AGN feedback effects on the 1D power spectrum from Ly-α forests

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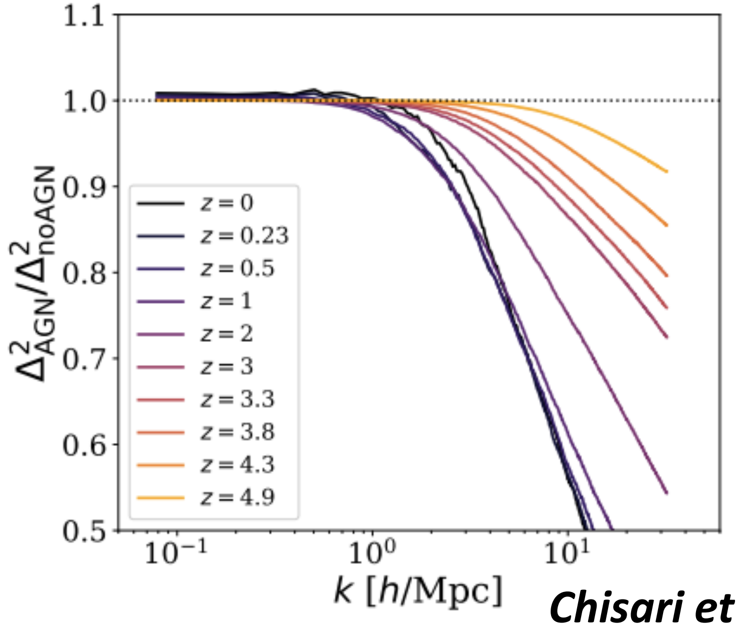
1- Motivations

Galactic feedback is known to

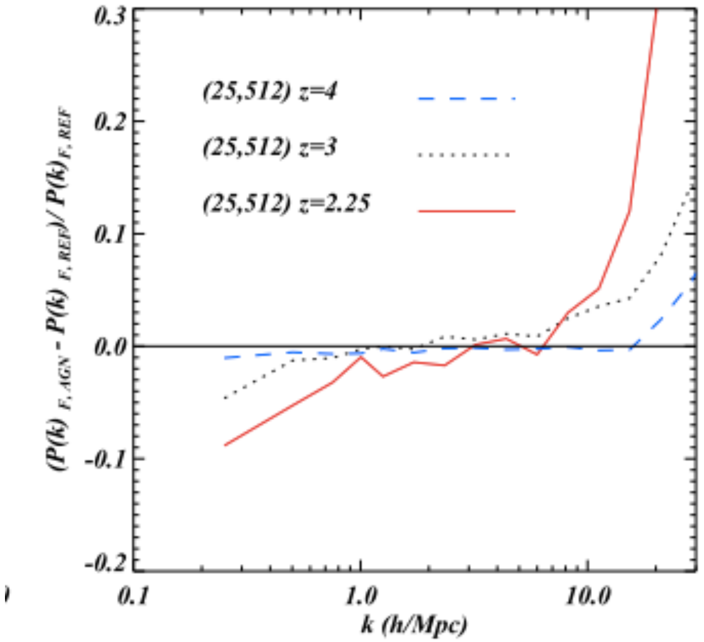
- Be responsible for the quenching of galaxies and their observed morphological diversity
- Modify the density profiles of haloes
- Modify the distribution of matter at cosmological scales
- Affect the properties of DLAs
- Modify the transmitted flux statistics of the Ly-α forests

Matter power spectrum



Chisari et al. 2018

Transmitted flux power spectrum



Viel et al. 2012

2- The HorizonAGN simulation

- Cosmological hydrodynamical simulation run with the Adaptative Mesh Refinement code RAMSES
- Run to z = 1.2 using 4 million CPU hours
- $L_{box} = 100h^{-1}Mpc$ with WMAP-7 cosmology
- cell size = 1 to 100 kpc

- Heating from a uniform UV background with $z_{reio} = 10$
  H and He cooling down to T=10^4K, below adiabatic cooling only
- Stellar formation and stellar feedback
- AGN feedback implemented with subgrid model

