Independent constraints on cosmological and astrophysical parameters using UV luminosity functions at z~6

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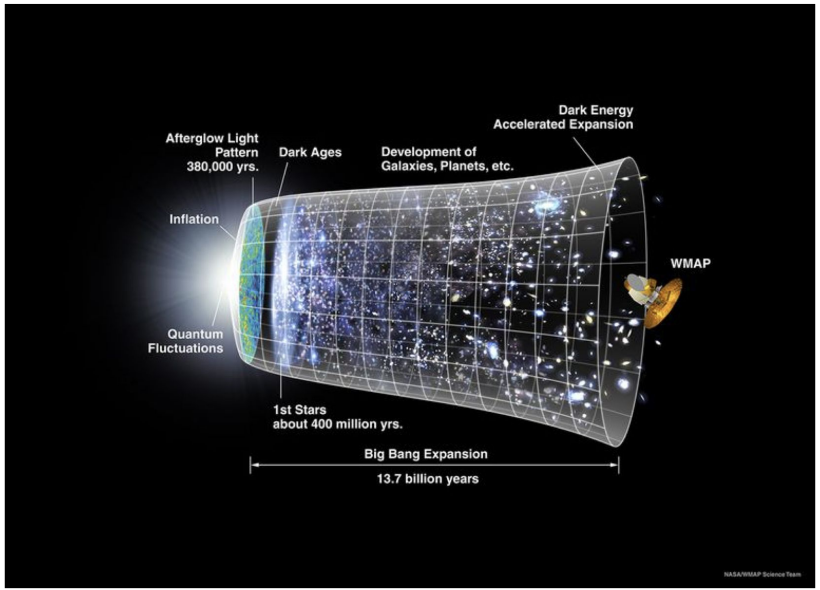
Cosmology & Astrophysics

- Study of the origin & ultimate fate of the Universe
- We study history of the universe mainly based off of cosmic microwave background(CMB) because it is the furthest back in time we can study using light - 380K years after Big Bang



The Standard Model

- Big Bang
- At large, Universe is isotropic & homogenous
- Theorizes Dark Matter & Energy

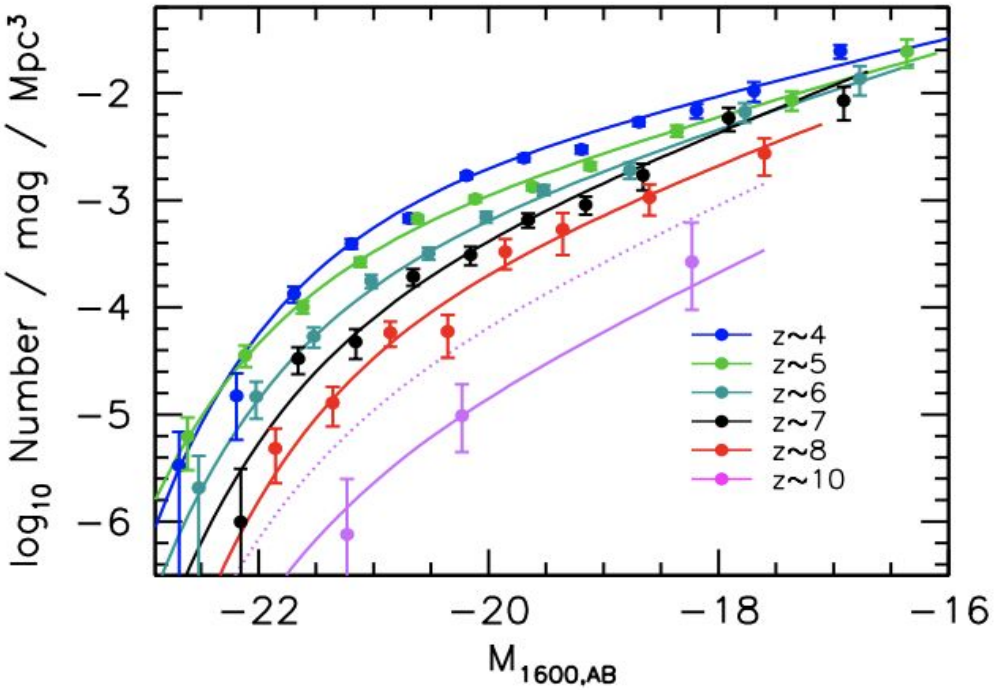
Cosmological Parameters

- Independent, Fixed & Calculated

Credit: NASA / WMAP Science Team

Luminosity Functions

- Are distribution functions of the luminosity of objects in a set.



