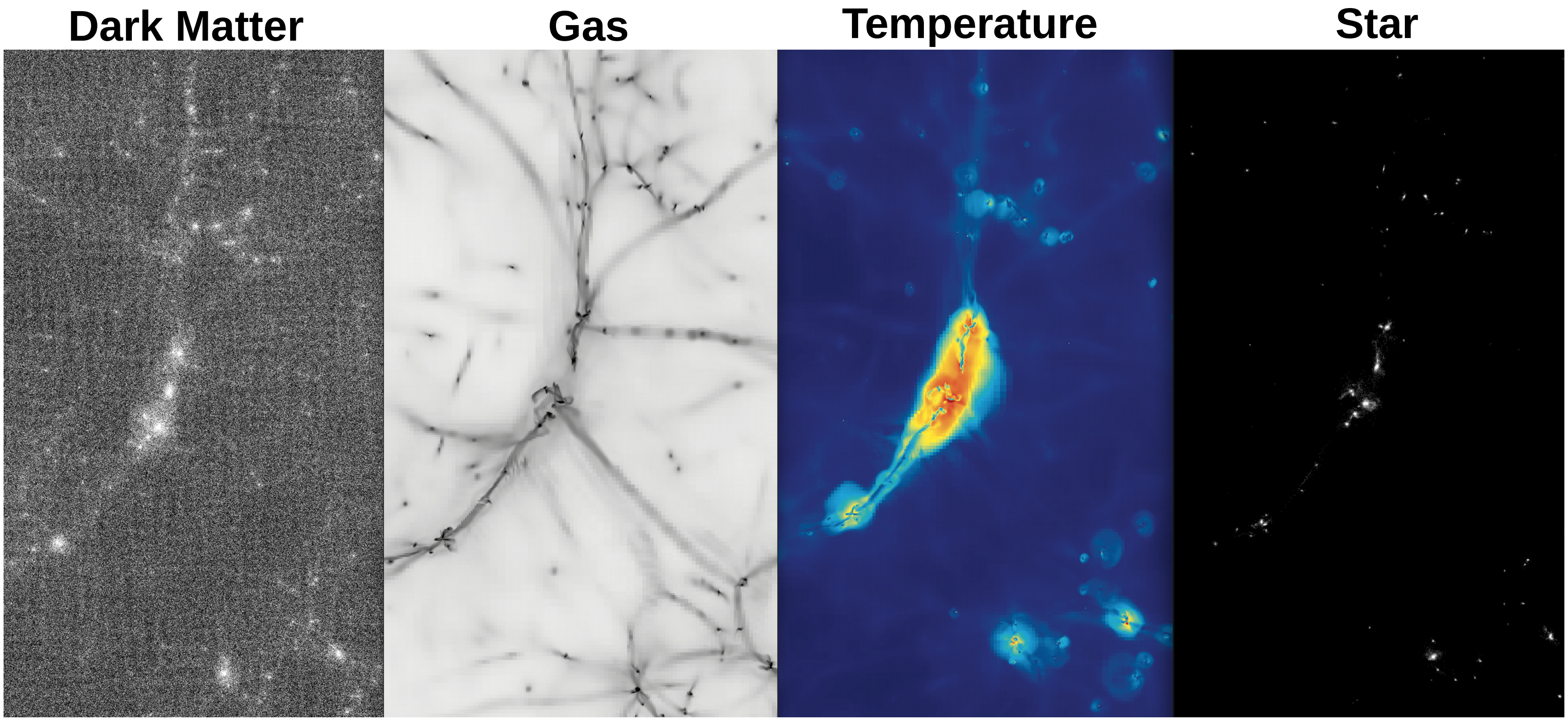


Horizon Run 5 – II. State of Affairs

Owain Snaith (KIAS)

& Juhan Kim, Changbom Park, Jihye Shin, Yonghwi Kim, Jaehyun Lee (KIAS)

HR5: Cosmological Hydrodynamical simulation

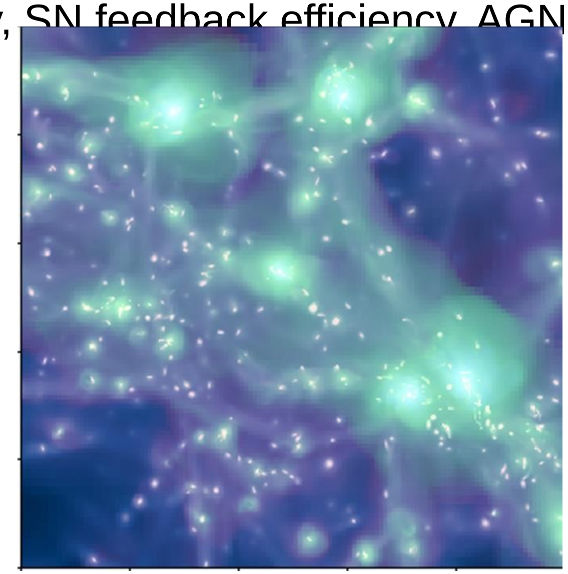
Compared to previous dark matter simulations hydrodynamical simulations are much more complex