- Companion simulation without AGN feedback: HnoAGN

2- The HorizonAGN simulation

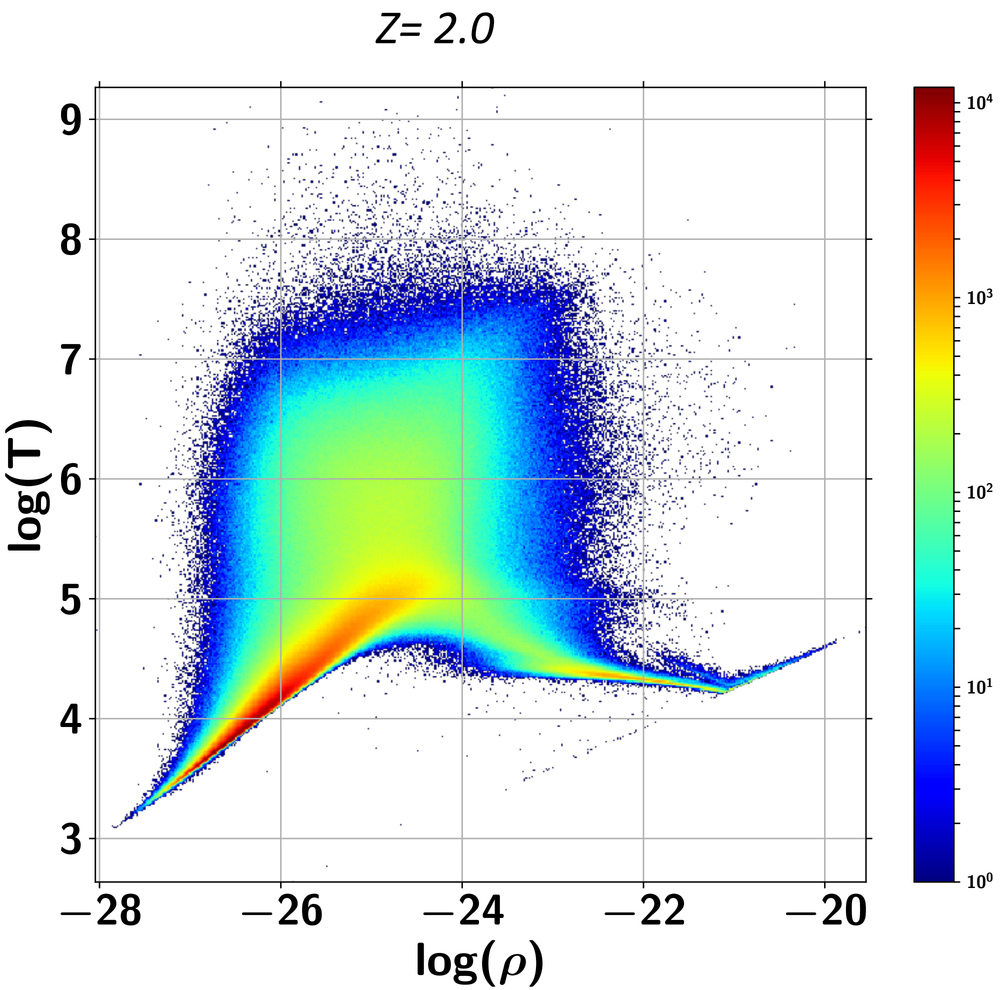
- AGN feedback modes

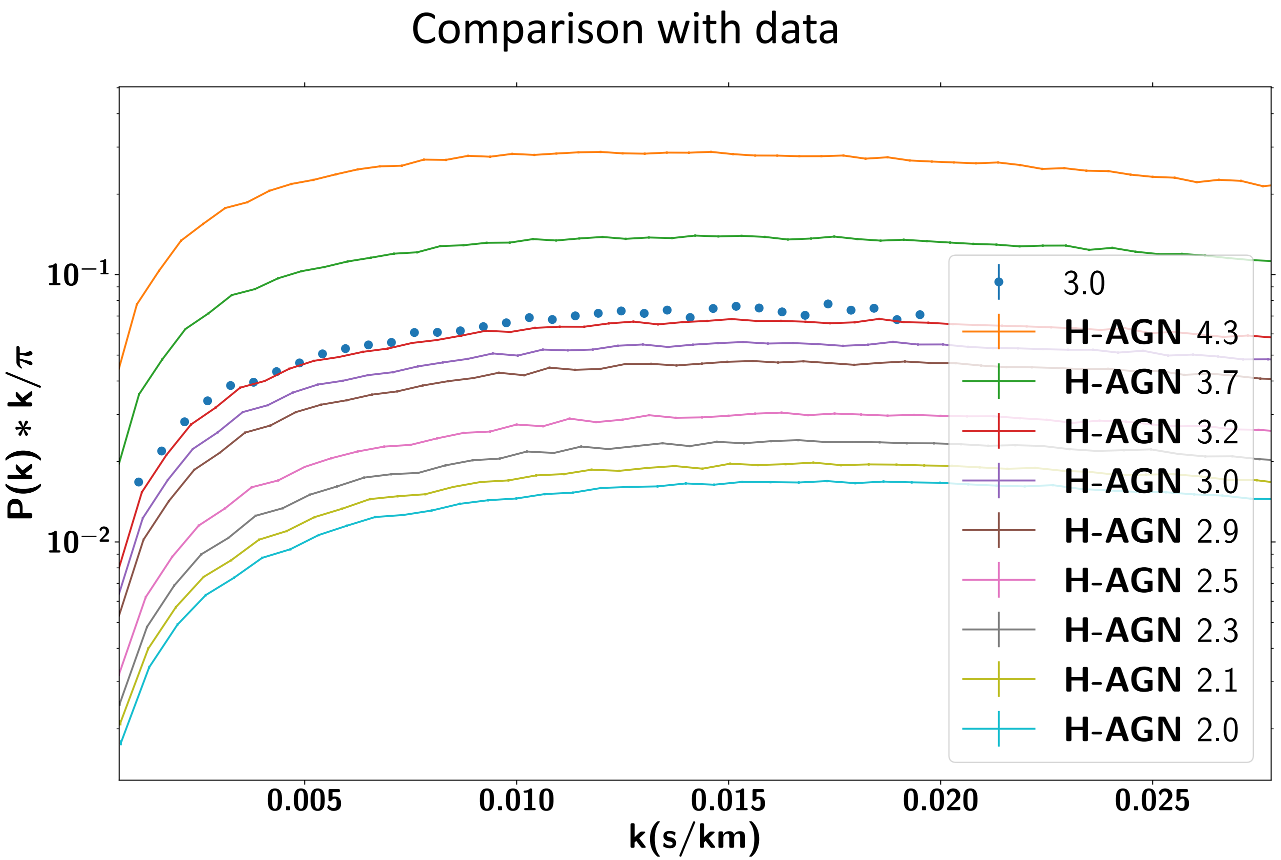
	QSO mode	Radio mode
Period of activity	High accretion rate	Low accretion rate
Energy injection	Isotropic injection of thermal energy	Bipolar outflows, injection of kinetic energy
Radius of energy deposition r_{AGN}	Δx	Δx
Energy deposition rate	$\Delta E_{IGM} = \varepsilon_F L_r = \varepsilon_F \varepsilon_r \dot{M}_{BH} c^2$ ε_F=0.15	$\Delta E_{IGM} = \varepsilon_F L_r = \varepsilon_F \varepsilon_r \dot{M}_{BH} c^2$ ε_F=1

