Quantifying the stellar ages of dynamically-separated bulges and disks of CALIFA spiral galaxies

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2nd Shanghai Assembly on Cosmology and Structure Formation

Background

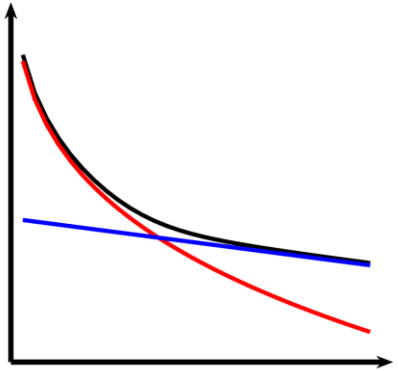
bulge

disk

How these galaxy structures form?

What's the age difference between bulges and disks?

Does this has relation with galaxy fundamental properties?

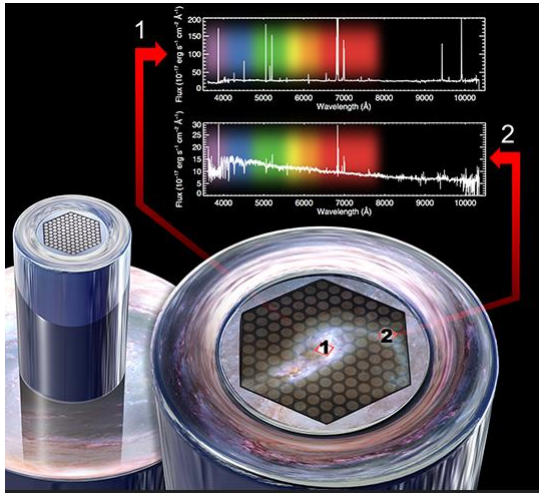


photometric bulge-disk decomposition

different surface brightness profiles

Background

IFS surveys → spectra across the entire face of target galaxies



stellar kinematics (V, σ...)
stellar population (t, Z...)
Population-orbit superposition method

Surveys based on MUSE
high resolution
individual galaxies
(Poci+2019,2021, Zhu+2020,2022a,b, Ding+2023)
Yuchen's talk this morning / Ling's previous talk

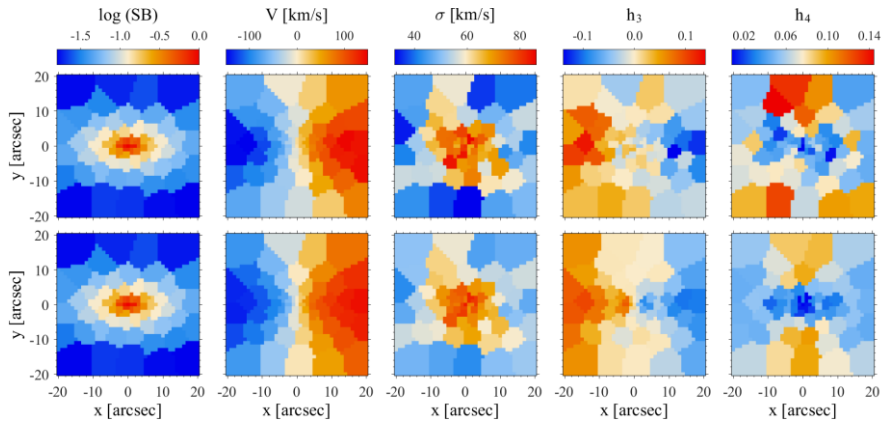
MaNGA, CALIFA, SAMI, …
medium resolution
large samples
This work

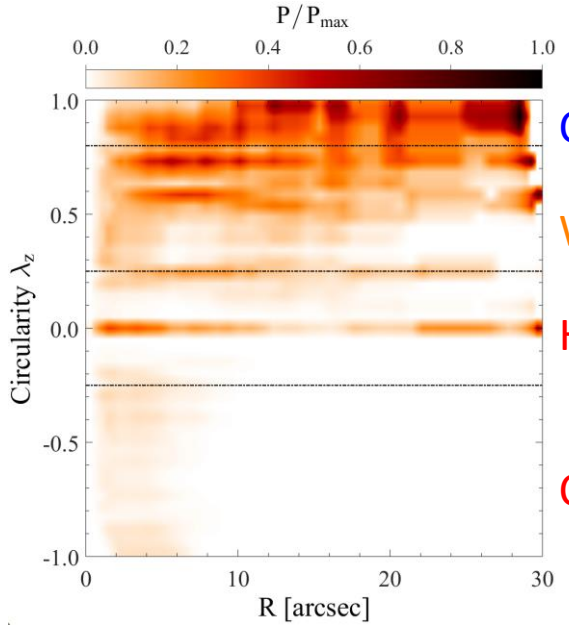
The population-orbit superposition method

