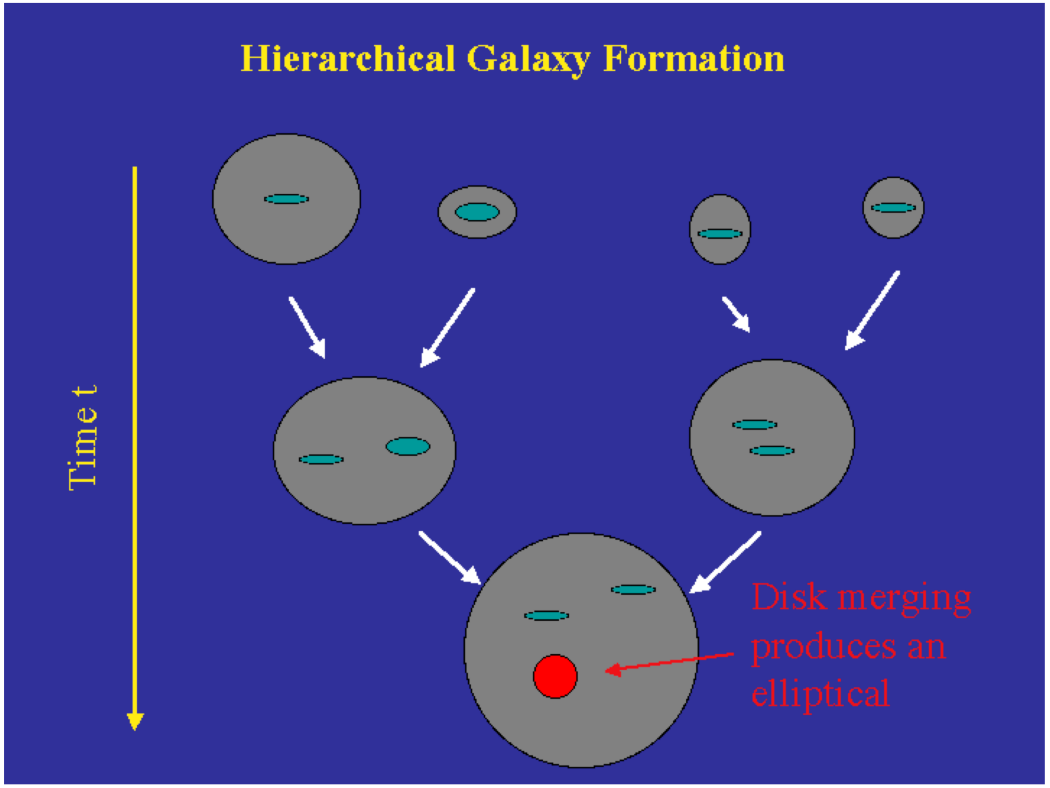
Formation of massive disc galaxies in the IllustrisTNG simulation

Speaker: Guangquan Zeng

Supervisors: Prof. Liang Gao, Dr. Lan Wang

2023, Shanghai

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**.

