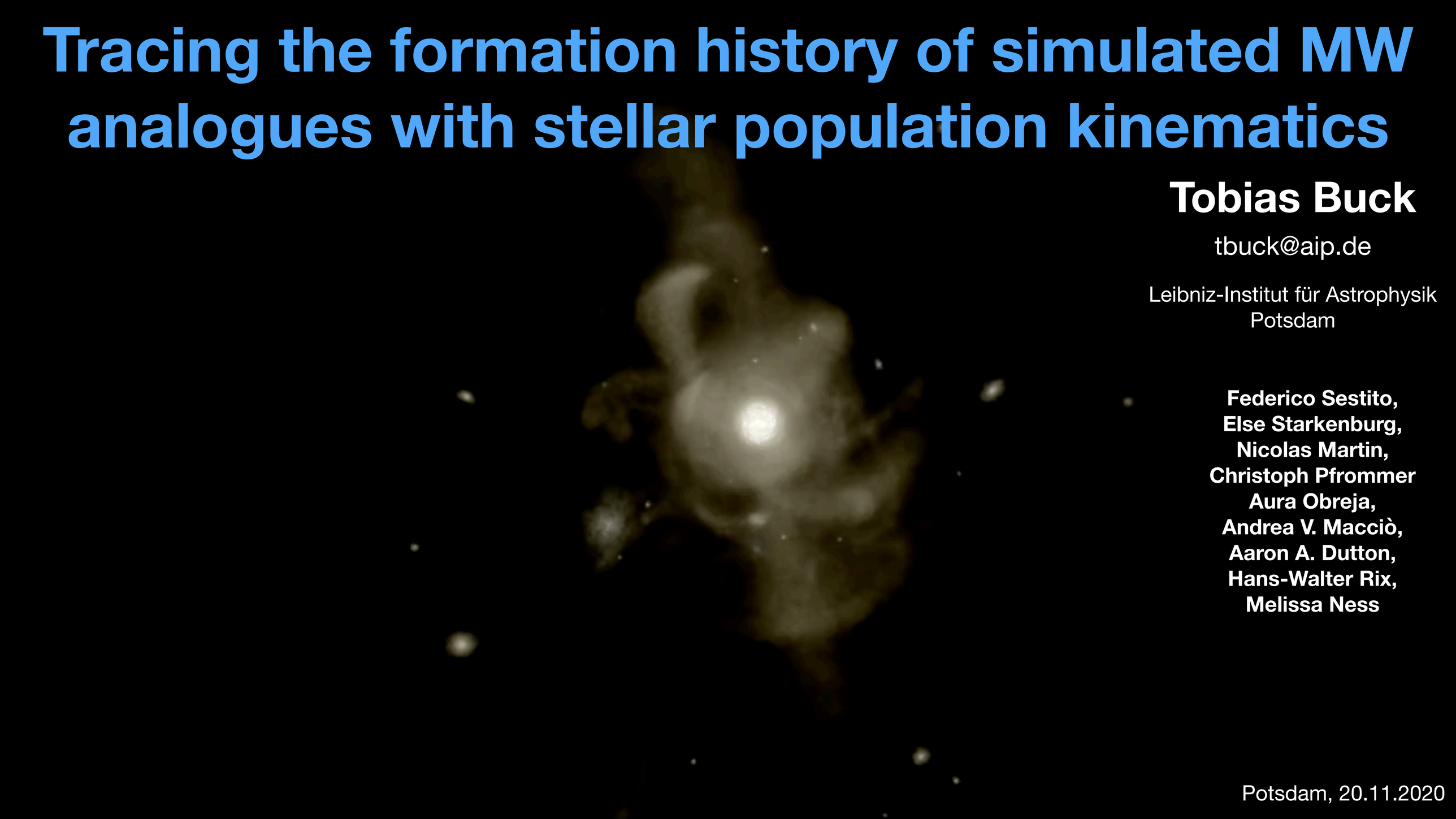
Tracing the formation history of simulated MW analogues with stellar population kinematics



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Potsdam, 20.11.2020

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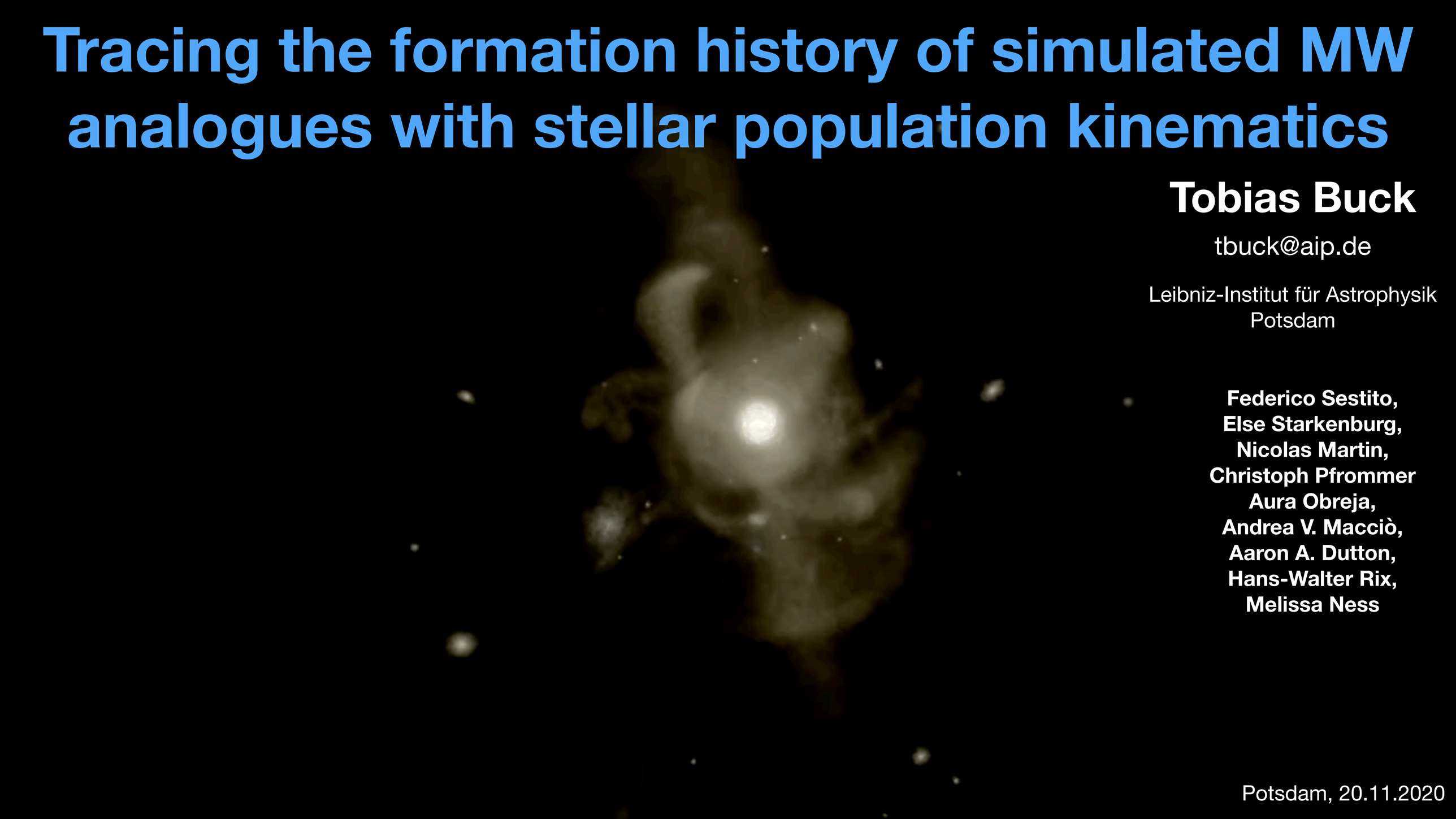

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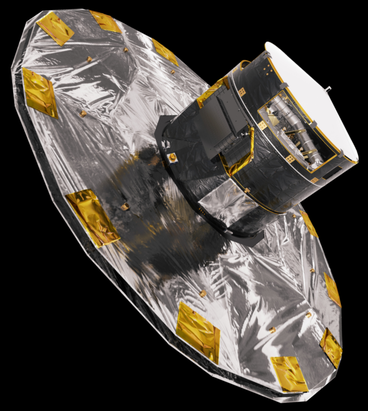
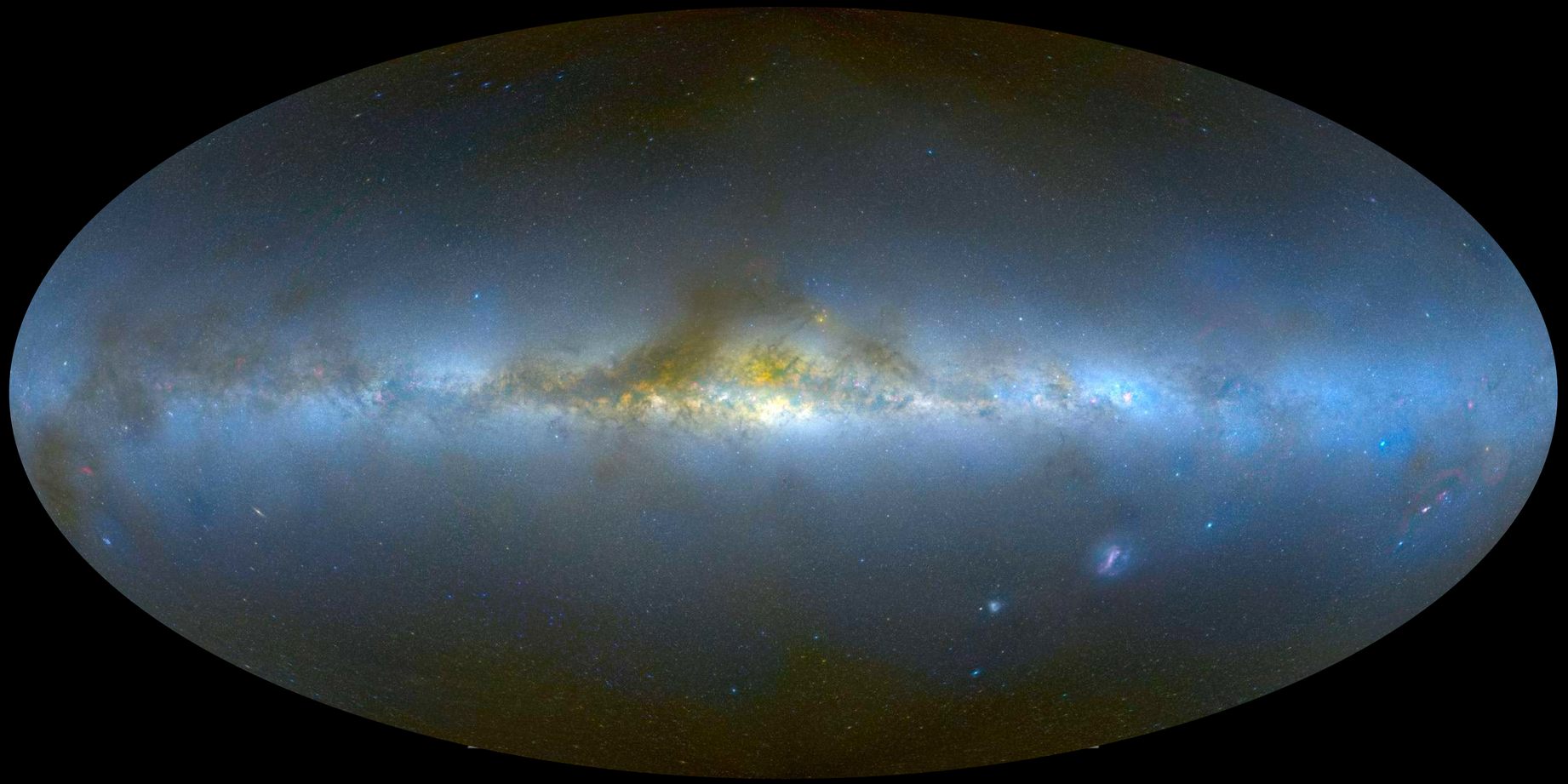
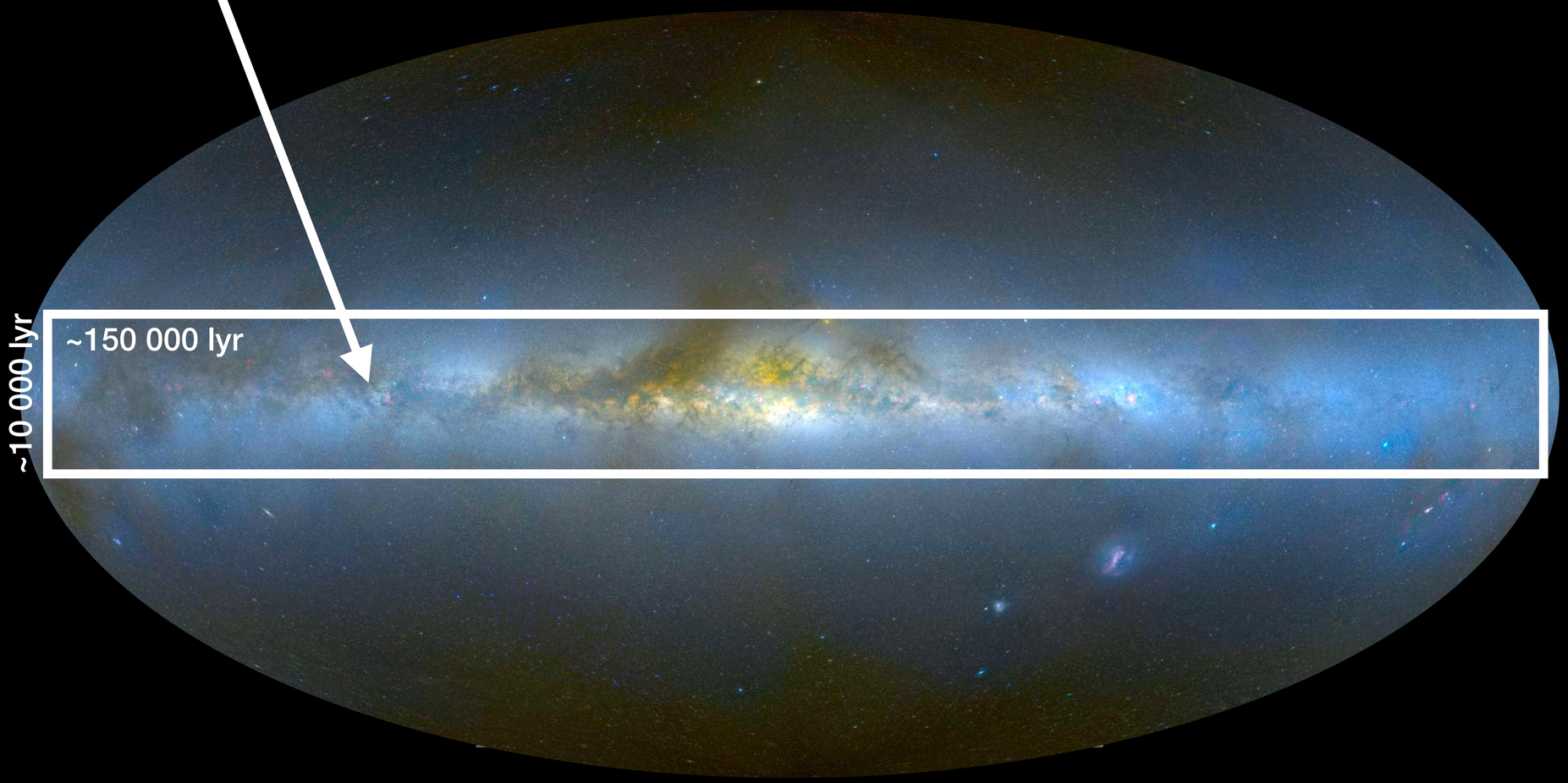