① Obtain the stellar orbit distributions by fitting SB and kinematic maps

Observation

Model





Cold → Dynamical disk

Warm

Hot → Dynamical bulge

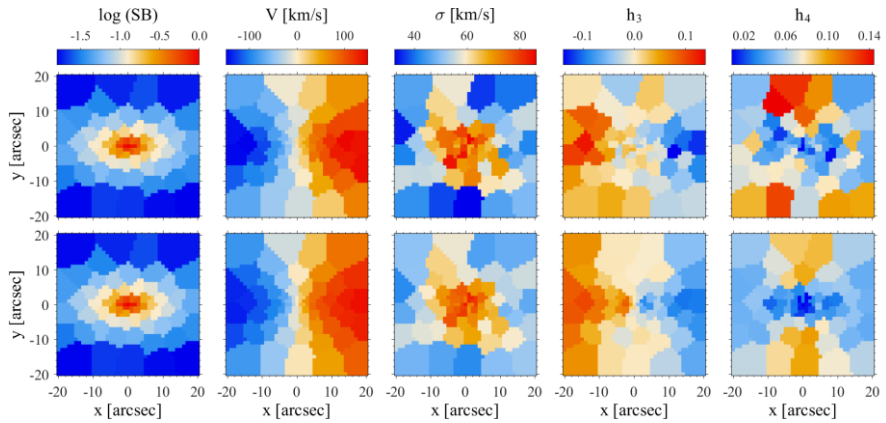
CR → Dynamical bulge

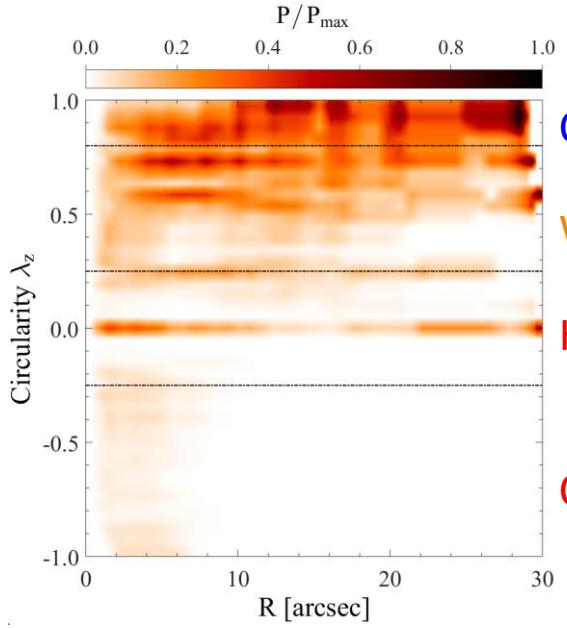
The population-orbit superposition method

