High resolution studies of massive primordial haloes

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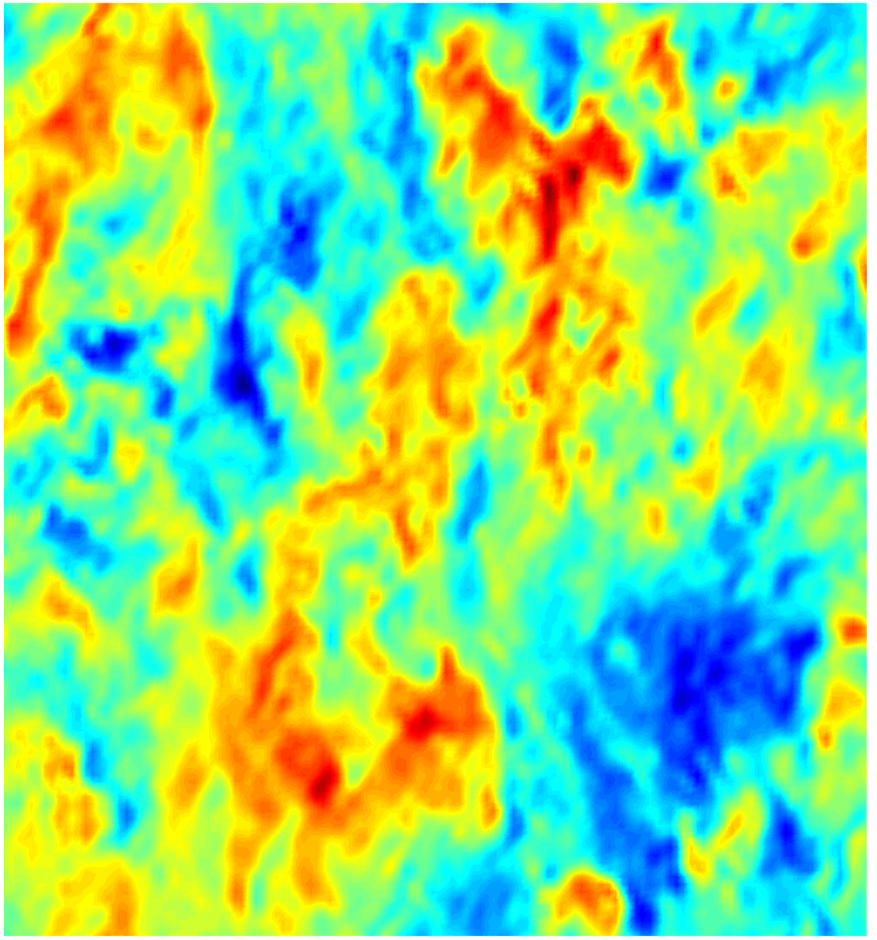
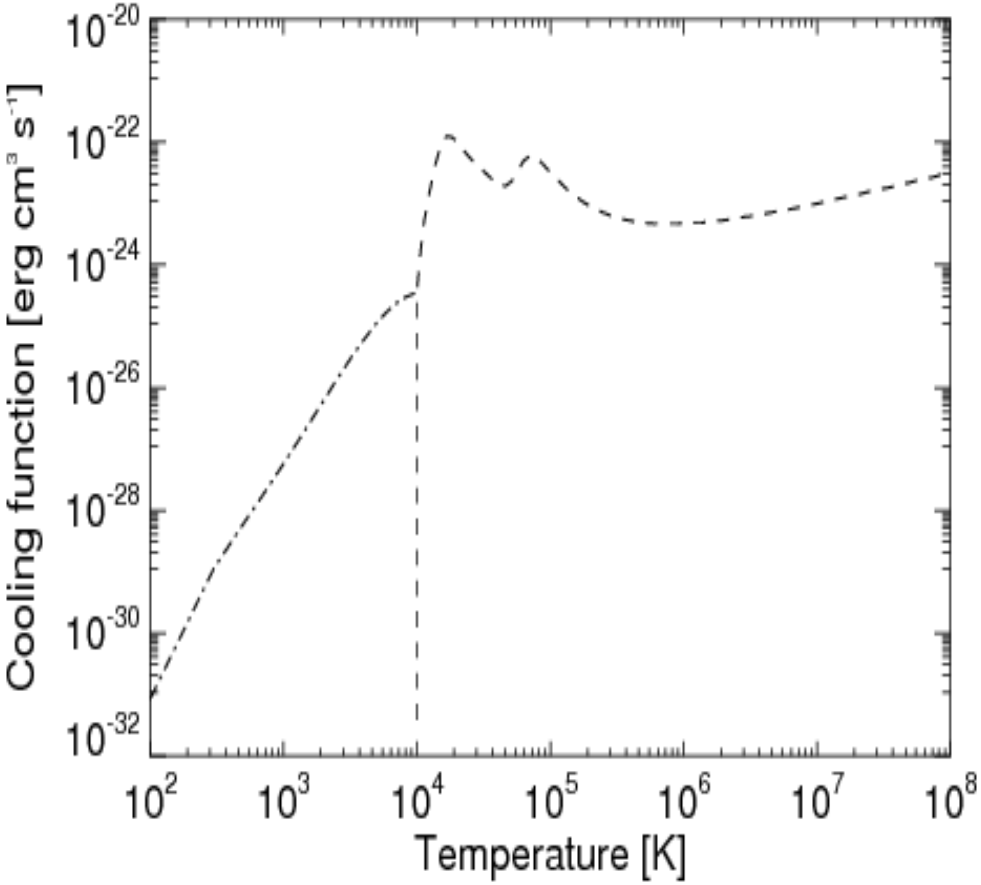
Outline

