Populating a dark Universe with SciPIC

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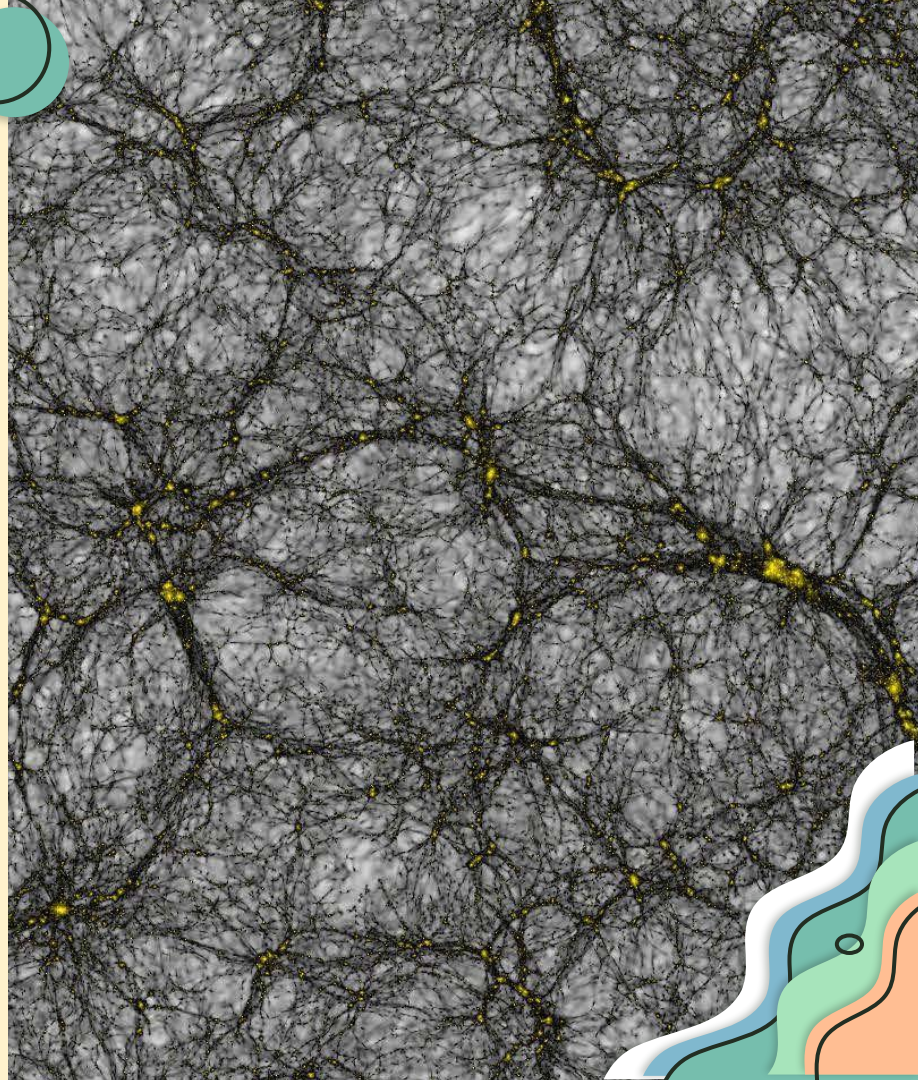
G. Parimbelli, S. Ramakrishnan, et al.

SciPIC

A flexible, modular pipeline
capable of generating mock galaxy catalogues
from a halo catalogue
that mimic the observed Universe



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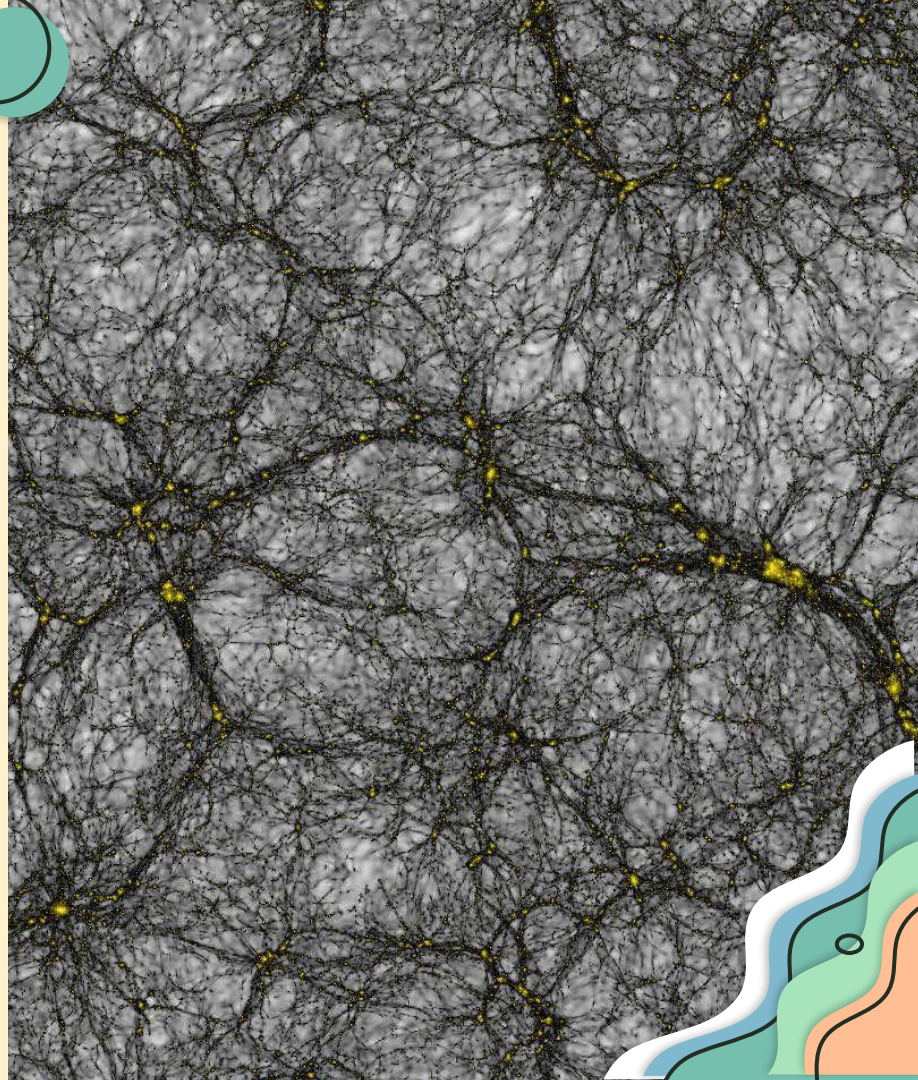