① Obtain the stellar orbit distributions by fitting SB and kinematic maps

Observation

Model





Cold → Dynamical disk

Warm

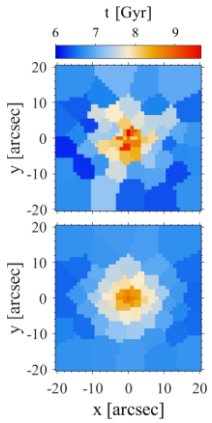
Hot → Dynamical bulge

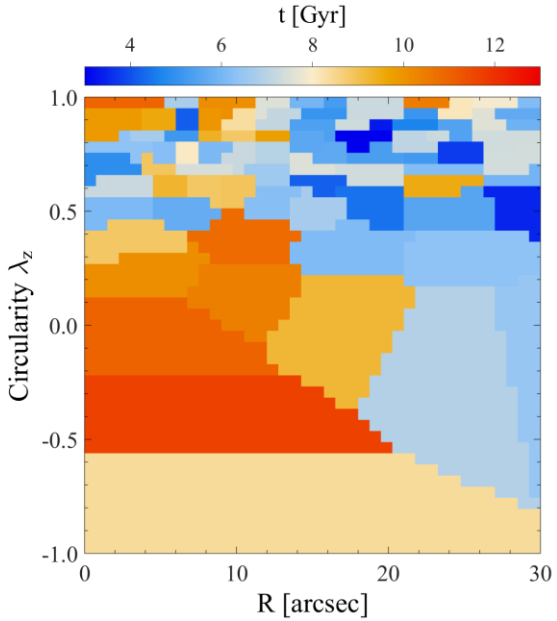
CR → Dynamical bulge

② Tagging the stellar orbits with ages by fitting the age map

Observation

Model





The ages of cold/warm/hot+CR components

Disk age

