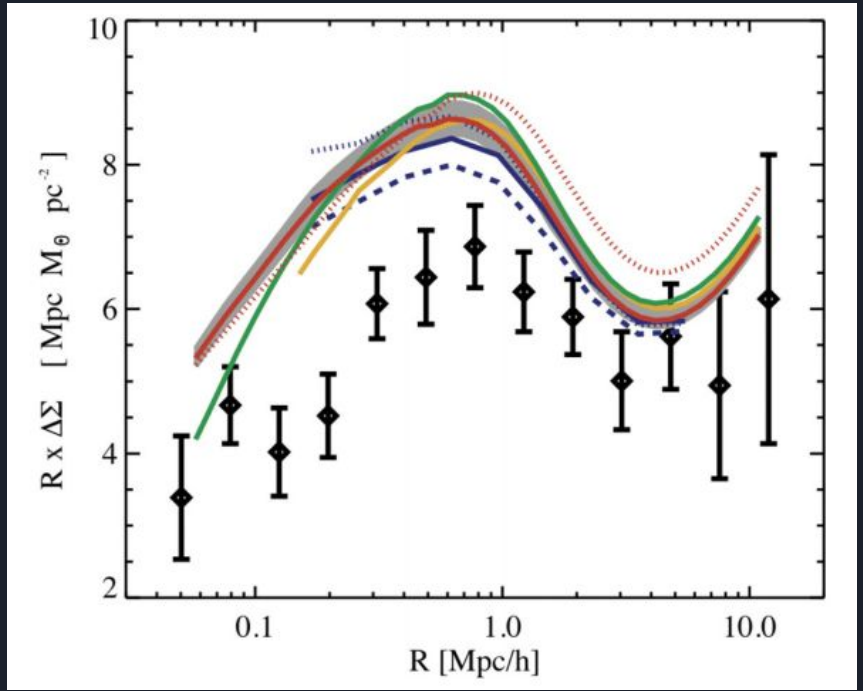


The lensing-is-low problem

Empirical models fitting the clustering (GC) of BOSS galaxies overpredict their galaxy-galaxy lensing (GGL) by ~30%



Lange+19 (adapted)



Leauthaud+17

Workflow of empirical models

1. Define framework
   a. Target data: projected clustering of BOSS galaxies
   b. Simulation (cosmology)
   c. Empirical model (astrophysics): HOD or SHAM

2. Compute best-fitting model
   a. Draw a value for each parameter of the empirical model
   b. Evaluate the model on the simulation (mock galaxies)
   c. Compare summary statistics from observations and mock
   d. Repeat from a to c to sample the posterior of model parameters

MCMC 

3. Theory: GC and GGL predictions from best-fitting model

Same galaxy-halo connection

Galaxy Clustering (GC):
positions of lens galaxies

Galaxy Galaxy Lensing (GGL):
shapes of background galaxies
around lens galaxies

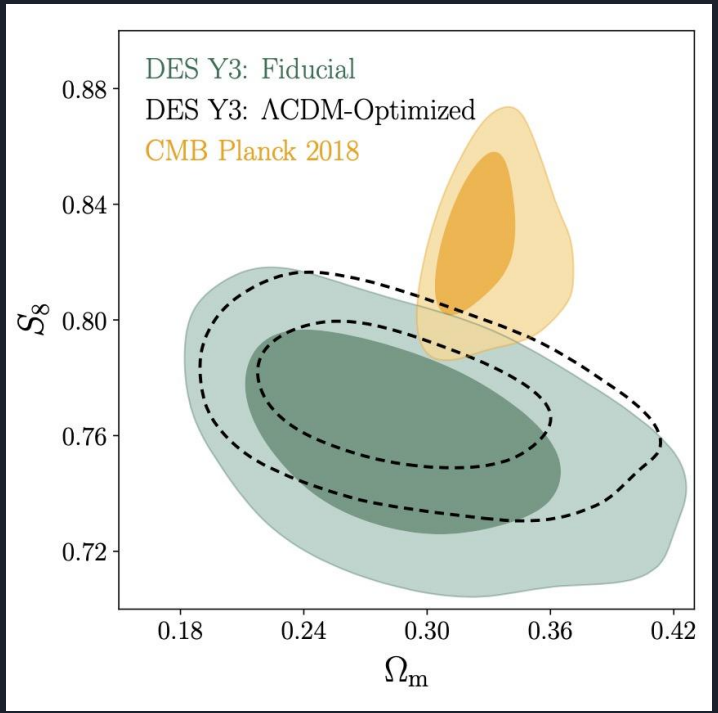
$$\Delta\Sigma(r_\perp) = \overline{\Sigma}(\leqslant r_\perp) - \overline{\Sigma}(r_\perp),$$

