Forming disc galaxies on a moving mesh

zoom-in simulations of Milky Way-sized haloes

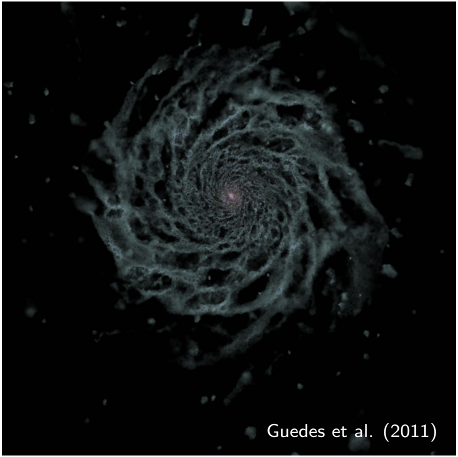
Federico Marinacci

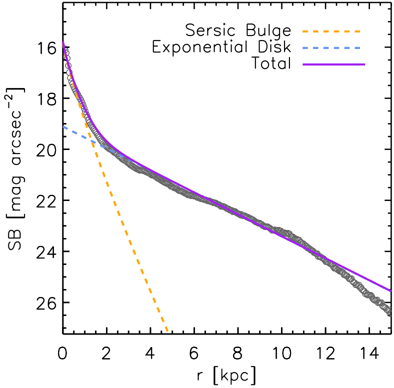
in collaboration with: R. Pakmor & V. Springel

Bologna, 31 October 2013

Simulations of disc galaxy formation

Eris simulation





$\sim 1.8 \times 10^7$ particles inside $r_{\rm vir}$

$m_{\rm SPH} = 2 \times 10^4\ \mathrm{M}_\odot$

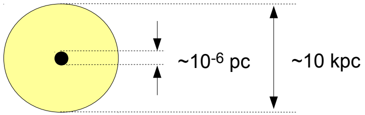
1.5 millions CPU-hours

Multi-scale physics in galaxy formation

Galaxy formation poses an enormous multi-scale physics problem

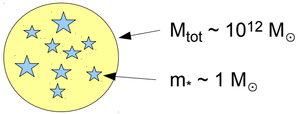
THE DYNAMIC RANGE CHALLENGE (slide taken from V. Springel's Mind the Gap conference talk)

A supermassive BH in a galaxy



dynamic range of 10^{10}

Star formation in a normal galaxy

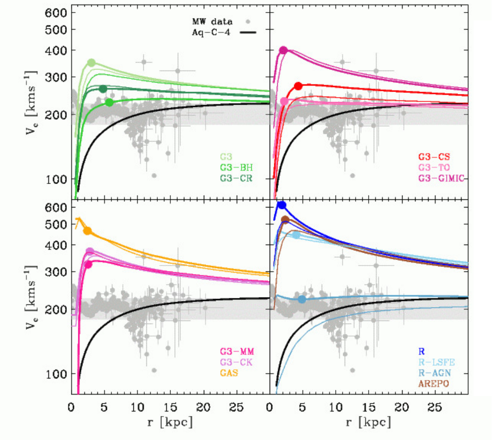


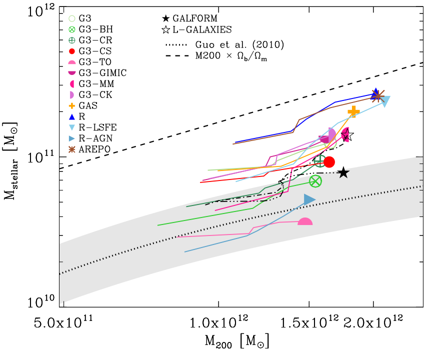
mass dynamic range of 10^{12}

Sub-grid prescriptions are implemented to simulate these physical processes

The importance of sub-grid physics

(Scannapieco et al. 2012)



