The Galaxy Size—halo Spin Relation and Angular Momentum Evolution of Disc Galaxy in the Hydrodynamical Simulations

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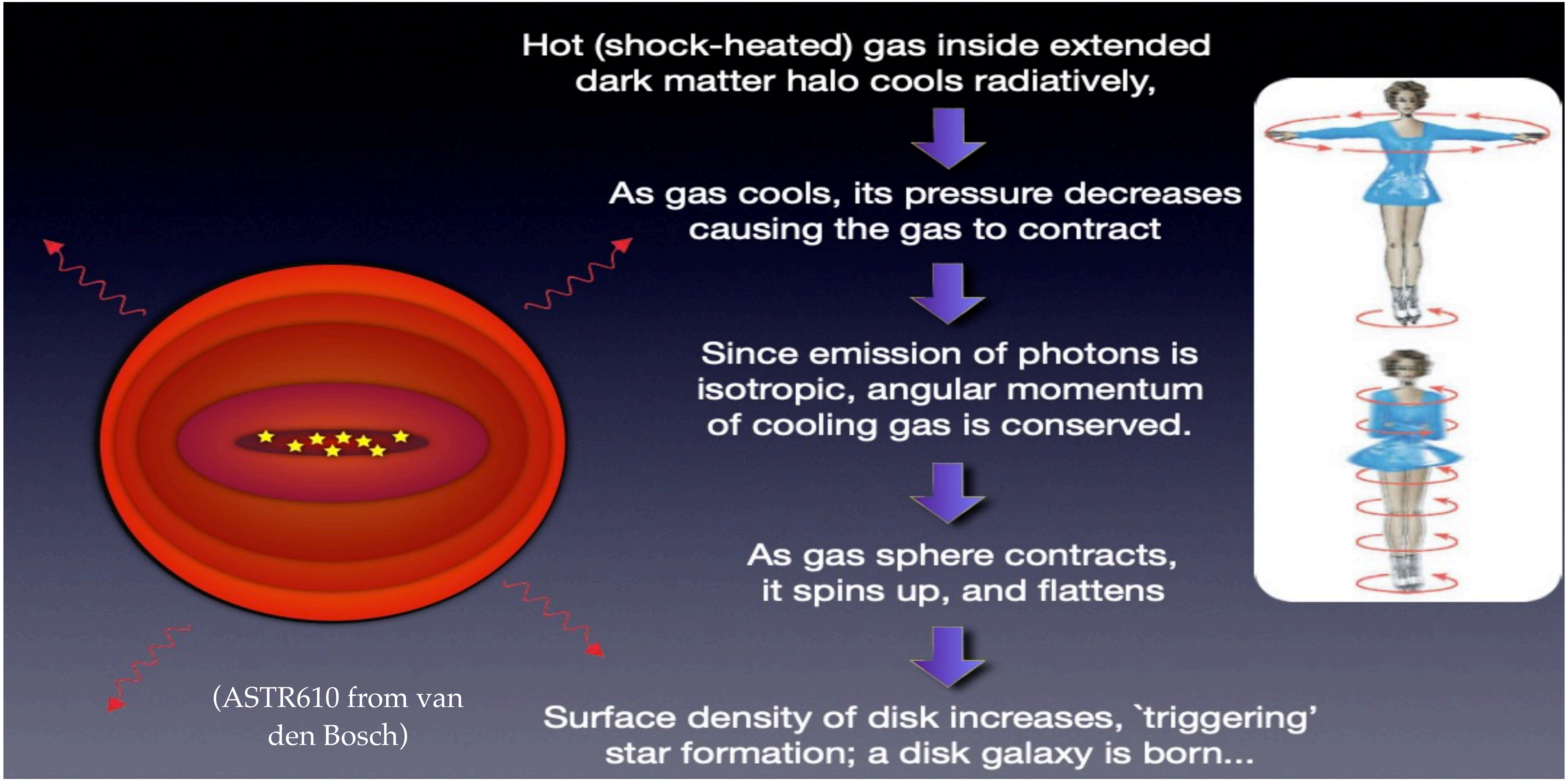
The classical formation picture of disk galaxies



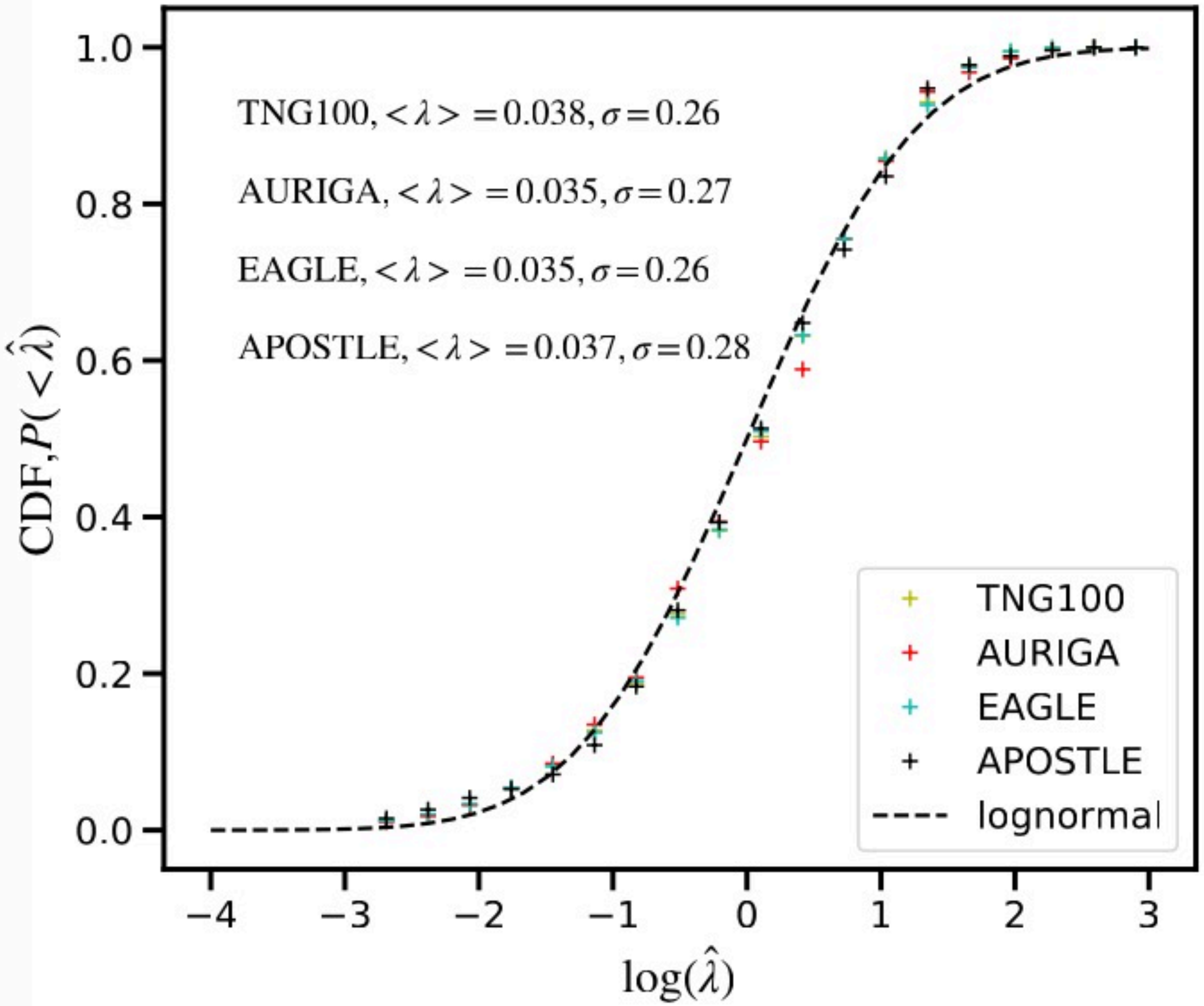
The classical formation picture of disk galaxies

spin parameter

$$\lambda' \equiv \frac{J}{\sqrt{2}MVR},$$

(Peebles, 1969; Bullock+, 2001)

$$P(\lambda') = \frac{1}{\lambda' \sqrt{2\pi}\sigma} \exp\left(-\frac{\ln^2(\lambda'/\lambda'_0)}{2\sigma^2}\right)$$



(Yang+, 2023; arXiv:2110.04434)

The classical formation picture of disk galaxies

Define the angular moment retain factor f_j (f_j = 1 for adiabatic process):

