Fantastic [galaxy simulations] and where to find them…

… a totally unbiased introduction to simulating galaxies, who does it and why

Dr. Elizabeth J Iles

Choose your adventure …

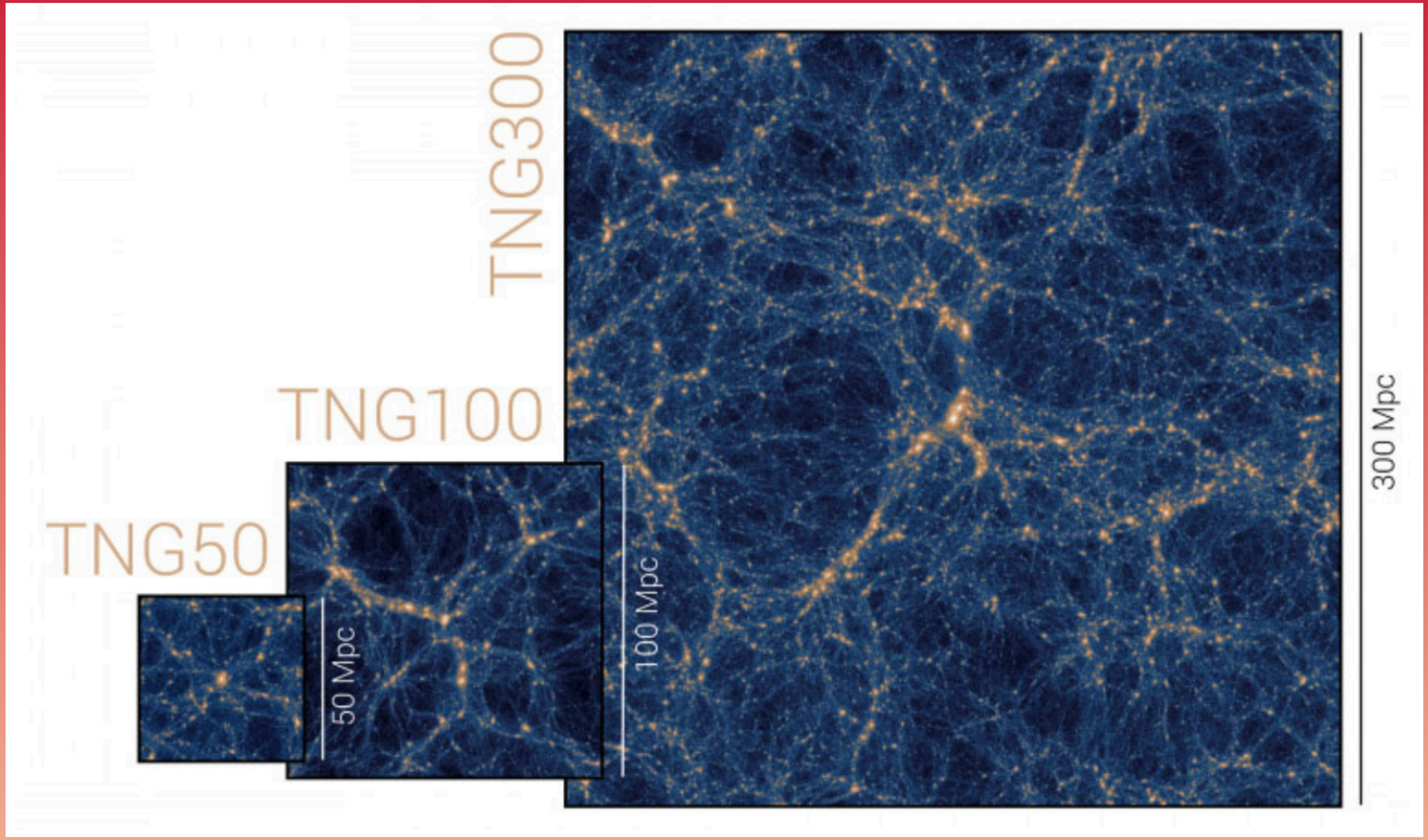
Cosmological Box

Not Cosmological Box

Choose your adventure …

Cosmological Box

Choose your adventure …



c/o The TNG collaboration

Cosmological Box Simulations

The Millenium Simulation (~2005)

EAGLE: Evolution and Assembly of GaLaxies and their Environments (~2015)

Magneticum (~2013)

Illustris (~2014)

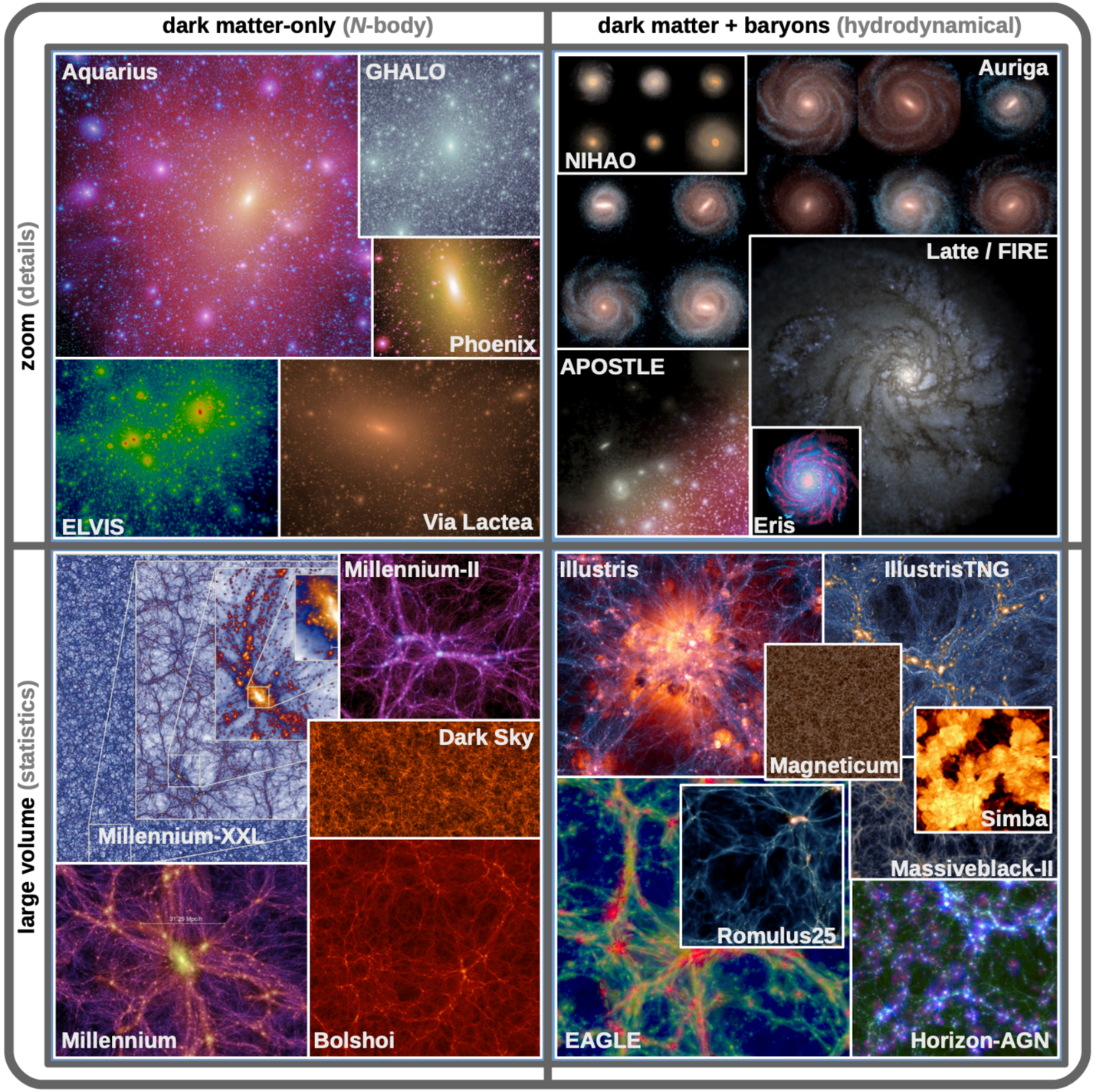
IllustrisTNG (~2018)

FIRE: Feedback in Relativistic Environments (~2014)

FIRE2: Feedback in Relativistic Environments 2 (~2018)

NIHAO Project (~2015)

… and others



c/o Vogelsberger et al (2020)
Cosmological Simulations of Galaxy Formation
Nature Reviews Physics

Cosmological Box Simulations

Why is a cosmological box good for galaxies?