Bulge age

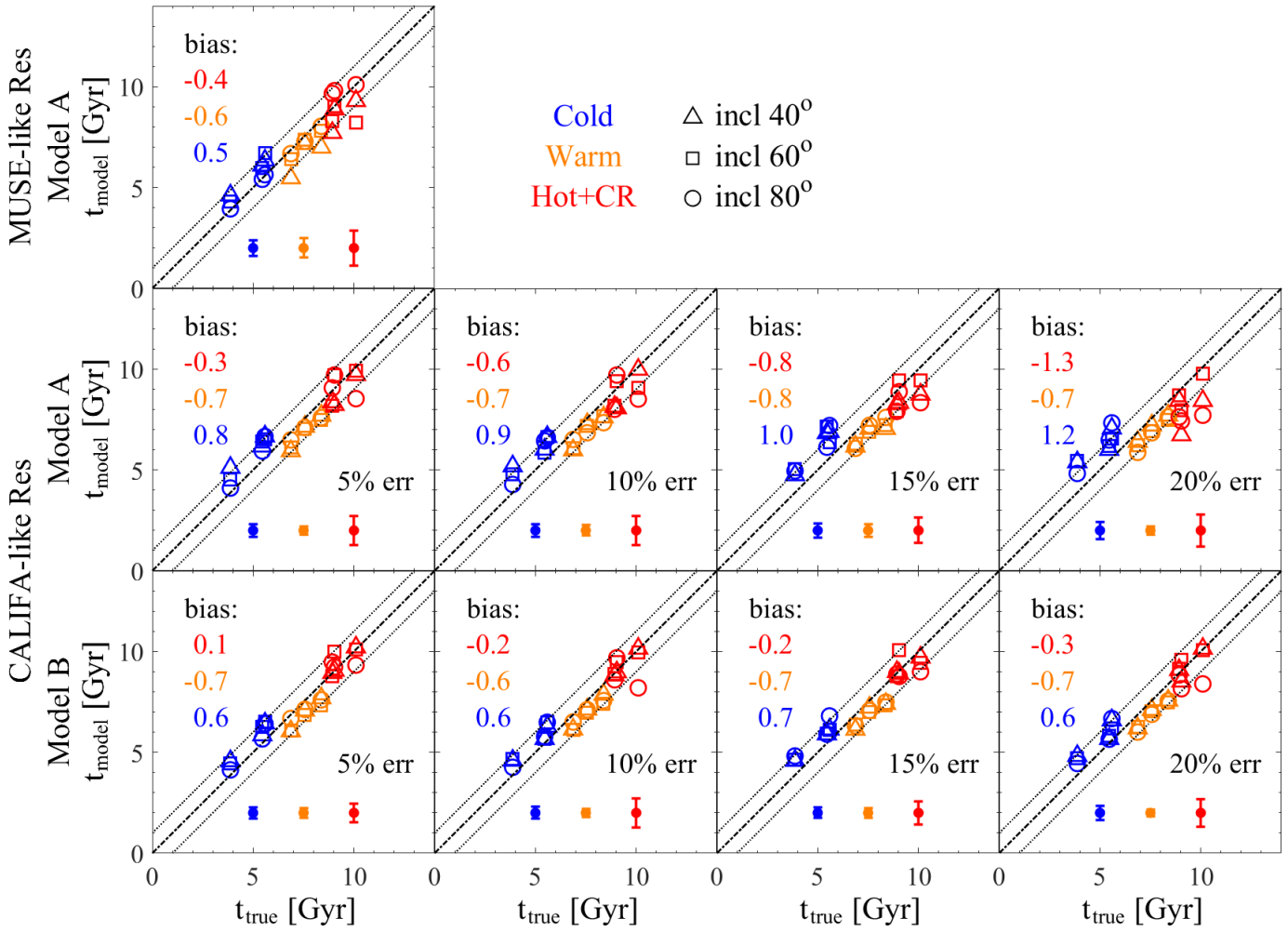
Method validation

3 simulated spiral galaxies from Auriga, each with 3 different viewing angles

Original model (Model A)
MUSE-like mock data
(Zhu+2020)
Bias < 0.6 Gyr

Original model (Model A)
CALIFA-like mock data
Bias > 1.2 Gyr

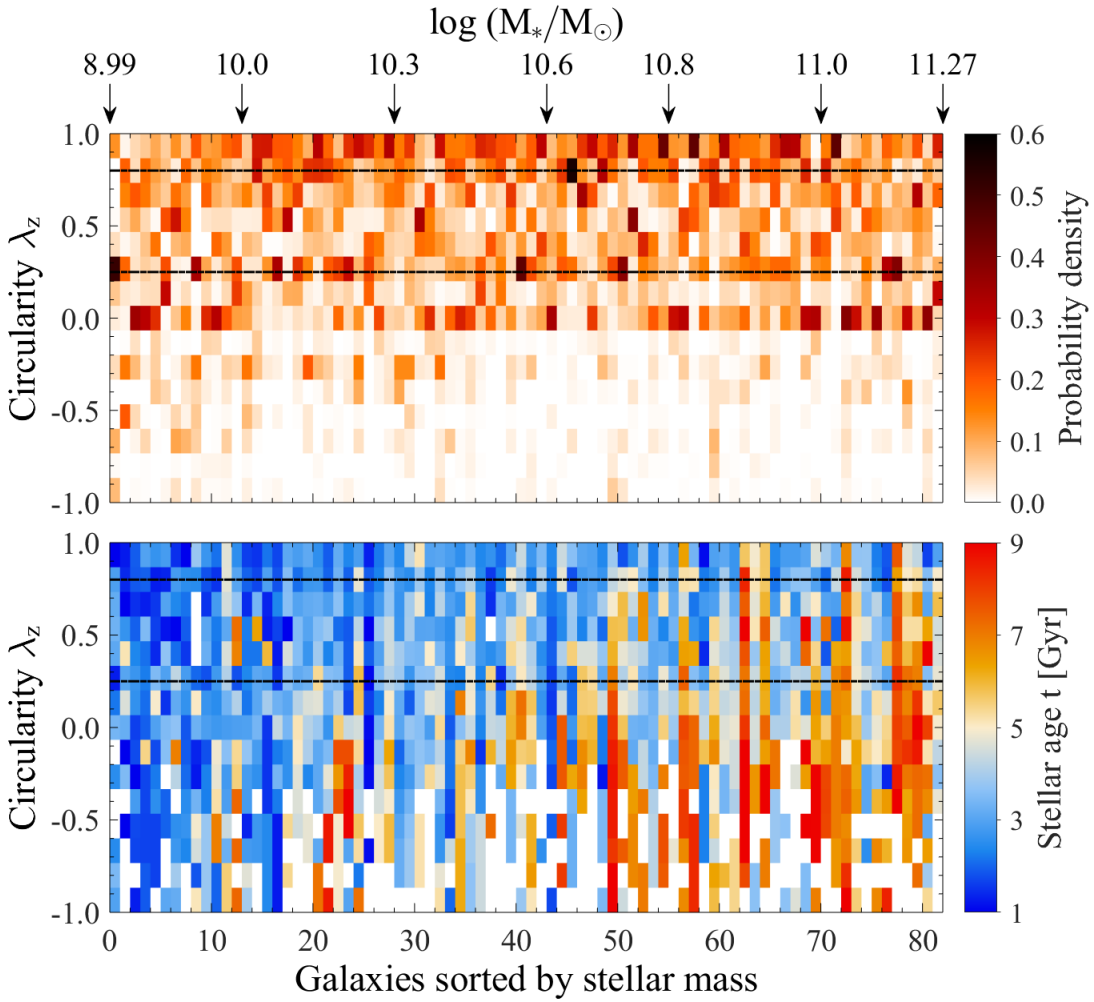
Revised model (Model B)
CALIFA-like mock data
Bias < 0.7 Gyr