L_r: radiated energy
ε_F: fraction of radiated energy tuned to match the observations
ε_r: radiative efficiency, fixed to 0.1
$\dot{M}_{BH}$: accretion rate

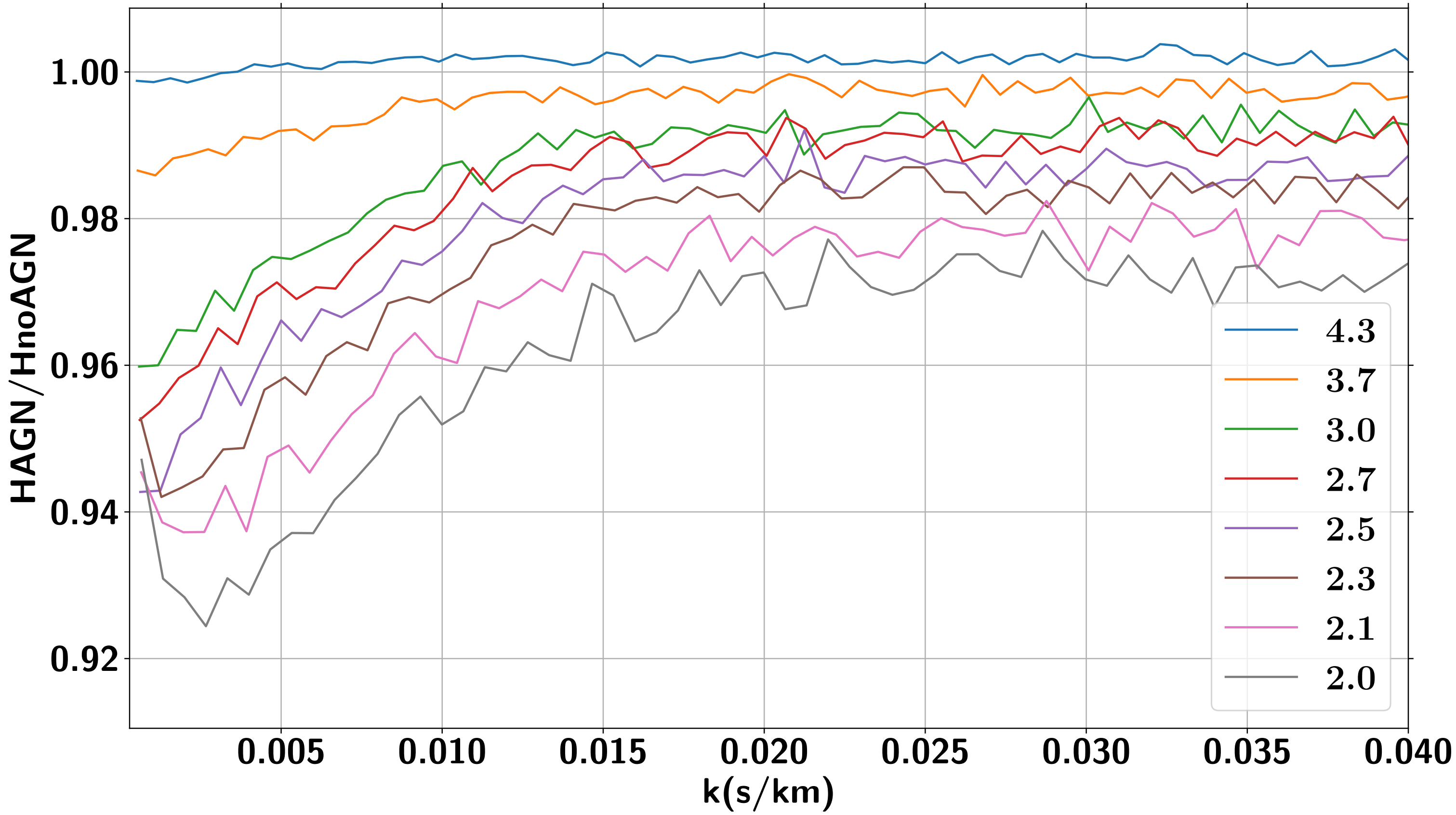
→ $\varepsilon_F \times \varepsilon_r$ is the fraction of the *total* energy transferred to the IGM

