EAGLE simulation limitations

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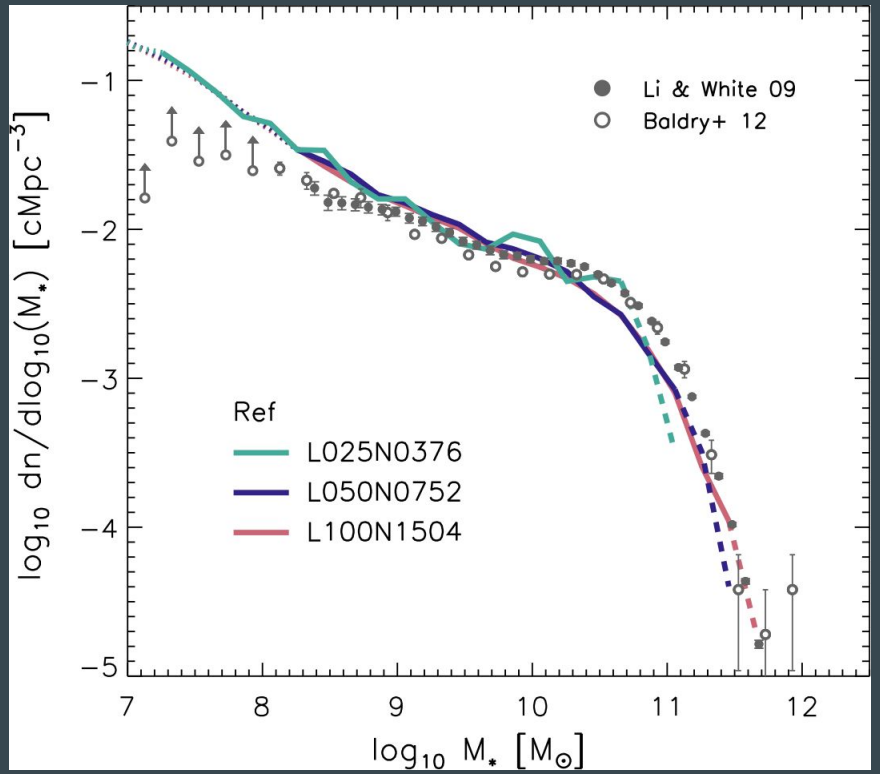
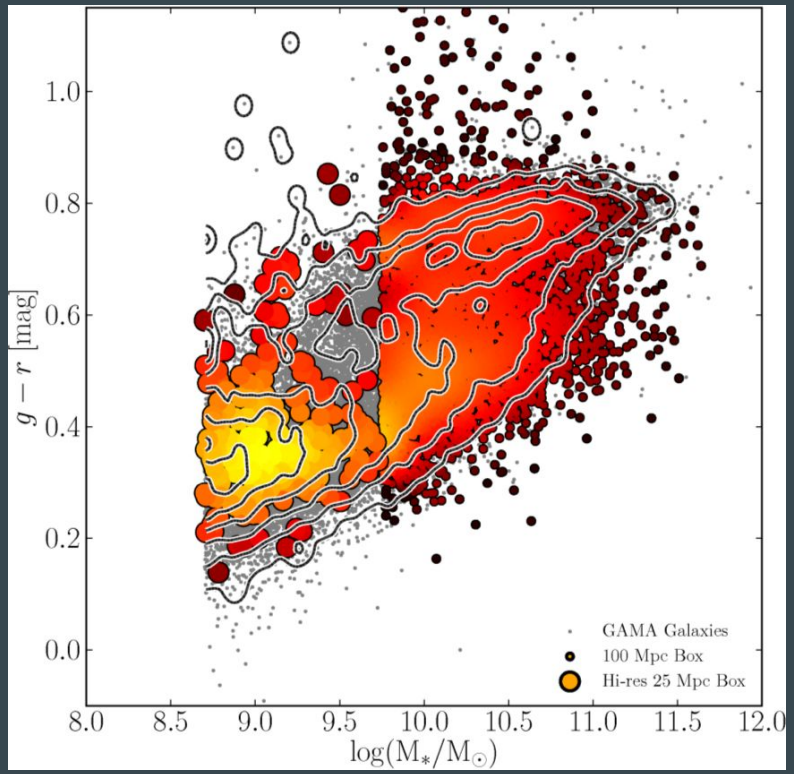
EAGLE 101