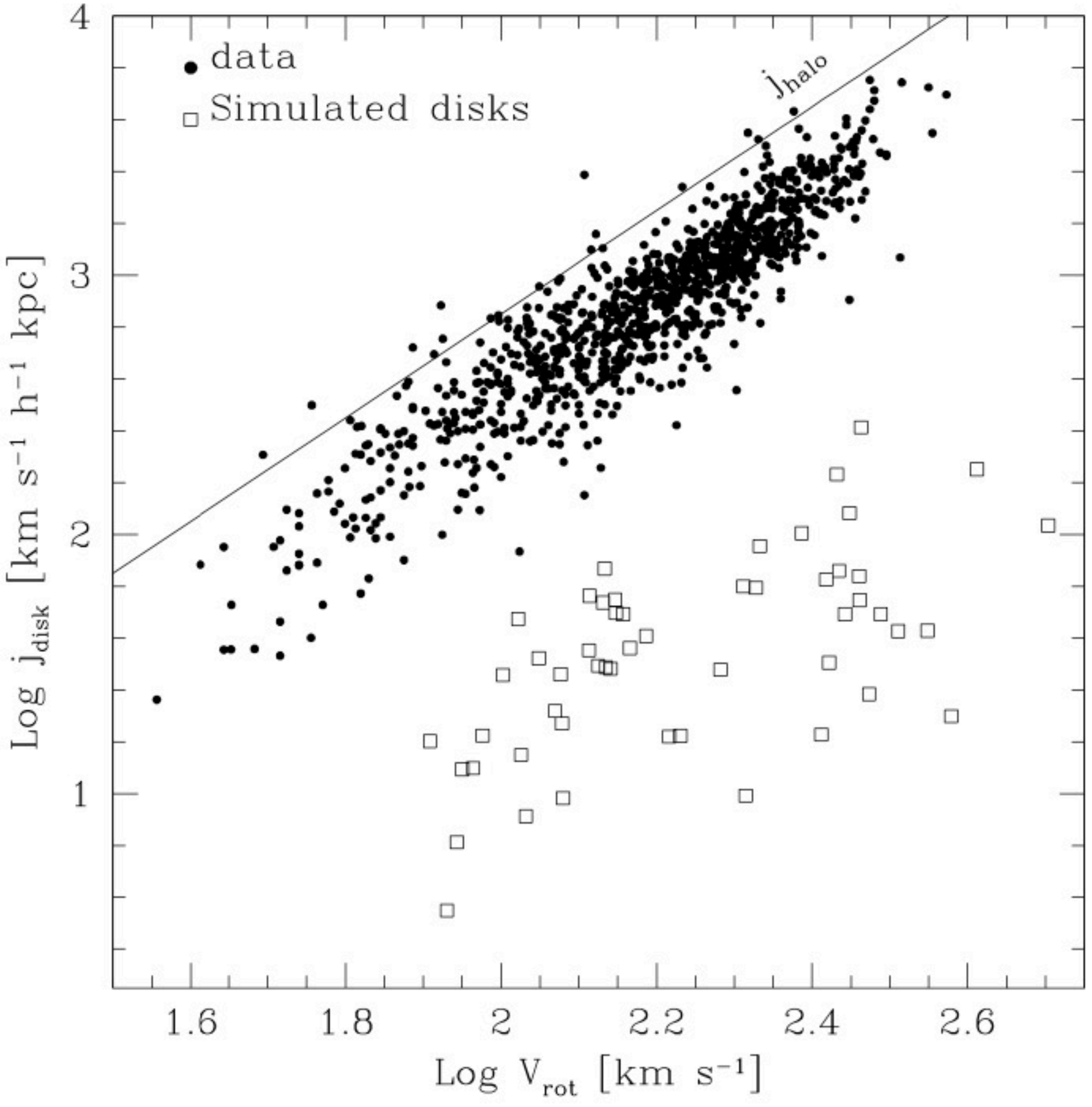
$$f_j = j_*/j_{halo}$$

The galaxy size could be written as:

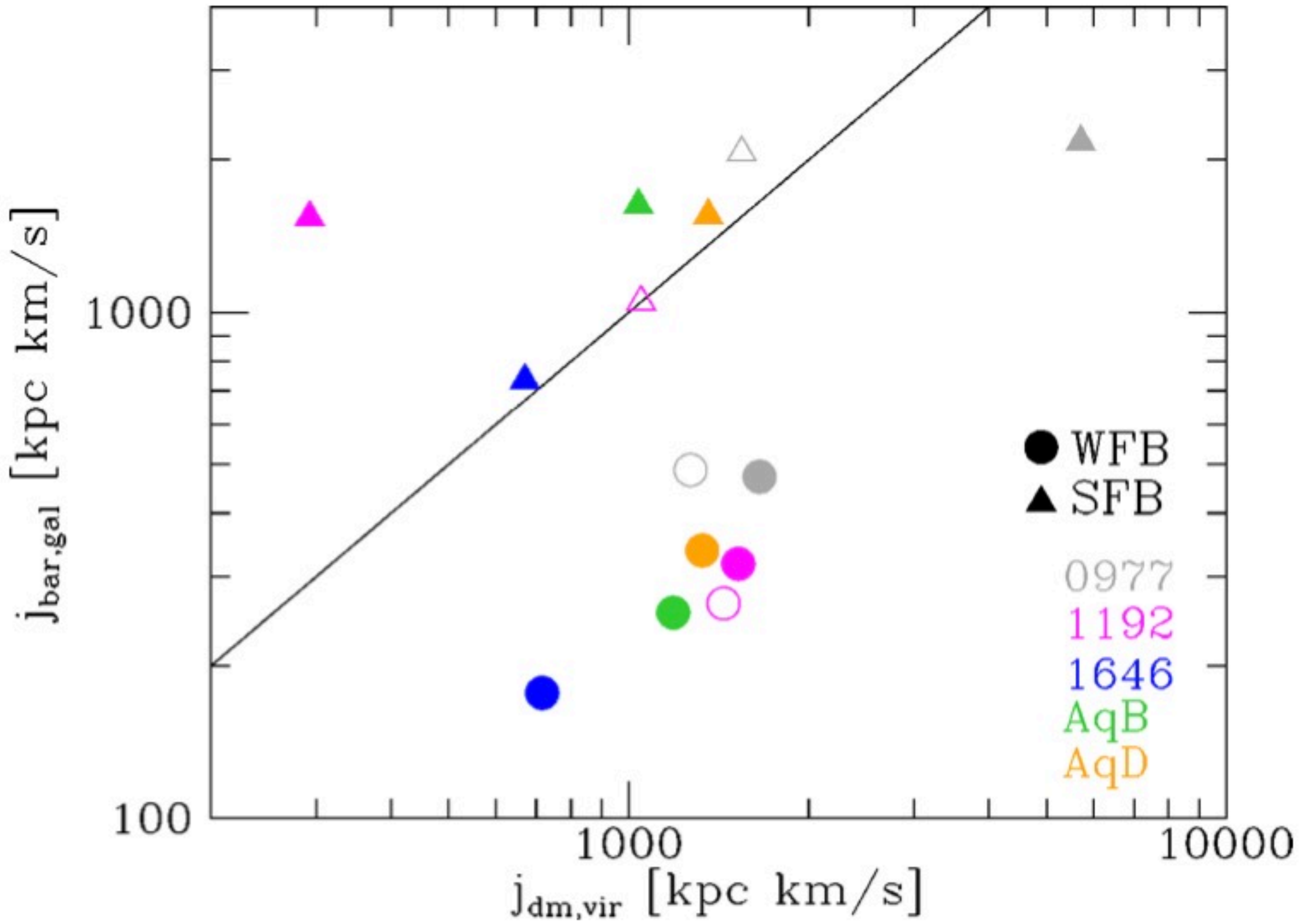
$$\frac{r_{1/2}}{R_{200}} = \frac{1.68}{\sqrt{2}} f_j f_R \lambda$$

- Stand picture suggest the sizes of galactic disks are tightly related to the halo spin (Fall+ 1980; Mo, Mao & White 1998). This model has been extremely successful to interpret a large body of observational data.

Over-cooling and Angular Momentum Catastrophe in Simulation



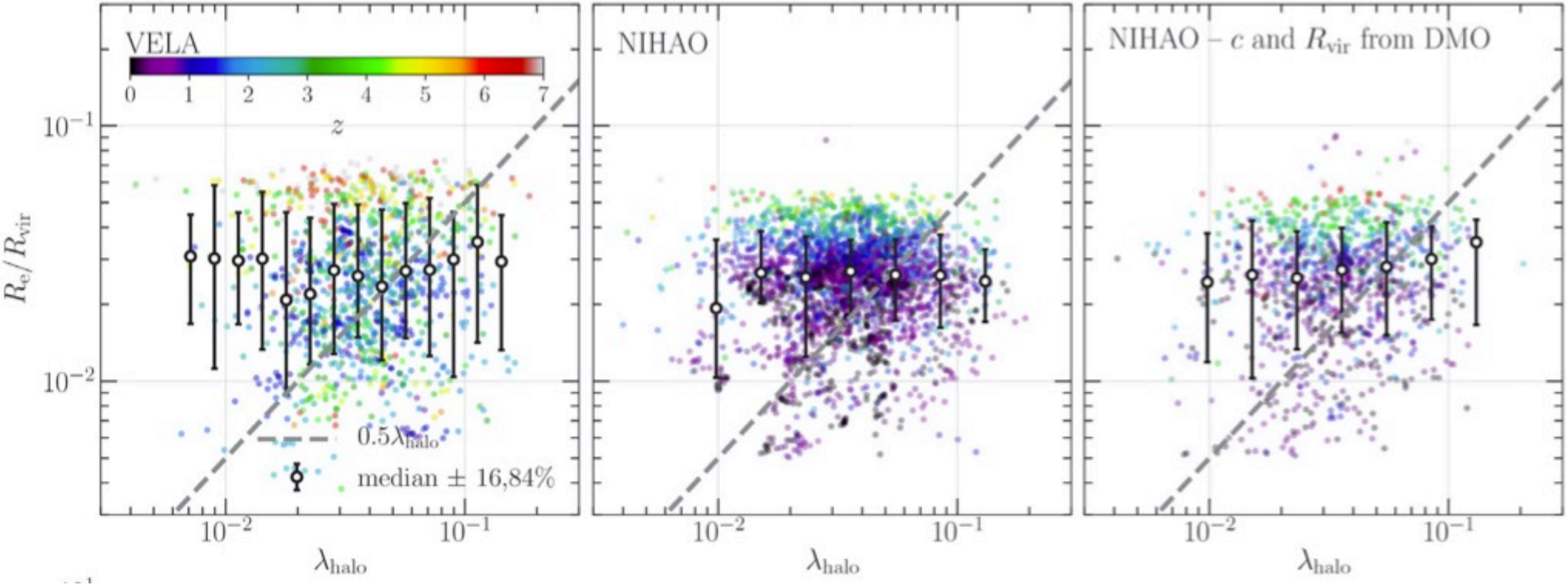
(Steinmetz&Navarro, 1999)



(Ubler+, 2014)

- Invalid feedback.
- More drastic dynamical friction by low resolution.

