Finding Observable Environmental Measures of Halo Properties using Neural Networks

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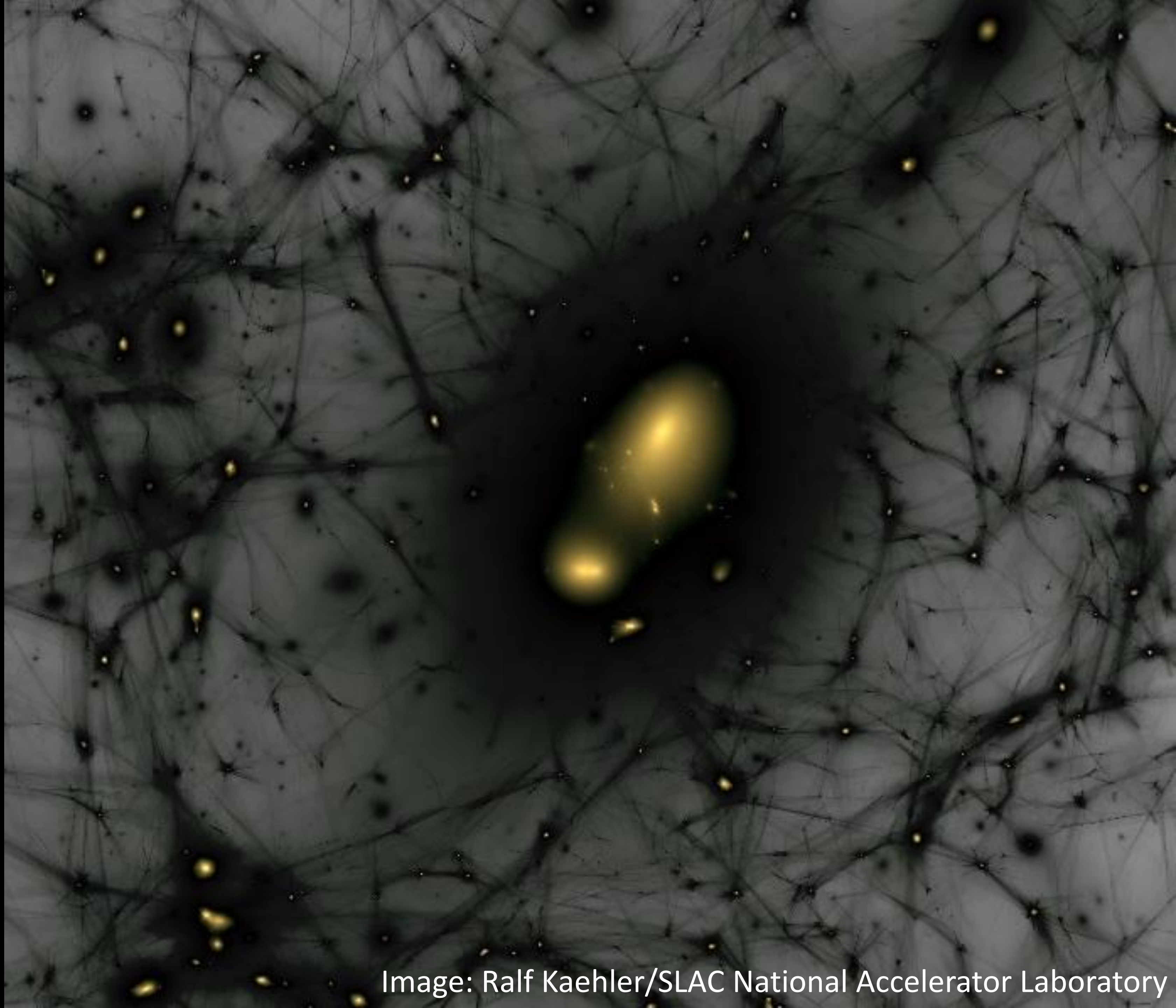


Image: Ralf Kaehler/SLAC National Accelerator Laboratory

Outline

1. Question: What can we learn about the properties of dark matter halos from their observable environments (with machine learning)?