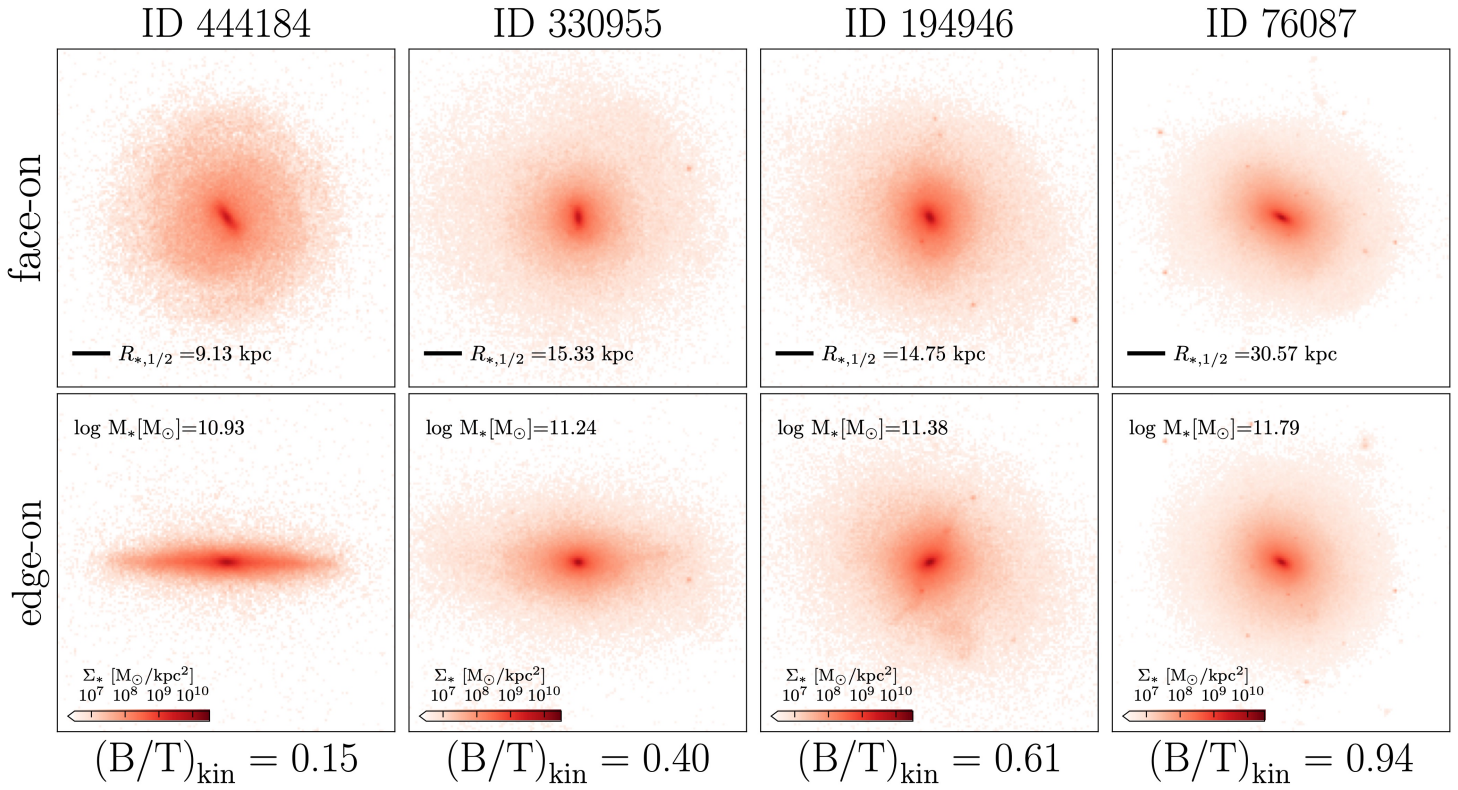
This prediction is statistically consistent with observations. (e.g. Buitrago et al. 2013; Conselice 2014; van der Wel et al. 2014)

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)

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.