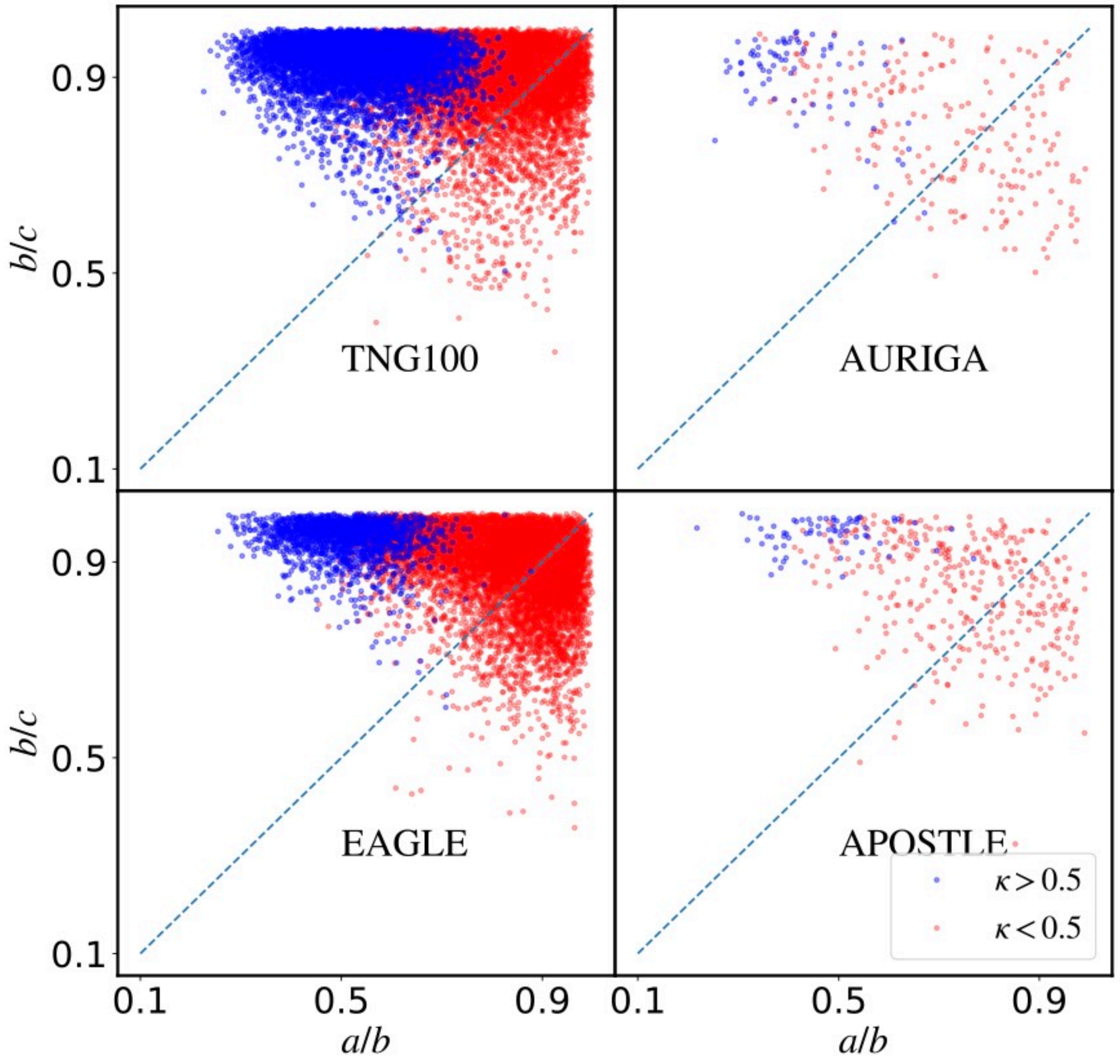
Galaxy Size—Halo Spin Relation in NIHAO and VELA



(Jiang+, 2019)

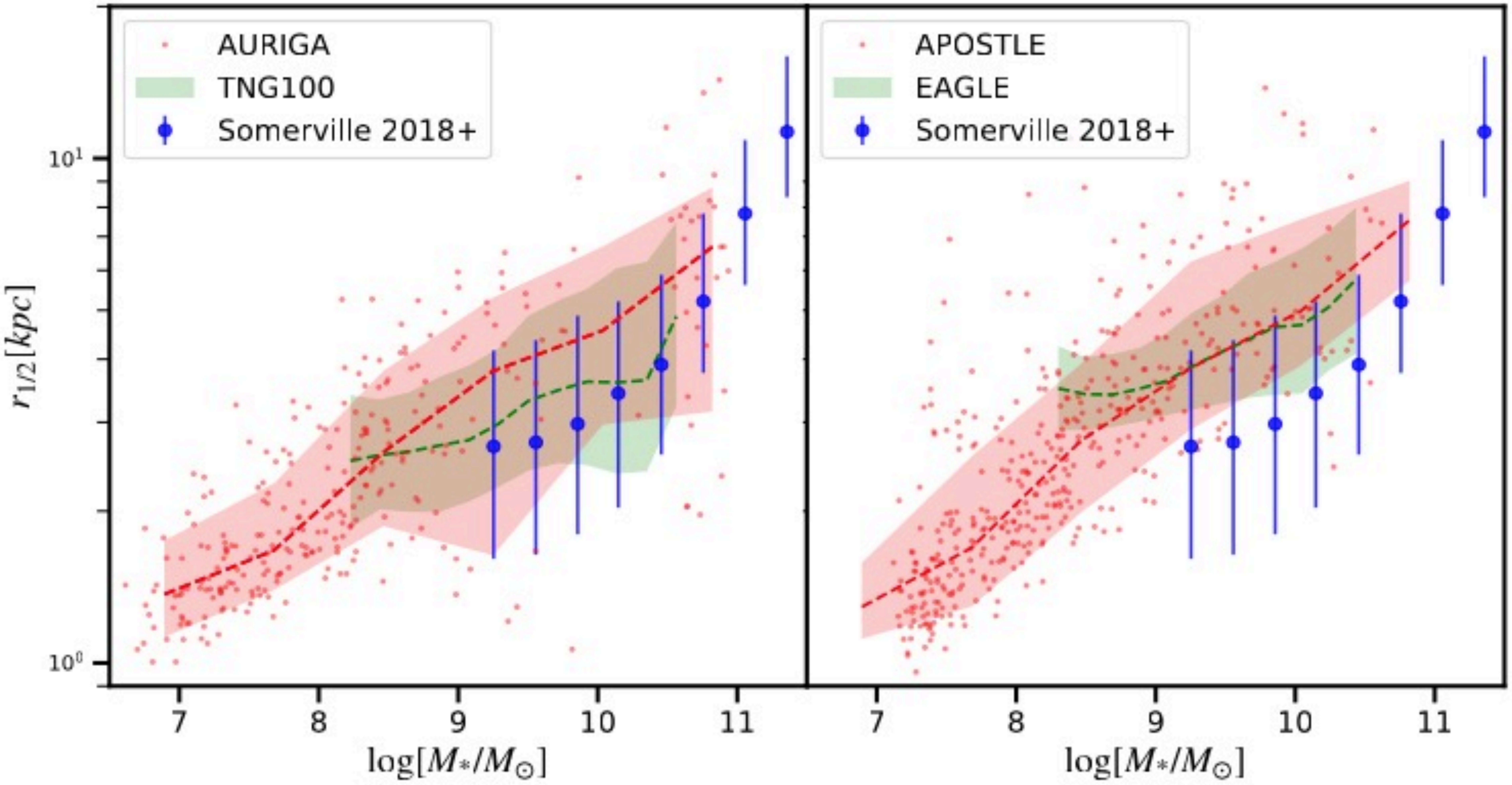
Galaxy Size—Halo Spin Relation in EAGLE and TNG

Project	Sovler	StellarFeedbck
IllustrisTNG	AREPO	Kinetic
AURIGA	AREPO	Kinetic
EAGLE	GADGET	Thermal
APOSTLE	GADGET	Thermal



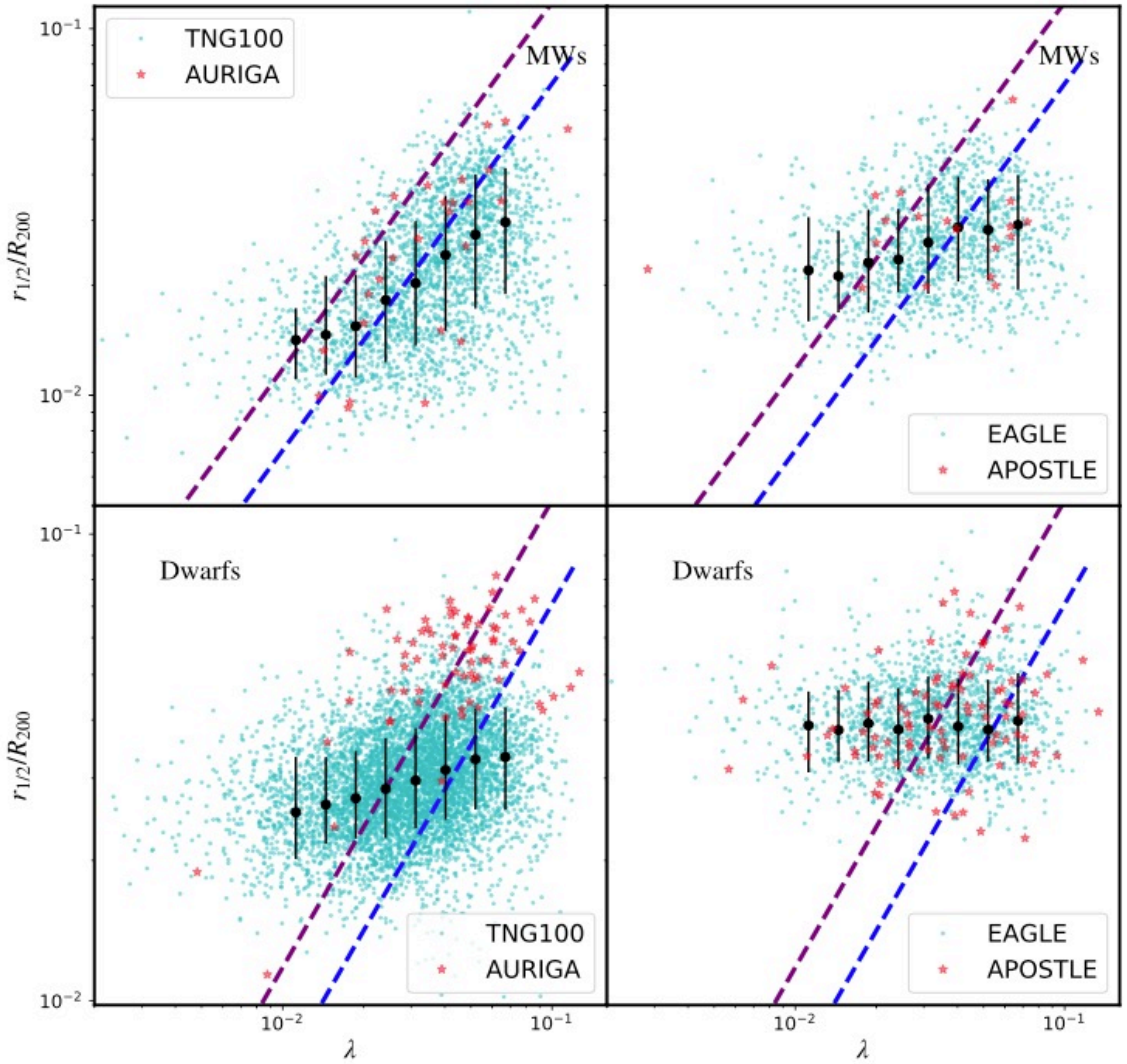
$$\kappa = \frac{K_{rot}}{K} = \frac{\sum_i 1/2 m_i \{(\hat{\boldsymbol{L}} \times \hat{\boldsymbol{r}}_i) \cdot \boldsymbol{v}_i\}^2}{\sum_i 1/2 m_i v_i^2}$$