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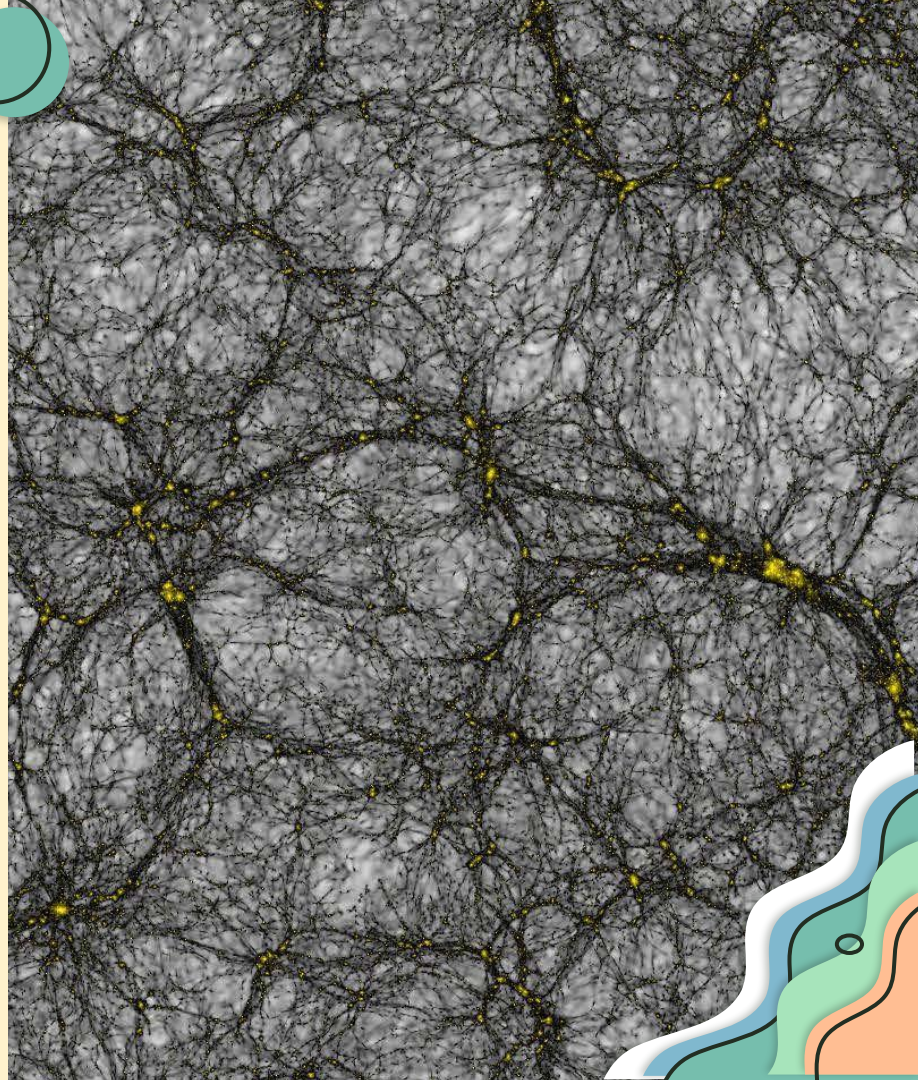

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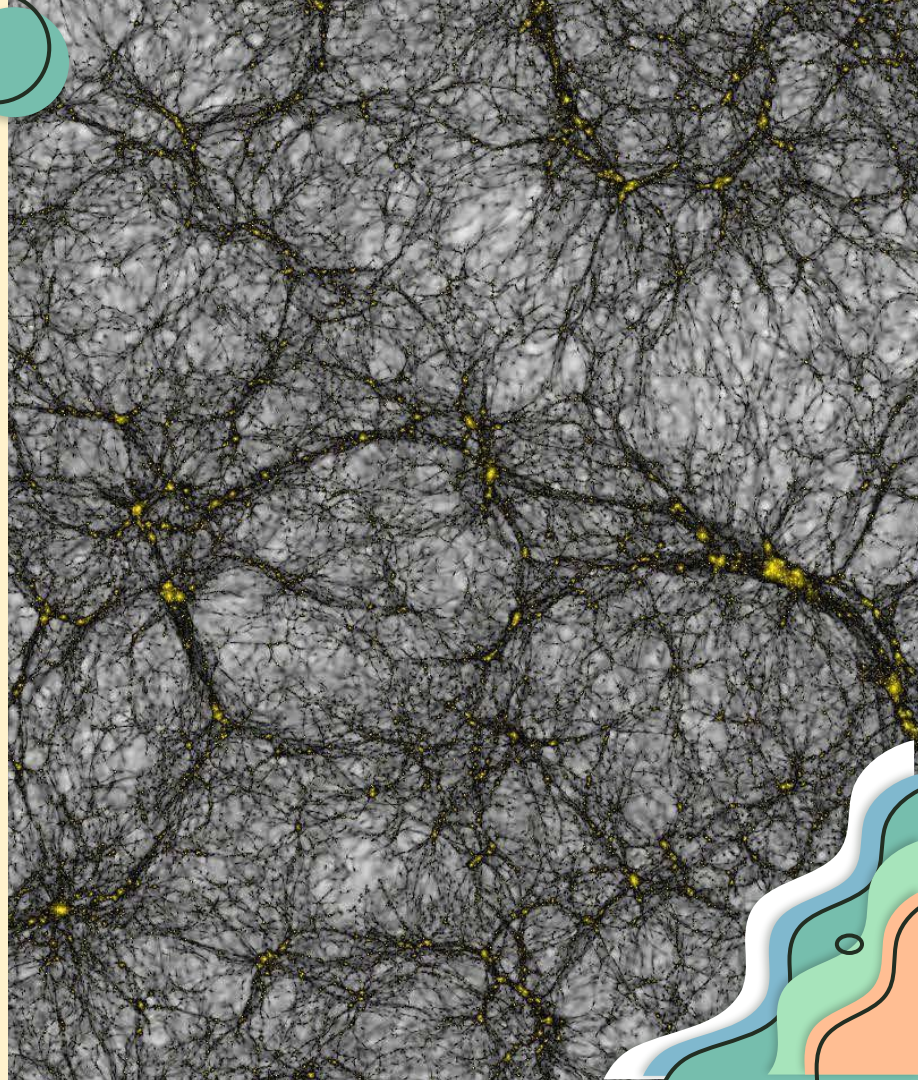


