Preparation for Horizon Run 5:

RAMSES: An improved global refinement approach

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Introduction – Horizon Run 5

- Large cosmological volume simulation with a dynamic range between Gpc to kpc – including baryons
  - Large scale modes to capture the largest scales
  - Small scale modes to capture galaxy formation physics
  - Includes star formation & AGN etc.
  - Zoom simulation of region 1 Gyr x 60 Mpc x 60 Mpc

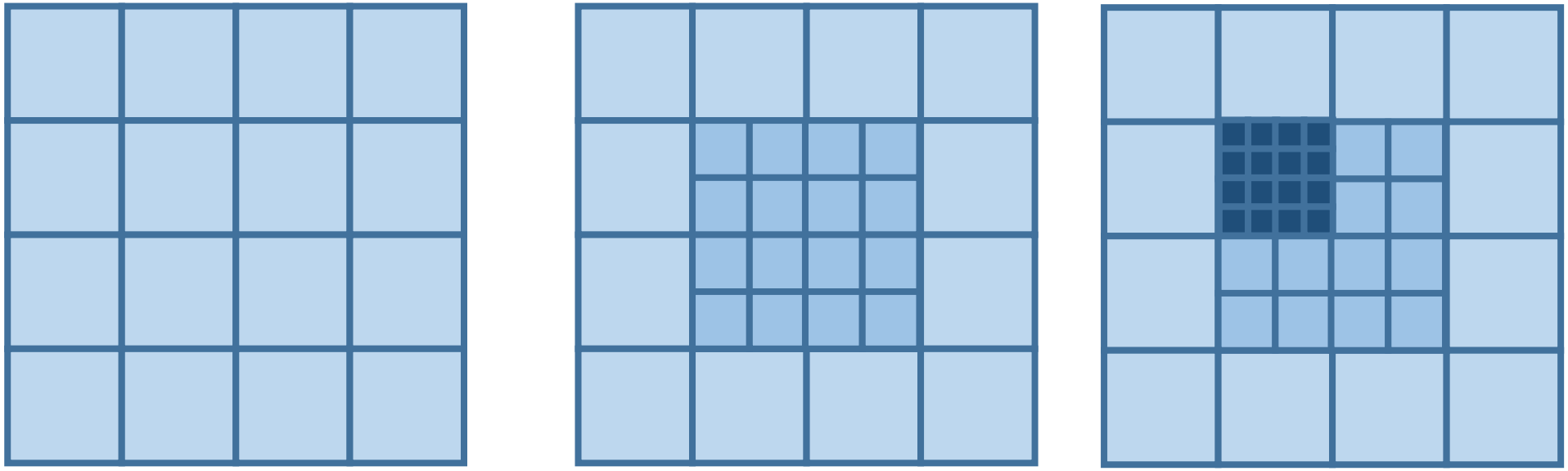
- Smaller scale, higher resolution simulation with detailed baryonic physics.
  - E.g. chemistry

Introduction

- Uses RAMSES (Teyssier 2002)
- Adaptive mesh refinement code which follows dark matter, gas and stars.
- Grid code for hydrodynamics – hydrodynamics solved on a mesh
- Dark matter sampled using particles – gravity solved on the mesh
- Mesh adapts to local density using quasi-Lagrangian method
  - `m_refine`