Galaxy Size—Mass Relation in TNG and Eagle



(Yang+, 2023)

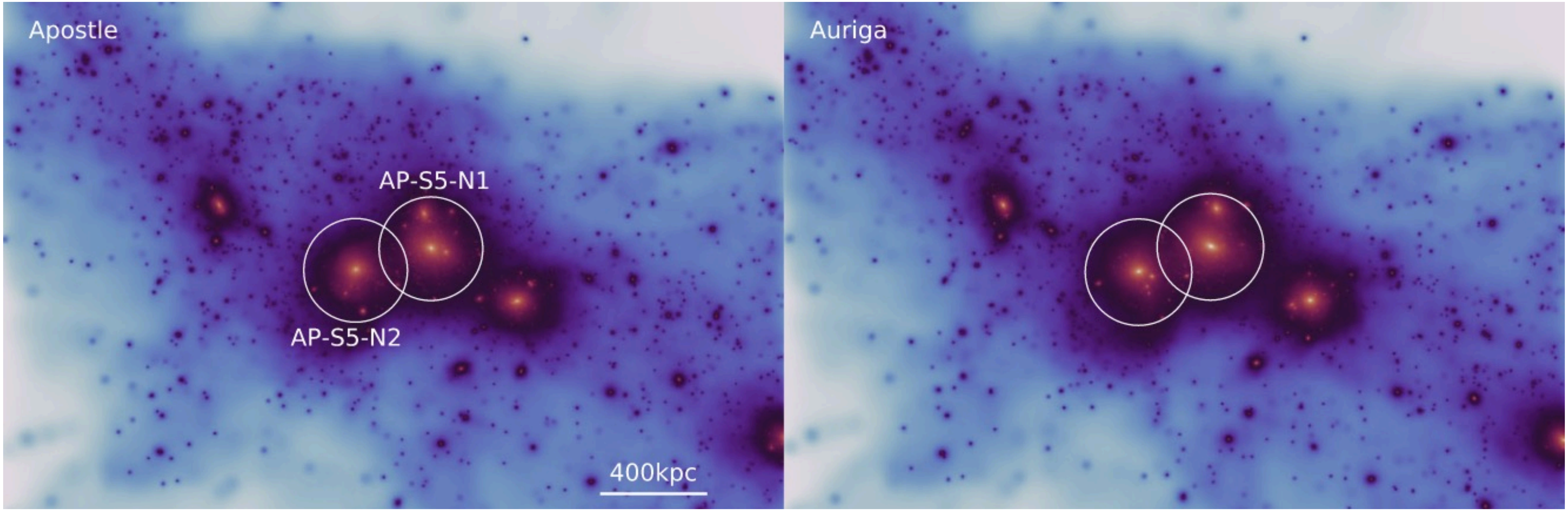
Galaxy Size—Halo Spin Relation in EAGLE and TNG



	MW-like	Dwarf
ρ(TNG100&Auriga)	0.50 ± 0.05	0.38 ± 0.05
ρ(Eagle&Apostle)	0.32 ± 0.07	0.02 ± 0.09

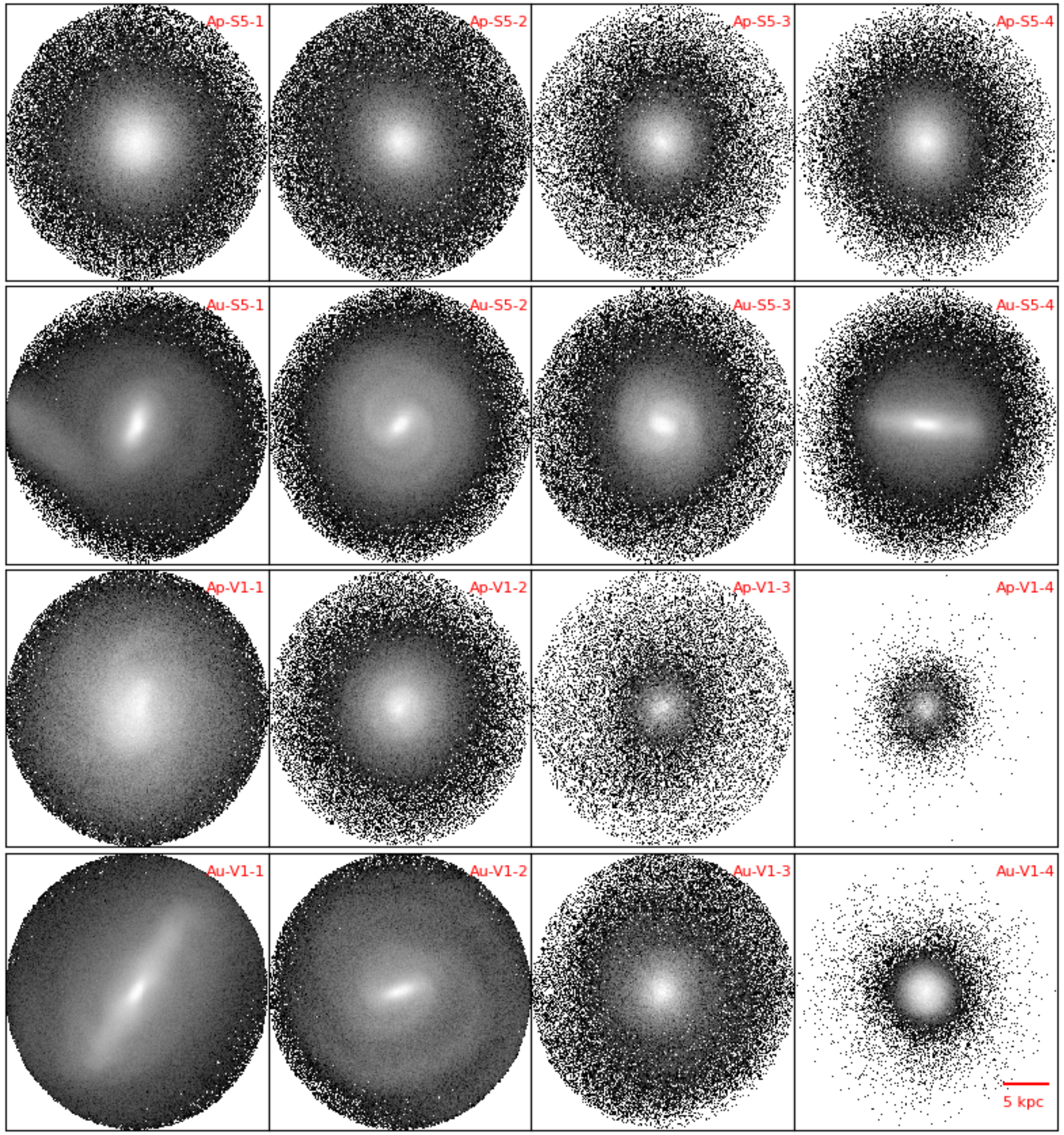
- There is a size—spin positive correlation for the Milky way analogies.
- For the dwarfs in the simulations from the Eagle collaboration, there is Null correlation. (Yang+, 2023; arXiv:2110.04434)

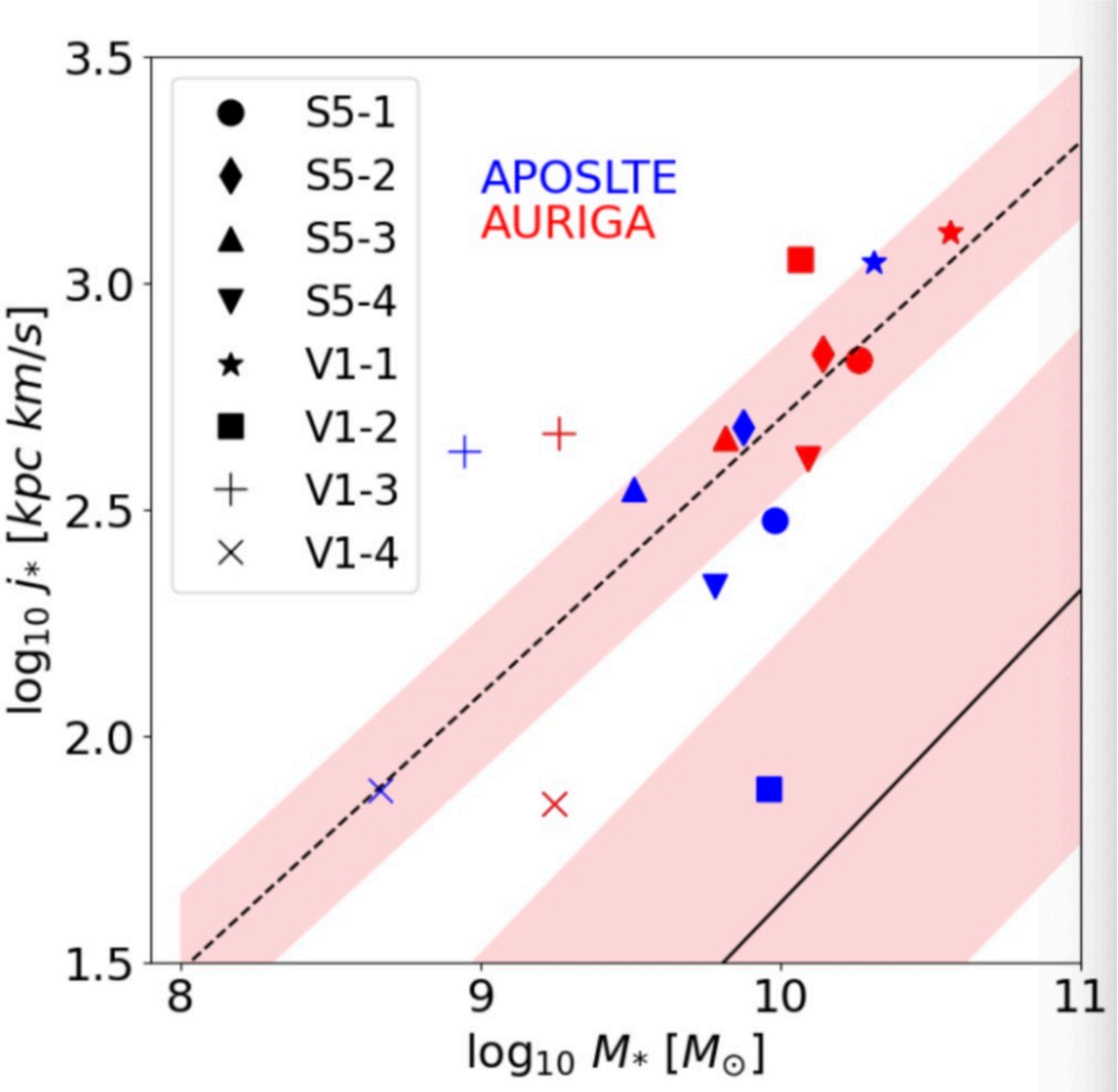
Two Zoom-in Simulations with Identical ICs