$$\omega_{\rm p}(r_\perp) = \int_{-s_\parallel^{\rm max}}^{s_\parallel^{\rm max}} \xi_{\rm gg}(r_\perp, s_\parallel)\,{\rm d}s_\parallel,$$

$$\overline{\Sigma}(r_\perp) = \Omega_{\rm m}\,\rho_{\rm crit} \int_{-r_\parallel^{\rm max}}^{r_\parallel^{\rm max}} \xi_{\rm gm}(r_\perp, r_\parallel)\,{\rm d}r_\parallel,$$

Possible solutions

Cosmological: another face of the S_8 tension

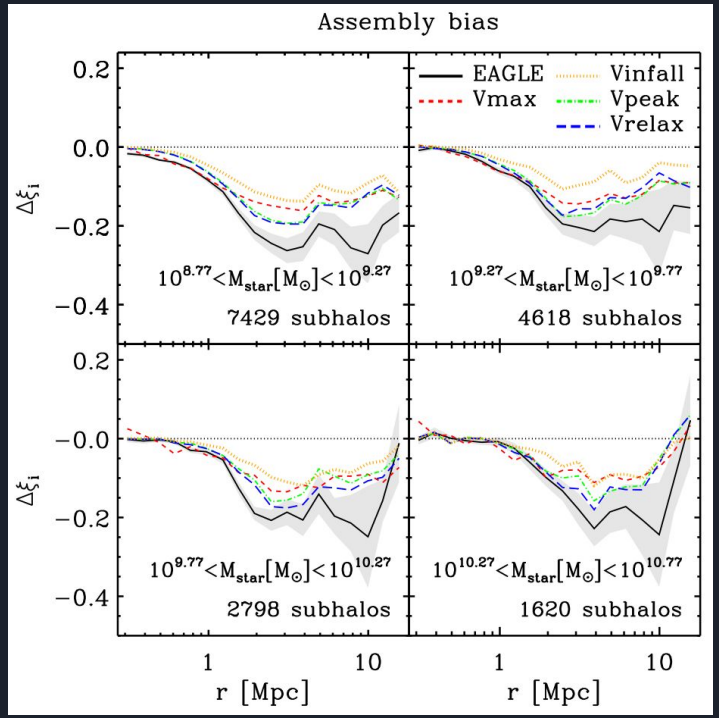


DES (Amon+22)

Possible solutions

Cosmological: another face of the S_8 tension

Astrophysical: limitations of empirical models (e.g. assembly bias)



