Machine Learning Galaxy Simulations

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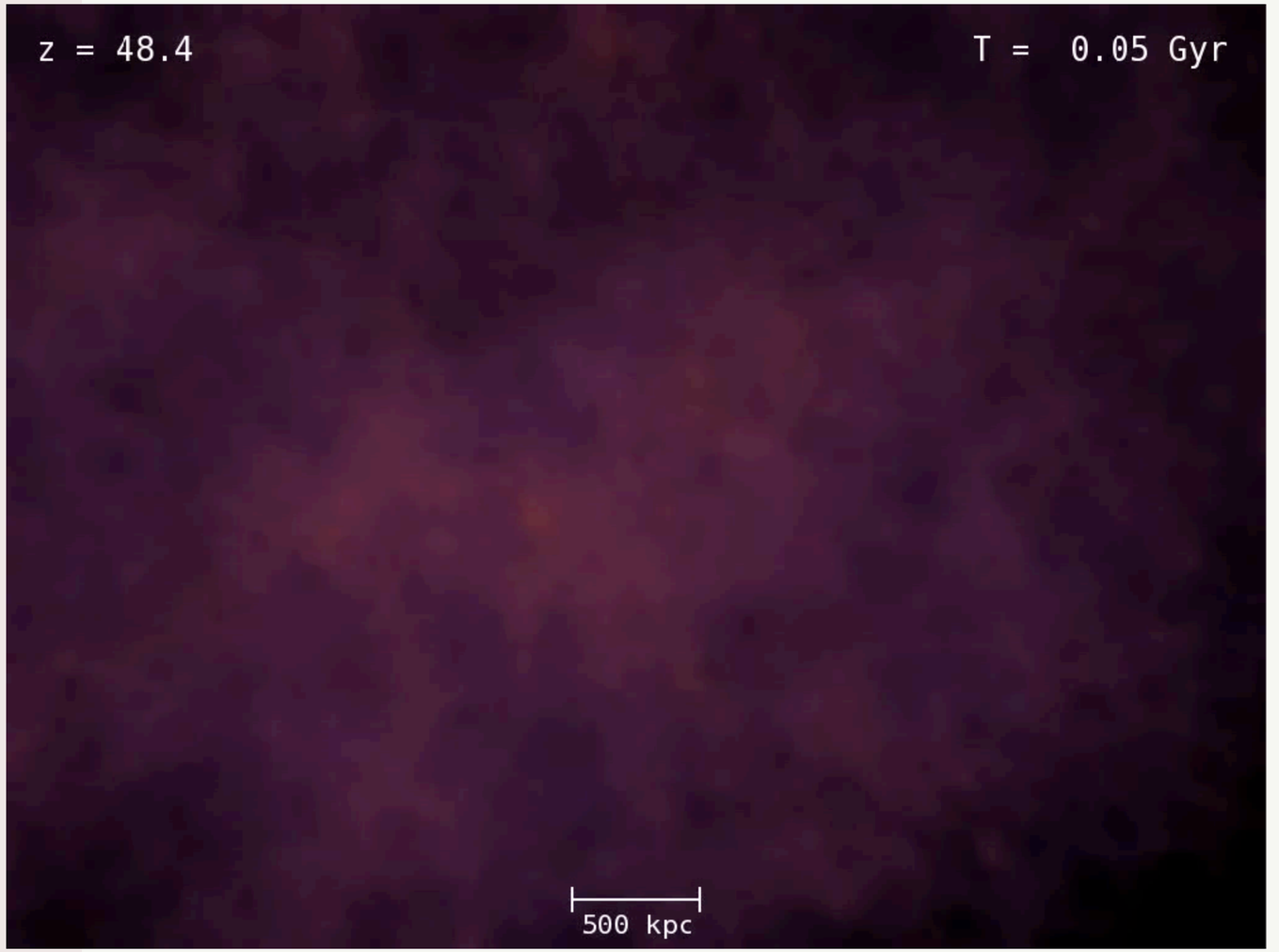
Galaxies are the fundamental building blocks of the Universe, so we would like to understand how they form and evolve.

- We can observe millions of galaxies with different colors, sizes, masses and shapes.
- What causes this diverse population?
- What is likely to be the future of past of a given galaxy?
- What physics drive galaxy evolution and are missing anything?

Numerical Simulations

- Numerical simulations are able to produce realistic galaxies with many properties like those observed.
- Interestingly, even though we know everything that goes into a given simulation that doesn’t mean we understand why things turn out the way that they do.
- Recently it has become fashionable to use Machine Learning to study what is happening in complex situations like this.



