

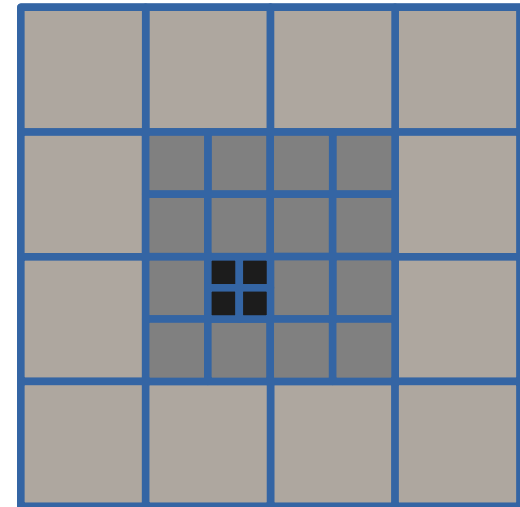
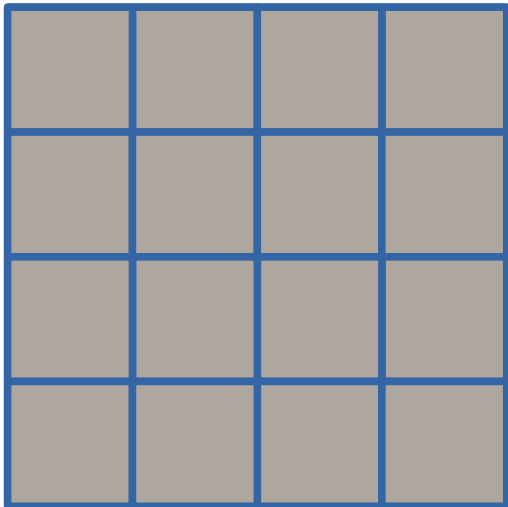
Cosmological Gas distribution in RAMSES

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RAMSES

- Cosmological hydrodynamics code (Teyssier 2002)
 - Dark matter, gas, stars
- Adaptive mesh refinement for gravity + hydro
- Refines cells according to the local density
- More efficient than fixed grid



RAMSES

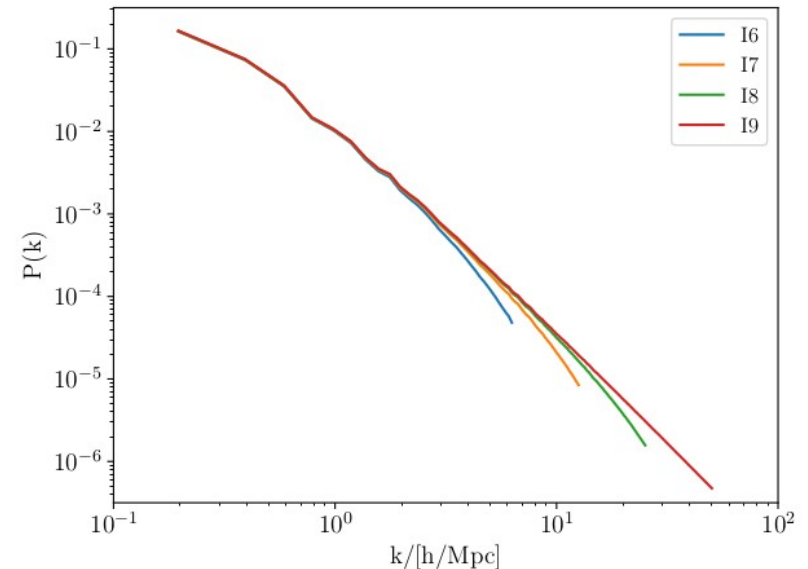
- Set the minimum resolution in the initial conditions: `levelmin` (I)
- Maximum resolution by `levelmax` (F)
- Comoving resolution = $\text{boxsize}/2^F$
- Star formation from set of physical prescriptions

Power spectrum

- Power spectrum parametrises the density contrast of a distribution
- Initial conditions have a characteristic power spectrum
- Truncated by simulation volume and resolution
- Fourier transform of the density field
 - ‘ \mathbf{k} ’ and $P(\mathbf{k})$