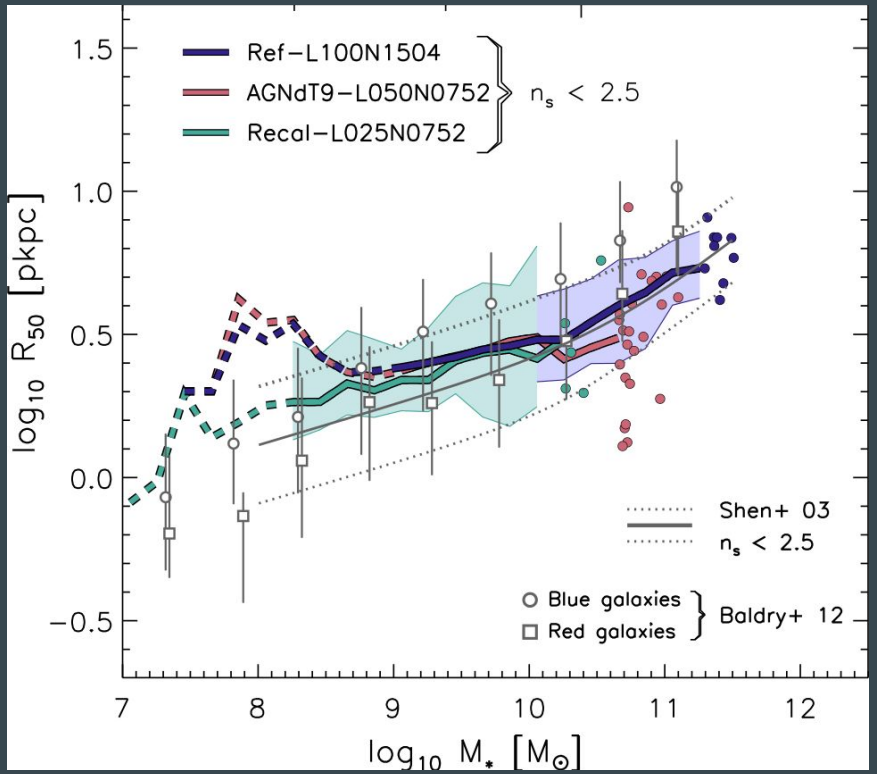
- 100^3 Mpc^3 simulation with 2×10^6 $M_\odot$ gas mass resolution.
- Resolving the warm ISM phase with the hydrodynamics solver.
- Sub-grid model for galaxy formation calibrated to match:
  - The z=0 stellar mass function.
  - The z=0 galaxy mass-size relation.

- Led to more than 80 publications thus far.