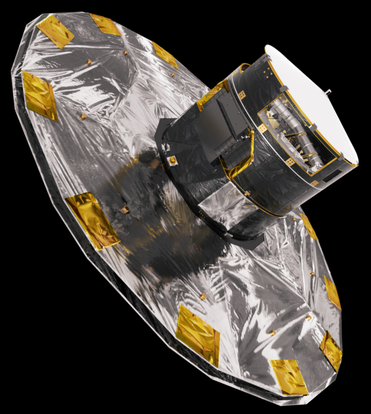
Gaia



Gaia

the stellar disc





Gaia

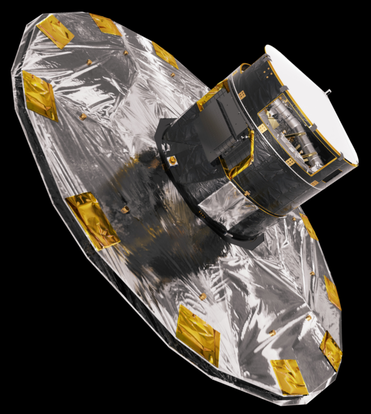
the stellar disc

the bulge

~10 000 lyr

~150 000 lyr

~15 000 lyr



Gaia

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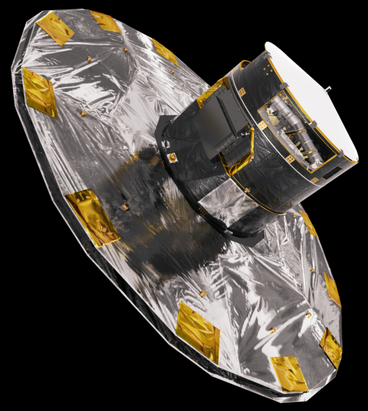
d~200 000 lyr

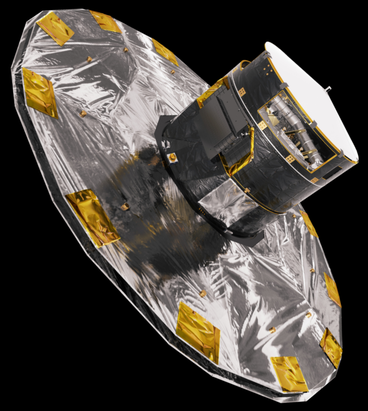
dwarf galaxy population



Gaia

not to scale!

~1 000 000 lyr



Gaia

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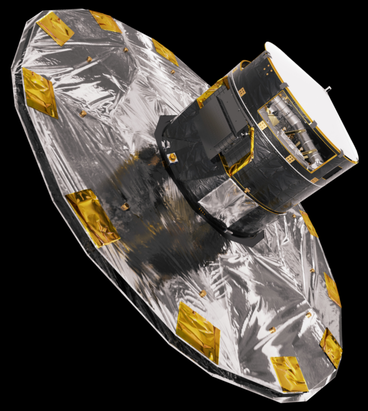


Gaia

How did the Milky Way form?

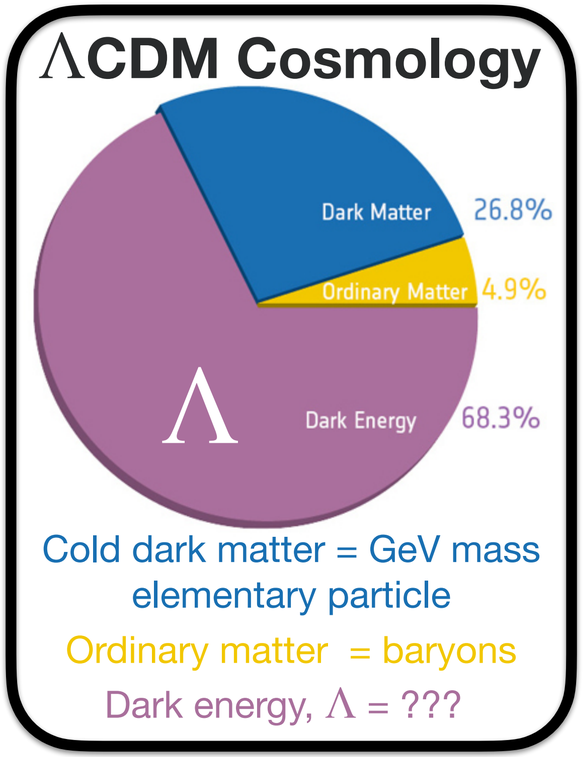
~1 000 000 lyr

How did the Milky Way form?

What can we learn about
Cosmology from the Milky Way?

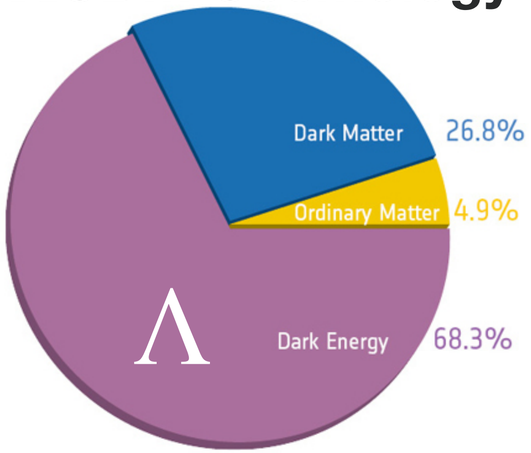
~1 000 000 lyr

A galaxy formation model



A galaxy formation model

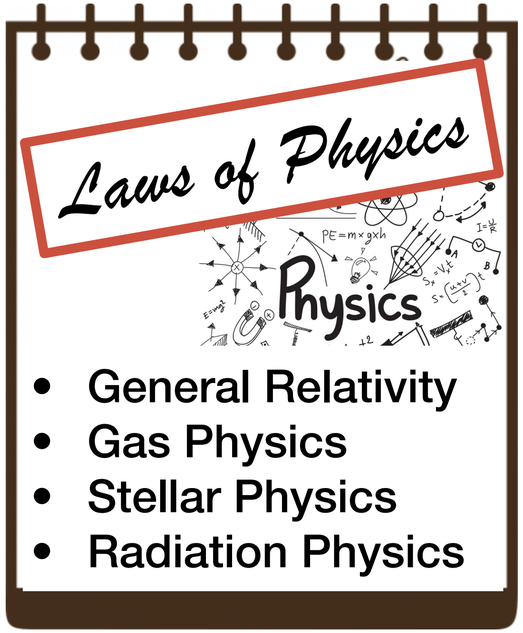
ΛCDM Cosmology



Cold dark matter = GeV mass elementary particle

Ordinary matter = baryons

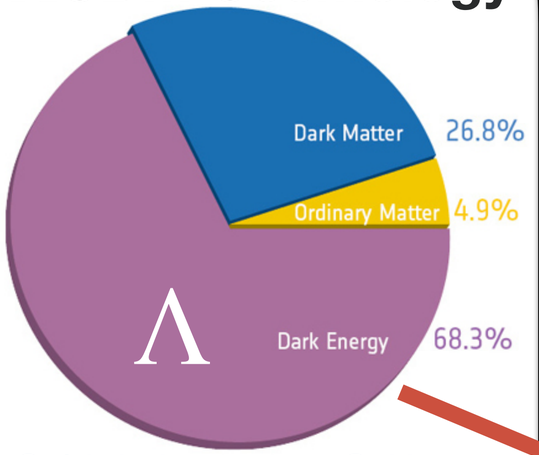
Dark energy, Λ = ???



- General Relativity
- Gas Physics
- Stellar Physics
- Radiation Physics

A galaxy formation model

ΛCDM Cosmology



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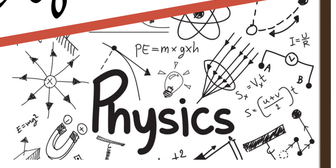
Computer

Laws of Physics



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A galaxy formation model

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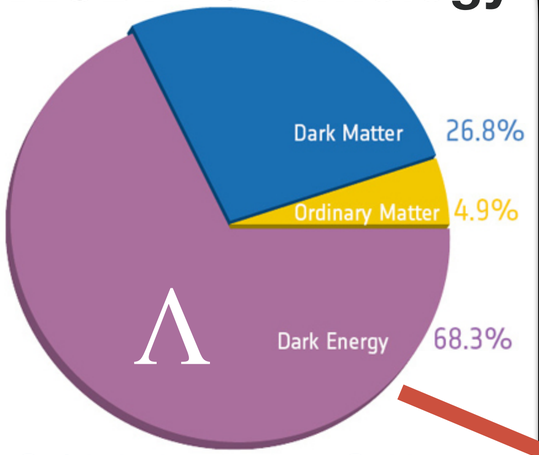

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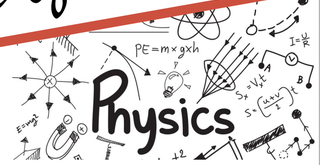

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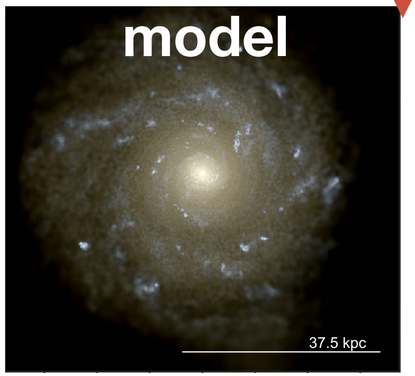

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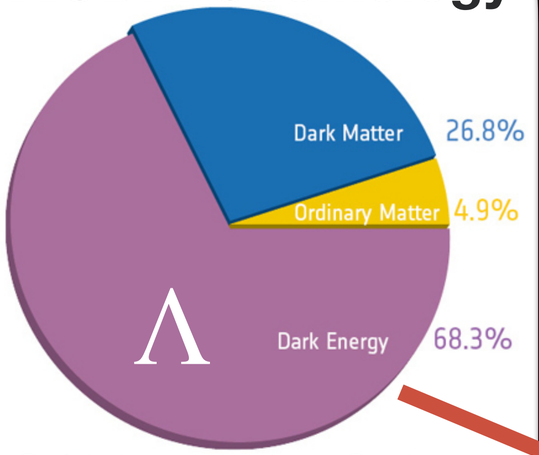

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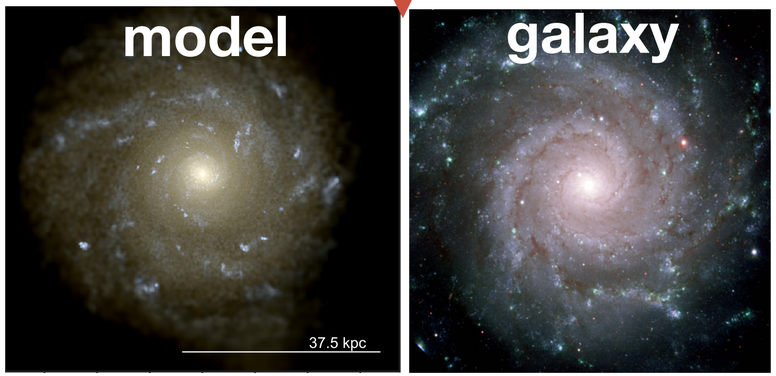

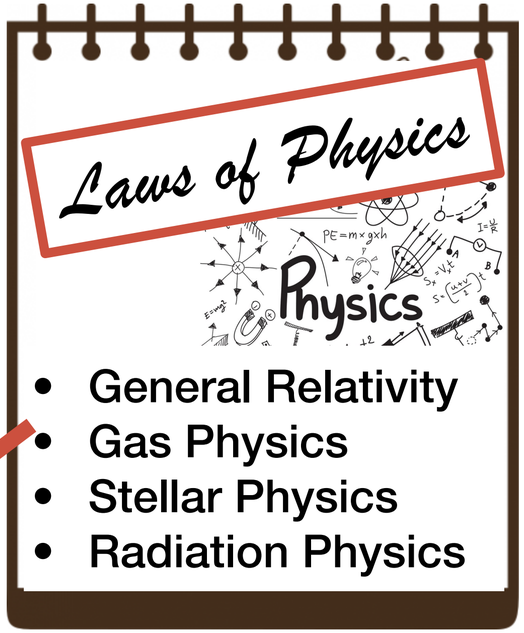

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Simulation Physics

1

GASOLINE2.1
smooth particle hydrodynamics

„modern“ implementation of hydrodynamics, metal diffusion

Wadsley+2017, Keller+2014

2

gas cooling
via hydrogen, helium and various metal lines

gas heating
via Photoionisation (e.g. from the UV background)

Shen+2010, Haardt&Madau 2012

3

self consistent star formation from cold, dense gas + stellar evolution

Stinson+2006

star formation regions

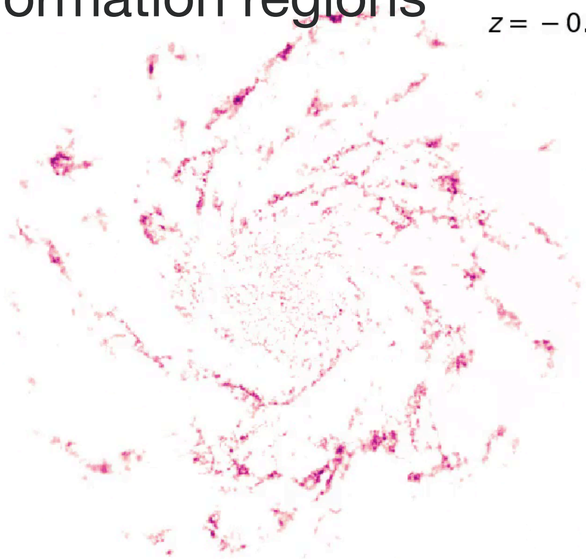

image size: 50x50 kpc

Animation by T. Buck (MPIA, NYUAD) based on NIHAO simulations

Buck+2019a

4

energetic feedback from young massive stars and supernovae

Stinson+2013

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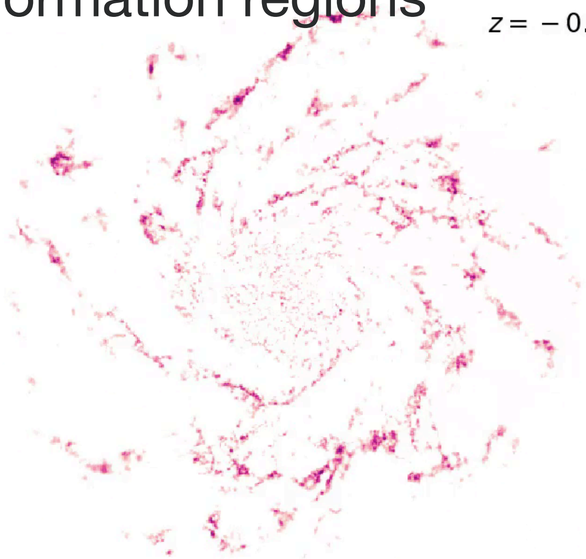