small B/T for more disc-like



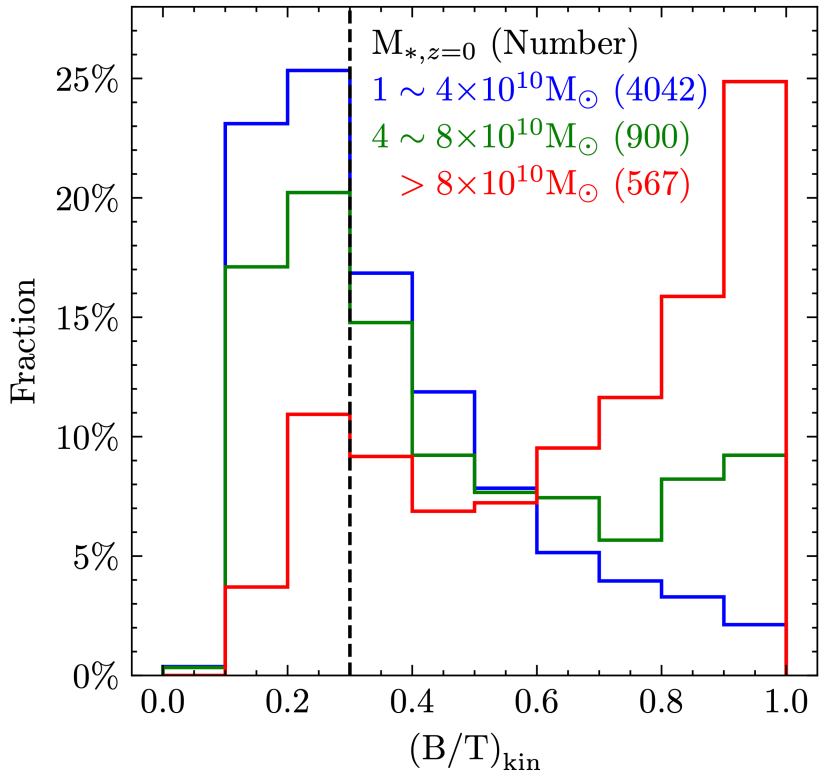
large B/T for more elliptical

Sample Selection

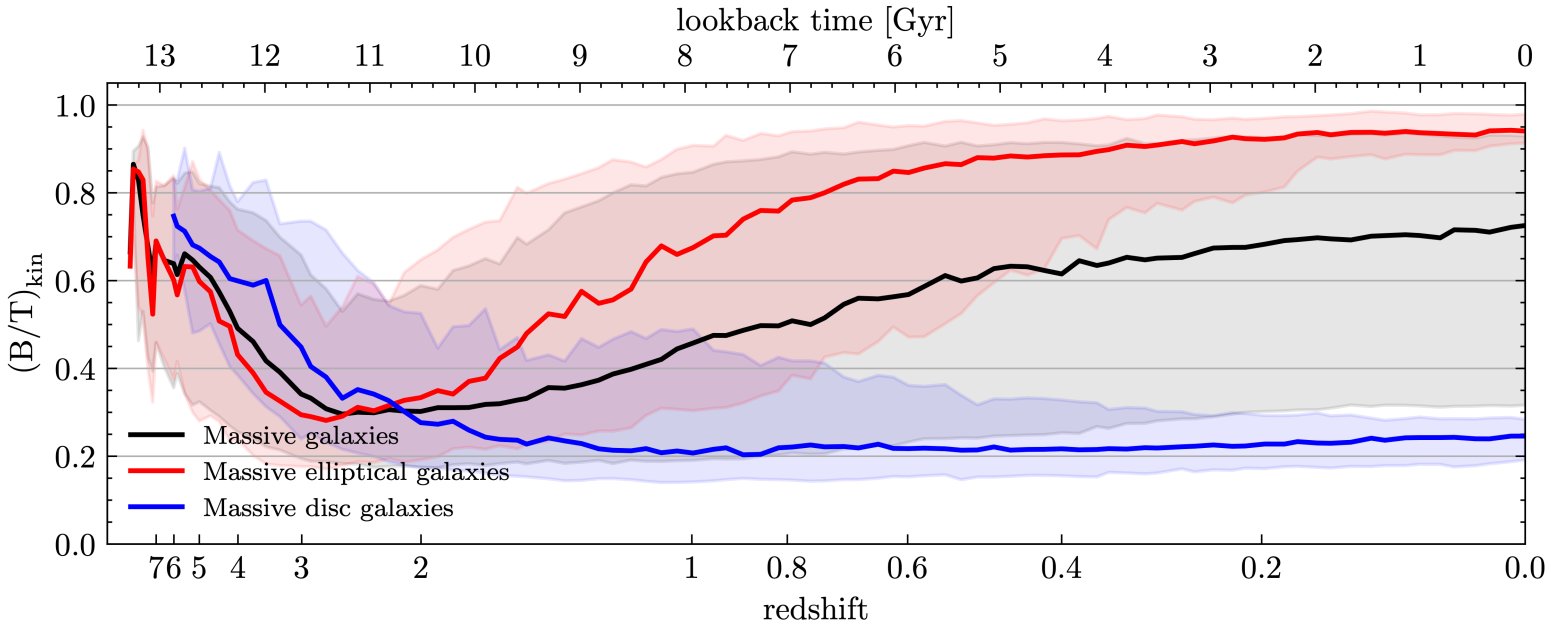
We select out 567 massive galaxies at $z = 0$ in TNG100-1, 83 of them are massive disc galaxies and 142 are massive elliptical galaxies.

