Title: Mergers in the cosmic ecosystem

Speakers: Andrew Pontzen

Collection/Series: Cosmic Ecosystems

Subject: Cosmology

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Abstract:

I will present an overview of the work of the "GM Galaxies" project, which explores the relationship between history of a galaxy and its observable traits. I will give three examples of our work, looking at how dwarf galaxies change their properties based on their mass assembly, the Milky Way stellar halo responds to variations in its merging history, and the circumgalactic medium of massive galaxies mediates the transition from star-forming to quiescent.

The interplay between galactic feedback and history

Andrew Pontzen **gmgalaxies.org**

Durham University

Institute for Computational Cosmology

1. Brief introduction to the GMGalaxies project

2. Some slightly more detailed results at the dwarf galaxy scale

The genetically modified family


Oscar Agertz, Lund


Corentin Cadiou, UCL


Akaxia Cruz, Flatiron CCA

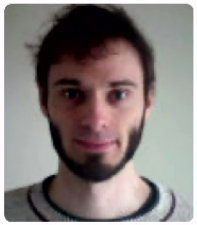

Jonathan Davies, LJMU


Grace Lawrence, Durham


Luisa Lucie-Smith, Hamburg


Gandhali Joshi, Durham


Claudia Muni, Durham


Matthew Orkney, Barcelona


Justin Read, Surrey

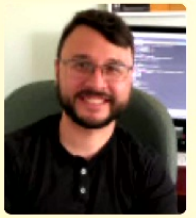

Hiranya Peiris, Cambridge


Martin Rey, Bath


Nina Roth, Industry


Nicole Sanchez, Carnegie


Stephen Stopyra, Stockholm


Michael Tremmel, Cork

Galaxies are diverse, even once you control for mass and large-scale environment

NGC 2403

M_V = -19

NGC 2865

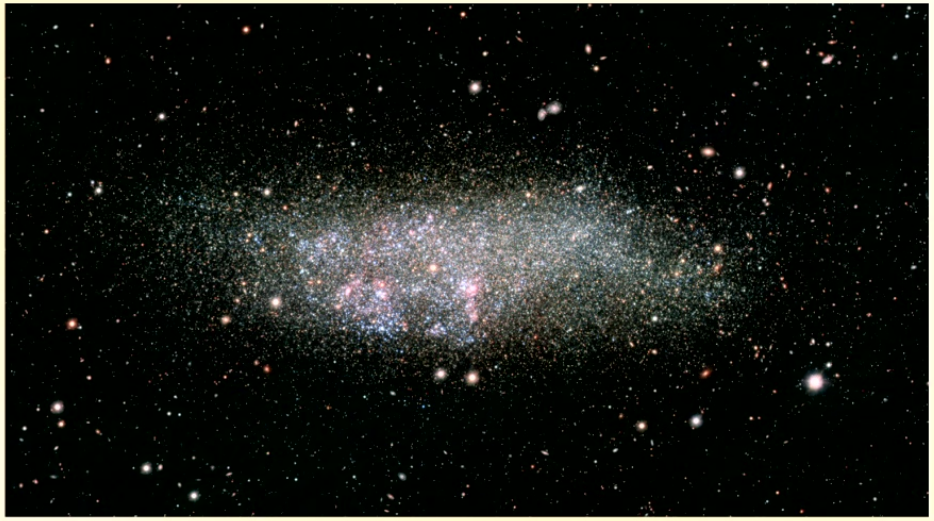
M_V = -20

Galaxies are diverse, even once you control for mass and large-scale environment

IC10

M_V = -14

$R_{1/2}$ = 0.6 kpc



WLM

M_V = -14

$R_{1/2}$ = 1.6 kpc

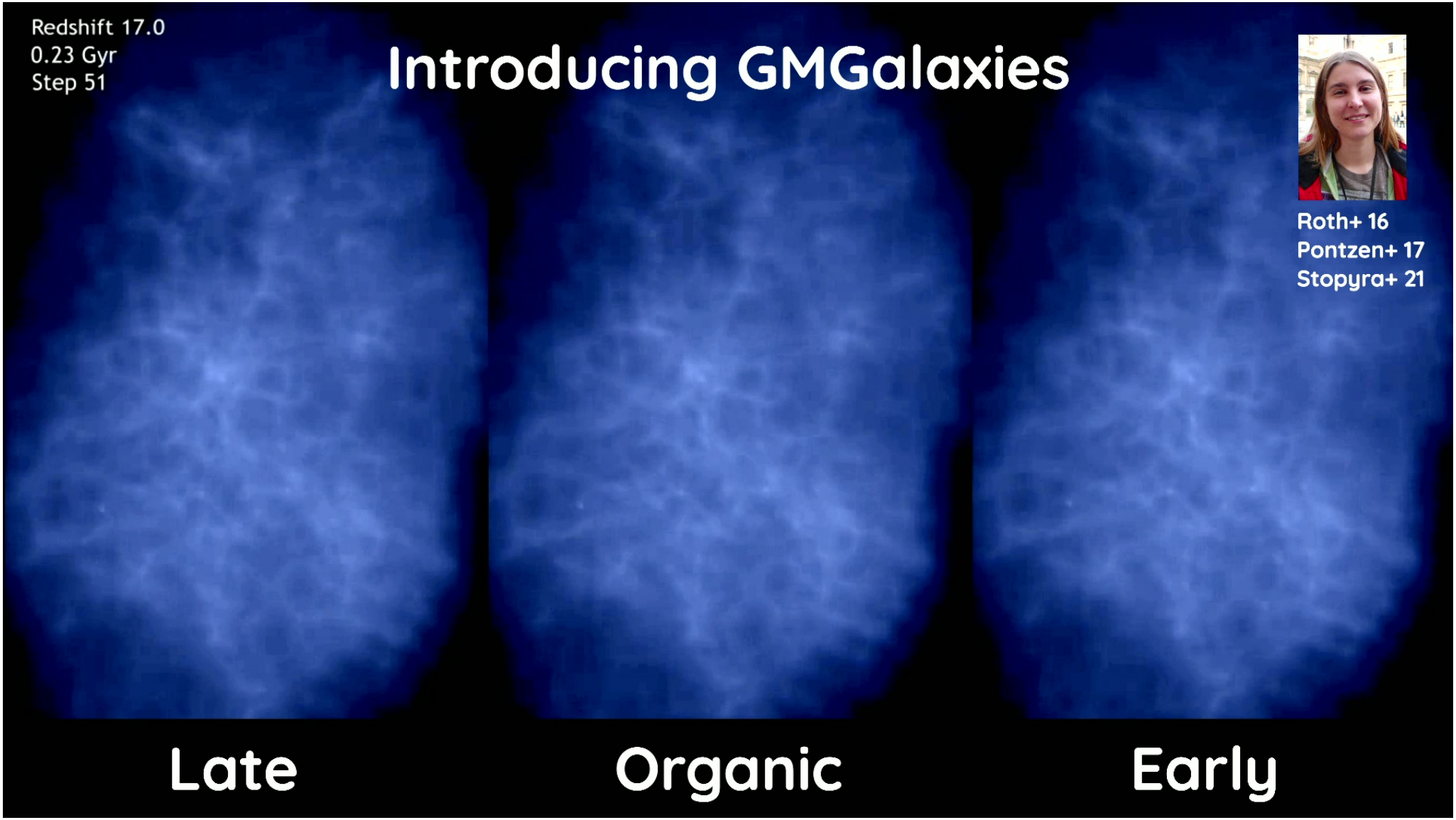
Why does this matter?