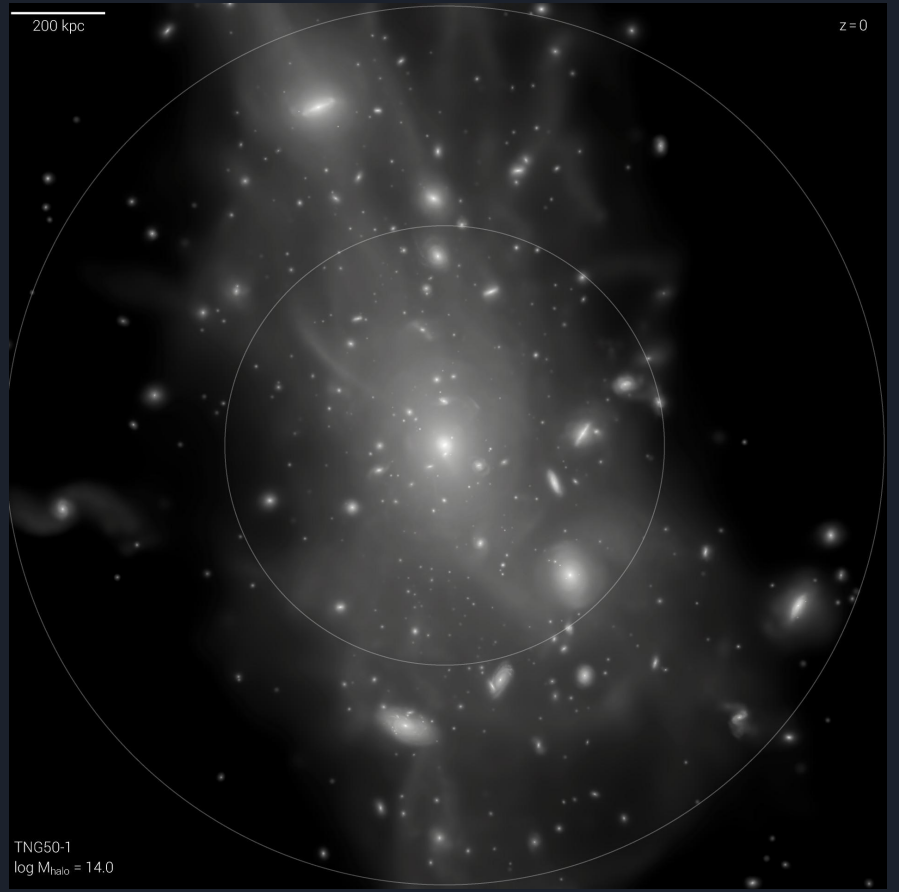
Chaves-Montero+16

Possible solutions

Cosmological: another face of the S_8 tension

Astrophysical: limitations of empirical models (e.g. assembly bias)

Which one? Repeat BOSS analysis under controlled conditions in the TNG300 hydrodynamical simulation (Pillepich+2018)

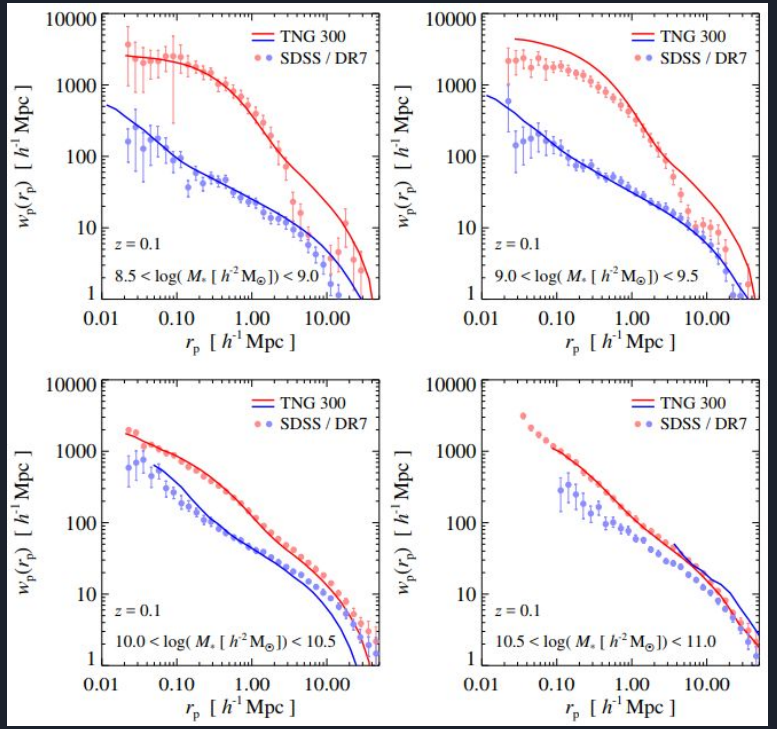


TNG simulation

Reproduces multiple observables:

- Broad-band galaxy colors
- Clustering of red and blue galaxies

BOSS-TNG sample: TNG galaxies selected according to same colour-based criteria as BOSS galaxies



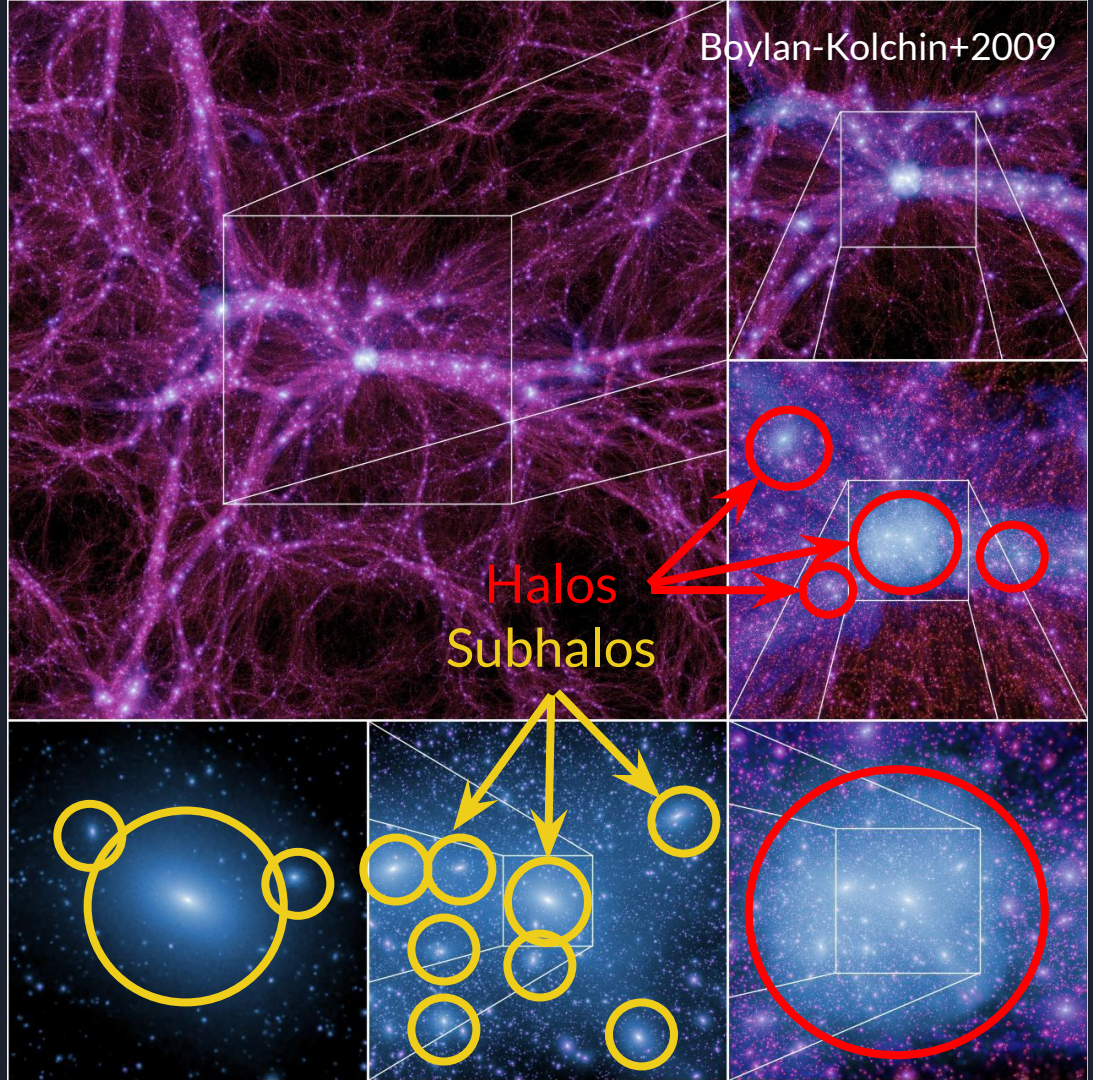
Springel+18

Framework

Target data: projected clustering of BOSS-TNG galaxies

Simulation: gravity-only version of TNG simulation

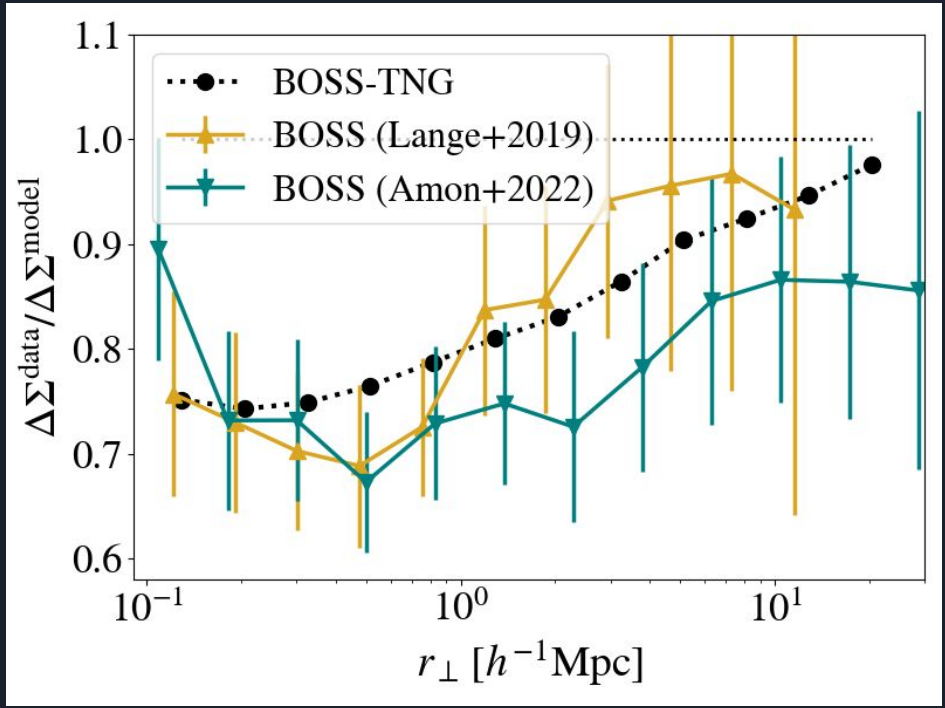
Empirical model: standard HOD implementation



Lensing-is-low at fixed cosmology

We reproduce the lensing-is-low problem at fixed cosmology!
Origin must be **astrophysical**

Similar amplitude and scale dependence as in observational studies of BOSS galaxies



Chaves-Montero, Angulo & Contreras 2023

HOD assumptions

Standard 5-parameter HOD implementation (Zheng+05):

- Parametric, mass-dependent galaxy occupation
- Satellites trace the distribution of matter within halos
- No baryonic effects
- Poisson distribution for satellite occupation

None of these assumptions is fulfilled by BOSS-TNG galaxies

Could the breaking of these result in the lensing-is-low problem?