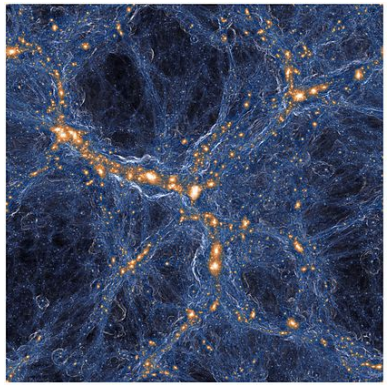
$$n(L)\,\mathrm{d}L = \phi^* \left(\frac{L}{L^*}\right)^{\alpha} \mathrm{e}^{-L/L^*}$$

Schechter et al 1976

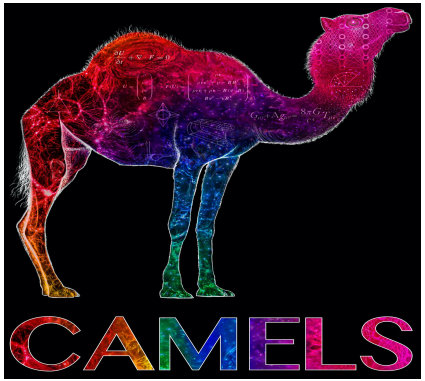
Bouwens et al 2015

Why CAMELS?

- Predicting quantities that we can define the universe with as functions of cosmological & astrophysical parameters
- Using machine learning to extract information from the simulation & make predictions about the observations
- Find mapping between different types of simulations