2. Case Study: Training a neural network to estimate halo masses.

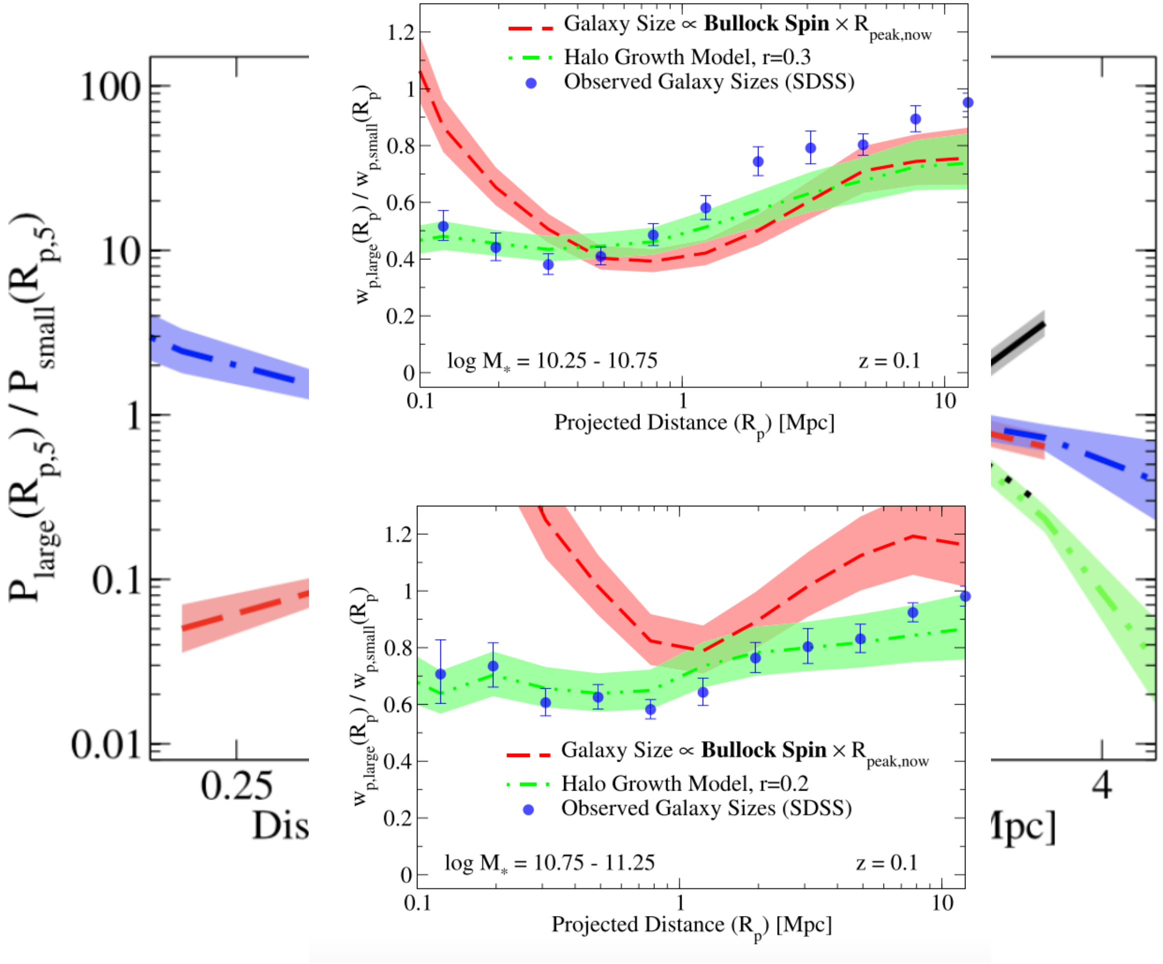
3. Opening the box: Determining which information is most important for making these estimate

4. Outlook: An overview of ideas and plans for expanding to secondary halo properties and applying to observations.

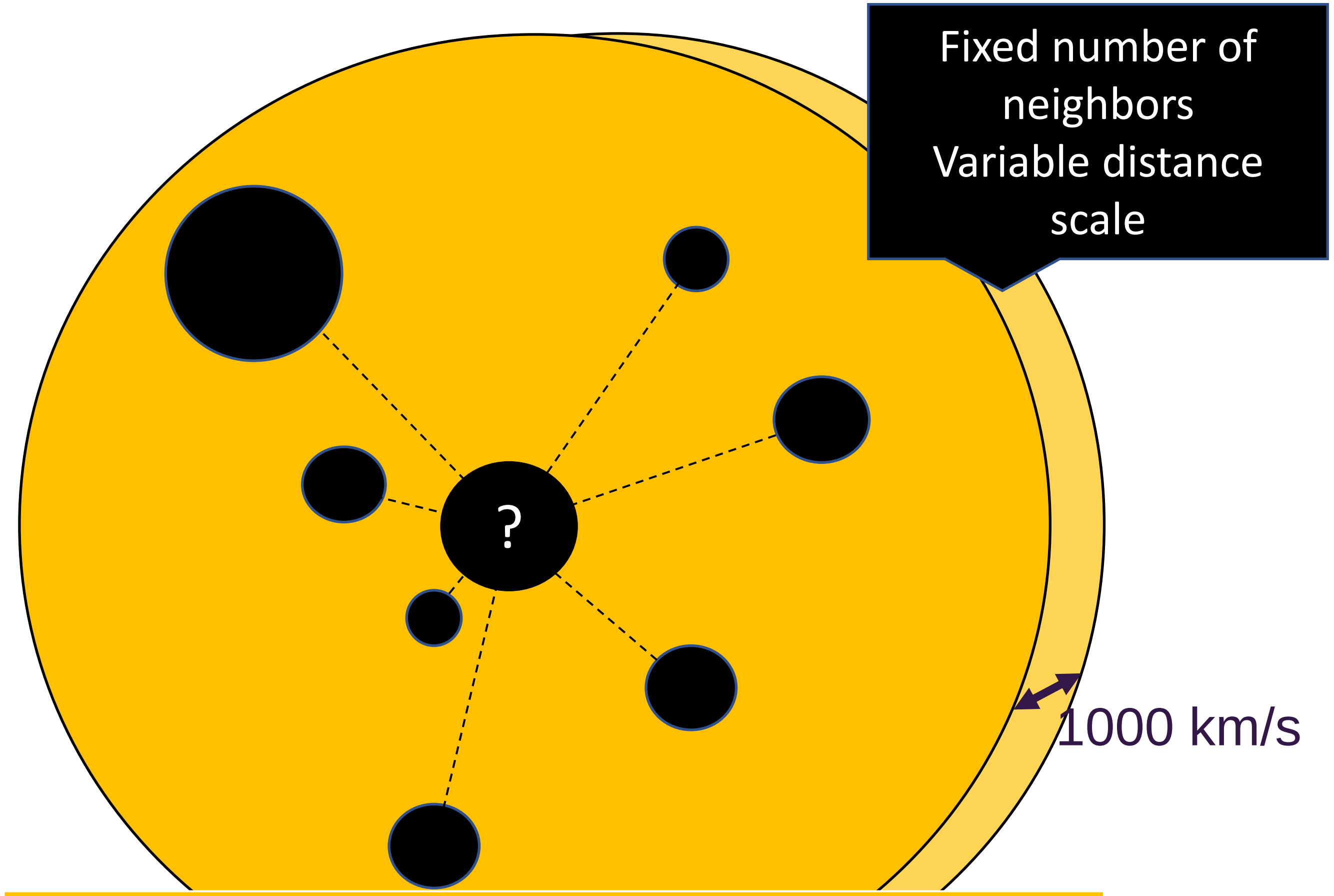
Halo properties have measurable correlations with the local environment

