Analogues of the Milky Way in Cosmological Simulations

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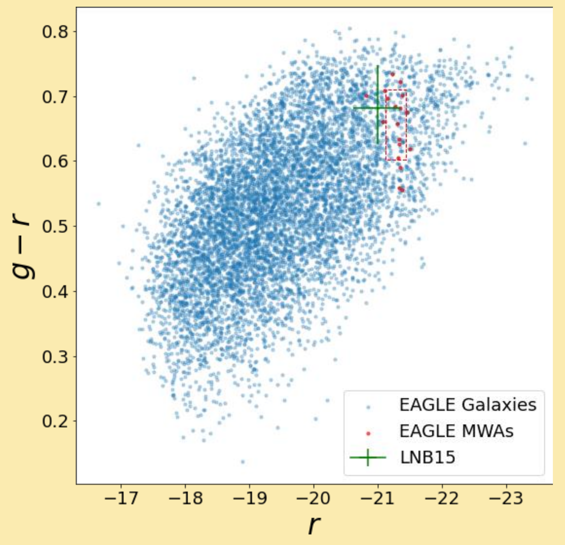
Introduction

The Milky Way (MW) is the galaxy we can study in the greatest detail.

We wish to study galaxies similar to our MW, "Milky Way Analogues" (MWAs), which can help us make predictions for properties that can't be directly measured, and improve our understanding of the MW in an extragalactic context.

How typical is the MW amongst its analogues, and relative to all other galaxies?



Colour-magnitude diagram, including dust, showing MWAs (red) against all other galaxies (blue) and value for the MW [1] (green).

Methods

The total data sample comes from the EAGLE suite of cosmological simulations. After controlling for mass, we use two methods to select our analogues:

1) Selection of galaxies within 1σ of the observed value of stellar mass and SFR for the MW at $z = 0$
2) Apply a "*Milky-Way-ness*" *parameter*, γ, to the data, determined by stellar mass and SFR at $z = 0$

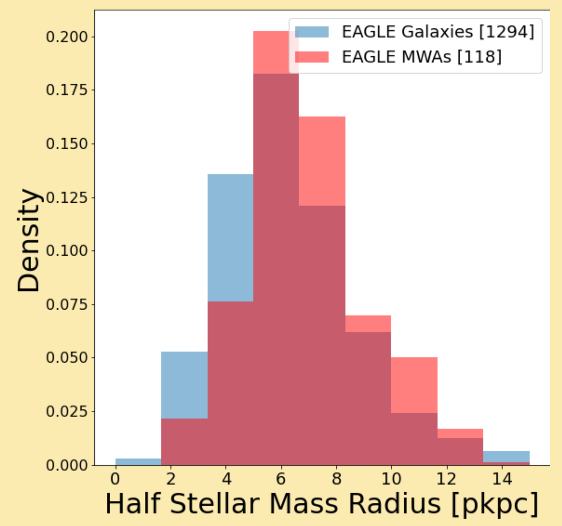
The values used to select MWAs and for comparison to the MW are $M_\star = 6.08 \pm 1.14 \times 10^{10} \mathrm{M}_\odot$, and $\dot{M}_\star = 1.65 \pm 0.3 \mathrm{M}_\odot \mathrm{yr}^{-1}$ [1].

Milky Way Analogues at $z = 0$

From the colour-magnitude diagram (left), we can see that the simulations predict well for the colour of the MW and that the MWAs are redder than most other galaxies, indicating that the MW and its analogues may be red spirals (see [1]).

The density of the half stellar mass radius (right) of our analogues against the mass-controlled sample shows that on average, the MWAs are slightly more massive than the other galaxies in the simulation.

When varying B/T ratio against multiple other properties, we found that the B/T ratio does not significantly affect the "Milky-Way-ness" of our galaxies (see [2]).

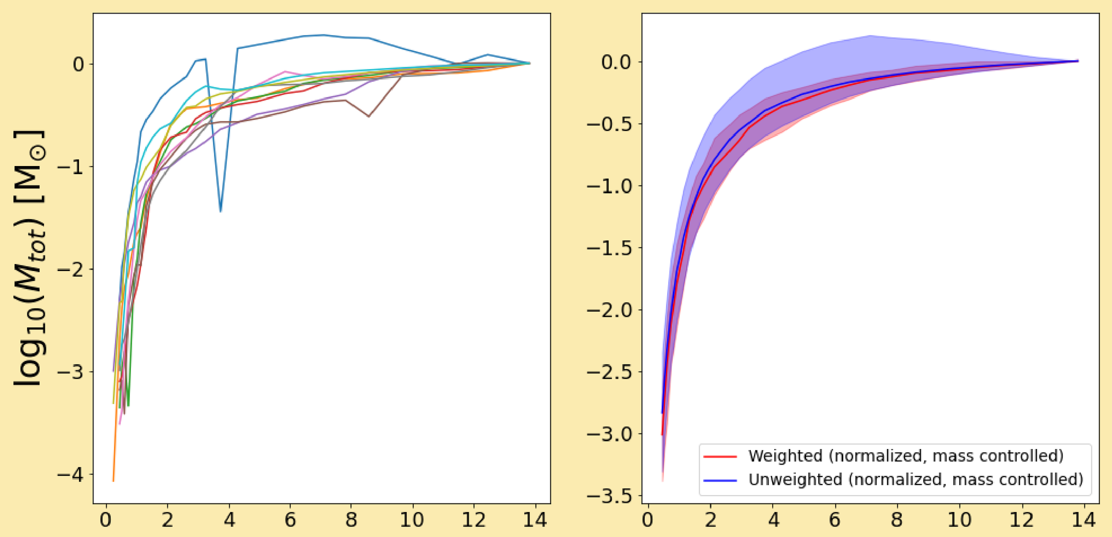


Histogram showing the half stellar mass radius of the MWAs (red) overlaying all other galaxies (blue).