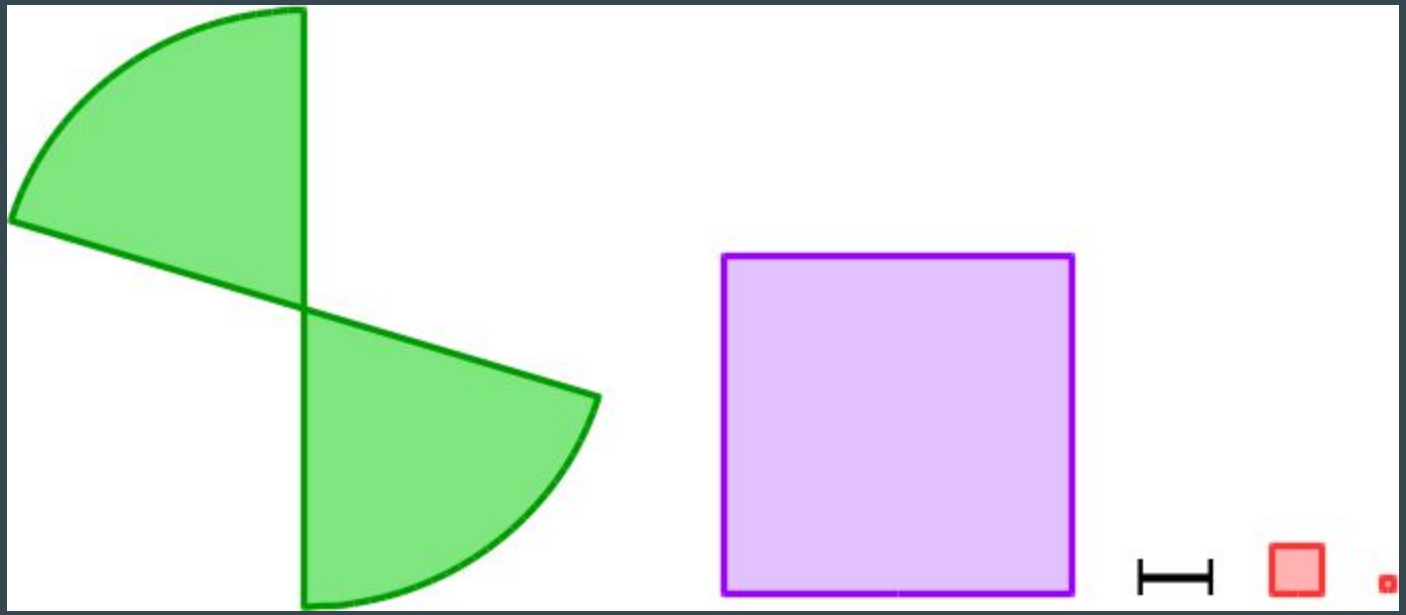
EAGLE 101


$g-r$ [mag]
$\log(M_*/M_\odot)$
GAMA Galaxies
100 Mpc Box
Hi-res 25 Mpc Box


Ref−L100N1504
AGNdT9−L050N0752
Recal−L025N0752
$n_s < 2.5$
$\log_{10} R_{50}$ [pkpc]
$\log_{10} M_*$ [$M_\odot$]
Shen+ 03
$n_s < 2.5$
Blue galaxies
Red galaxies
Baldry+ 12

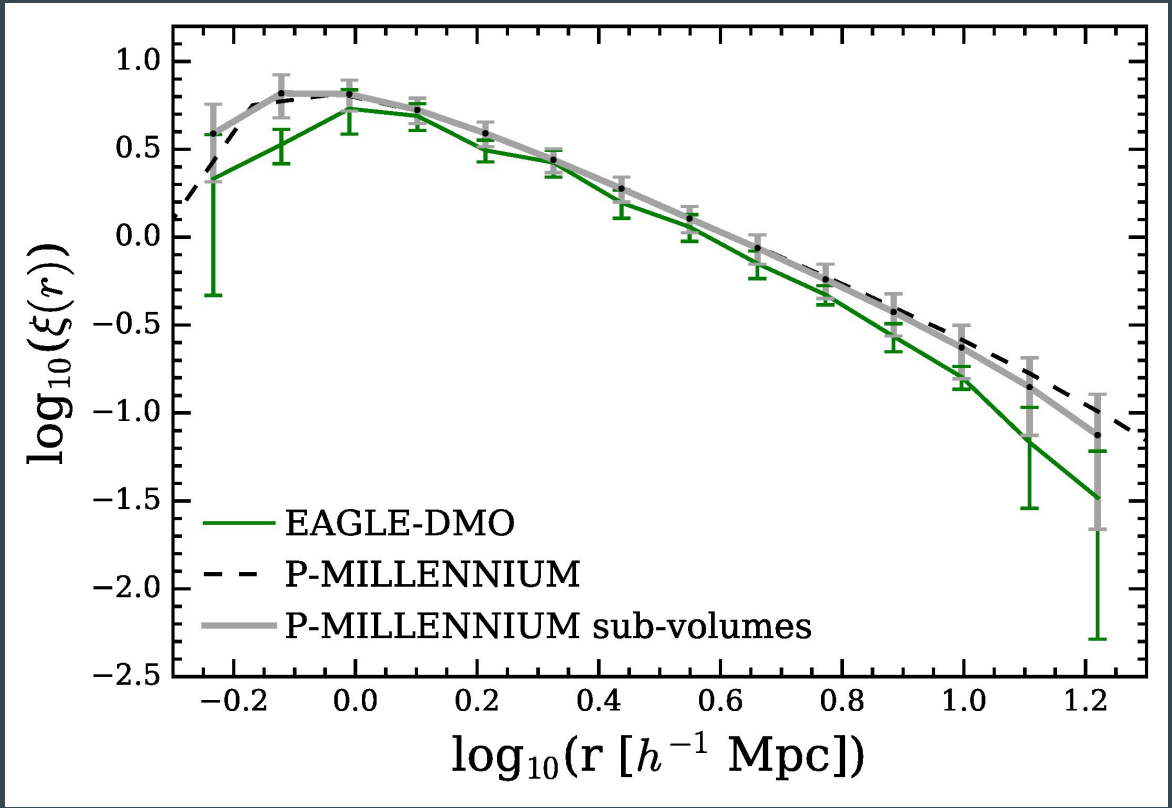
So far, so good...