<u>Behroozi, Hearin, & Moster 2021</u> found that halo properties beyond mass show *unique* and *scale-dependent* correlations with environment.

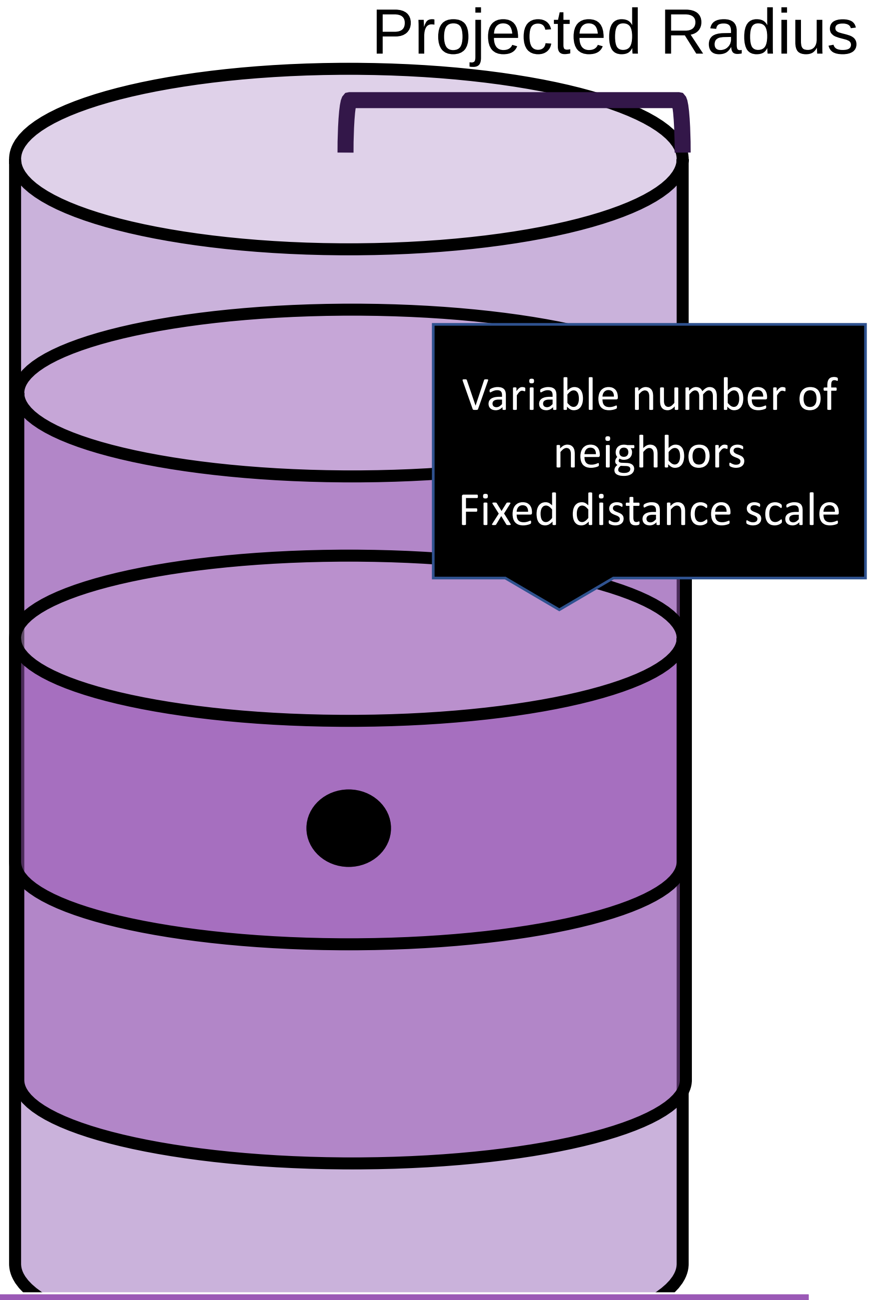
Exciting note about galaxy properties:
We can use estimates of secondary halo properties for observational data to consider the relationship between galaxy properties and halo spin, concentration, growth rate, and merger history



Defining different environmental measures



Distances to Nearest Neighbors (plus their stellar masses)