It must be understood before we can reliably infer cosmology/particle physics

e.g. scatter in M_{halo} – M_*, M_{BH} – M_*;
intrinsic alignments; assembly biases;
gas redistribution (M_{DM} – f_{gas}); DM redistribution; …

It's a clue to how we should think about galaxy physics – in particular that feedback is multidimensional, and galaxies have multiple quasi-equilibrium points

(cf Mark Voigt's framing talk)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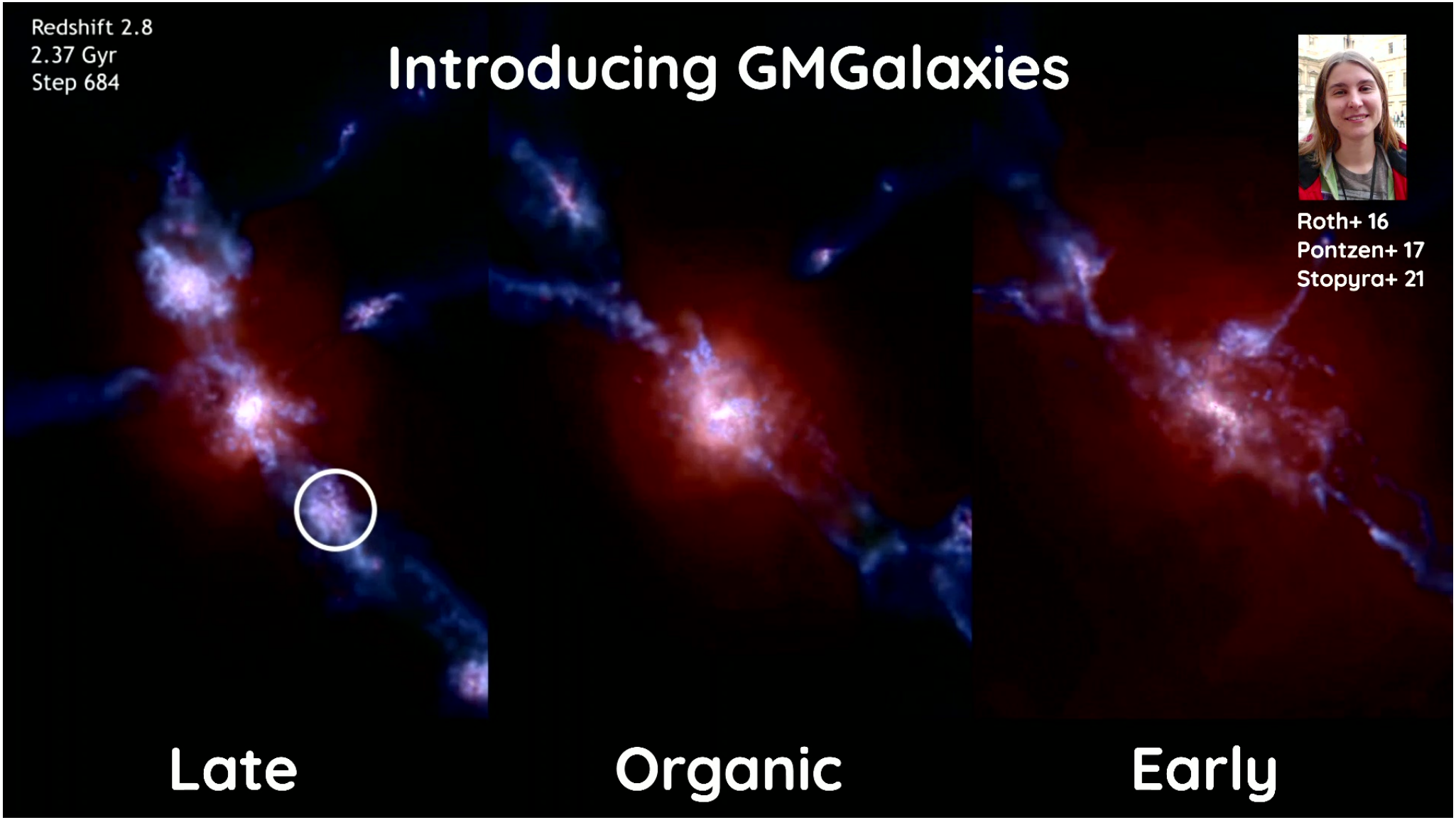
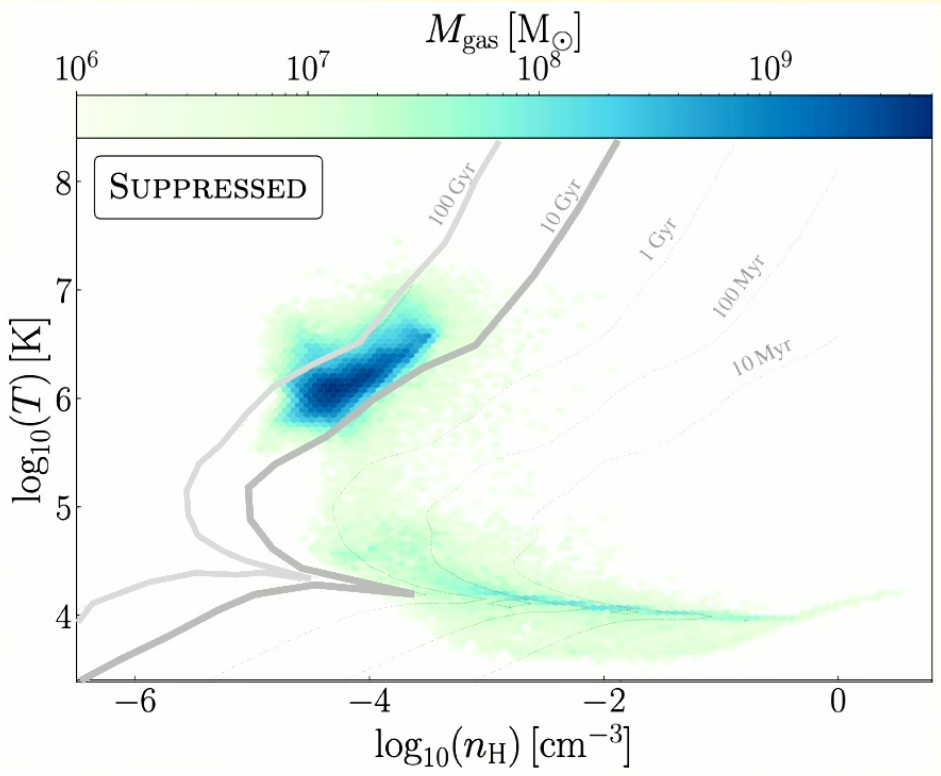
0.23 Gyr
Step 51
Introducing GMGalaxies
Roth+ 16
Pontzen+ 17
Stopyra+ 21
Late
Organic
Early

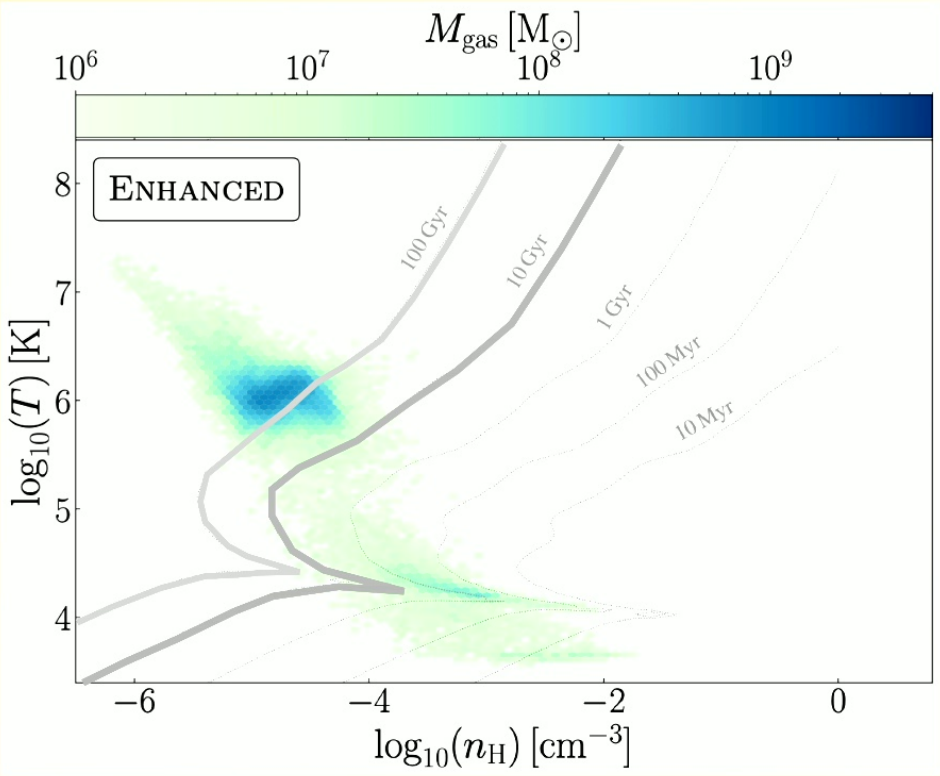

Redshift 2.8
2.37 Gyr
Step 684
Introducing GMGalaxies
Roth+ 16
Pontzen+ 17
Stopyra+ 21
Late
Organic
Early