An obvious size issue…



Clearly far from even the smallest modern cosmological surveys...

… seen also in the clustering

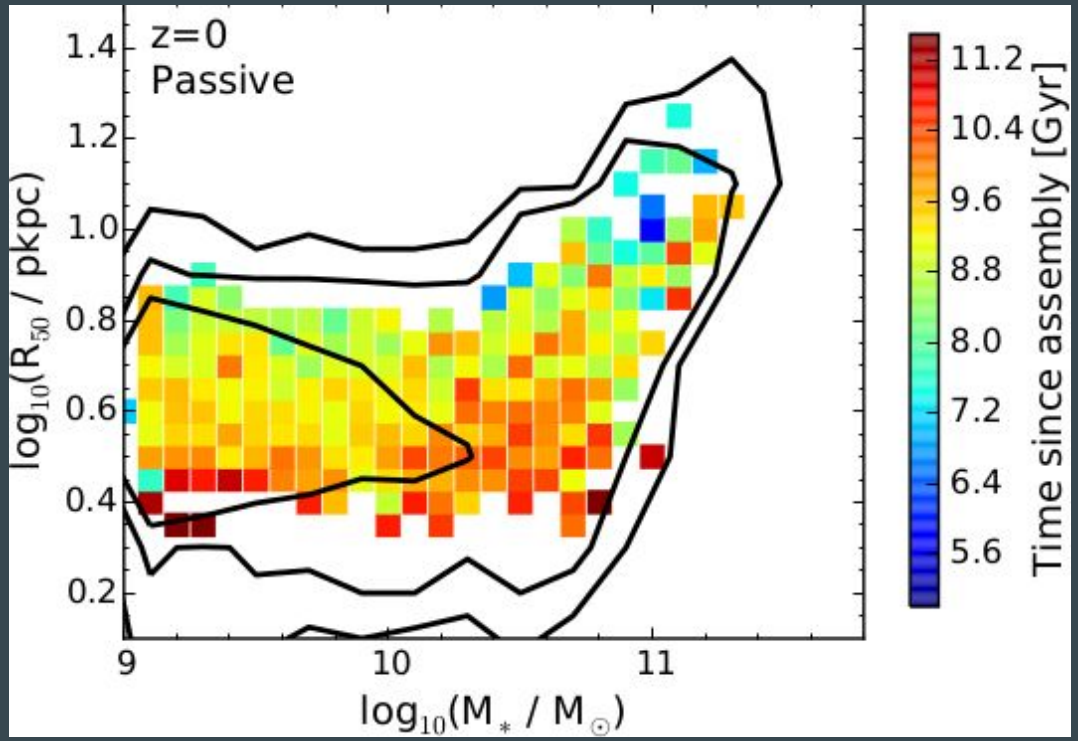


Also a problem of statistics for galaxy studies

If you split the galaxy population by 3 criteria, you typically end up with ~10 galaxies per bin.

→ Hard to explore scatter.