Counts in Cylinders

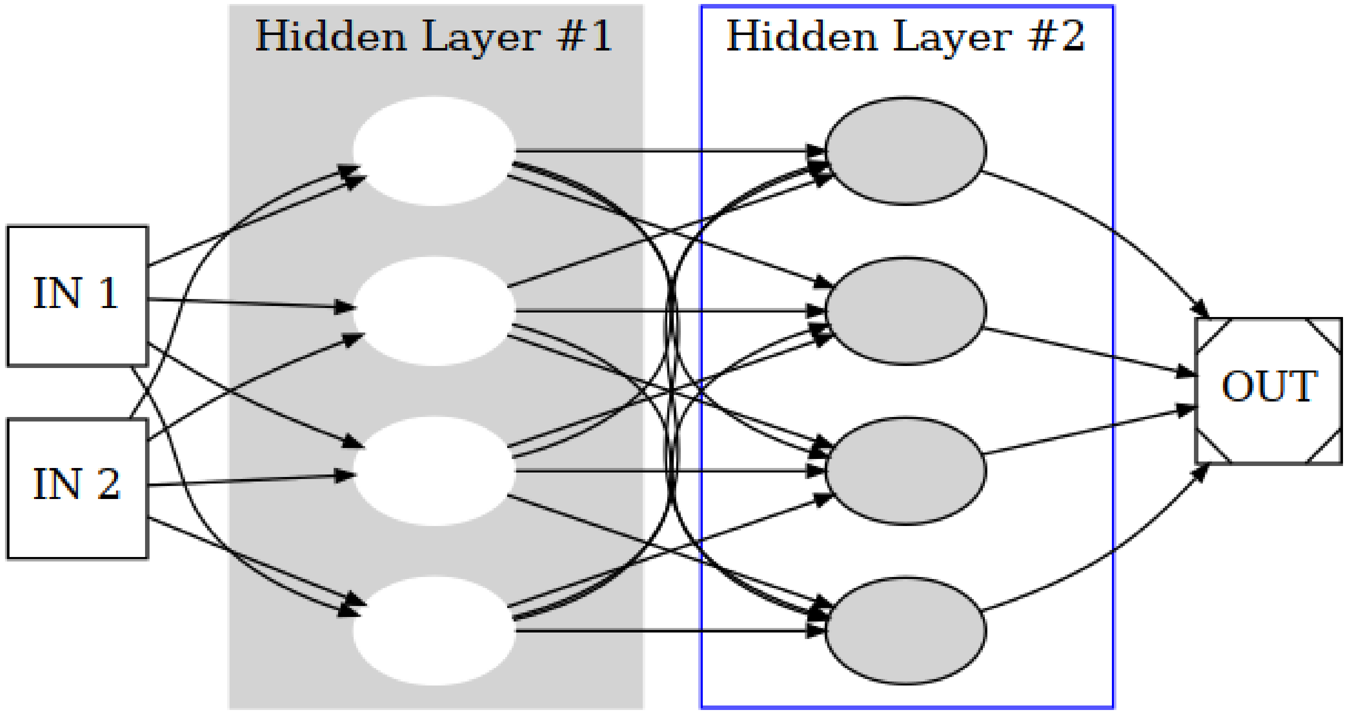
Network = Non-linear function of environment

Using data from UNIVERSEMACHINE train a neural network to predict halo properties given observable data

Distance to Target Galaxy

Stellar Mass

(x50)