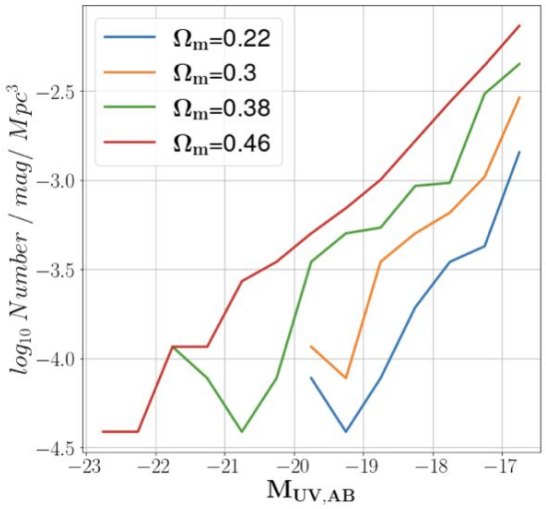


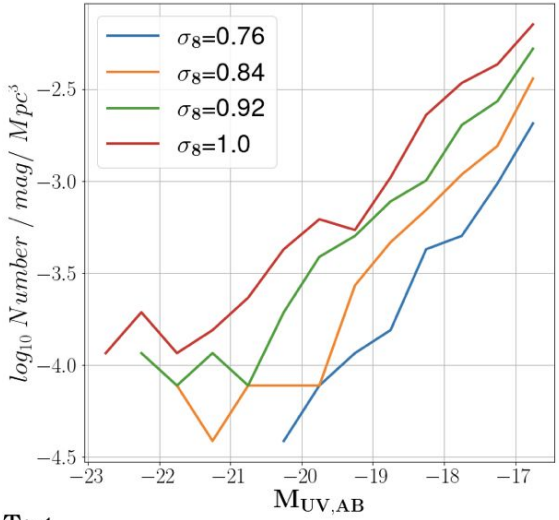
TNG Collaboration

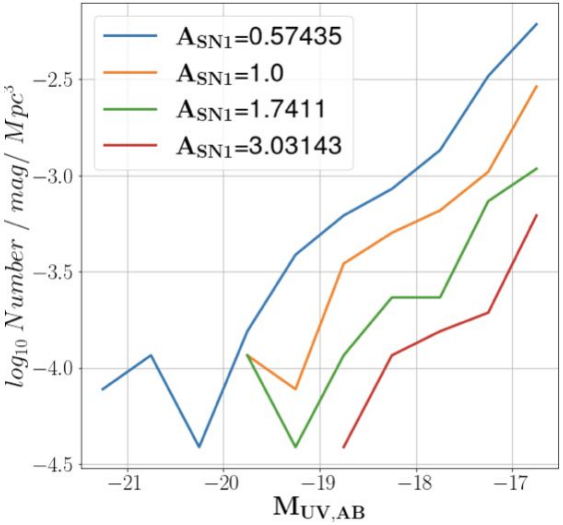


Villaescusa-Navarro et al.

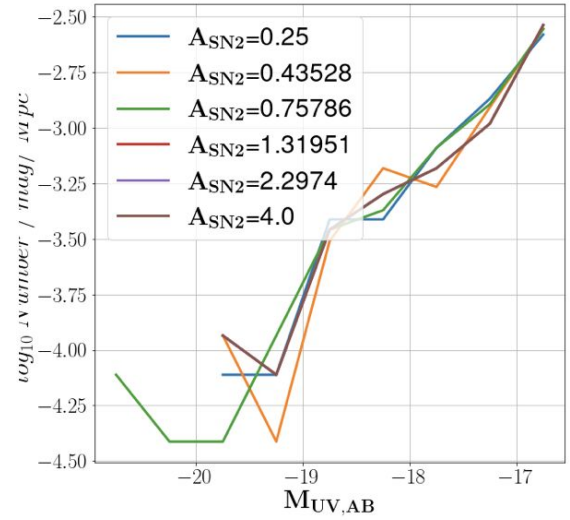
The SIMBA Team

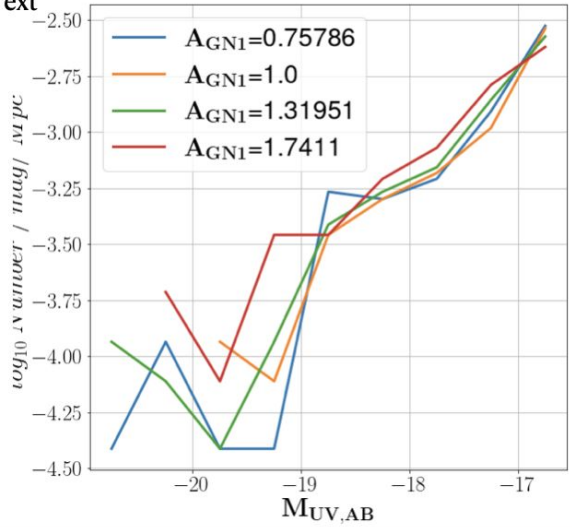

Ω_m=0.22
Ω_m=0.3
Ω_m=0.38
Ω_m=0.46
$log_{10}\,Number\ /\ mag/\ Mpc^3$
$M_{UV,AB}$

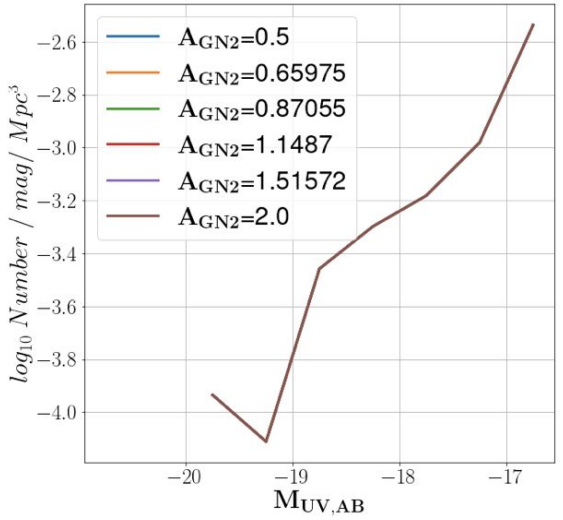

σ_8=0.76
σ_8=0.84
σ_8=0.92
σ_8=1.0
$log_{10}\,Number\ /\ mag/\ Mpc^3$
$M_{UV,AB}$