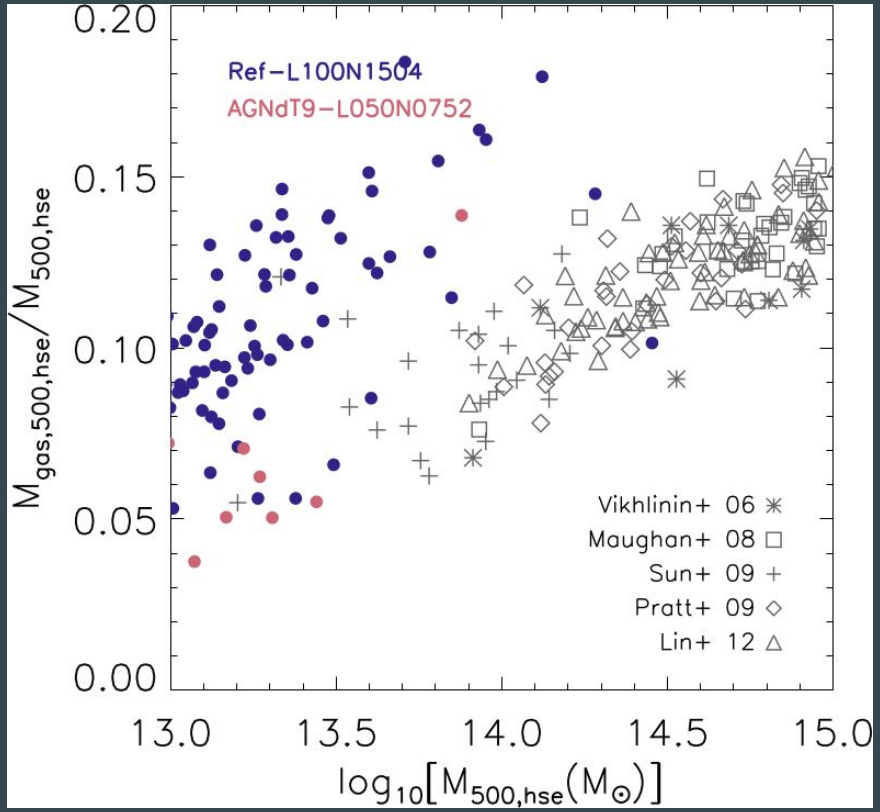
→ Hard to explore rare objects.



Gas fractions in clusters

- More serious issue.
- Gas fraction in groups is too high, entropy profile is also wrong.

  → A worry for cluster cosmology projects using X-ray selection for instance.



Solutions ?

- No obvious way to fix this by tweaking the AGN parameters.

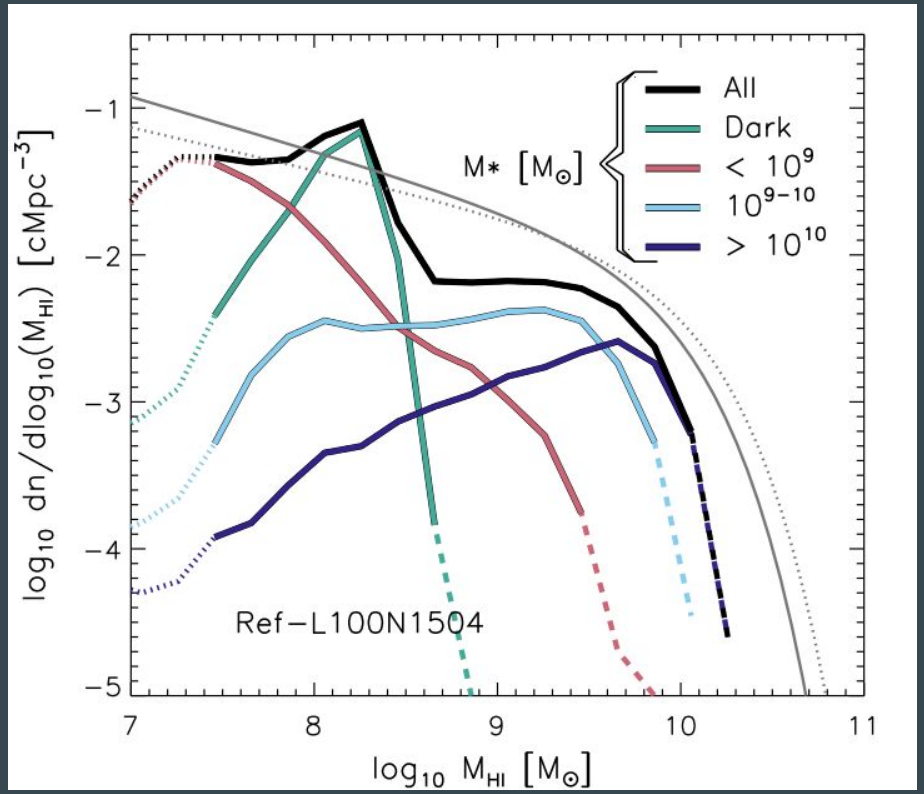
- Might be a fundamental issue with:
  - The hydro scheme (conduction, equation of state of the gas, ...)
  - A problem of resolution of the gas around the super-massive black hole.
  - Missing physics (cosmic rays, magnetic fields, jets, ...)