CALIFA Results

Apply to 82 CALIFA spiral galaxies

stellar mass: $10^{8.9}\sim10^{11.3}M_{sun}$



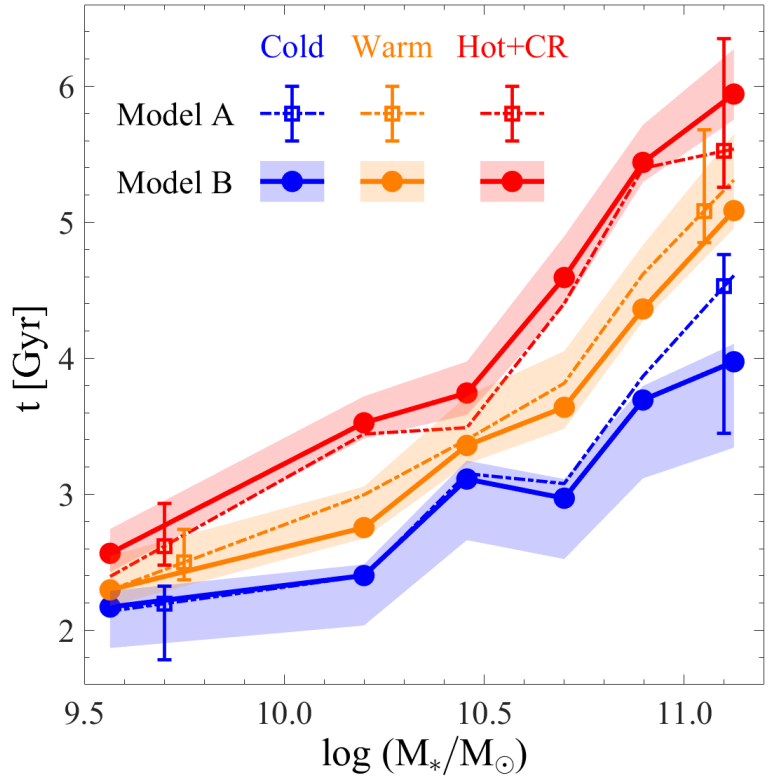
Stellar orbit distributions P(λz)