- It covers the whole assembly history
- Galaxies form naturally
- We can see the things around galaxies
- And whether the age of the Universe has any effects

Cosmological Box Simulations

Why is a cosmological box good for galaxies?

- It covers the whole assembly history
- Galaxies form naturally
- We can see the things around galaxies
- And whether the age of the Universe has any effects

Why is a cosmological box not so good for galaxies?

- It covers the whole assembly history
- Galaxies form naturally
- We can’t get rid of the things around galaxies
- And don’t know whether the age of the Universe has any effects

Choose your adventure ...

Not Cosmological Box

Specific Context Simulations

Single Galaxies

Zoom-ins

Small Number Interactions

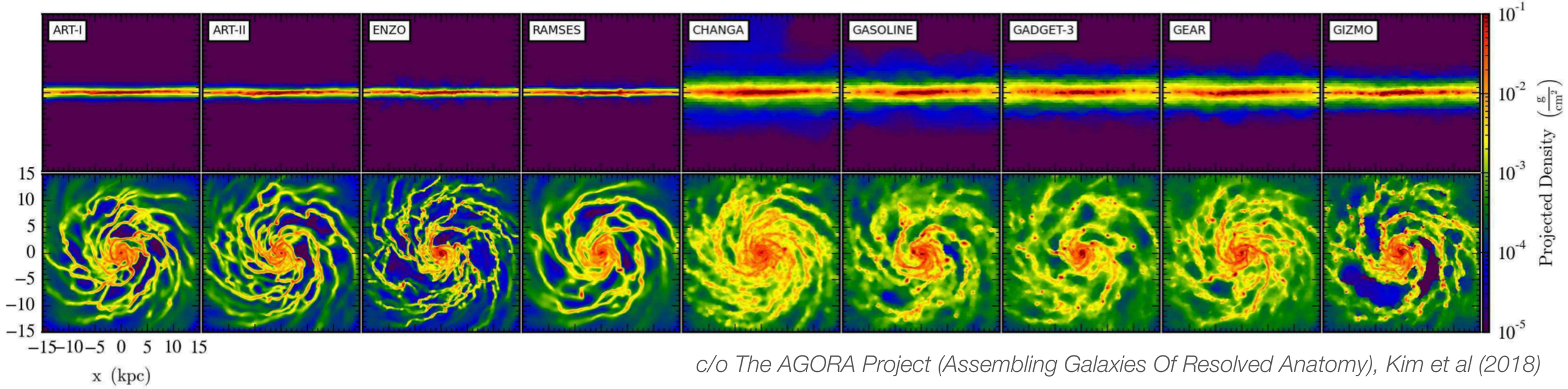
Milky Way Analogues

Slices of Interest (i.e. ISM)

Galactic Potentials

Specific Context Simulations

Single Galaxies



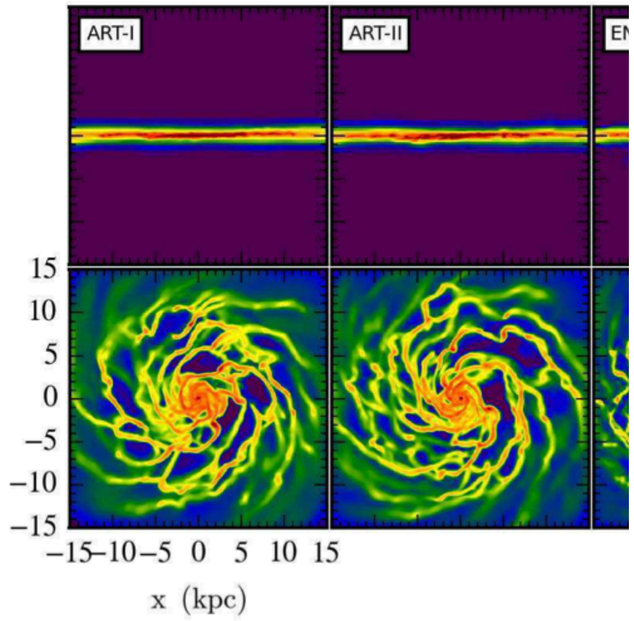
c/o The AGORA Project (Assembling Galaxies Of Resolved Anatomy), Kim et al (2018)

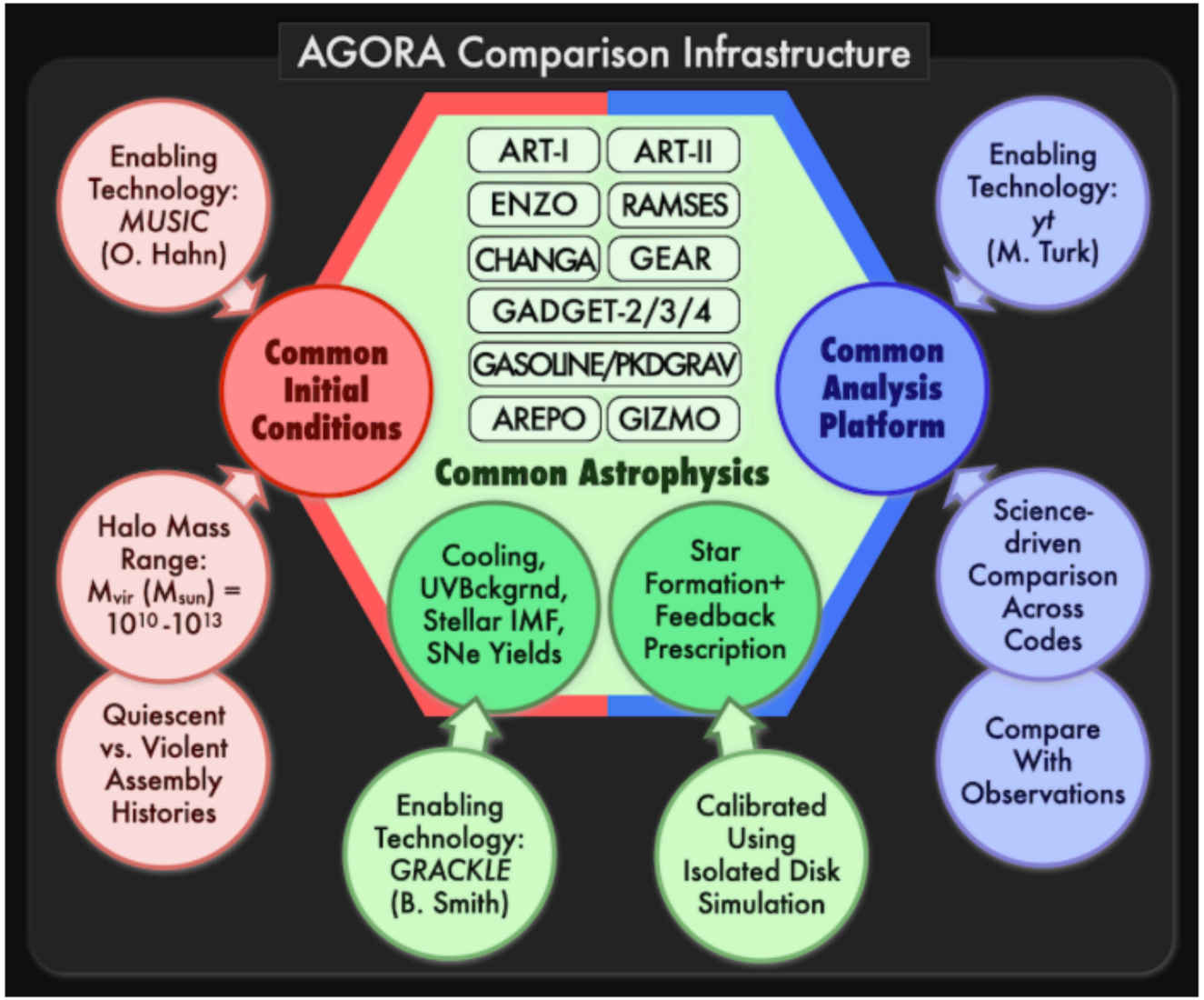
Isolated Milky Way-mass galaxies' disk gas surface densities at 500 Myr epoch