HR5 includes: dark matter and stars (particles), gas (grids) and sink particles

Much of the additional physics occurs on scales smaller than one resolution element (1 kpc)

Requires subgrid physics – physical prescriptions that model complex phenomena using a small set of parameters

Includes: Star formation efficiency, SN feedback efficiency, AGN feedback



Sub-grid physics

Subgrid physics is used for various processes including:

Gas Cooling, SN feedback, Stellar yields, Black holes, AGN feedback

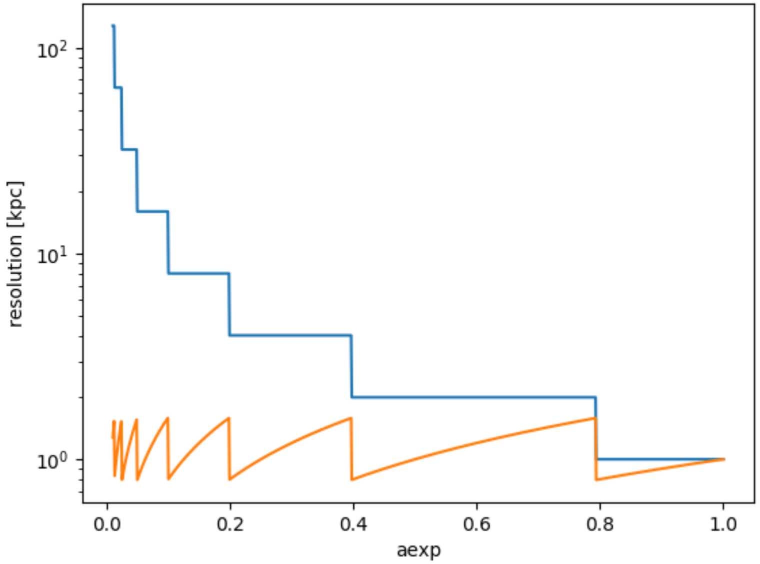
Use RAMSES + CH (Few et al 2014) + AGN (Dubois et al. 2013)

But many sub-grid processes depend on the simulation resolution – parameters need to be set by comparing test simulations to observations

HR5 is run at 1 kpc (physical resolution) at z=0

Changing co-moving resolution

Maintain ~constant physical resolution



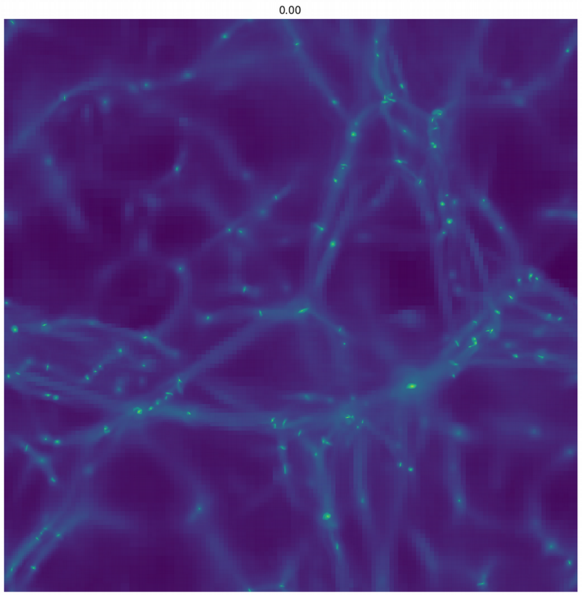
Tuning hydro-dynamical simulations

Pick your observables to tune to:

Cosmic star formation history (integrated) + CMD (colour-magnitude diagram)

cSFR sensitive to the overall rage of star formation – SF efficiency + feedback

CMD sensitive to the recent SFH of individual objects – low recent SF = red, high recent SF = blue



Use a smaller volume to run test simulations:

22.4 Mpc/h, 256^3 particles/initial grids

Same cosmology/ resolution as main run

HR5 – Tuning expectations

Expectations:

Star formation efficiency affects the normalization

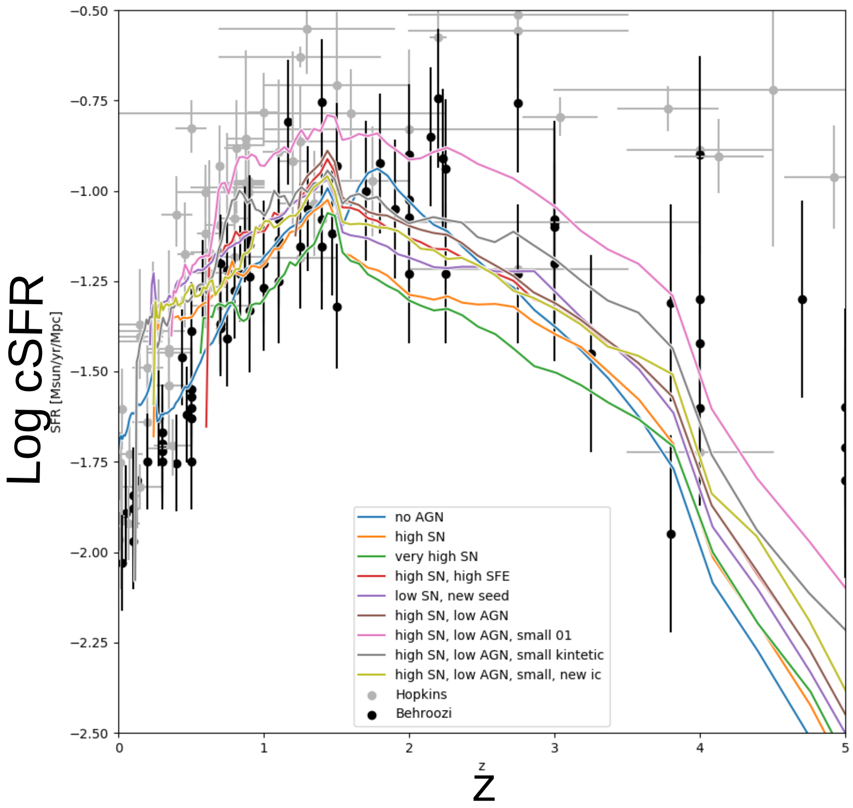
SN feedback important at early times / small objects

AGN important later (BH)

Run many tests

Compare cSFR to Hopkins et al (2006),

and Behroozi et al. (2012) data



HR5 – Tuning in practice

SF efficiency and SN feedback play off against each other

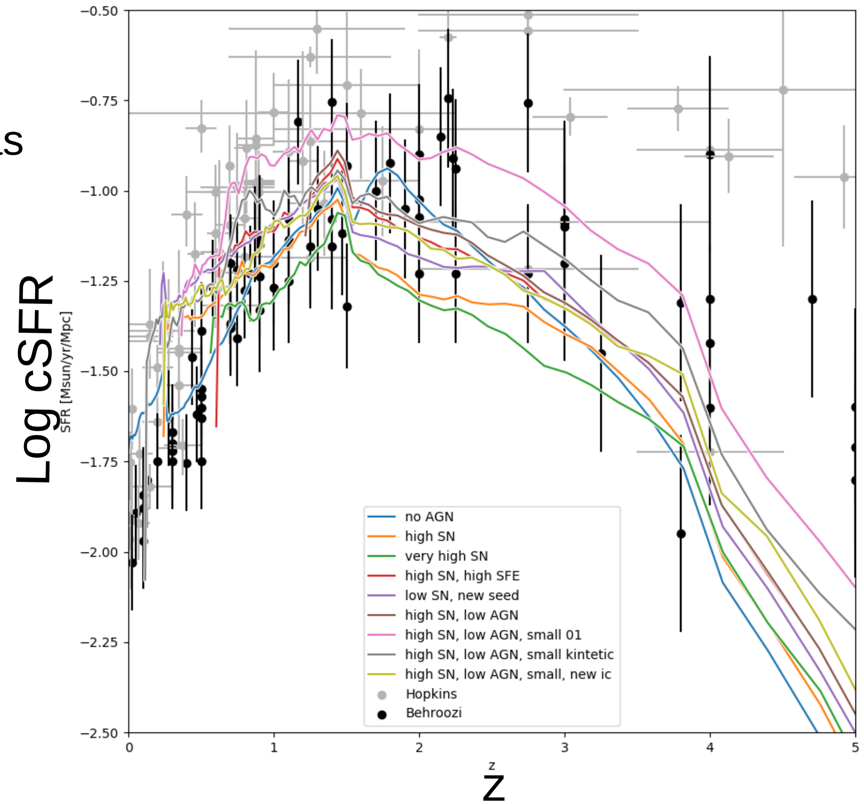
Late time slope hard to control – need AGN feedback

