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Star Formation Histories in Cosmological Simulations

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1. Introduction

Cosmological simulations offer the advantage of time-reversal, allowing us to actively study evolutionary processes, while observations provide only static snapshots. However, there are many simulations available, each with different input physics. Examining **Star Formation Histories** (SFHs) reveals a window into these various input physics such as the key physical processes driving star formation within galaxies [1].

In our project, we hope to answer:

- **What are the differences and similarities between the SFHs produced by different simulations?**

This project is thus an investigation into the comparison of SFHs across different simulations based on their shape and distribution.

2. Data/Methods

We used data from the following large-scale hydrodynamical simulations: **EAGLE** [2], **Illustris** [3], **IllustrisTNG** [4], **Mufasa** [5], **Simba** [6], **SC-SAM** [7], and **UniverseMachine** [8].

This data was analyzed with **UMAP** (Uniform Manifold Approximation and Projection), a dimensionality reduction tool used to identify patterns in the SFHs as a 2D projection in UMAP space. Then using a **K-Nearest Neighbors** (K-NN) approach, we were able to predict which simulations lived where in UMAP space.

Therefore, we can predict which simulations produce which SFH shapes.

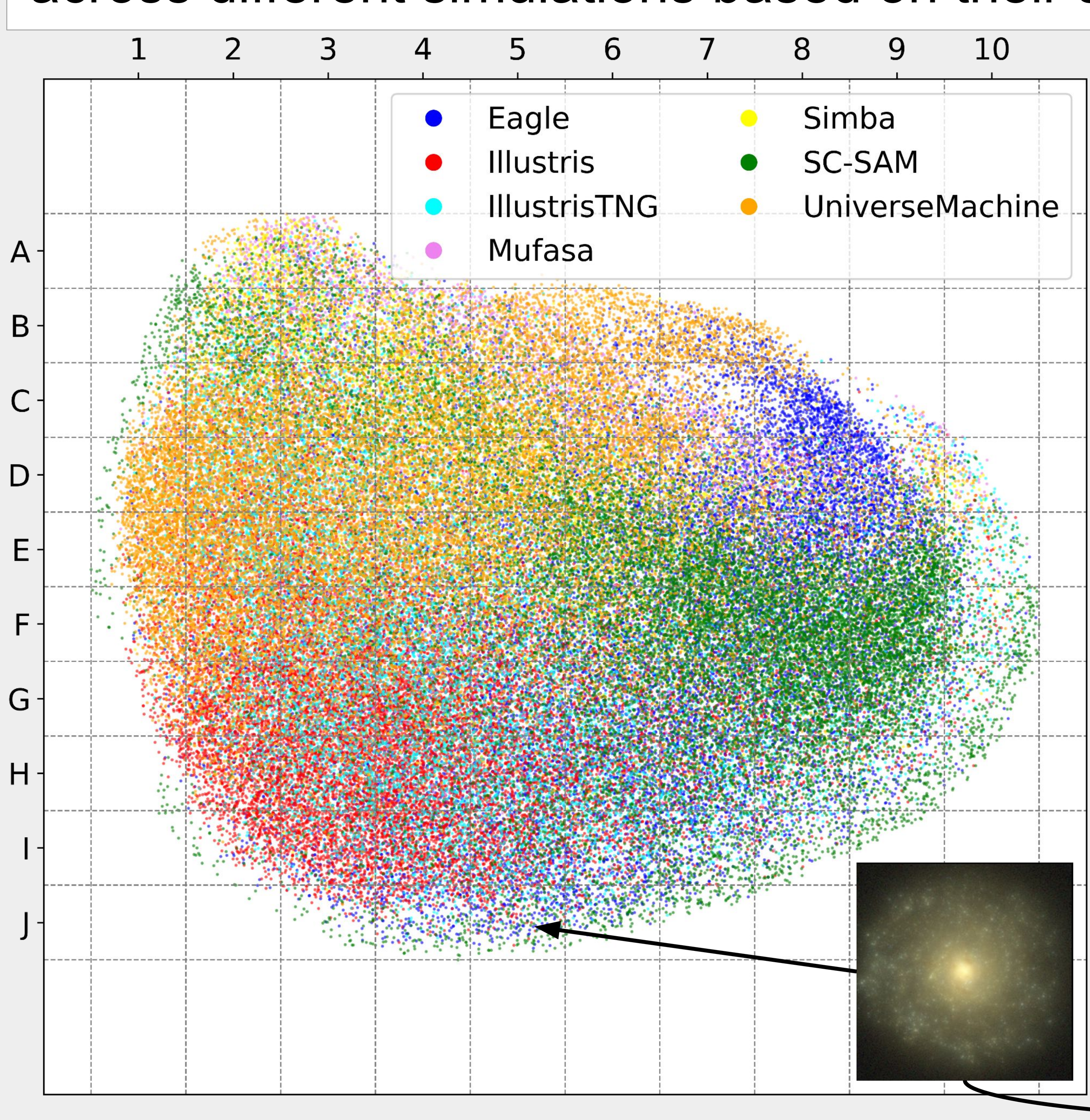

Figure 1: UMAP Projection

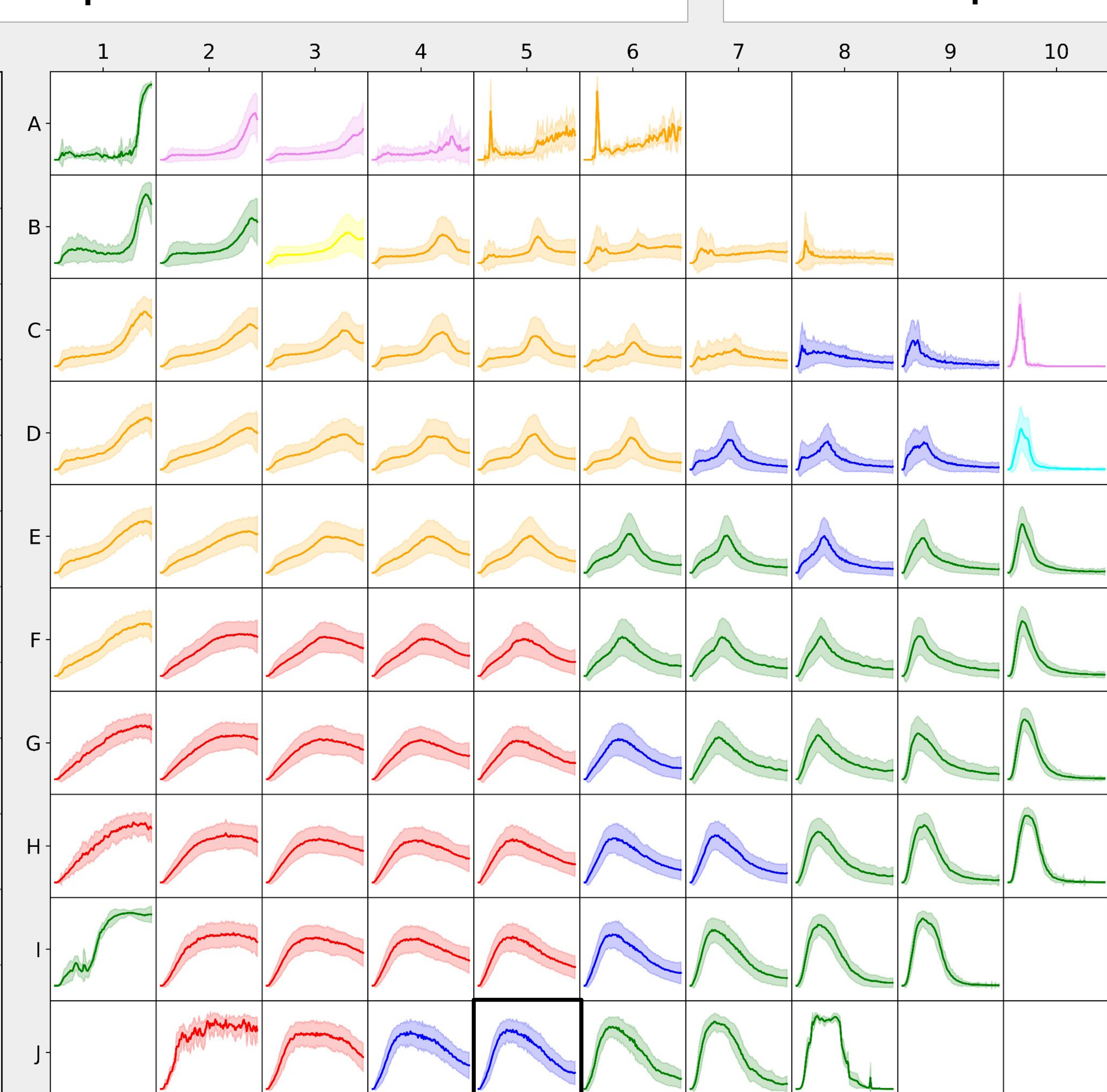

Figure 2: Average SFHs, per grid space.