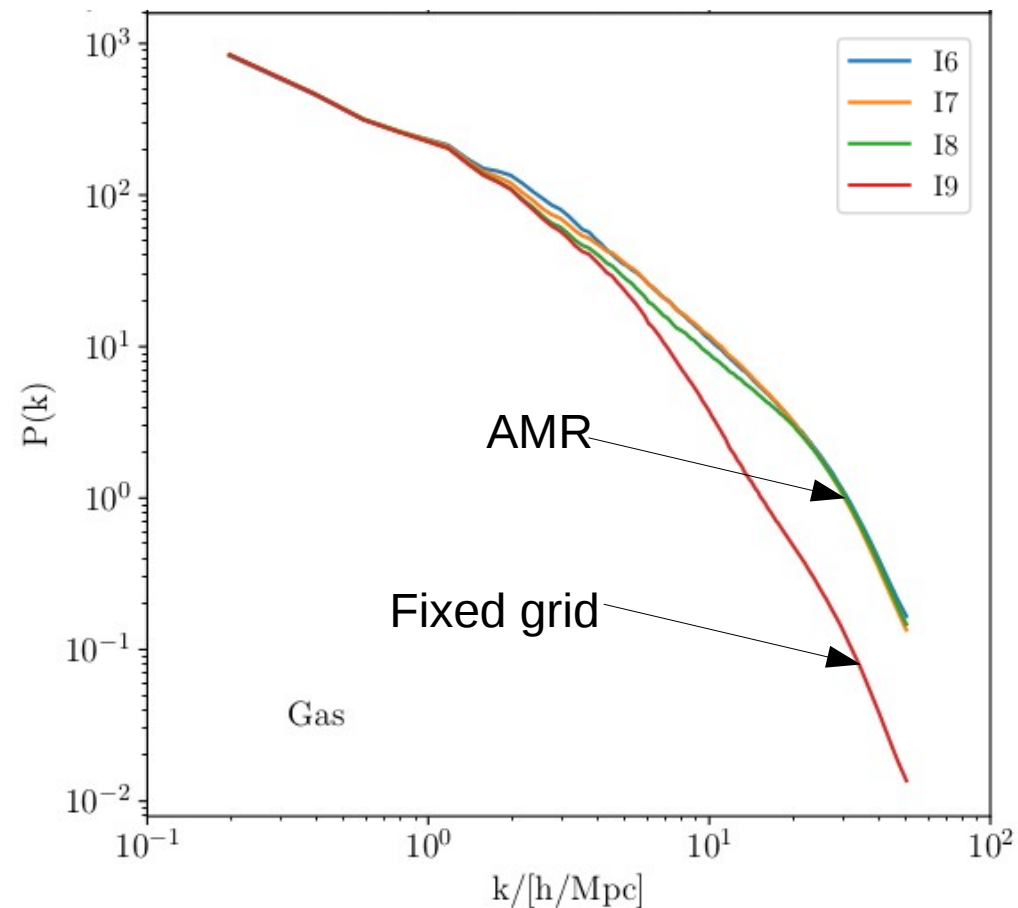
Setup

- Effect of resolution (maximum spatial refinement and IC) on the recovered power spectrum
- Initial power spectra I6, I7, I8, I9 in a box $32 h^{-1}\text{Mpc}$ on the side (resolution = $500 h^{-1}\text{kpc}$, $250 h^{-1}\text{kpc}$, $125 h^{-1}\text{kpc}$, $64.5 h^{-1}\text{kpc}$)