- Both two simulations used the same initial conditions, but different solver and sub-grid models. (Kelly+, 2022)

The matched disc galaxies and j—M relation

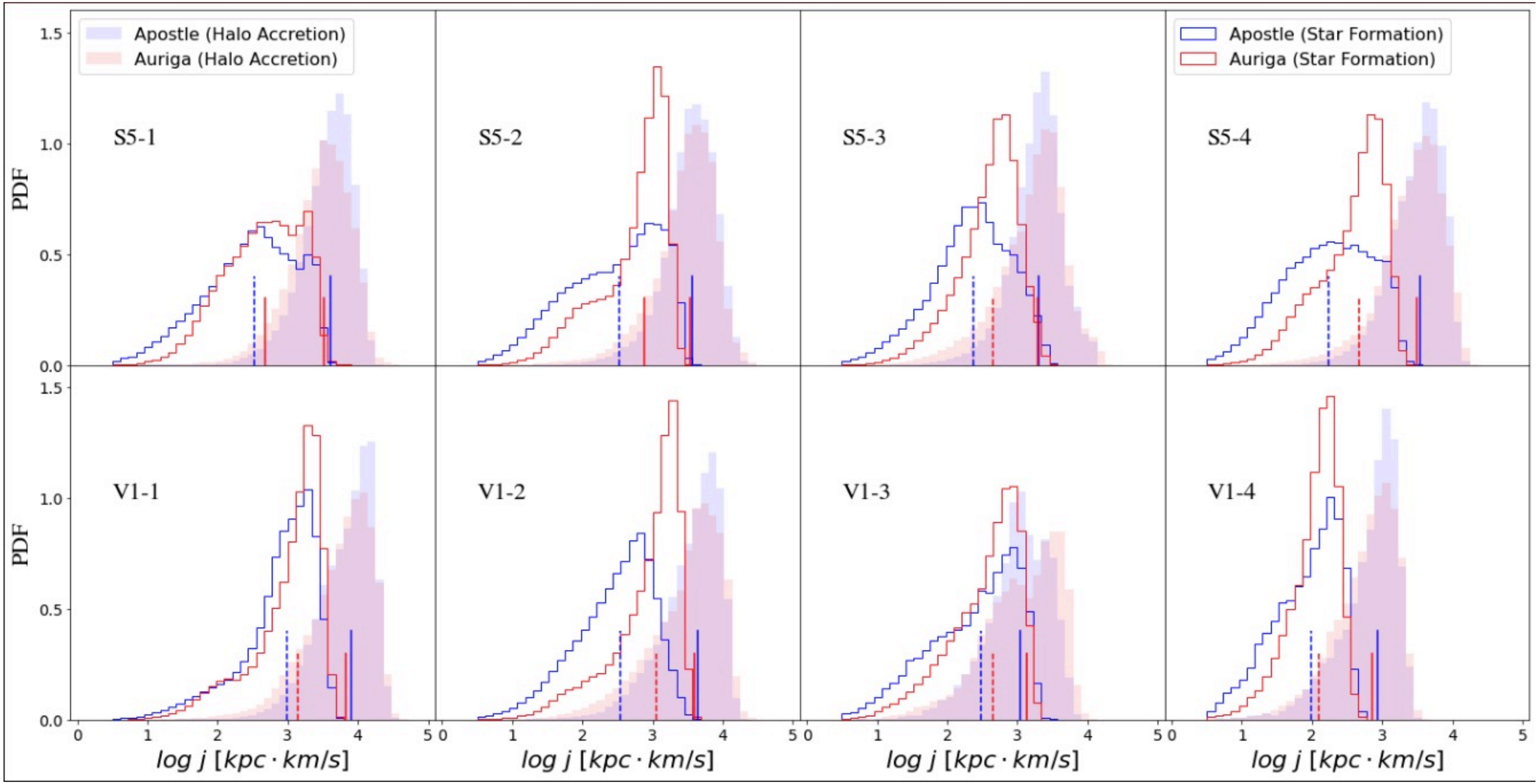




$$M_{200} = 6.1 \times 10^{10} \text{ to } 1.6 \times 10^{12} M_\odot$$

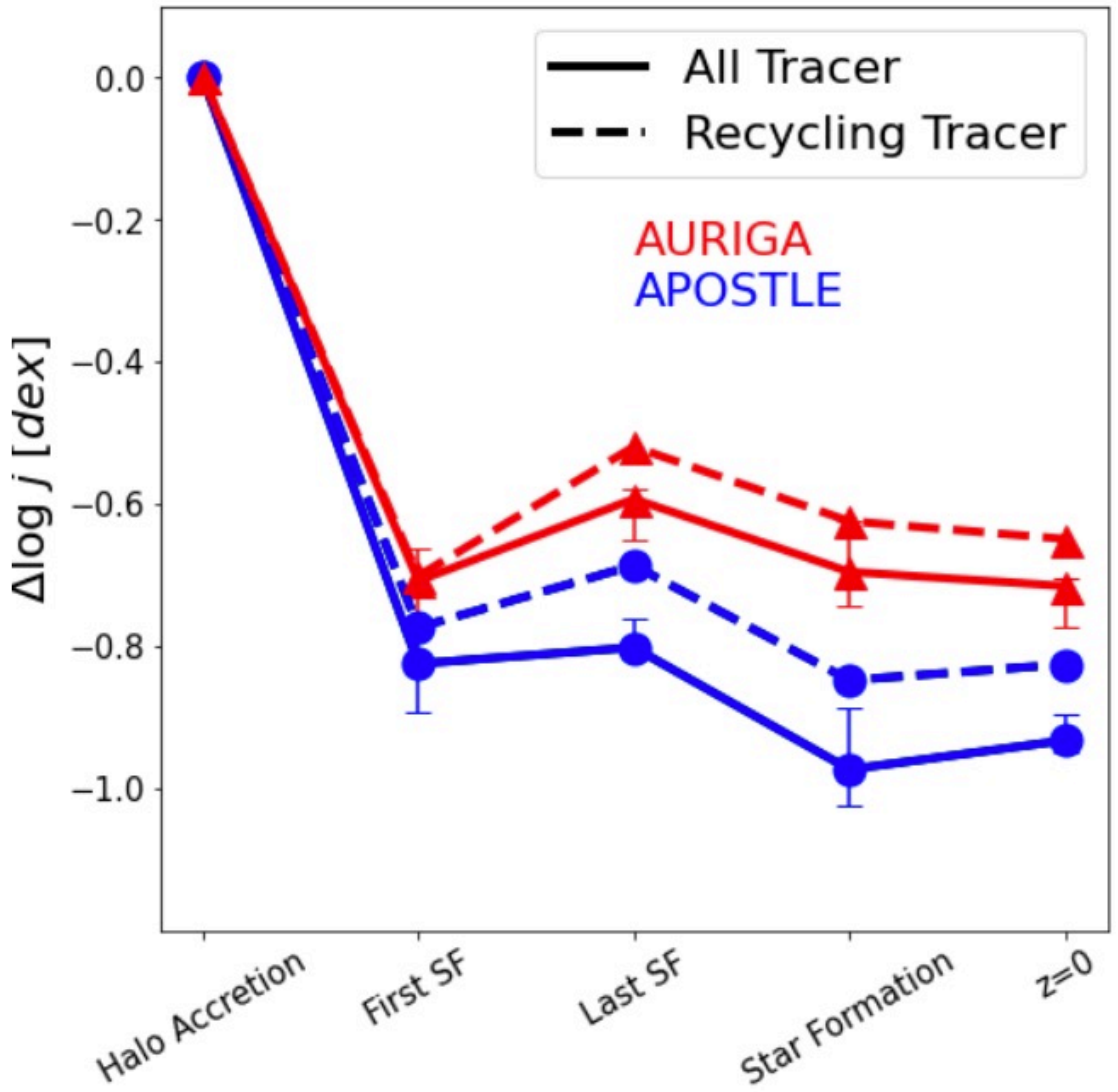
(Yang+, to be submit)

