Mining the Information Content of Member Galaxies in Halo Mass Modeling

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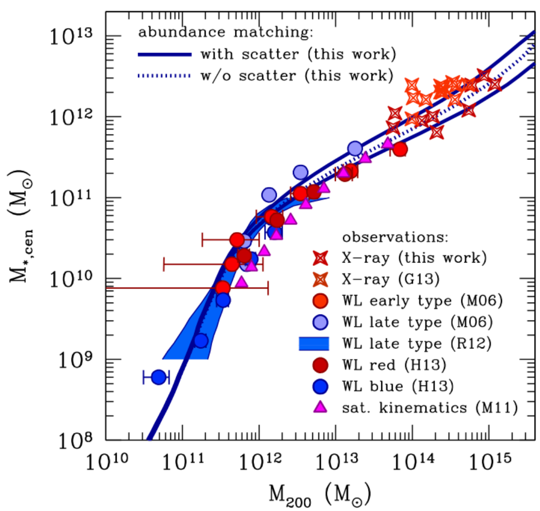
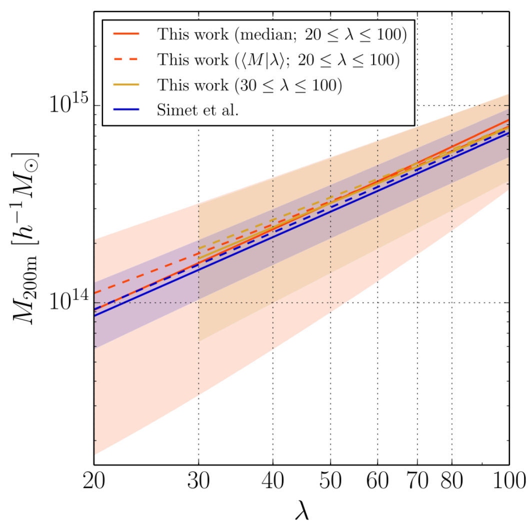
Background

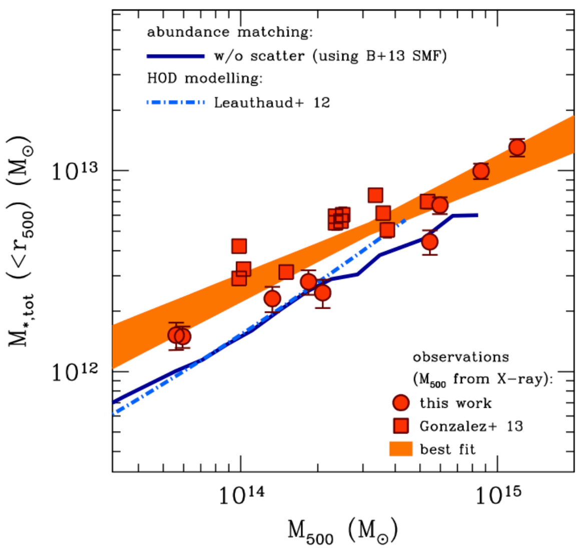
- Halo mass proxies based on galaxy content
  - stellar mass of the central galaxy
  - richness
  - total luminosity



(Kravtsov et al.2018)



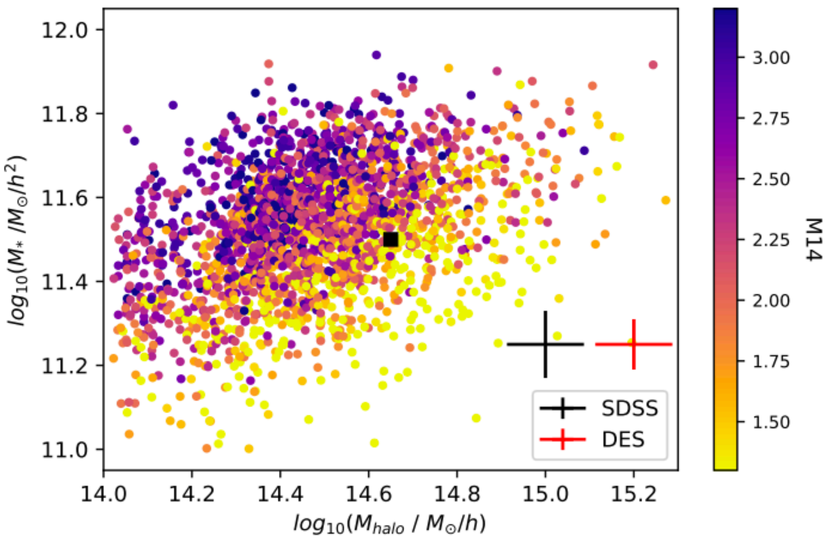
(Murata et al.2018)



