Structural Evolution of Galaxies from Cosmic Assembly Near-infrared Deep Extragalactic Legacy Survey and Cosmological Simulations

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Introduction

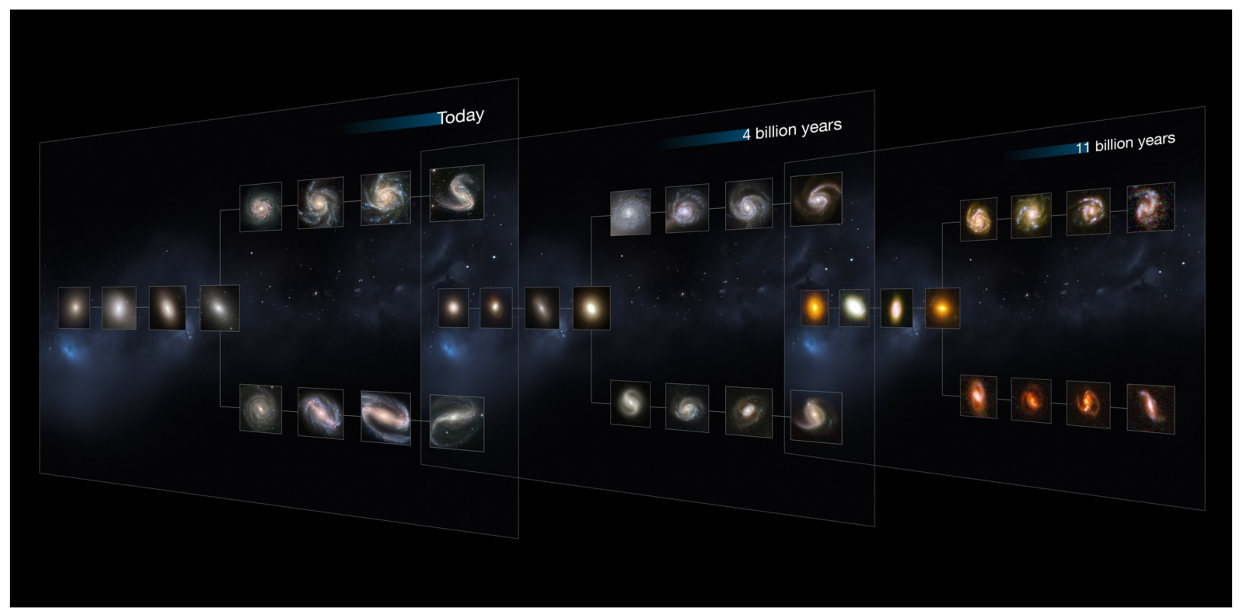


FIGURE 1: Hubble Sequence; dividing galaxies into groups based on visual appearance. [1]

- To understand structural and morphological evolution of galaxies, we need to look far back in time and compare the differences between older and younger galaxies.
- Early star forming galaxies have distorted, irregular appearance while present day star forming galaxies tend to be flat disks and have spiral arms.

I. Observation: CANDELS

- CANDLES is the largest project in history of Hubble Space Telescope with 902 assigned orbits of observing time. Equivalent to observing 4 months consecutively, it captures images of galaxies far in deep space at high redshifts as well as those in the local universe.
- In astronomy, redshift is used to determine how far objects are in the skies. By measuring the wavelength of emitted light from stars and galaxies, astronomer can determine their ages, speeds, and distances away from us. The higher the redshift, the further away they are from us.
- From observation, galaxies from early epochs were smaller than present day. They were bluer than older galaxies as the stars were younger and hotter than older galaxies, which tend to be redder.

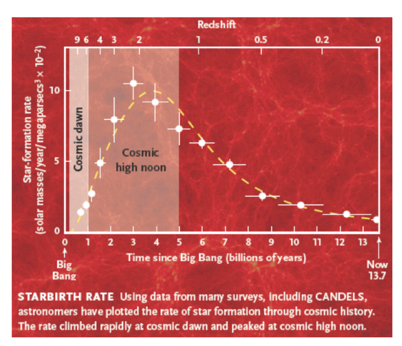


FIGURE 2: Relationship between redshift and age of galaxies. [2]

II. Cosmological Simulations: With Radiative Pressure (RP) Feedback

- The primary effect of RP feedback is to suppress star formation.
- In galaxy simulations, those that were simulated without the mechanism of RP feedback tend to overproduce stars, which does not match well with observations. And those that were simulated using RP feedback produced less stars, by about a factor of 2 at all redshifts.