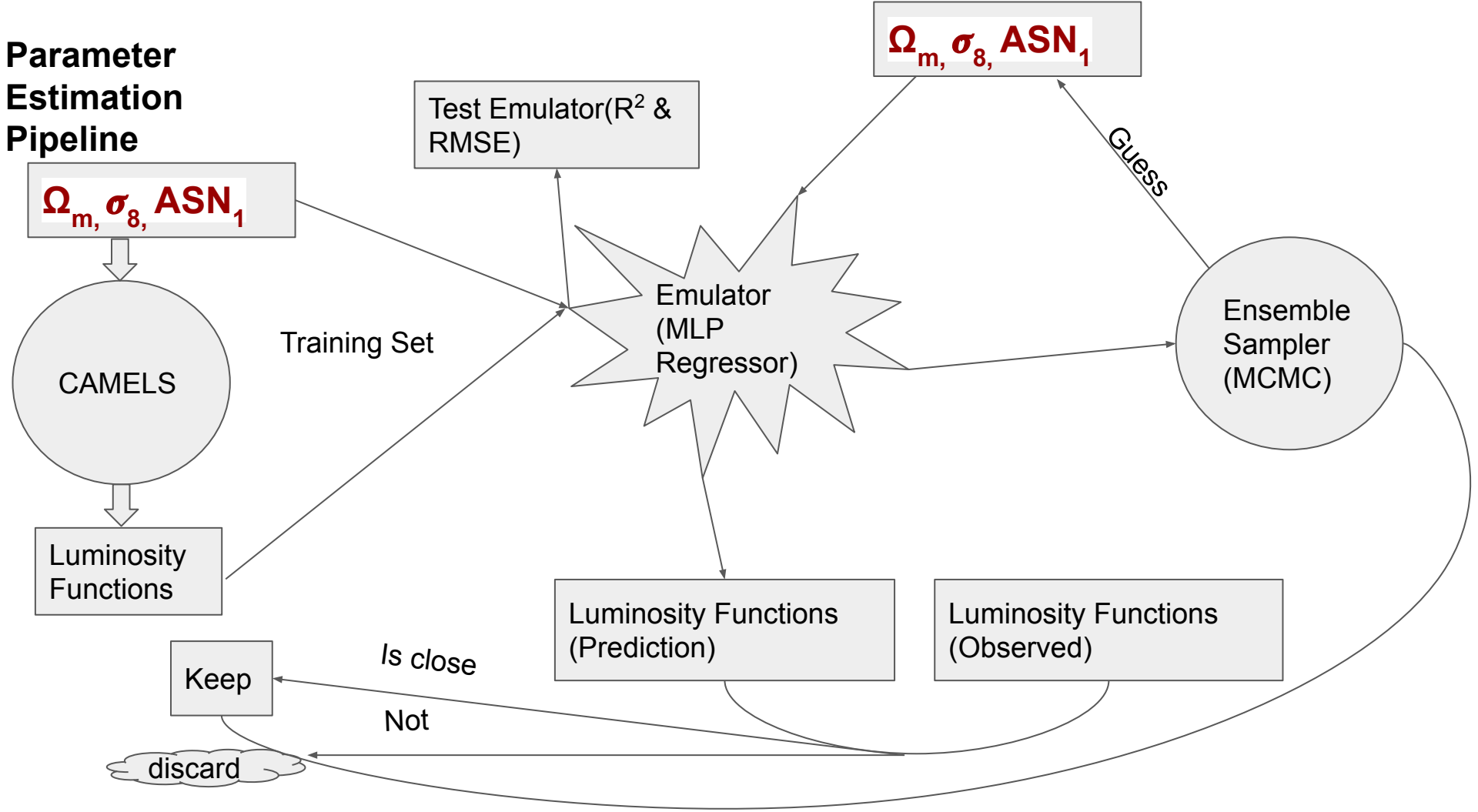

A_{SN1}=0.57435
A_{SN1}=1.0
A_{SN1}=1.7411
A_{SN1}=3.03143
$log_{10}\,Number\ /\ mag/\ Mpc^3$
$M_{UV,AB}$