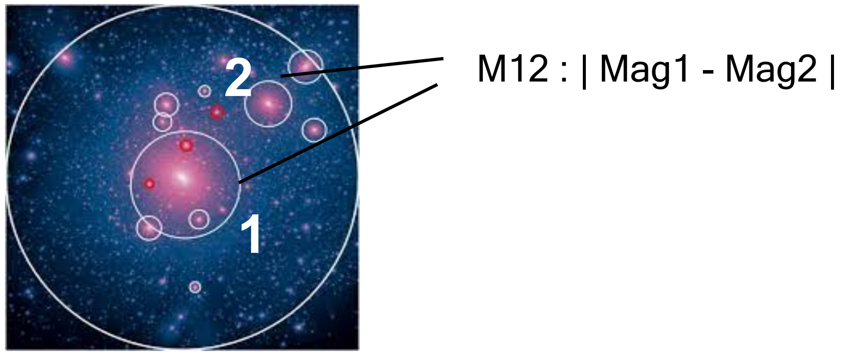
(Kravtsov et al.2018)

Background

▪ Magnitude gap



(Golden-Marx et al.2021)



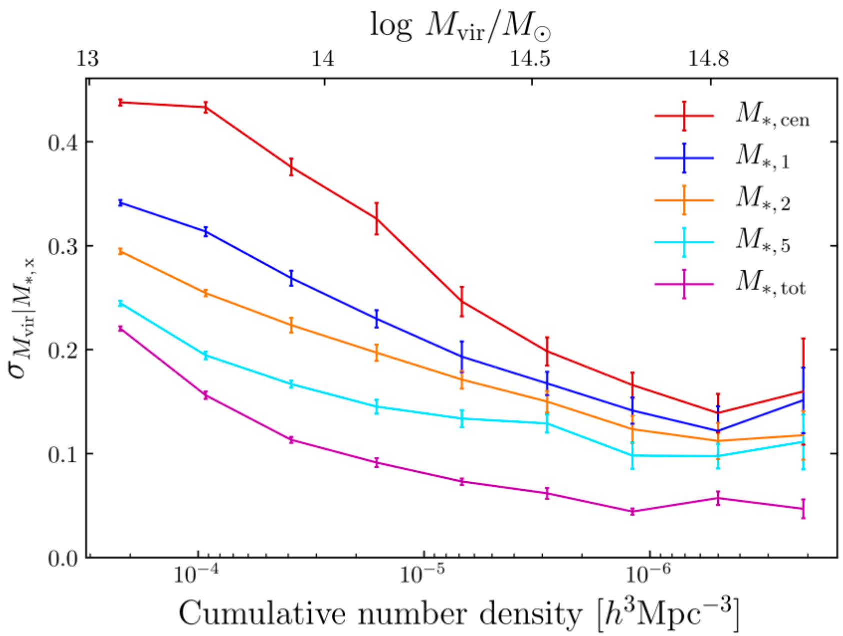
- Magnitude gap between BCG and certain satellite galaxies can improve the estimation of halo mass
- Most commonly used gap is M12 or M14

Which satellite galaxy provides the most information in halo mass estimation?

Background

How many satellites are needed to optimally constrain the halo mass?

- cen + N



(Bradshaw et al.2020)

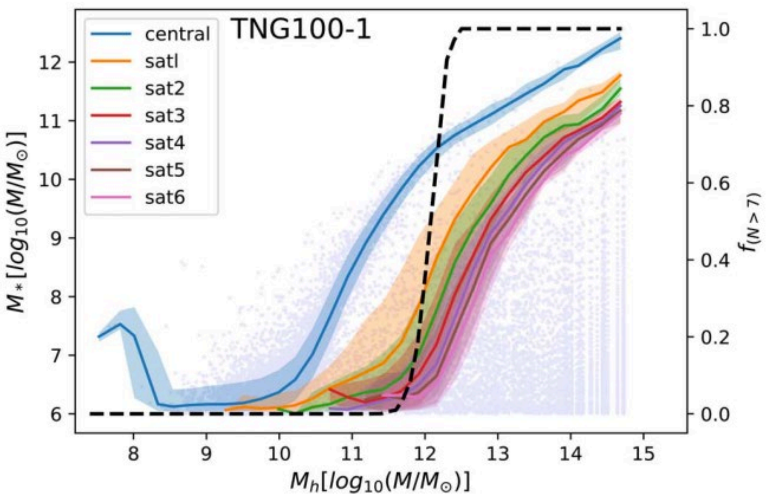
$M_{*,N}$: the cen+N mass, the sum of $M_{*,cen}$ and the stellar mass of the N most massive satellites