III. The Project: Observations vs. Simulations

- The main motivation for this project is to systematically compare projected axis ratio distributions under random viewing angles in simulated galaxies to those of the observed galaxies which have unknown viewing angles. In particular, we focus on galaxies in the range of redshift 1 to 3 in both simulation and observation.
- In both observations and simulations, wealth of data allow us to do statistical studies. By looking at how the distributions change over cosmic time, we can statistically determine how the shape and formation of galaxies evolve.
- Study done previously by van der Wel et al. have shown that observed galaxies in the lower-mass range from CANDELS are elongated, rather than disk-like or spheroidal, and the axial ratio is skewed for higher redshift galaxies.
- To investigate this observation, we obtain the axis ratio distributions from simulated galaxies as a function of redshift, stellar mass, size, and Sersic index with and without RP feedback and compare to those found by van der Wel et al.
- We suspect that simulated galaxies with RP feedback represent observation more correctly, thus we will also compare the axis ratio distributions of simulated galaxies with and without RP feedback to see how RP feedback affect each of the parameters.

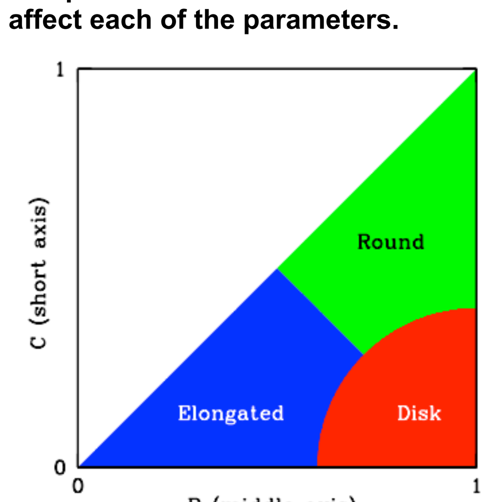


FIGURE 3: Model shape parameter defined by colour [3]

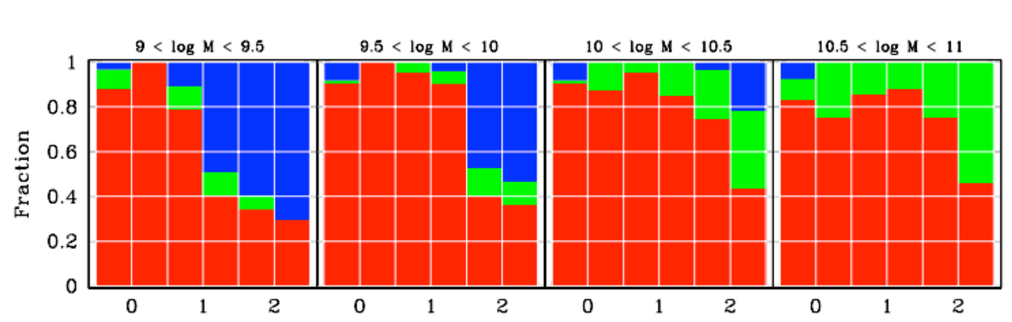


FIGURE 4: van der Wel *et. al* have shown that lower-mass galaxies at higher redshift are more elongated [3]

Methods

I. CANDELization

- High resolution images of simulated galaxies need to go through a process called CANDELization before the analysis. To CANDELized an image, the Sunrise radiative transfer code is applied, as well as the Point Spread Function. Noise is also added and the end result is an image with the same resolution to those of the observed galaxies from Hubble Space Telescope.
- It is necessary for simulated images to be CANDELized since in reality we do not observe distant galaxies with high resolution.

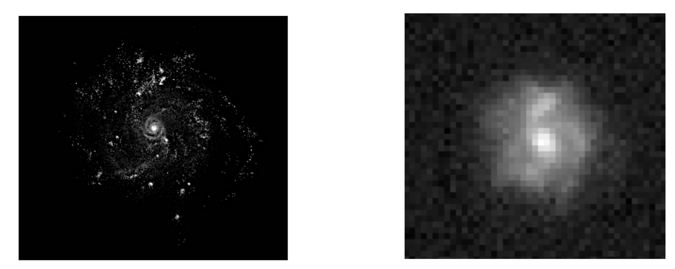
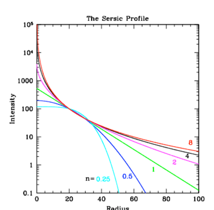


FIGURE 5: Before (left) and after (right) CANDELization

II. GALFIT

- After CANDELizing images, GALFIT, a data analysis algorithm that fits 2D analytic functions to galaxies, is used for analysis. Each function in GALFIT corresponds to a component that creates a model for image fitting. For this project we have chosen to use a single component fit.
- Output from GALFIT contains best fit parameters which can be used for statistical studies. These include the Sersic index, axis ratio, and effective radius.
- The Sersic index describes radial distribution of light; the effective radius is defined as containing half of the total luminosity from the galaxy, and the axis ratio is simply the minor axis divided by major axis.