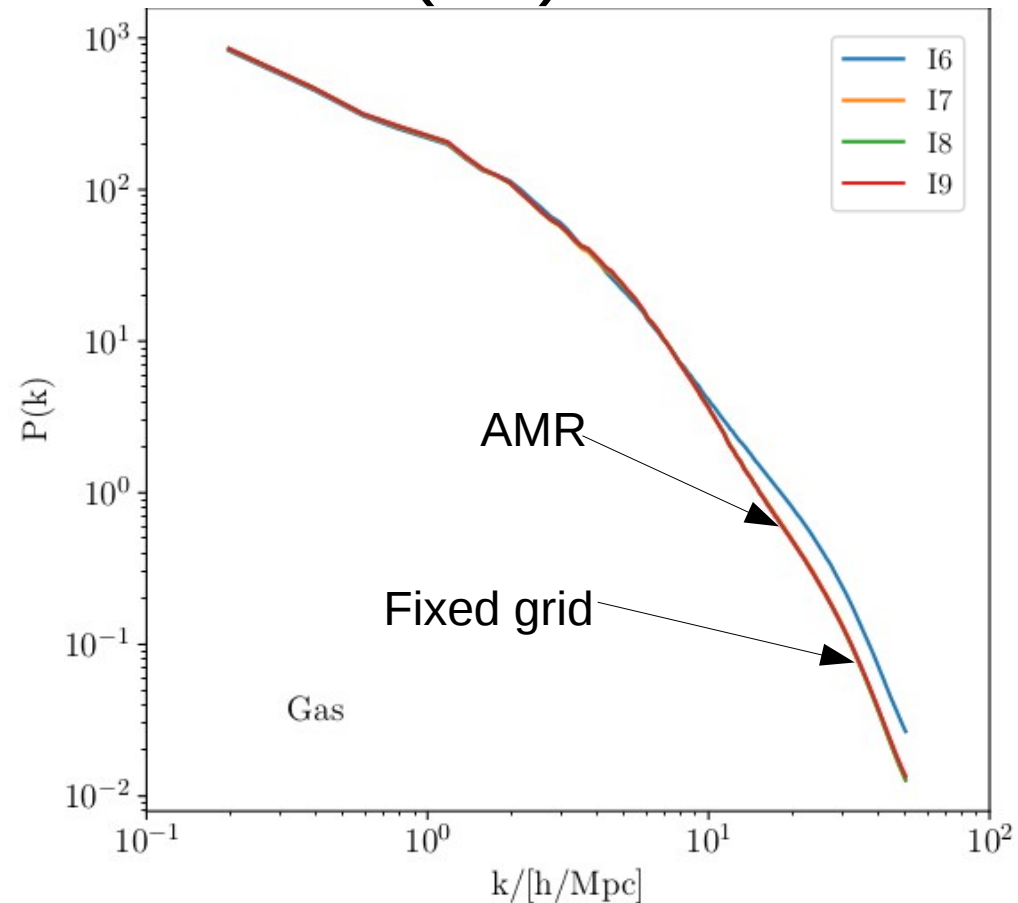
Results

- Compare gas power spectra at $z=0$ with AMR, compared to a fixed grid simulation with the same maximum spatial resolution
- AMR simulations converge on similar profiles
- Large difference (factor of 10) to the fixed grid



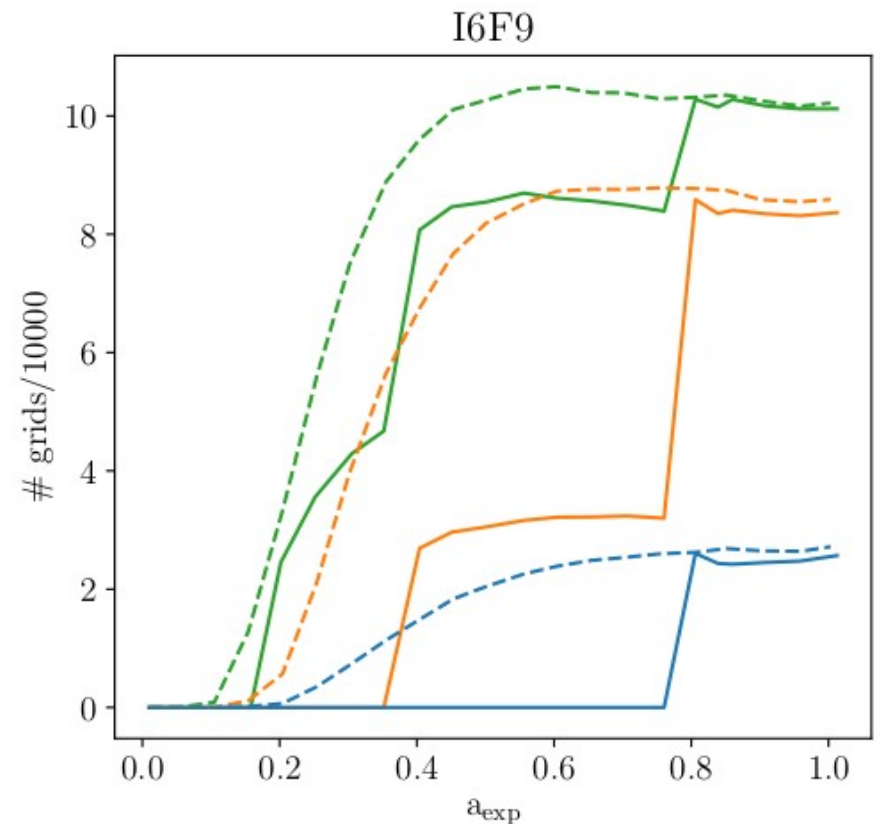
Results

- Compare gas power spectra at $z=0$ with AMR, compared to a fixed grid simulation with the same maximum spatial resolution (F9)
- AMR simulations converge on similar profiles
- Large difference (factor of 10) to the fixed grid
- Difference less without star formation BUT simulation forms few stars