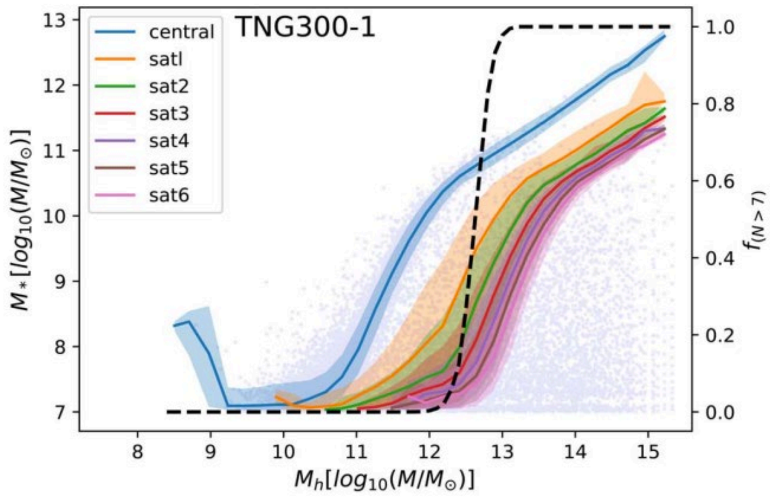
- Employing the "cen + N" estimator can effectively reduce the scatter.
- The scatter adopting this estimator approaches that using the total stellar mass.

How to combine the galaxy to maximize the accuracy of halo mass prediction?

Data

- TNG100-1 & TNG300-1





Halo mass range:

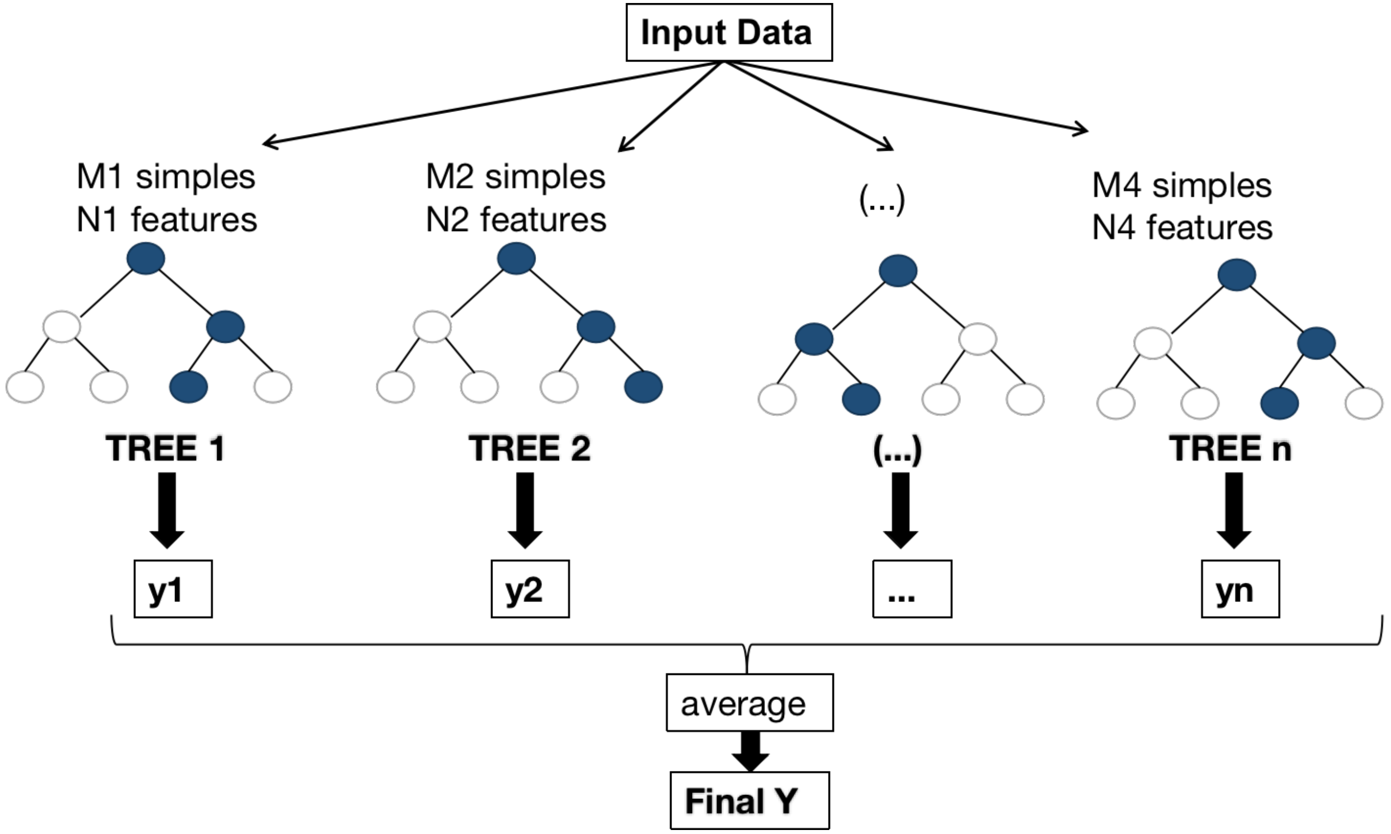
$$10^{12.3} < M_{\rm halo}/M_\odot \lesssim 10^{15.3}$$