Adaptive mesh refinement

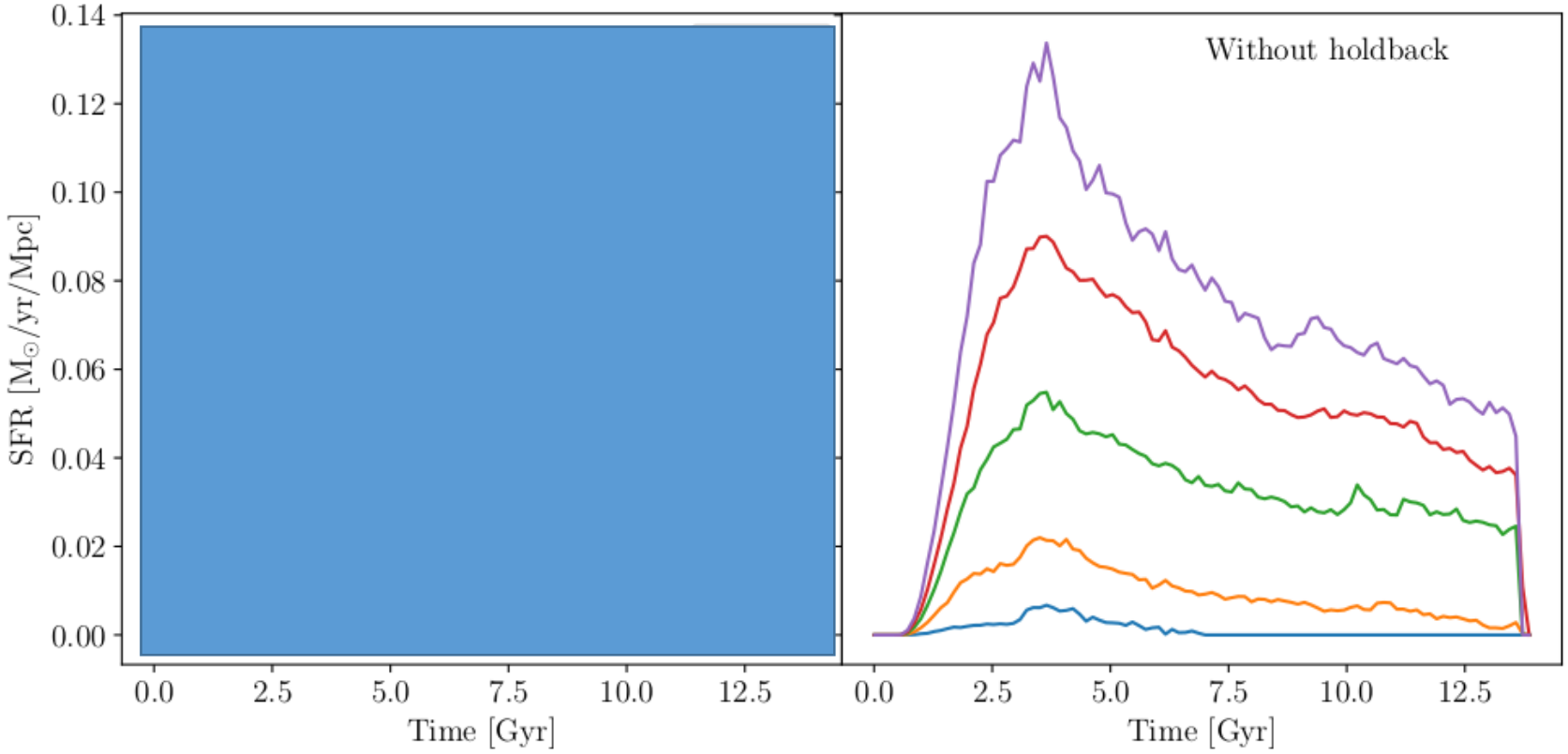
- Involves discretizing gravity and gas on a mesh which adapts to the local density