Best initial run – without AGN feedback but with BH – efficient late-time quenching (Dubois et al. 2013)

AGN feedback reduces quenching by heating gas

Carefully constrain AGN parameters:

→ Jet/heating mode

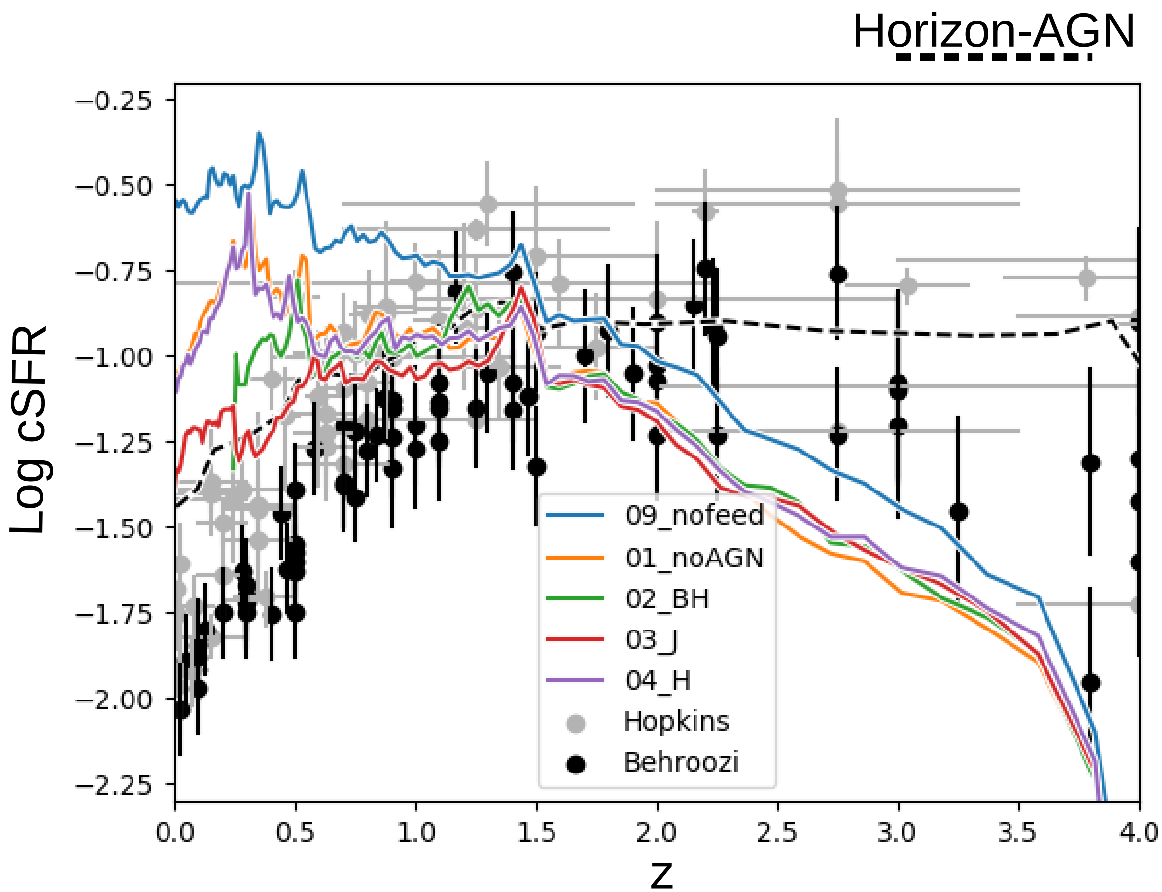


HR5 – Tuning the AGN parameters

Without feedback SF increases over time

With feedback SF suppressed after z=2 – with AGN stronger suppression