Workflow

Target data: mock samples breaking different HOD assumptions

Simulation: gravity-only version of the TNG simulation

Model: standard 5-parameter HOD implementation

Observables: GC (fit), GGL (predict)

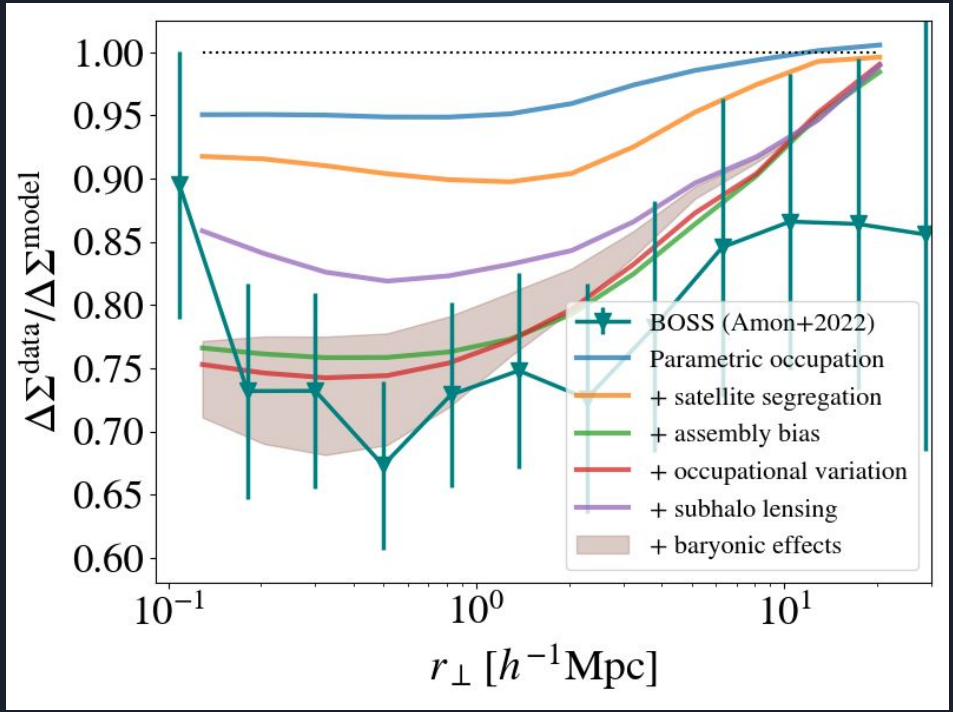
Mock samples increasingly similar to BOSS-TNG sample as we break more HOD assumptions

Origin of the problem

Multiple galaxy formation effects affect GC and GGL

Standard empirical models are flexible enough to fit GC despite not accounting for these effects

However, to accommodate for their impact, these models overpredict GGL (lensing-is-low)