z=0 galaxies retain memory of history

Davies+ 2022

Increasingly major mergers



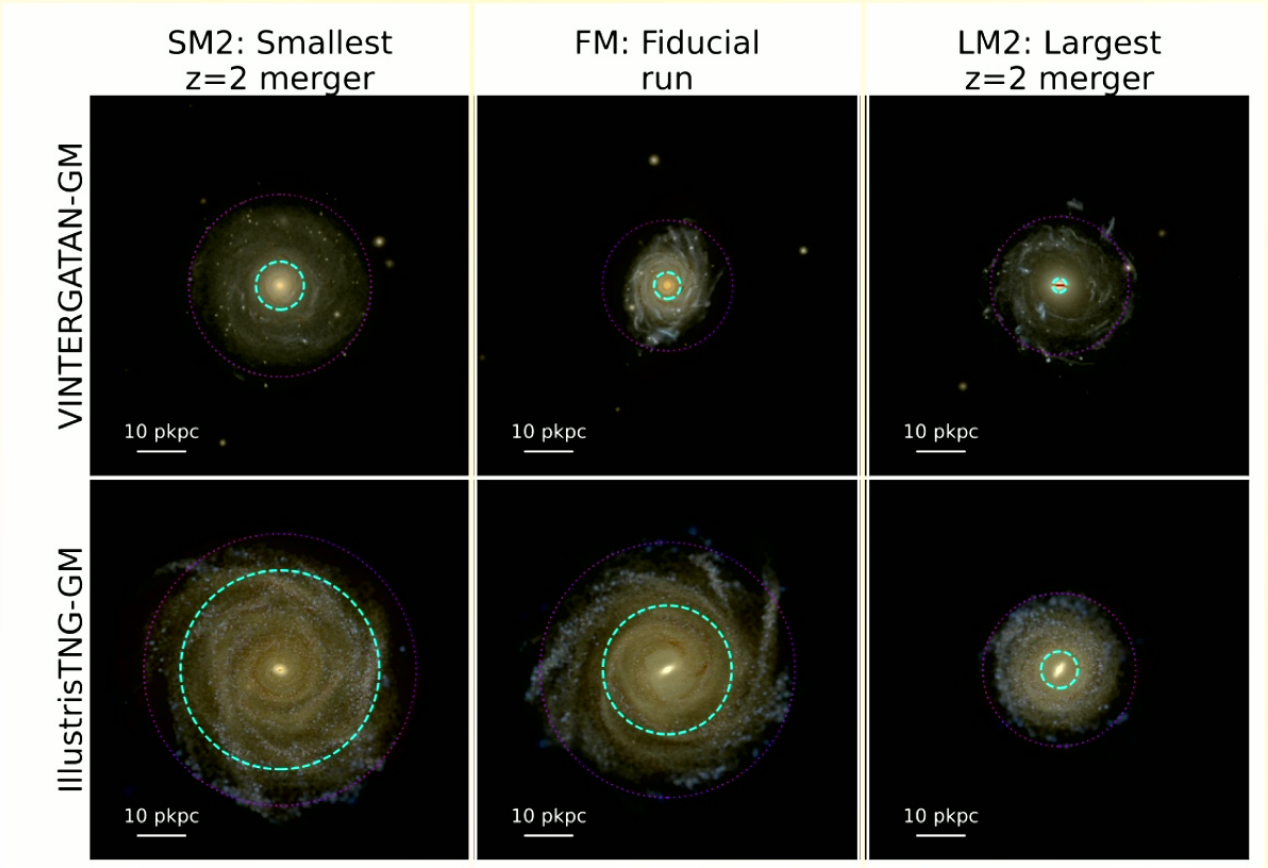


z=0 galaxies retain memory of history

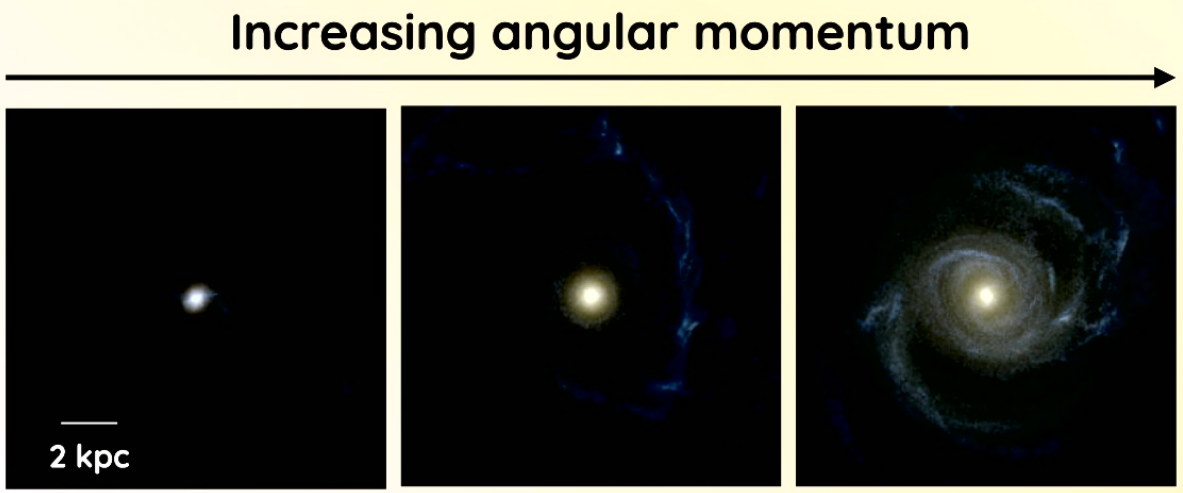
Joshi+ 2025a, 2025b

Increasing z=2 merger strength

Alternative galaxy formation codes

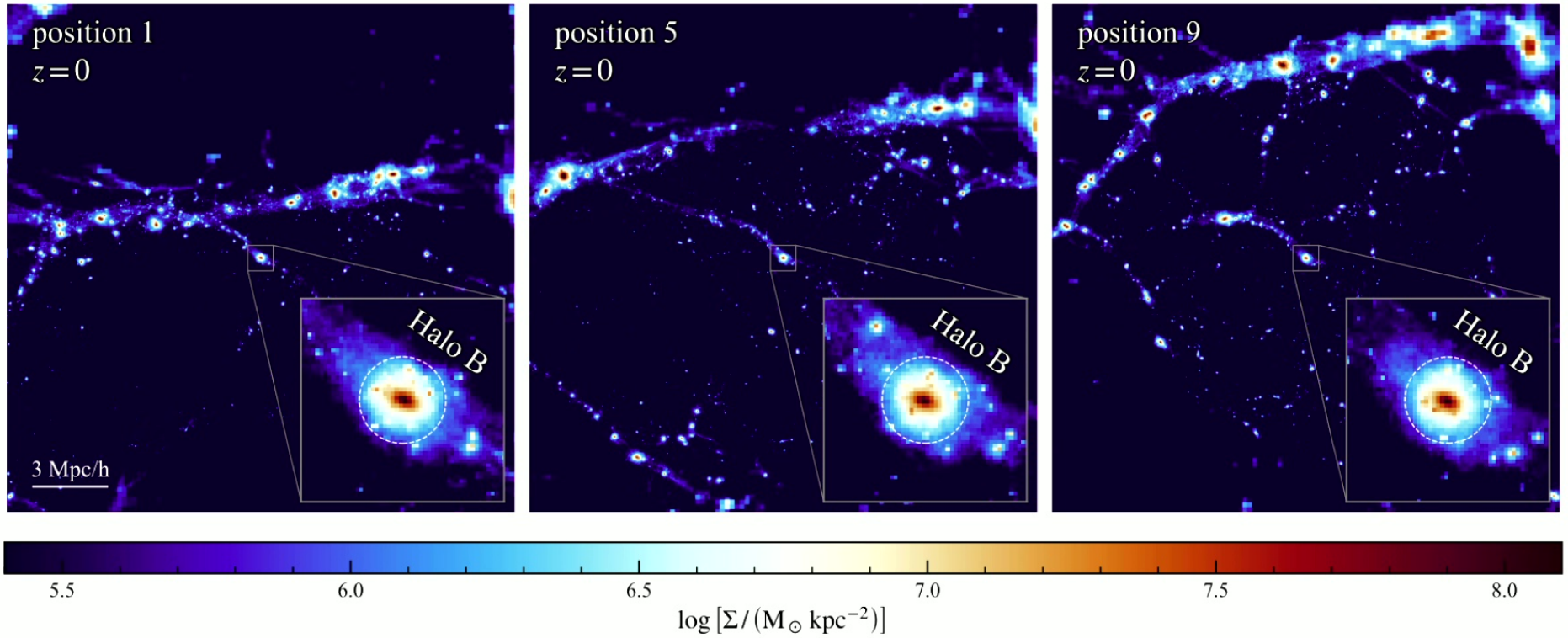


z=0 galaxies retain memory of history



Cadiou, Pontzen & Peiris 2022

Place halo in different locations relative to filament



Storck, Cadiou+ 2025

$z = 23.57$

Gas density

The EDGE project