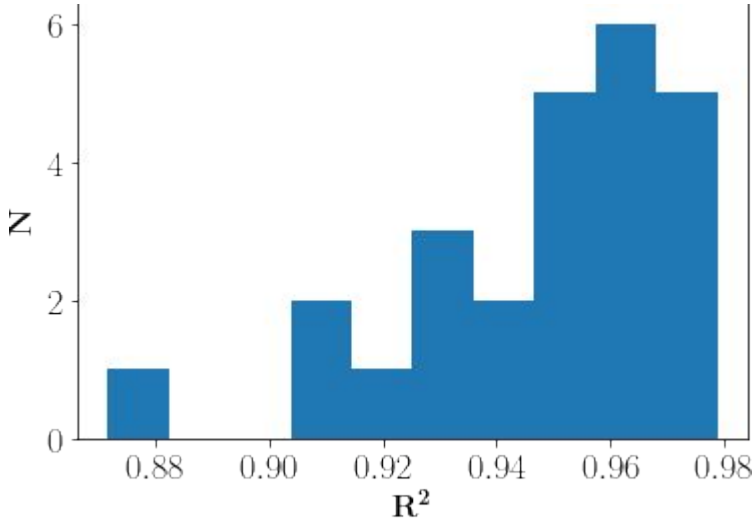
Text

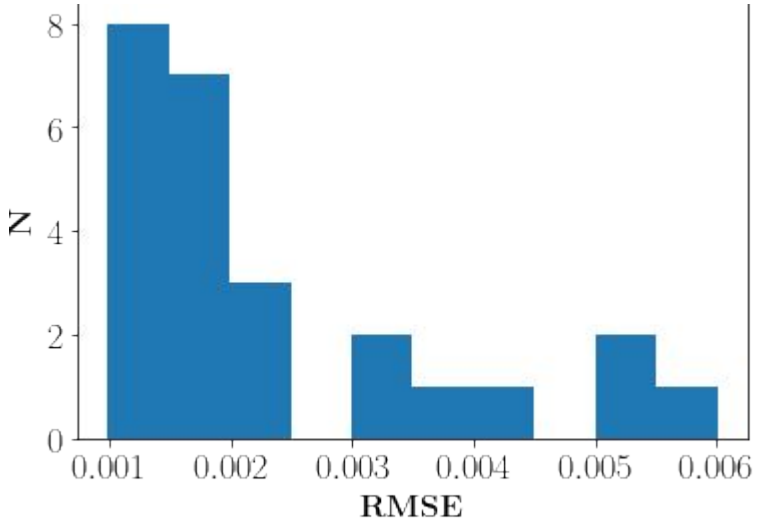

A_{SN2}=0.25
A_{SN2}=0.43528
A_{SN2}=0.75786
A_{SN2}=1.31951
A_{SN2}=2.2974
A_{SN2}=4.0
$M_{UV,AB}$


A_{GN1}=0.75786
A_{GN1}=1.0
A_{GN1}=1.31951
A_{GN1}=1.7411
$M_{UV,AB}$


A_{GN2}=0.5
A_{GN2}=0.65975
A_{GN2}=0.87055
A_{GN2}=1.1487
A_{GN2}=1.51572
A_{GN2}=2.0
$log_{10}\,Number\ /\ mag/\ Mpc^3$
$M_{UV,AB}$