- Problem is hard to solve as simulations of clusters are really expensive to perform. Especially if the resolution needs to be increased.

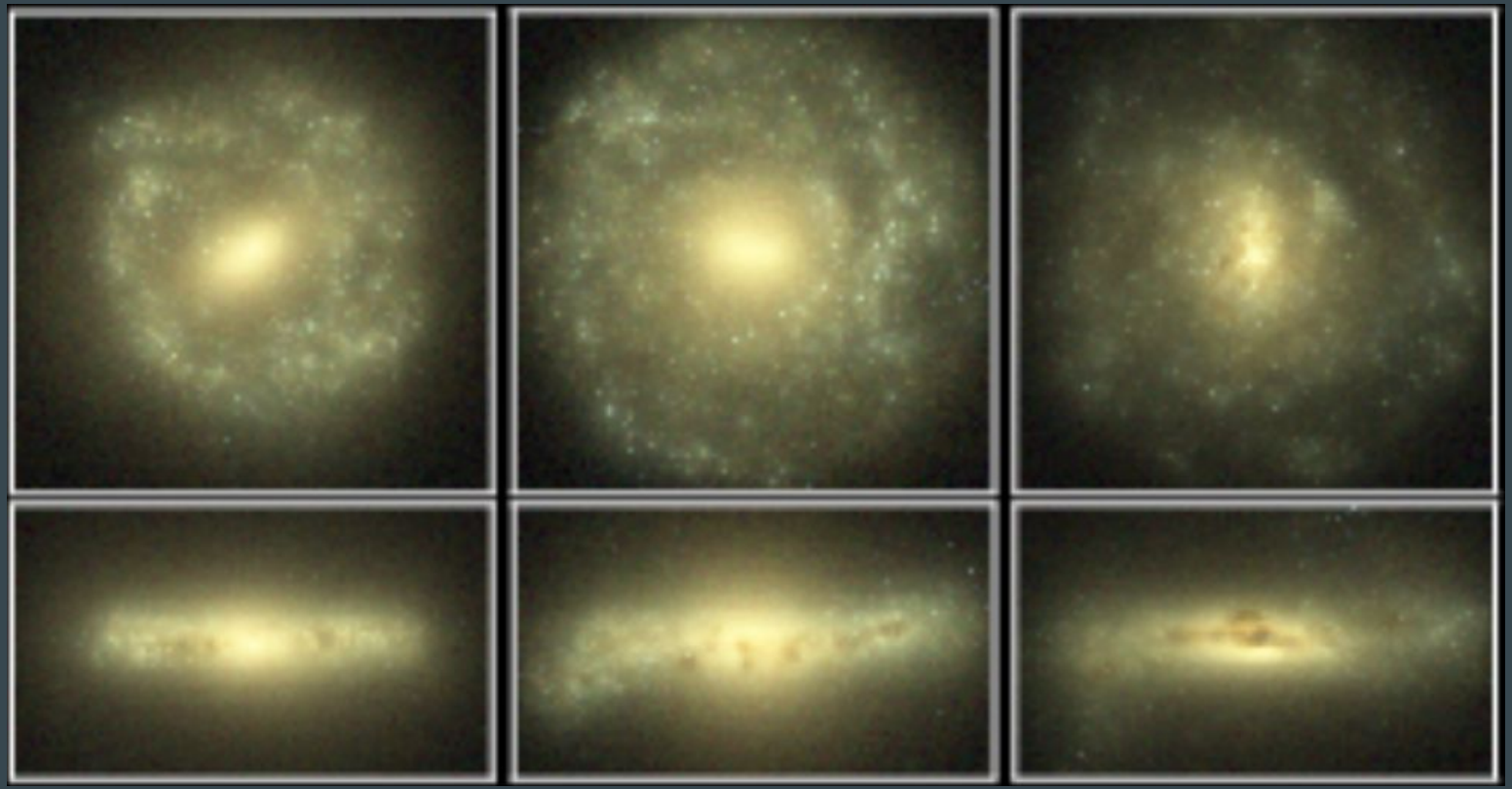
Let’s get technical !