~3pc, 300 $M_\odot$ resolution

AMR cosmological "genetically modified" dwarfs

Resolved supernovae

Radiative transfer

Non-equilibrium ionisation

No calibration

Justin Read,
Oscar Agertz

$z = 9.18$

Gas density

The EDGE project

~3pc, 300 $M_\odot$ resolution

AMR cosmological "genetically modified" dwarfs

Resolved supernovae

Radiative transfer

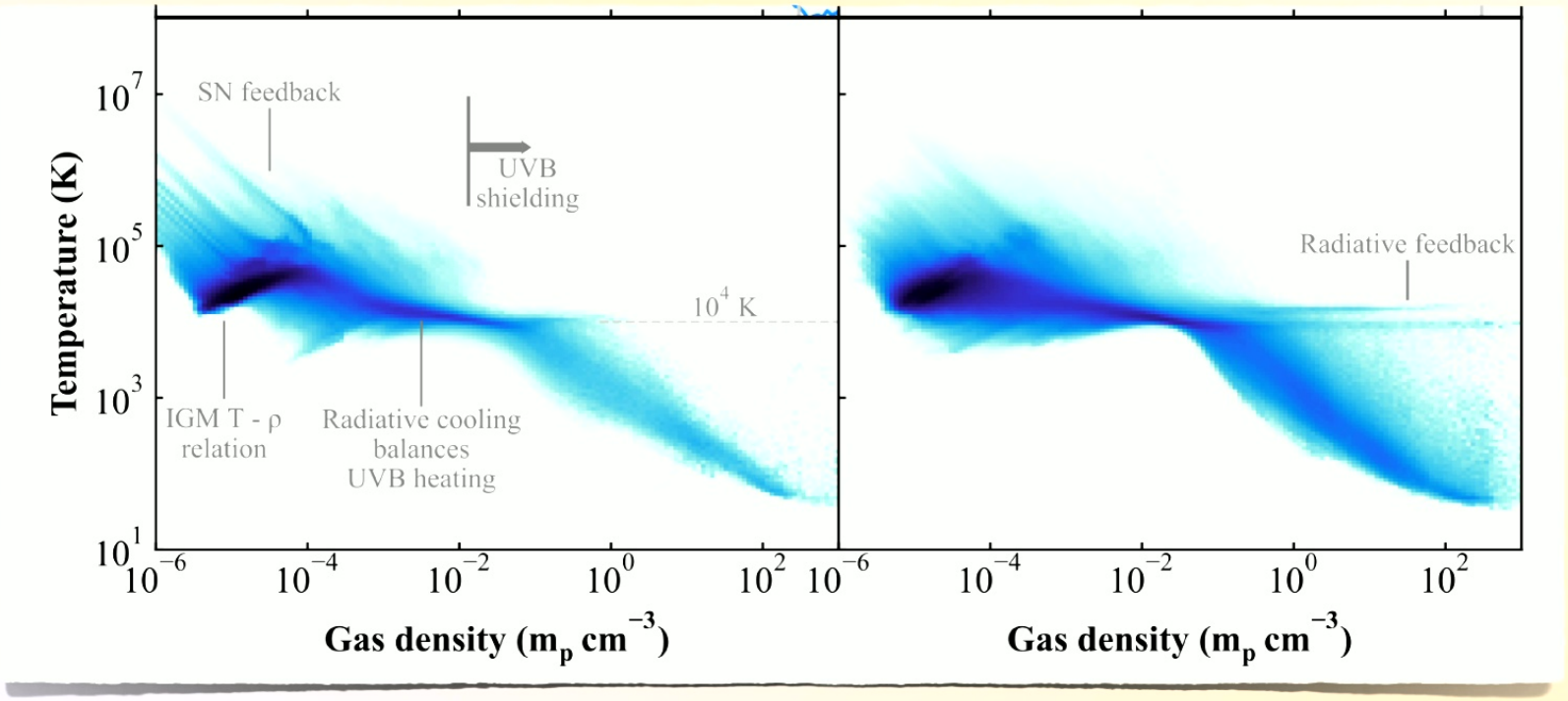
Non-equilibrium ionisation

No calibration

Justin Read,
Oscar Agertz

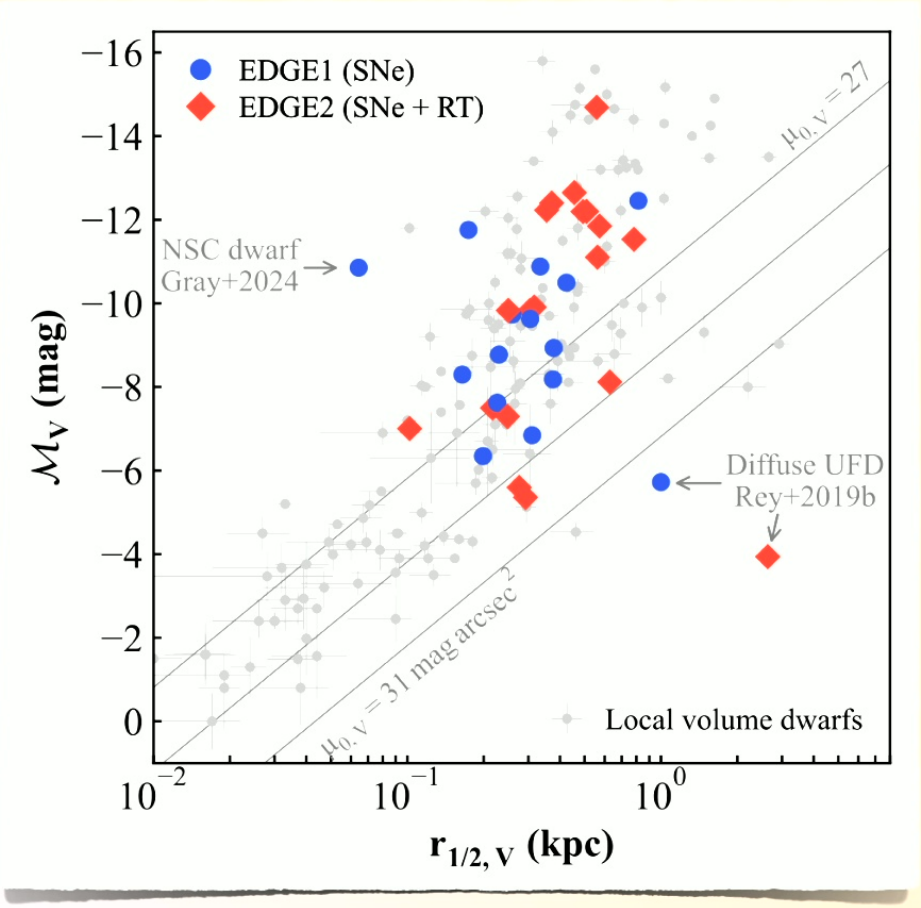
Feedback coupling, not just energy, matters