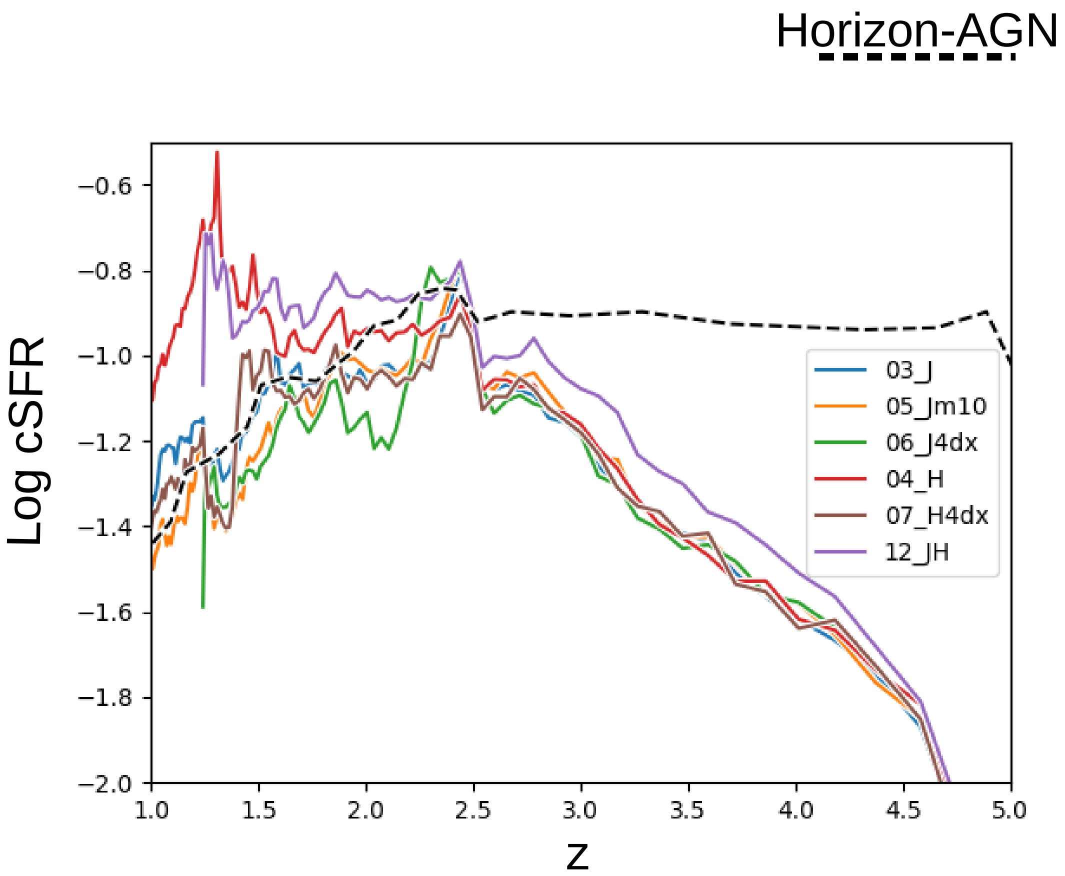
AGN with **Jet** is best



HR5 – Fixing the tuning parameters cont.

Other parameters can improve fit to the SFR

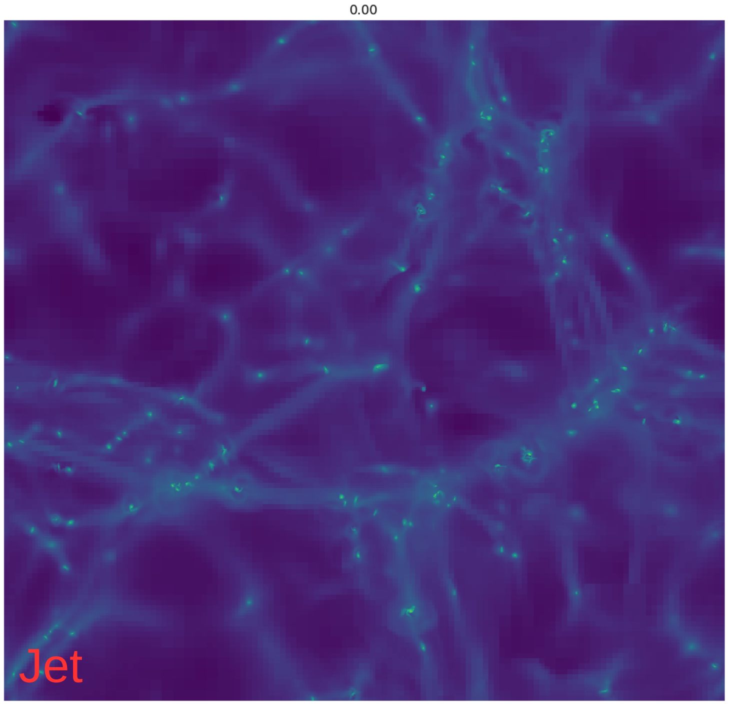
- J – jet only
- Jm10 – wait for 10% mass to be accreted before releasing jet as burst
- Strongest in Dubois et al. (2013)
- Jdx4, Hdx4 – area of effect