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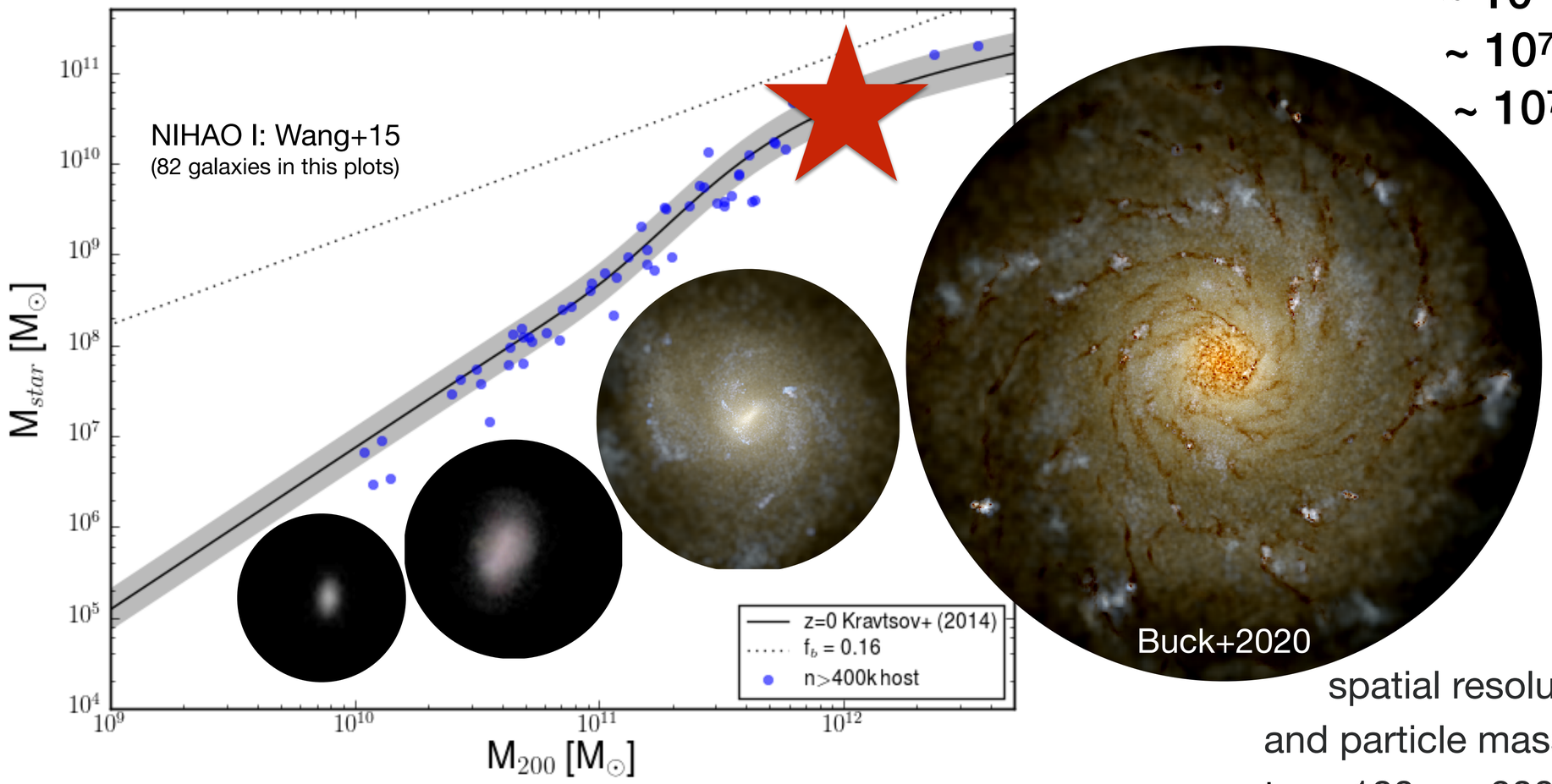
energetic feedback from young massive stars and supernovae

Stinson+2013

Milky Way mass simulations

halo masses: 5 x 10^{11} to 2.8 x 10^{12} M

~ 3x10^7 resolution elements
~ 10^7 star
~ 10^7 gas
~ 10^7 dm

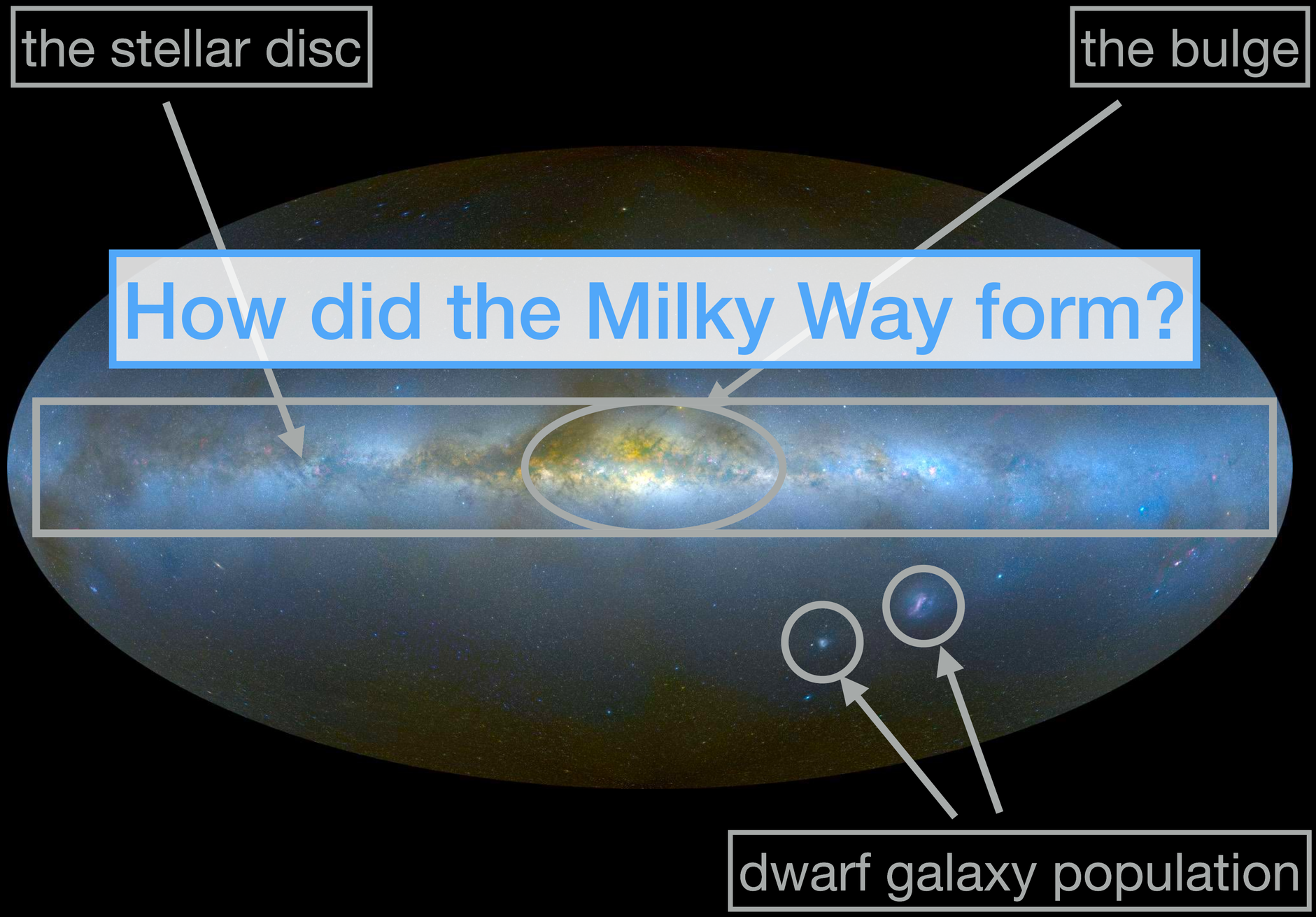


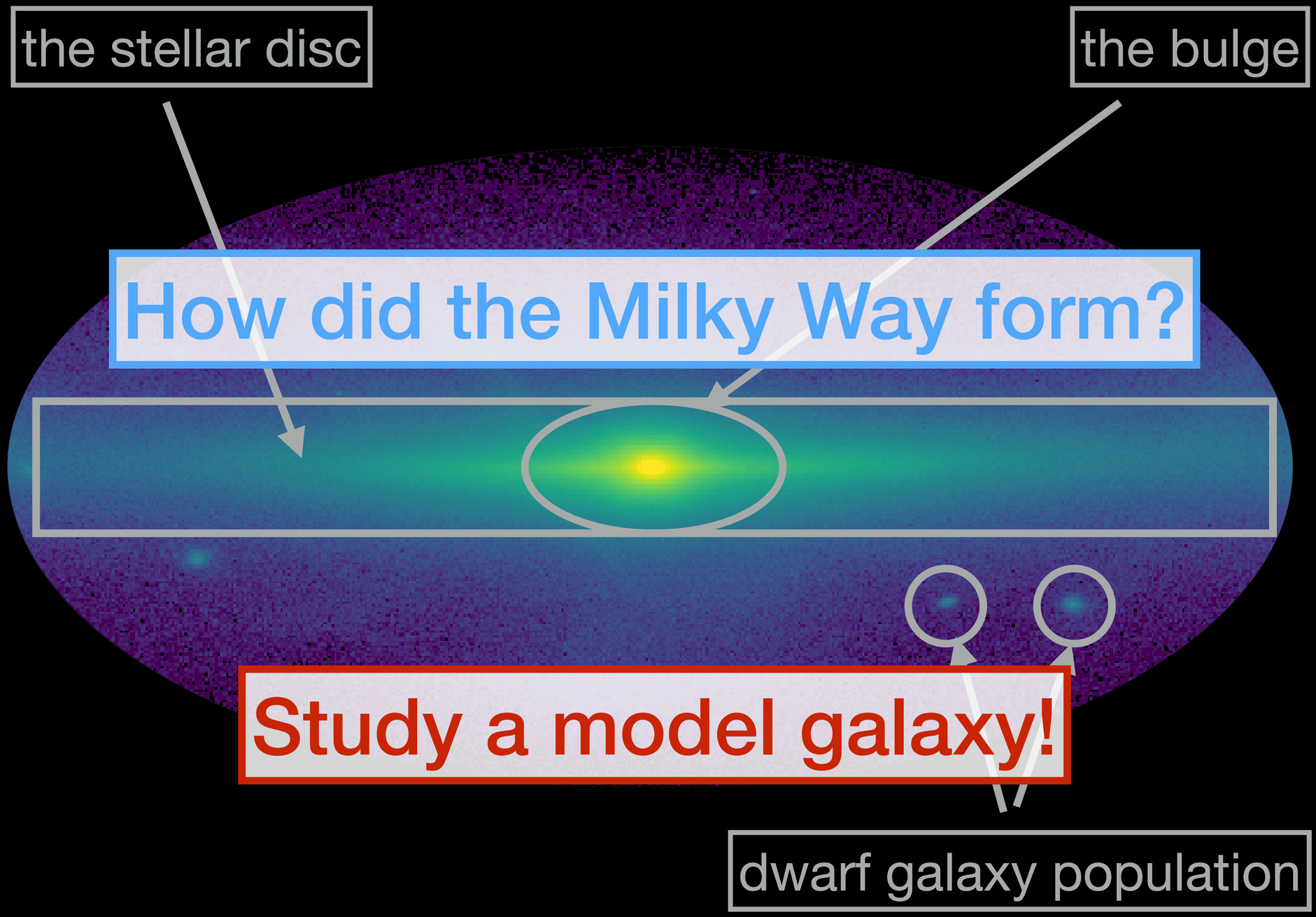
spatial resolution
and particle masses:
stars: 180 pc, 9300 $M_\odot$
gas: 180 pc, 2.8 x 10^4 $M_\odot$
dark matter: 400 pc, 1.5 x 10^5 $M_\odot$

similar projects: Wetzel+2016, Sawala+2016, Grand+2017

Results look pretty realistic!