- Chemistry
- Turbulence
- Numerical Methods
- Results
- Summary



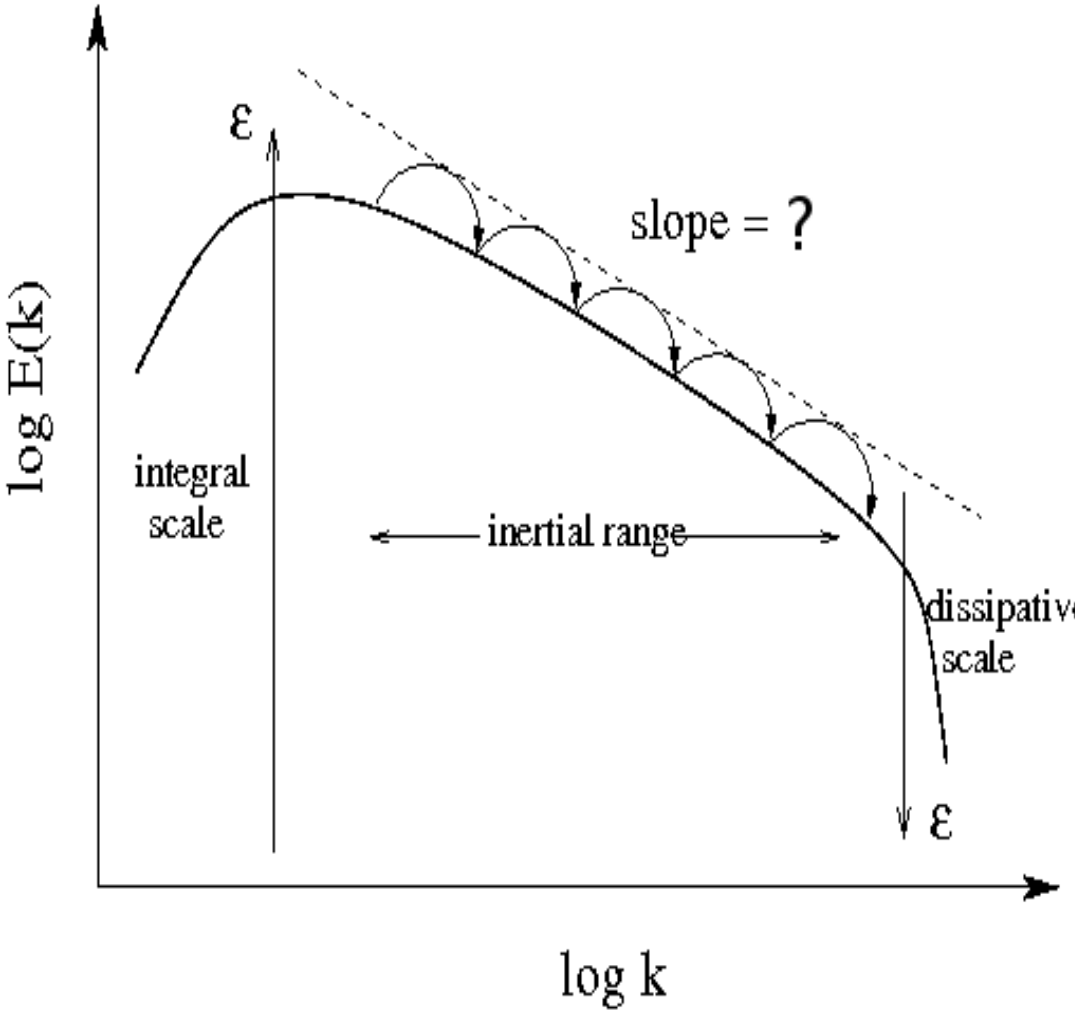
Chemistry

- Ly α is an efficient coolant
- For $T_{vir} > 10^4$ K halos
- At T<8000 K, H_2 cooling
- Strong Lyman Werner flux
- Photodissociation of H_2