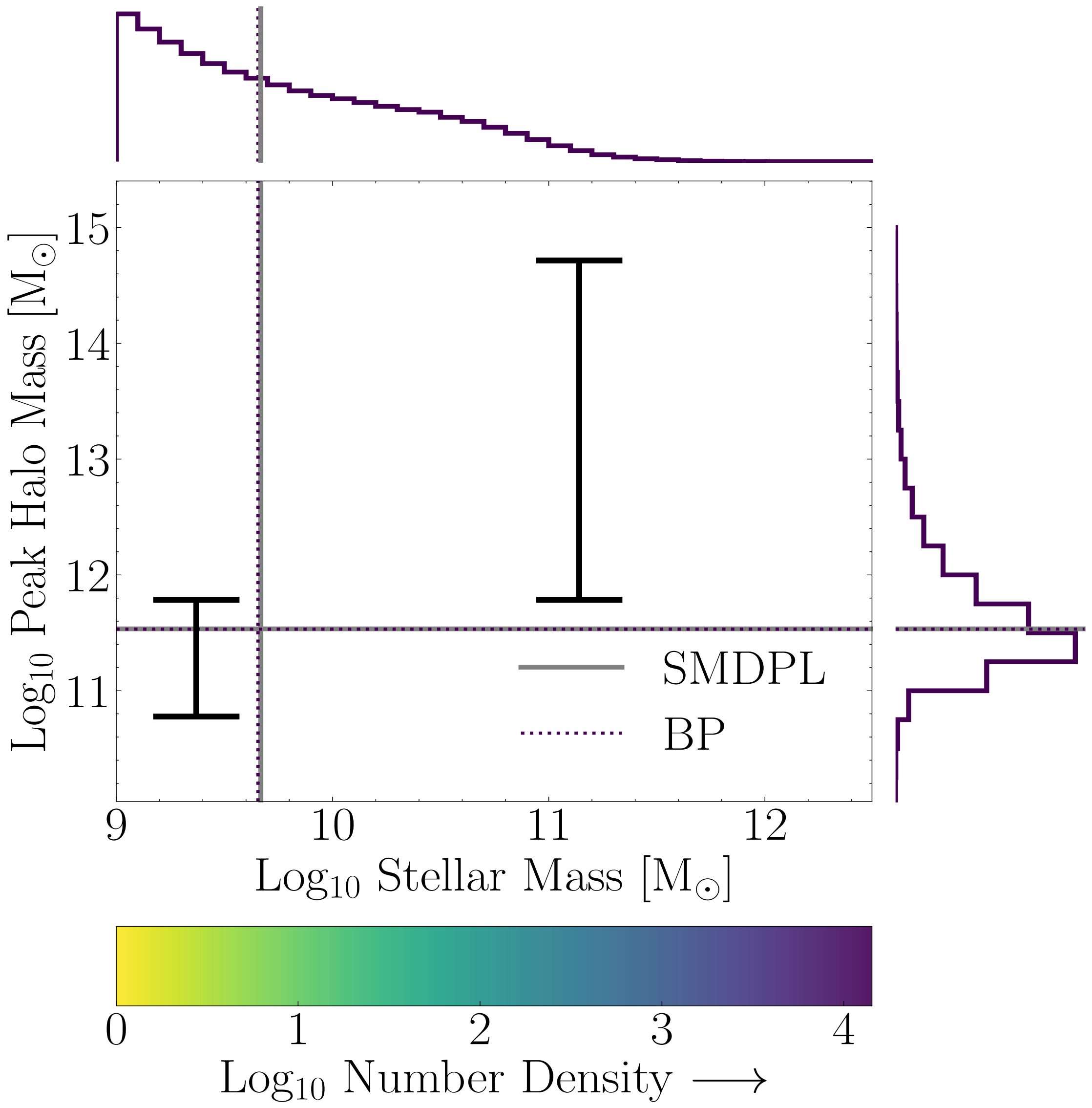


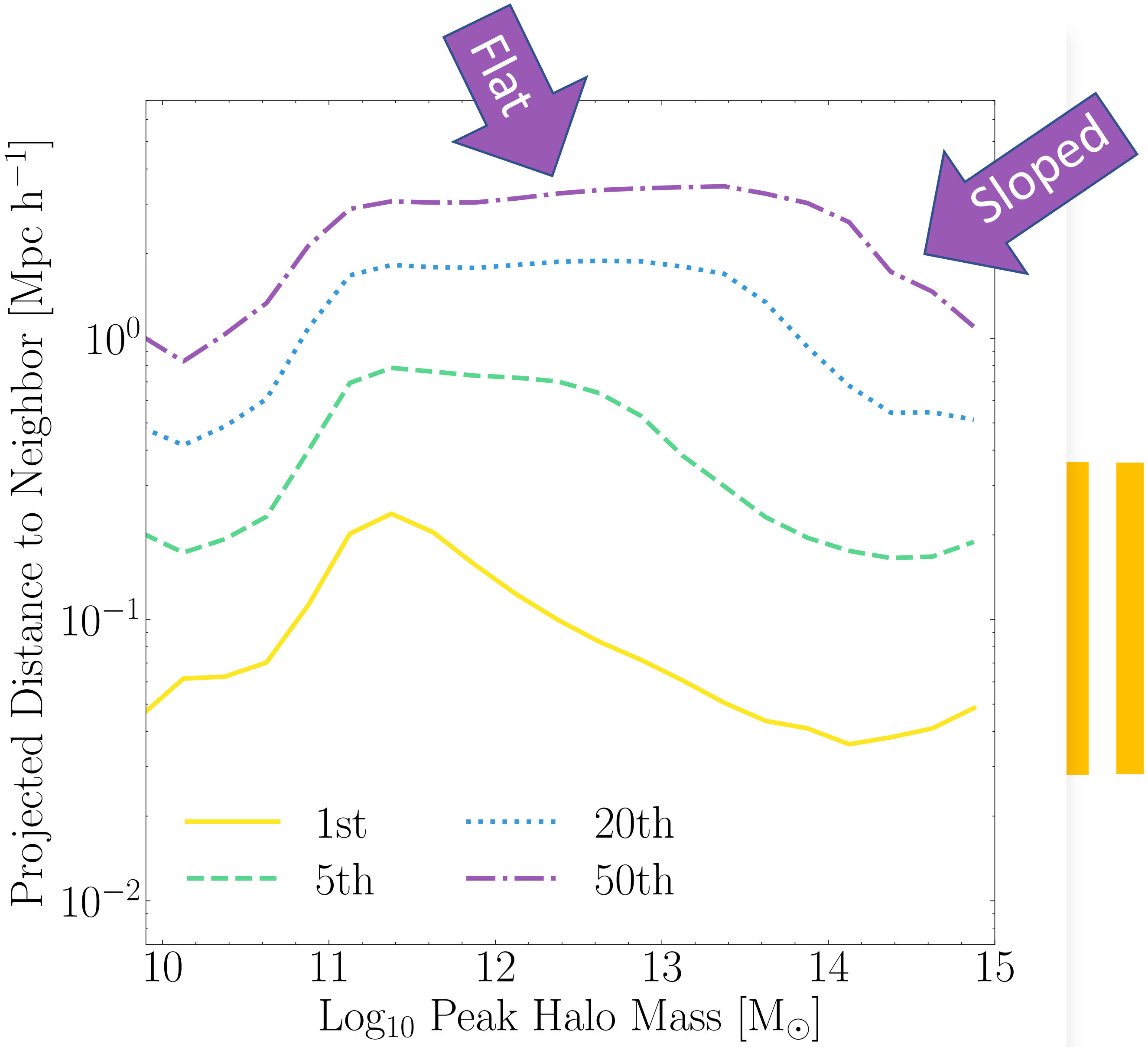
Halo Property

Estimating Halo Mass

The learned stellar-mass halo-mass relation serves as a baseline but is less effective for more massive galaxies.