Buck+2020


the stellar disc
the bulge
How did the Milky Way form?
dwarf galaxy population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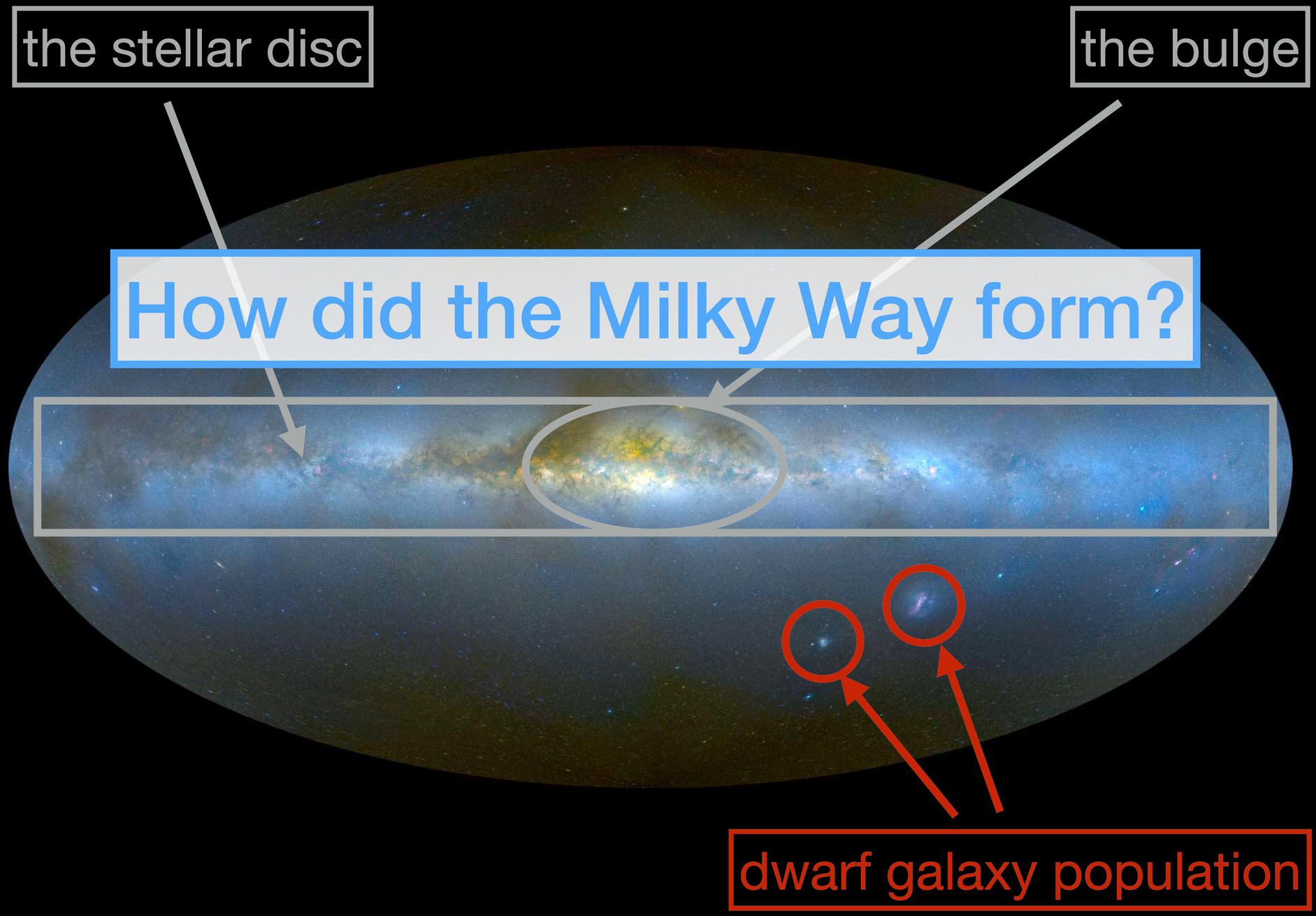
the bulge
How did the Milky Way form?
Study a model galaxy!
dwarf galaxy population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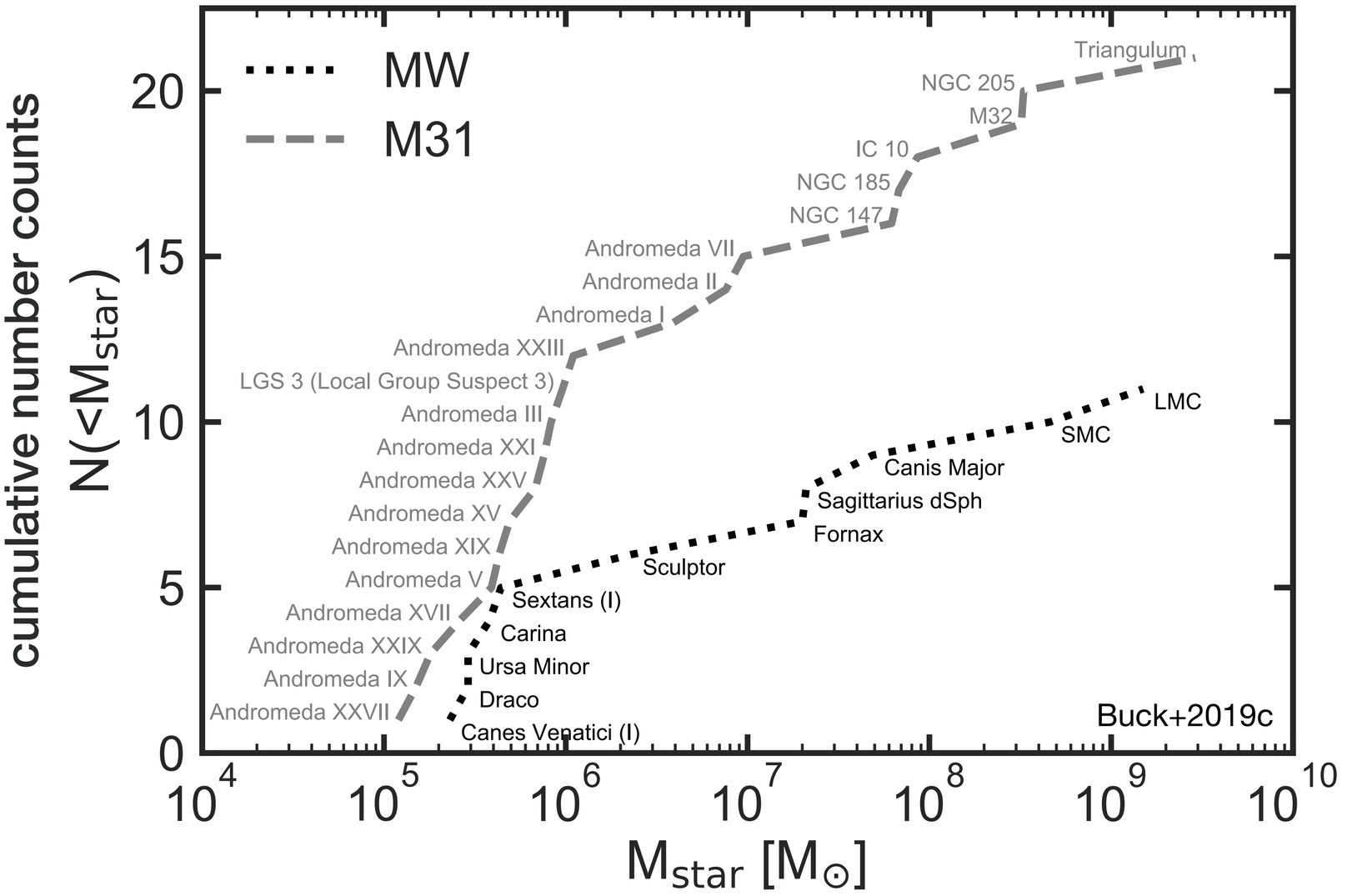
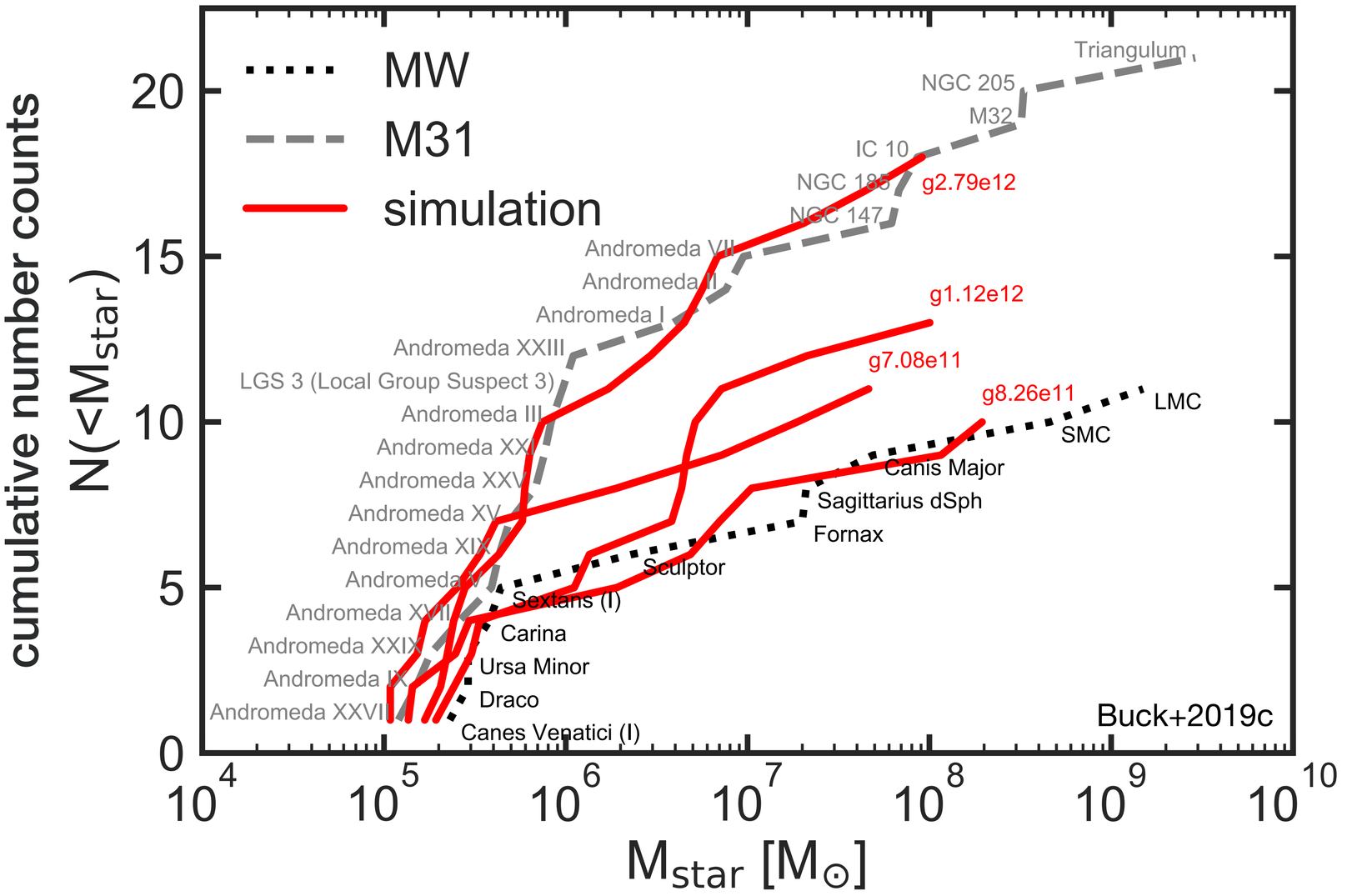
Satellite galaxy mass function



see also: Sawala+2015, Simpson+2017, Despali&Vegetti 2017

Satellite galaxy mass function



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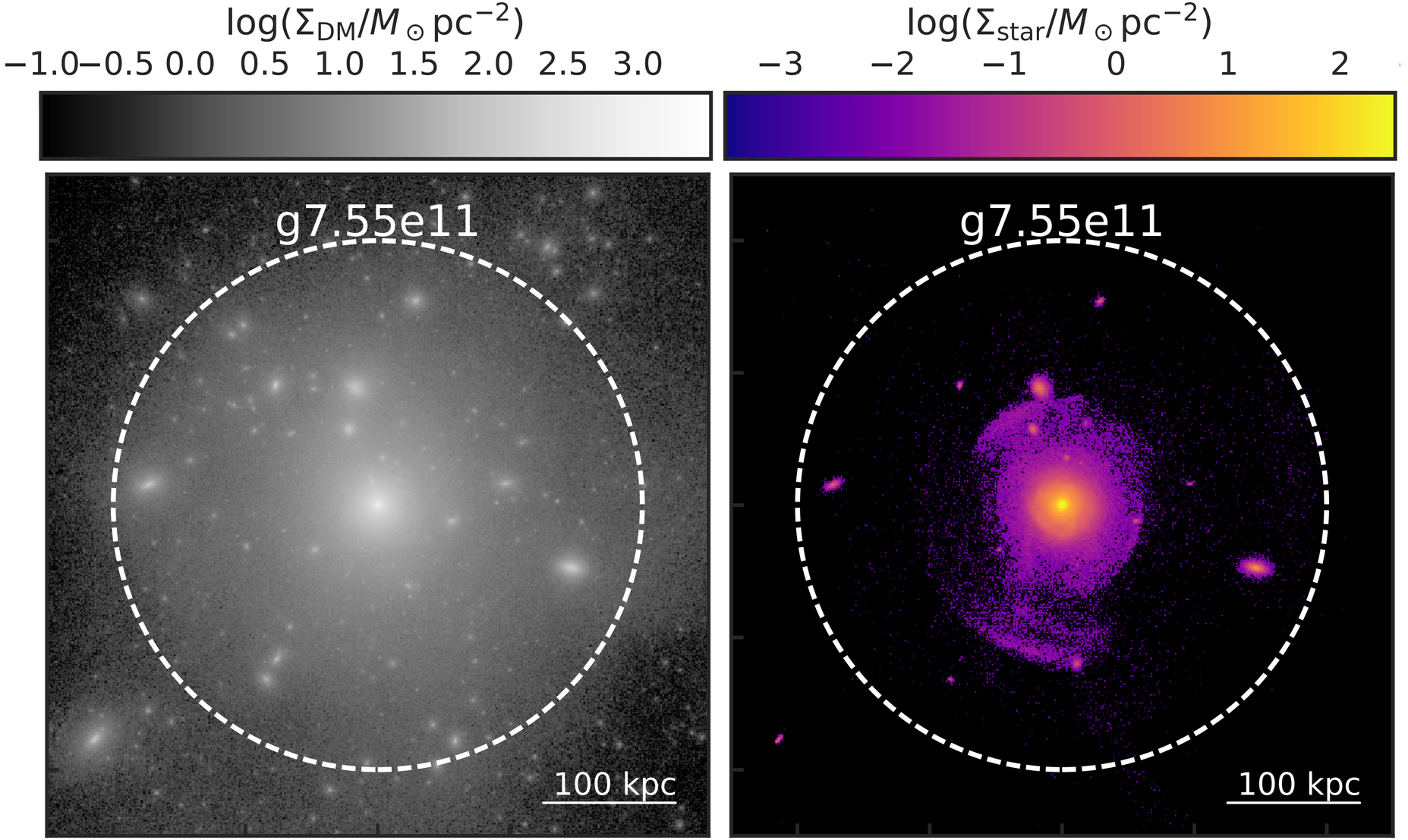
Satellite destruction and dark sub-halos