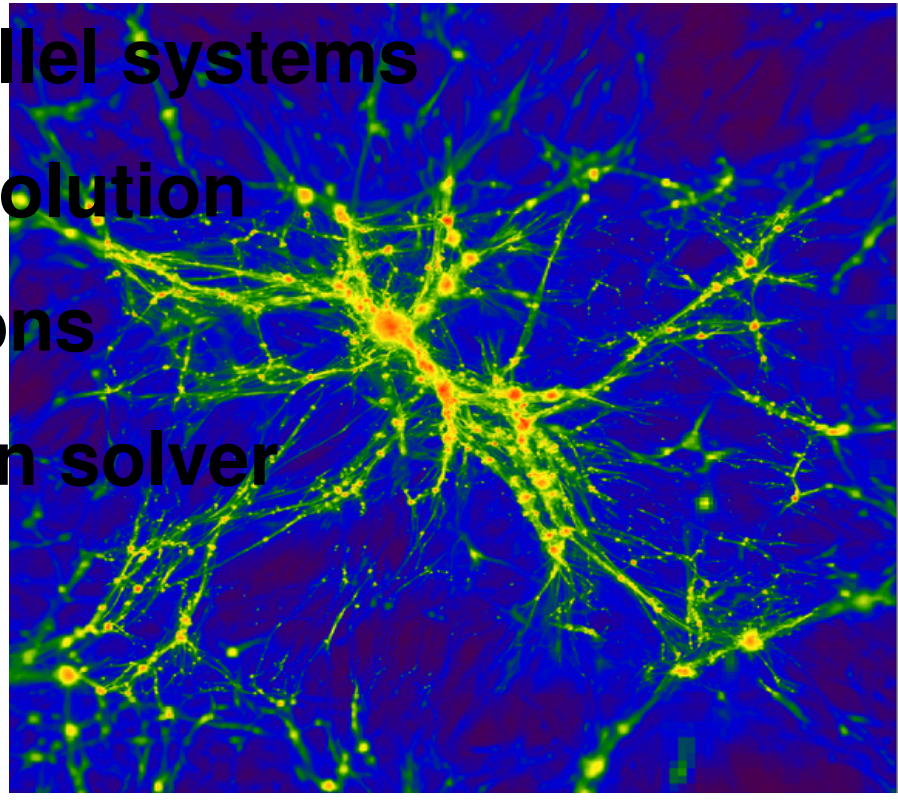
Turbulence

- SGS Turbulence model
- Separates resolved and unresolved scales
- Connects them via eddy-viscosity closures
- LES are used in CFD
- FEARLESS (Maier, Schmidt, Niemeyer 2009, Schmidt & Federrath 2011)