Flagship (FS) DM simulation

Simulation box of 3600 Mpc/h. 16 000^3 particles. Mass resolution = 10^9 $M_\odot/h$

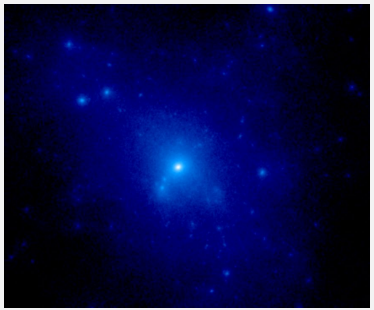
Performed using PKDGRAV3. $\Omega_m = 0.319$, $\Omega_b = 0.049$, $\Omega_\Lambda + \Omega_\gamma = 0.681$, $A_s = 2.1 \times 10^{-9}$, $n_s = 0.96$, $h = 0.67$

The dark matter halos were identified directly on the light cone particle data using ROCKSTAR

Mock galaxy catalogue capable of reproducing the **observed** clustering of **several galaxy populations**

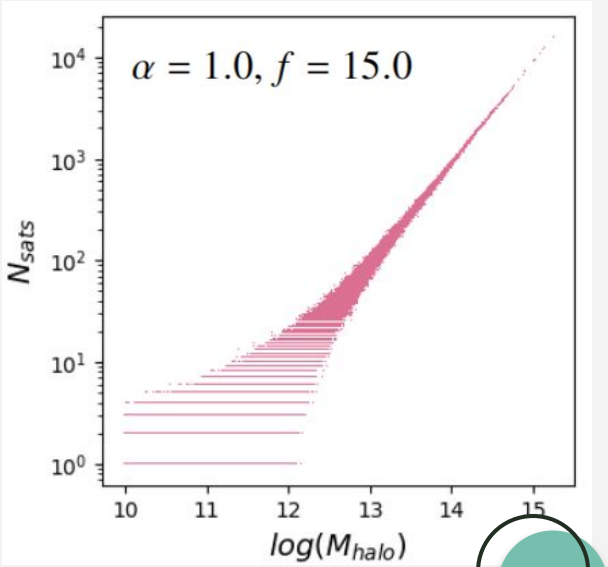
SciPIC - From halos to galaxies

Assume that each halo has a **central galaxy** and may host other galaxies (**satellite galaxies**) following the halo mass distribution



Halo mass

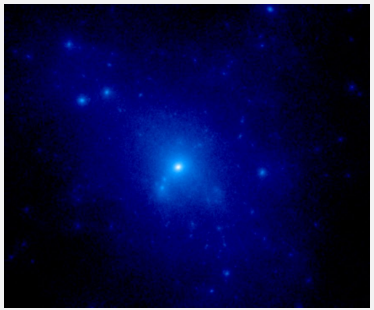
$$N_{\rm cen} = 1,$$
$$\langle N_{\rm sat} \rangle = \left(\frac{M_{\rm halo}}{M_1} \right)^{\alpha},$$
$$M_1 = f M_{\rm min}.$$



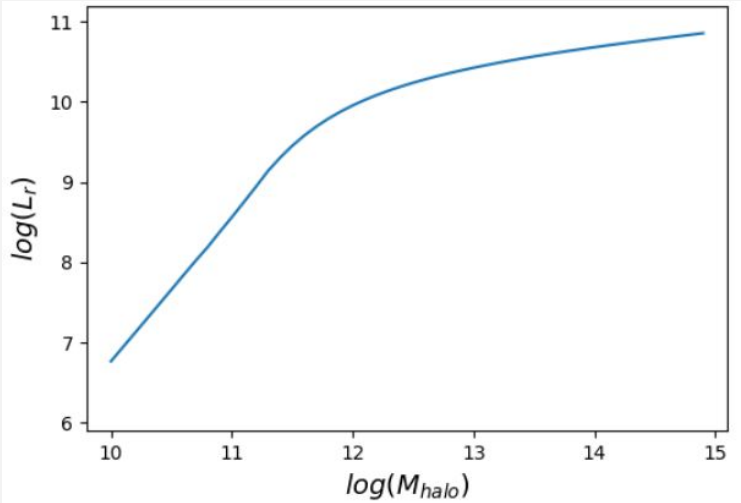
SciPIC - From halos to galaxies

Assign the luminosity to central galaxies following and abundance matching approach

$$\int_{M_{\rm min}}^{\infty} n(M') \left[1 + \left(\frac{M'}{f\,M_{\rm min}}\right)^{\alpha}\right] {\rm d}M' = \int_{L}^{\infty} \Phi(L')_{\rm unscat}\, {\rm d}L'$$



Halo mass and redshift



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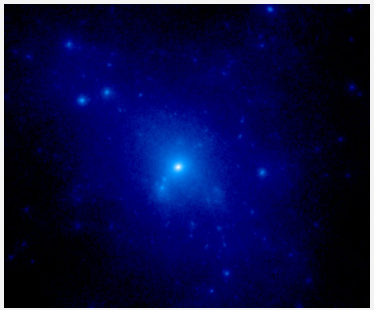

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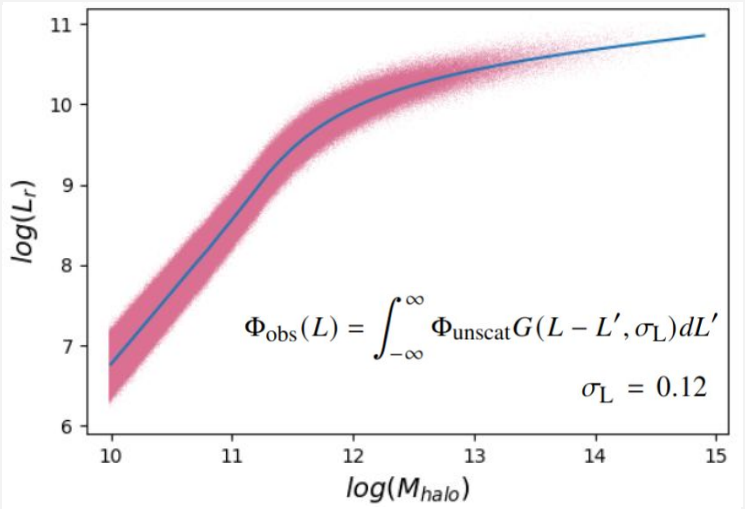
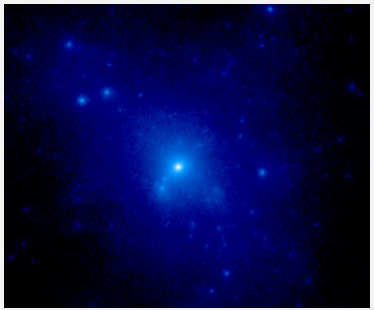