3- The Ly-α forest in HorizonAGN





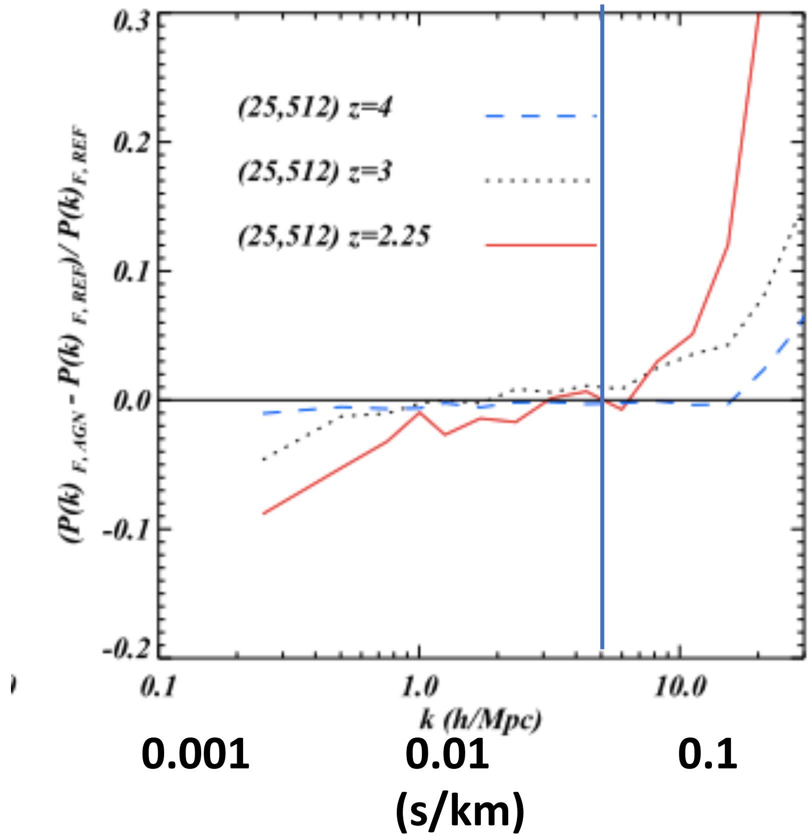
4- AGN feedback effects



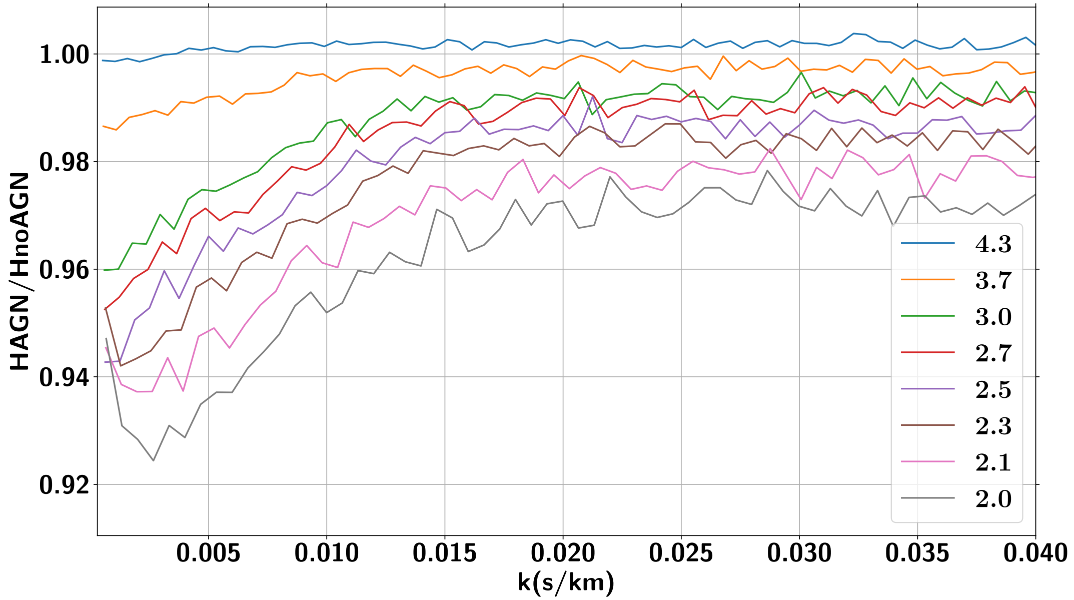
This work

- Decrease of power on large scales
- Effect increases with decreasing redshift

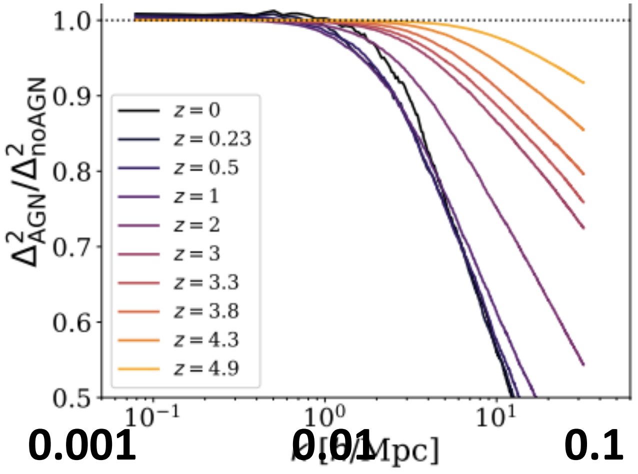
Viel et al. 2012



4- AGN feedback effects



This work



(s/km)