9648 samples

Method

- Random forest (RF)

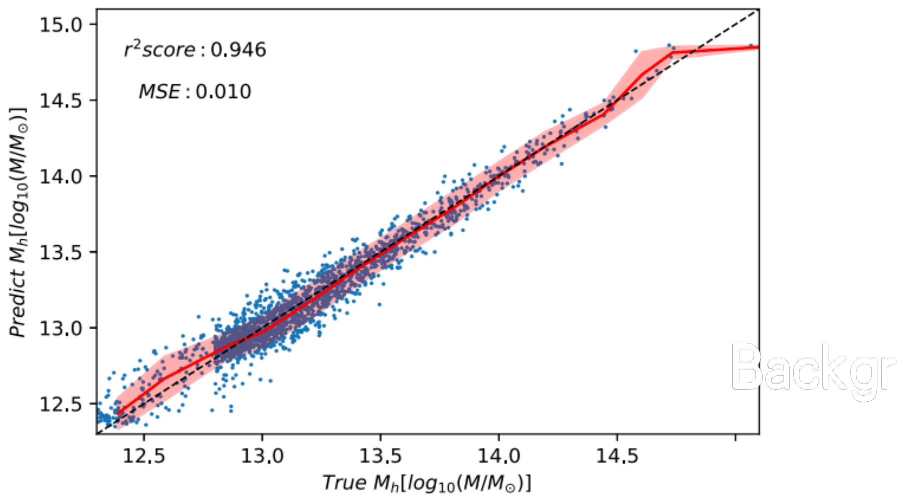
Input: stellar mass of the top 7 massive galaxies



Output: halo mass

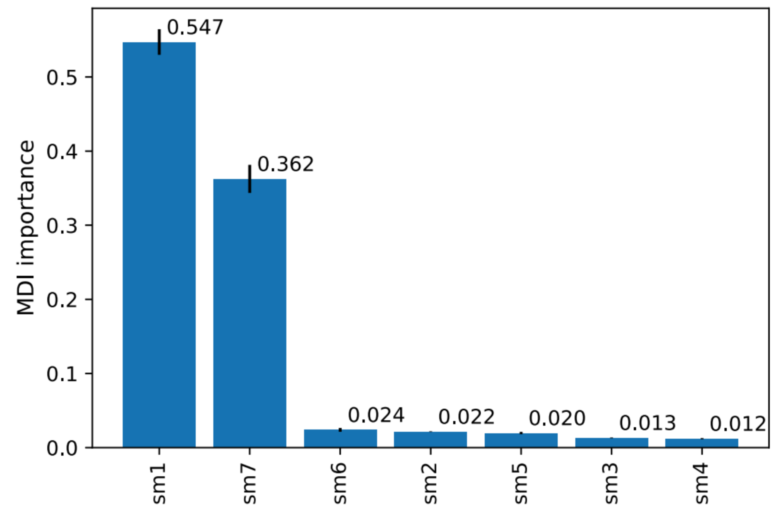
Result

- Model performance



- The model can unbiasedly predict the true halo mass across the entire mass range.