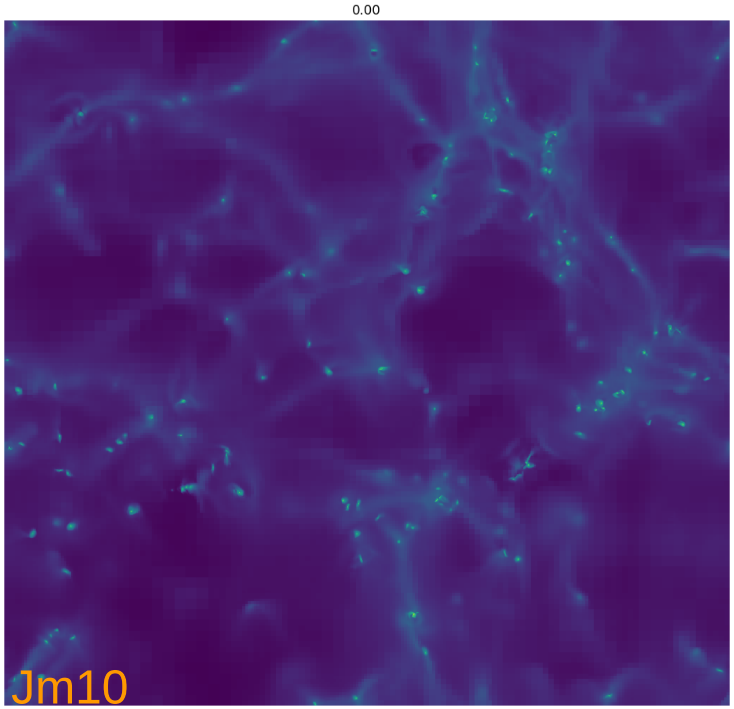


How to Set HR5

Other parameters can improve fit to the SFR

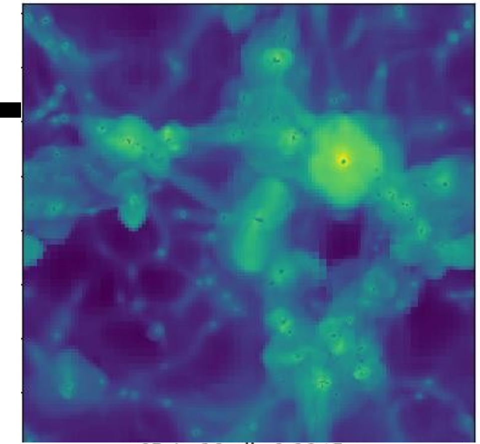
- J – jet only
- Jm10 – wait for 10% mass to be accreted before releasing jet as burst
- Strongest in Dubois et al. (2013)
- Jdx4, Hdx4 – area of effect