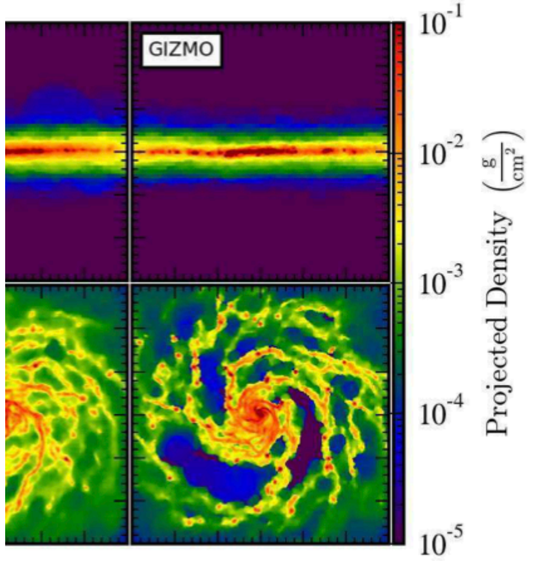
e.g. tells us how (sub-grid) physics can impact galaxy formation/structure…

Specific Context Simulations

Galaxies







ed Anatomy), Kim et al (2018)

Isolated Milky Way

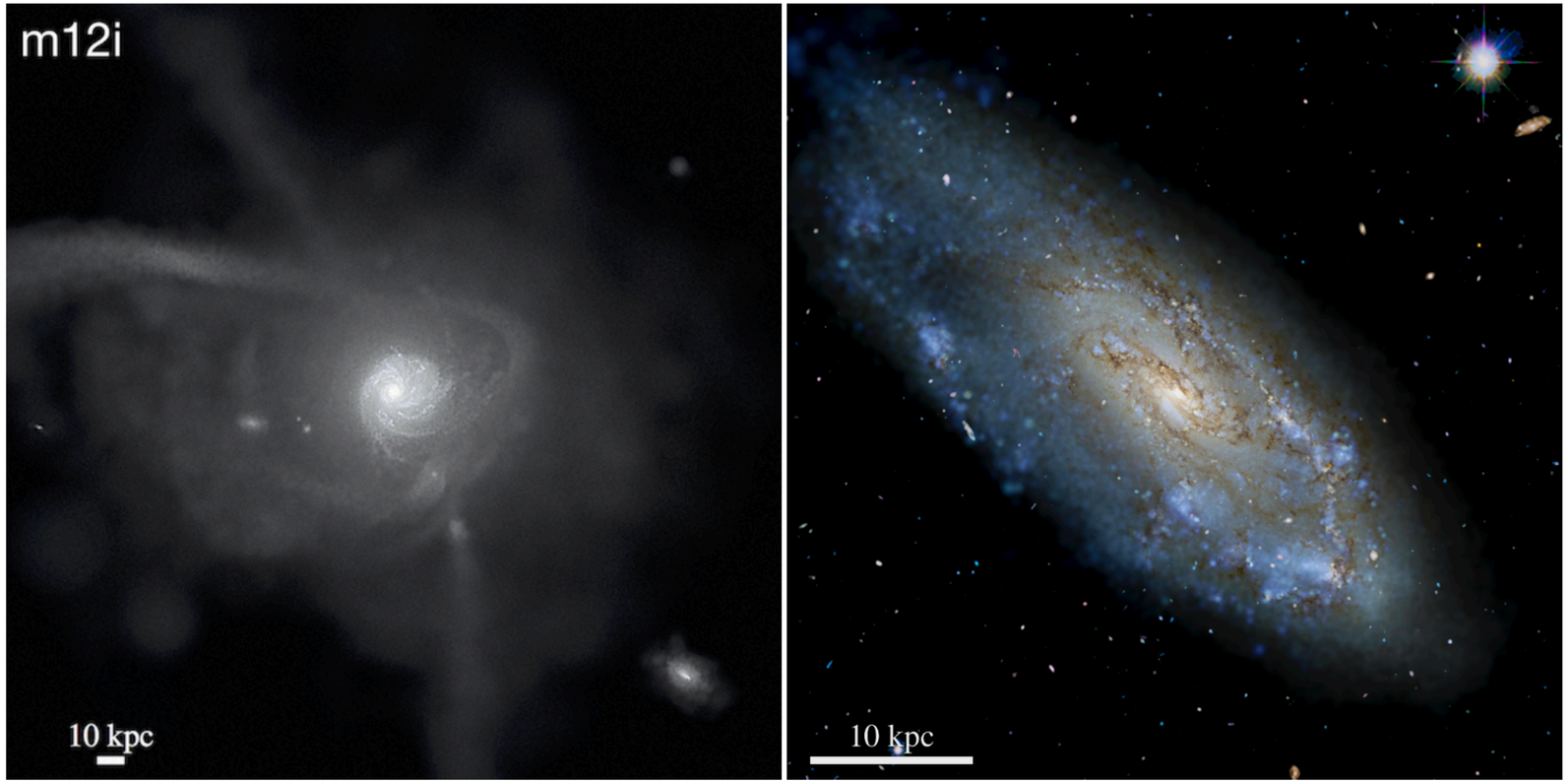
e.g. tells us how

500 Myr epoch

n/structure…

Specific Context Simulations

LATTE



Zoom-ins

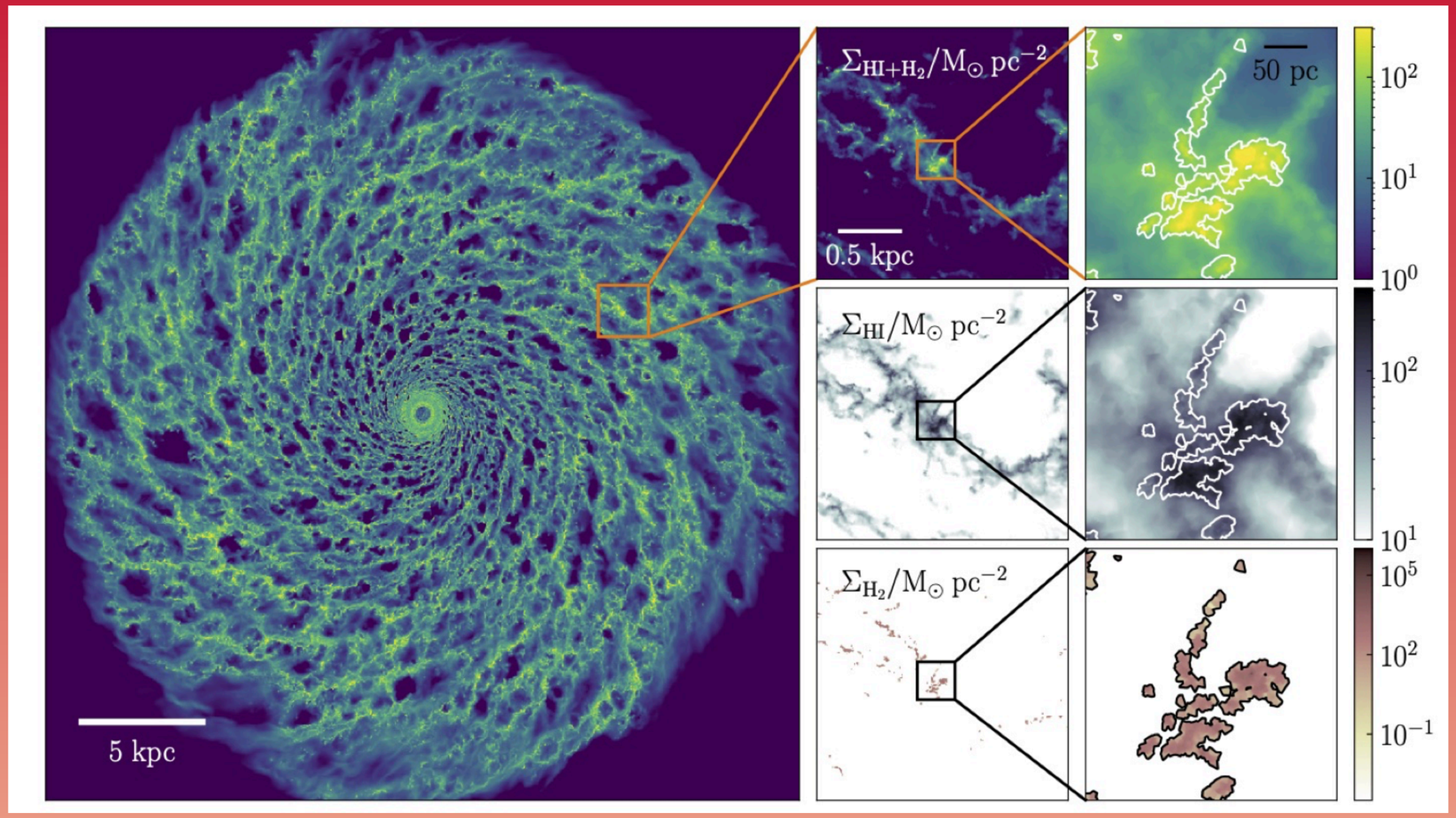
Milky Way Analogues

c/o The Latte Team in the FIRE Collaboration