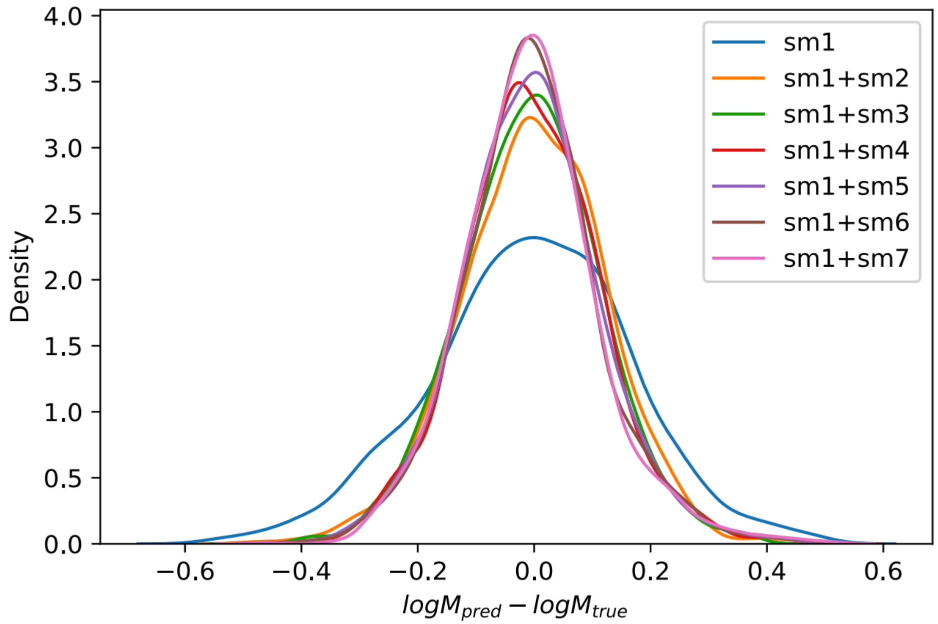
- Importance given by RF



- Central is the most informative； the Nth is almost as important as central

Result

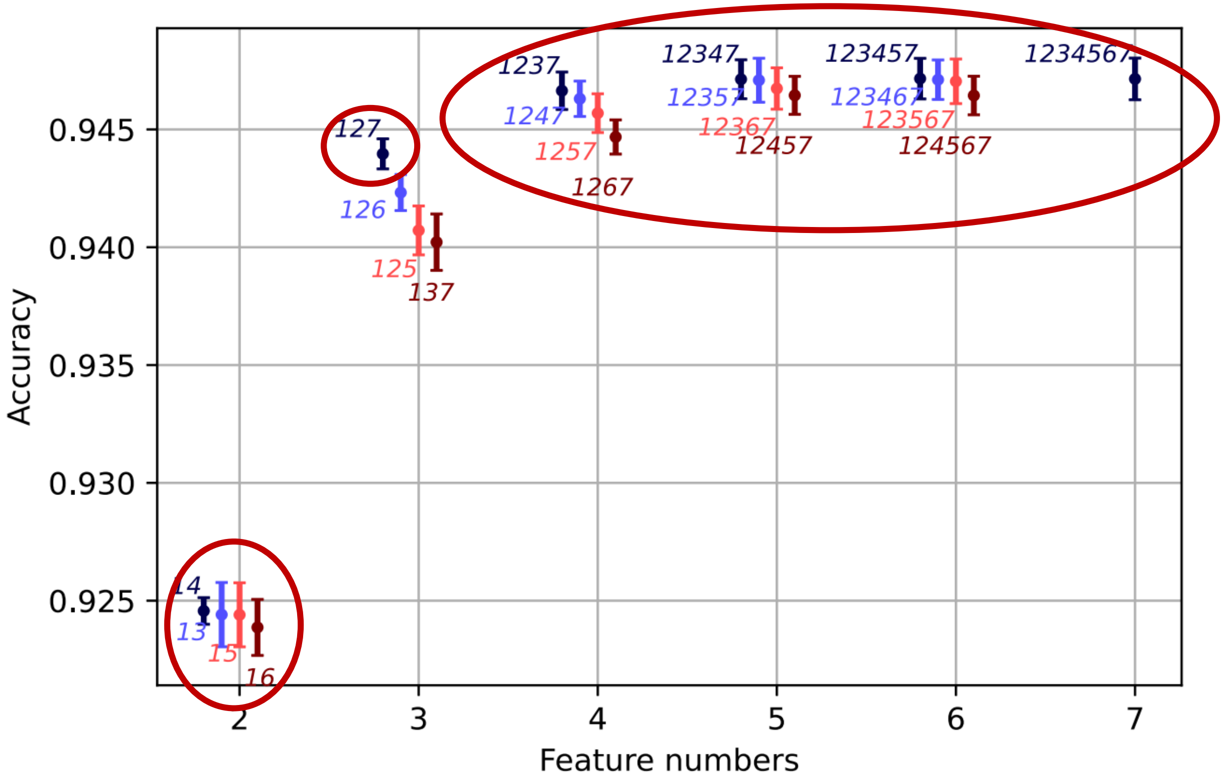
- Contribution of single satellite galaxy



- The inclusion of any of the satellite does improve the estimation of the halo mass.
- No single satellite significantly outperforms the others in the improvement.