- Refinements set between Lmin and Lmax

Star formation in RAMSES

- Refinement has strong impact on the star formation history



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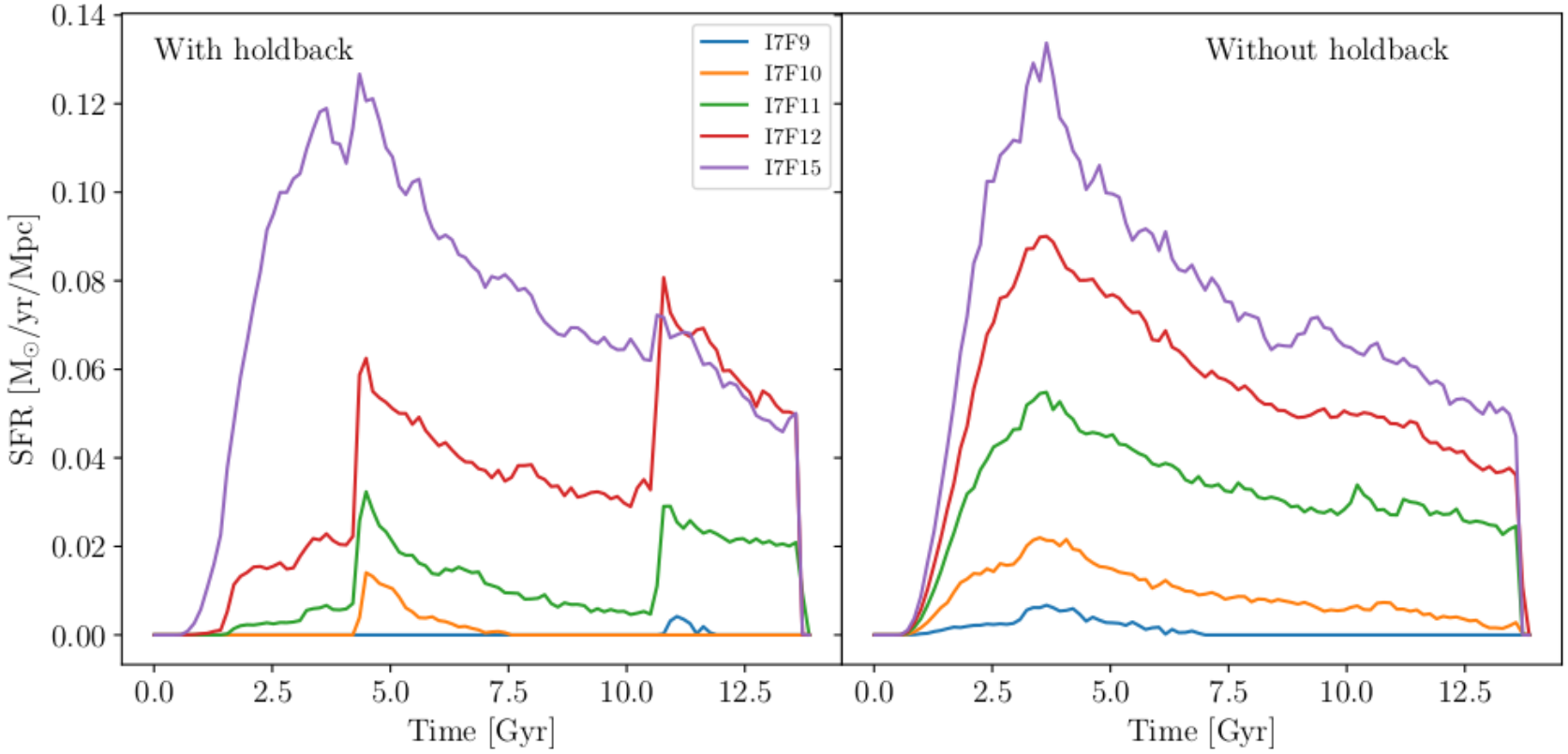


Global refinements

- As currently implemented the upper grid levels are held back and released at given values of the expansion factor
- It is then released all at once throughout the volume
- This changes the maximum achievable density and so impacts the subgrid physics
- Effectively a grid level is either allowed or forbidden
- We want to do this more gradually to give the system chance to adapt