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

B/T distribution in different stellar mass ranges

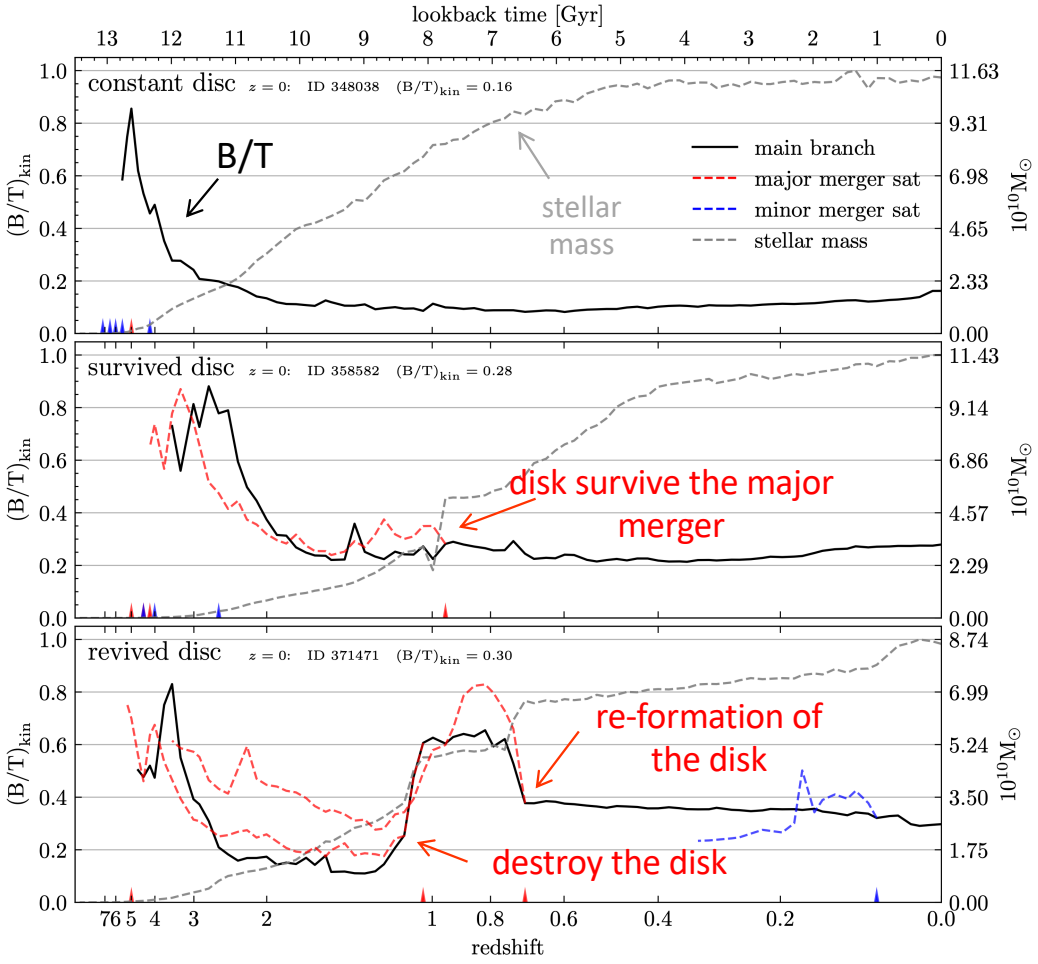


Morphology Evolution of Massive Galaxies



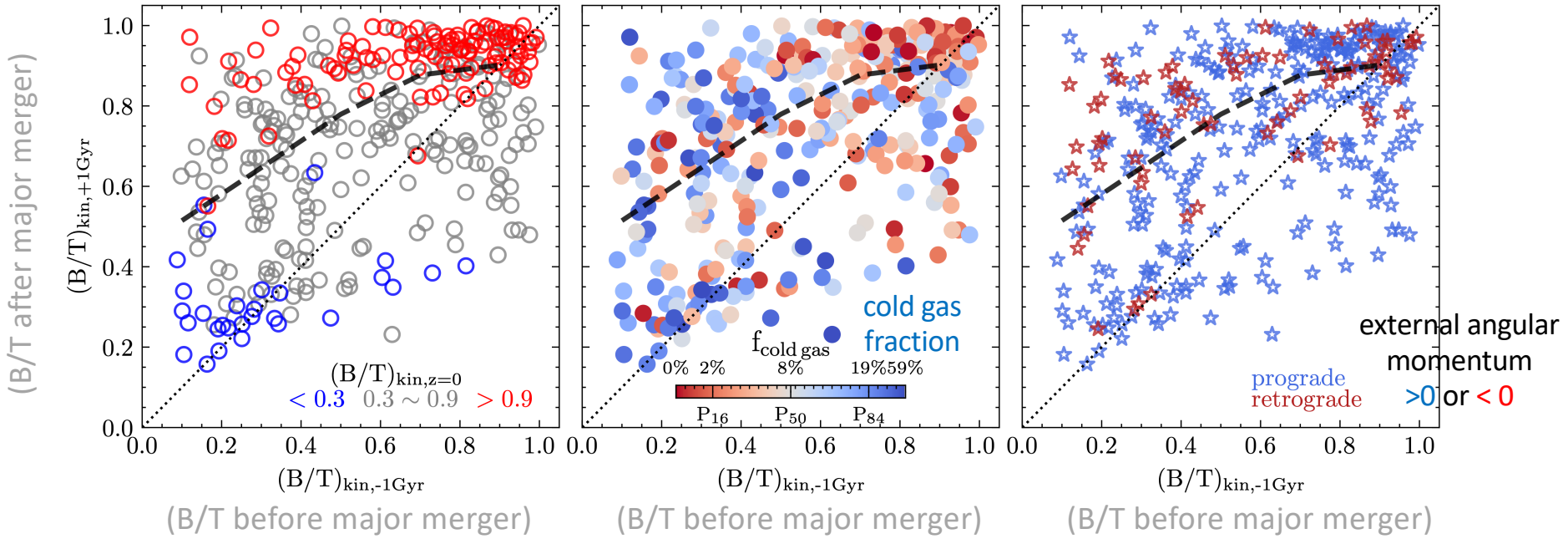
- In general, massive galaxies have large $(B/T)_{kin}$ at high z. The $(B/T)_{kin}$ decreases with time till $z = 2 \sim 3$, then increases gradually.
- After $z \sim 2$, massive ellipticals grow their $(B/T)_{kin}$ relatively fast. In contrast, the massive discs keep decreasing their $(B/T)_{kin}$.