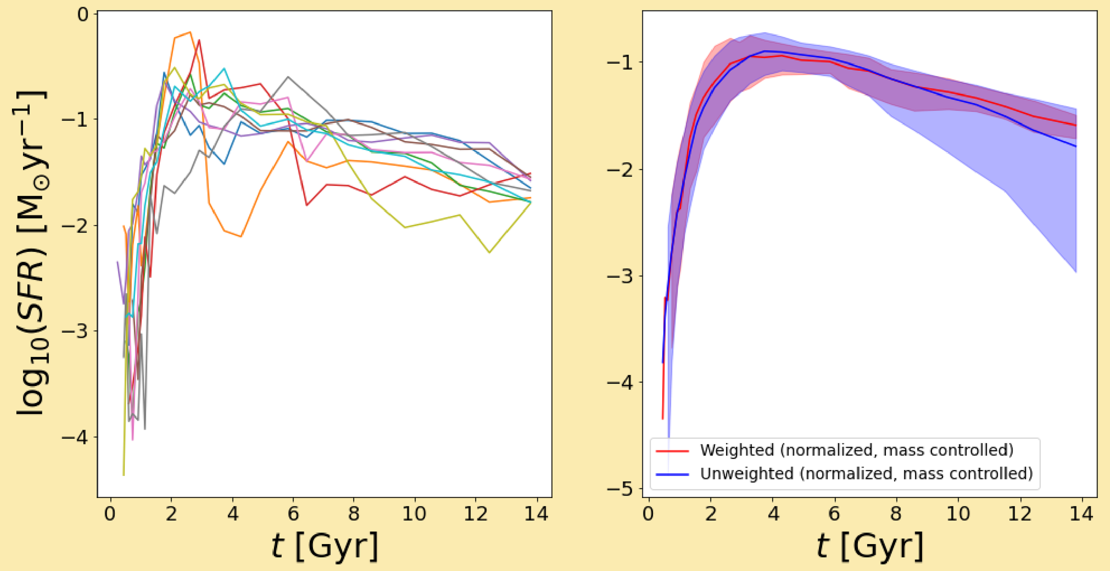
Milky Way Analogues over Time

The assembly (right, top) and star forming (right, bottom) histories of the top 10 MWAs (images along bottom panel) were compared both to the remaining MWAs and to the mass-controlled sample. Both top 10 histories follow the overall trend of the MWAs, with a rapid increase in mass collection and star formation until about 2-3 Gyrs, followed by a slow decline, with sometimes a second star forming burst at around 6 Gyrs.

Compared to the other galaxies in the simulation, the MWAs appear to have assembled their mass more slowly and to have a less steep drop-off of star formation.



Assembly histories for top 10 MWAs (left) and for all mass-controlled galaxies weighted by the Milky-Way-ness parameter (red) and unweighted (blue), normalized according to final M_{tot}.



Star forming histories for top 10 MWAs (left) and for all mass-controlled galaxies weighted by the Milky-Way-ness parameter (red) and unweighted (blue), normalized according to total SFR.

Discussion & Next Steps

Although there has been recent interest in MWAs in observational studies, not much research has yet been done regarding MWAs in simulations. Through the study of the simulations, we were able to analyze multiple properties of our MWAs and compare their values to the known values for the MW.

To continue this research, more MWA properties should be studied and compared against the greater sample and observational results, both at higher redshifts and at present day. The simulations should also be examined in greater detail on a particle-by-particle basis. The study should also be extended to analogues of other galaxies within the reach of observation, and even to analogues of the Local Group.

References

[1] Timothy C. Licquia, J. Newman, & J. Brinchmann (2015). Unveiling the Milky Way: A New Technique for Determining the Optical Color and Luminosity of our Galaxy. *arXiv: Astrophysics of Galaxies*.
[2] Catherine E. Fielder, Jeffrey A. Newman, Brett H. Andrews, Gail Zasowski, Nicholas F. Boardman, Tim Licquia, Karen L. Masters, & Samir Salim. (2021). Constraining the Milky Way's Ultraviolet to Infrared SED with Gaussian Process Regression.

Top 10 Milky Way Analogues

#1

$\gamma = 0.9815$

#2

$\gamma = 0.9770$

#3

$\gamma = 0.9649$

#4

$\gamma = 0.9126$

#5

$\gamma = 0.9121$

#6

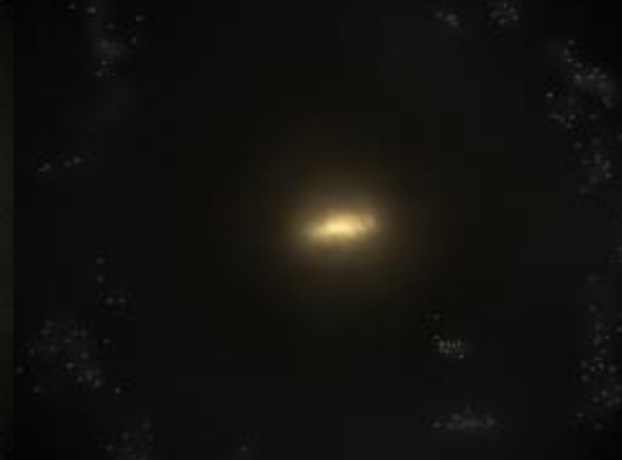
$\gamma = 0.8288$

#7

$\gamma = 0.8115$

#8

$\gamma = 0.8084$

#9

$\gamma = 0.8083$

#10

$\gamma = 0.8066$