But there is more information to be extracted from the environment!



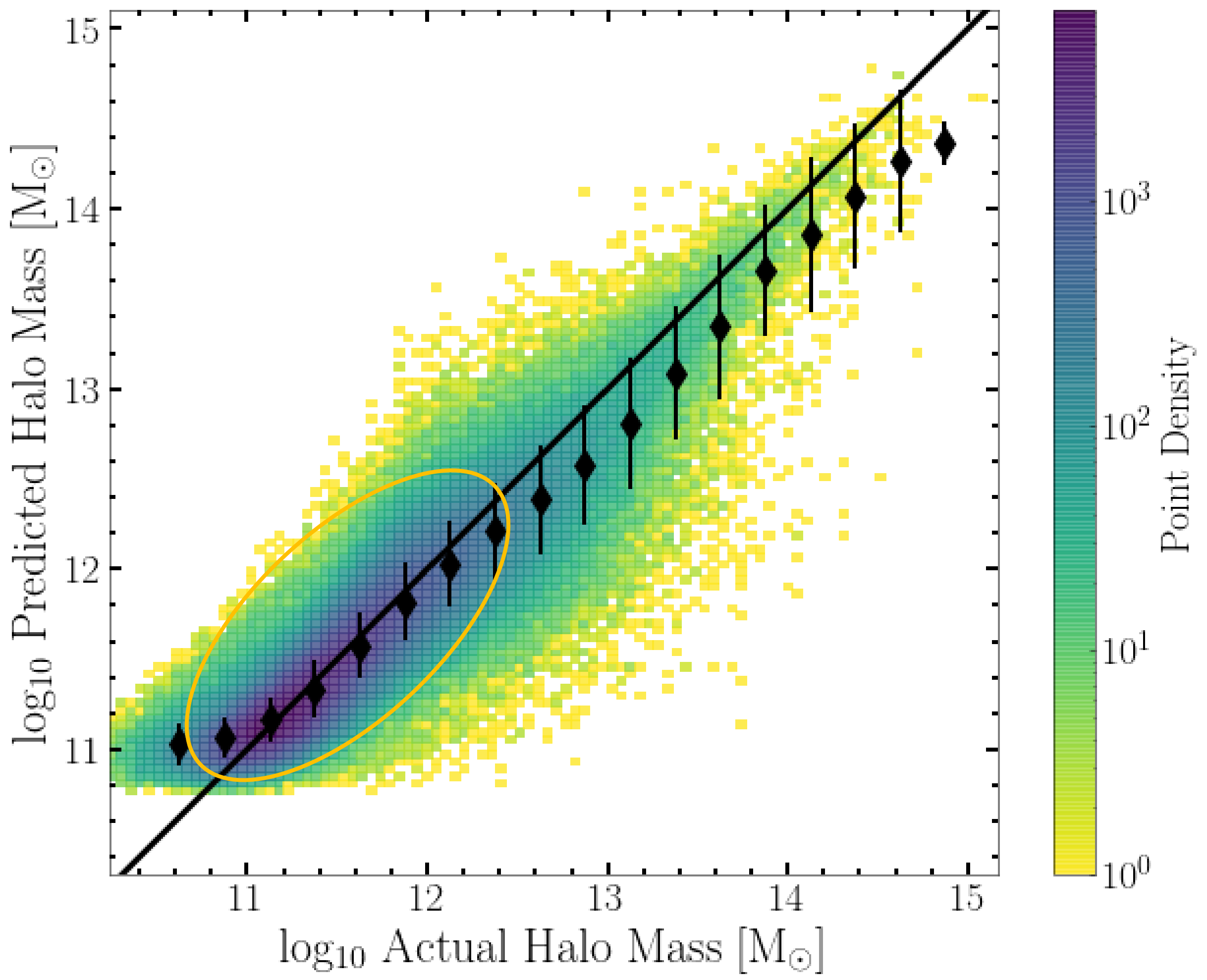


What can we learn from the environment?