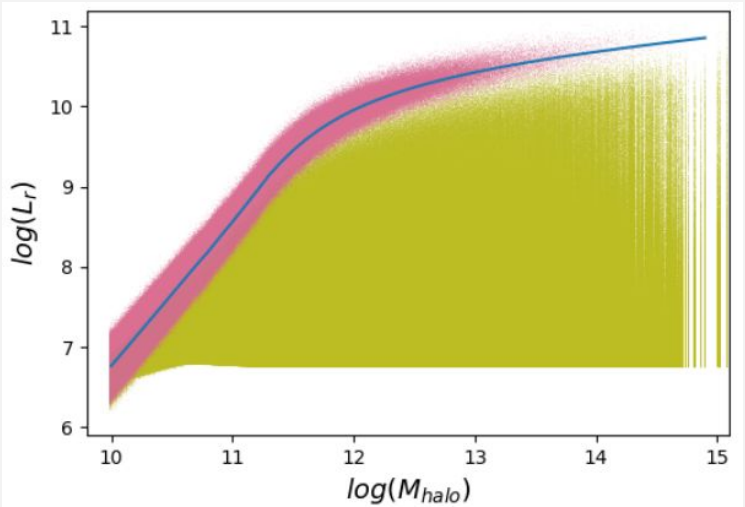
SciPIC - From halos to galaxies

Assign the luminosity to satellite galaxies by fitting the cumulative satellite galaxy luminosity function within each halo:

$$N_{\rm sat}^{\rm halo}(>L) = A\left(\frac{L}{aL_{\rm cen}+b}\right)^{\alpha}\exp\left[-\left(\frac{L}{aL_{\rm cen}+b}\right)^{\beta}\right]$$

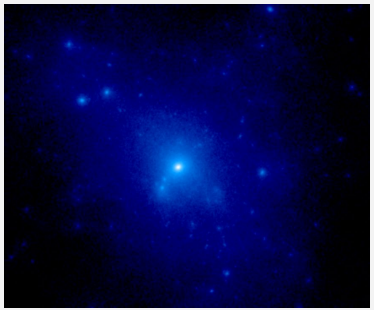


Halo mass and redshift

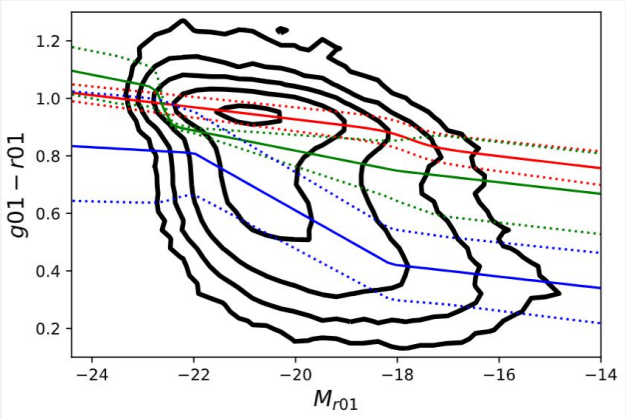


SciPIC - From halos to galaxies

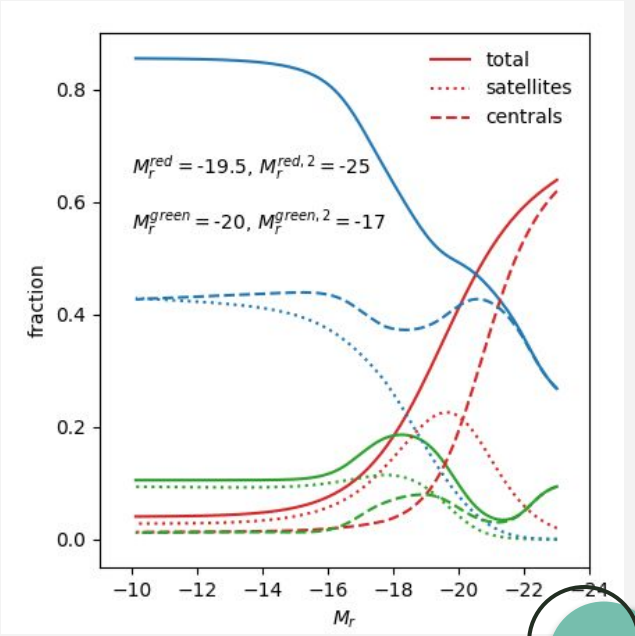
Assign color-kind



Halo mass and redshift

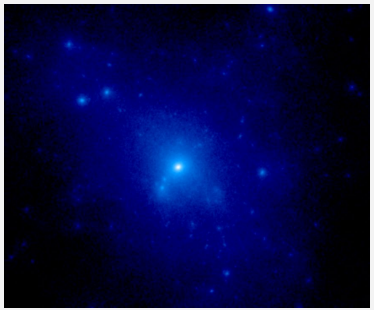


Castander et al. (2024)