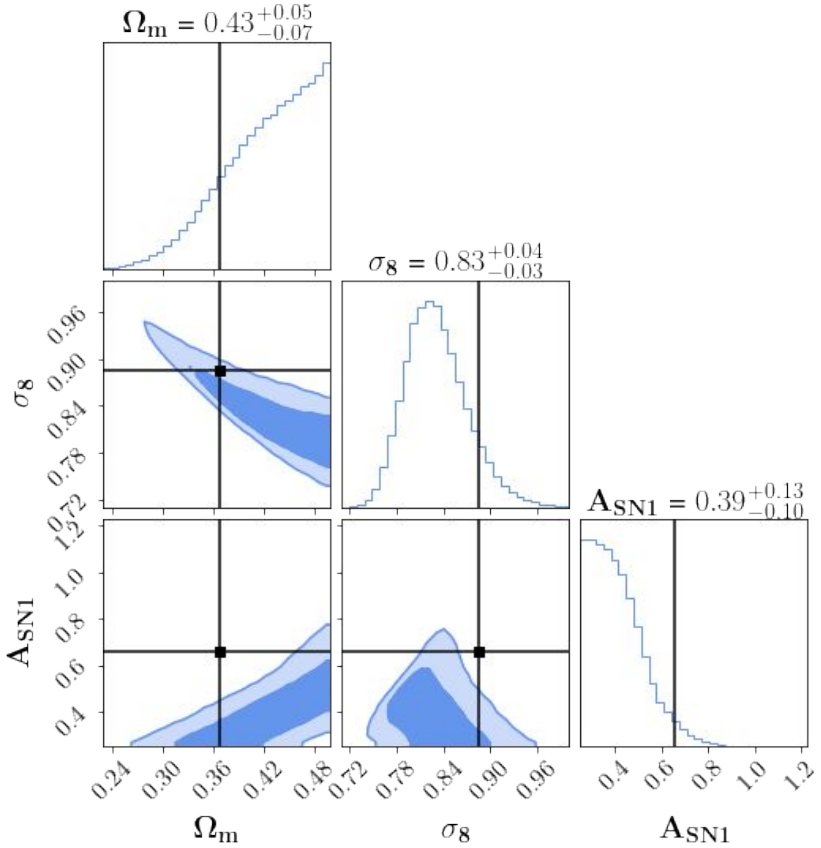

Parameter Estimation Pipeline
$\Omega_m, \sigma_8, ASN_1$
Test Emulator(R^2 & RMSE)
$\Omega_m, \sigma_8, ASN_1$
Guess
$\Omega_m, \sigma_8, ASN_1$
CAMELS
Training Set
Emulator (MLP Regressor)
Ensemble Sampler (MCMC)
Luminosity Functions
Luminosity Functions (Prediction)
Luminosity Functions (Observed)
Keep
Is close
Not
discard





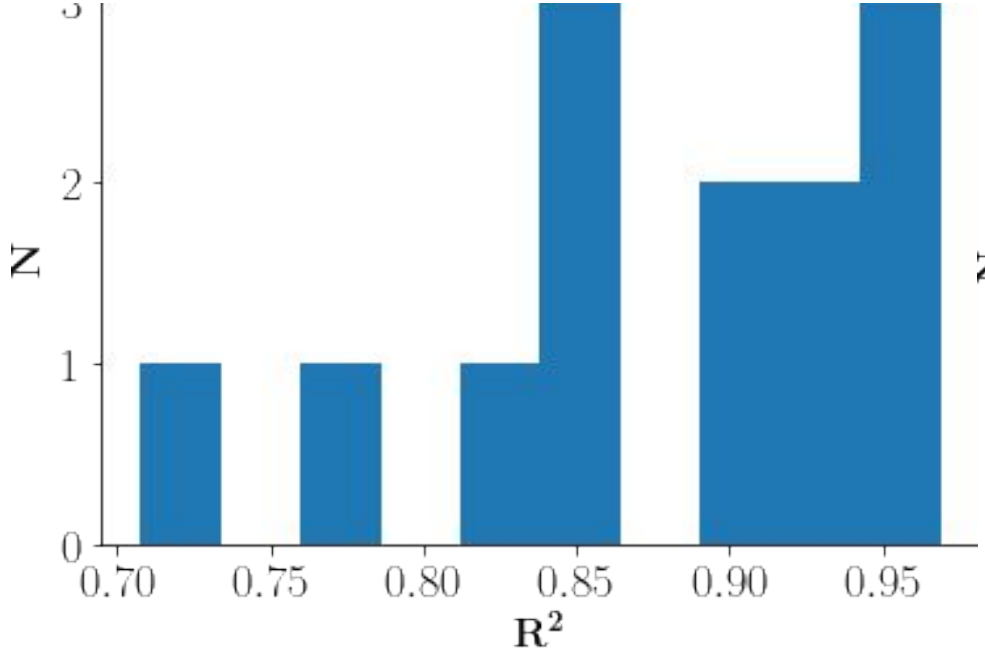
This shows that we can trust our model(good R^2 & Low RMSE)

