Formation of massive disc galaxies in the IllustrisTNG simulation

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Zeng G., Wang L. (王岚), Gao L. (高亮), 2021, MNRAS, 507, 3301

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Motivation

As predicted by the standard hierarchical model of galaxies formation,

- massive galaxies at low z should have experienced many mergers,
- so **they are likely to have an elliptical morphology**.

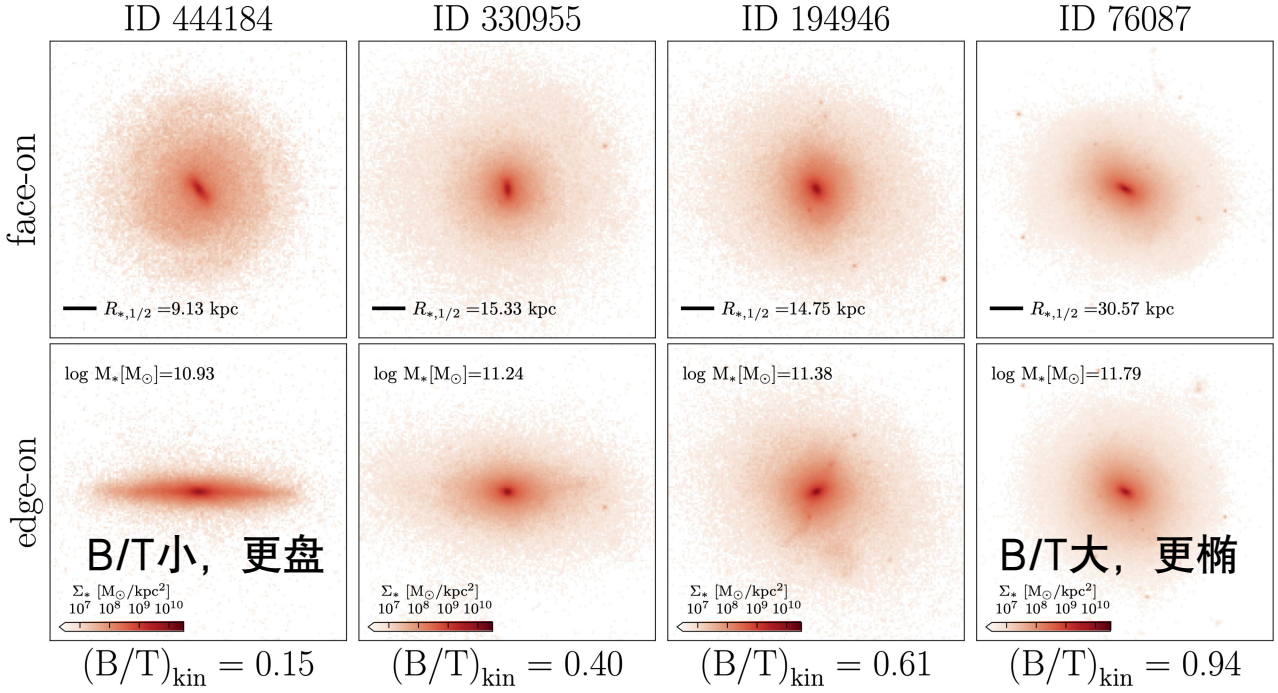
This prediction is statistically consistent with observations.
(e.g. Buitrago et al. 2013; Conselice 2014; van der Wel et al. 2014)

However, **a number of massive disc galaxies at low z were also reported in observations**. (e.g. Ogle et al. 2016, 2019; Luo et al. 2020)

In this work, we use the state-of-the-art cosmological hydrodynamical simulation IllustrisTNG to explore the morphology evolution of massive disc galaxies and compare their morphology evolution and merger history with massive elliptical galaxies.

Sample Selection

We use the kinematics-based bulge-to-total stellar mass ratio, $(B/T)_{kin}$, to quantify the morphology of simulated galaxies in TNG100-1.