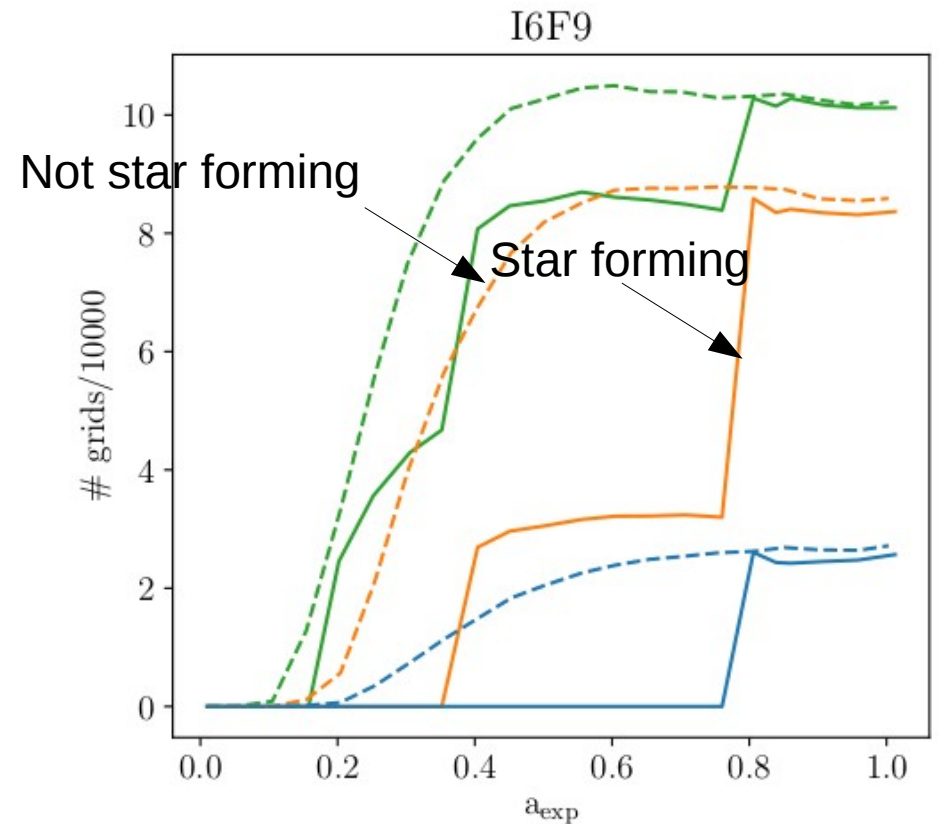
Results

- AMR (I6F9, I7F9, I8F9) runs diverge considerable from the fixed grid (I9F9) with star formation but not without
- Why?



Results

- At certain epochs the system suddenly refines almost everywhere
- Upper grid levels are 'held back' to maintain physical resolution (Dubois et al. 2012).
- Required to maintain physical density
- Only implemented when star formation takes place