Global refinements

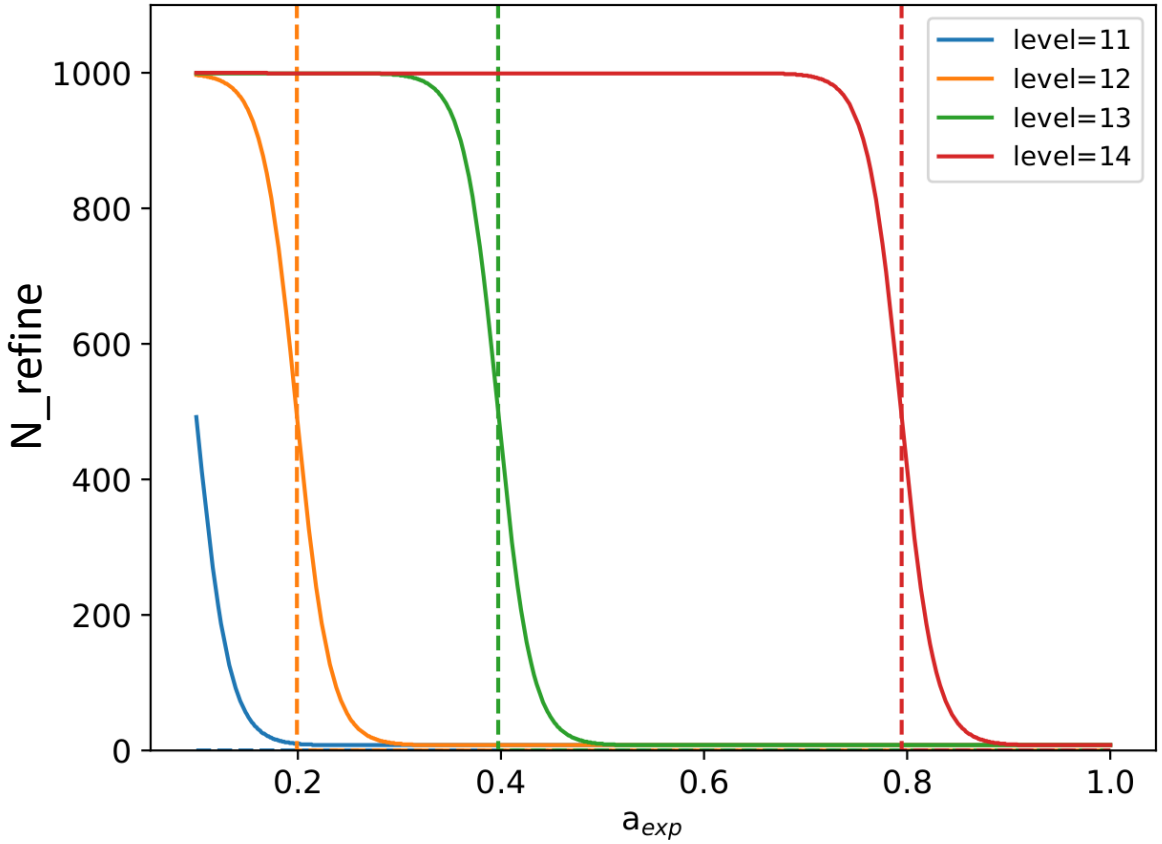
- The effect shrinks are the resolution of the simulation increases but it is still there
- We need to improve this

- Many parts of the subgrid physics (star formation, cooling and feedback etc.) require approximately constant physical resolution
- AMR naturally has a fixed co-moving resolution on a given grid level
- Prevent too high resolution at early times etc.