Milky Way analogues from Zoom-ins of Cosmological Simulations

e.g. allows us to cheat and increase resolution on the things we're interested in…

Specific Context Simulations



Zoom-ins

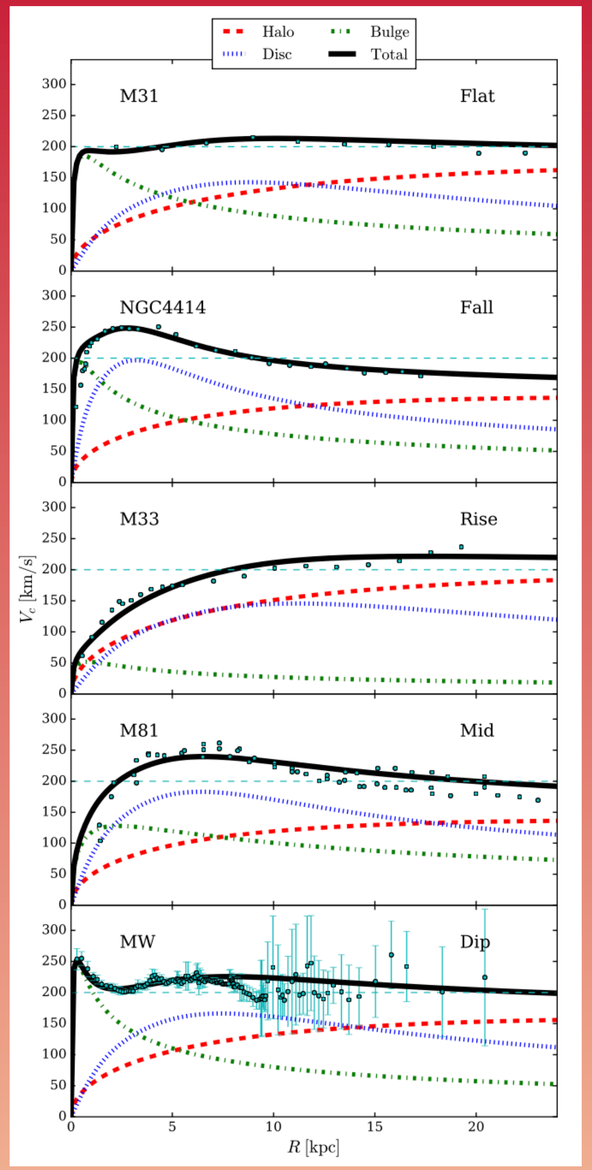
Single Galaxies

c/o Jeffreson et al. (2020)
Shout out: Clare Dobbs

Molecular Cloud properties from Zoom-in Single Galaxy Simulations

e.g. allows us to cheat and increase resolution on the things we're really interested in…