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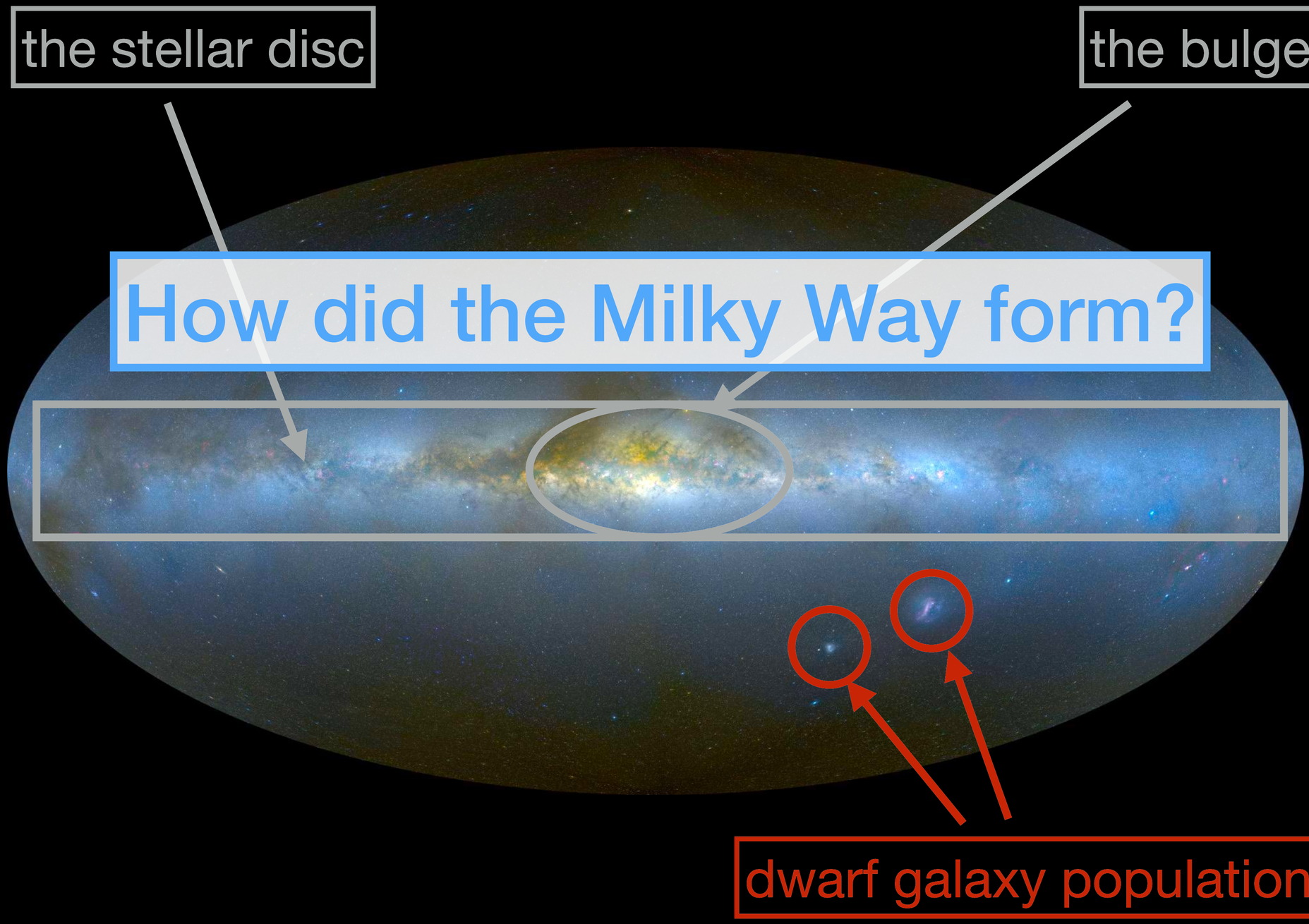
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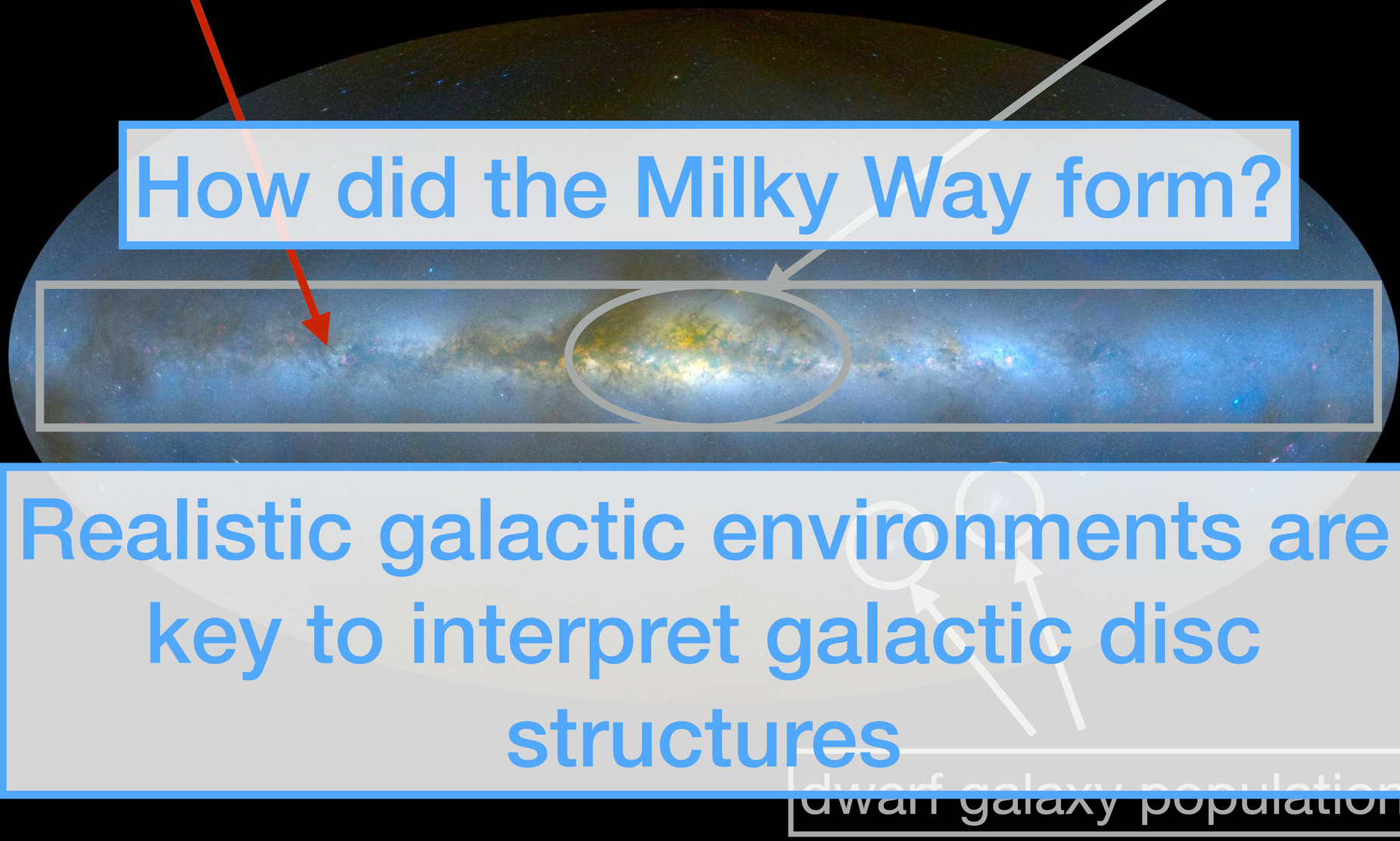
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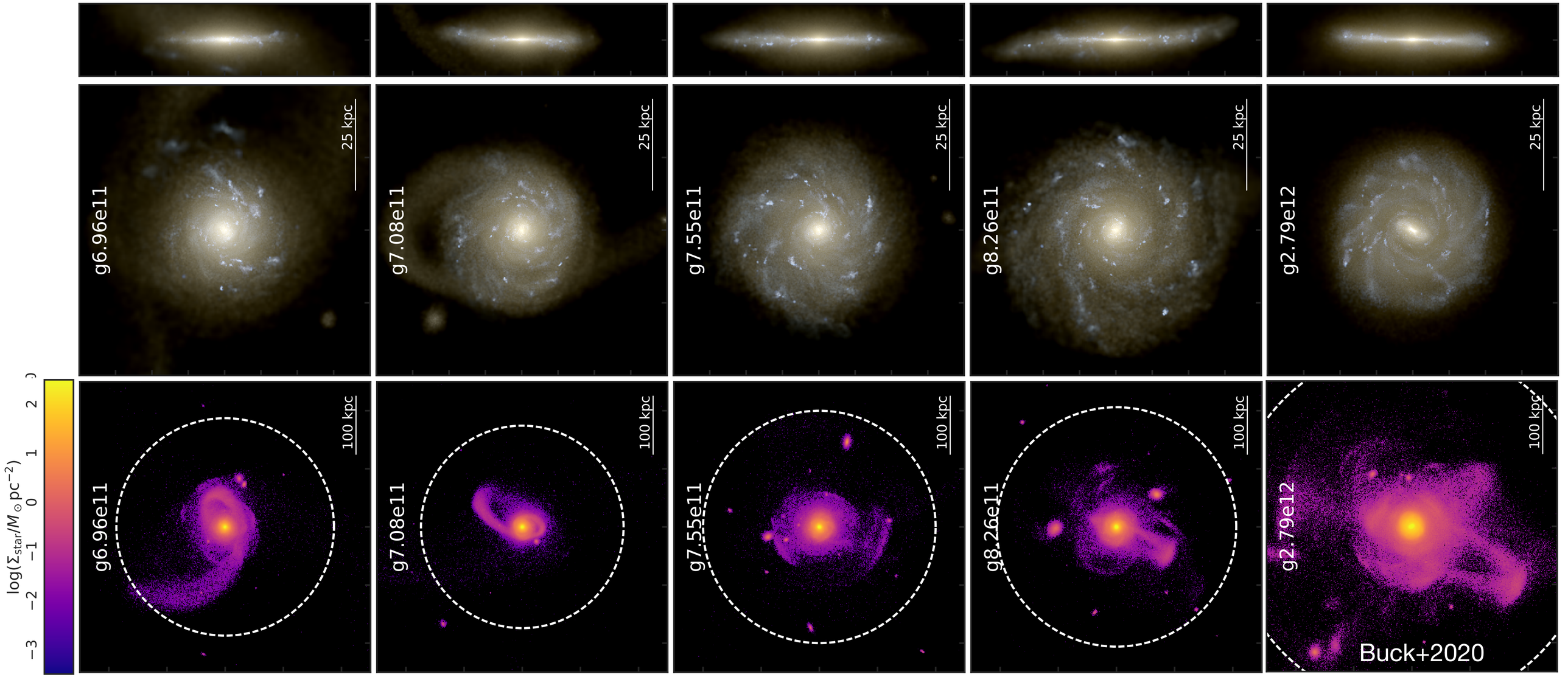
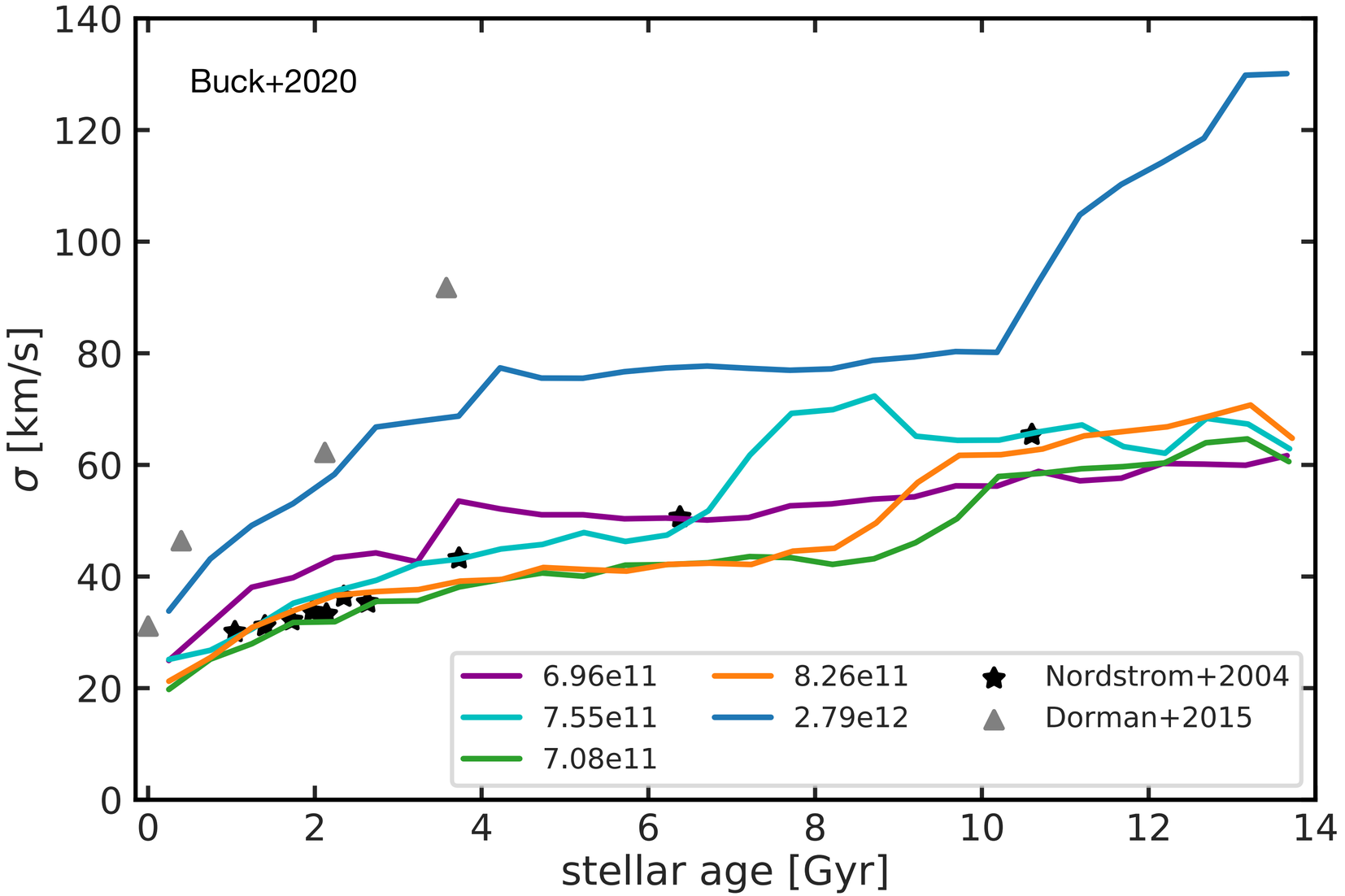
How did the Milky Way form?
Realistic galactic environments are key to interpret galactic disc structures
dwarf galaxy population

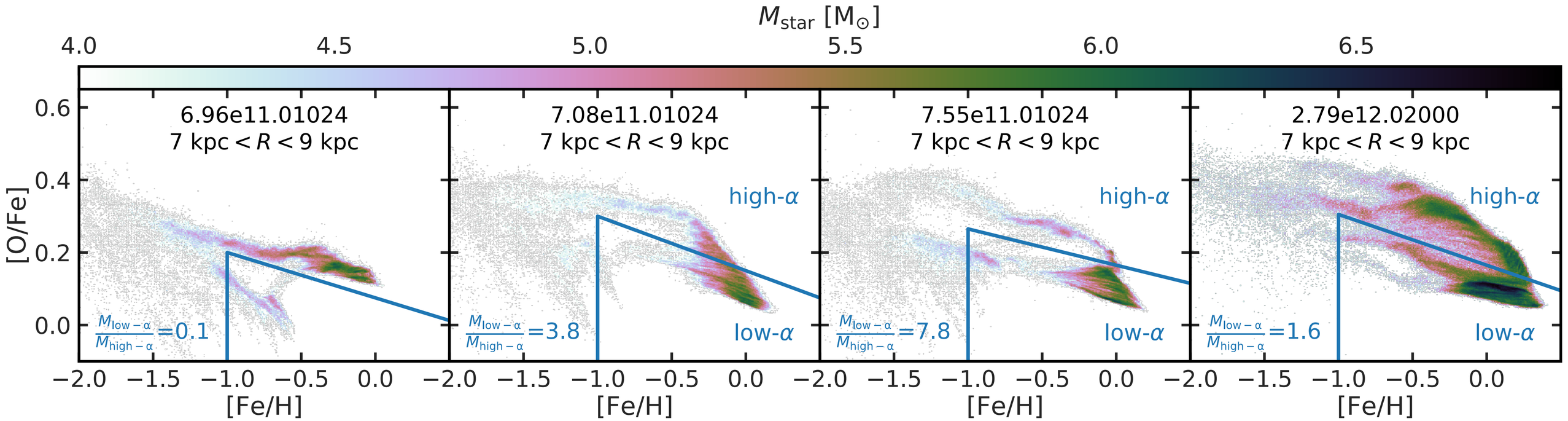
Mass selected disc galaxies with different formation scenarios



Age-velocity dispersion relation



Bimodality in [α/Fe] vs. [Fe/H] plane



Buck 2020

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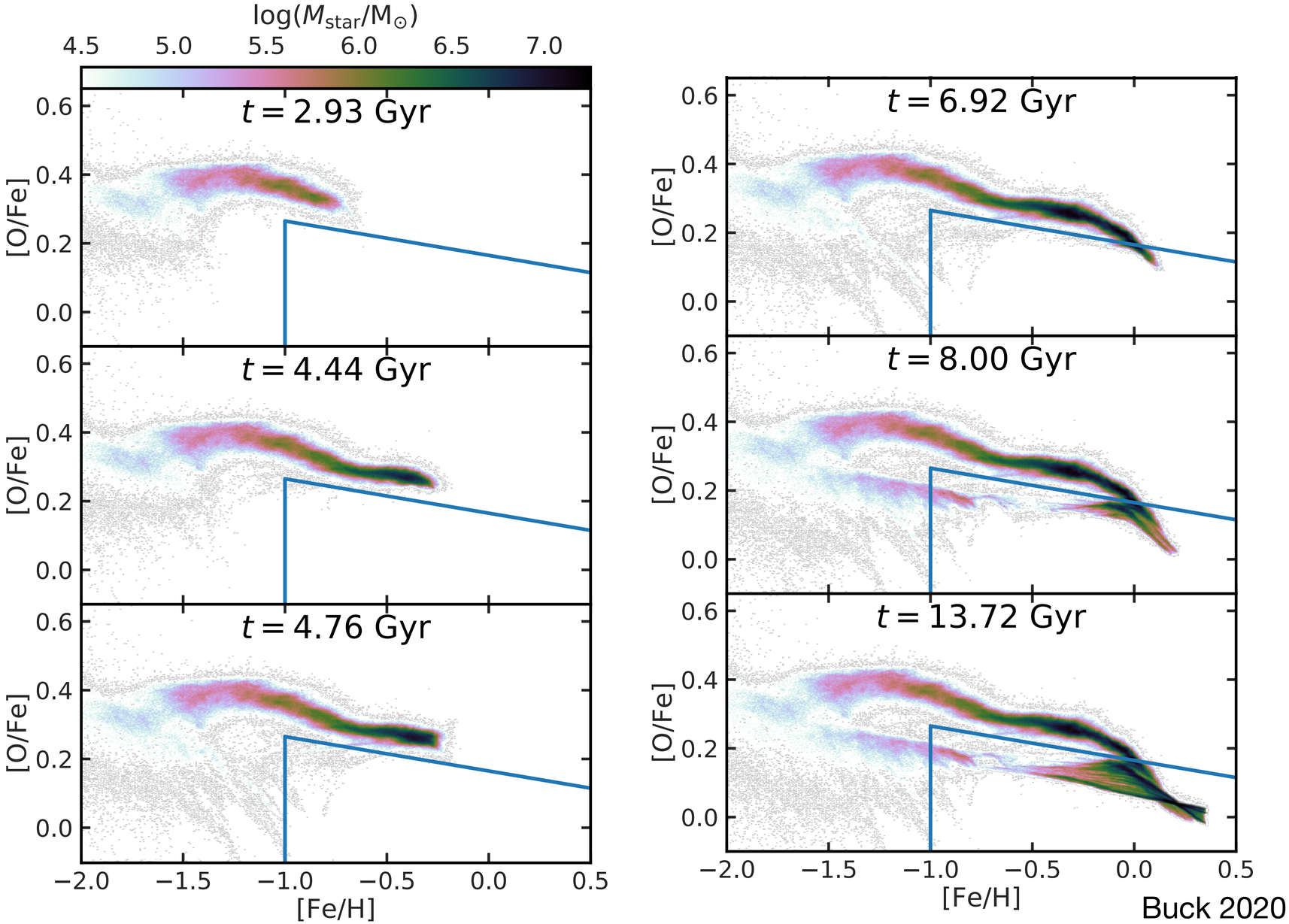