Three Different Evolution Pathways for Massive Disc Galaxies



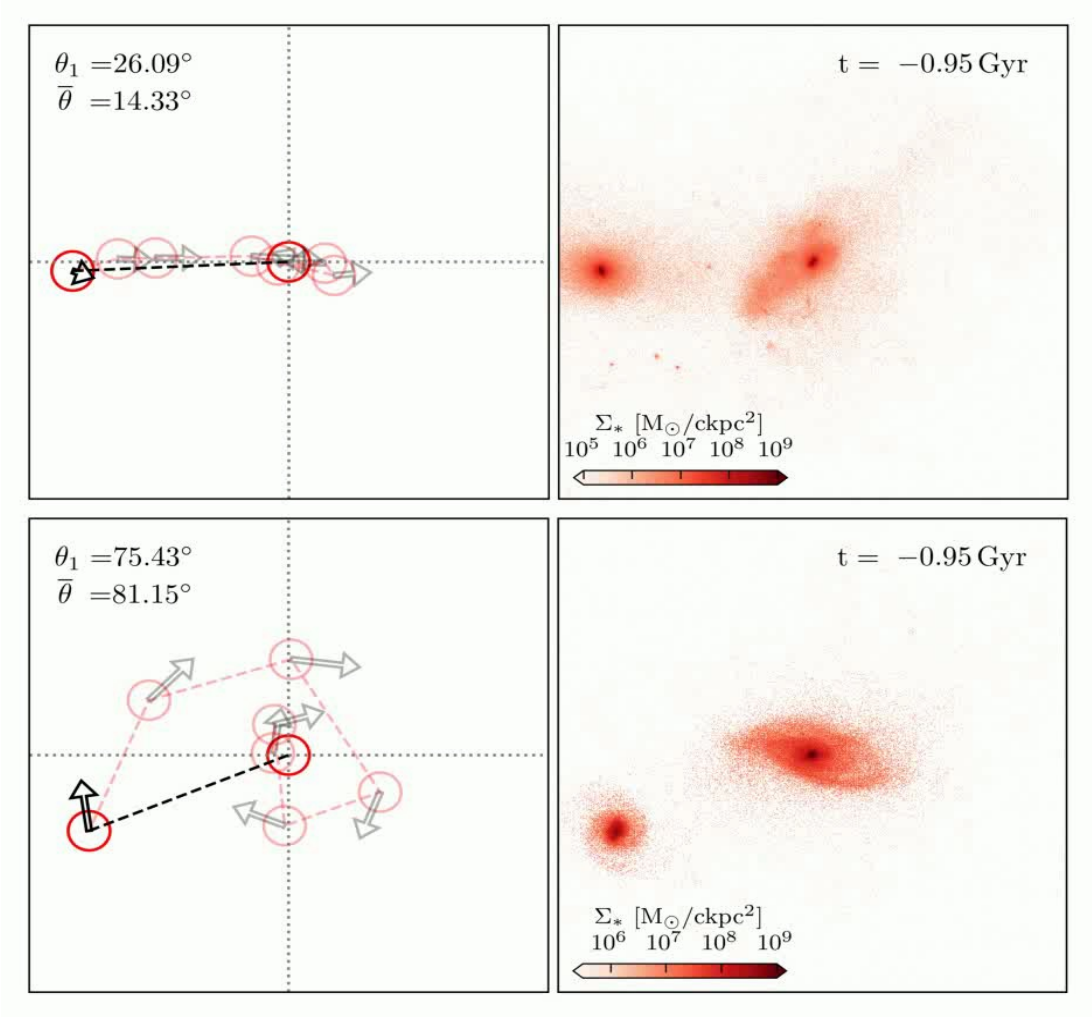
- **constant disc**
  8.4% have quiet merger histories
- **survived disc**
  37.3% experience mergers but survive to remain discy
- **revived disc**
  54.2% have a significant increase in $(B/T)_{kin}$ in history, but finally become discs again