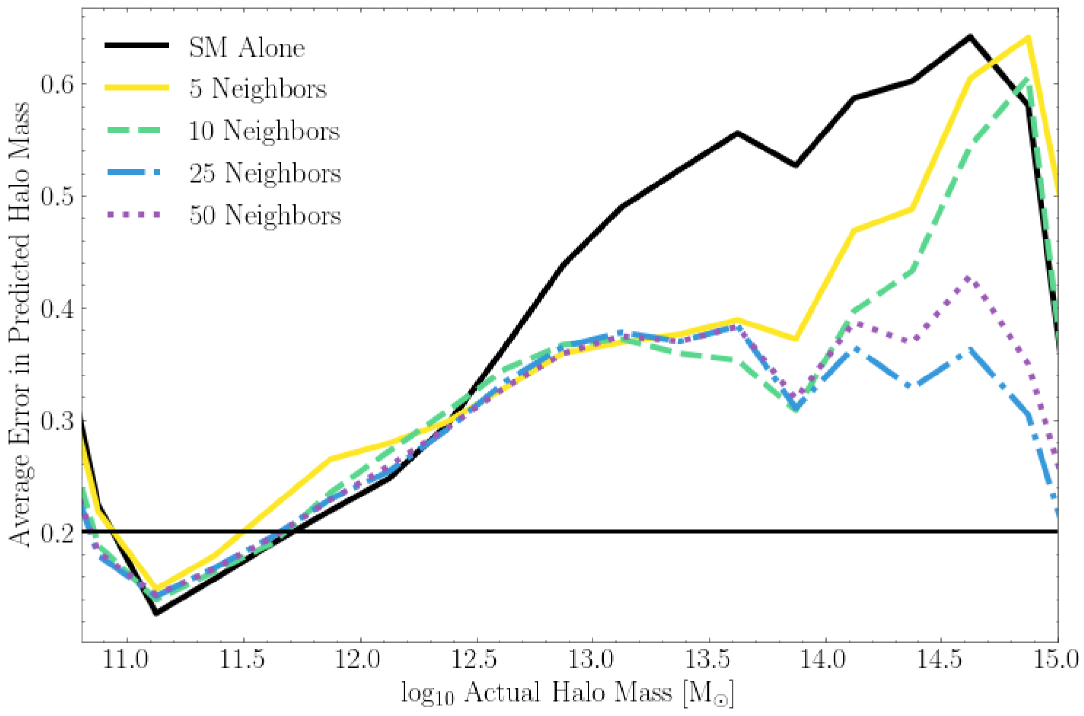
Improved Accuracy with Neural Network

Little improvement on the stellar-mass halo-mass relation for halos below ~$10^{12.5}$ $M_\odot$.

Substantial reduction in average error in prediction at group and cluster scales.