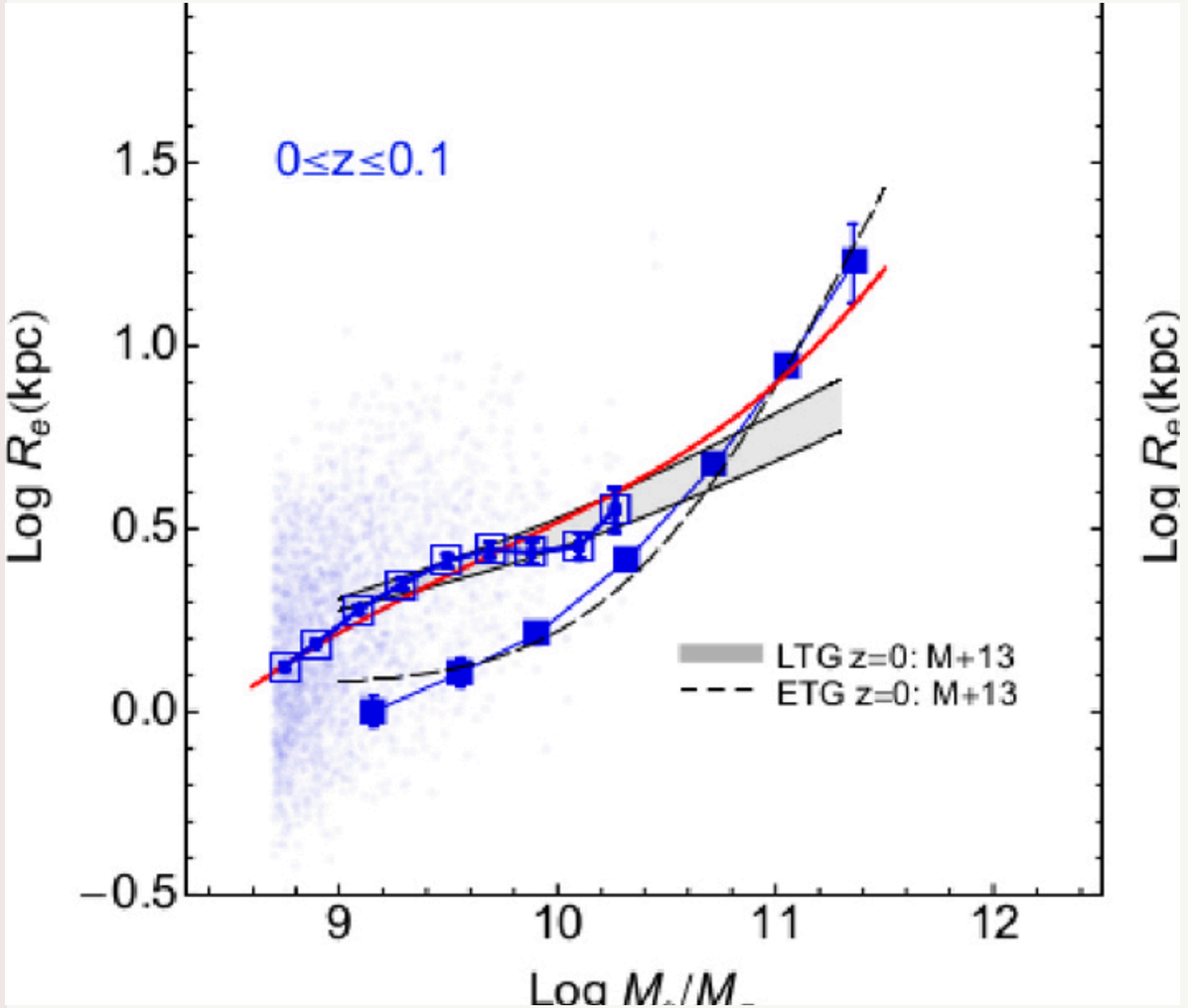
Machine Learning

aka Artificial Intelligence

- Machine learning is a technique where computers are trained to perform tasks that we used to think required people. It turns out in most cases all you really need is a lot of data.
- Through a variety of algorithms, computers can learn to predict what will happen in a given situation if they can analyze enough data. This works very will in doing things like predicting what you are searching for (Google), what else you want to buy (Amazon), what posts you will repost (Facebook) or what video you want to watch next (TikTok).
- However, these algorithms in general to not worry about why those predictions are made, just that they work.
- We can use these techniques on galaxy formation simulations to understand the relationship between different properties (called features ion Machine Language speak) in the simulation.