Stellar age t

Bulge ↓ Disk ↓

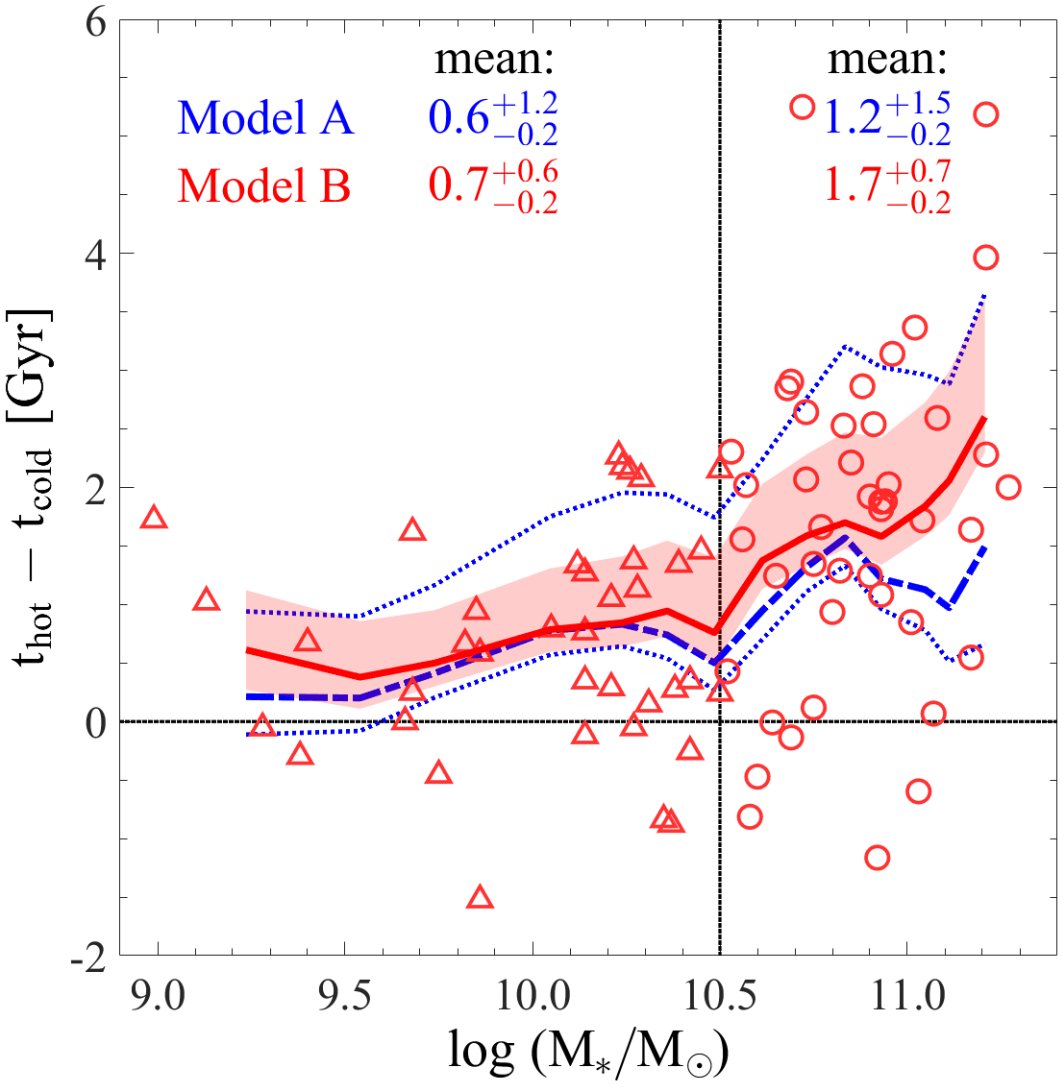
- t(hot+CR)>t(warm)>t(cold)
- t(hot+CR), t(warm), t(cold) all increase with stellar mass
- The increase of t(hot+CR) is faster than t(cold)

Binned ages of different components



CALIFA Results

Age differences between dynamical bulges and disks



$M_* \sim 10^{10.5} M_{sun}$:

the increase of t(hot+CR)-t(cold) become rapid

Lower mass spirals ($M_* \leq 10^{10.5} M_{sun}$):

young bulge + young disk

→ form at intermediate redshift

→ assembled right after the formation of bulges experienced longer period of star formation