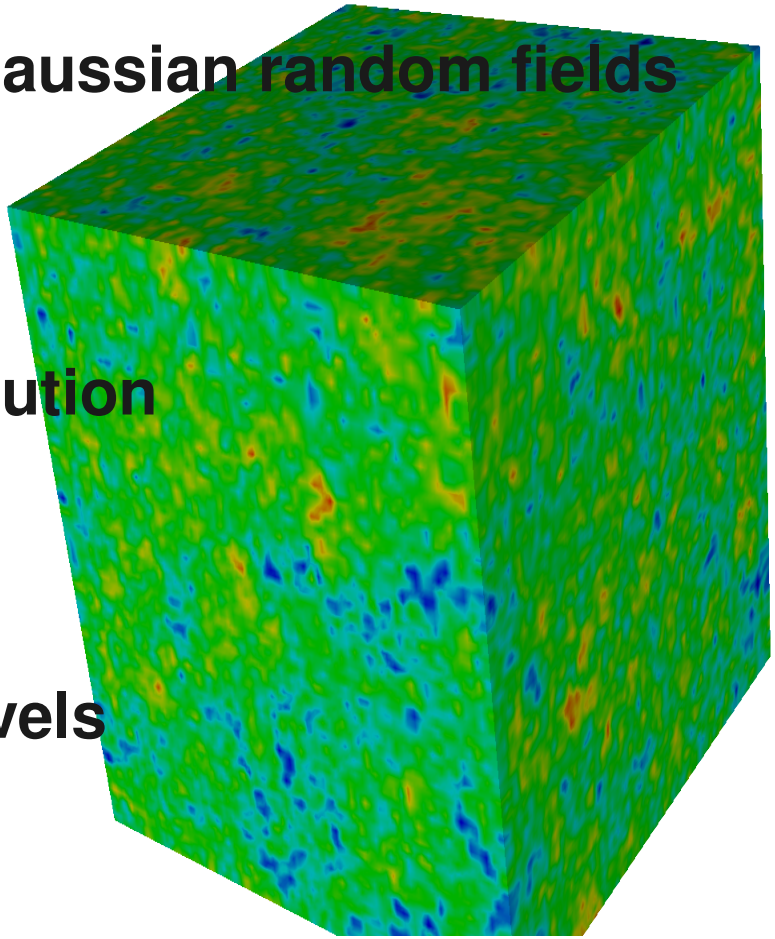
Numerical Methods

- Enzo is an AMR, parallel grid based code
- Designed for compressive flow problems
- Can solve a broad range of astro-physics problems
- Portable runs on massively parallel systems
- Capable of handling extreme resolution
- PPM method for hydro calculations
- For Self gravity multigrid Poisson solver
- N body simulations