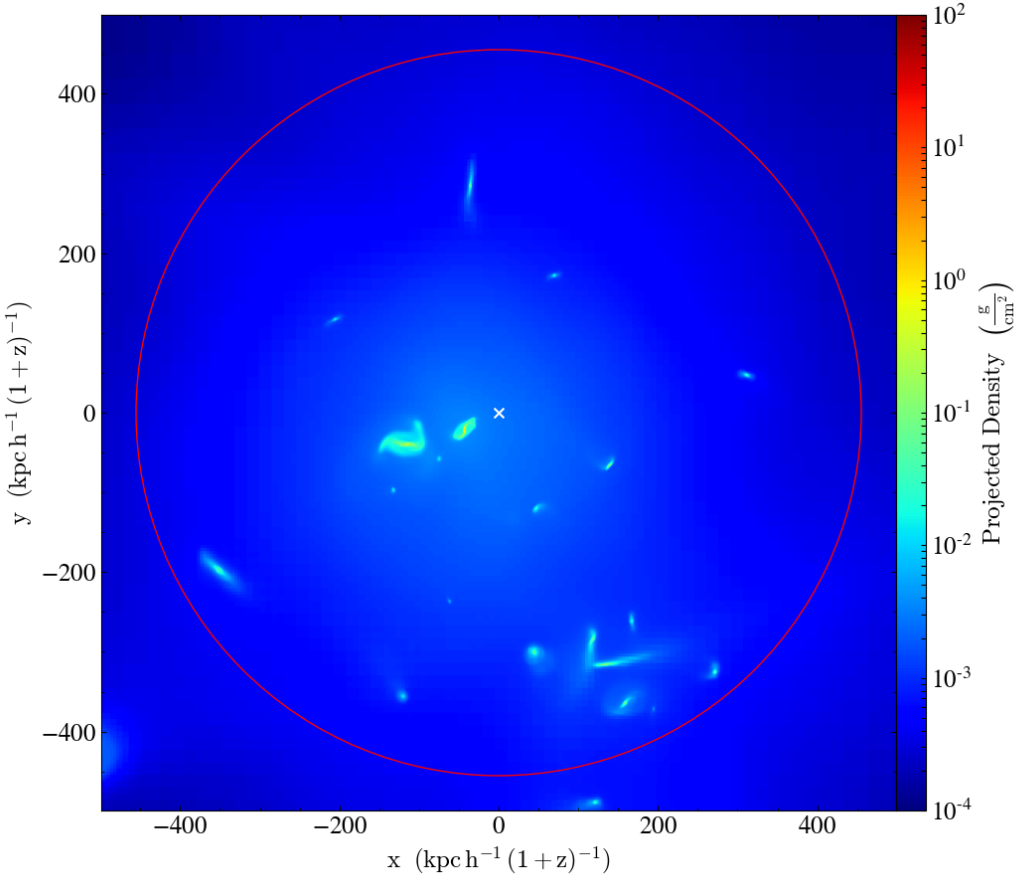
New global refinements

- Use Logistic function: $$n_{\rm refine}(a) = n_{\rm max} + (n_{\rm max} - n_{\rm f}) \left(1 - \frac{1}{1+\exp^{-S(a-c)}}\right),$$

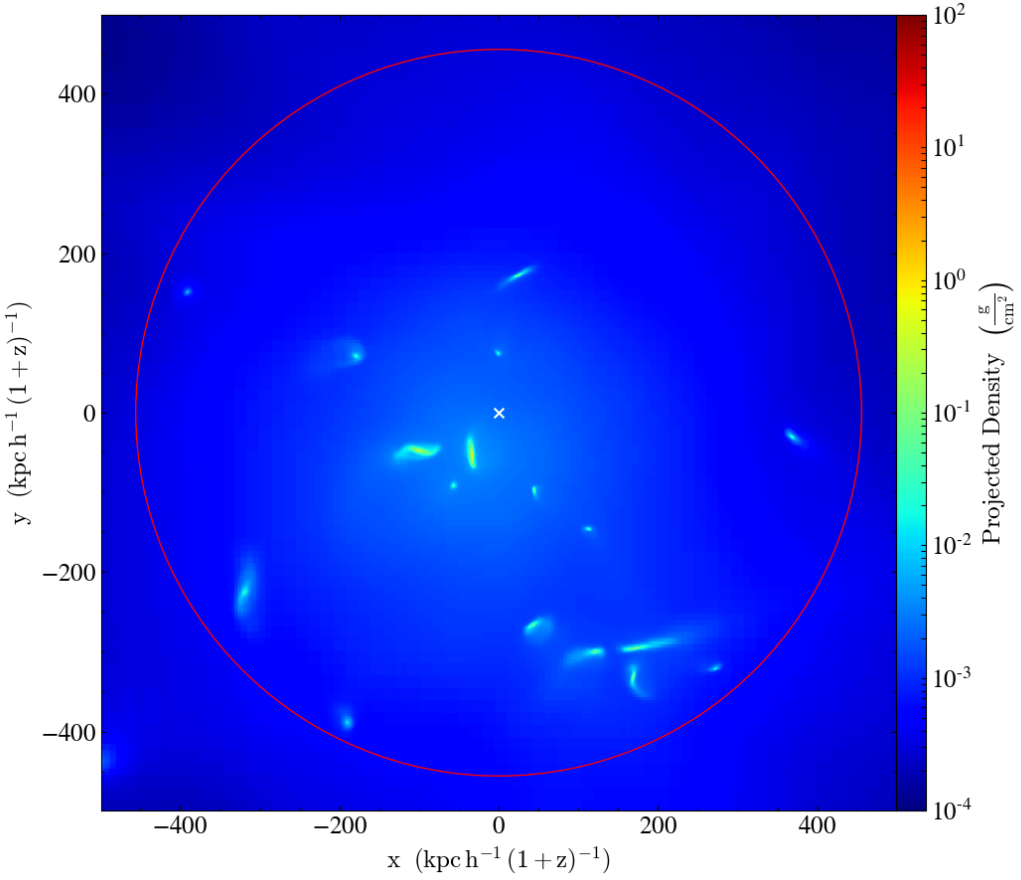
- Refinement is prevented at early times by setting `m_refine` very high
- Close to the transition epoch the number of particles begins to fall
- Reaches the normal value at soon after