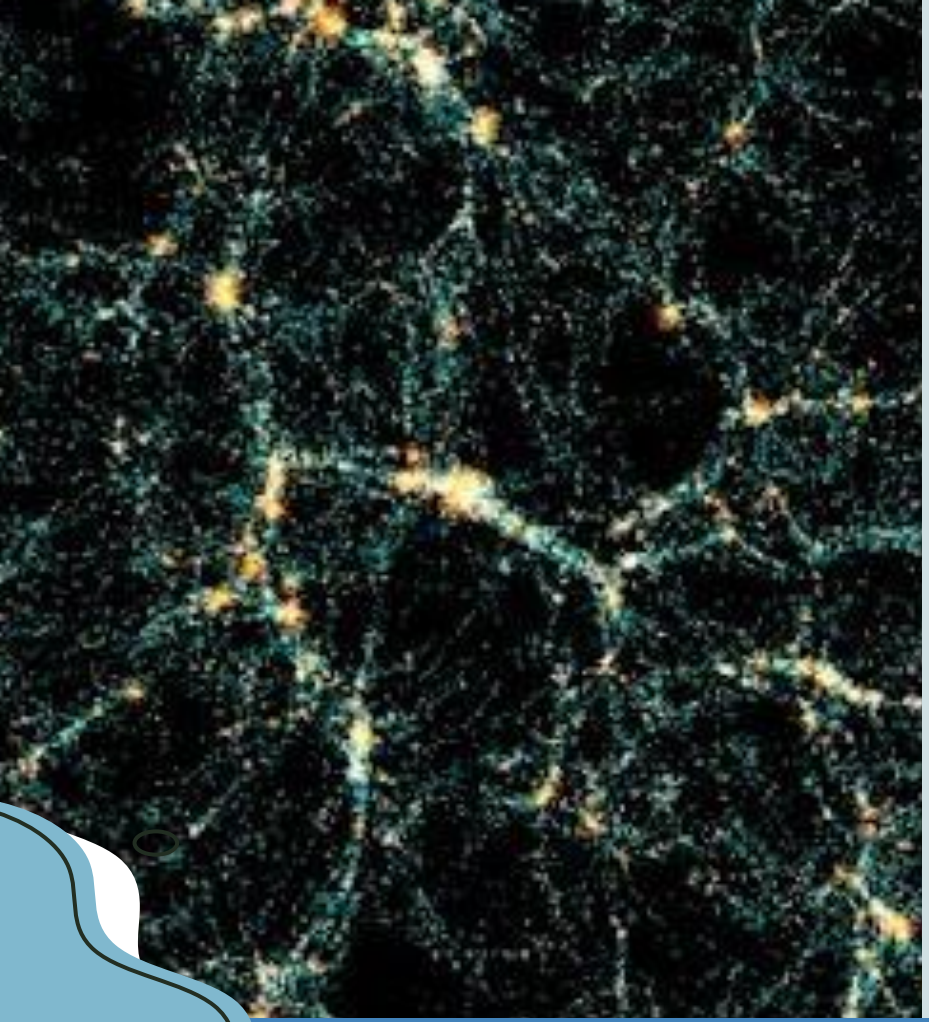
SciPIC - From halos to galaxies

Assign positions: Assume an ellipsoidal NFW mass distribution



Halo mass, concentration and redshift

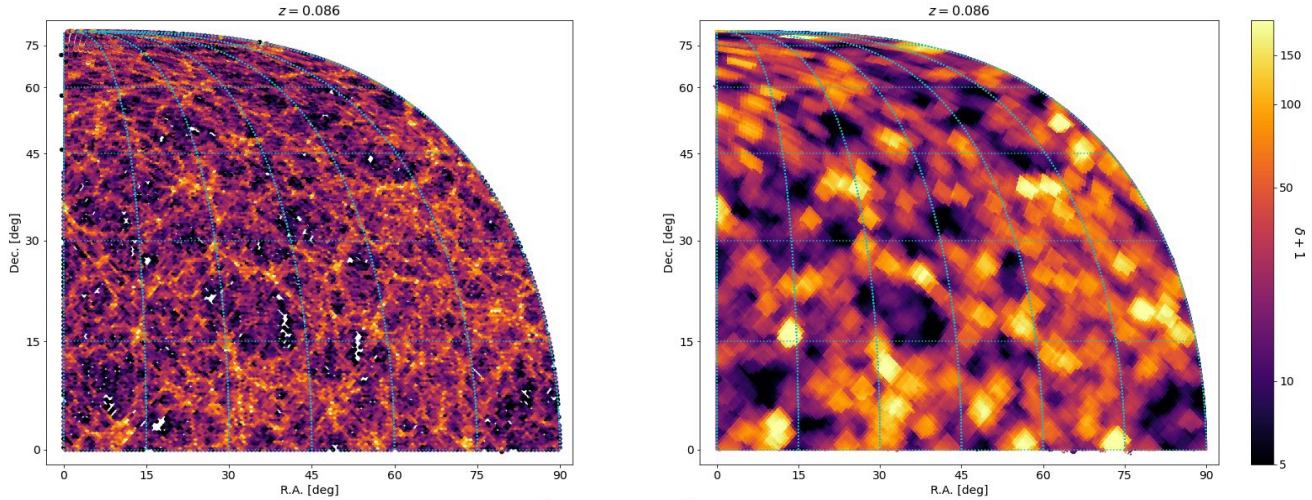
- Red sequence galaxies -> halo concentration
- Green valley galaxies -> 0.5 x halo concentration
- Blue cloud galaxies -> 0.25 x halo concentration



Including environment information

Contrast density

Measured in comoving slices within a volume of a sphere of ~8.6Mpc/h radius, **according to the halo distribution**