Result

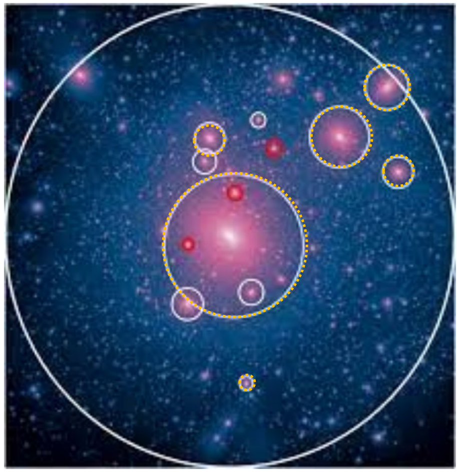
- Joint contribution from different numbers of satellite galaxies

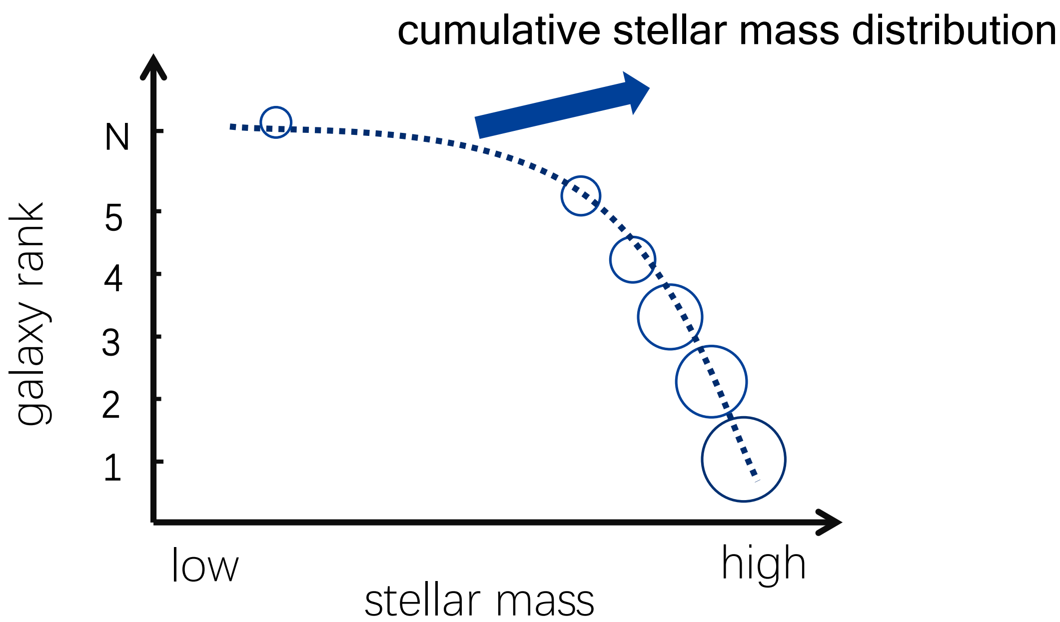


- When only two features are available,the scores of the different combinations do not differ significantly and that no combination is outstanding.
- When only three features are input, the [127] combination gives the highest model score and is almost as high as the highest score attainable.
- Once the input feature number reaches four, the improvement of the model becomes less noticeable and even almost absent with a further increase in feature number.

Discussion

- Understanding the gaps in the conditional galaxy distribution





Halo mass information provided by gap hidden in galaxy mass distribution

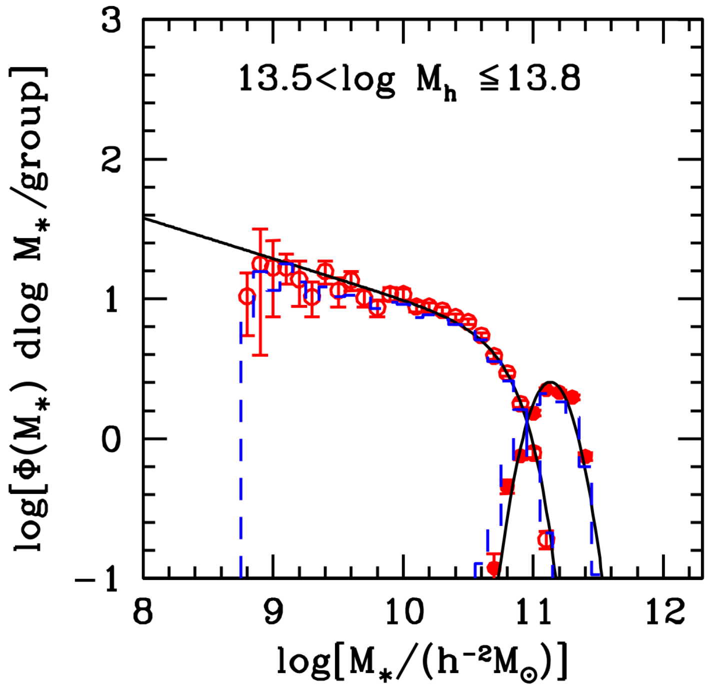
Discussion

- Conditional Stellar Mass Function

$$\Phi(M_*|M_h) = \Phi_{\rm cen}(M_*|M_h) + \Phi_{\rm sat}(M_*|M_h)$$

$$\Phi_{\rm cen}(M_*|M_h) = \frac{A}{\sqrt{2\pi}\sigma_c}\exp\left[-\frac{(\log M_* - \log M_{*,c})^2}{2\sigma_c^2}\right]$$

$$\Phi_{\rm sat}(M_*|M_h) = \phi_s^*\left(\frac{M_*}{M_{*,s}}\right)^{(\alpha_s^*+1)}\exp\left[-\left(\frac{M_*}{M_{*,s}}\right)^2\right]$$