Supernovae + UV background … **… + UV from young stars**



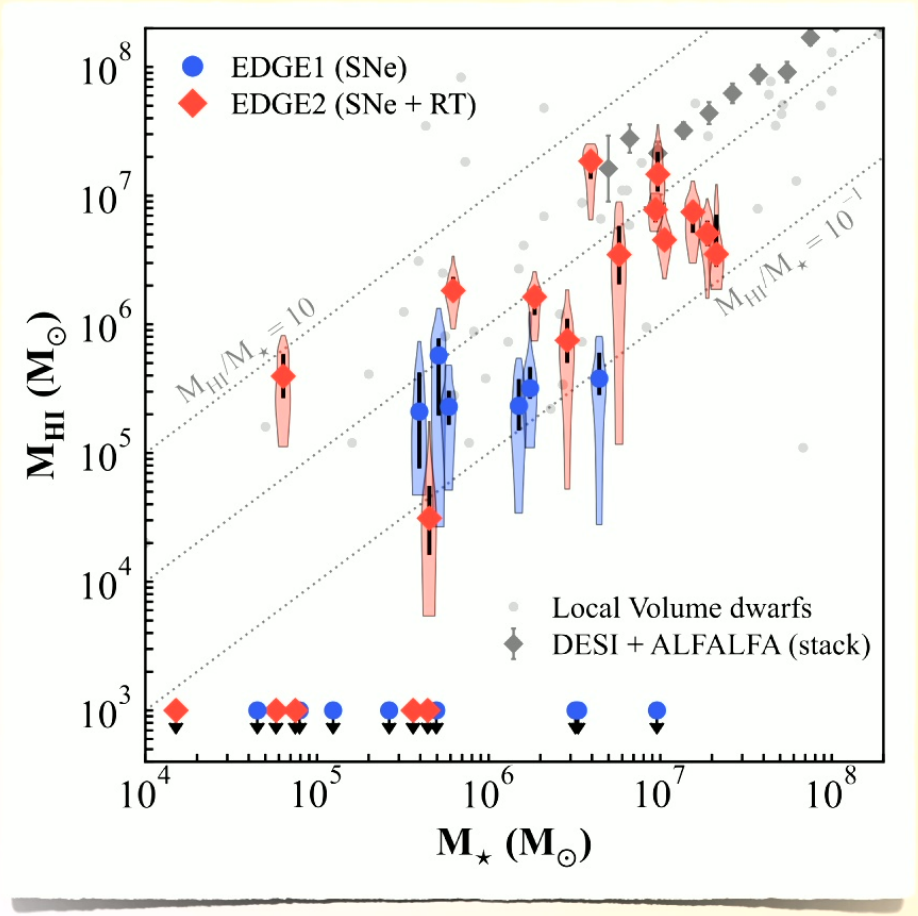
Rey+ 2025

Feedback coupling, not just energy, matters



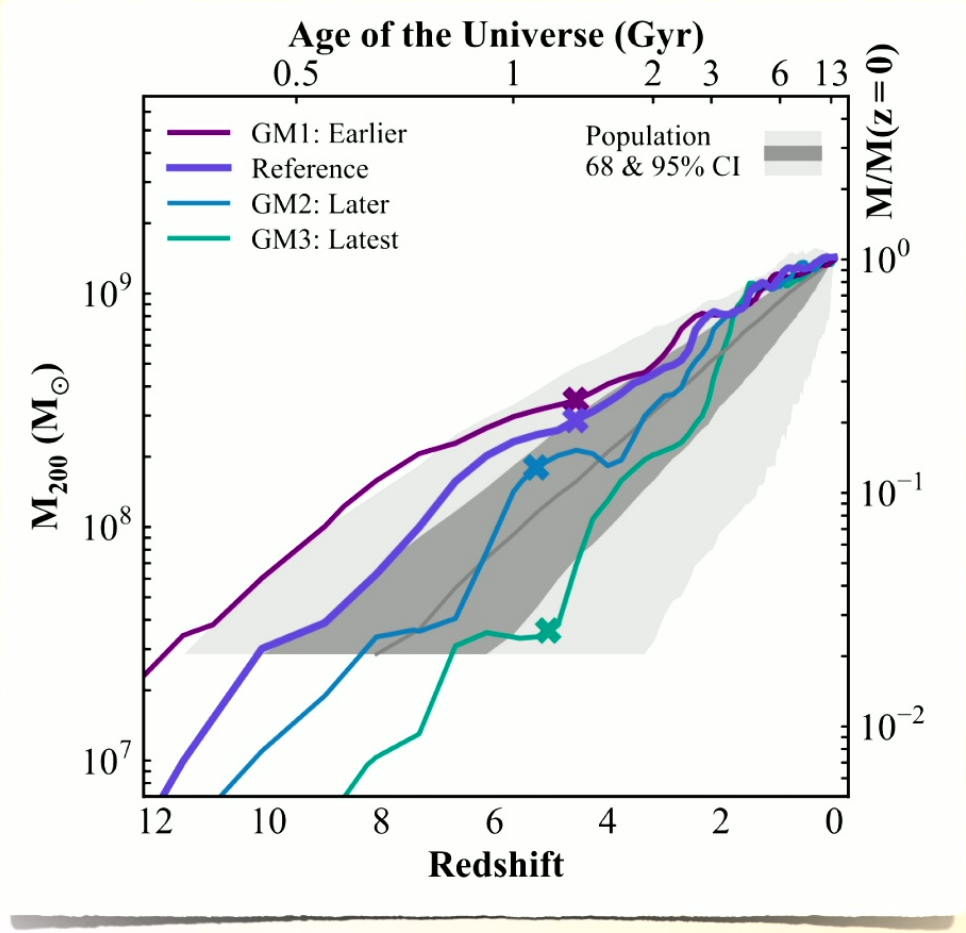
Rey+ 2025

Feedback coupling, not just energy, matters

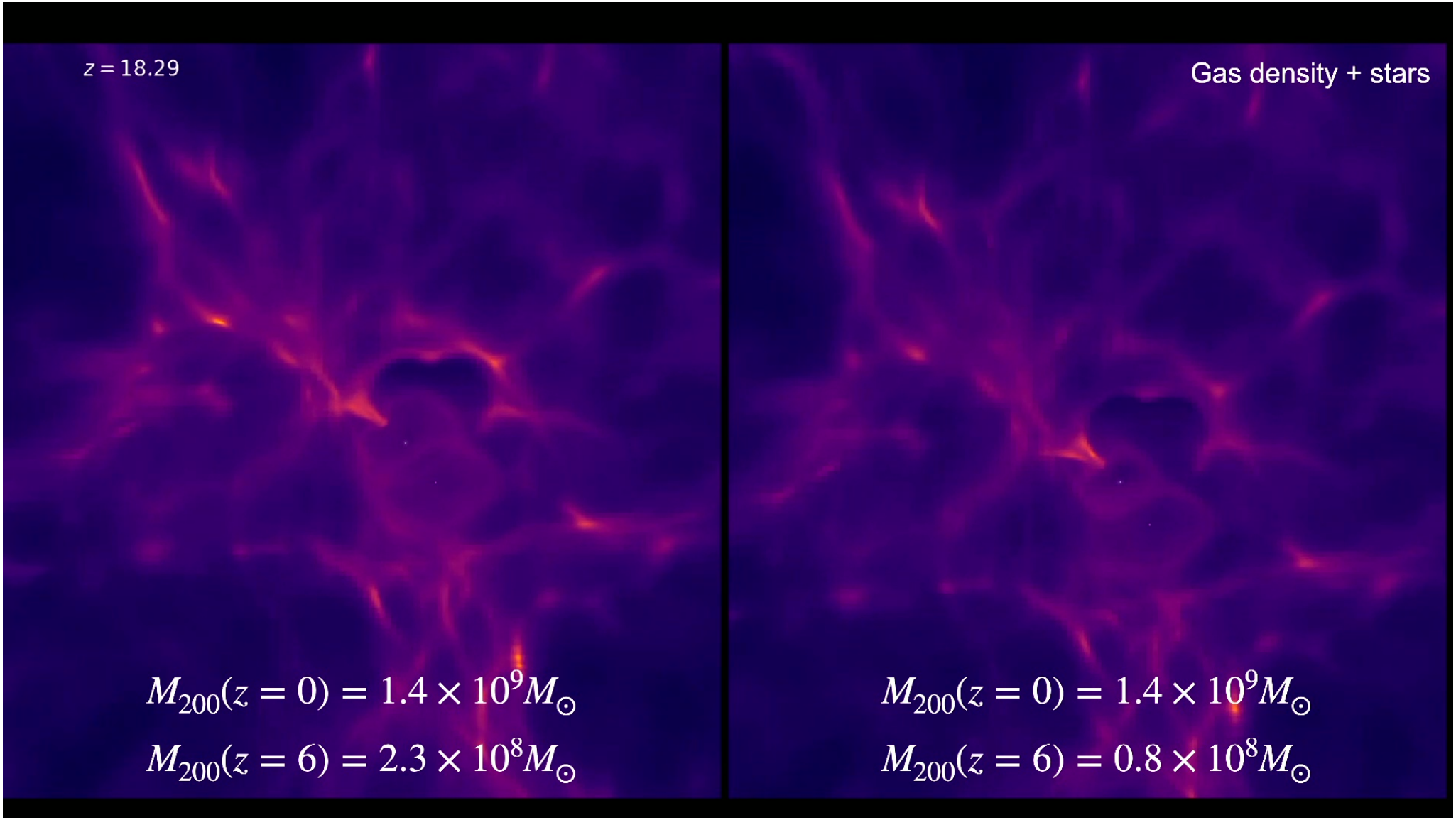