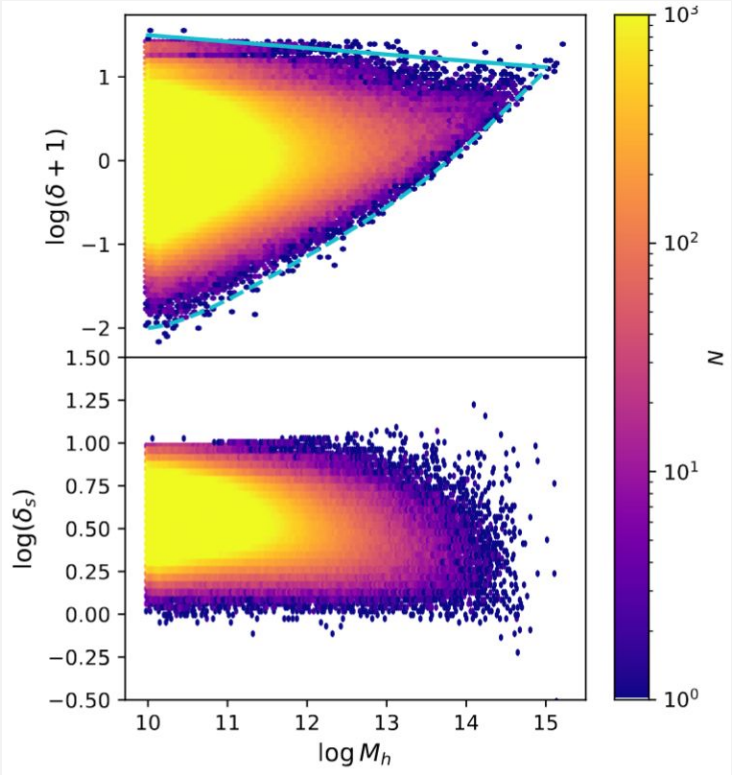


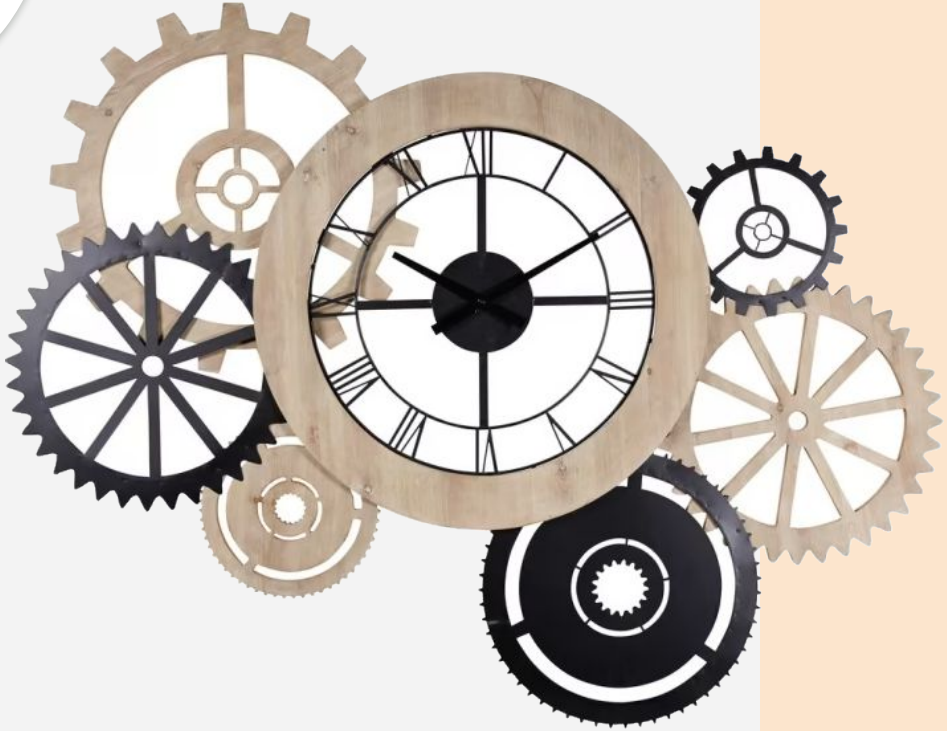
$$\delta = \frac{\rho_{\text{cylinder}} - \rho_{\text{shell}}}{\rho_{\text{shell}}}$$

HOD modification

We compute δ_s that characterises the halo environment, relative to the average environment of halos within the same mass bin

$$M_\delta = M_h \left(\frac{\delta_s}{\delta_0} \right)^\gamma$$





Calibrating SciPIC

Procedure outline

- **Parameters to be optimised**

  M_{δ} parameters: δ_0 and γ

  HOD parameters: α and f

- **Constraints**

  SDSS 2-point correlation function (Zehavi+2011)

- **Methodology**

  TreeCorr

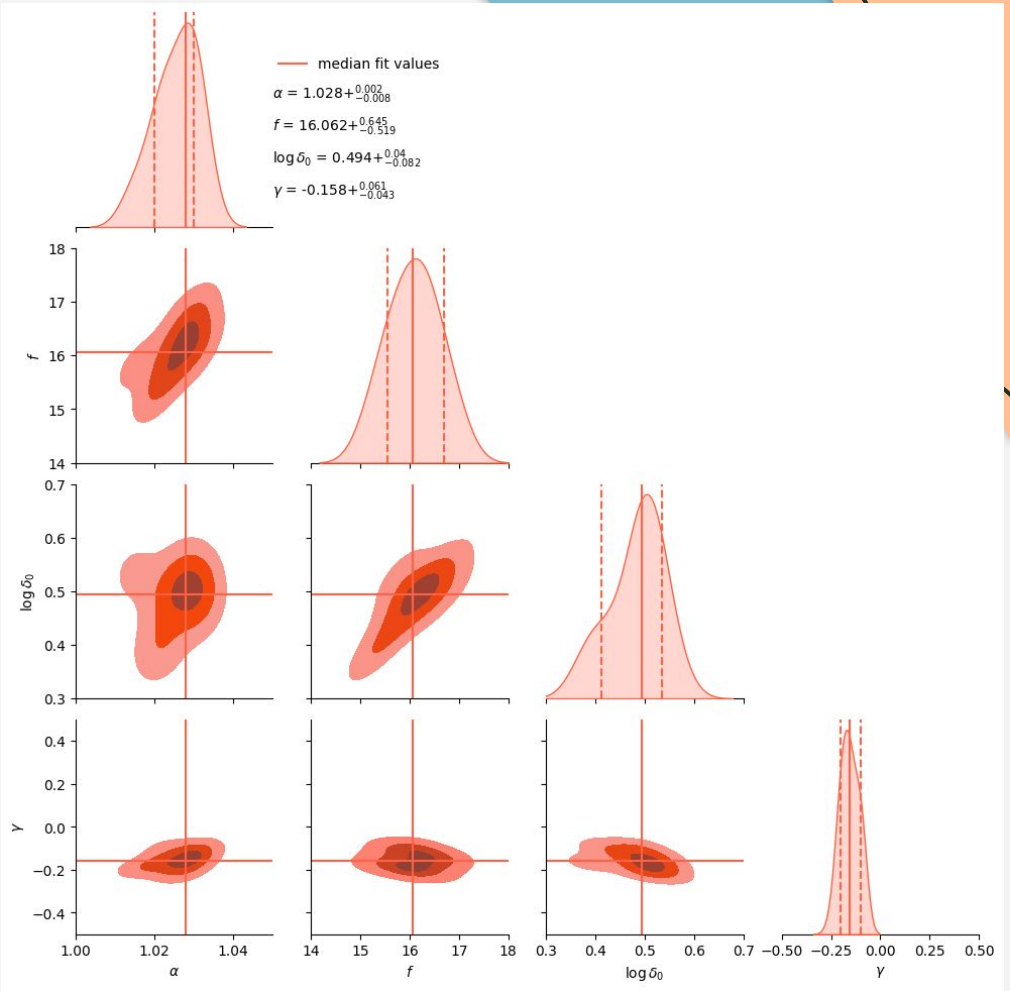
  emcee for the optimization

HOD modification

Calibrate neglecting a scatter in the assignment of the luminosity for the central galaxies

$$M_\delta = M_h \left(\frac{\delta_s}{\delta_0}\right)^\gamma$$

Older halos
of a given mass
have more satellites and
brighter central galaxies
(e.g., Zehavi et al. 2018; Bose et al. 2019; Contreras et al. 2019; Xu & Zheng 2020; Wang et al. 2022)