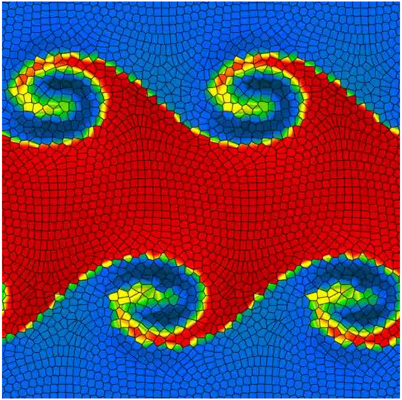


Making disc galaxies is a challenging task in cosmological simulations

The simulation set

The moving-mesh code AREPO

Kelvin-Helmholtz instability



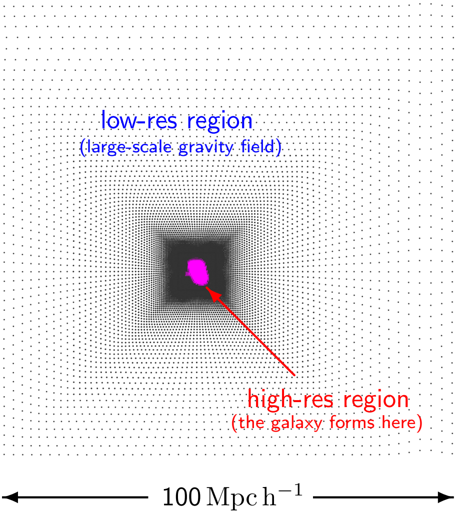
credit: V. Springel

- Unstructured Voronoi tesselation
- Mesh moves with the flow
- Galileian invariance

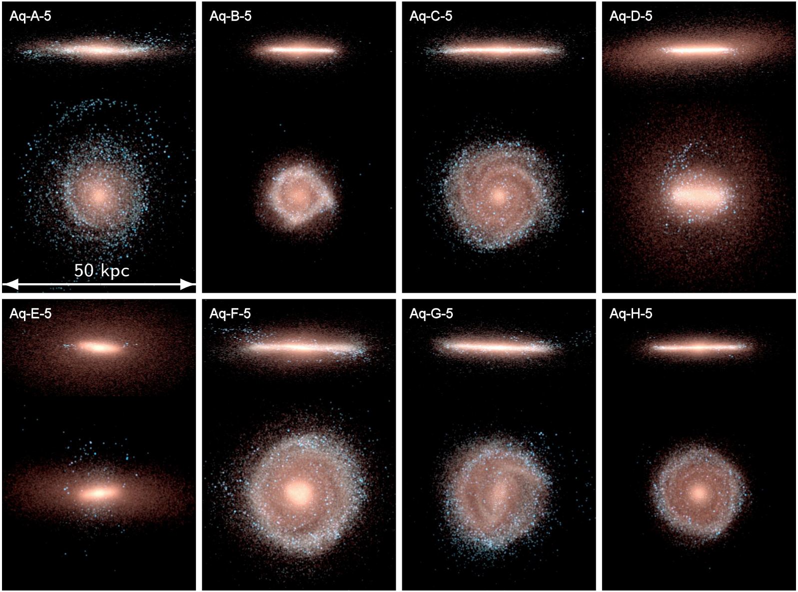
Set-up of the simulations

- cosmological hydrodynamic simulations with AREPO of 8 Aquarius haloes (also MHD version)

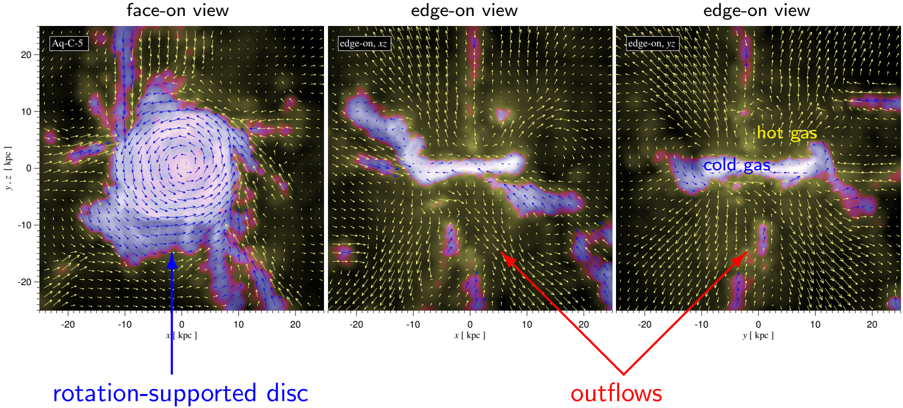
- baryonic physics includes (Vogelsberger+ 13):
  - sub-resolution model for ISM
  - metal cooling
  - stellar evolution
  - kinetic galactic winds
  - black hole feedback