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



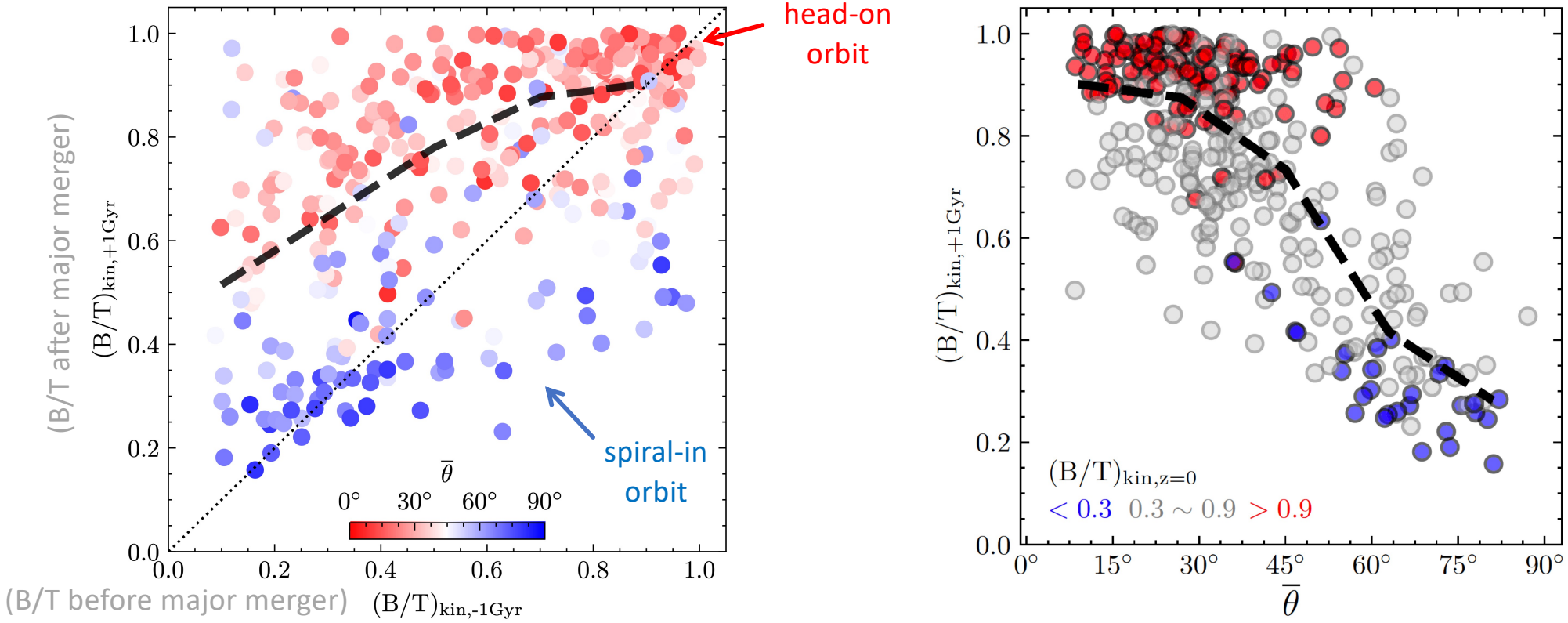
At each snapshot, the satellite is

- 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.