Cold gas problems

- H I mass function is fine(-ish) at masses above ~10^9 $M_\odot$.
- At lower masses, lack of sources and weird peak/feature.
- In the simulation this peak is due to “dark” haloes that have not formed a single star.

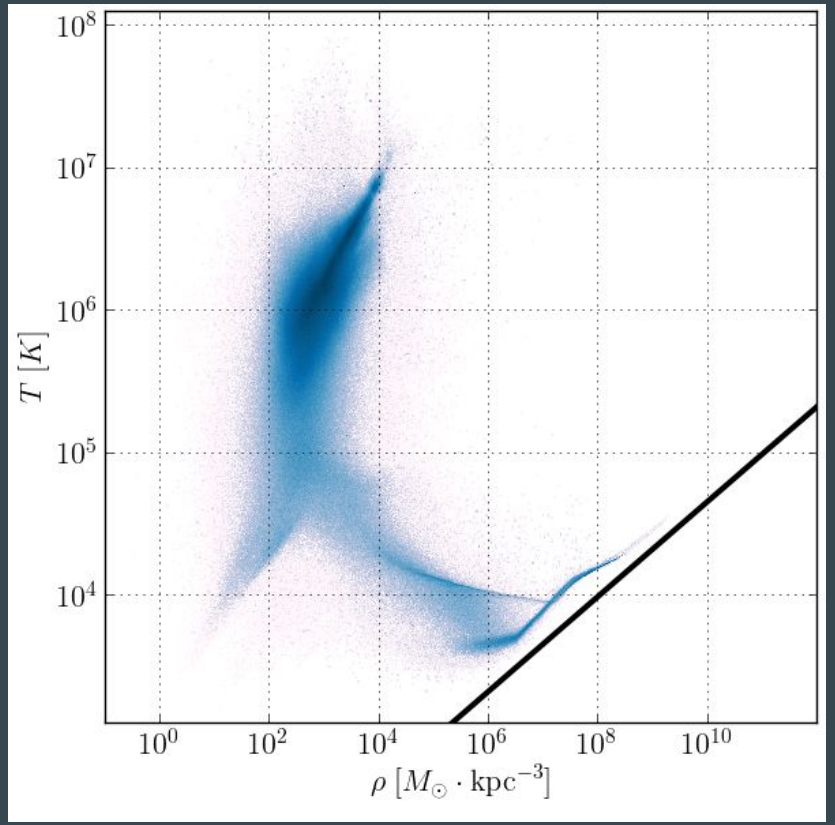


Visually discs are too thick



Disc thickness explained

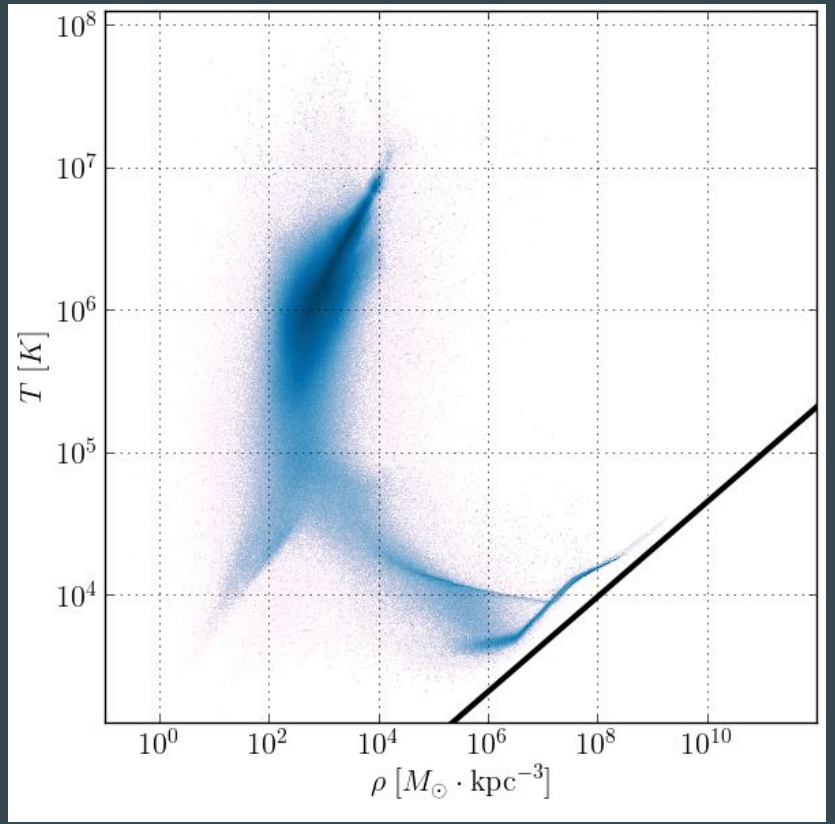
- Finite resolution limit of EAGLE.
- 2×10^6 $M_\odot$ is the mass that can be (barely) resolved.
- This defines a region in the density-temperature that can't be tracked by the gravity-hydro solver.