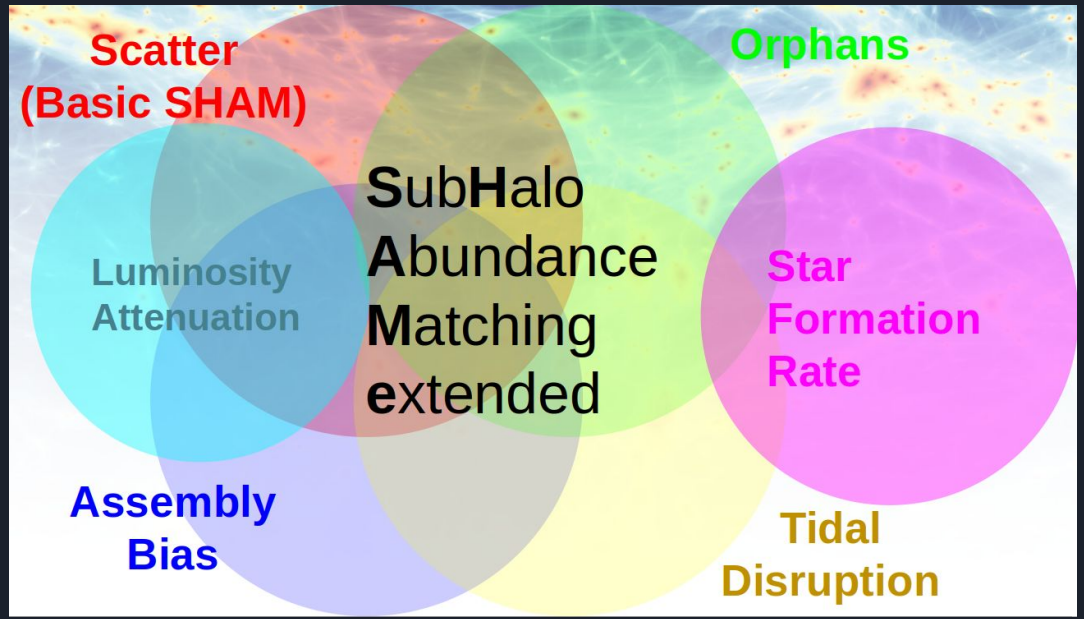


Chaves-Montero, Angulo & Contreras 2023

SHAMe

Lensing-is-low problem caused by standard empirical models not accounting for multiple galaxy formation effects

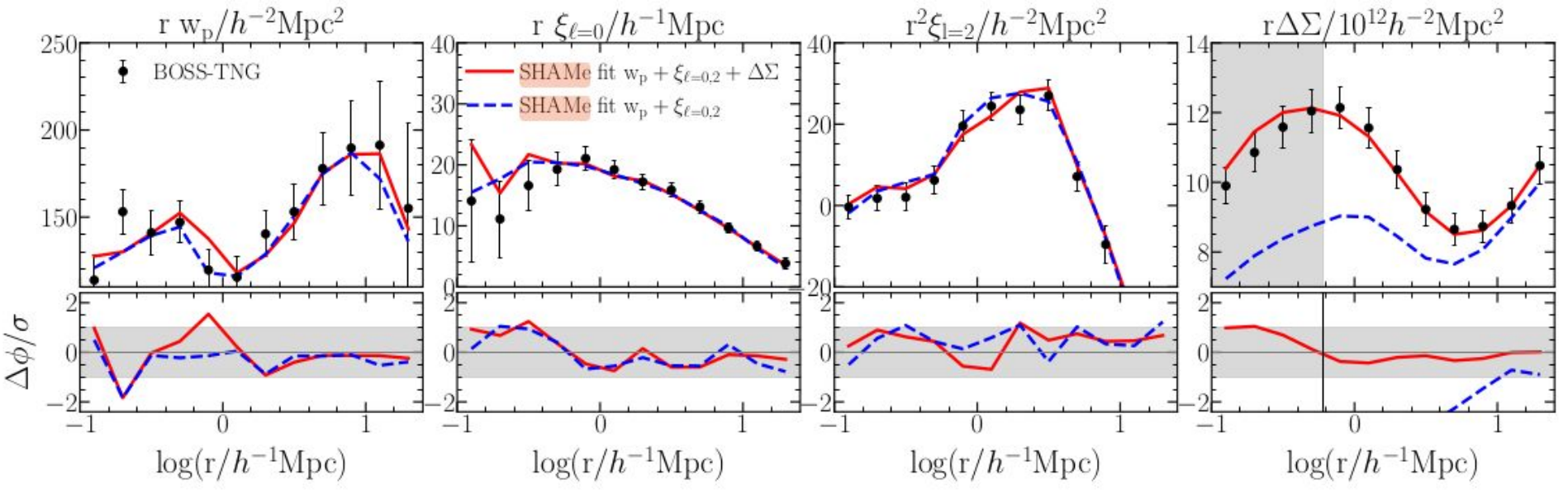
We thus need a more sophisticated model



Contreras+21a,b; Contreras+23; Ortega-Martínez+23 (in prep.)