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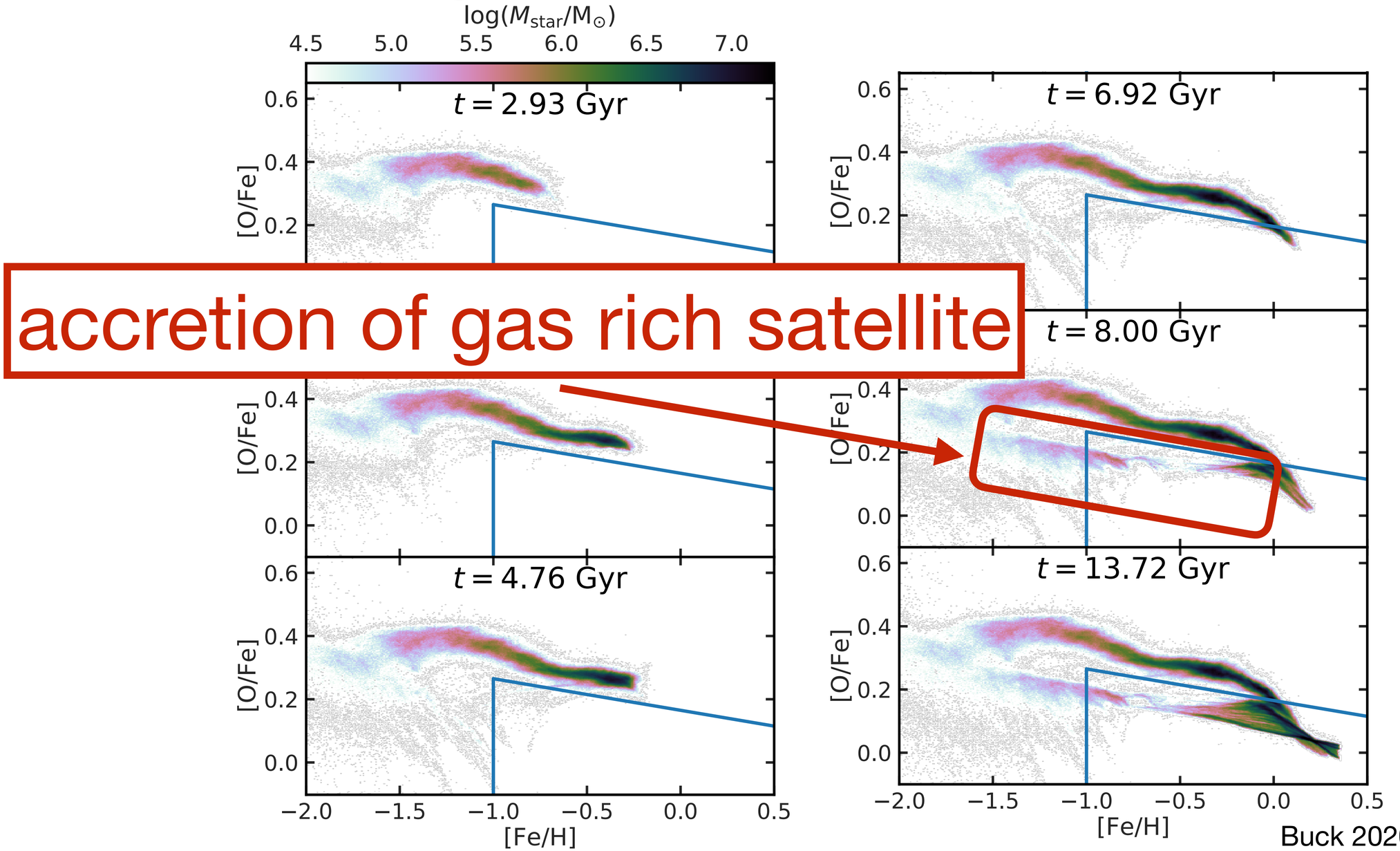
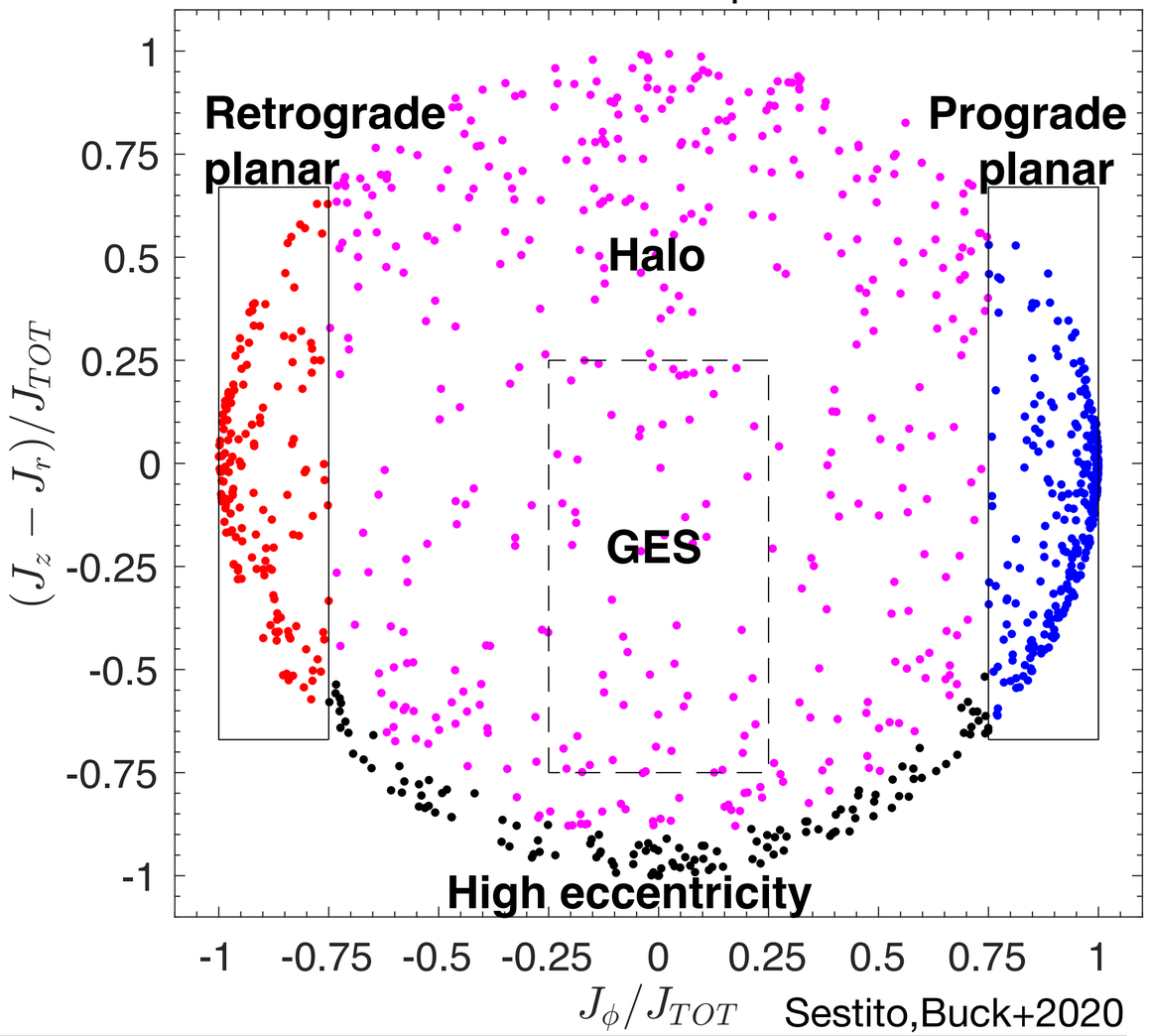


Metal-poor stars trace the early formation of the Milky Way

The action space



Sestito,Buck+2020

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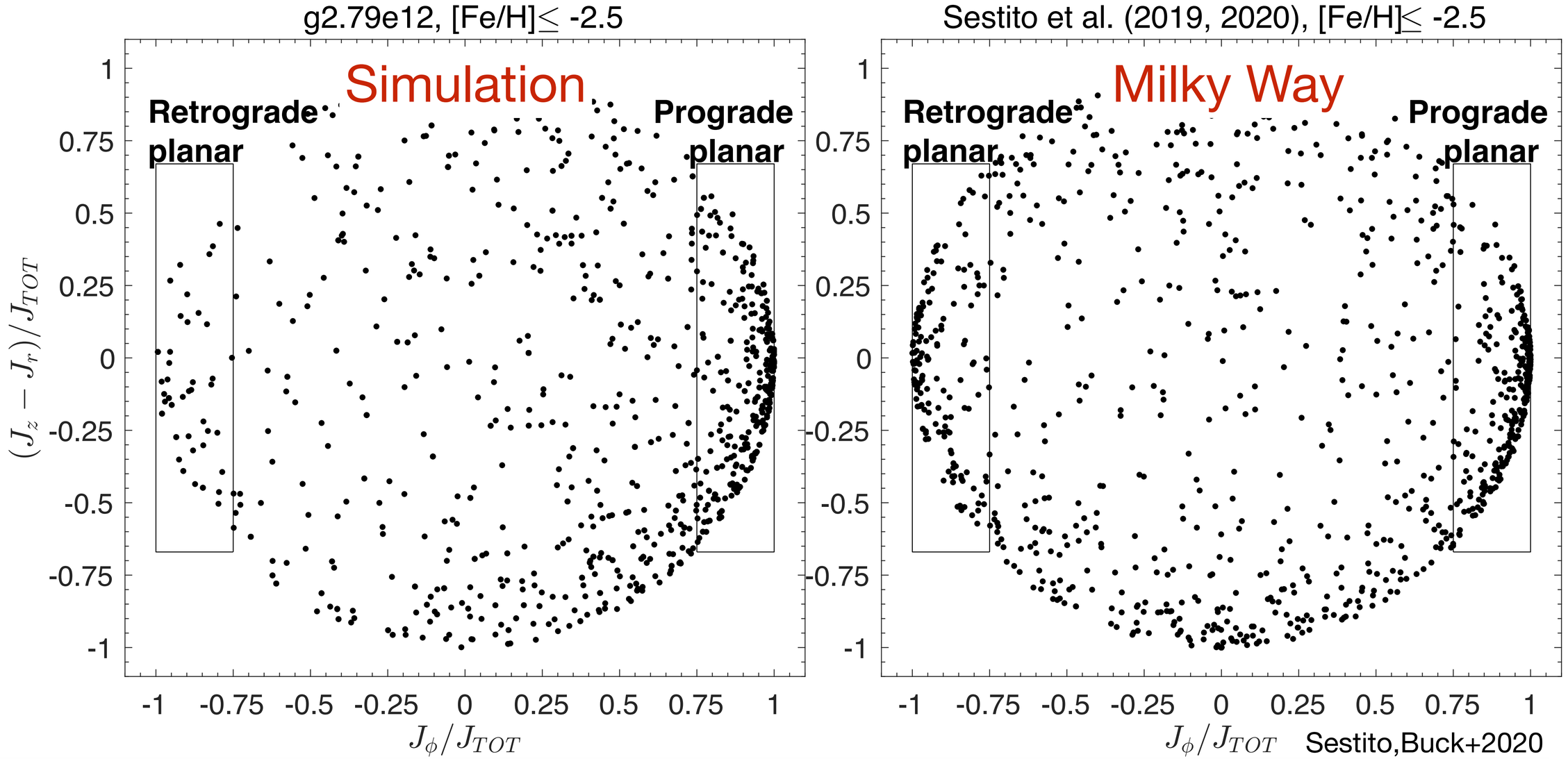