Impact on the results



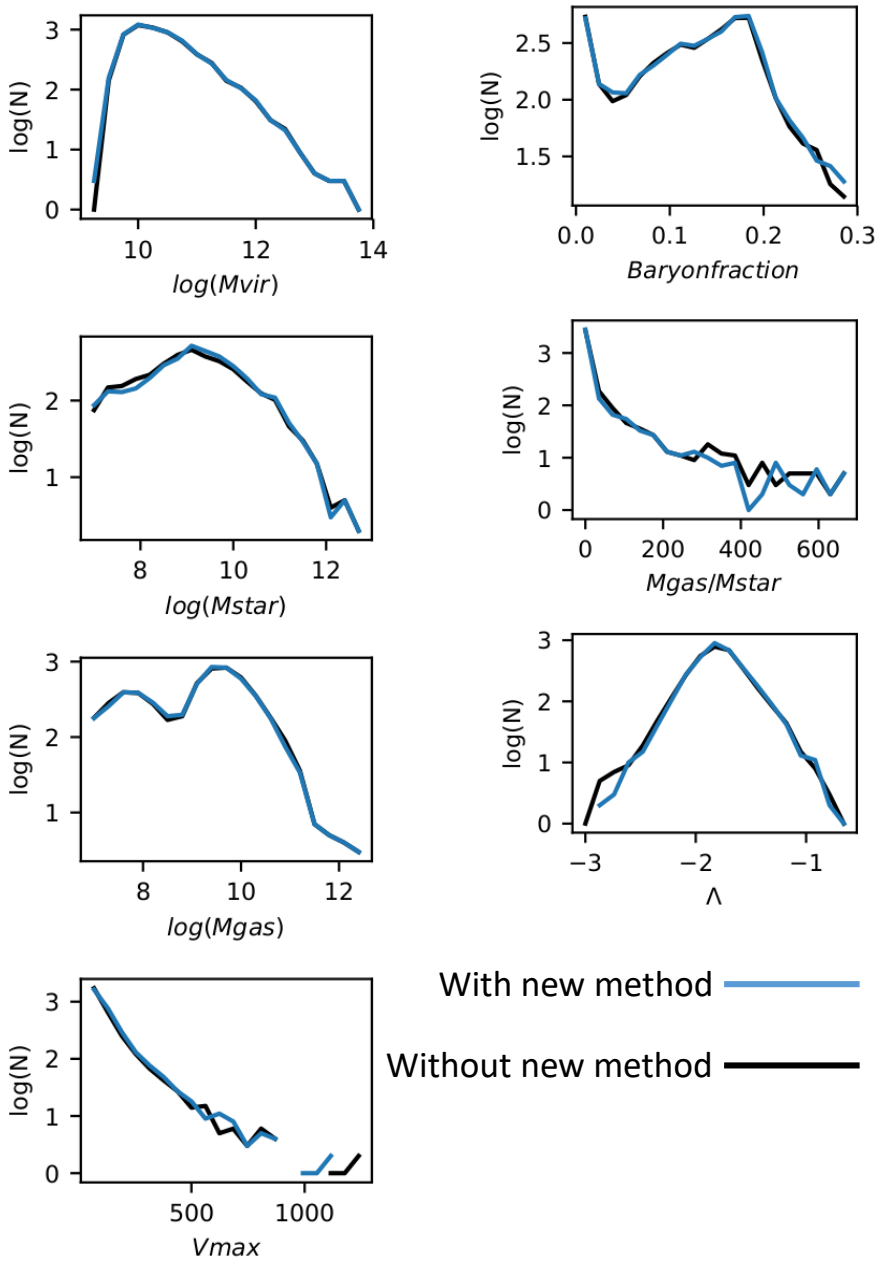
Without new method



With new method

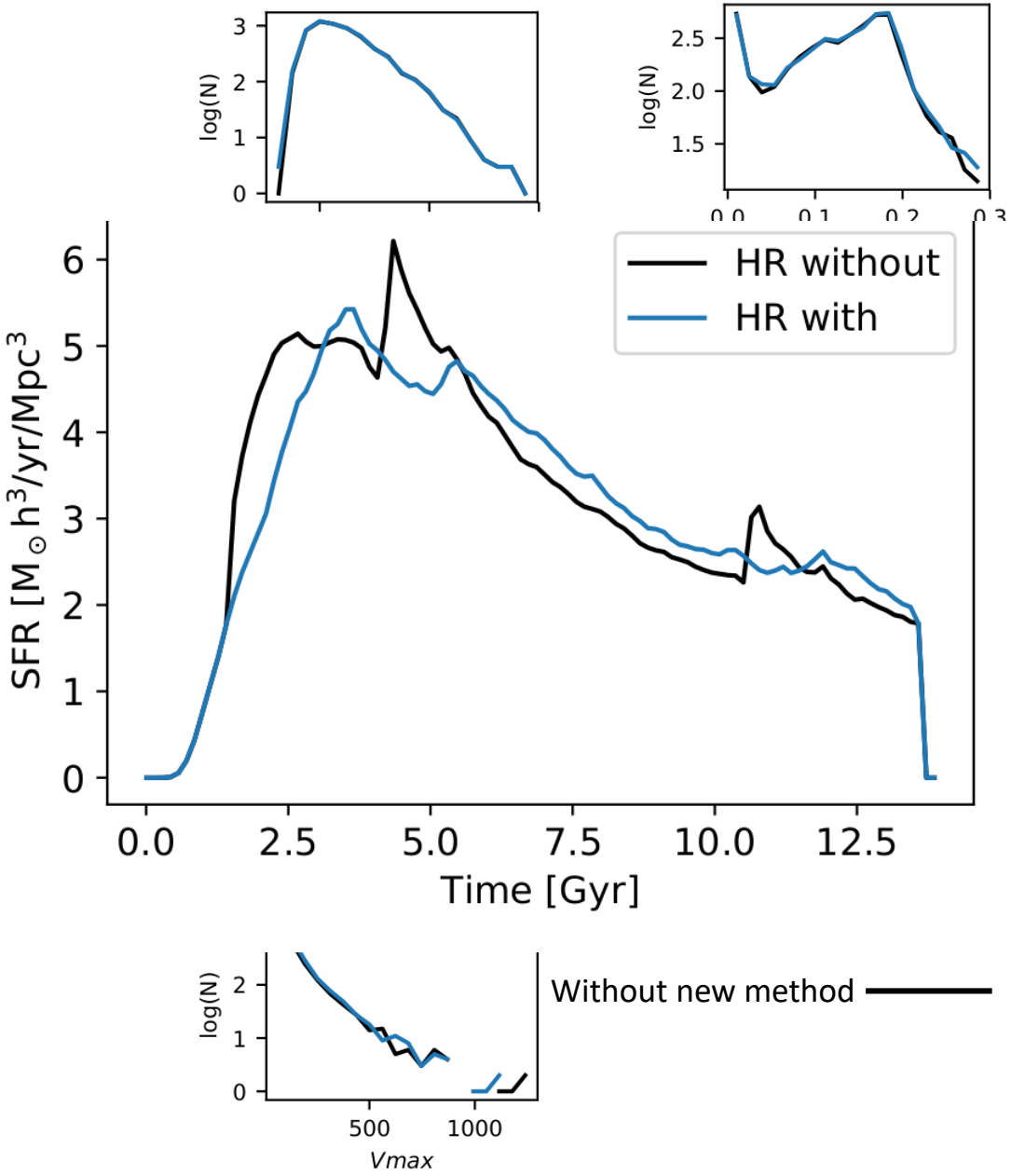
Impact on the results

- New method has little impact on the bulk halo properties



Impact on the results

- New method has little impact on the bulk halo properties
- But improves the star formation history as expected – at least in higher resolution simulations



Conclusions

- Grid hold back is required to maintain approximately constant physical resolution
- But it introduces artefacts into the system
- The new method of grid hold back reduces these impacts – especially on the SFH
- But does not strongly affect the bulk properties of the simulation