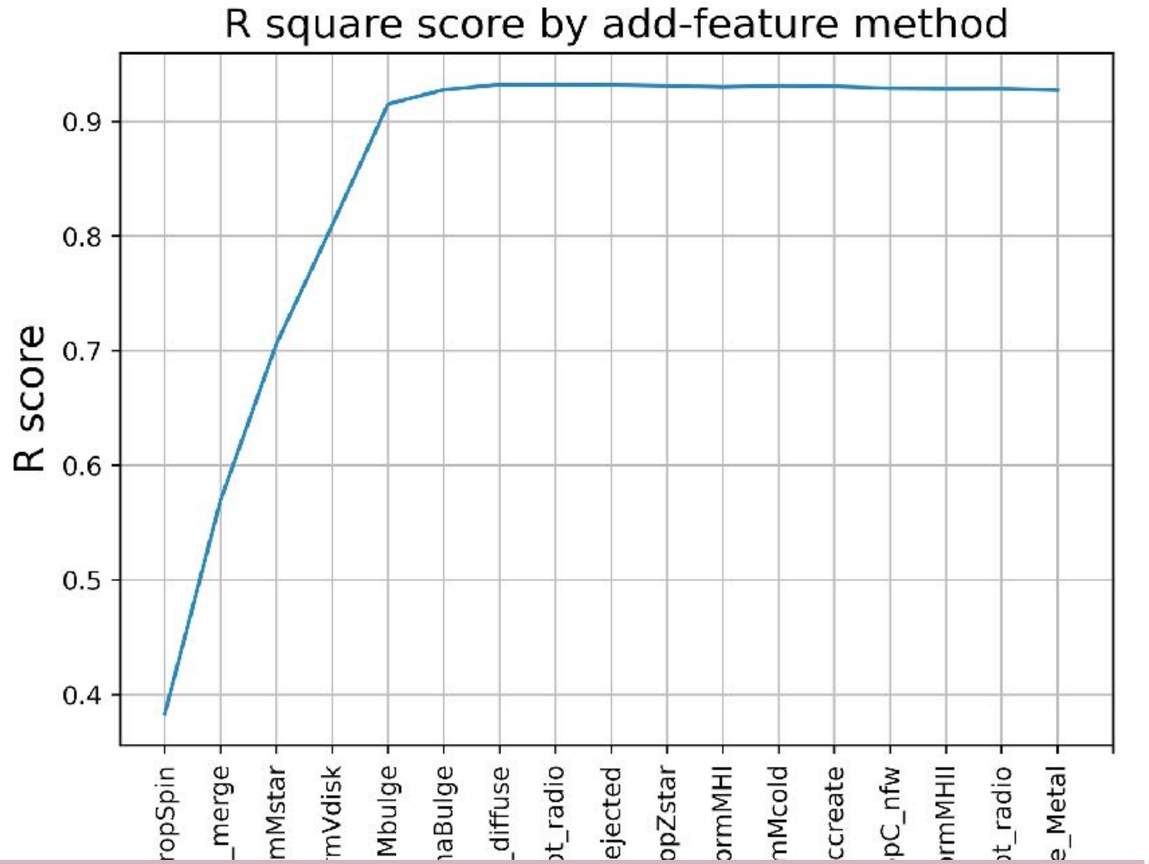
Galaxy Sizes

- Galaxy sizes are a simple property that we might expect a simple model (higher angular momentum implies larger size) to explain.
- However, numerous studies of simulations find conflicting results and none show the simple model to really work.
- Can machine learning give us a better idea of what is going on?



Feature Ranking

- We can use Machine learning to study how much any property contributes to the target property (in this case size).
- We see that angular momentum (Spin) by itself is a poor predictor of size, but adding in time since a merger, stellar mass, the disk velocity and bulge mass leads to a good prediction.
- With this information we can now work on a physical model of what is setting the galaxy size in this simulation.



Future Projects

1. The same exact approach can be used on other simulations to see if the properties tha predict galaxy size are the same or if they differ. If they differ we can try to understand why that might be the case.

3. Other properties can be explored like the galaxy morphology, black hole mass, star formation rate ,etc. as the target of the prediction. We. can the learn what features predict these properties and develop simple models of what is going on in the situation.