Stellar projections

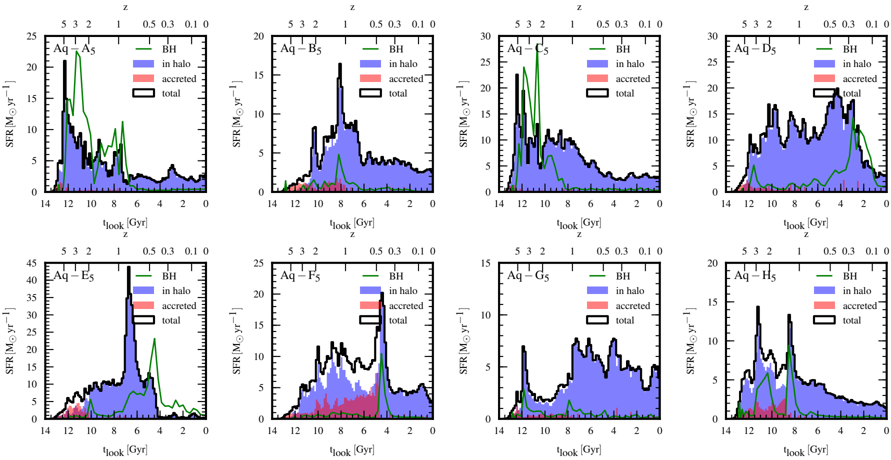


Gas projections



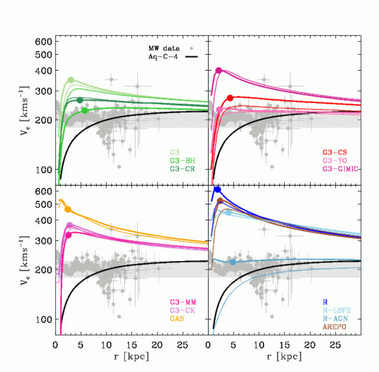
Features of the simulated systems

Star formation histories

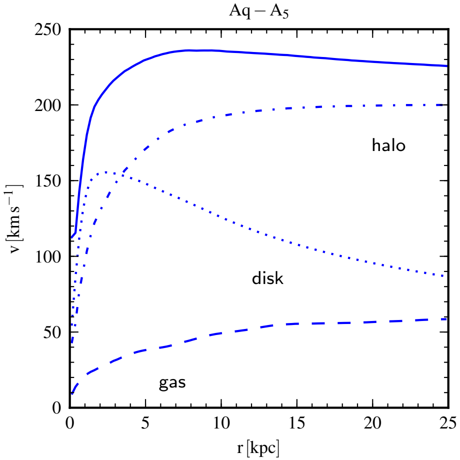


Circular velocities

Flat rotation curve

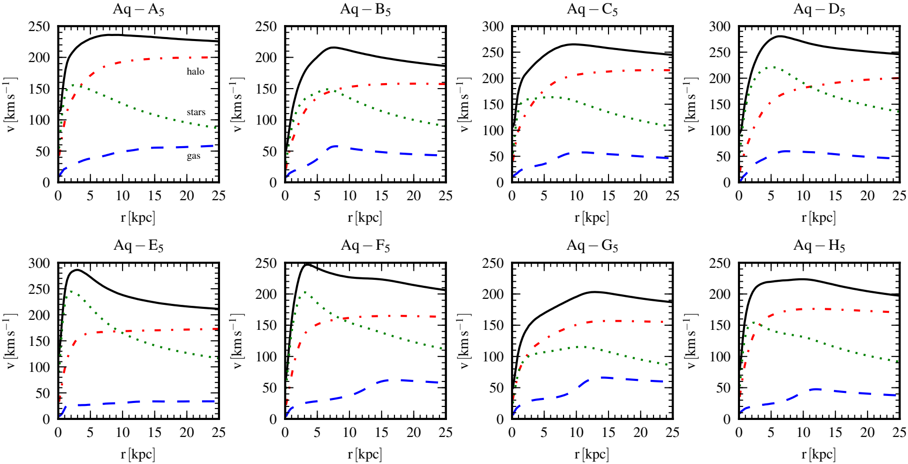


(Scannapieco et al. 2012)