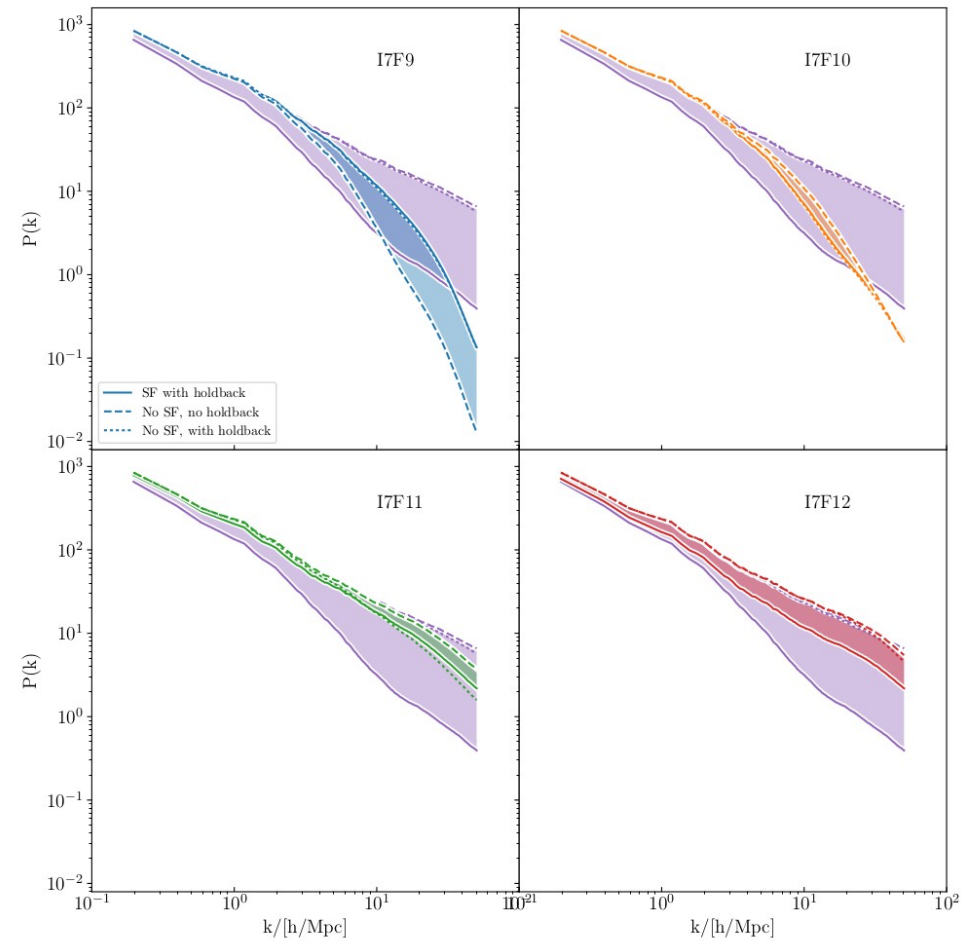


Consequences

- Important at low resolution
- Less so at higher maximum spatial resolution because star formation becomes dominant
- The large refinement episodes add spurious small scale power
- Star formation reduces the small scale power due to feedback
- As resolution increases star formation becomes more efficient and becomes dominant

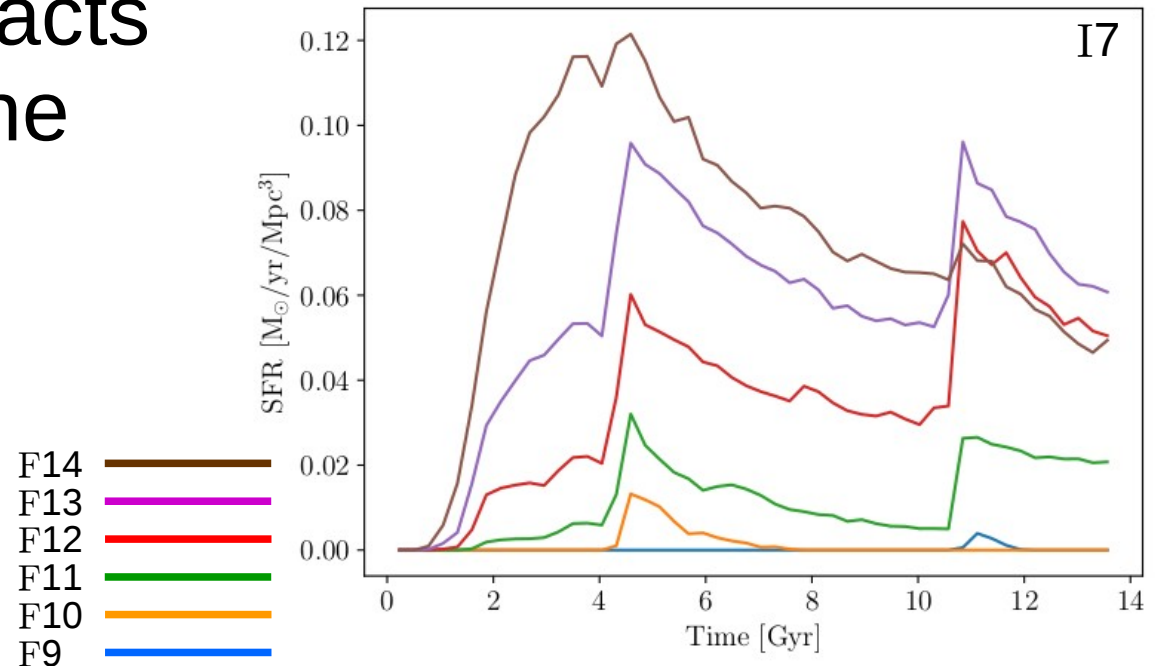
Results

- For fixed initial resolution increasing the final resolution reduces the spurious power