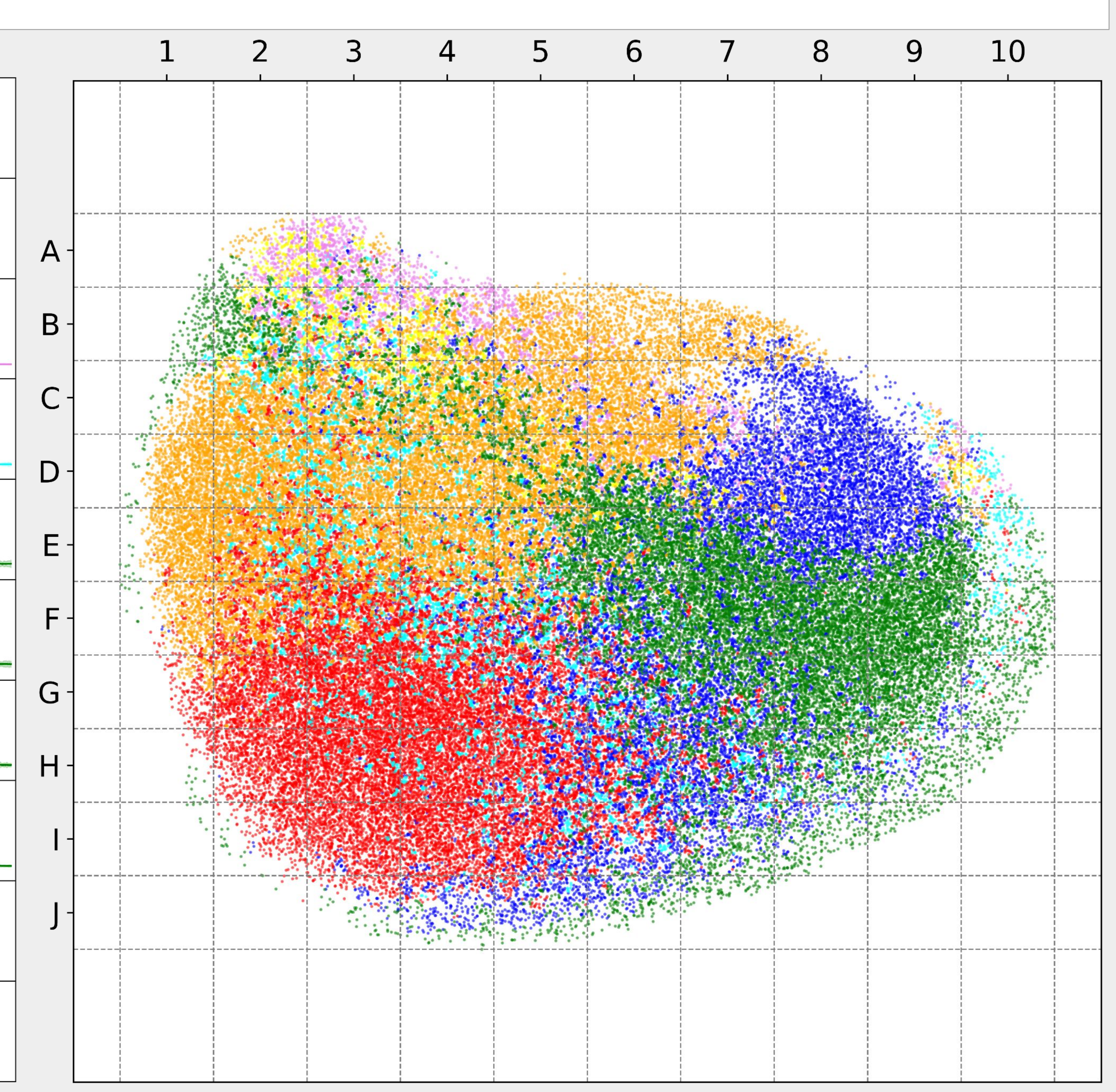

Figure 3: Predicted simulations

3. Results

Figure 1 displays the UMAP projection of SFHs, colour-coded by simulation. The continuous structure suggests the existence of axes in UMAP space defined by physical parameters. The image of a galaxy showcases that each point represents a specific galaxy's SFH [2].

To determine these axes parameters, we divided the plot into a grid, and plotted the average SFH for each gridspace in **Figure 2** in order to analyze changes along the axes. The colour indicates which simulation is most likely to produce this SFH. The highlighted box represents the average SFH of the shown galaxy image.

Figure 3 shows the K-NN prediction for which simulation occupies a given region.

4. Conclusions

Figure 2 shows the **horizontal axis** is determined by when SFR peaks and the **vertical axis** is determined by quenching.

Additionally, Figure 3 shows **distinct regions** where the simulations live in UMAP space.

5. Summary & Next Steps

Figure 2 and 3 provide evidence that **different simulations** tend to **produce different types of SFHs**. Such a distribution in SFHs is likely due to the underlying physics governing each simulation. For example, the SFH in grid space (H,8) are likely the result of blackhole feedback causing an early peak and rapid quench.

Moving forward, our objective is to quantify these differences by using other Machine Learning techniques. Then link them to the diverse underlying physical processes in each simulation, which would provide deeper insights into their distinctive behaviors.

References

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