$$v = \sqrt{\frac{GM(<r)}{r}}$$

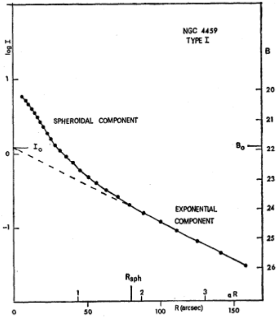
Circular velocities



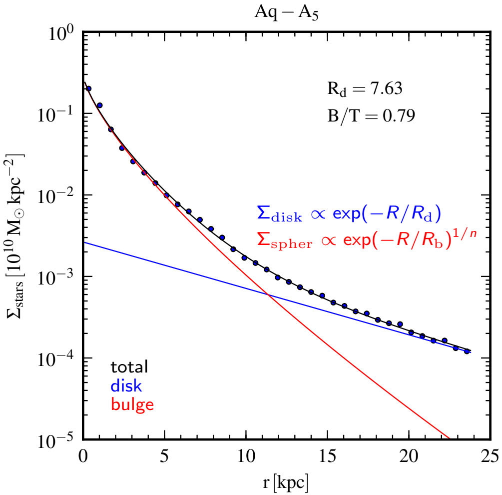
$$v = \sqrt{\frac{GM(<r)}{r}}$$

Disc-bulge decomposition

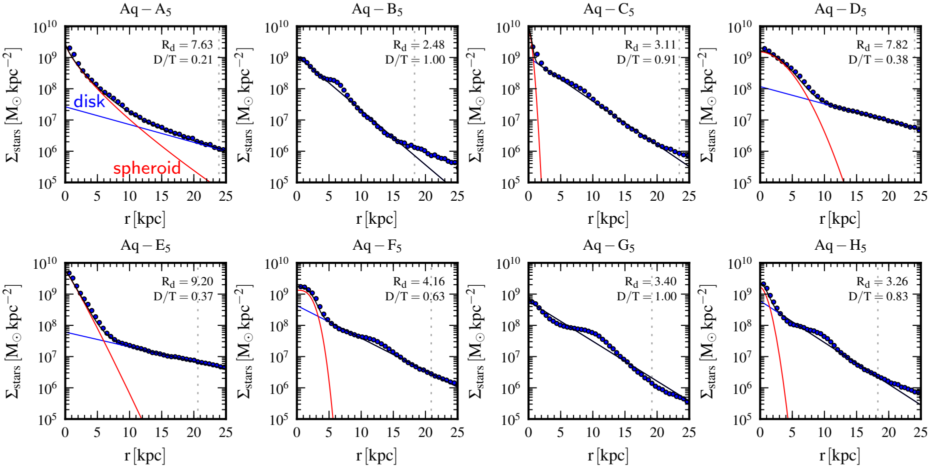
Exponential stellar disk



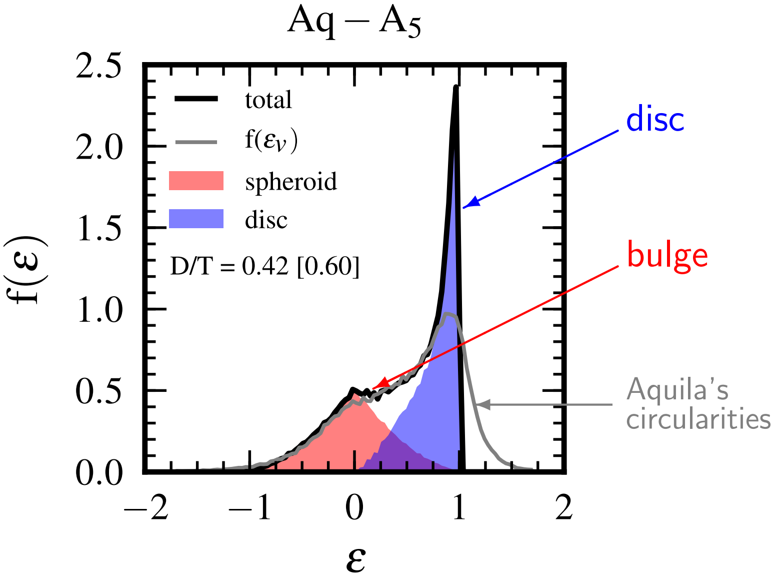
(Freeman 1970)