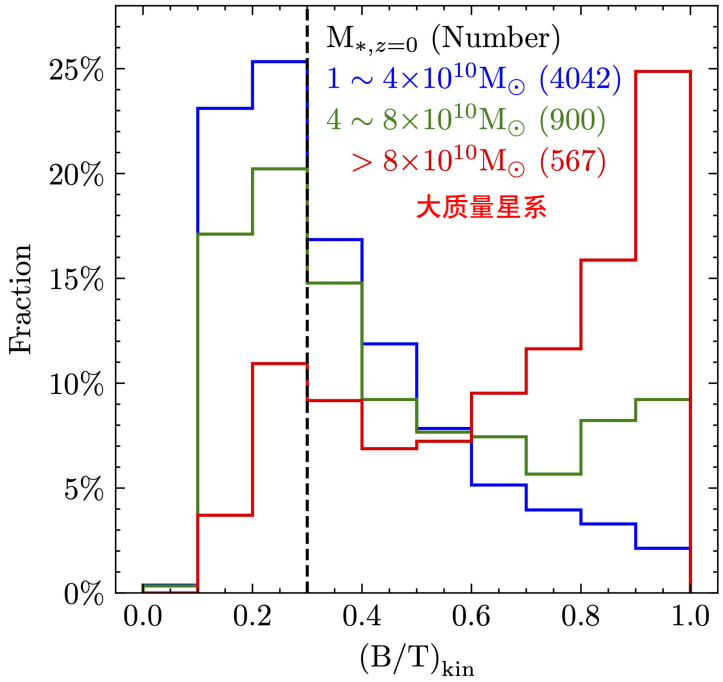


Sample Selection

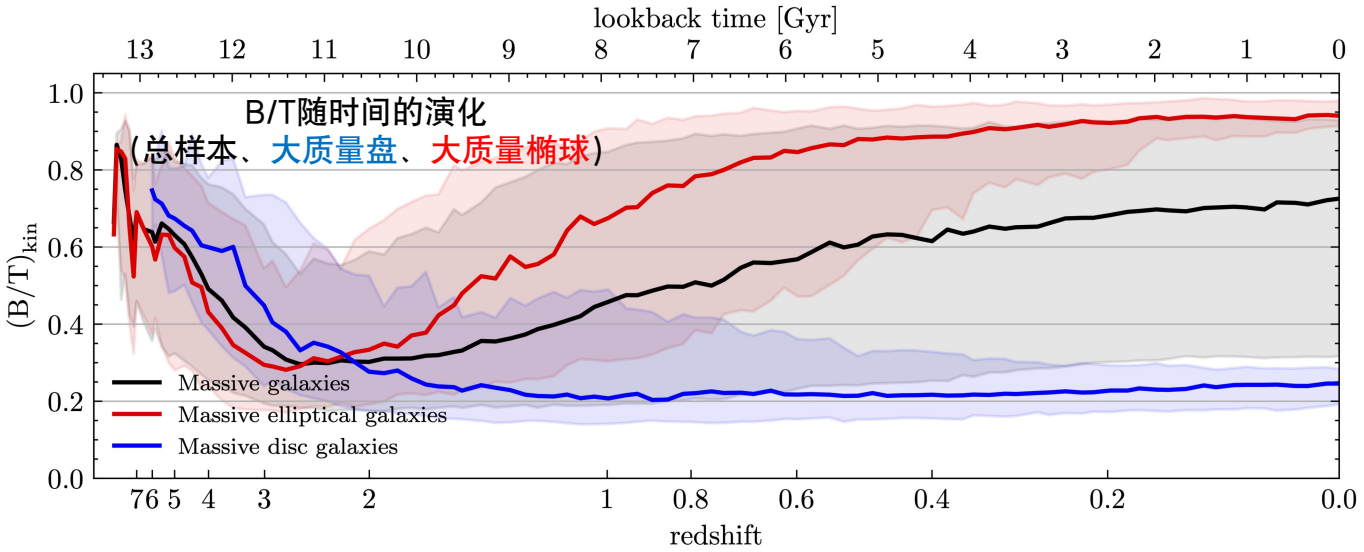
We select out 567 massive galaxies at $z = 0$ in TNG100-1, 83 of them are massive disc galaxies and 142 are massive elliptical galaxies.

- **Massive:** $M_{*,z=0} > 8 \times 10^{10} M_{\odot}$
- **Disc:** $(\mathrm{B/T})_{\mathrm{kin,z=0}} < 0.3$
- **Elliptical:** $(\mathrm{B/T})_{\mathrm{kin,z=0}} > 0.9$