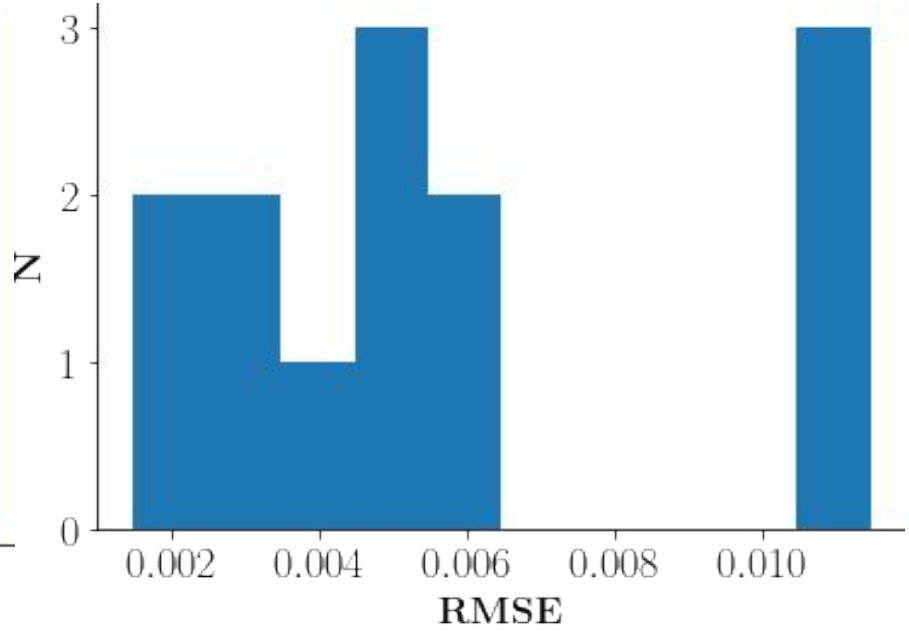
Test: parameter recovery of a random Luminosity Function



3 Parameters - Ω_m, σ_8, and ASN_1

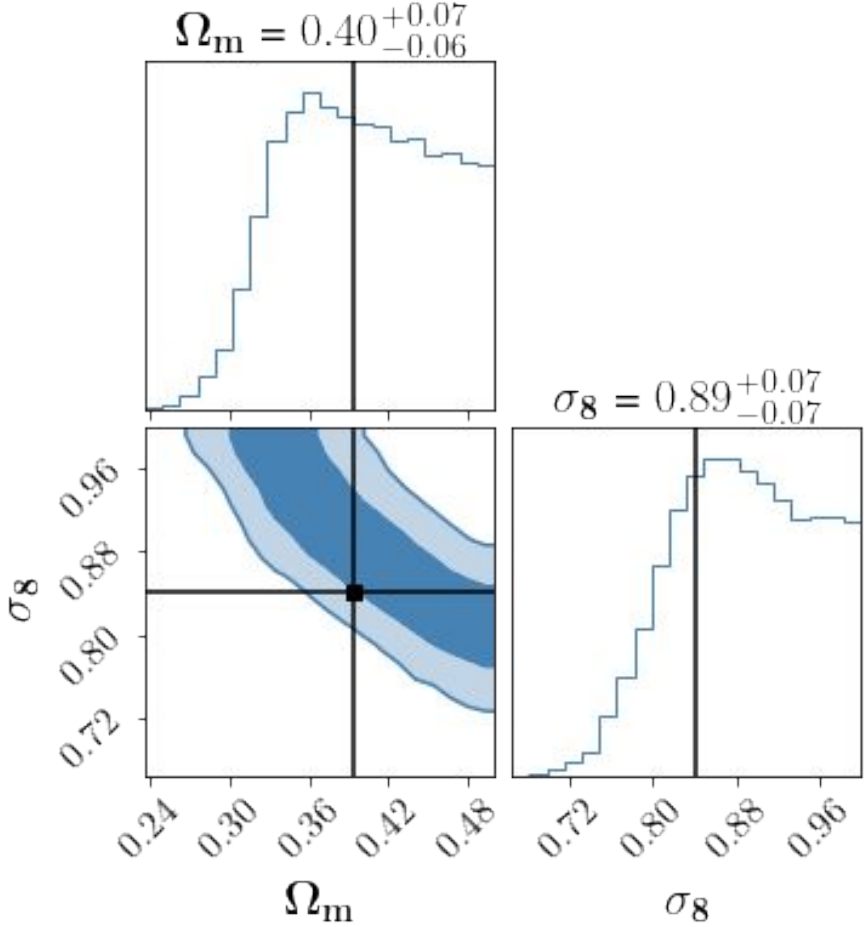
- We recover parameters within the 2-sigma level (black point) between σ_8 and Ω_m.
- However, we can't recover parameters between ASN_1 and Ω_m & ASN_1 and σ_8
- We also recover the negative correlation between σ_8 and Ω_m
- Test: FAIL, lets remove the third parameter