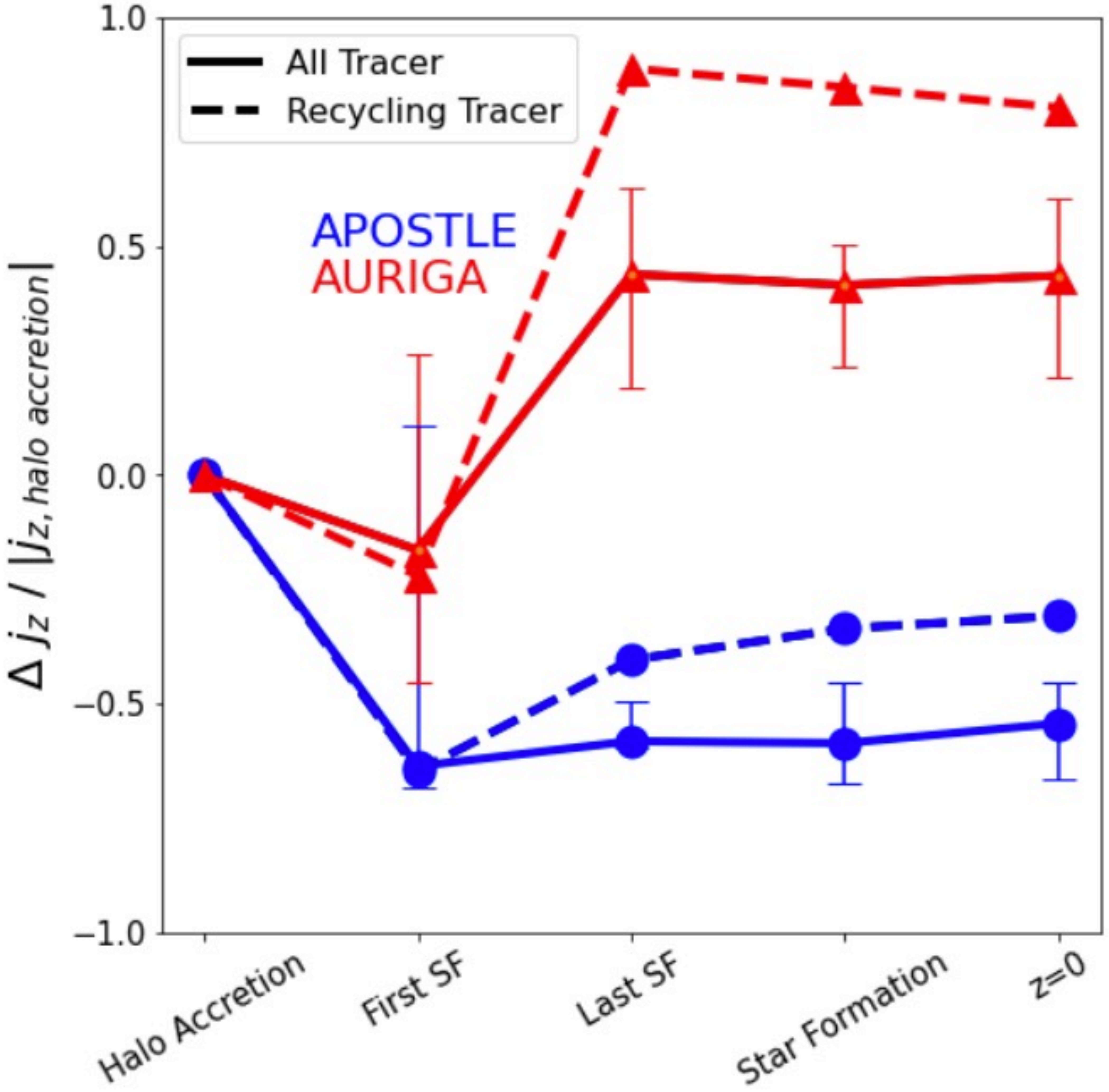
Angular Momentum Evolution in Two Simulations



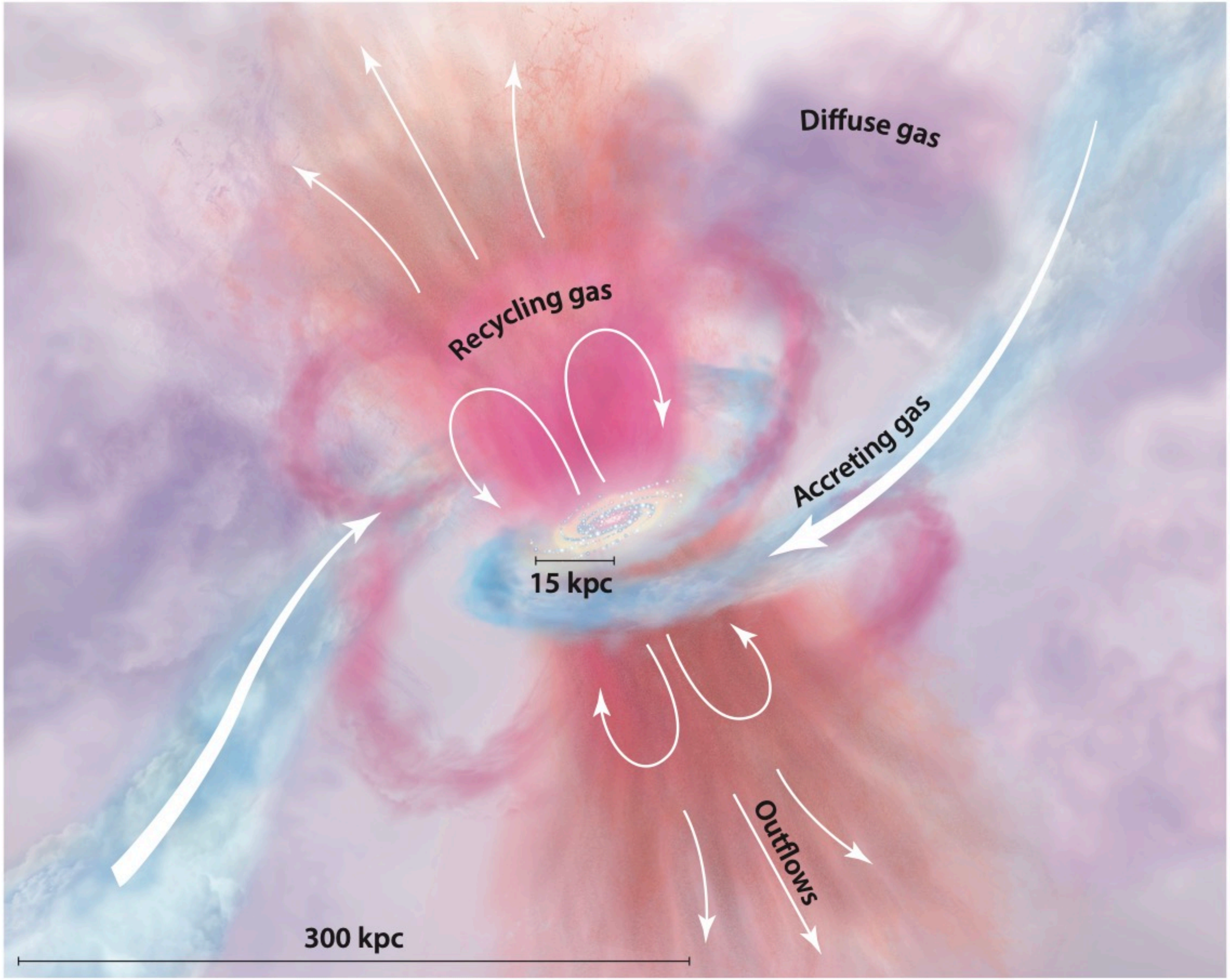
(Yang+, to be submitted)

Angular Momentum Evolution in Two Simulations





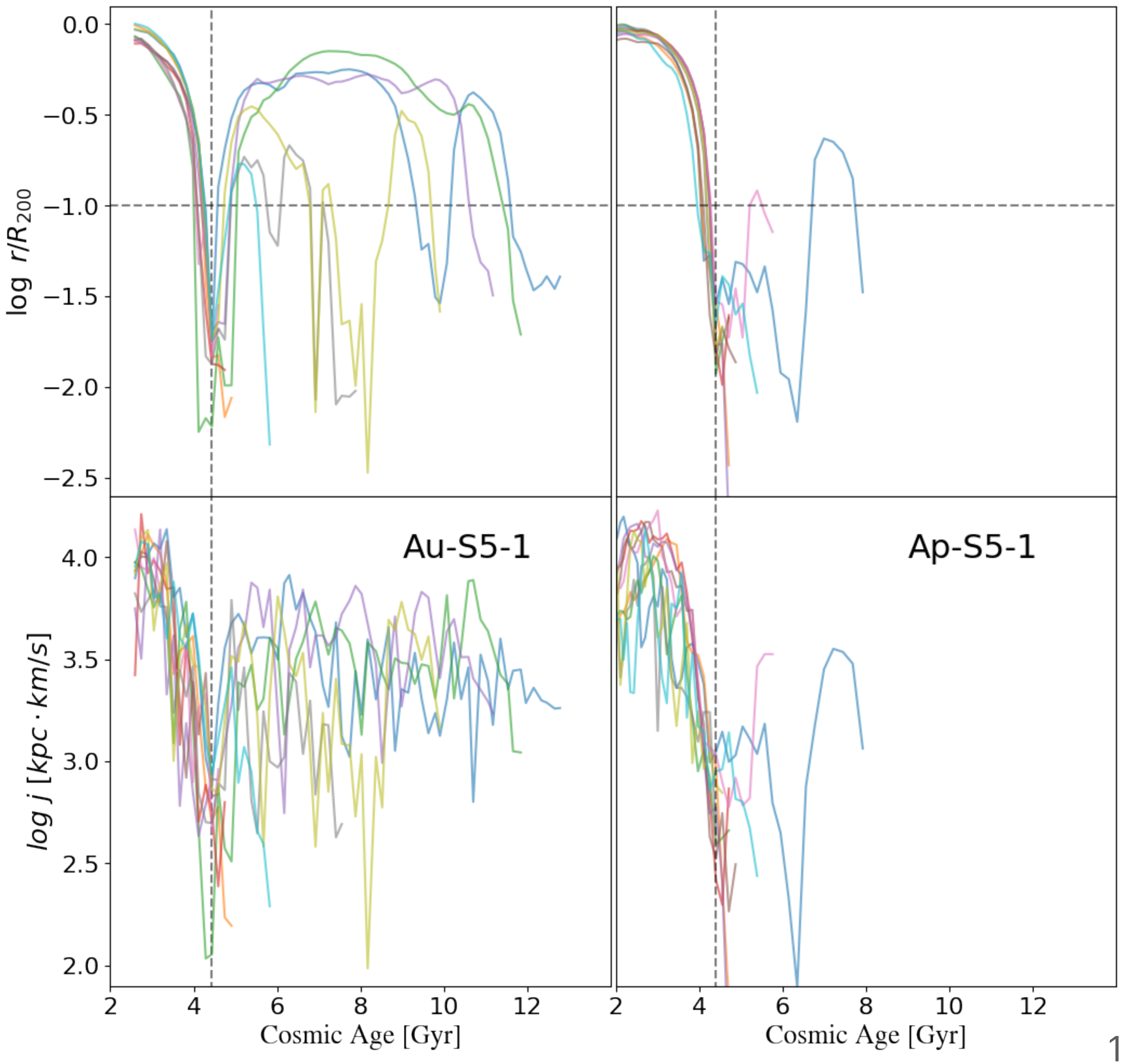
(Yang+, to be submitted)