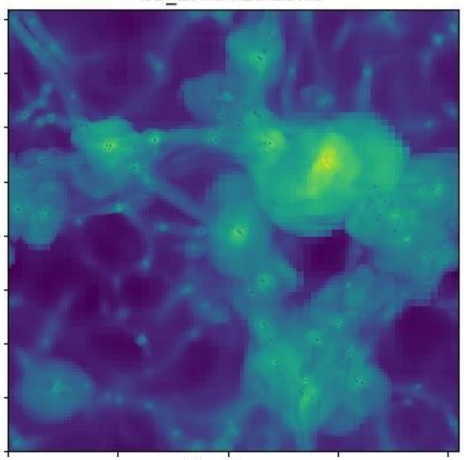


HR5 – fixing the tuning parameters – gas

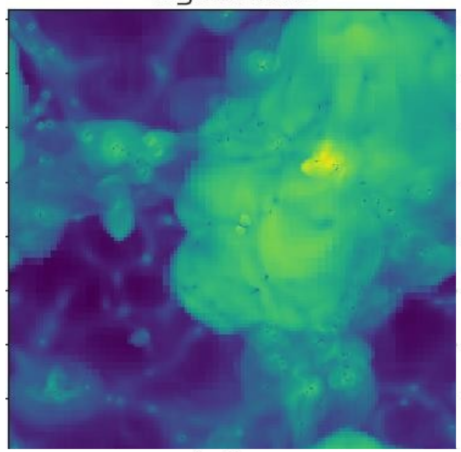
01_noAGN.all.z0.00.t5



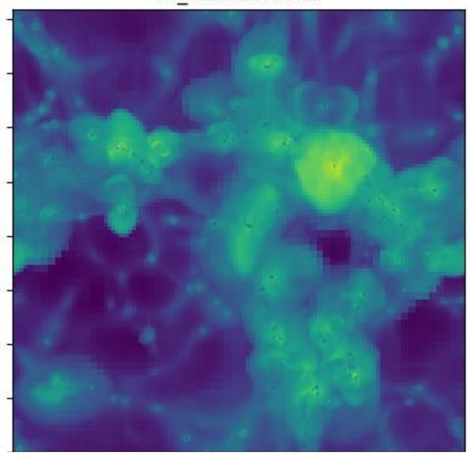
02_BH.all.z0.25.t5



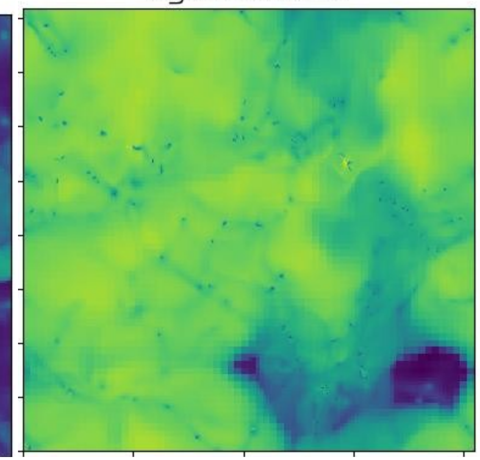
03_J.all.z0.00.t5



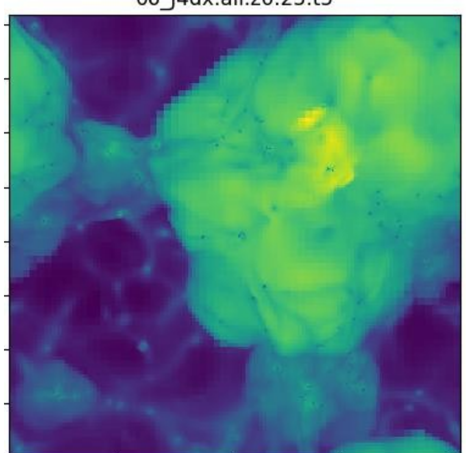
04_H.all.z0.00.t5



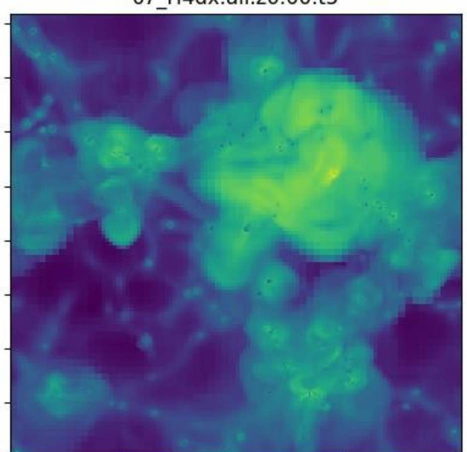
05_Jm10.all.z0.00.t5



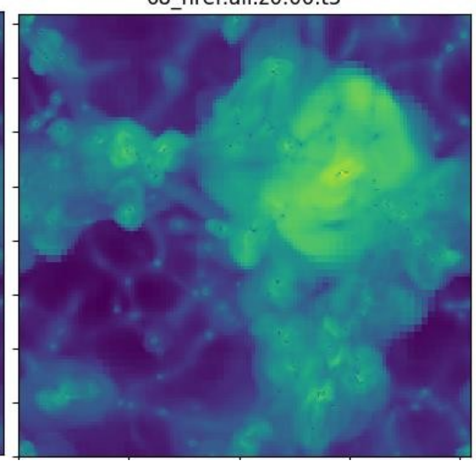
06_J4dx.all.z0.25.t5



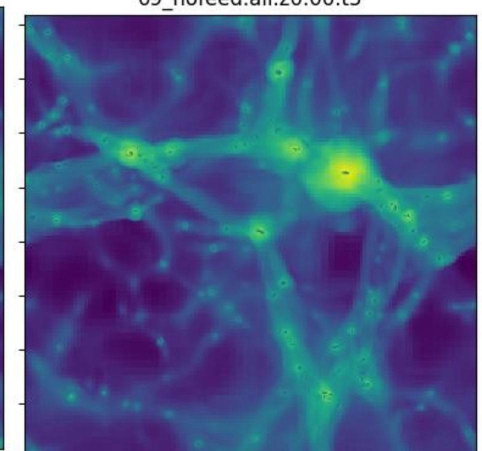
07_H4dx.all.z0.00.t5



08_nref.all.z0.00.t5



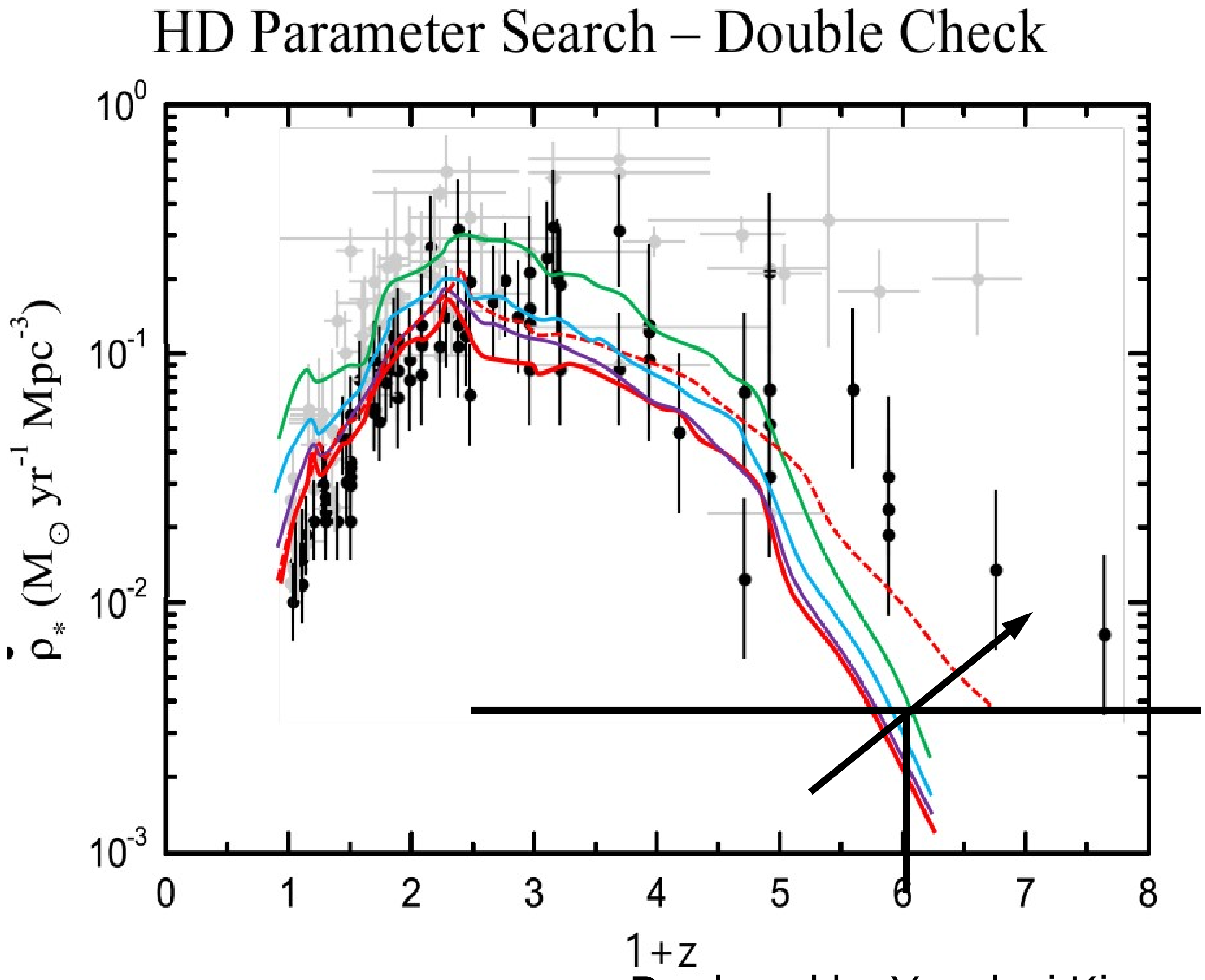
09_nofeed.all.z0.00.t5



HR5 – Impact of the box size

Box size has an impact on the early star formation – the larger the box the more early star formation

Increase volume from 11.9 to 23.8 Mpc/h



Produced by Yonghwi Kim

HR5 – Final parameters

```
eps_star=0.03

f_w = 0. ! SN wind

f_ek = 0.  ! kinetic feedback

eps_sn2 = 2. ! SNII efficiency

eps_sn1 = 2. ! SNIa efficiency

eAGN_K=1d0 ! Efficiency of the radio mode – jet

eAGN_T=0.0 ! Efficiency of the quasar mode - heating
```

Conclusions

Many parameters must be set – which are resolution (and problem) dependent

Simulation outcomes very sensitive to the chosen parameters

We have constrained the cSFR

HR5 has a resolution competitive with Illustris (Vogelsberger et al. 2014) and Eagle (Scheye et al. 2014)

But a much larger volume (probes more the power spectrum)