SHAMe and BOSS-TNG

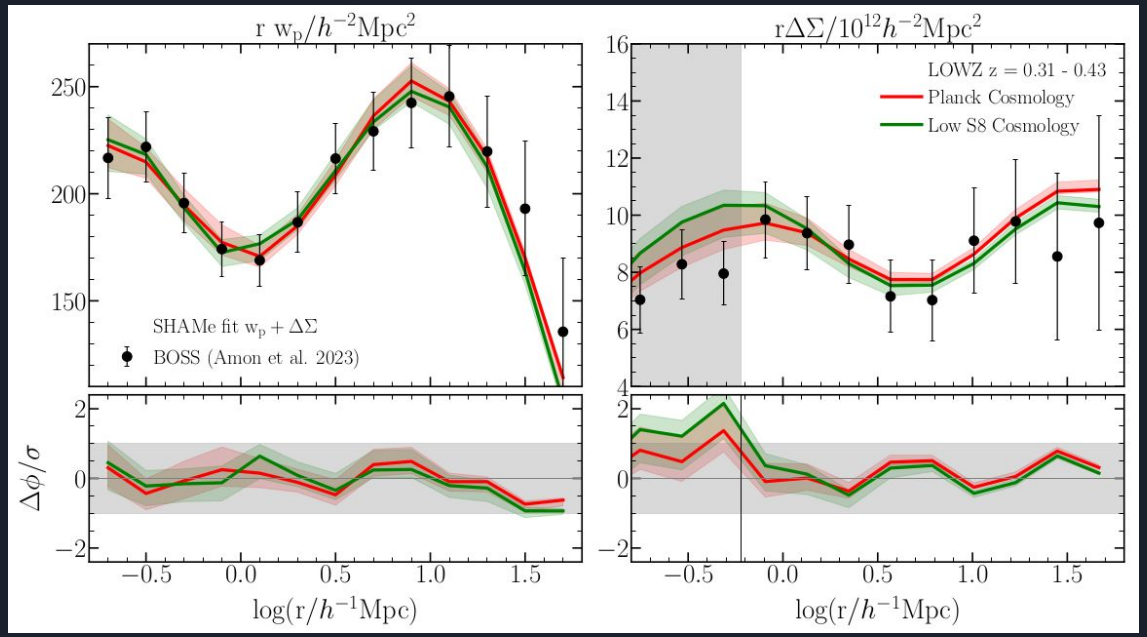
No lensing-is-low when fitting GC and GGL jointly

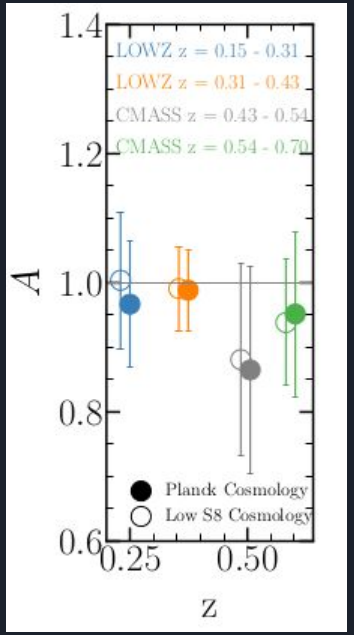


Contreras, Chaves-Montero & Angulo 2023

SHAMe and BOSS

No lensing-is-low for either Planck or low-S8 cosmology





Contreras, Chaves-Montero & Angulo 2023

Conclusions

Standard empirical models do not account for multiple galaxy formation effects affecting GC and GGL

These models overpredict GGL to accommodate for the impact of these effects on GC, which results in the lensing-is-low problem

SHAMe (sophisticated model) does not encounter this problem, but the additional flexibility comes at the cost of less constraining power

(WIP) Modelling other observables to improve cosmological constraints