Results

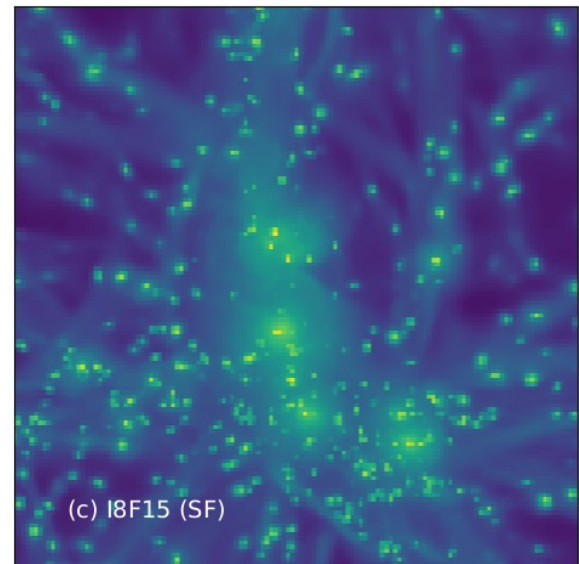
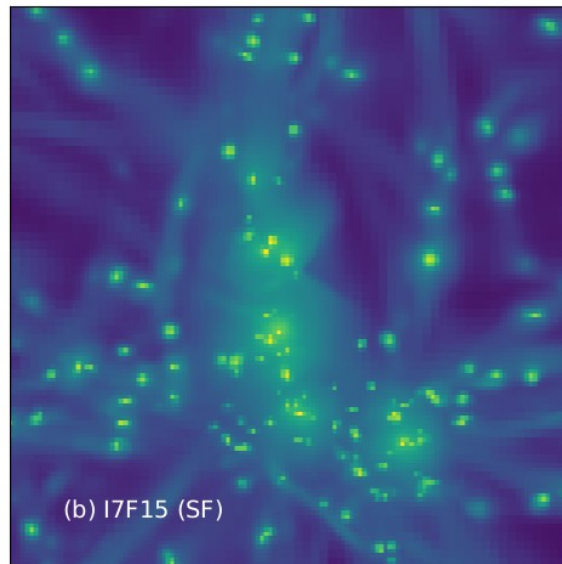
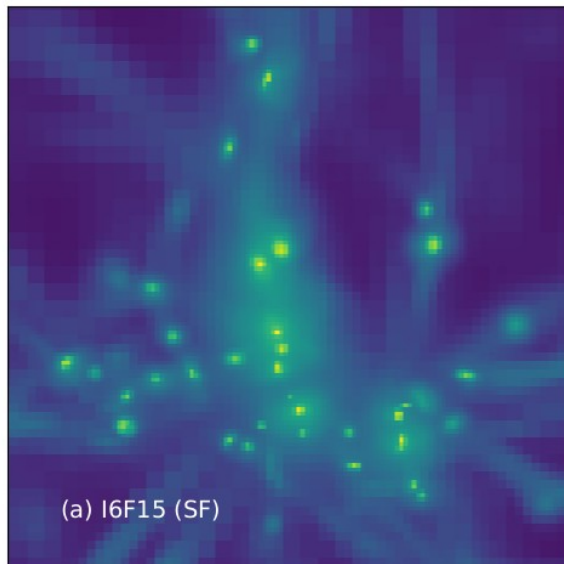
- However, the effect of star formation is very sensitive to the resolution
- A change in maximum resolution requires re-tuning of the physical parameters
- Simulation also reacts to the release of the upper grid levels
- Reduces with resolution



I7

Impact of initial conditions

- Higher the resolution in the initial conditions the more small scale structures
- Effectively different cosmologies



- Initial and final resolution should be stated in simulations

Conclusions

- Gas distribution of RAMSES simulations depends on refinement
- But also on the star formation physics
- Simulations require careful retuning if the resolution is changed
- The resolution of the initial conditions effectively changes the cosmology.