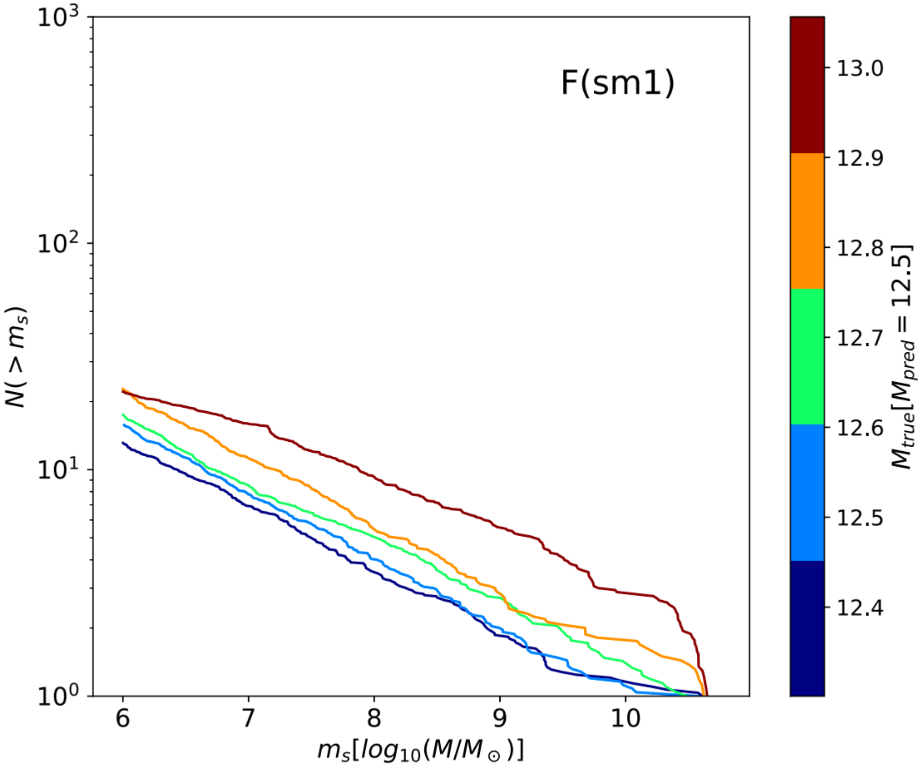


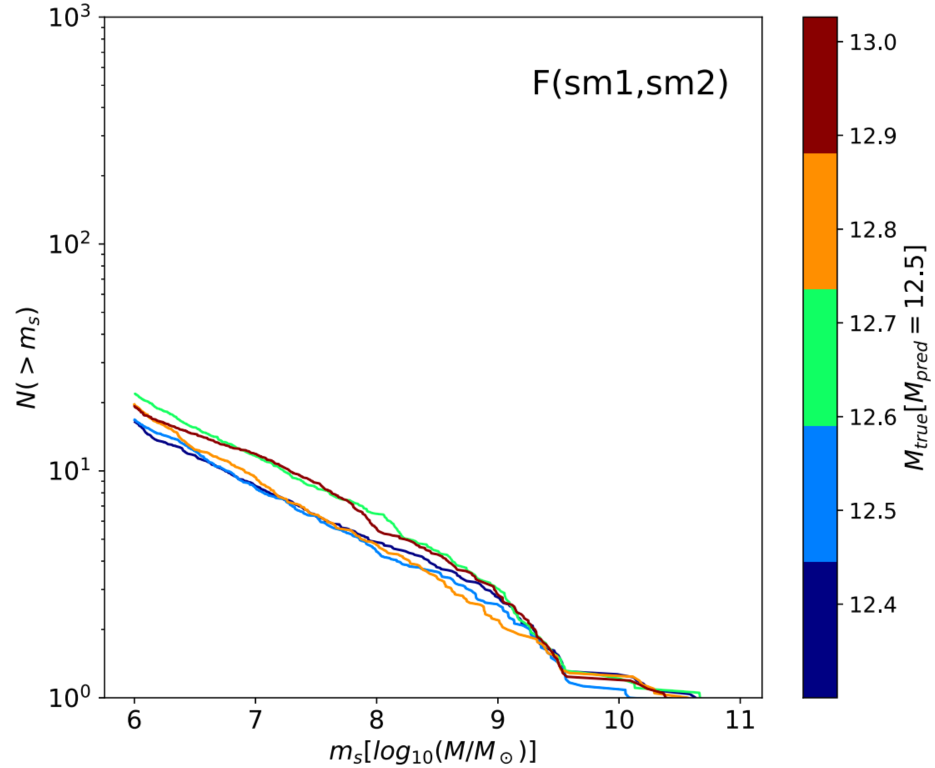
Understand the dependence of satatellite and halo mass by the halo mass dependent parameters