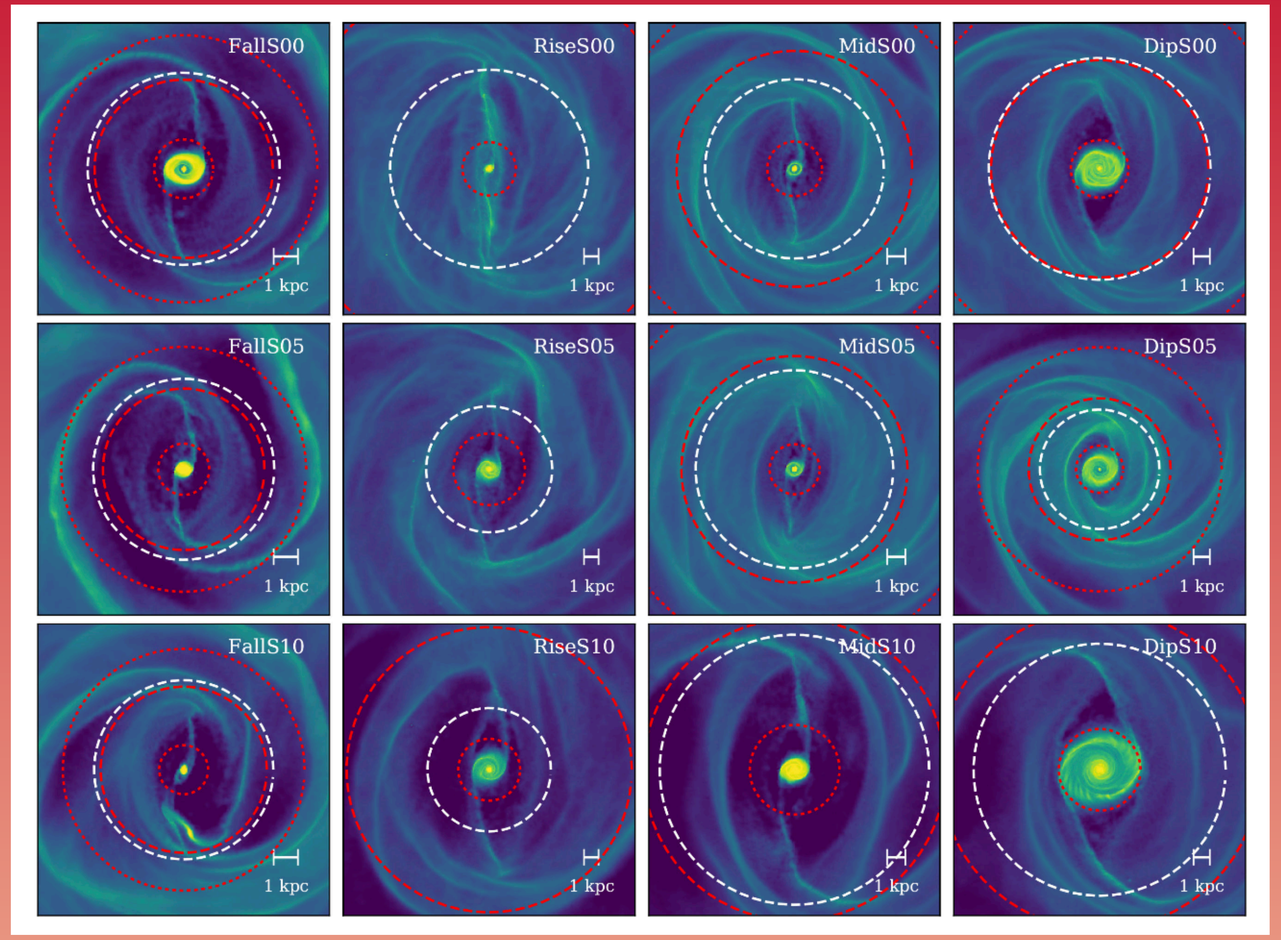
Specific Context Simulations



—

5%

10%



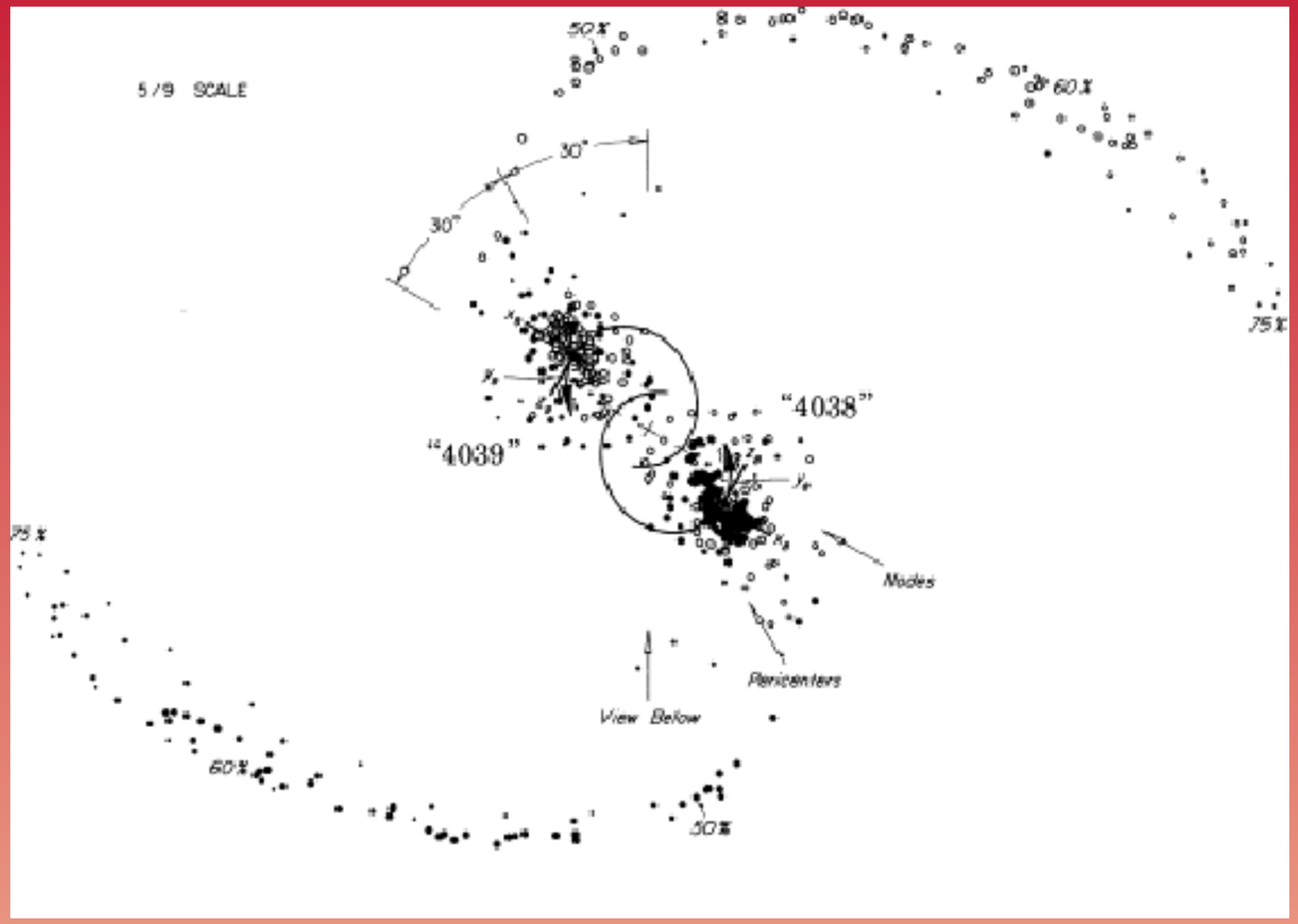
Small Number Interactions

c/o Pettitt & Wadsley, (2018)