Chisari et al. 2018

<u>On Lya 1D power spectrum</u>

- **Decrease of power on large scales**
- Effect increases with decreasing redshift

<u>On matter power spectrum</u>

- **Increase of power on large scales**
- Decrease of power on small scales

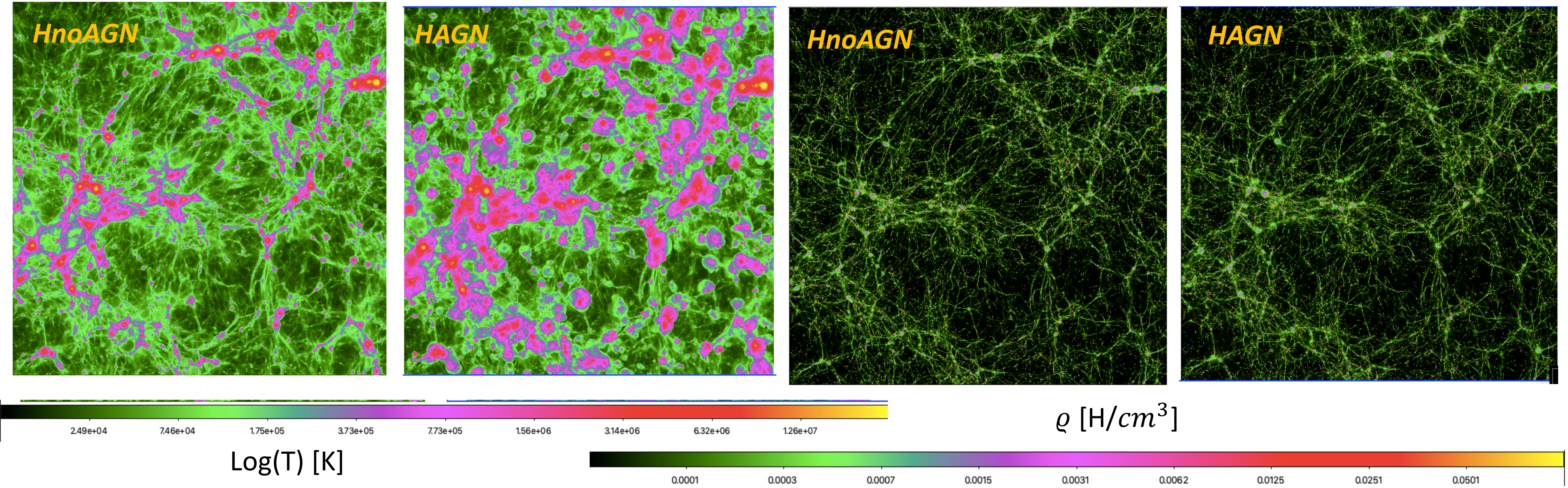
→ Why do we observe a decrease of power on large scales with P_{Lya} ?

4- AGN feedback effects

- Why do we observe a decrease of power on large scales with P_{Lya} ?
  - Feedback efficiently heats the gas.
  - On small scales: dense gas cools down easily
  - On large scales: low density IGM stays hot

HAGN

→ **with feedback gas is more ionized on large scales, hence less power in P_{Lya}**



4- AGN feedback effects

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→ **Feedbacks redistribute HI to large scales**

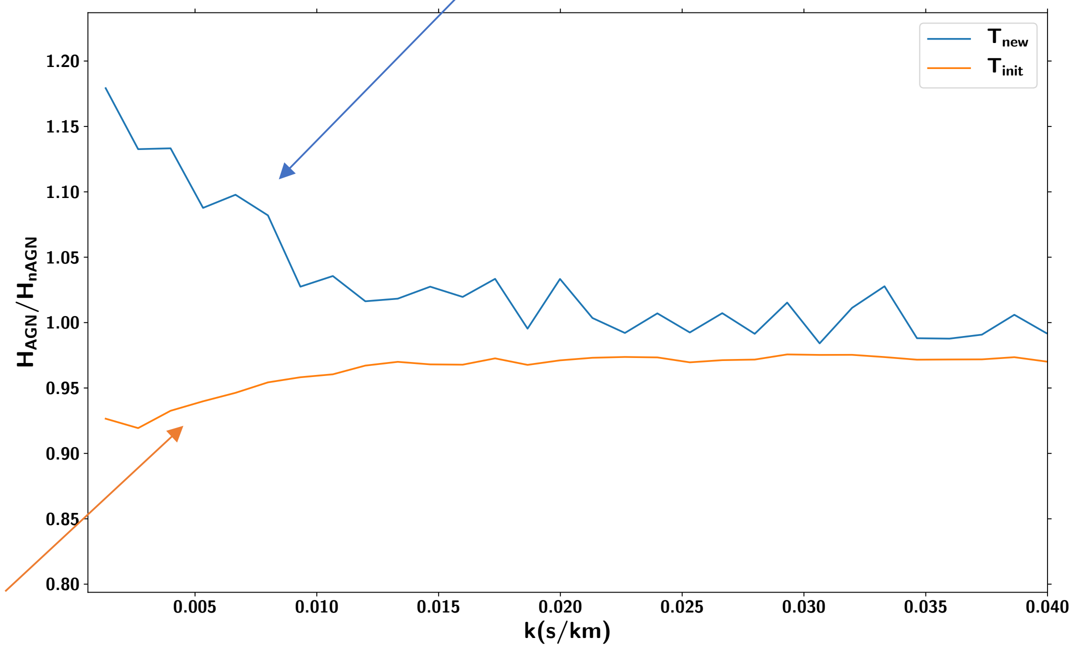
Feedbacks heat hence ionize

T_{init}: $T_{HAGN} = T_{HAGN}$

T_{new}: $T_{HAGN} = T_{HnoAGN}$

Z = 2.0

Heating switched off
Redistribution only



Heating switched on
Redistribution + ionization

5- Uncertainties on the feedback model

- 4 re-runs from z = 7.0
- Resulting M_{BH}=f(M_{stars}) ,SFR have to be **within 3σ of the observations**