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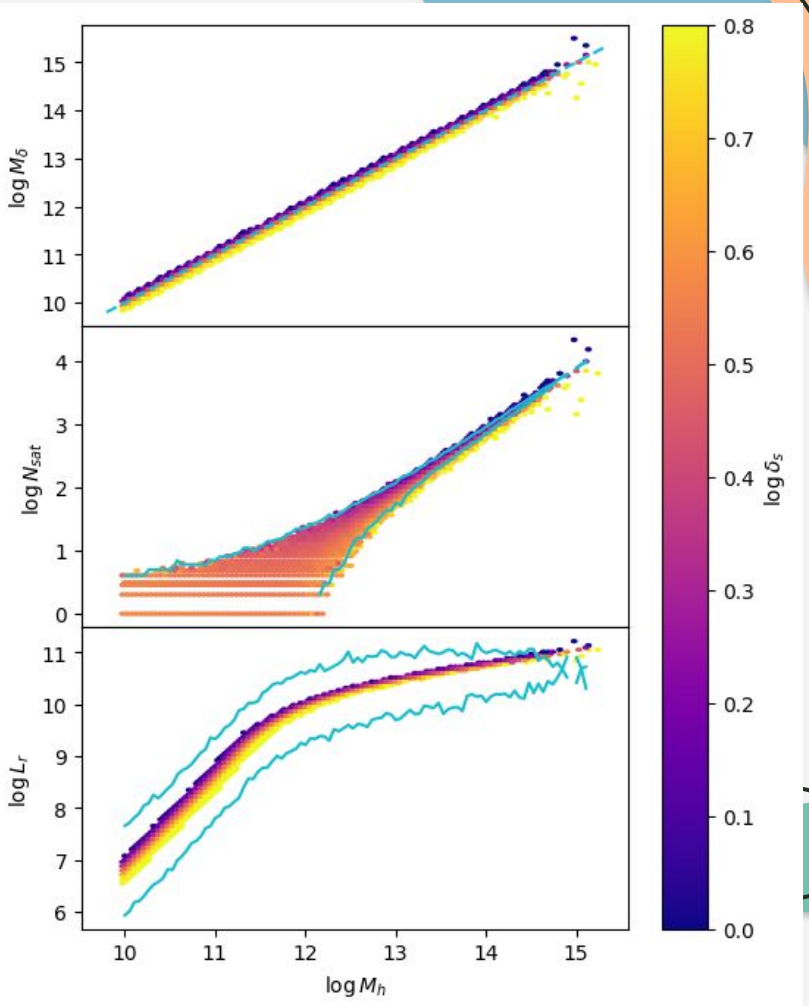
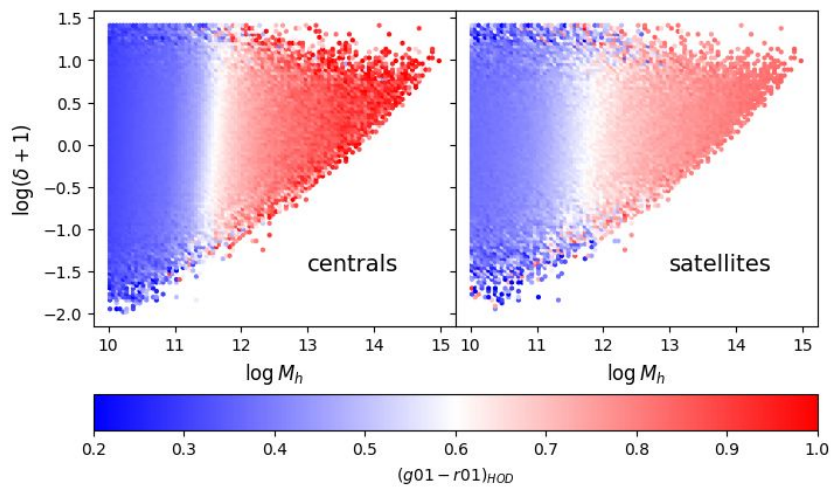
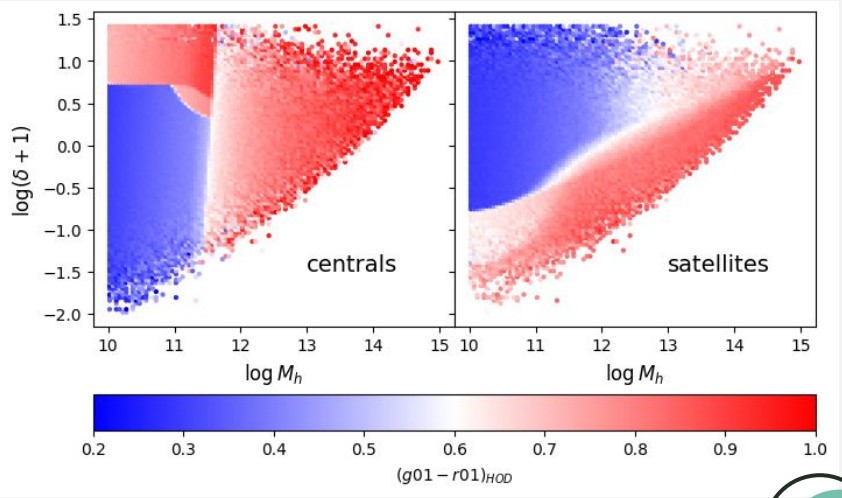


