Testing the Star-Formation Histories of Massive Galaxies in the UniverseMachine Model at z~0.8 with the LEGA-C Survey

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Question 1: How well do Formation Timescales Agree?

We compare star formation histories of massive ($10.5 < \log(M_*/M_\odot) < 12$) galaxies in the UniverseMachine model (Behroozi et al. 2019) to those measured from the Large Early Galaxy Astrophysics Census (LEGA-C) Spectroscopic Survey (Van der Wel et al. 2021, 2016).

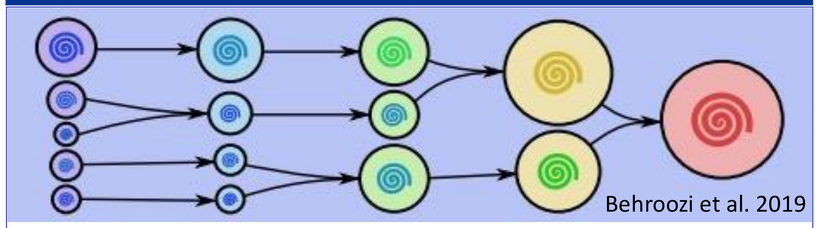
The empirical work leverages Bayesian stellar population synthesis (SPS) modeling of a mass-complete sample of ~3000 galaxies LEGA-C.

Following the LEGA-C study (Kaushal et al. 2023), we investigate how 50% (t_{50}) and 90% (t_{90}) formation timescales depend on total stellar mass.

Question 2: How Common is Rejuvenation in the Model and Data?

We explore the importance of rejuvenation amongst massive galaxies, defined as an episode of star-formation after a period of quiescence. Although this phenomenon is rare at this epoch (~1%-4% of massive galaxies experience a recent rejuvenation event within the last ~Gyr), we find obvious examples in both LEGA-C and the UniverseMachine.

The UniverseMachine Model



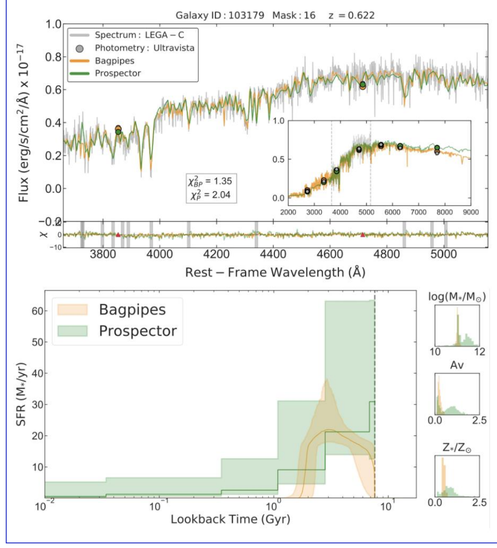
The UniverseMachine is a highly sophisticated galaxy-halo connection model that tracks galaxy demographics across cosmic time.

The model is physically motivated by simulations and is tuned to accurately reproduce a wide variety of observed galaxy populations.

A primary feature of the UniverseMachine model is that the growth of each galaxy is connected to its dark matter halo assembly.

Observational Measures of Star-Formation Histories

Kaushal et al. 2023



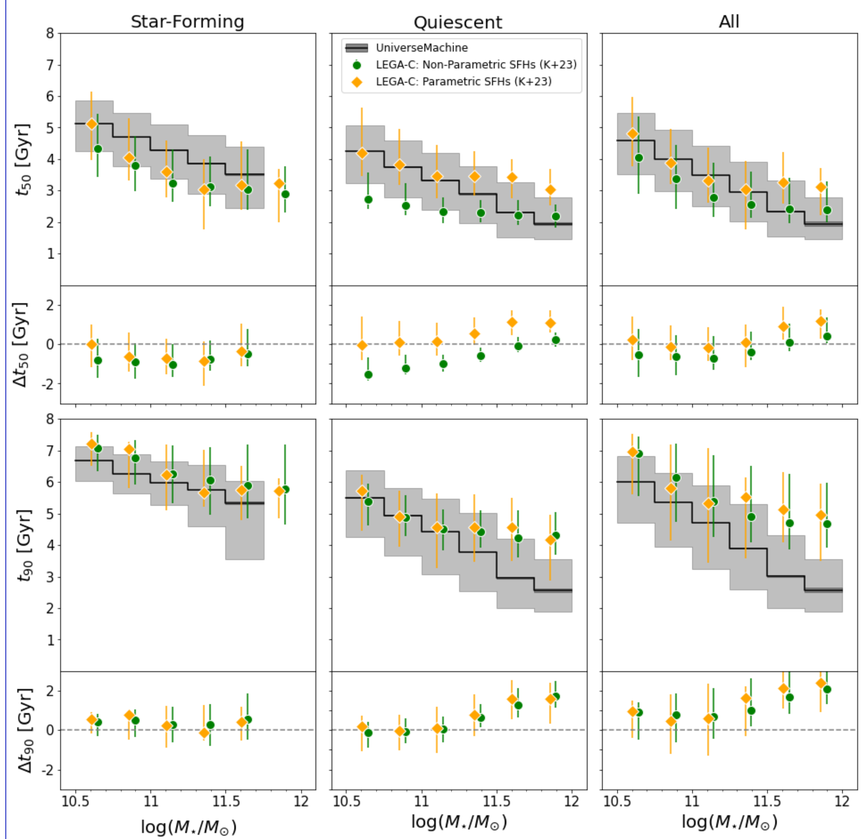
LEGA-C is a high resolution, 130-night spectroscopic survey of ~3000 galaxies from when universe was 6 billion years old.