	Modified parameter	Running time
HAGN_2Dx	$r_{AGN} = 2 * \Delta x$	3 millions CPU hours
HAGN_05Dx	$r_{AGN} = 0.5 * \Delta x$	3.5 millions CPU hours
HAGN_033e	ε_F=0.33*$\varepsilon_{F,init}$	2millions CPU hours
HAGN_3e	ε_F=3*$\varepsilon_{F,init}$	/

$$\Delta E_{IGM} = \varepsilon_F L_r$$

ε_F: fraction of radiated energy injected in the medium

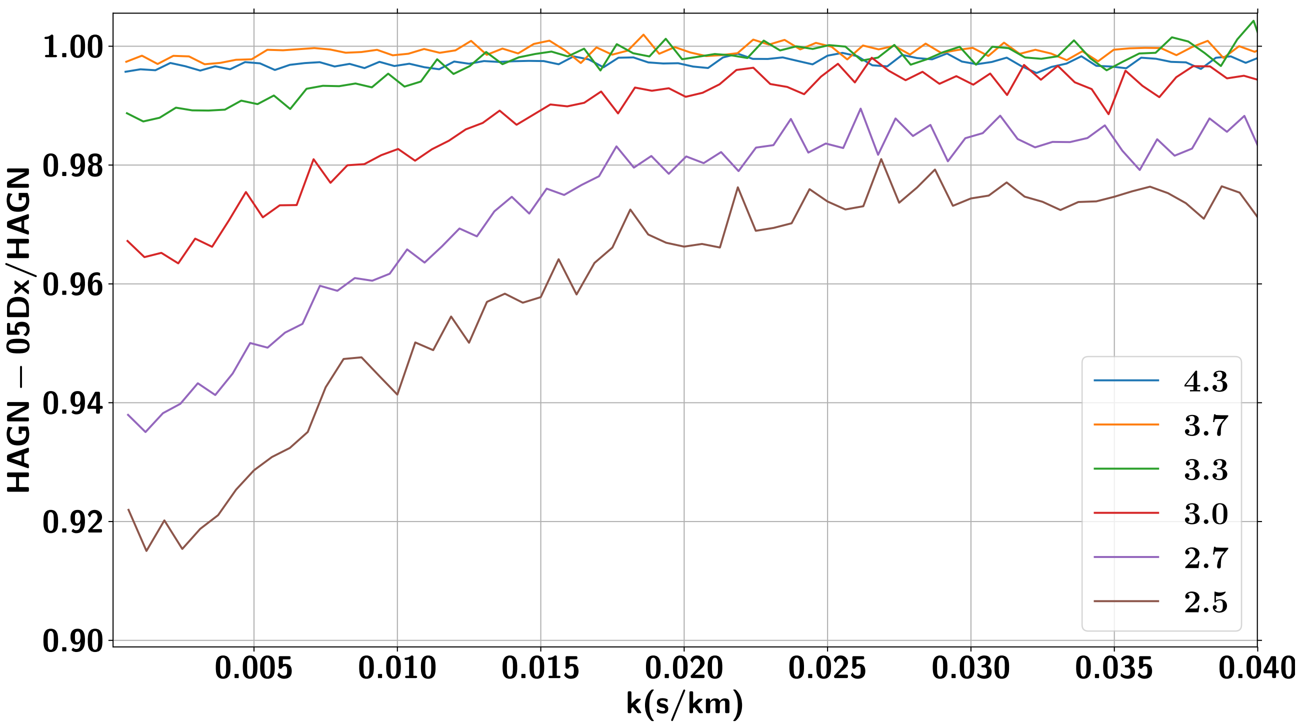
L_r: radiated energy

5- Uncertainties on the feedback model

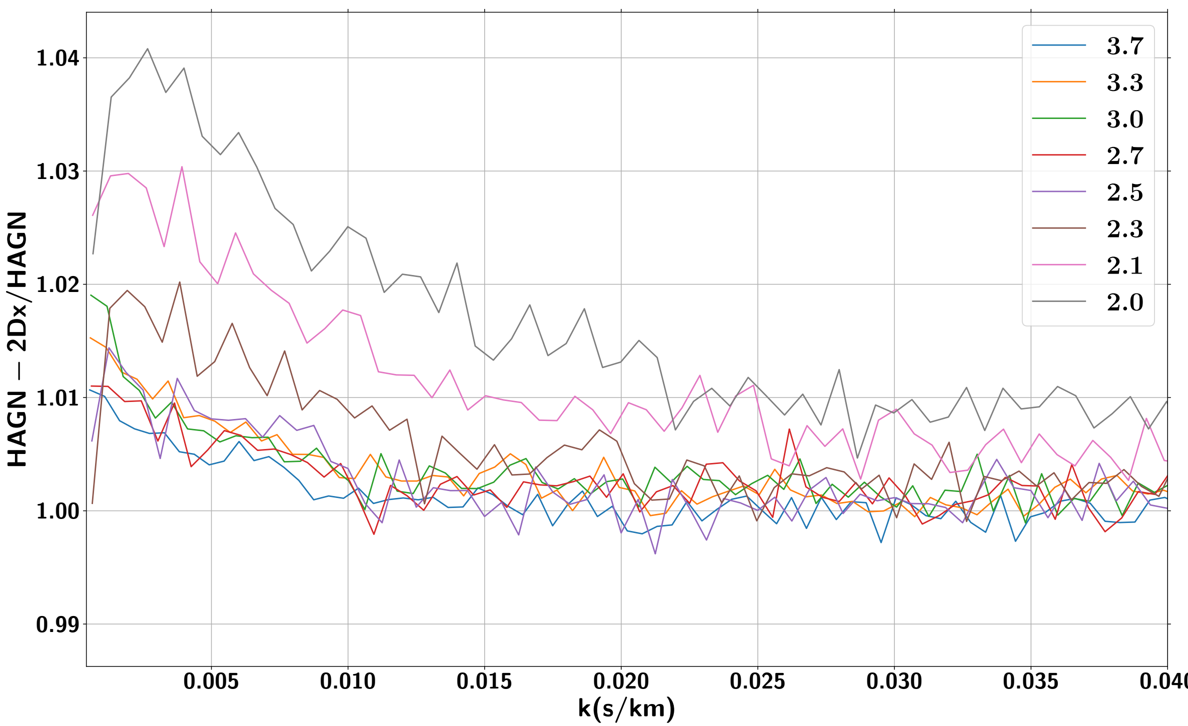
- Radius of energy deposition r_{AGN}