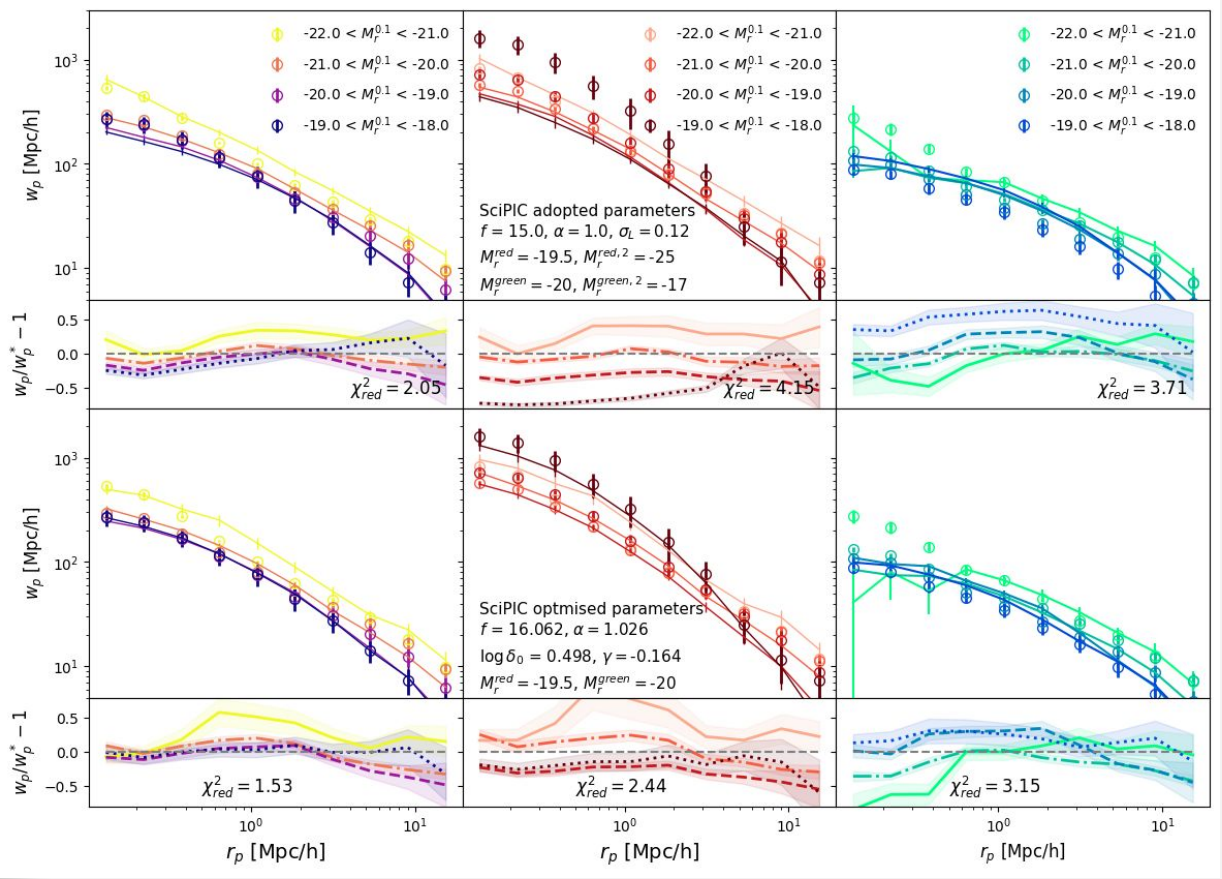
Considering the density in the colour assignment

Faint (Mr > -19) red centrals (satellites) in overdense (underdense) environments

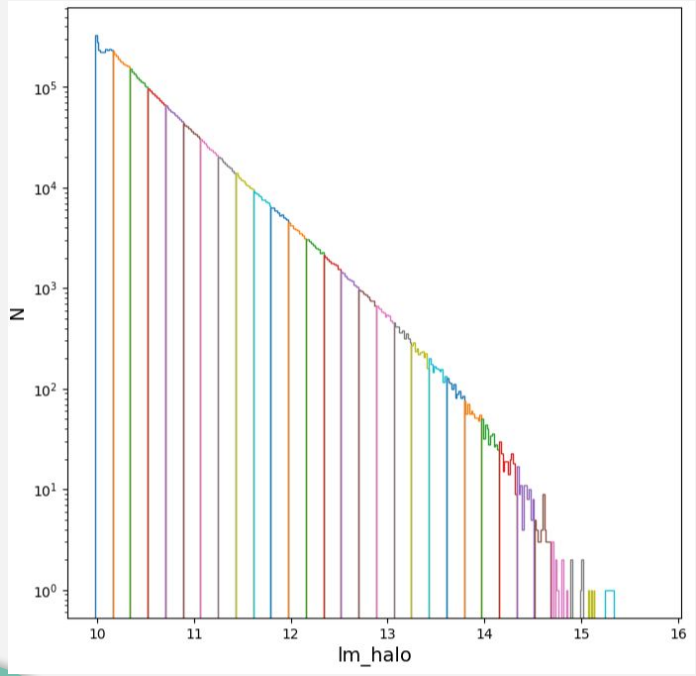


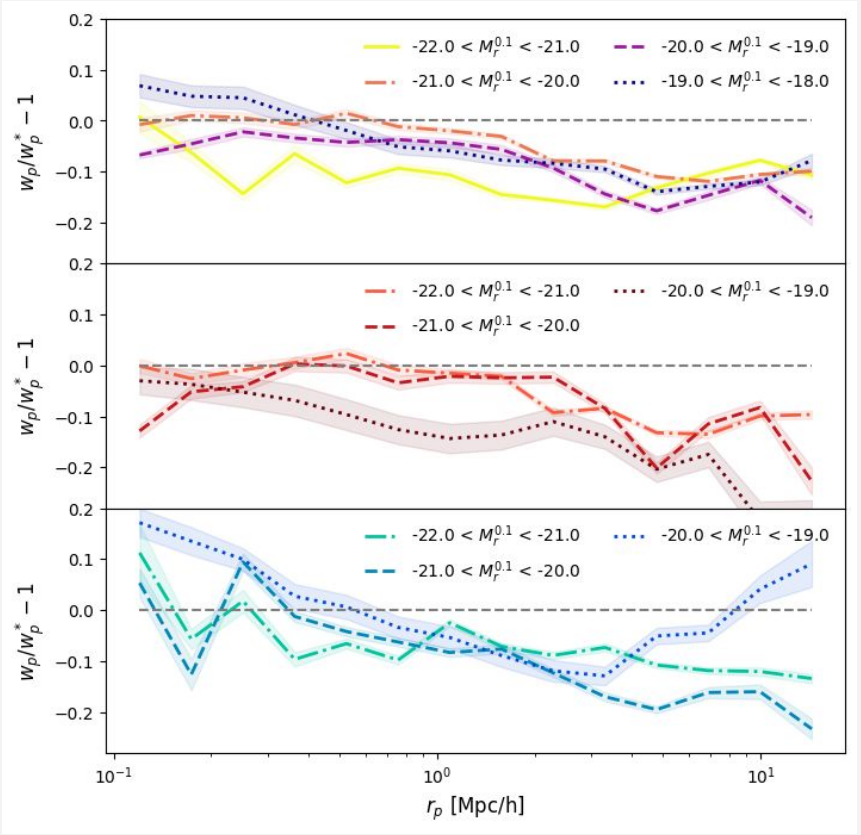


Projected 2-point correlations



Characterising the Assembly Bias





Future works

Produce different mocks with different degrees of assembly bias

Extend the HOD_δ recipe to higher redshift

Check if the FS predictions improves
(Clustering from DES, PAUS, galaxy-galaxy lensing, dependence of morphological parameters with environment and more...)

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Thanks! :)