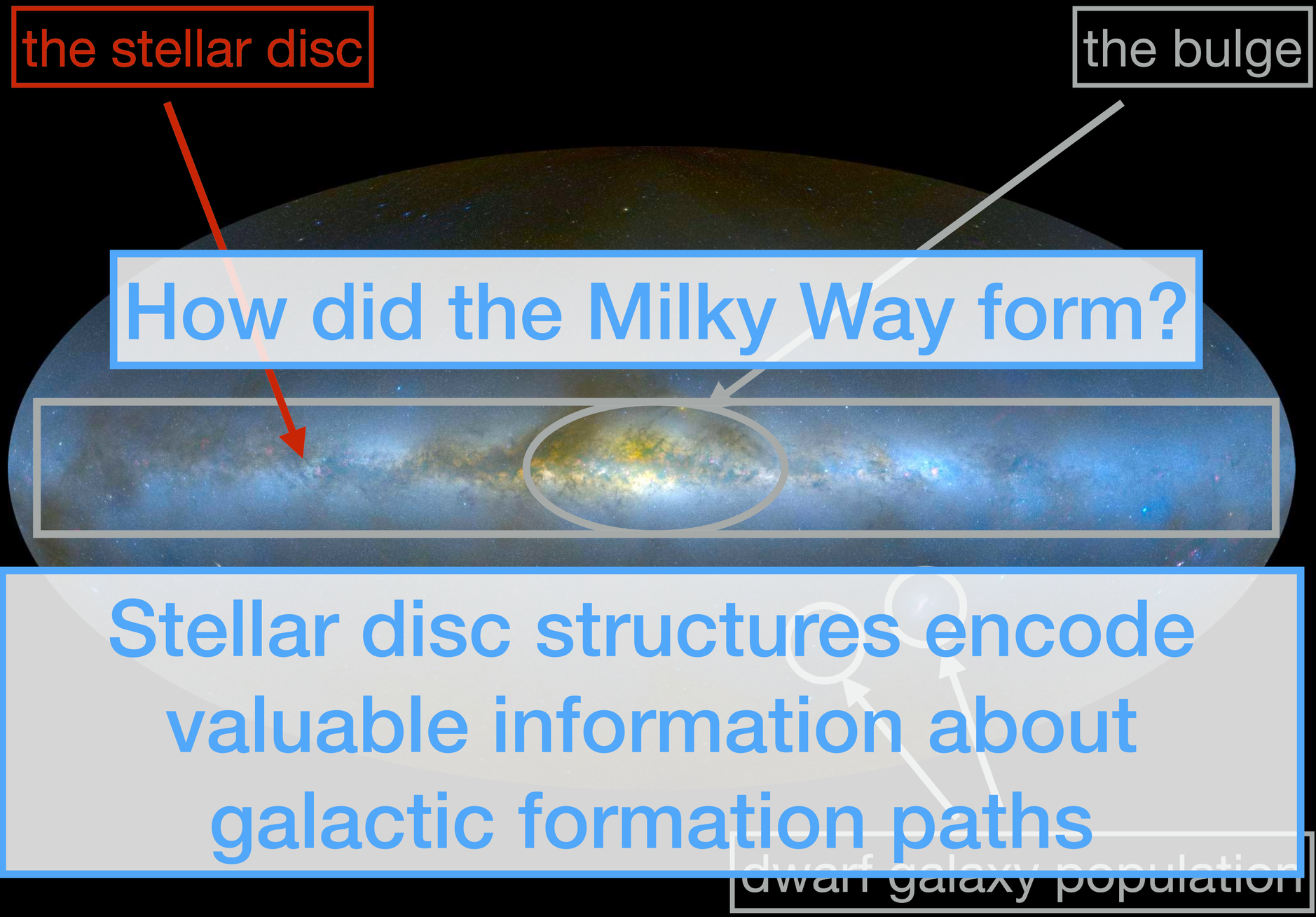
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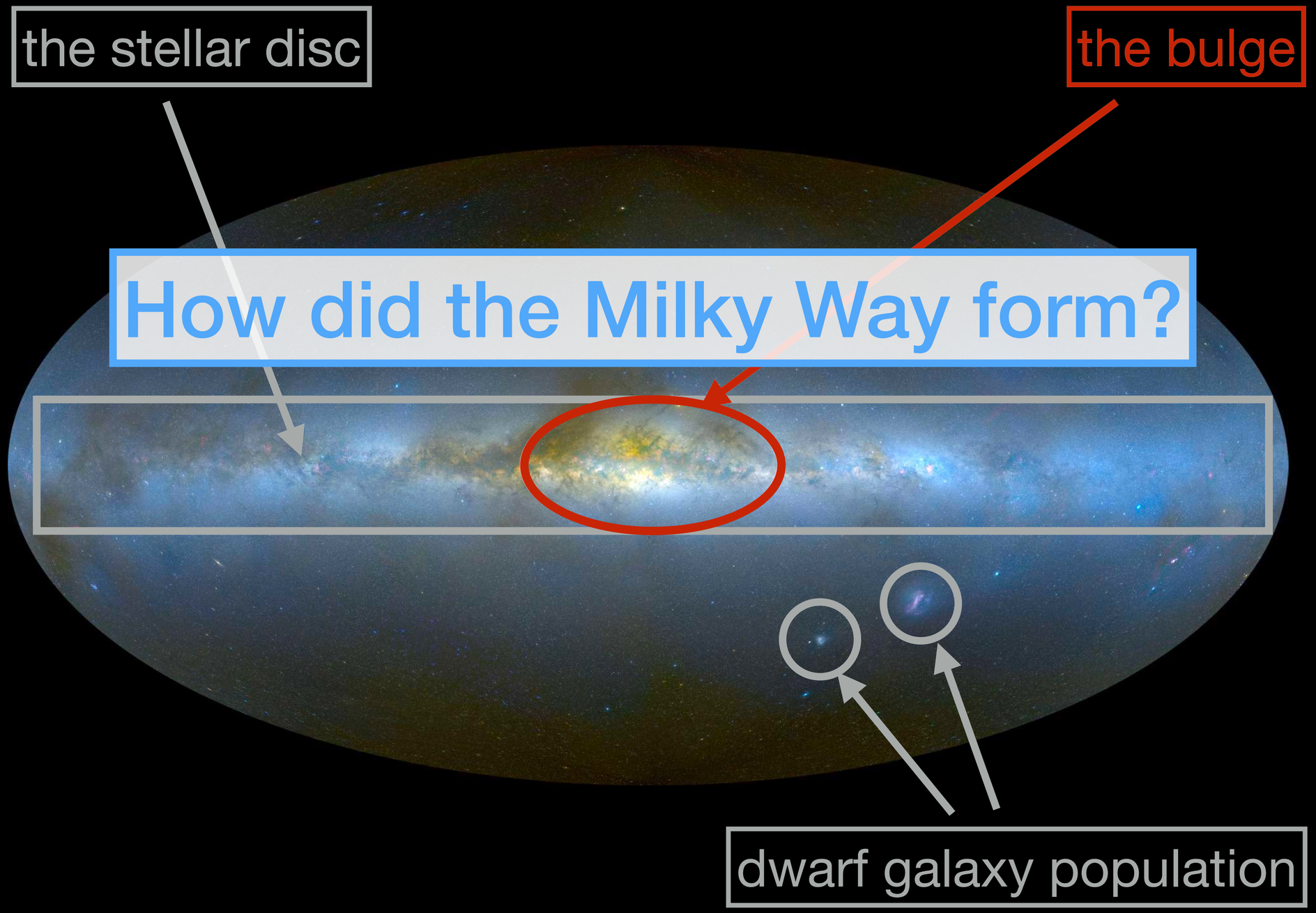
How did the Milky Way form?
Stellar disc structures encode valuable information about galactic formation paths
dwarf galaxy population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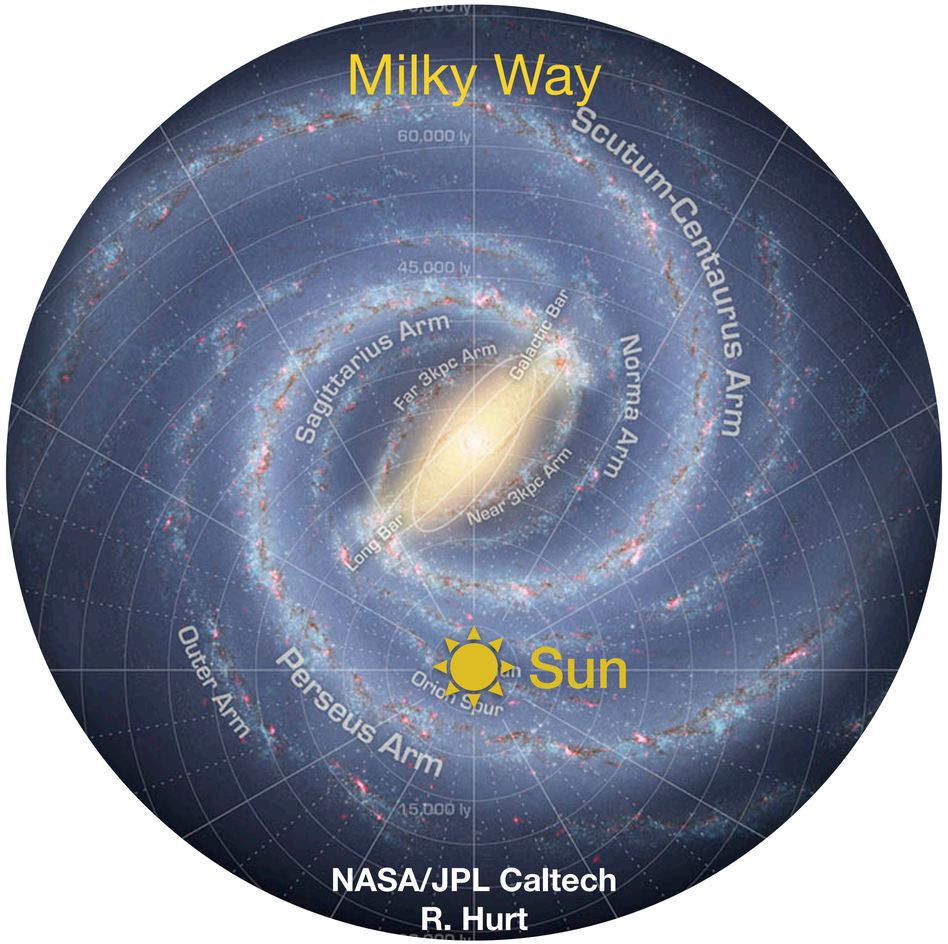
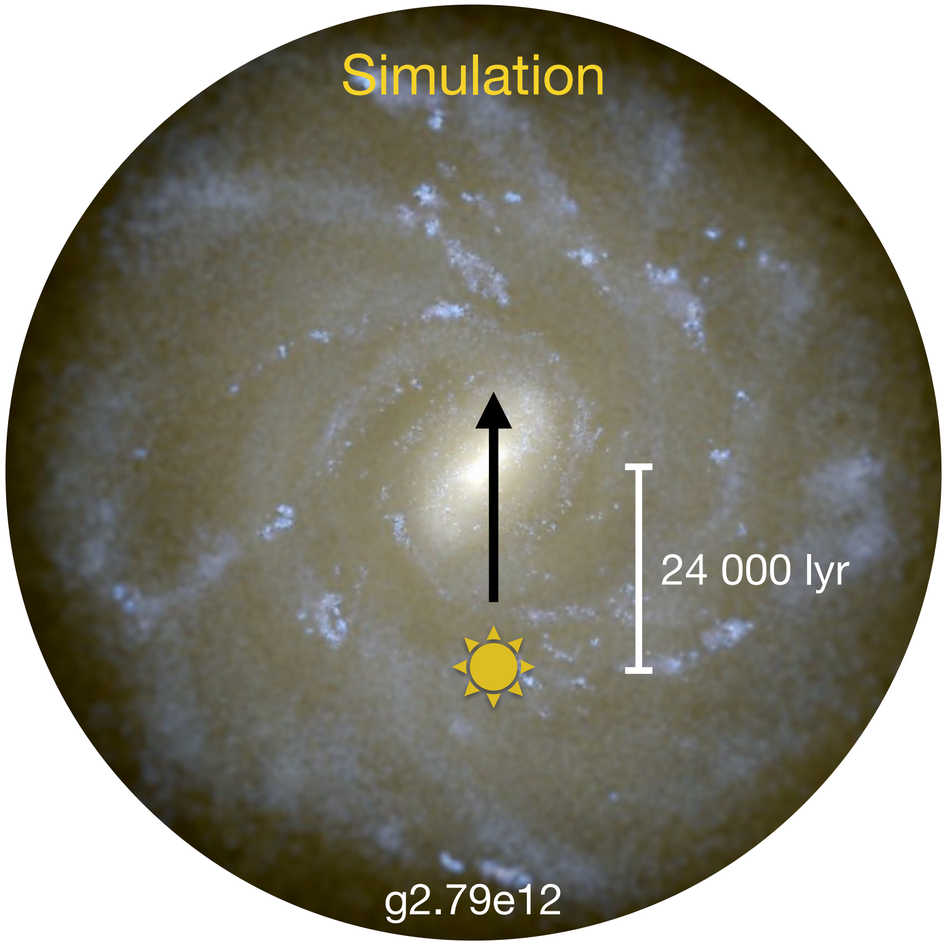
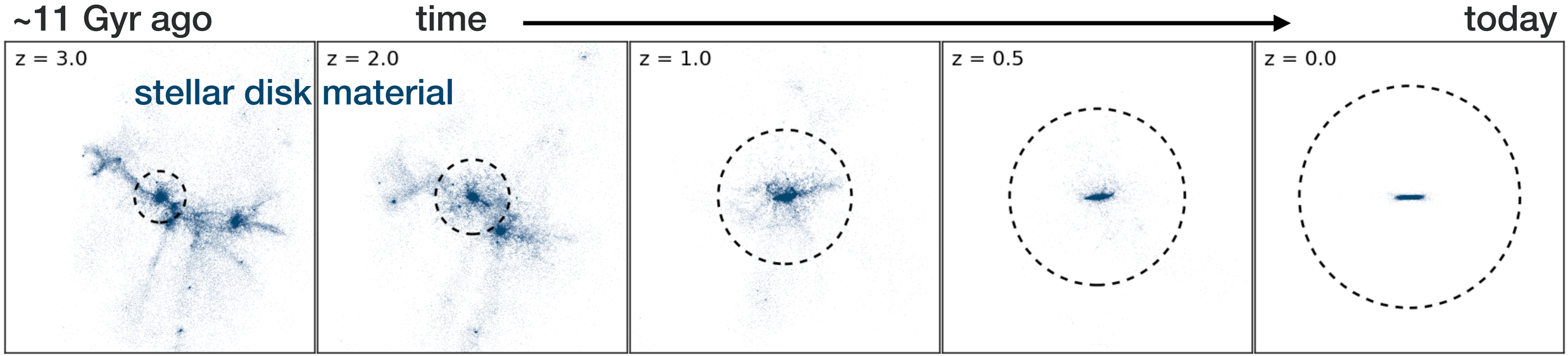
MW bulge: morphology and kinematics





Buck+2018a, Buck+2019b for bulge kinematics / Hilmi,Minchev,Buck+2020 for careful tests of methods to derive bar length and pattern speed