Only modifies the radius, the **amount of injected energy is conserved**

HAGN_05Dx



HAGN_2Dx



5- Uncertainties on the feedback model

- <u>Radius of energy deposition r_{AGN}</u>

Feedback efficiency: HAGN_05Dx > HAGN > HAGN_2Dx

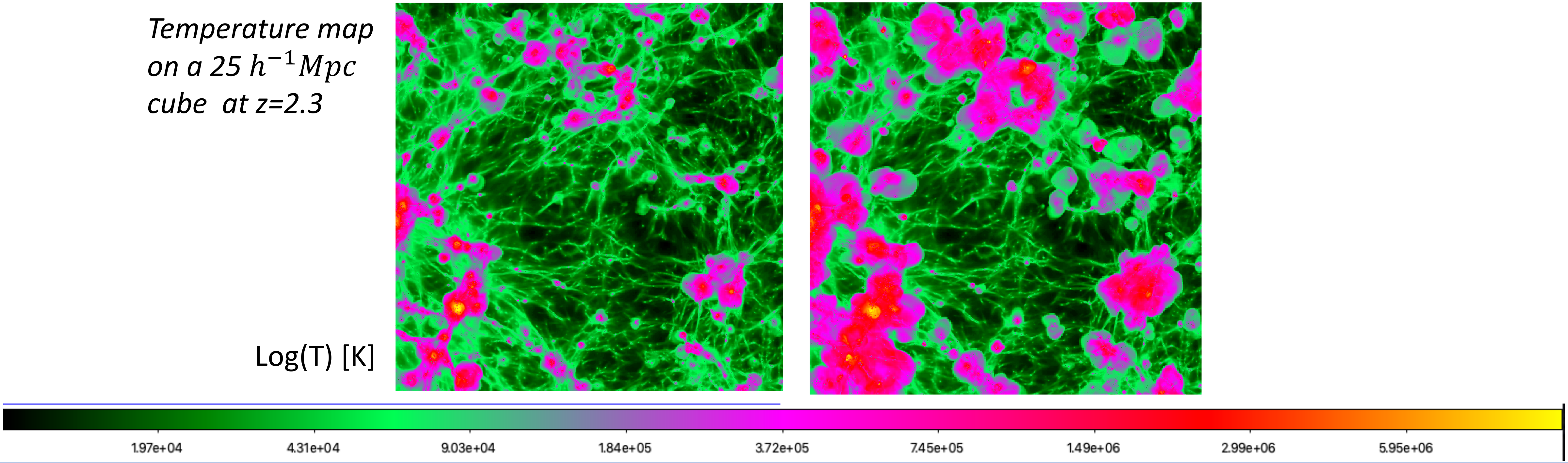
The more r_{AGN} is high, the less energy per unit volume is deposited, hence the energy is injected to larger scales but is not able to efficiently heat the gas (not more than $10^6, 10^7$ K)

→ **gas cools down more easily, and is less ionized for high $\boldsymbol{r_{AGN}}$**