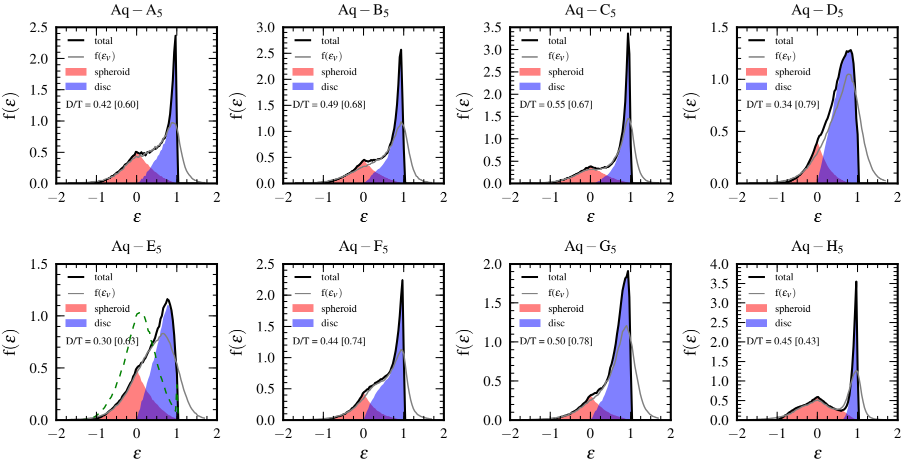
Disc-bulge decomposition



Circularity distributions

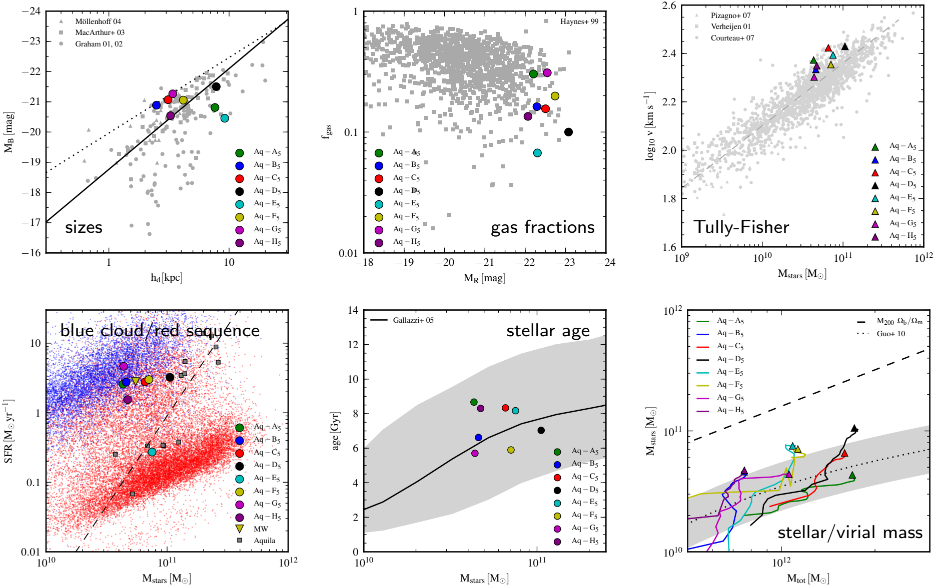


Circularity distributions

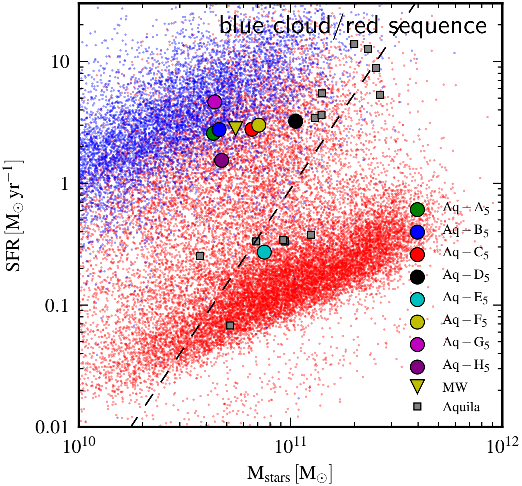


Well defined discs in most of the systems

Selected galaxy properties



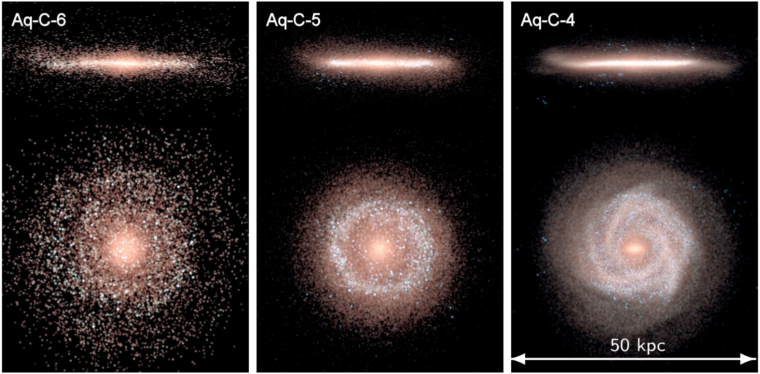
Selected galaxy properties



- Realistic late-time SFR for the galaxy's stellar mass

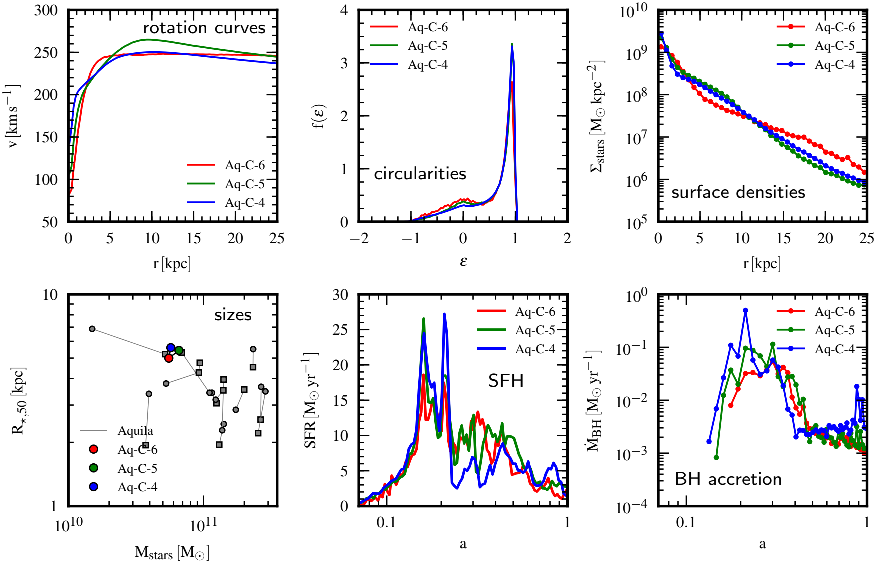
Sub-grid physics & resolution