不同质量区间的星系的B/T分布

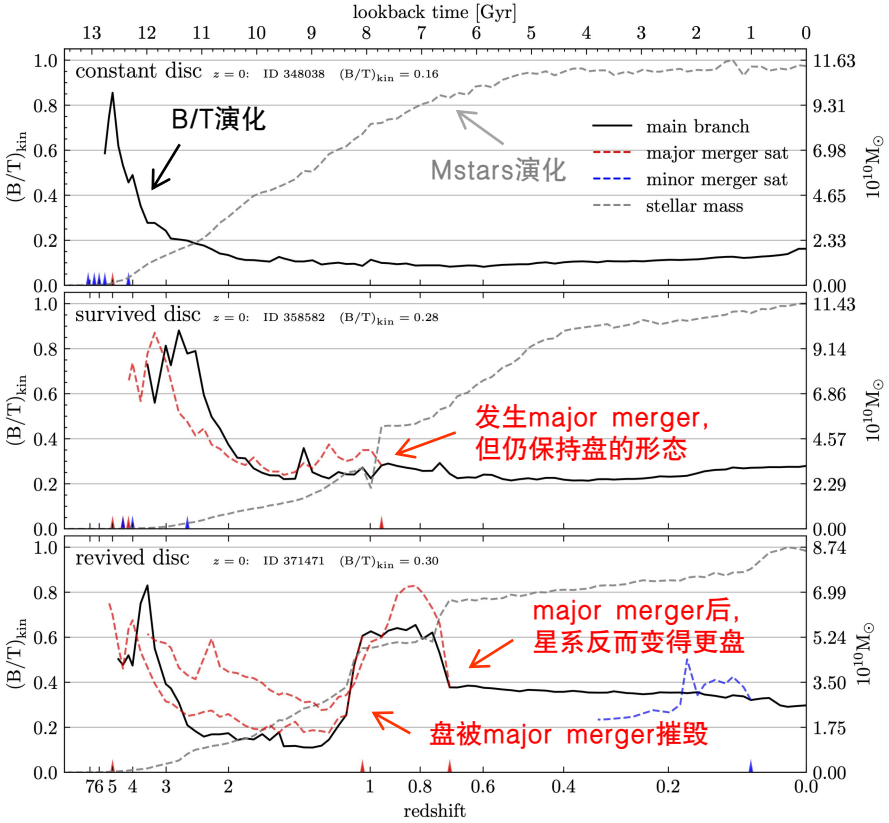


Morphology Evolution of Massive Galaxies



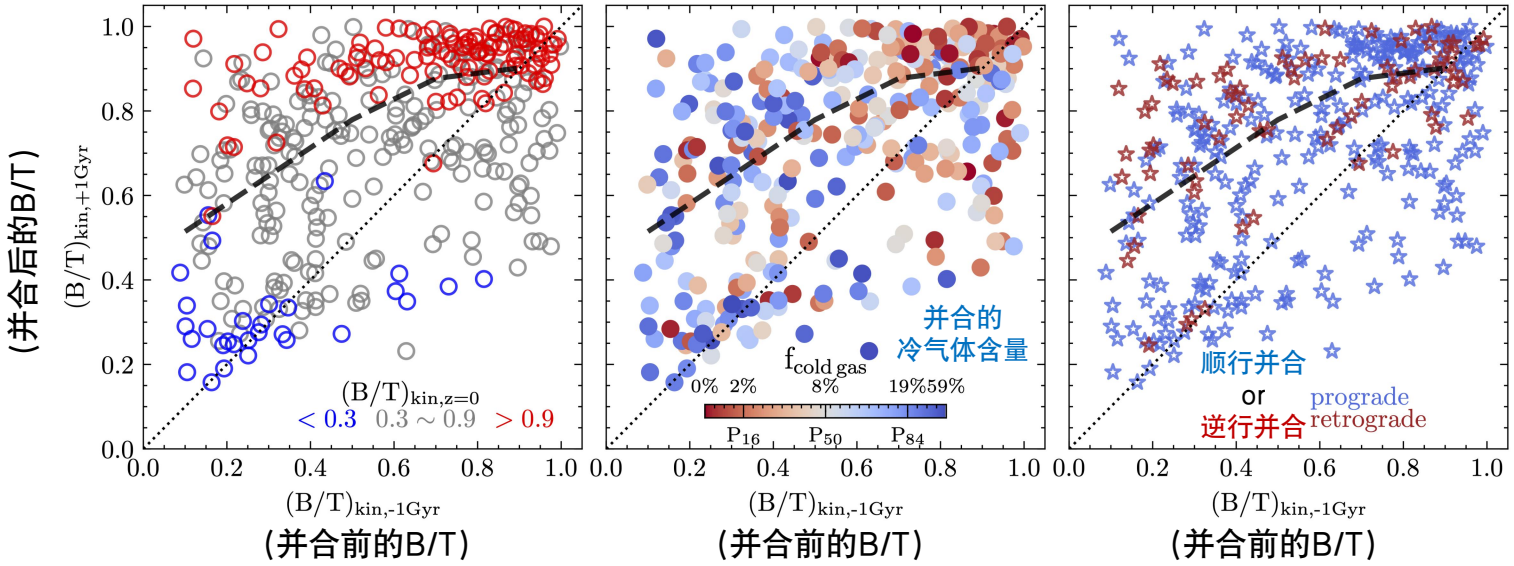
- In general, massive galaxies have large $(B/T)_{kin}$ at high z. The $(B/T)_{kin}$ decreases with time till $z = 2 \sim 3$, then increases gradually.
- After $z \sim 2$, massive ellipticals grow their $(B/T)_{kin}$ relatively fast. In contrast, the massive discs keep decreasing their $(B/T)_{kin}$.