Simulations testing the effect of a small interaction on the bar

e.g. tells us how changing one specific parameter can influence a galaxy

Specific Context Simulations



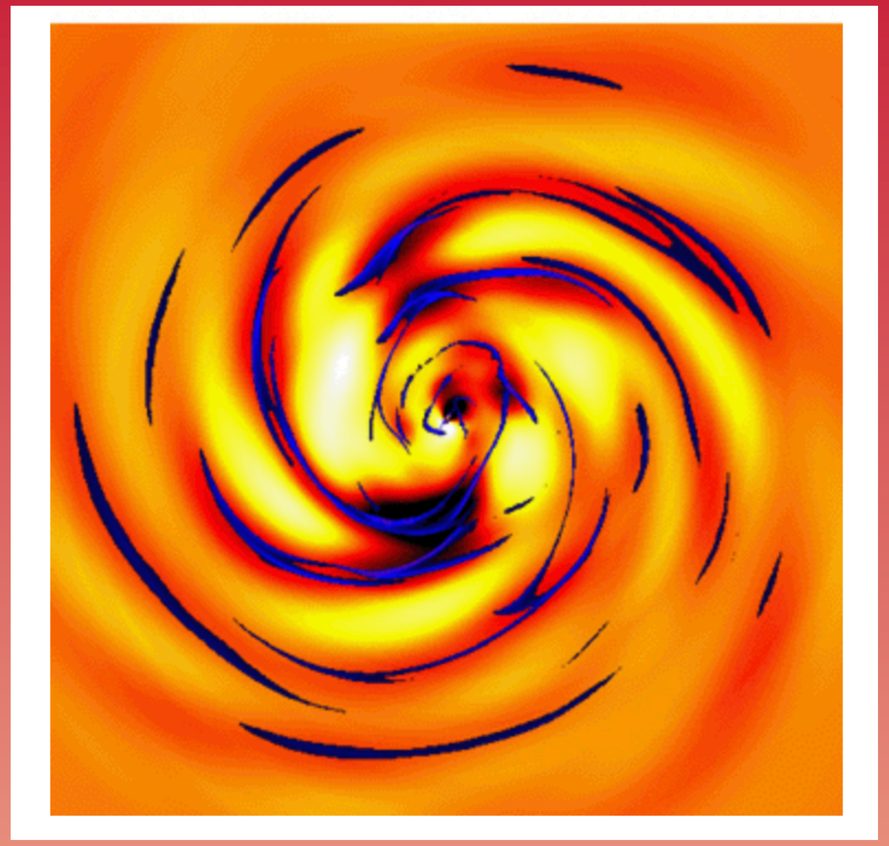
Small Number Interactions

c/o Toomre & Toomre 1979
Galactic Bridges and Tails

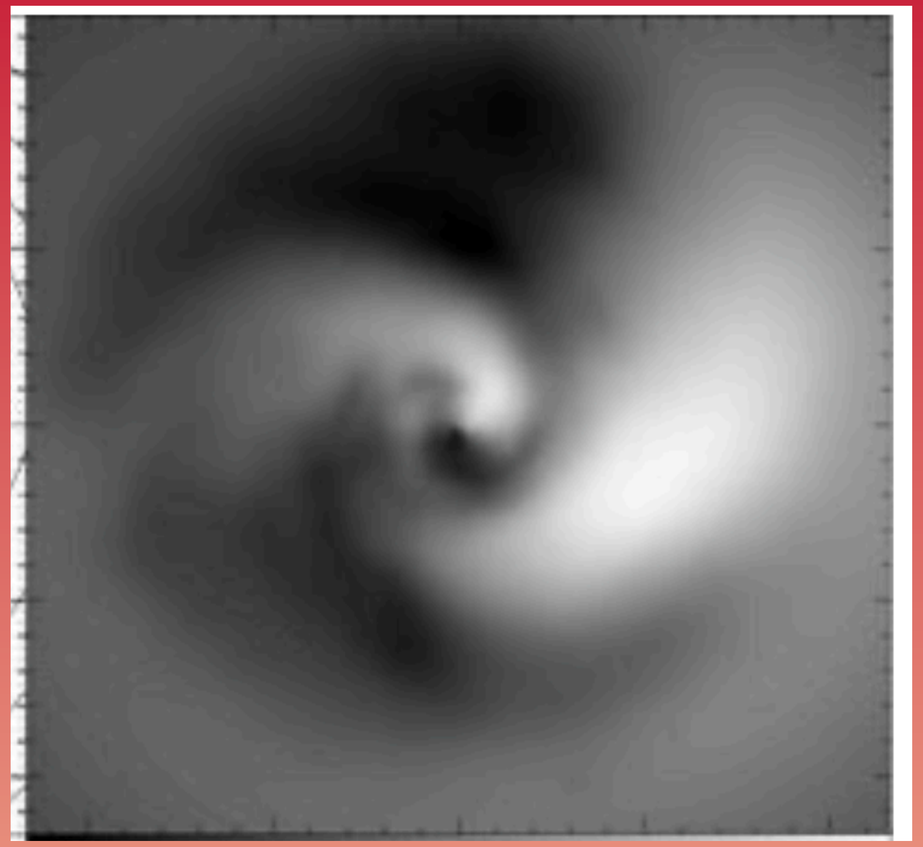
An n-body model of two identical disks interacting and merging.

e.g. allows us to explain the origin of strange features we observe…

Specific Context Simulations



c/o Dobbs et al (2008)



c/o Slyz et al (2002) - axisymmetric potential subtracted from the potential of NGC 4254

Galactic Potentials

A spiral potential (either real or contrived) with n-body gas evolution

e.g. allows us to focus on the component we are interested in…

Particles vs. Grids

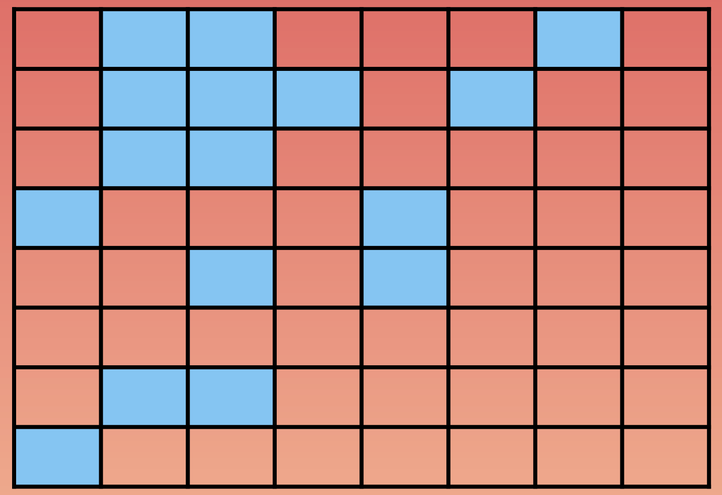
Particles

Grids

Particles vs. Grids

Lagrangian

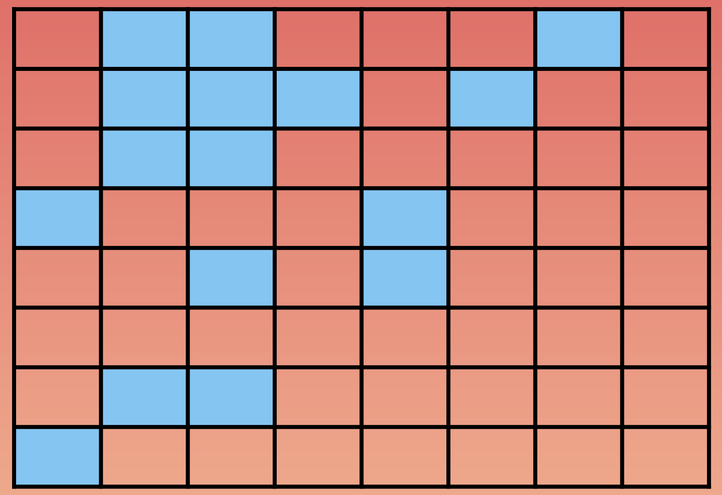
Eulerian



Particles vs. Grids

SPH
“Smoothed Particle Hydrodynamics”

AMR
“Adaptive Mesh Refinement”

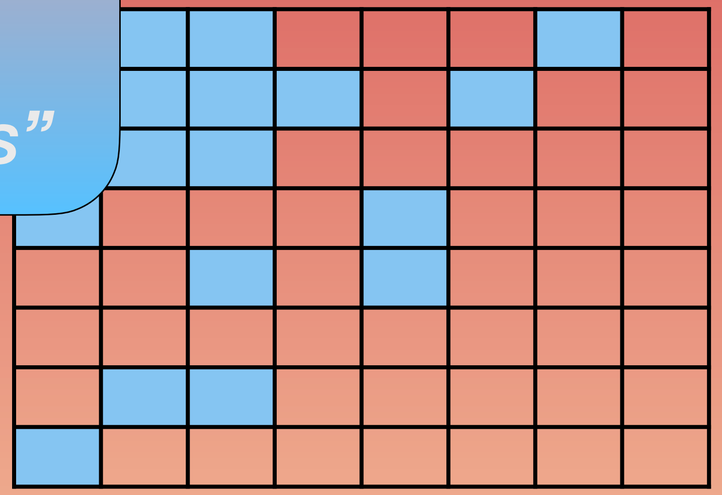


Particles vs. Grids

SPH
"Smoothed Pa
Hydrodynam

AMR
daptive Mesh
Refinement"

+
Eulerian-Lagrangian/
quasi-Lagrangian
"Moving Mesh"
"Meshless Finite Mass"



Advertisement

Smoothed Particle Hydrodynamics: Things I wish my mother taught me

Daniel J. Price

Monash Centre for Astrophysics (MoCA), School of Mathematical Sciences, Monash University, Vic 3800, Australia

Abstract. I discuss the key features of Smoothed Particle Hydrodynamics (SPH) as a numerical method — in particular the key differences between SPH and more standard grid based approaches — that are important to the practitioner. These include the exact treatment of advection, the absence of intrinsic dissipation, exact conservation and more subtle properties that arise from its Hamiltonian formulation such as the existence of a minimum energy state for the particles. The implications of each of these are discussed, showing how they can be both advantages and disadvantages.