FIGURE6: Elliptical like structure corresponds to a Sersic index value of n=4. Spiral, bulgeless disk like structure corresponds to a Sersic index value of n=1. [4]



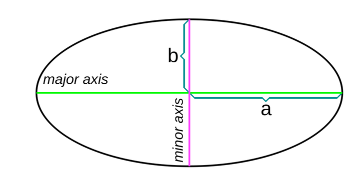
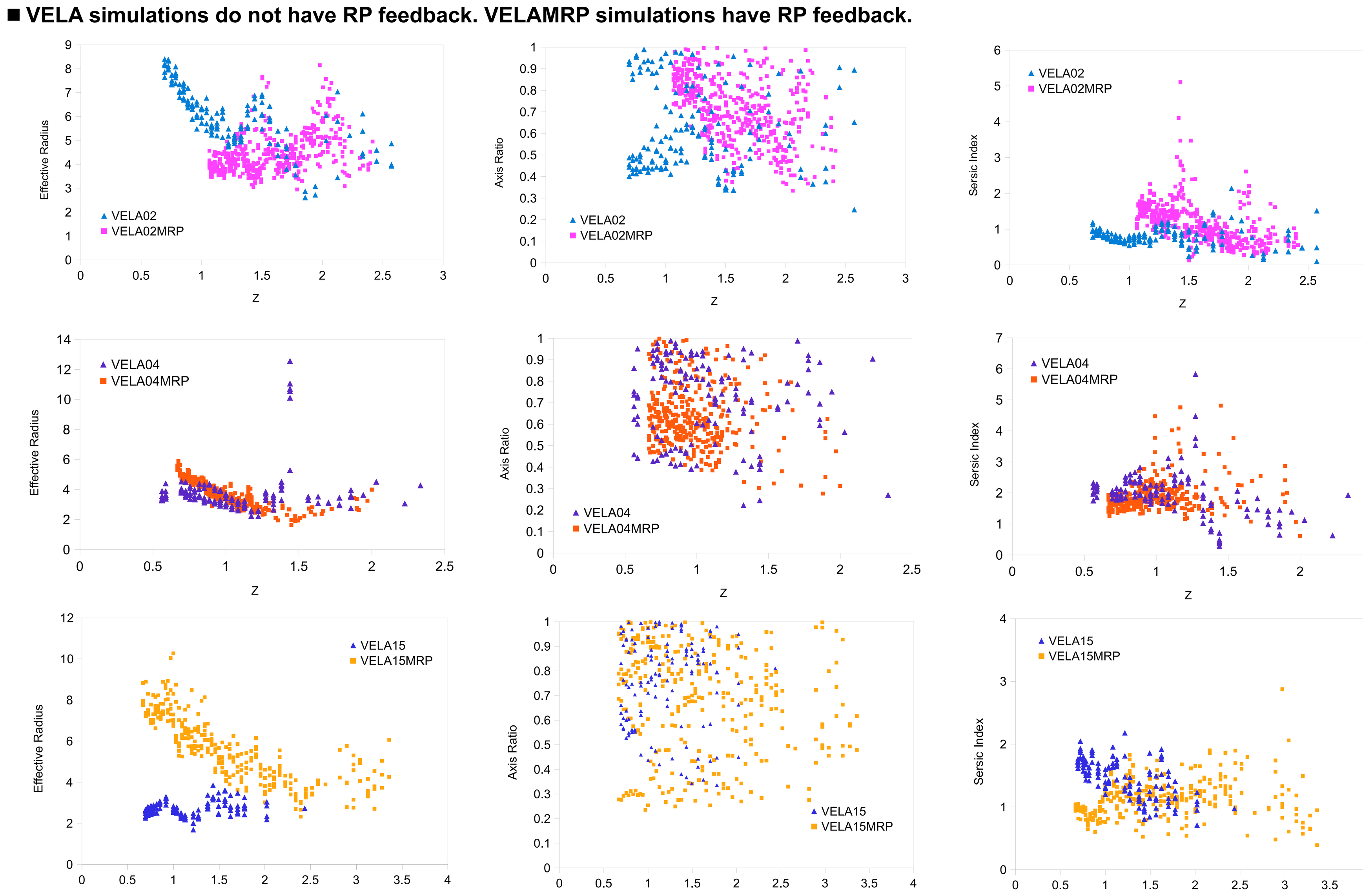