Different formation scenarios for disc and bulge



Obreja+(incl. Buck)2018

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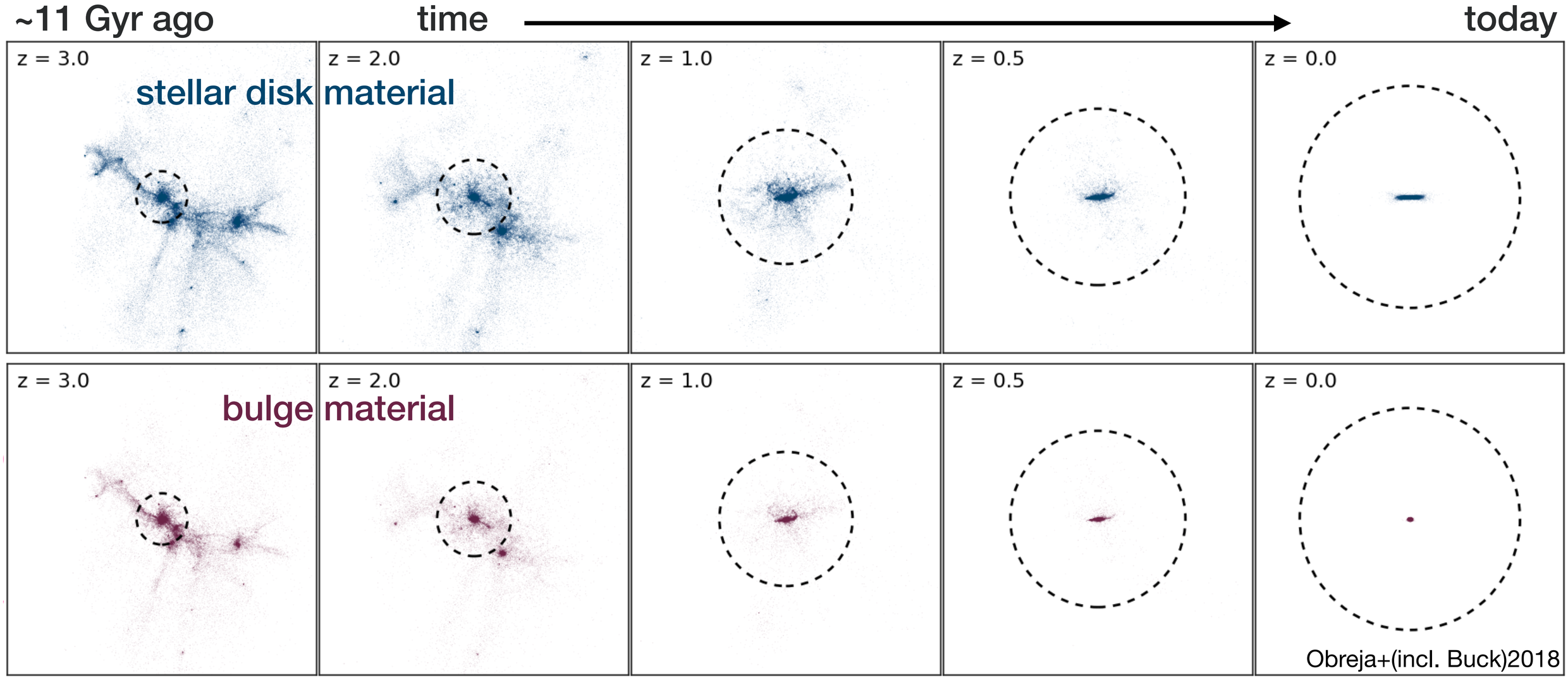
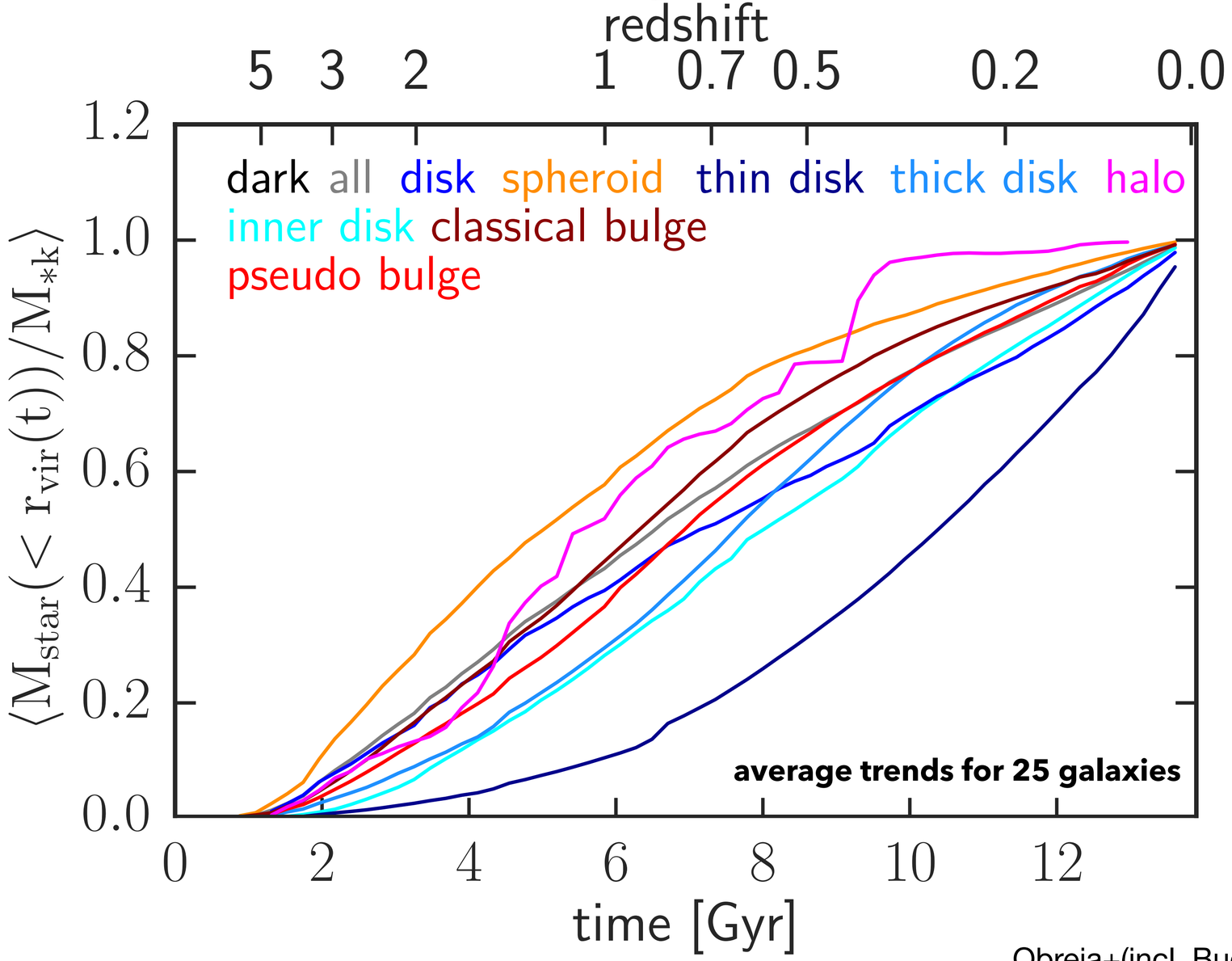


Cold disks take longest to assemble



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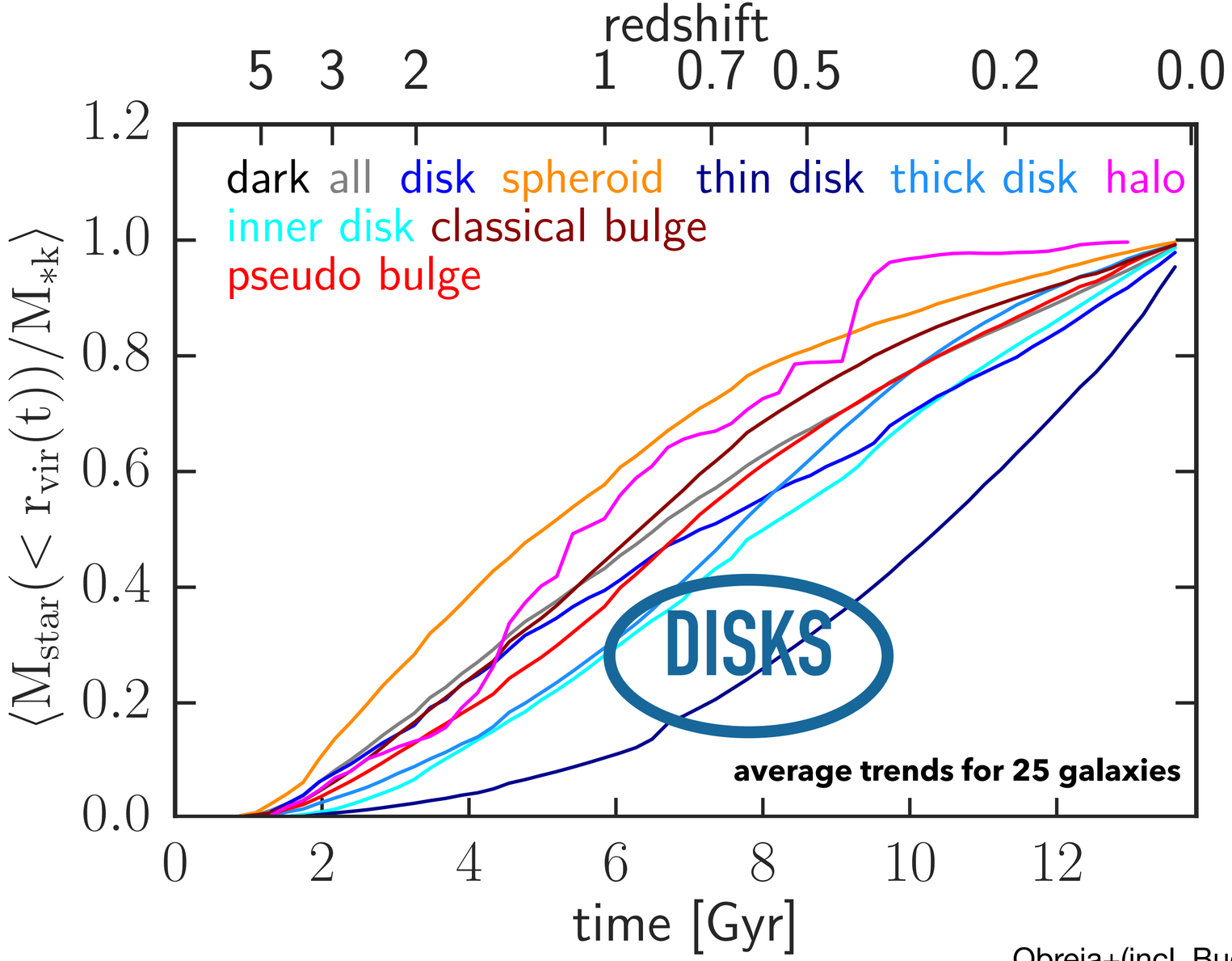

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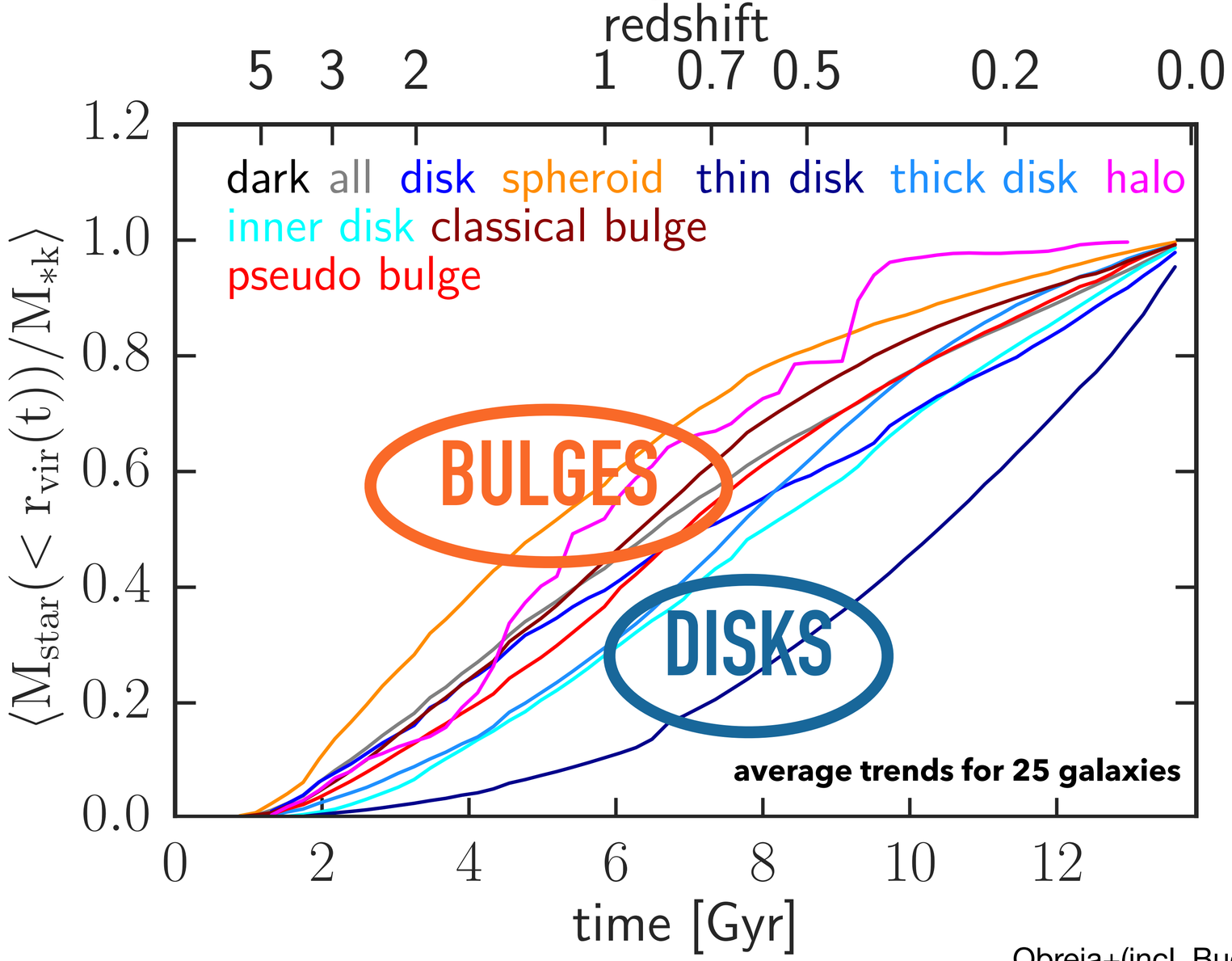

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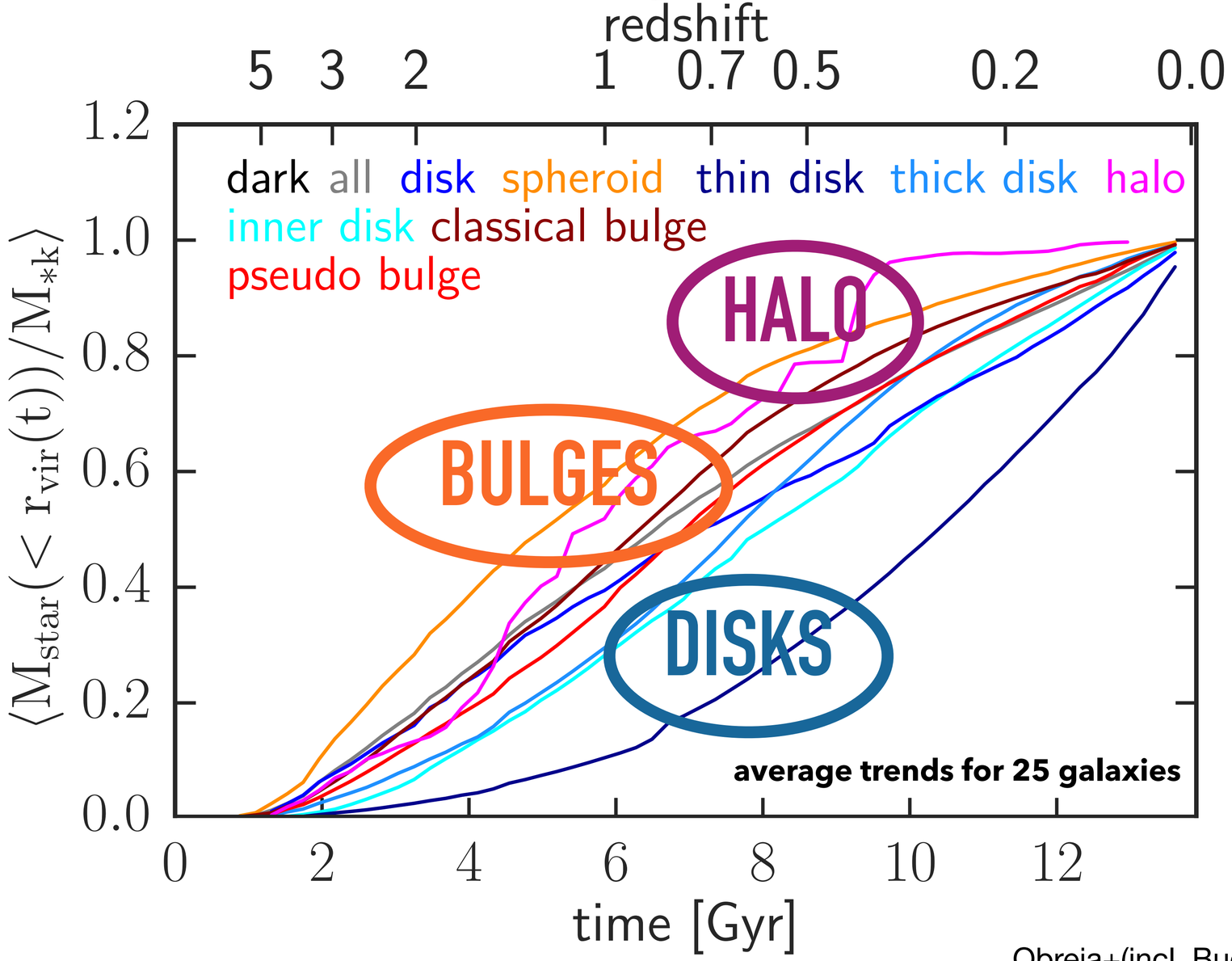

Obreja+(incl. Buck)2019


the stellar disc
the bulge
How did the Milky Way form?
Bulge and disc follow separate formation paths
dwarf galaxy population


How did the Milky Way form?
NIHAO 你好
Galaxy Simulations

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- realistic dwarf galaxy population (Buck et al. 2019c, Buck et al. 2016)
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NIHAO 你好 Galaxy Simulations

The early stellar disc

- early disc morphology (Buck et al. 2017)
- disc structure evolution (Buck et al. 2020)

dwarf galaxy population

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Linking the Galactic and
Extragalactic via realistic simulations
can help unravel
MW's formation history!
Buck+2020