Stellar disc morphology

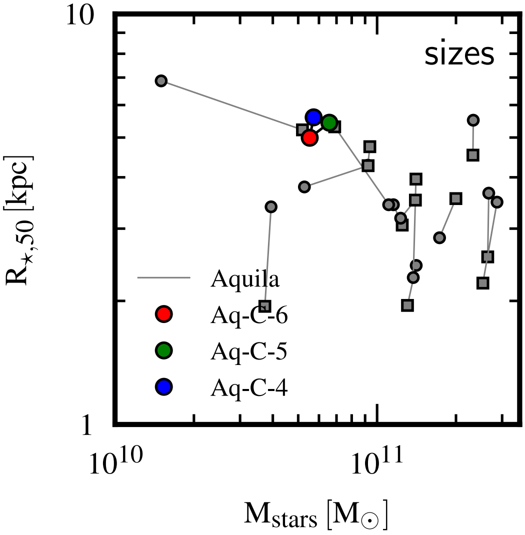


Increasing resolution

Comparison of galaxy properties



Comparison of galaxy properties



- No change in the feedback parameters

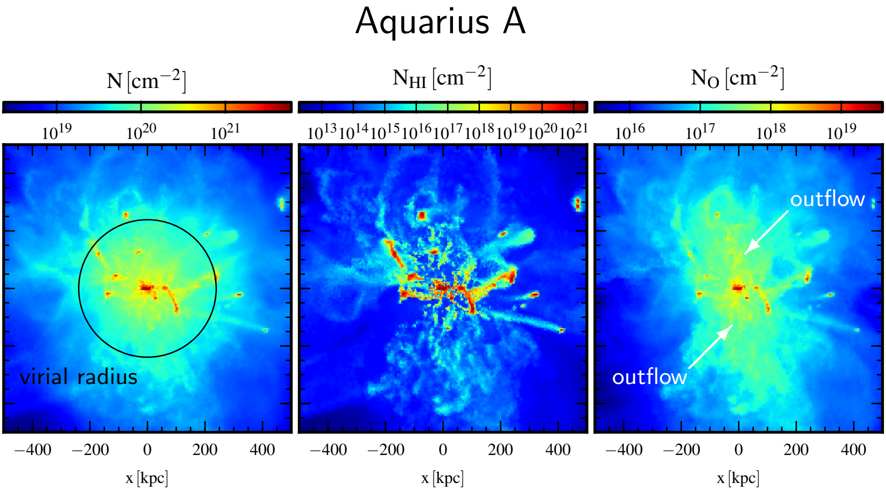
Summary

Simulations produce realistic Milky Way-like galaxies:

- well defined discs in most of the simulated systems
- many key observational properties are reproduced
- good convergence properties of the sub-resolution physics