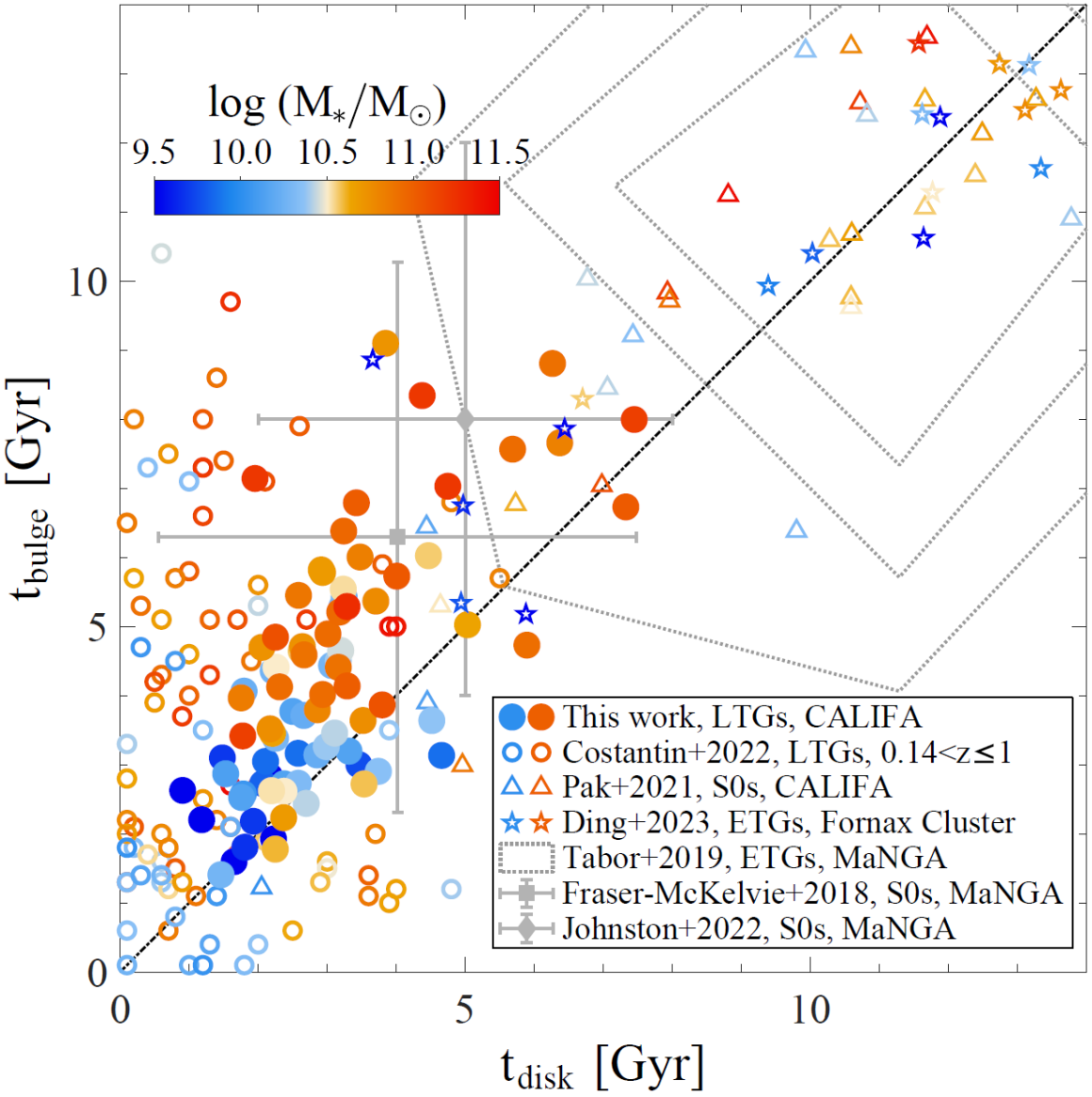
Higher mass spirals ($M_* > 10^{10.5} M_{sun}$):

