on the star formation histories of distant galaxies

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Galaxy Formation, Durham University
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credit: Volker Springel et al.
what are the star formation histories of galaxies?

\[ \text{SFR} \sim M^* \]
high duty cycle

\[ \frac{d(SFR)}{dt} > 0 \]

star formation and mass growth in distant galaxies

do high redshift galaxies have star formation rates that rise with time?
Empirical constraints on star-formation histories

- Trace mass growth by comparing massive high-z galaxies at constant number density:
  - Track descendants and progenitors in galaxies in a relatively robust way (van Dokkum et al. 2010; similar to abundance matching Conroy & Weschler 2009)
  - SFRs of galaxies with $n=2 \times 10^{-4} \text{ Mpc}^{-3}$ increase from $z=8$ to $z=3$.
  - Galaxies with this number density have $M=1.5 \times 10^{11} \text{ M}_\odot$ at $z=0$.
  - Star formation history of these galaxies matches stellar mass growth.
track the descendants of distant galaxies by comparing at constant number density

Mass Functions and Halo Merger Trees from Millennium (Springel+05)
track the descendants of distant galaxies by comparing at constant number density

Mass Functions and Halo Merger Trees from Millennium (Springel+05)

descendants of $z=7.5$ galaxies
track the descendants of distant galaxies by comparing at constant number density.

Completeness = Fraction of selected galaxies with a progenitor selected at $z=7.5$ (descendant selected at $z=3.0$).

Similar results from simulations of the effects of mergers on mass functions (van Dokkum et al. 2010).

Integrated UV Luminosity Functions (Reddy & Steidel 2008; Bouwens et al. 2007, 2010).

Galaxy Populations selected at constant luminosity (or mass) correspond to very different number densities at different redshifts.

\[ n = 2 \times 10^{-4} \text{ Mpc}^{-3} \]

track the descendants of distant galaxies by comparing at constant number density.
SFH of galaxies with $n(>L_{UV}) = 2 \times 10^{-4}$ Mpc$^{-3}$

Daddi et al. 2005

Log star formation rate [solar masses per year]

Star formation histories of distant galaxies

Redshift

SFR $\sim (t/\tau)^\alpha$


Time since $z=11$ [Log yr]
galaxies in cosmological simulations show rising star formation rates (Finlator, Davé, Papovich & Hernquist 2006)
Mass growth of galaxies

Masses of galaxies with $n(>L_{\text{UV}}) = 2 \times 10^{-4} \text{ Mpc}^{-3}$ (Shapley et al. 2005; Gonzalez et al. 2010; Finkelstein et al. 2010)

Mass Growth of Galaxies

- UV-selected galaxies

Papovich et al. 2011
stellar mass growth of distant galaxies

Mass Growth of Galaxies

- UV-selected galaxies
- Stellar Mass inferred from SFR(z)

Papovich et al. 2011
Masses of galaxies with $n(>M) = 2 \times 10^{-4}$ Mpc$^{-3}$ from stellar-mass functions (Marchesini et al. 2009)

Mass Growth of Galaxies

Papovich et al. 2011

Stellar mass growth of distant galaxies

Mass Growth of Galaxies

- UV-selected galaxies
- Mass-selected galaxies

Stellar Mass inferred from SFR(z)
empirical constraints on star-formation histories

- Trace mass growth by comparing galaxies at constant number density:
  - Empirically, galaxies have average star-formation rates that increase from $z=8$ to $z=3$.
  - Basic agreement between empirical and theoretical SFHs.
  - Star formation History of these galaxies matches stellar mass growth:
    - if near unity “Duty cycle” of Star-formation, then high-mass end of IMF approximately Salpeter/Chabrier-like.
I. Period from $z \sim 8$ to 3 characterized by increasing SFRs.
average star formation rate per unit stellar mass

star formation histories of distant galaxies

average rate for all galaxies

average star formation rate in most massive galaxies $M > 10^{11} M_\odot$

Papovich et al. 2006
I. Period from \( z \approx 8 \) to 3 characterized by increasing SFRs.

II. Period from \( z \approx 3 \) to 0 characterized with declining SFRs.

star formation histories of distant galaxies

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I. Period from \( z \approx 8 \) to 3 characterized by increasing SFRs.
Summary

• Trace star formation histories and mass growth in galaxies empirically by comparing galaxies at constant number density:
  - empirically, galaxies have average star-formation rates that increase from $z=8$ to $z=3$. Basic agreement between empirical and theoretical SFHs.
  - Star formation History of these galaxies matches stellar mass growth:
    ▶ if near unity “Duty cycle” of Star-formation, then high-mass end of IMF approximately Salpeter/Chabrier-like.
  - Distinct Periods of Star Formation for Galaxies:
    ▶ empirically rising SFRs from $z=8$ to $3$; declining SFRs from $z=3$ to $0$.

• Prediction: Star-formation and Mass growth predict Gas masses must Increase and that the Gas Accretion Rate tracks SFR.

• Questions: How and when do galaxies acquire their gas?
  - How well do we know the duty cycles of distant star-forming galaxies?
  - What causes galaxies to stop forming stars?