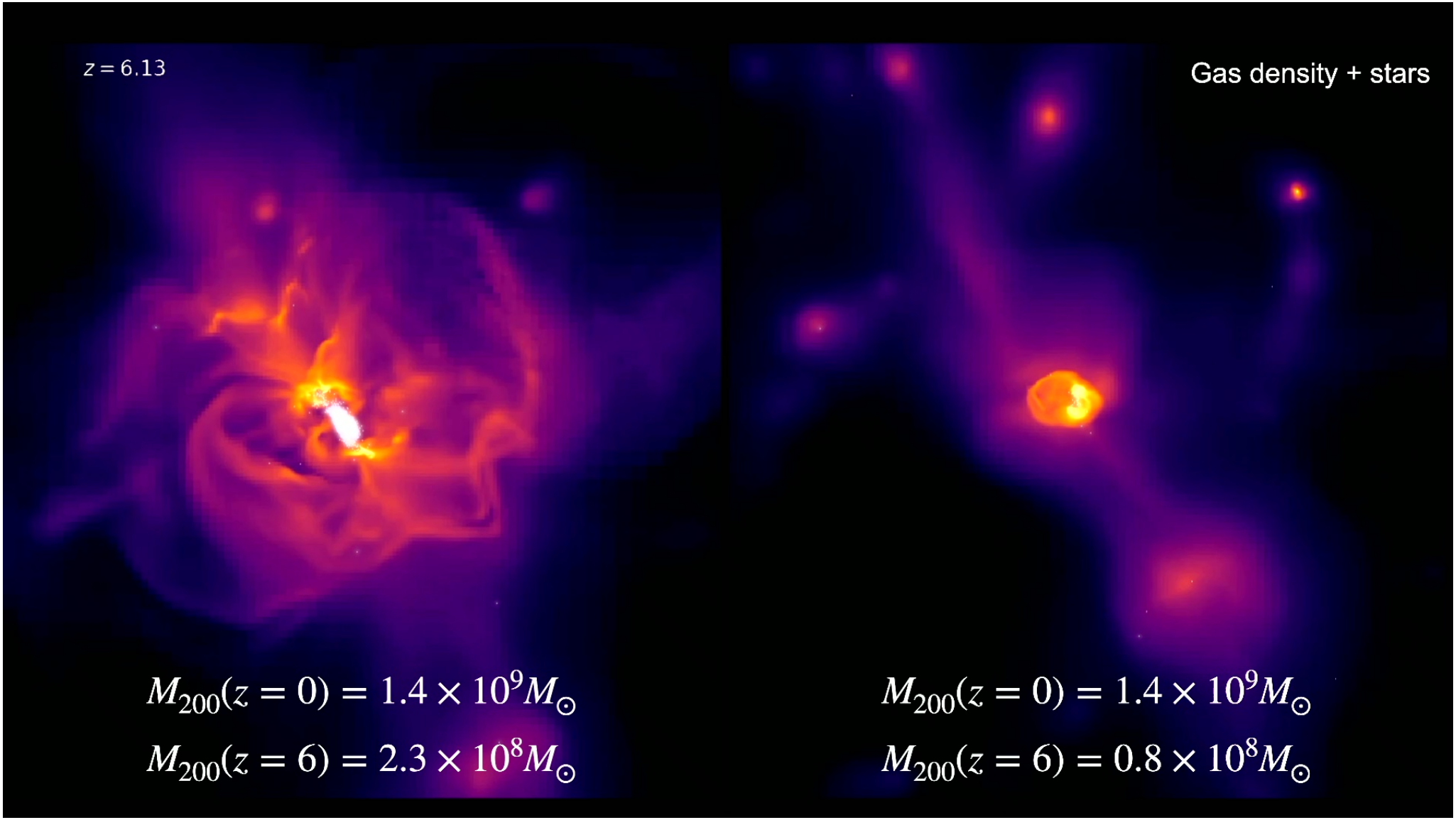
Rey+ 2025

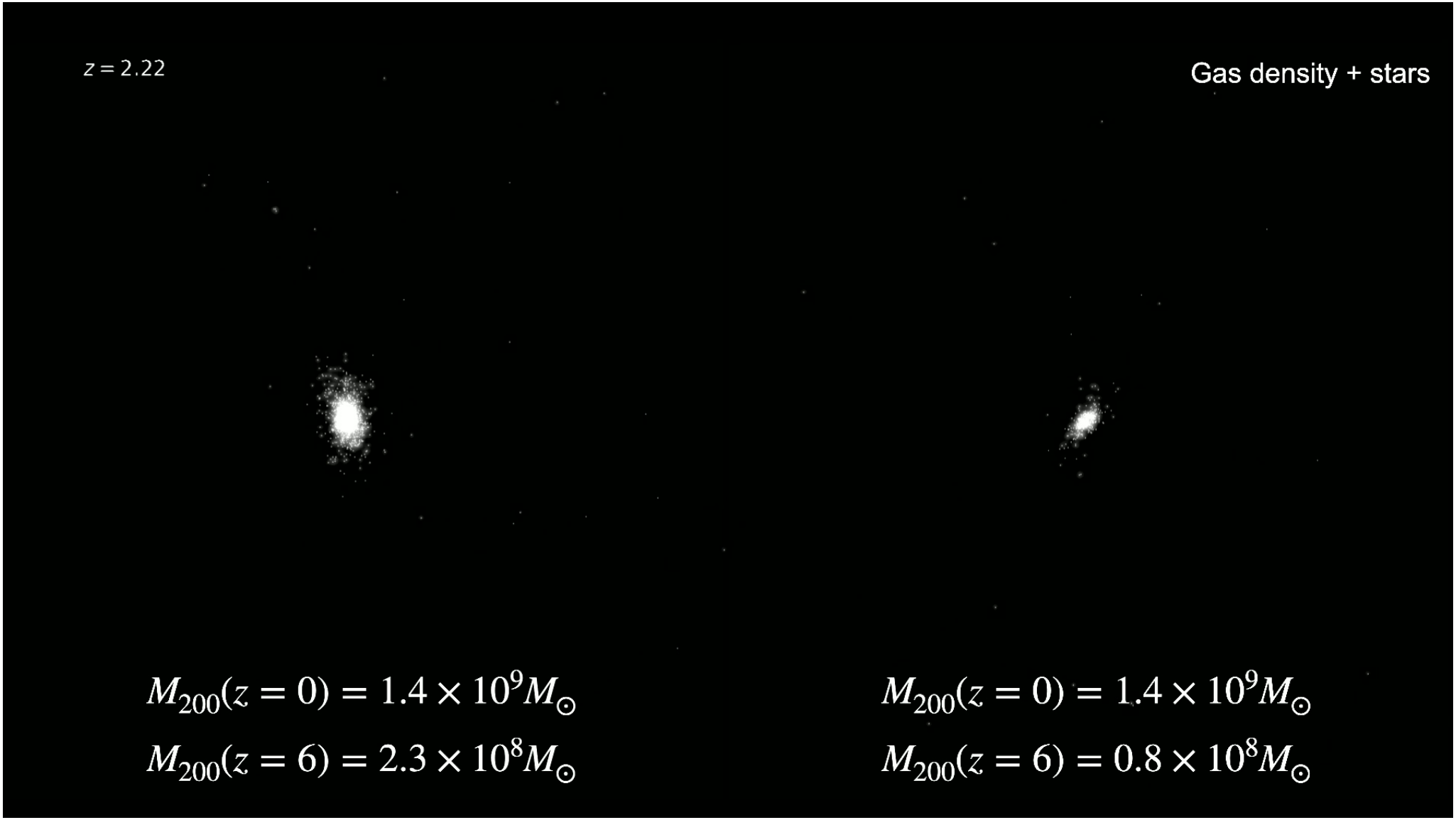
Study interaction with reionisation



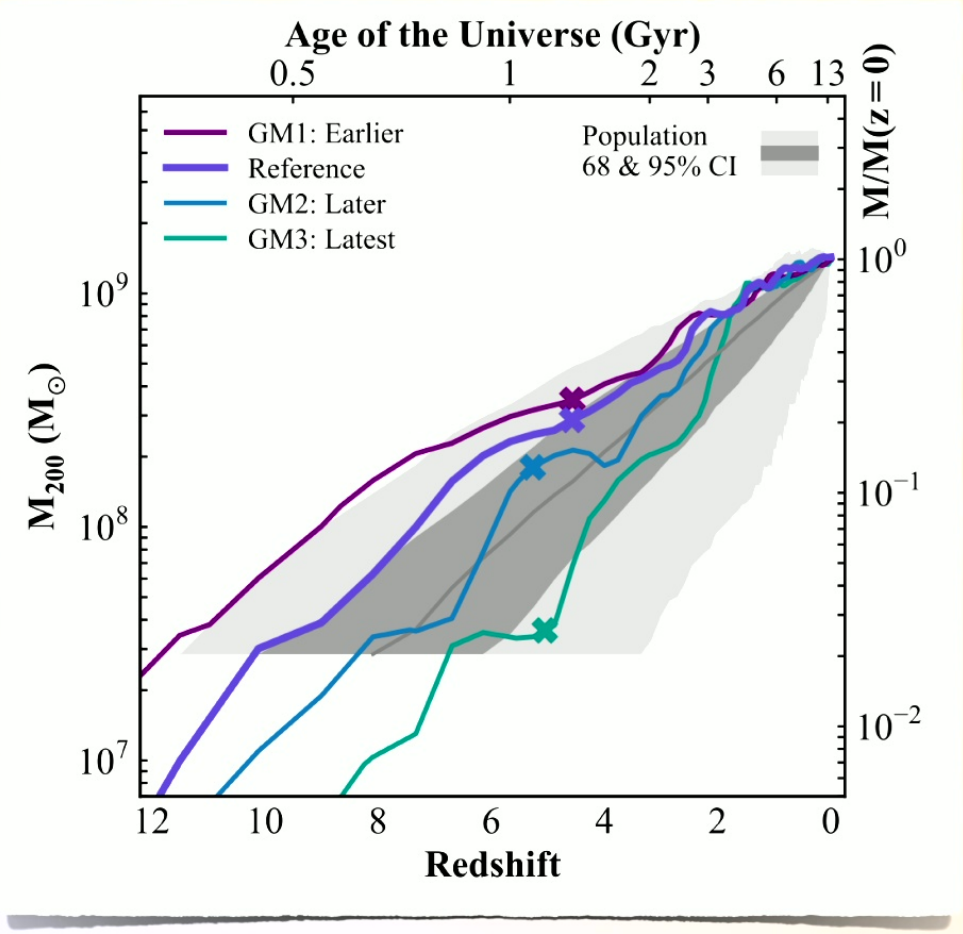
Rey+ 2019

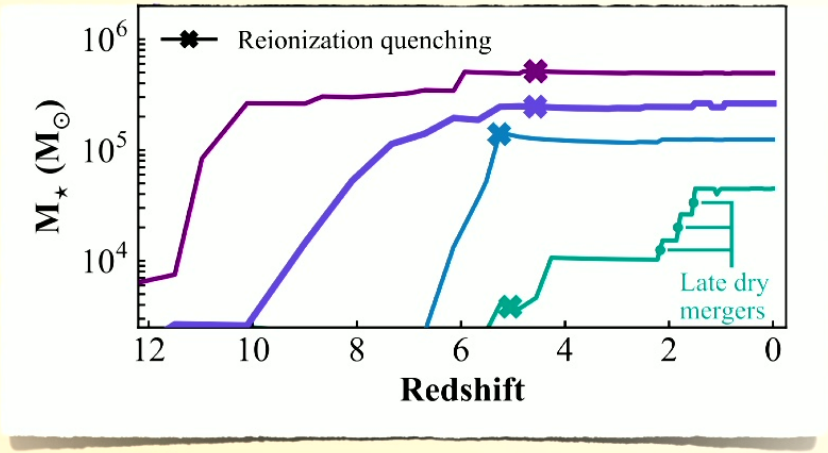

$z = 18.29$
$M_{200}(z = 0) = 1.4 \times 10^9 M_\odot$
$M_{200}(z = 6) = 2.3 \times 10^8 M_\odot$
Gas density + stars
$M_{200}(z = 0) = 1.4 \times 10^9 M_\odot$
$M_{200}(z = 6) = 0.8 \times 10^8 M_\odot$


$z = 6.13$
Gas density + stars
$M_{200}(z = 0) = 1.4 \times 10^9 M_\odot$
$M_{200}(z = 6) = 2.3 \times 10^8 M_\odot$
$M_{200}(z = 0) = 1.4 \times 10^9 M_\odot$
$M_{200}(z = 6) = 0.8 \times 10^8 M_\odot$