(2011)

‘Modern’ Simulation Codes

Art-I,II

Arepo

Changa

Cosmological Adaptive Mesh Refinement[CD]

Enzo

Gadget 1-4

Gasoline

Gear

Gizmo

MLAPM

Ramses

‘Modern’ Simulation Codes

Art-I,II

Arepo *e.g. Illustris, IllustrisTNG*

Changa

Cosmological Adaptive Mesh Refinement[CD]

Enzo

Gadget 1-4 *e.g. Millenium, Magneticum, EAGLE*

Gasoline *e.g. NIHAO*

Gear

Gizmo *e.g. FIRE, FIRE2*

MLAPM

Ramses

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Cosmological Adaptive Mesh Refinement[CD]

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Gasoline e.g. NIHAO, AGORA, Iles (USyd, HokuDai)

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MLAPM e.g. Knebe, Binney (Oxford)

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Cosmological Adaptive Mesh Refinement[CD] e.g. (France) ?

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Grid

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Grid

Particle

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Ramses *e.g. AGORA, Bland-Hawthorn (USyd)*

Grid

Particle

\o/

Choose [my] adventure …

Not Cosmological Box

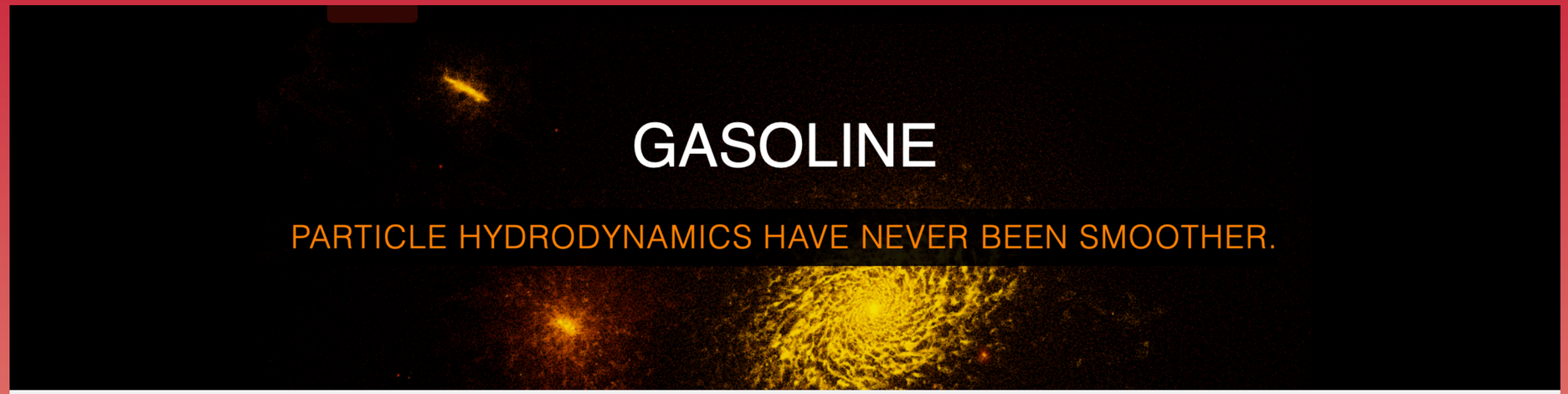
Choose [my] adventure …

Particles!

Choose [my] adventure …

Lagrangian (SPH)

Choose your adventure …



WHAT IS GASOLINE?

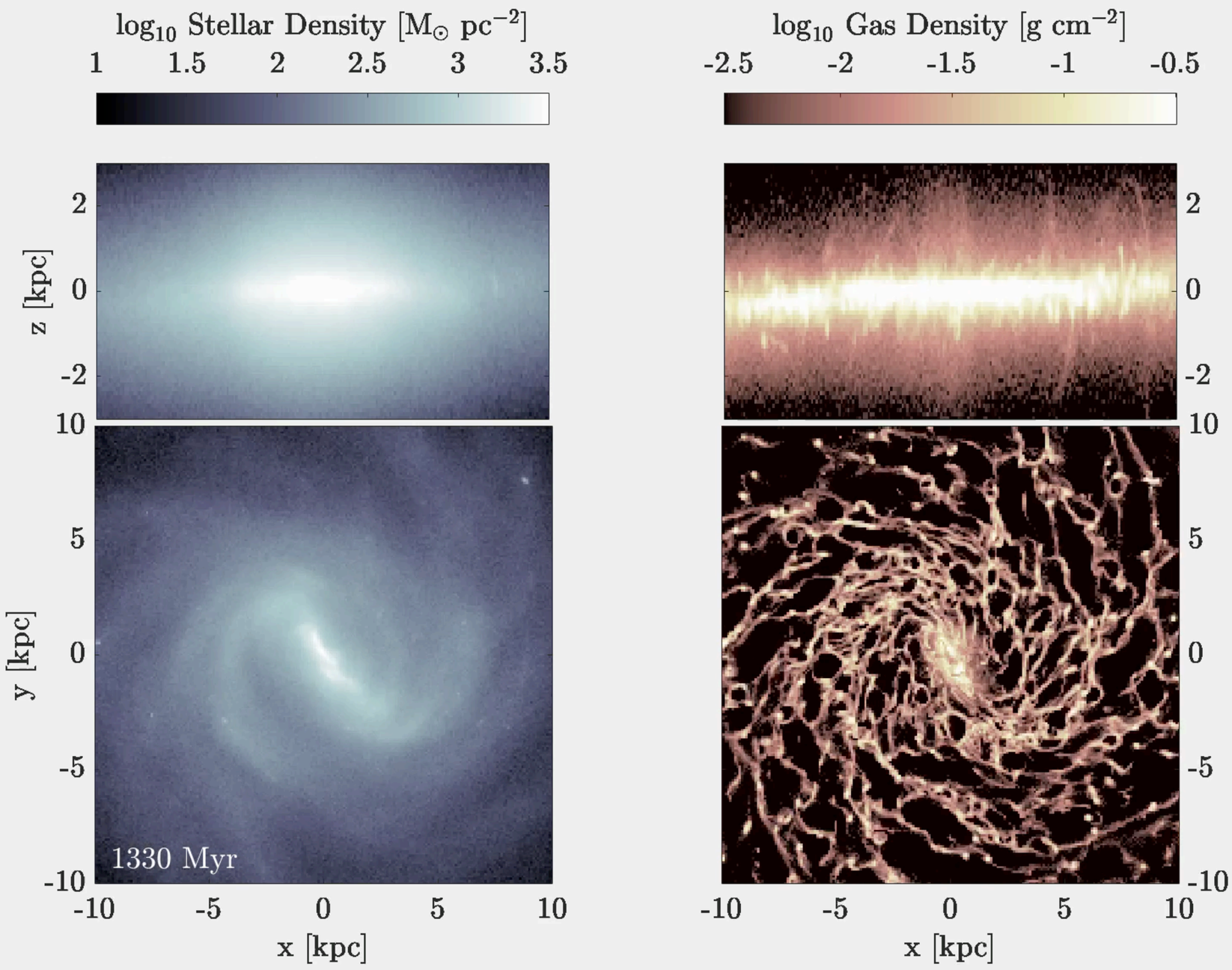
Gasoline Is A Modern SPH Simulation Code For Astrophysical Problems.

GET GASOLINE

Gasoline is written in modern C. All you need to build it is the MDL helper library and a C compiler.