(Yang et al.2009)

Discussion

- Understanding the gaps in the conditional galaxy distribution





Discussion

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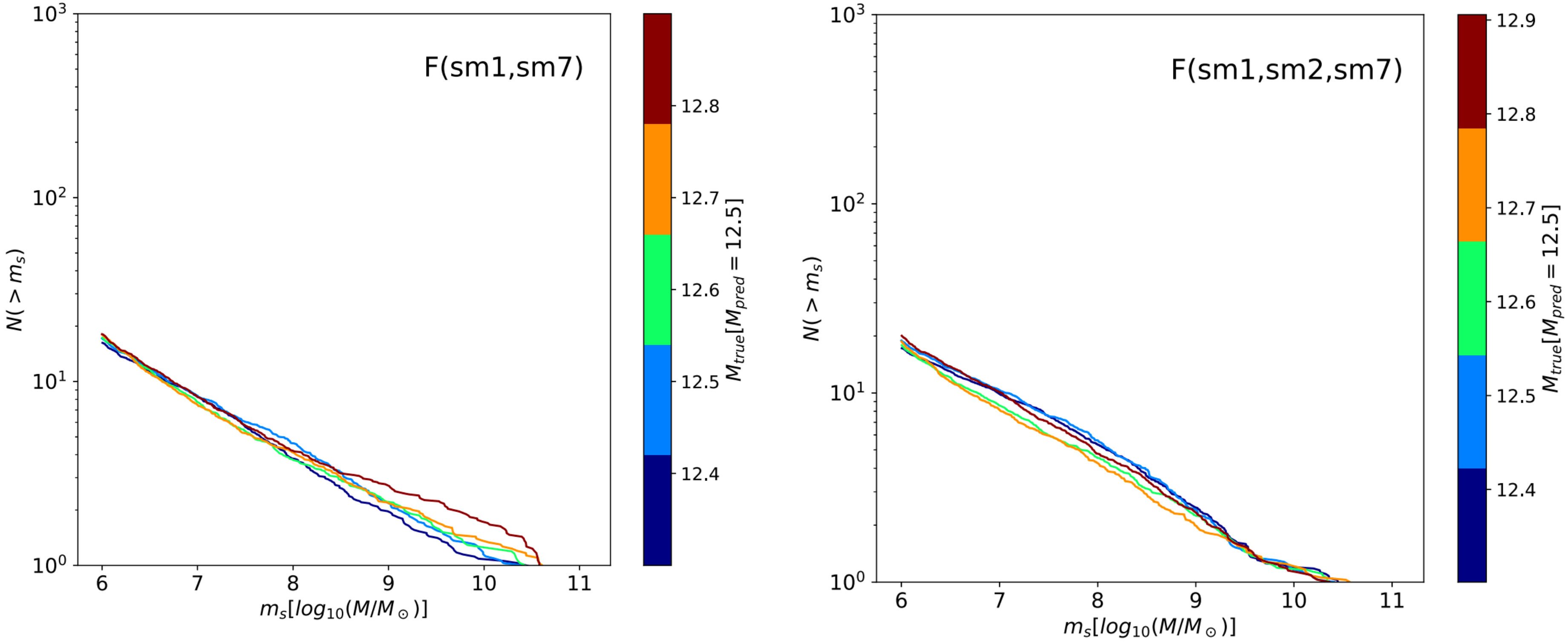

Different member galaxies accounting for distinct halo-dependent features in different parts of the stellar mass function

Summary

- One galaxy： central is the most informative； the Nth is almost as important as central.
- Two galaxies: satellite does improve the eatimation compared with central alone, but no outstanding satellite.
- Three galaxies: the best combination is always that of the central galaxy with the most massive satellite and the smallest satellite
- The combination of a central galaxy and two or three satellite galaxies gives a near-optimal model performance.
- Different member galaxies accounting for distinct halo-dependent features in different parts of the cumulative stellar mass function.

Thanks!