These data allow reconstruction of star formation histories into the early universe via SPS modeling.

Bagpipes (parametric) and Prospector (non-parametric) are used for modeling galaxy data, extracting properties like SFH from spectral and photometric information.

Testing Average Star-Formation Histories in the UniverseMachine Model

Steel et al. 2024



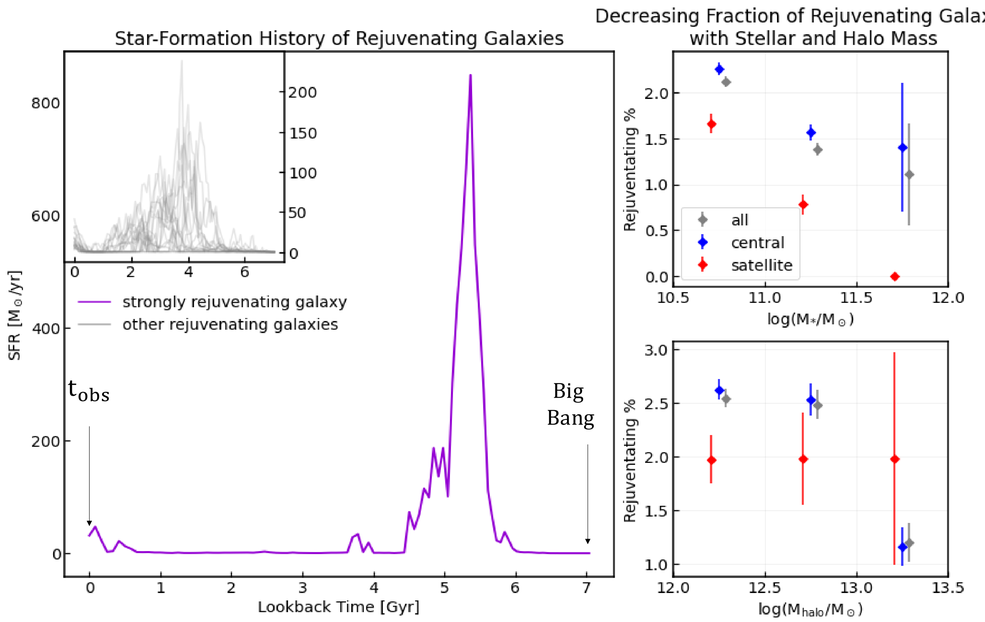
t_{50} and t_{90} formation times (forward in time) for star-forming (left), quenched (middle), and all galaxies (right). Black lines represent UniverseMachine medians with dark gray errors and light gray 16-84% population scatter. Colored points depict LEGA-C population trends (median and scatter). Residuals between the UniverseMachine and LEGA-C medians are shown below.

Generally, star-forming UniverseMachine predictions agree well at all masses and for low-mass quiescent populations.

For quiescents, the observed age-mass correlation is much stronger in the UniverseMachine than in observations, especially at the high-mass end.

This points to the scope of improvement in recovering early stellar mass growth of quiescent galaxies from SPS modeling as well as late time assembly of massive galaxies in the UniverseMachine at this epoch

Rejuvenation in the UniverseMachine Model



The left panel shows the UniverseMachine star formation histories for a strongly rejuvenating galaxy (purple) and 20 random rejuvenating galaxies (gray). The right panels show the decreasing fraction of rejuvenating galaxies as a function of stellar mass (top) and halo mass (bottom) for all (gray), central (blue), and satellite (red) galaxies.

We define rejuvenating galaxies to be those that satisfy the following condition:

$$(sSFR_{0-100} > 1e-10) + (sSFR_{100-1000} < 5e-11)$$

The rejuvenation fraction decreases with increasing stellar mass in both, but not so sharply with halo mass and central galaxies are more likely to resurrect in the UniverseMachine model than satellites.