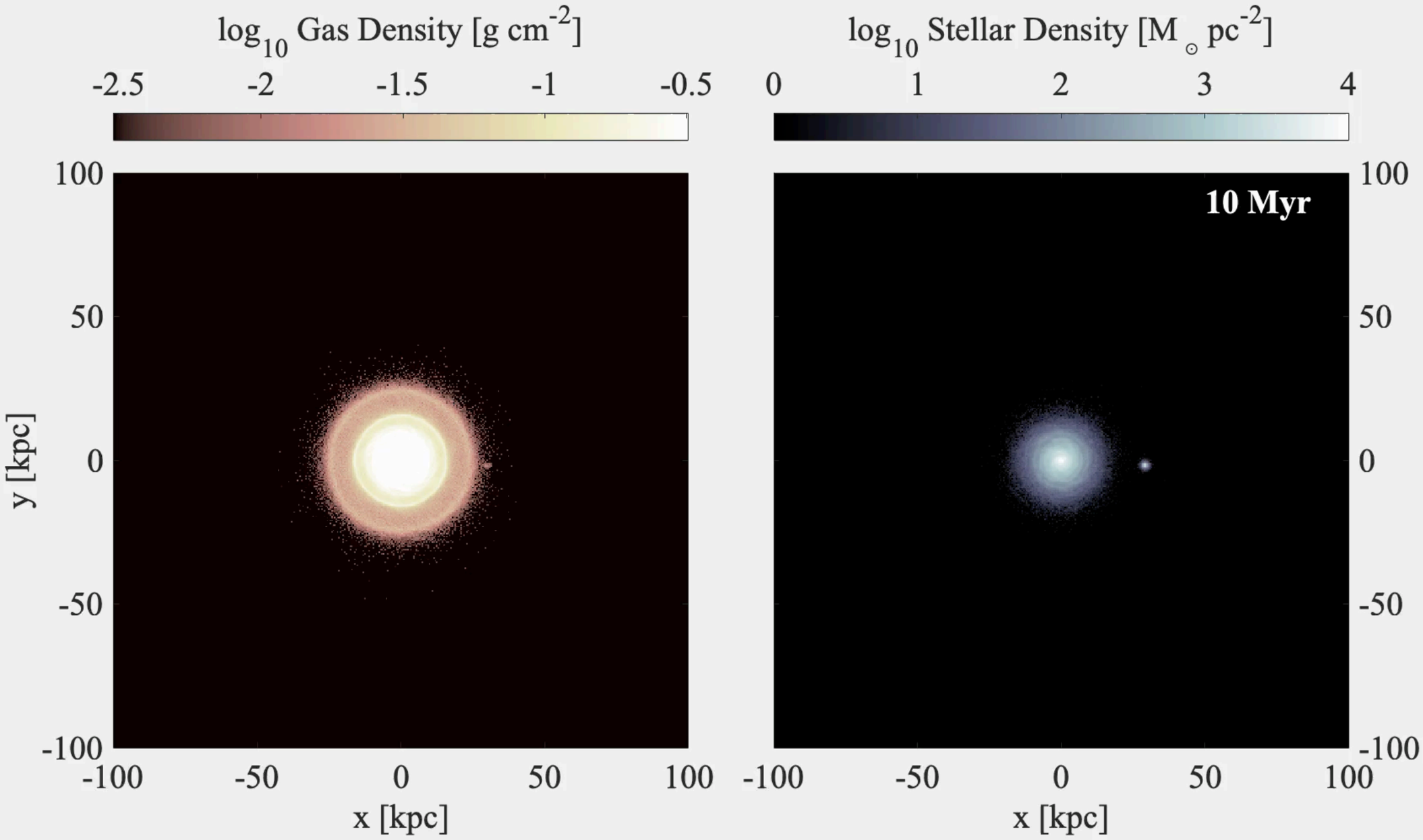
BUILDING GASOLINE

Single Galaxy



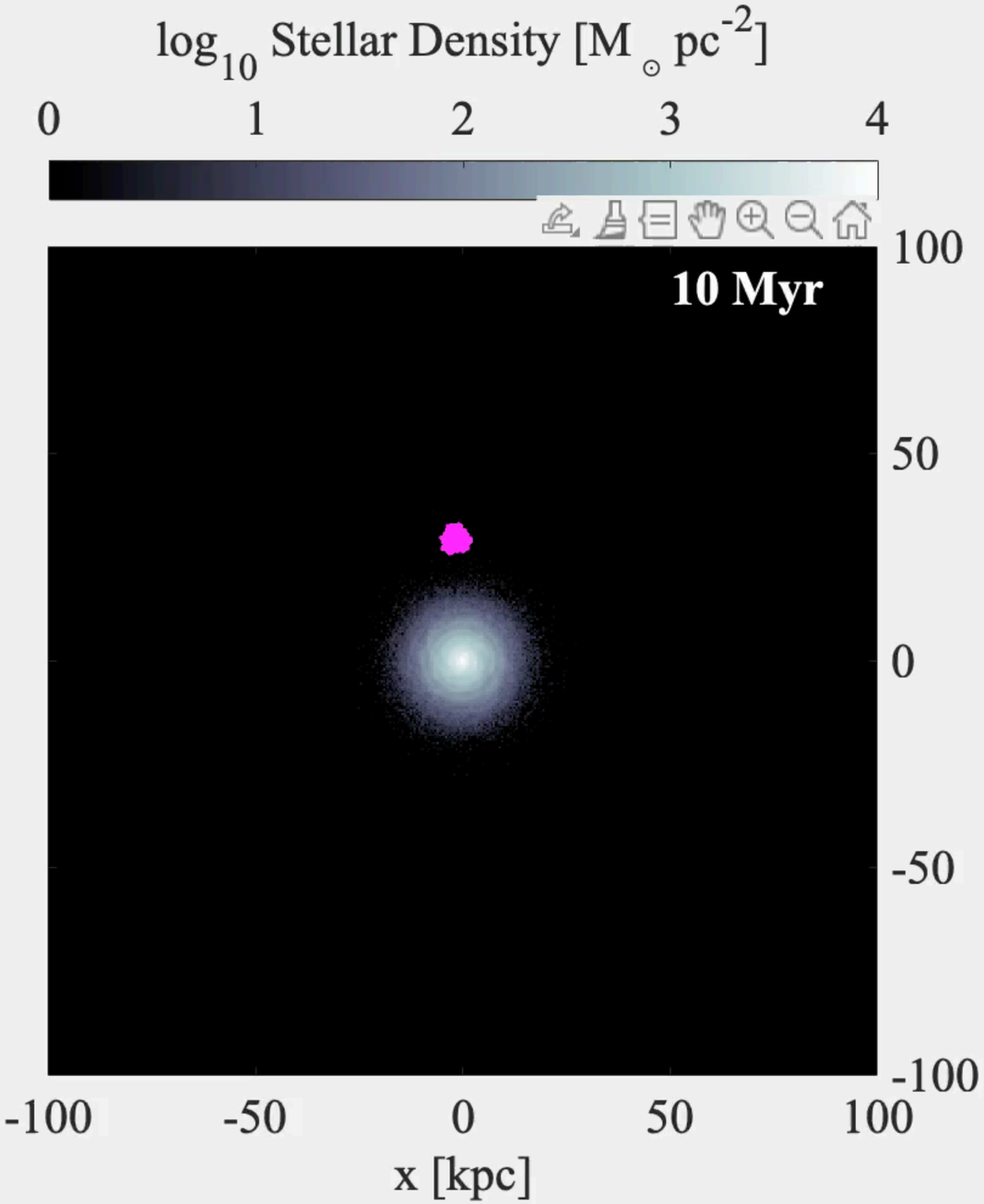
Iles, van de Sande, et al (in prep.)

Small Number Interaction
(S = 10%)



Iles et al (2022)

Why particle codes are the best codes!



Iles et al (2022)