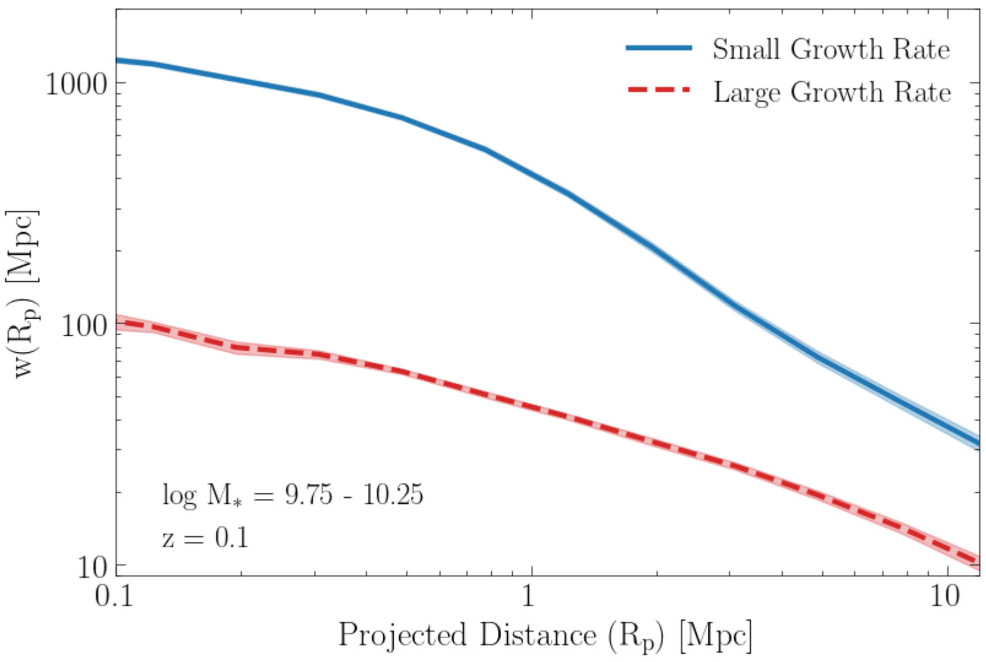
Sorting out the relevant information

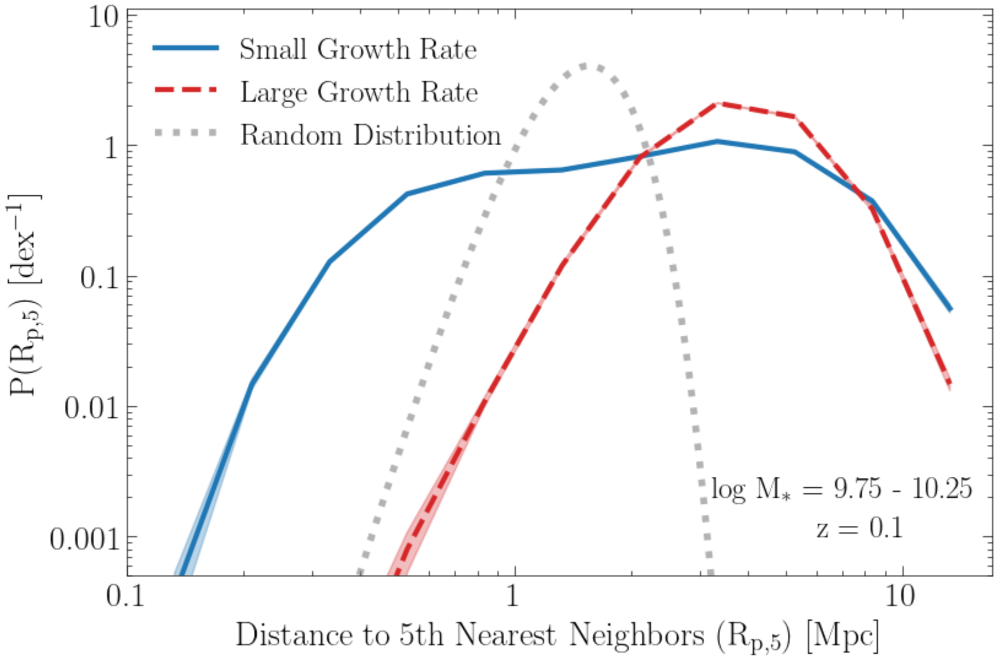


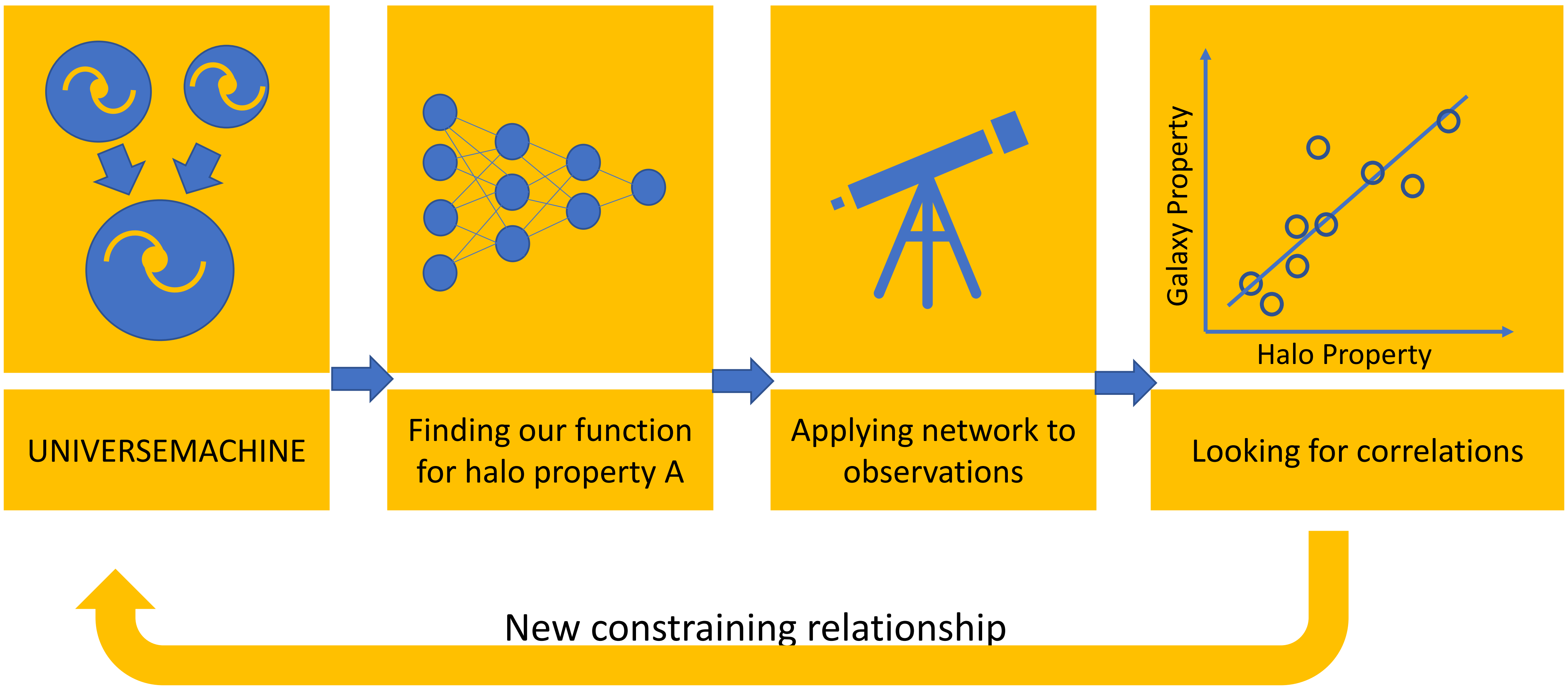
- How does the error in our prediction depend on halo mass? On other properties?
- Does including more neighbors improve our estimates?
- What is the best loss function for our science goal?

Future Work

Secondary Halo Properties






Galaxy Property
Halo Property
UNIVERSEMACHINE
Finding our function for halo property A
Applying network to observations
Looking for correlations
New constraining relationship

Big Takeaways!

We are developing networks to summarize the information in environment in ways that are sensitive to different halo properties.

The current network can accurately estimate halo masses for the Bolshoi-Planck simulation.

By varying the number of neighbors included and the loss function applied we can alter the performance in different mass regimes.

Looking forward: We are looking to train networks on different halo properties AND to apply these networks to observational surveys.

Centrals vs. Satellites