WHAT DOES MORPHOLOGY TELL US?

EMPLOYING GALAXY MORPHOLOGY TO DECODE GALAXY EVOLUTION

GALAXY EVOLUTION IS THE PROCESS OF HOW GALAXIES CHANGE OVER THEIR LIFETIME, IN TERMS OF BOTH MORPHOLOGY AND STAR FORMATION ACTIVITY. THE CHANGING MORPHOLOGY OF GALAXIES ACROSS VARYING REDSHIFTS PROVIDES INSIGHT INTO THE PROCESSES THAT SHAPE GALAXIES ACROSS COSMIC TIME. COMPARING OBSERVATIONS, WHERE WE ARE UNCERTAIN WHAT IS HAPPENING, WITH SIMULATIONS, WHERE WE HAVE ACCESS TO ALL THINGS WE CANNOT OBSERVE – DARK MATTER, GAS, BLACK HOLES – ALLOWS US TO BETTER UNDERSTAND WHAT IS HAPPENING IN OUR OWN UNIVERSE.

UNIVERSITY OF TORONTO | DUNLAP INSTITUTE for ASTRONOMY & ASTROPHYSICS

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INTRODUCTION

The study of galaxy evolution is a fundamental part of understanding our own galaxy, as well as the universe as a whole. Simulations provide insight into the formation and evolution of galaxies as we know it – but is this comparable to real observations? In this project, we study the morphological characteristics of galaxies in the SIMBA cosmological simulations (Davé et al. 2019) through physical property maps and mock observations. In addition, we will compare these results to the galaxies in the Hubble eXtreme Deep Field (XDF) (Illingworth et al. 2013), which contain some of the Hubble Space Telescope's (HST) deepest resolved imaging to date. We aim to bridge the two current gaps in this field of research: (i) the comparison of simulations to real observations at high redshifts, and (ii) the use of mock observations to better understand real observations.

METHODOLOGY

COMPARING MOCK OBSERVATIONS AND SIMULATIONS

Measurements of the half-light radii for the mock observations, via `STATMORPH` (Rodriguez-Gomez et al. 2019), and simulations, via aperture photometry through `ASTROPY`, were compared for a galaxy at redshift z=2, as observed through 9 HST filters.

COMPARING MASS- AND LIGHT-WEIGHTED MORPHOLOGIES

Using the stellar half-mass radius as measured from the simulated mass maps of the z=2 galaxy, the ratio of half mass-to-light was derived at all 9 wavelengths

PIPELINE DEVELOPMENT

Analyze Simulations
- Measure half-light and half-mass radii for simulated galaxies

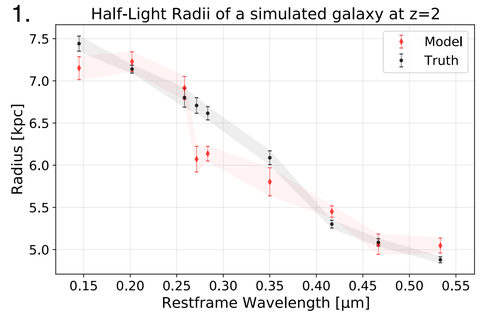
Analyze Mock Observations
- Measure half-light radii for mock observations

Compare Measurements
- Compare the half-light radii of simulations and mock observations
- Find and compare half mass-to-light radii ratios

Analyze Real Observations
- Repeat the half-light radii measurements for the 9000+ galaxies in the XDF
- Repeat the comparisons of half mass-to-light radii

COMPARE MEASUREMENTS: ANALYSIS PIPELINE APPLIED TO A SINGLE GALAXY

1.



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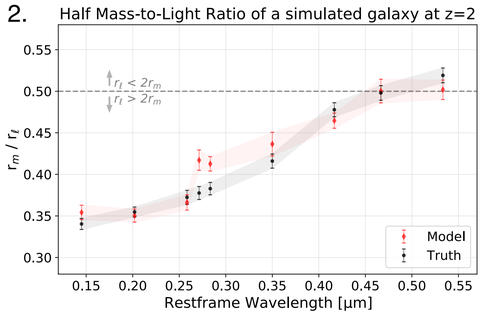
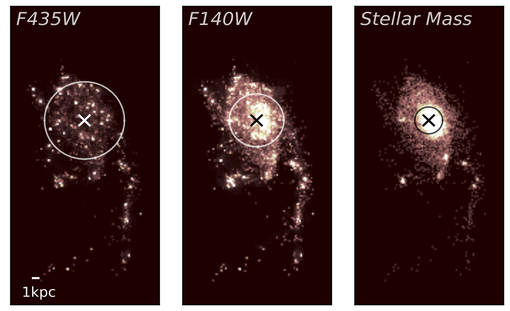