old bulge + young disk / old disk

→ form at high redshift

→ different star formation histories various merger histories

Bulge versus disk stellar ages



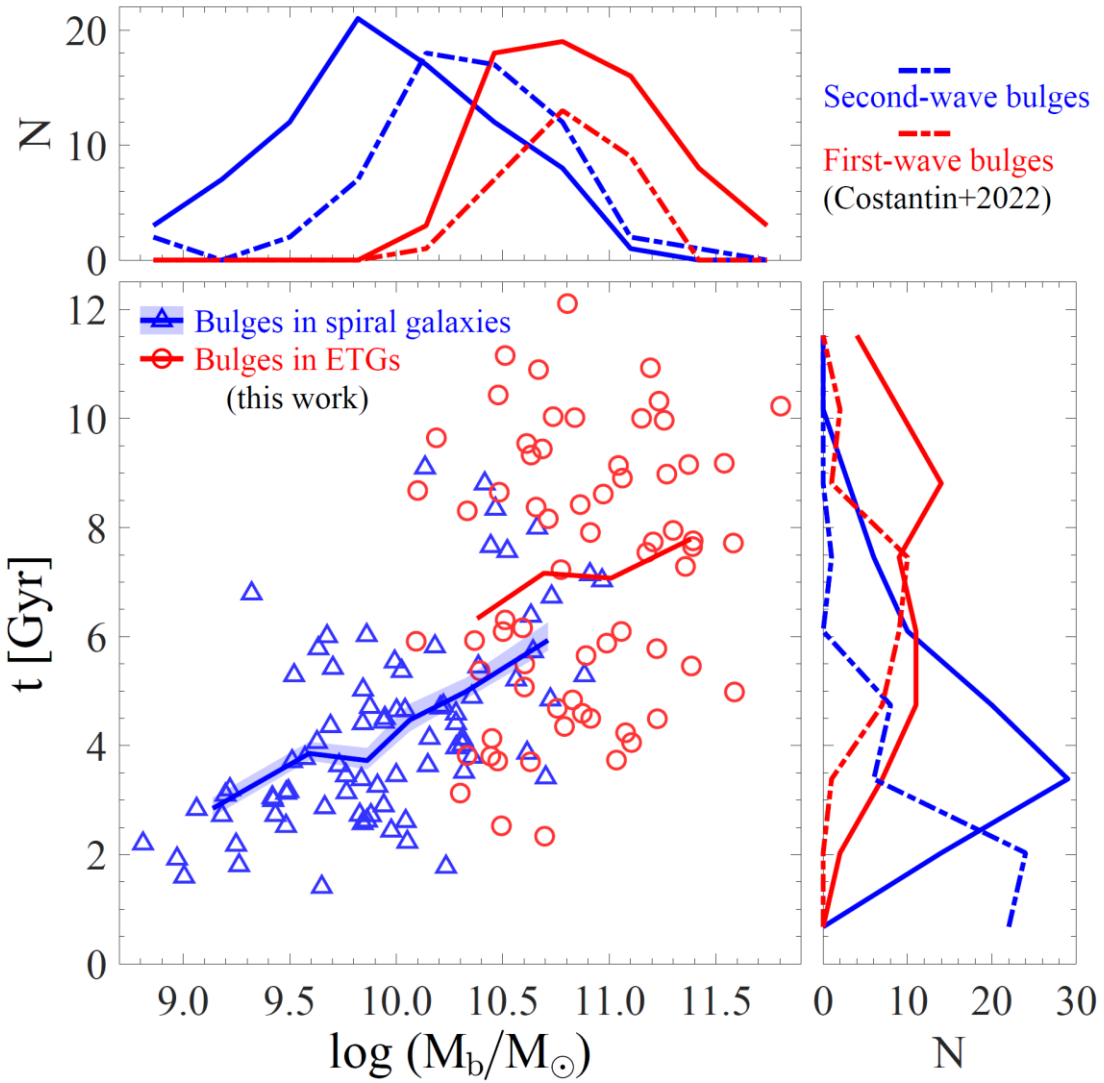
Spiral galaxies in CALIFA/higher redshift:
most galaxies have bulges older than disks
t(bulge)-t(disk) increase with stellar mass

S0 galaxies in MaNGA/CALIFA:
bulges are slightly or 2~3 Gyr older than disks

Early-type galaxies in MaNGA:
similar bulge ages and disk ages

Early-type galaxies in the Fornax cluster:
ancient infallers: similar bulge ages and disk ages
recent infallers: bulges are ~ 2 Gyr older than disks
(Yuchen's work)

Bulge stellar age versus bulge mass



This work (z≈0):
82 spirals in CALIFA
67 ETGs in CALIFA

similar origins

Costantin+2022 (0.14<z≤1):
spirals with first-wave bulges
spirals with second-wave bulges

similar origins

The bulges display a bimodal distribution of ages

Summary

- We validate the population-orbit superposition method with CALIFA-like mock data, thus can quantify the luminosity fractions and stellar age of different dynamical structures.

- We apply the method to 82 CALIFA spiral galaxies, and find:

(1) Both the dynamical disks and bulges are older in more massive galaxies.

(2) The bulges are older than disks in ~80% CALIFA spiral galaxies, with their age difference become larger in more massive galaxies.

(3) Combining 82 spirals with 67 ETGs, the bulges in CALIFA galaxies show bimodality in both stellar age and mass distributions, which is consistent with the two-wave bulge formation (Costantin+2022).

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https://arxiv.org/abs/2310.07201

Thank you!

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