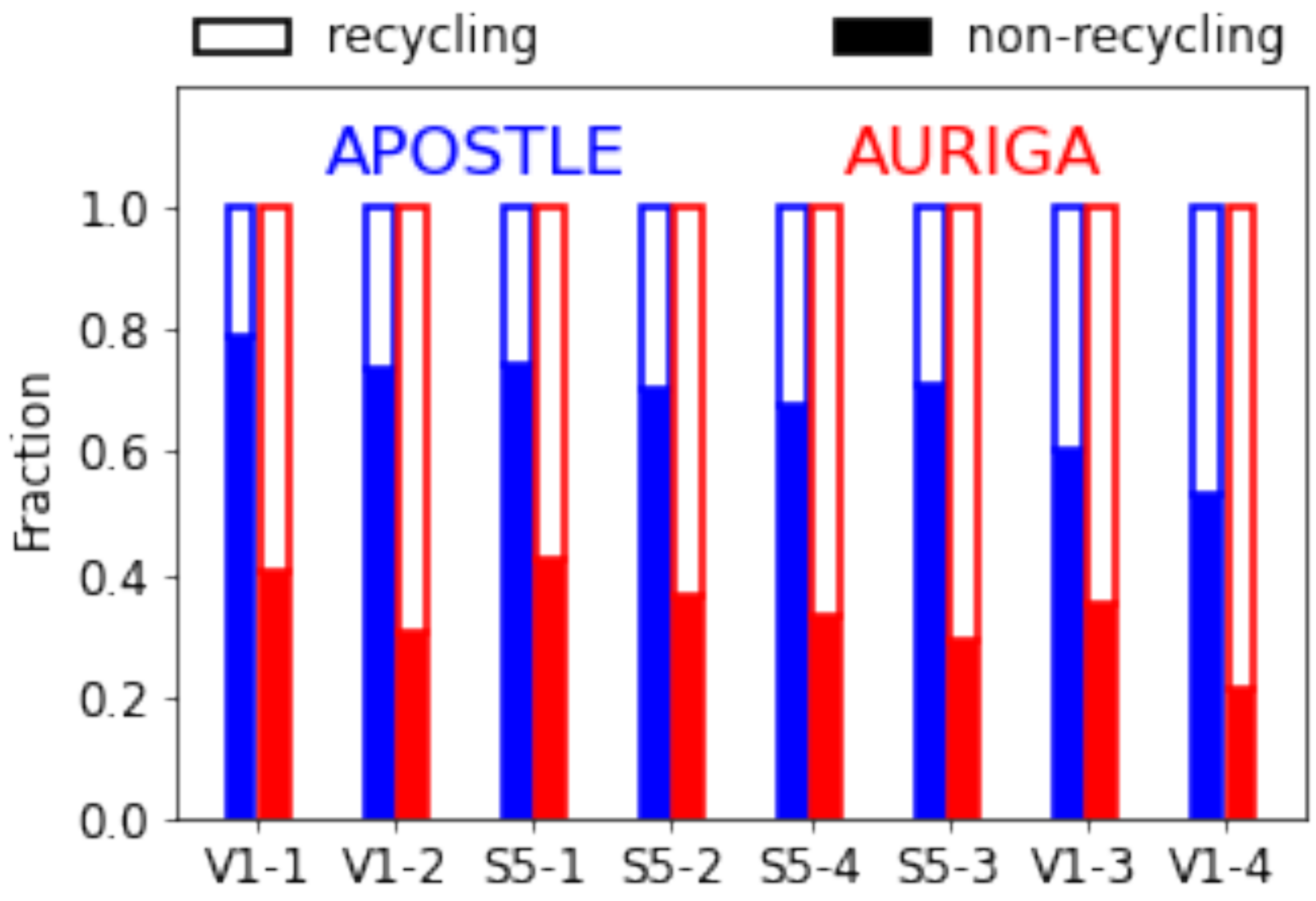


Baryon Recycling for a example

(Tumlinson+, 2017)

Baryon Re-cycling and Fountain Flow

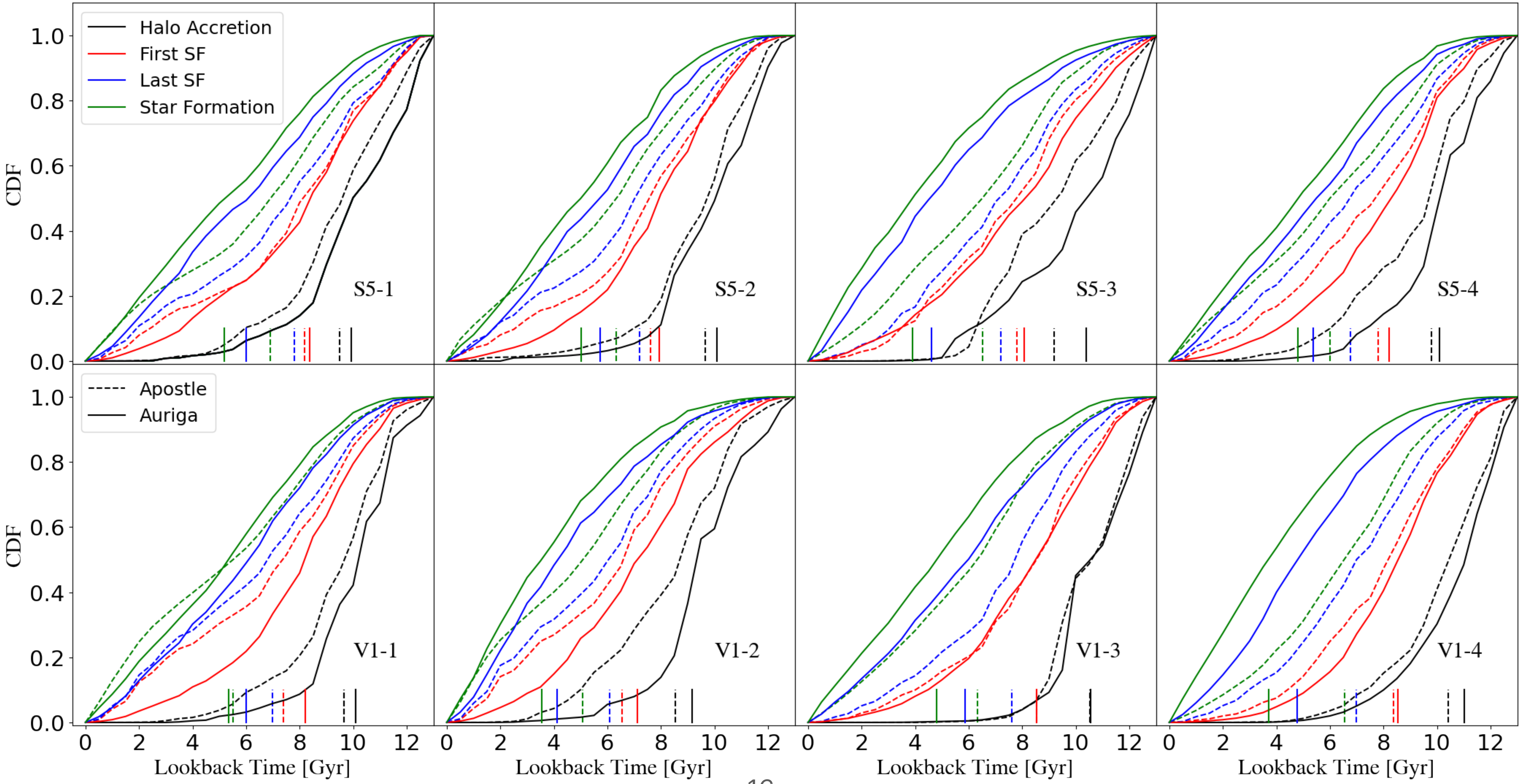




- The recycling efficiency is different in Auriga (Illustris family) and Apostle (Eagle family) simulation.