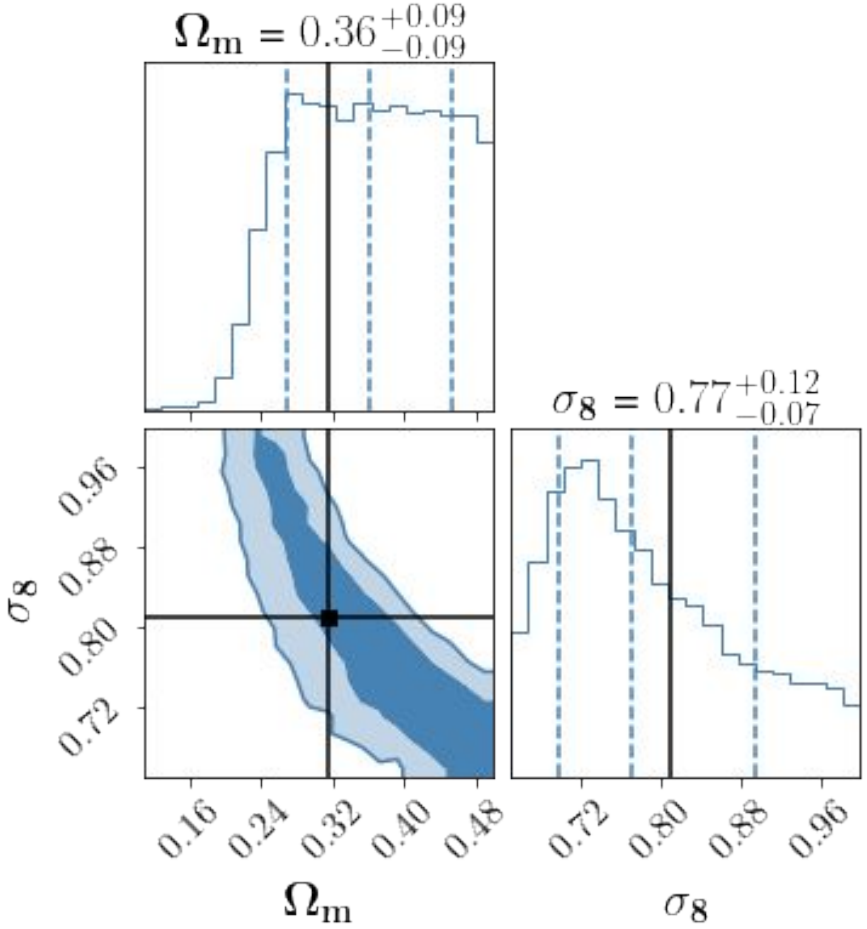
Again, we can see that our emulator works well.

Test: parameter recovery of a random Luminosity Function



- We nicely recover parameters within 1-sigma level (black point).
- We also recover the negative correlation between σ_8 and Ω_m
- Test: Pass

Deriving new independent constraints using observed LF from Bouwens et al 2015



- **Planck 2018 (black point):**
  Ω_m = 0.315±0.007
  σ_8 = 0.811±0.006

- **Tighter constraints might be obtained by using several LFs from different redshifts**

Thank You
Questions?