The significance of galaxy mergers as a function of galaxy and halo mass

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• How massive galaxies increase their mass

• Clues from observations

High disturbed fraction in red early types in the local Universe due to recent mergers (Van Dokkum 2005; Sheen et al. 2012)

High pair fraction of massive (log M/M>11) red spheroidal at z~1 (Bundy et al. 2009)

Downsizing trends (e.g. Cowie et al. 1996; Glazebrook et al. 2004)

• Theoretical view

Stellar component fraction assembled via mergers (Oser et al. 2010; Lackner et al. 2012; Lee & Yi 2013)

Formation history of massive galaxies (Kauffmann 1996; Baugh et al. 1996; De Lucia et al. 2006; De Lucia & Blaizot 2007; Almeida et al. 2008)

Downsizing trend in SAMs (e.g. De Lucia et al. 2006; Lee & Yi 2013)
• Key questions
  • How does galaxy stellar mass grow as a function of halo and galaxy mass?
  • How many stars are coming from outside via mergers?
  • When is merger dominant?

• Semi-analytic model for galaxy formation and evolution
  • The simplest approach to investigate massive galaxy formation history
• ySAM (Lee & Yi 2013)
• Fully utilize N-body simulations and up-to-date physical prescriptions
• Available volumes
• $1024^3 (100\text{Mpc/h})^3, (200\text{Mpc/h})^3$
• In this study, we use $(200\text{Mpc/h})^3$ volume (min $M_{200} \sim 10^{10.5} M_\odot$)
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**Star formation density evolution**

![Star formation density evolution graph](image)

**MBH-M_{bulge} relation**

![MBH-M_{bulge} relation graph](image)

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Galaxy evolution in the hierarchical universe
• Mass growth history of direct progenitors

z=4

z=3

z=2

z=1

z=0

Courtesy: Sukyoung Yi
• Mass growth history of direct progenitors

Upsizing trend in direct progenitors

Centrals Only

- $11.5 < \log M_*/M_\odot < 12.0$ (z=0)
- $11.0 < \log M_*/M_\odot < 11.5$ (z=0)
- $10.5 < \log M_*/M_\odot < 11.0$ (z=0)
• Mass growth history of all progenitors
• Mass growth history of all progenitors

![Graph showing mass growth history](image)

**Clear downsizing trend in all progenitors**

- Redshift
- Log $M_*/M_\odot$ range:
  - $11.5 < \log M_*/M_\odot < 12.0$ (z=0)
  - $11.0 < \log M_*/M_\odot < 11.5$ (z=0)
  - $10.5 < \log M_*/M_\odot < 11.0$ (z=0)

Centrals Only

- Centrals with $\sim 10L^*$
- Centrals with $\sim 3L^*$
- Centrals with $\sim L^*$
• How does mass weighted age evolve according to halo and galaxy mass?

Older with increasing halo mass

Centrals Only

MW

M87

\[ P(M^*_|M_{200}) < 3\sigma \]
- Galaxy stellar age - model & empirical data

![Graph showing B-band luminosity weighted age and age estimated from Hβ absorption lines.](image)

**B-band luminosity weighted age**

**Age estimated from Hβ absorption lines**

**Model with errors**

**Obs**

**Preliminary!**

- Centrals Only

- MW

- M87

- Gaussian error 1σ: 0.25dex

- SDSS DR7
  - M: MPA JHU catalogue
  - Age: Hβ in OSSY catalogue

- MW

- M87

- Preliminary!
Origin of stellar components - *in situ* vs accreted via mergers

According to galaxy mass:
- $L^*_{z=0}$
- $3L^*_{z=0}$
- $10L^*_{z=0}$

According to halo mass:
- $\log M_{200}/M_\odot \sim 12.50 (z=0)$
- $\log M_{200}/M_\odot \sim 13.50 (z=0)$
- $\log M_{200}/M_\odot \sim 14.50 (z=0)$

Centrals Only
• The fraction of stellar components accreted via galaxy mergers

Strongly depend on halo mass

Centrals Only

z=0

MW

M87

Merger Accretion Fraction

Centrals Only
The fraction of stellar components accreted via galaxy mergers
- Specific mass growth rate channels
  - Specific Star Formation Rate \( \frac{SFR}{M_*} \)
  - Specific Stellar mass Accretion Rate (via Mergers) \( \frac{\dot{M}_{\text{acc}}}{M_*} \)

![Graph showing Specific Star Formation Rate (SSFR) and Specific Stellar mass Accretion Rate (SSAR) against Redshift and Age of the Universe (Gyr).]
- When is merger dominant?
- SSAR decays more slowly than SSFR
• When does merger become dominant?

**SSAR/SSFR at z=0**

- **Centrals Only**
- **MW**
- **M87**

- **Merger accretion dominant**
- **In-situ SF dominant**
- **Tie**
- When does merger become dominant?

**Epochs when SSAR=SSFR**

- In-situ star formation is always dominant
- Centrals Only
- MW
- M87

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Summary & Discussion

• The fraction of stellar mass in central galaxies accreted via mergers strongly correlates with halo mass

• The contribution of mergers to stellar mass growth decays slower than that of in-situ star formation

• Mergers become the dominant channel for mass growth of galaxies in haloes more massive than $10^{13} M_\odot$