1. The half-light radii measurements of a galaxy at redshift z=2 through simulations (**Truth**) and mock observations (**Model**) from the SIMBA suite of cosmological simulations at a selection of 9 HST filters: F435W (0.145 μm), F606W (0.202 μm), F775W (0.258 μm), F814W (0.271 μm), F850LP (0.283 μm), F105W (0.350 μm), F125W (0.417 μm), F140W (0.467 μm), F160W (0.533 μm). Truth values are measured via aperture photometry and model values are measured via the Python package `STATMORPH` (Rodriguez-Gomez et al. 2019).
2. The half-mass-to-half-light radii relation for a galaxy at z=2. The stellar half-mass radii are measured via aperture photometry for the simulated mass maps. The ratio of the mass-to-light radii is found using the measurements in (1).

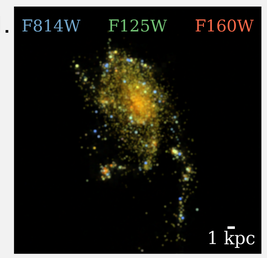
3.



3. SIMBA simulation of a galaxy at redshift z=2 through the F435W and F140W filters and its stellar mass map. The circular aperture in which half the flux or mass resides (half-light and half-mass radii) is overlain as the white and black rings, respectively, and the projected center of the galaxy is indicated with the marker 'x'. The half radii of the galaxy at the two filters and of its stellar mass are:
$r_{L,F435W}$ = 7.442 ± 0.089 kpc,
$r_{L,F140W}$ = 5.086 ± 0.043 kpc,
r_{SM} = 2.533 ± 0.039 kpc.
The half-mass radius is noticeably smaller than the half-light radii.

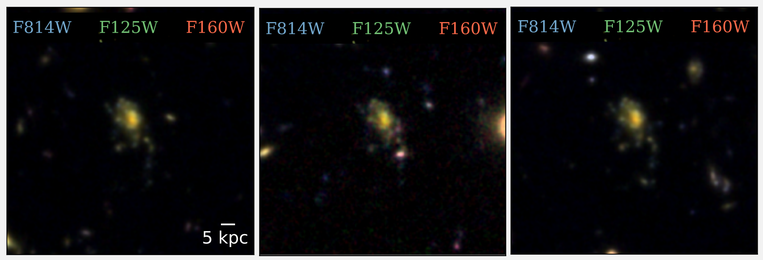
ANALYZE SIMULATIONS AND MOCK OBSERVATIONS

1.



1. SIMBA simulated galaxy at z=2, through 3 HST filters: F814W, F125W, F160W.
Credit: Dr. Lamiya Mowla.

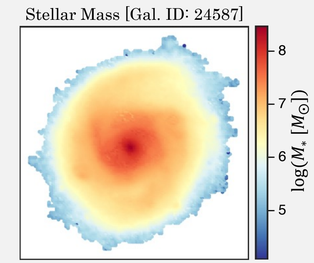
2.



2. Mock galaxy observations, created using Powderday radiative transfer package (Narayanan et al. 2020), at z=2 in 3 different XDF backgrounds, through 3 HST filters: F814W, F125W, F160W.
Credit: Dr. Lamiya Mowla.

NEXT STEPS: ANALYZE REAL OBSERVATIONS

The next steps of this research entail applying the pipeline to all 9000+ galaxies in the XDF. This will yield the comparison of galaxy morphology from real observations to that of mock observations and simulations across high redshifts, allowing for the mapping of galaxy evolution through the lens of galaxy morphology. Furthermore, comparing the mock and real observations will reveal any discrepancies in the simulations, that will thus improve our understanding of the physical processes that drive galaxy evolution and inform the next generation of simulations.



Stellar mass map of galaxy 24587 in XDF. Credit: Dr. Kartheik Iyer.