Three Different Evolution Pathways of Massive Discs



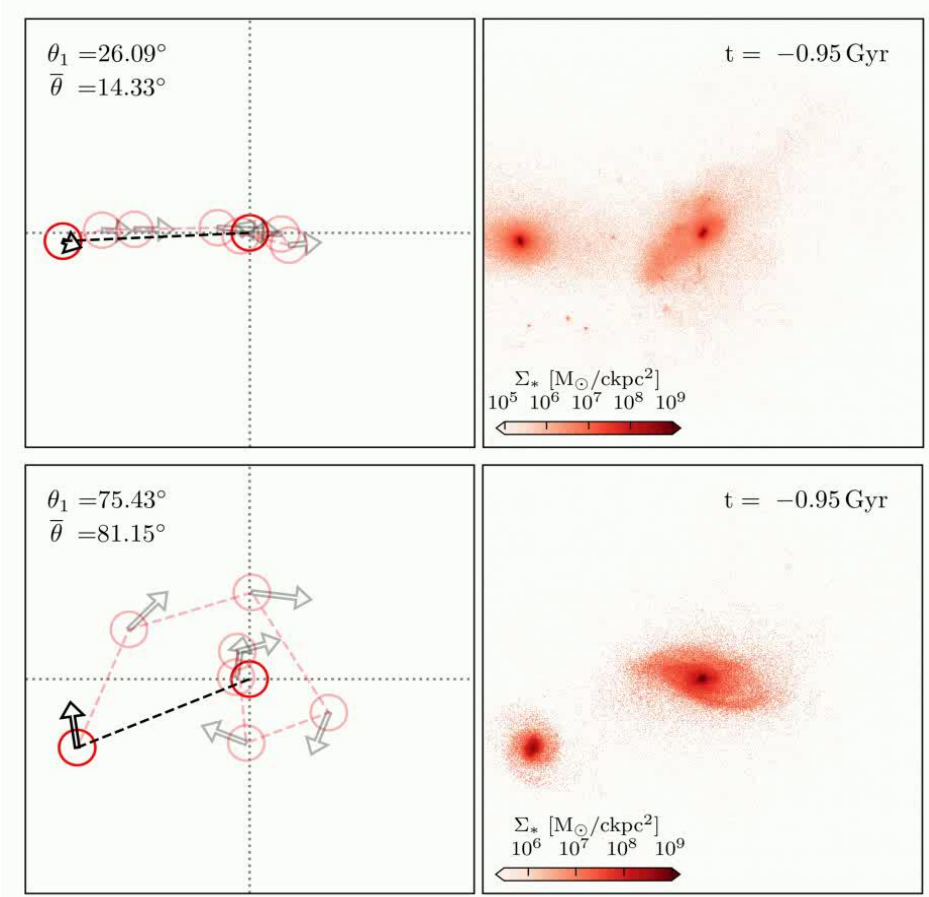
- **constant disc**
  8.4% have quiet merger histories
- **survived disc**
  37.3% experience mergers but survive to remain discy
- **revived disc**
  54.2% have a significant increase in $(B/T)_{kin}$ in history, then become discs again

Morphology Change of the Latest (and at $z < 1$) Major Merger of Each Massive Galaxy



- In general, major mergers turn galaxies into a more bulge-dominant morphology.
- Morphology change has **weak** dependence on cold gas fraction (gas-rich vs gas-poor) and orbital configuration (prograde vs retrograde) of the merging system.