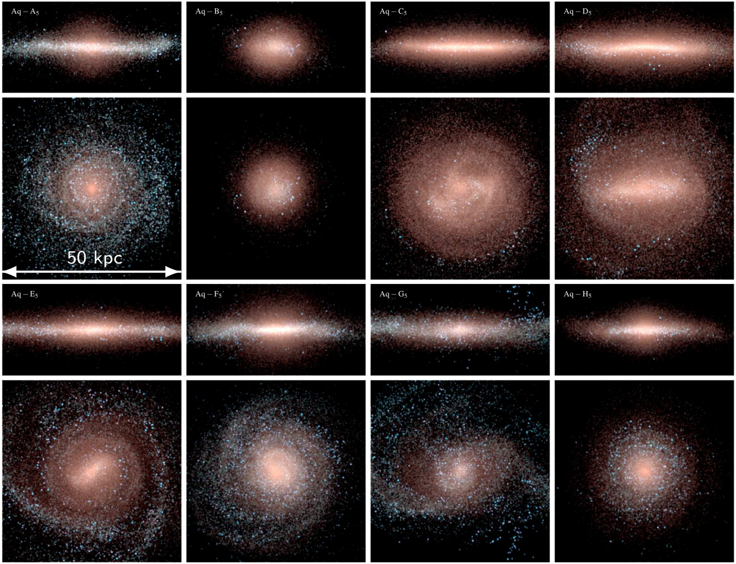
Ongoing work

The circum-galactic medium



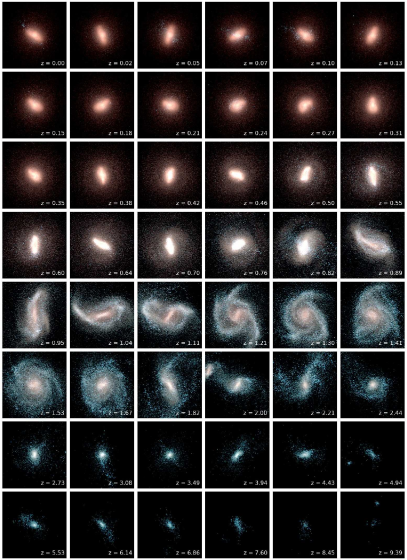
(Marinacci et al., in prep.)

Ideal magnetohydrodynamics simulations



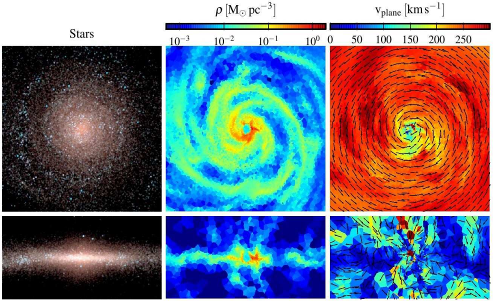
(Pakmor, FM+ in prep.)

Comparison with pure hydro simulations



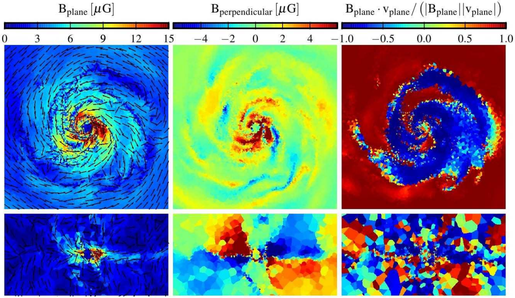
(Pakmor, FM+ in prep.)

Gas and B field structure



Gas structure & kinematics

B field structure



(Pakmor, FM+ in prep.)