HAGN_2Dx *HAGN_05Dx*

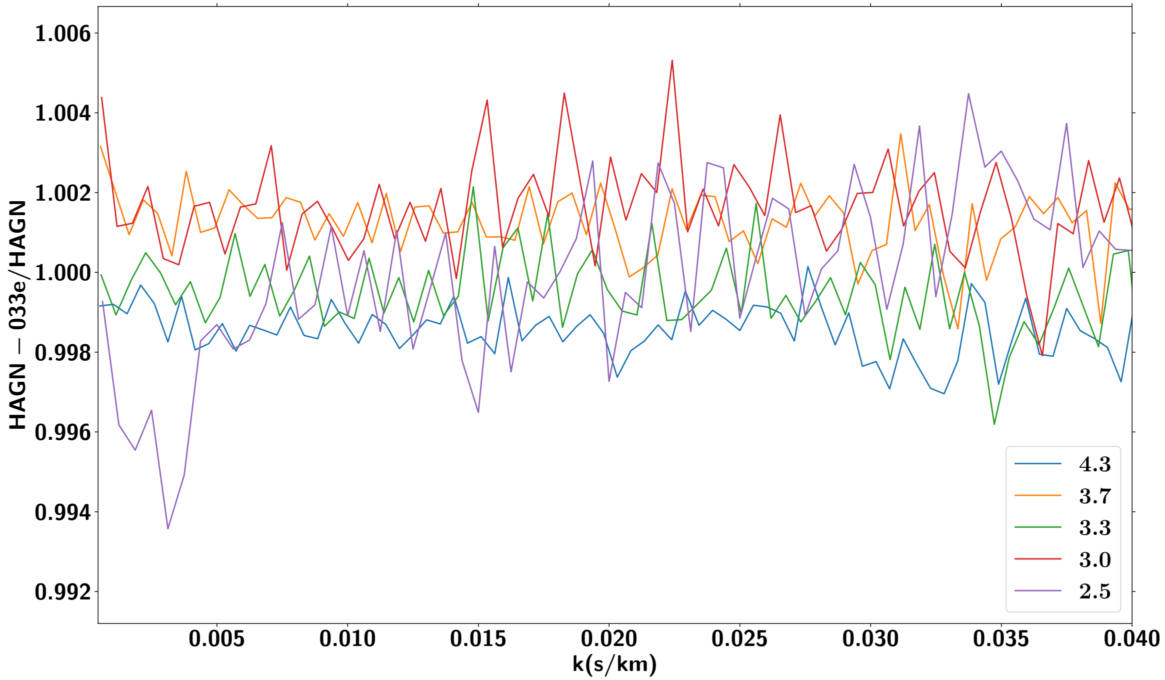
Temperature map on a 25 $h^{-1}Mpc$ cube at z=2.3

Log(T) [K]

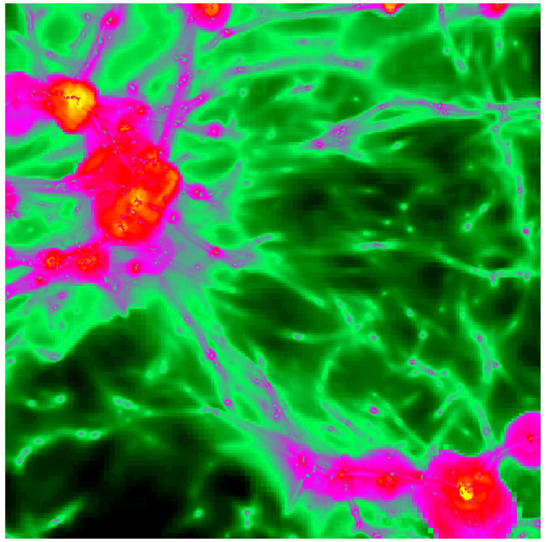


5- Uncertainties on the feedback model

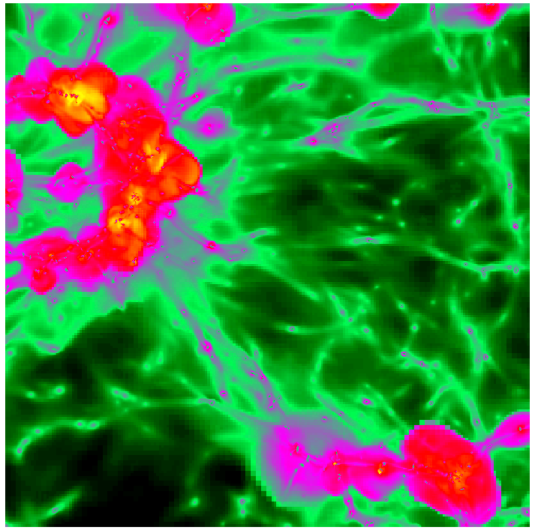
- Efficiency ε_F

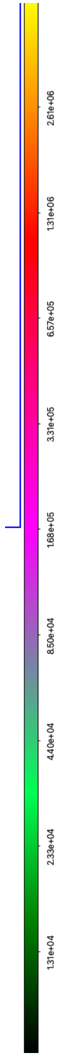


HAGN



Temperature map on a 10 $h^{-1}Mpc$ cube at z=2.5





HAGN_033e

6- Summary

- AGN feedbacks modify the $\mathrm{P_{Lya}}$ by **efficiently heating the low density regions on large scales**
- $\mathrm{P_{Lya}}$ is very dependent on the radius of energy deposition $\mathrm{r_{AGN}}$
- Decreasing the efficiency parameter has very little effect on $\mathrm{P_{Lya}}$

- Work in progress:
  - Increase the efficiency parameter
  - Modify the UV background
  - Switch off SN feedback