Merger Orbit Type: Head-on collision vs Spiral-in falling



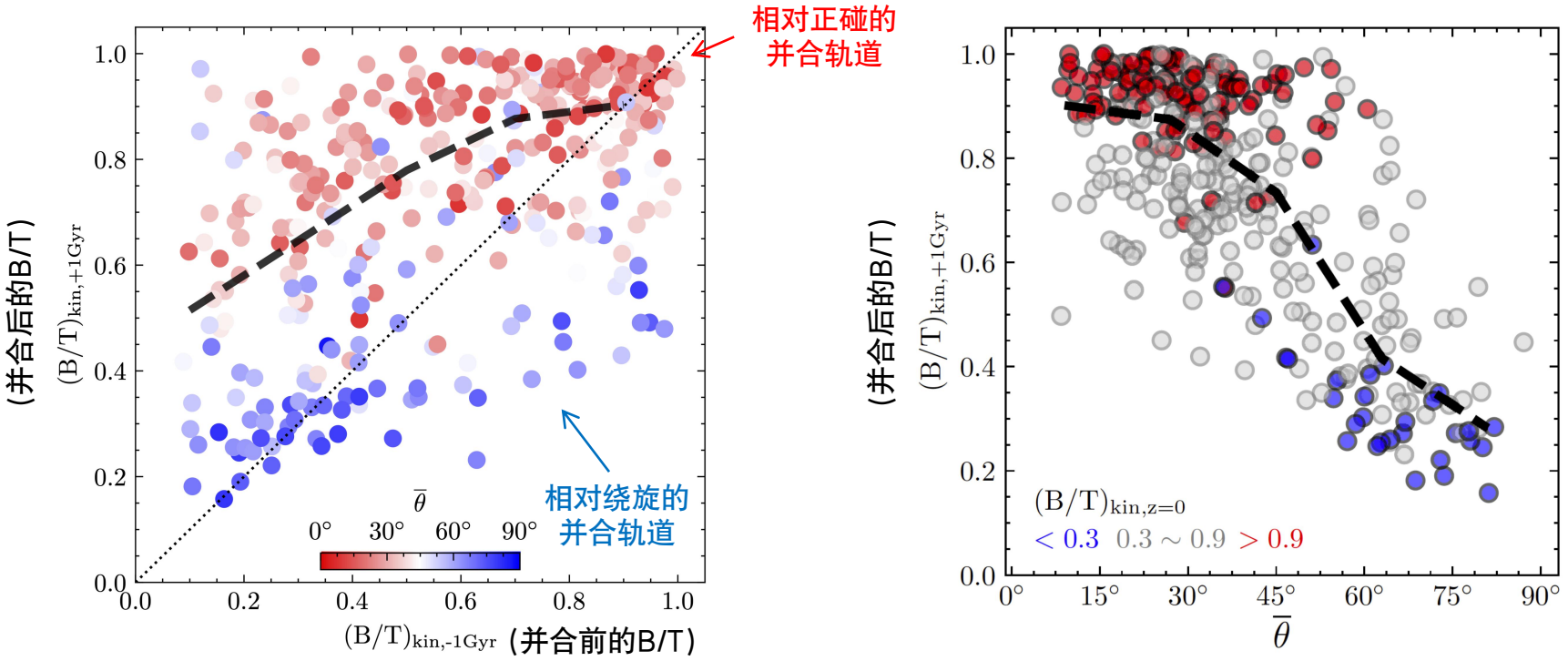
At each snapshot, the satellite is

- heading to the central straightly for $\theta = 0°$
- on a circular orbit around the central for $\theta = 90°$

Then, we calculate the $\overline{\theta} = \frac{1}{n}\sum_{i=1}^{n}\theta_i$ to represent the overall orbit type:

- head-on orbit for a small $\overline{\theta}$
- spiral-in orbit for a large $\overline{\theta}$

A strong dependence of remnant morphology on orbit type



- Almost all discy remnants correspond to spiral-in mergers with large $\overline{\theta}$
- Most bulge-dominated remnants are results of head-on collisions with small $\overline{\theta}$

Conclusions

- Three **different evolution pathways** of massive disc galaxies:
  - 8.4% of them have quiet merger histories and preserve disc morphology since formed. **(constant disc)**
  - 37.3% experience prominent mergers but survive to remain discy. **(survived disc)**
  - 54.2% have a significant increase in bulge components in history, then become discs again till present time. **(revived disc)**
- We find **a strong dependence of remnant morphology on the orbit type of major mergers**. Specifically, Major mergers with a spiral-in (head-on) orbit mostly lead to discy (elliptical) remnants.