Disc thickness explained

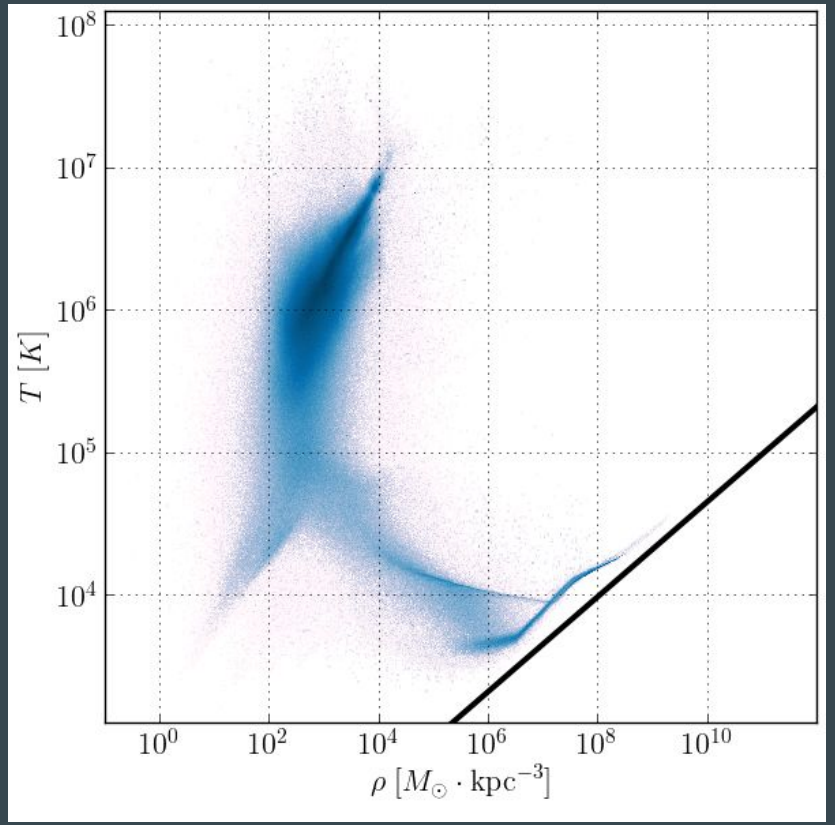
- To avoid issues, EAGLE (and many other simulations) prevent the gas to go in the “forbidden region” by imposing a different equation of state.
  Typically, we use $P \propto \varrho^{4/3}$.

- Creates an artificial pressure that prevents the collapse of structure below a certain scale ~ 1kpc.



Consequences

- Gas disc is too thick.
- Stars are born too far away from the plane of the disc .
  → Stellar disc is also too thick.
- Structure of the ISM is entirely artificial.
  (Although one could argue for additional forces to give it the structure we have in the run.)



Solutions ?

- Need to increase the resolution.

- Need to implement more physics, especially cooling channels and processes to really get a cold phase in the ISM.
  - Much more expensive simulations.
  - Likely need a re-calibration of other parameters.
  - Potentially need to de-couple the hydrodynamics temperature and the sub-grid temperature.

Work for the future

- Run larger volumes
  → EAGLE-XL

- Re-think the AGN model and explore options
  → Some work in the C-EAGLE project

- Improve the cold phase and run higher resolution simulations
  → EAGLE-2