FIGURE7: Axis ratio=b/a. [5]

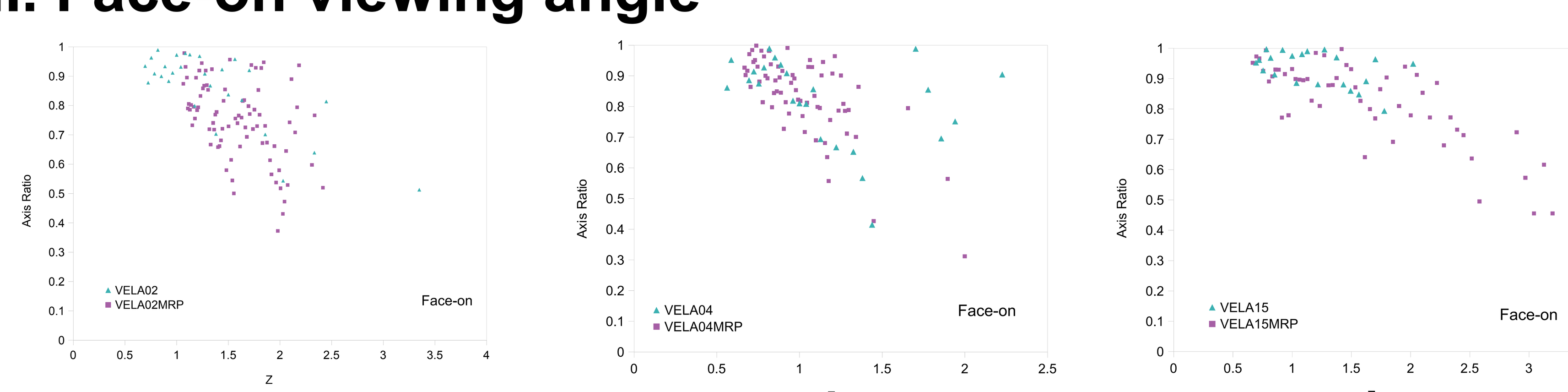
Results

I. Comparing Simulation with and without RF feedback

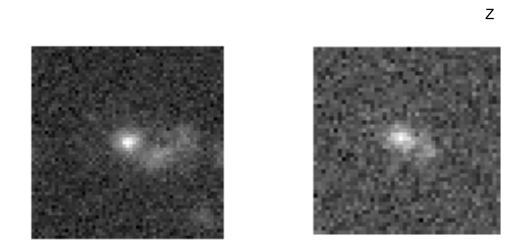
- VELA simulations do not have RP feedback. VELAMRP simulations have RP feedback.



II. Face-on viewing angle



- We have chosen images of galaxies with face-on orientation which would yield a higher axis ratio if they are disk-like or spherical, and a lower axis ratio if they are elongated.
- Images of face-on galaxies where the axis ratios were measured to be the lowest.



VELA04 VELA04MRP

Conclusion

- For the effective radius, each of the three pairs of simulations (with and without radiative pressure feedback) provides different indications as to how the size evolves over time.
- The axis ratios cover a wide range in both cases and we cannot determine from current results whether simulations with radiative pressure feedback would change the morphology of galaxies.
- The Sersic indexes ...
- Axis ratios decrease towards higher redshifts.
- More analysis between simulations with and without RP are needed in order to determine how much RF changes the structure and morphology of galaxies.

Future Work

- Determine whether simulations with RF is a more accurate representation than those without RF by comparing findings to the axis ratio distributions obtained previously by van der Wel et al.
- To obtain axis ratio as a function of stellar mass and redshift of simulated galaxies, in those that have been analyzed for this project as well as other simulations.
- Galaxies used for this project were selected based on acceptable uncertainties from GALFIT. We will compare those uncertainties for the face-on and edge-on galaxies to determine whether it has an effect on our previous selections.

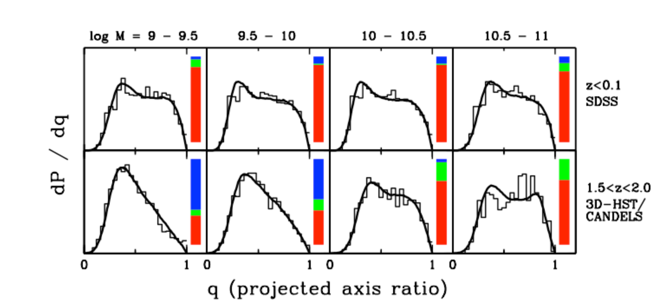


FIGURE 8: Axis ratio distributions of star forming galaxies from CANDELS. [3]

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Reference

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