(Yang+, to be submitted)

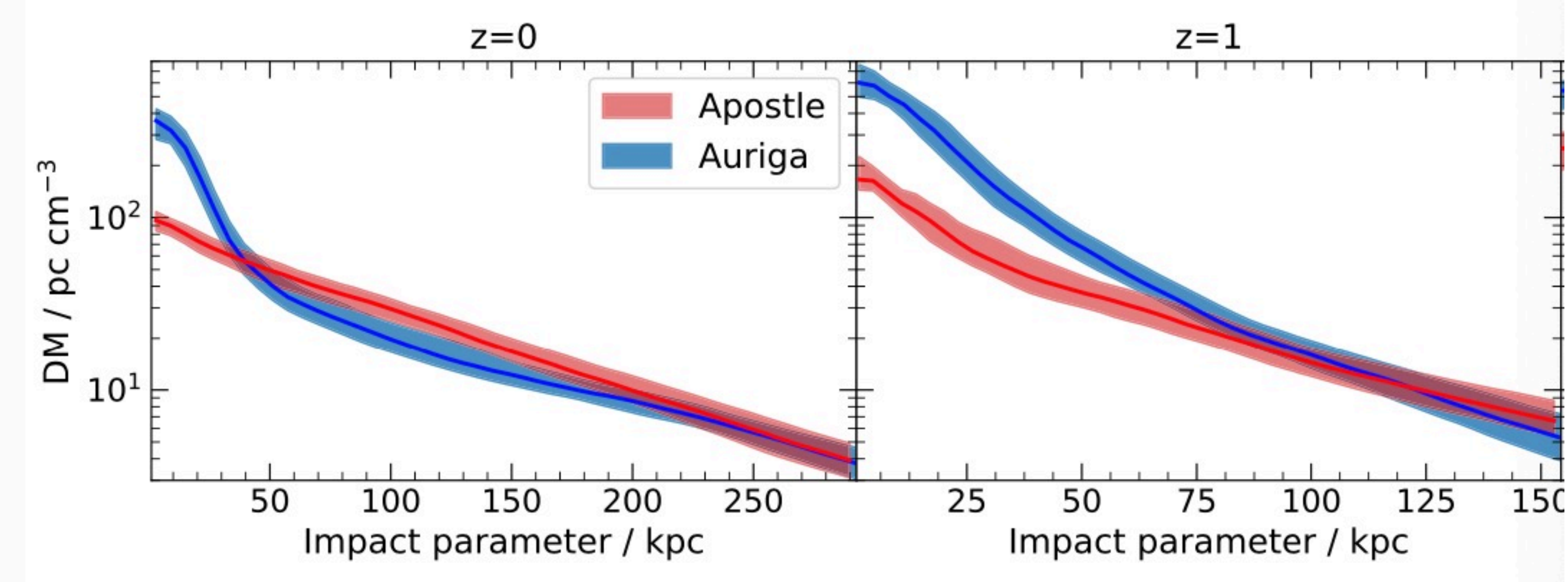
The Time Distribution



Summary

- We find that there is galaxy size—halo spin relation in Eagle family and IllustrisTNG family. However, the relevance in different simulations are divergent. (Yang+, 2023MNRAS.518.5253; arXiv:2110.04434)
- The gas which eventually make up the stellar composition have the similar initial angular momentum distribution. The higher baryon recycling efficiency in the AURIGA simulation leads to galaxies with higher angular momentum magnitude and alignment than in the APOSTLE simulation.

FRB Observation



- (Kelly+, 2022)

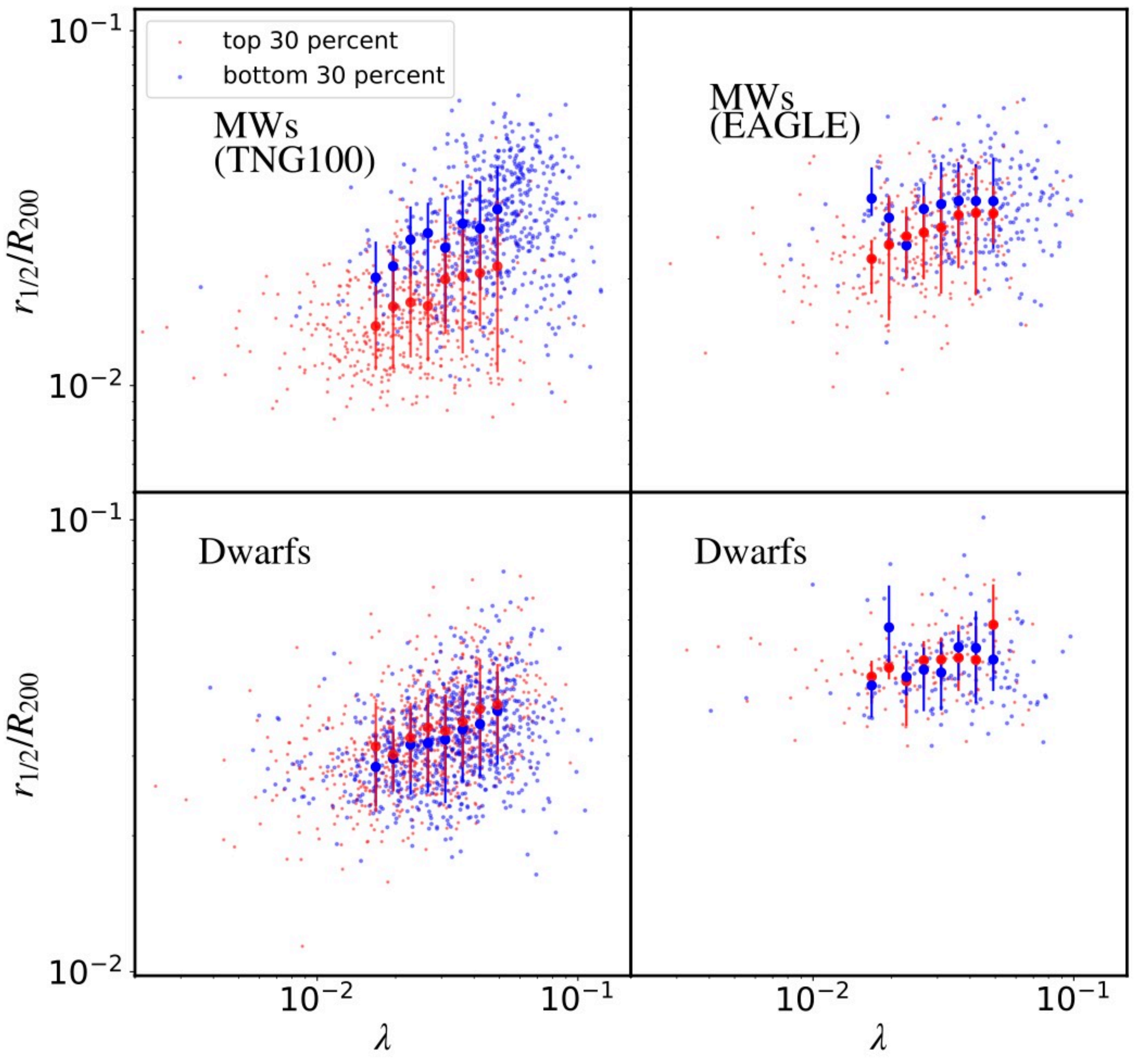


Figure A1. $r_{1/2}/R_{200}$–λ relation of MWs (top panels) and disk dwarfs (bottom panels) in IllustrisTNG (left panels) and EAGLE (right panels). The red and blue dots represent large and small concentration samples, respectively. The thick points and error bars show median value and 1σ scatter for the corresponding samples.

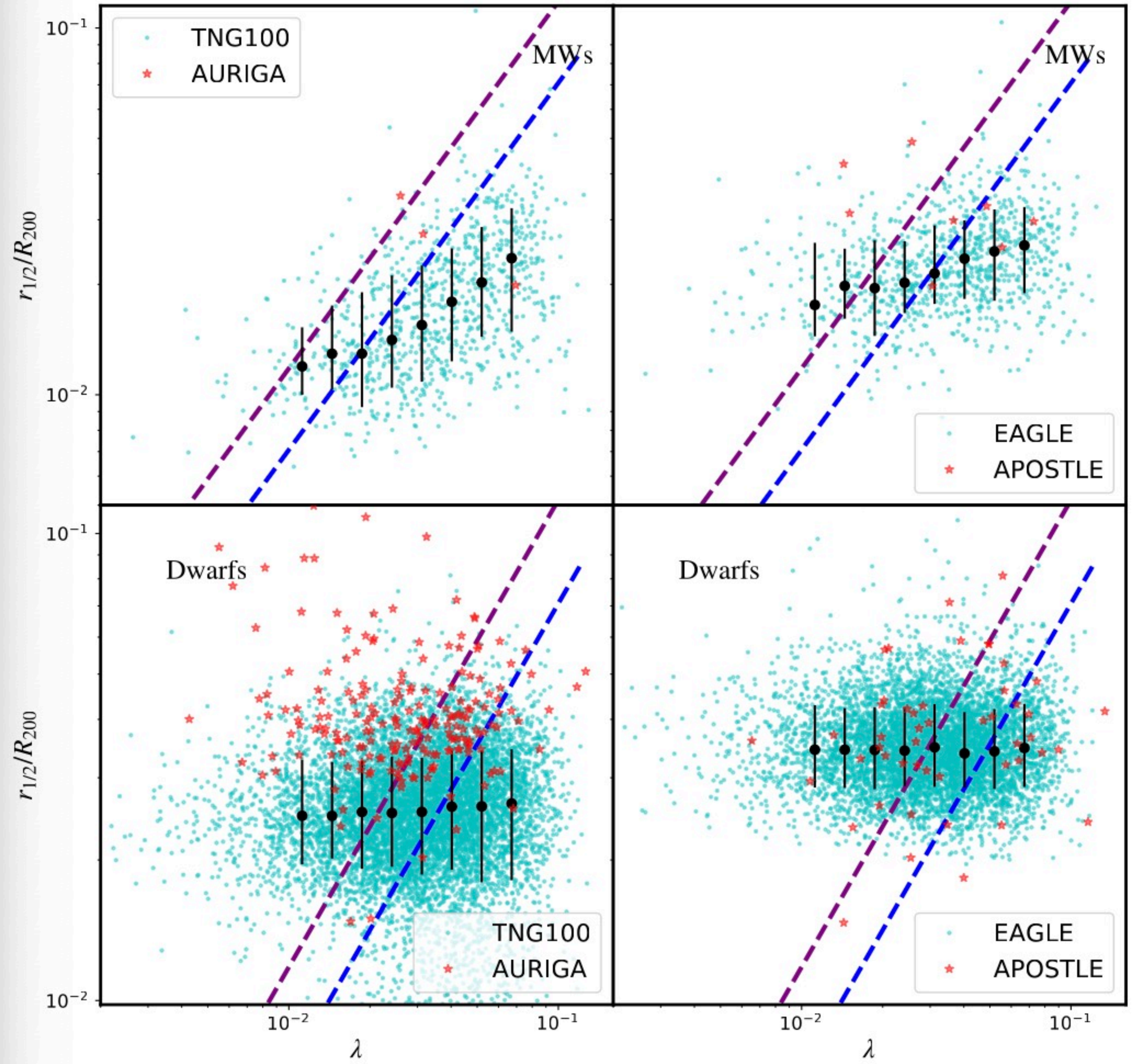


Figure 5: The size ratio–spin relation for spheroid-like galaxies.