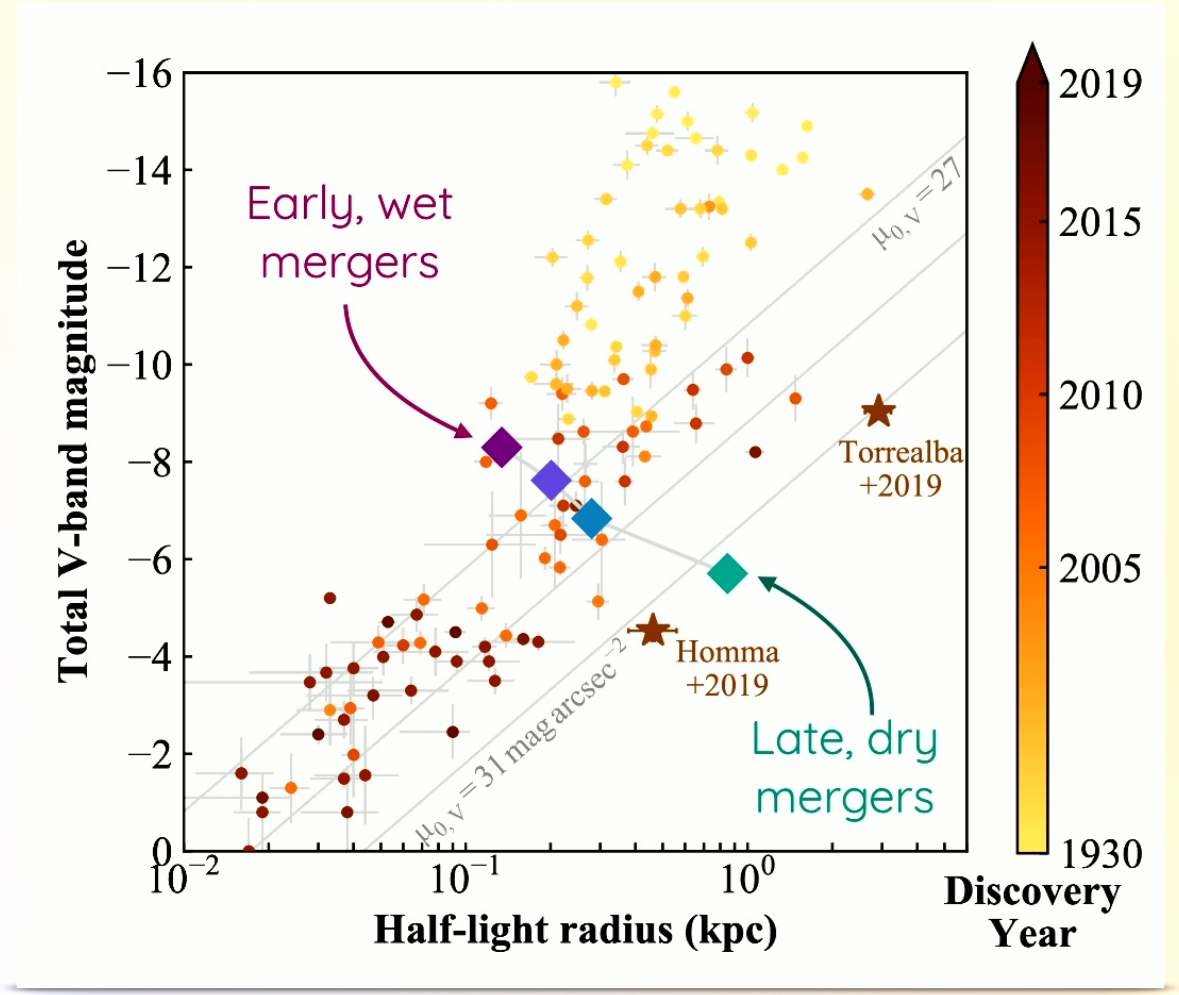

$z = 2.22$
Gas density + stars
$M_{200}(z = 0) = 1.4 \times 10^9 M_\odot$
$M_{200}(z = 6) = 2.3 \times 10^8 M_\odot$
$M_{200}(z = 0) = 1.4 \times 10^9 M_\odot$
$M_{200}(z = 6) = 0.8 \times 10^8 M_\odot$

Study interaction with reionisation





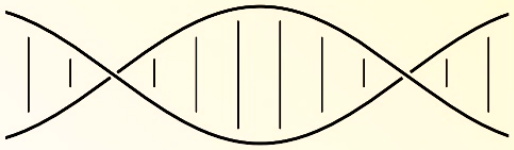
Rey+ 2019



Dry merging makes late-forming dwarfs diffuse

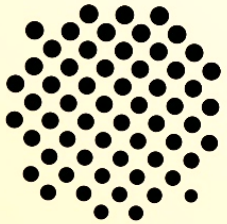
Rey+ 2019

gmgalaxies.org/#code



genetIC

Initial conditions
generator/modifier

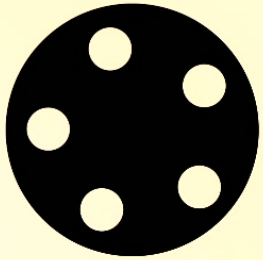


pynbody

Simulation analysis

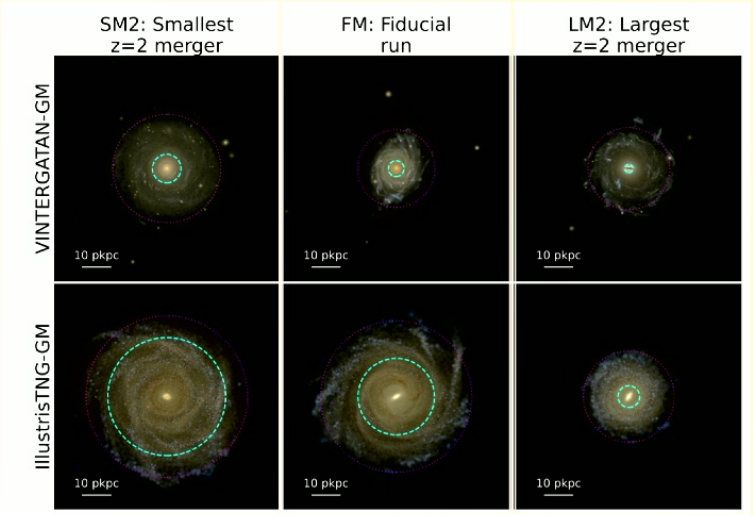
tangos

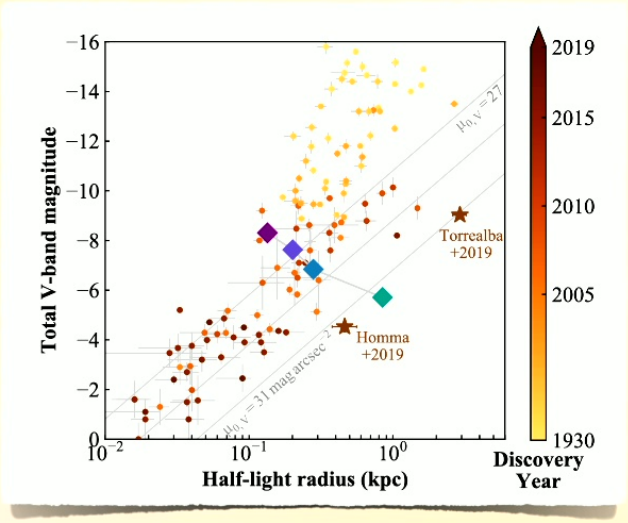
Database creation
and exploration



topsy

Interactive simulation
visualization





gmgalaxies.org

pontzen.uk

Response of galaxy formation simulations to history variations may be more 'converged' than absolute properties

Joshi+ 2025

Interaction between reionisation and mergers in dwarfs controls observable properties, e.g. surface brightness, cusp/core etc

e.g. Rey+ 2019
Muni+ 2025