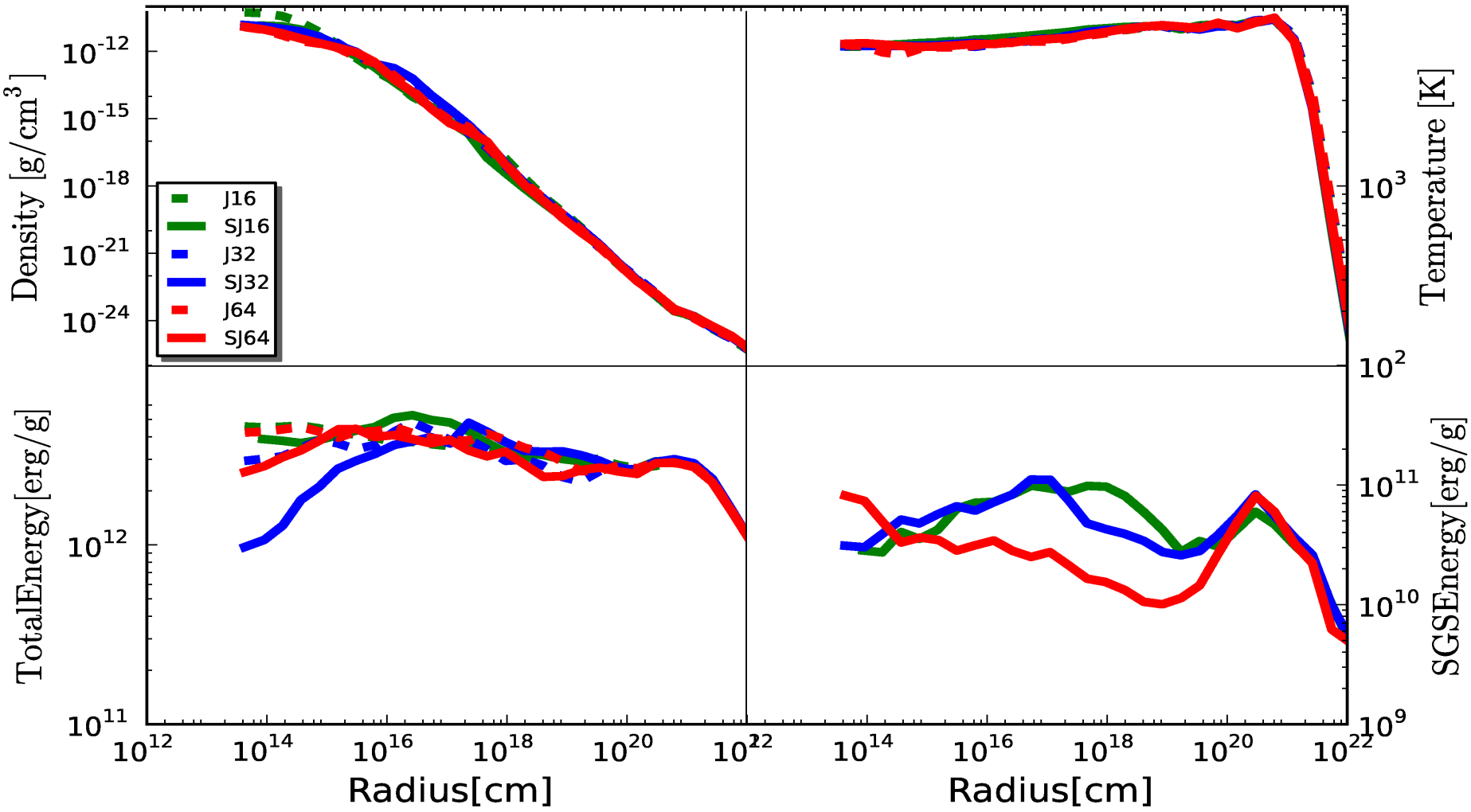


Initial Conditions

- Comoving period box of 1mpc/h in size
- Cosmological Initial conditions i.e., Gaussian random fields
- CDM cosmology power spectrum
- 6 Million particles to simulate DM evolution
- Two initial nested grid
- 27 additional dynamical refinement levels
- SGS Turbulence model

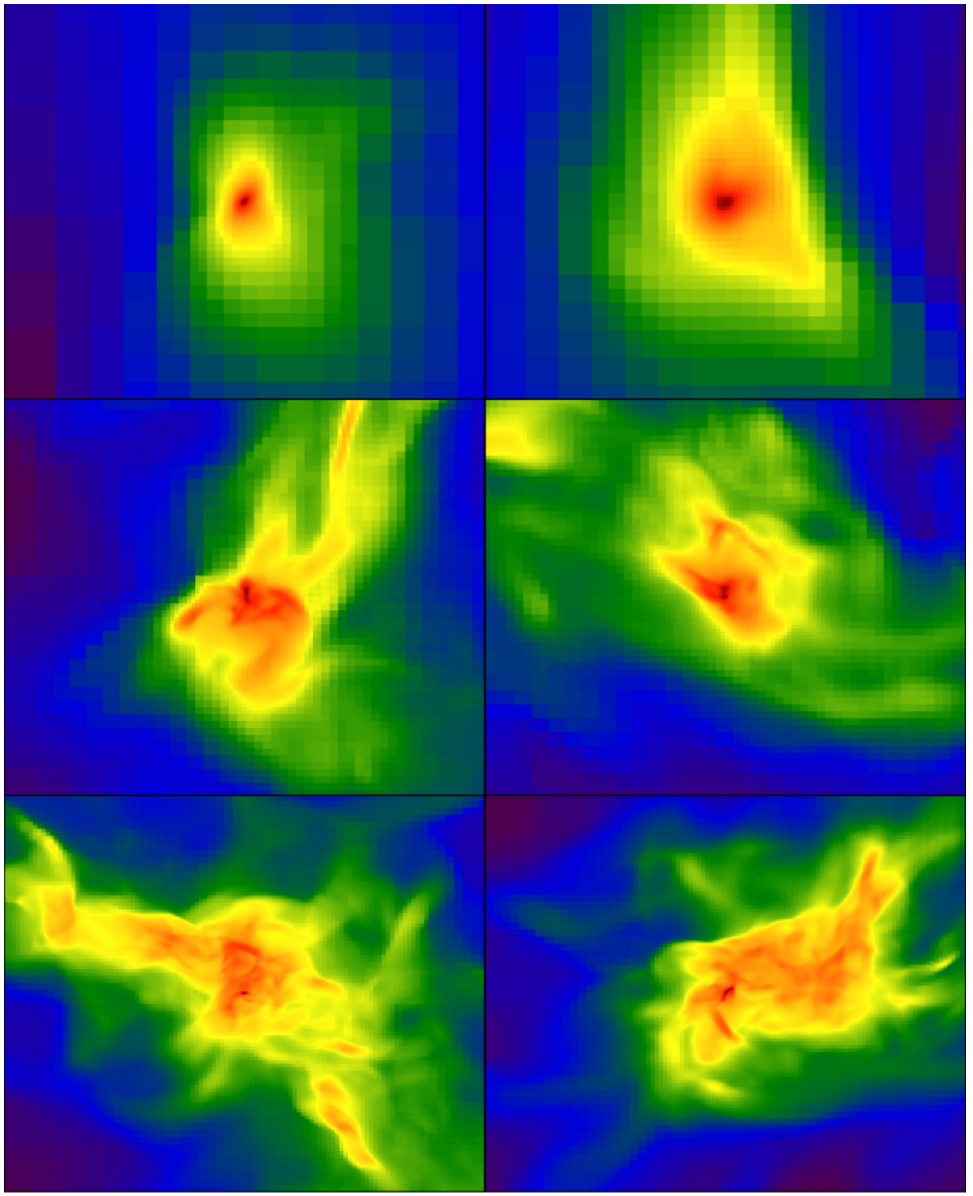


Resolution Comparison



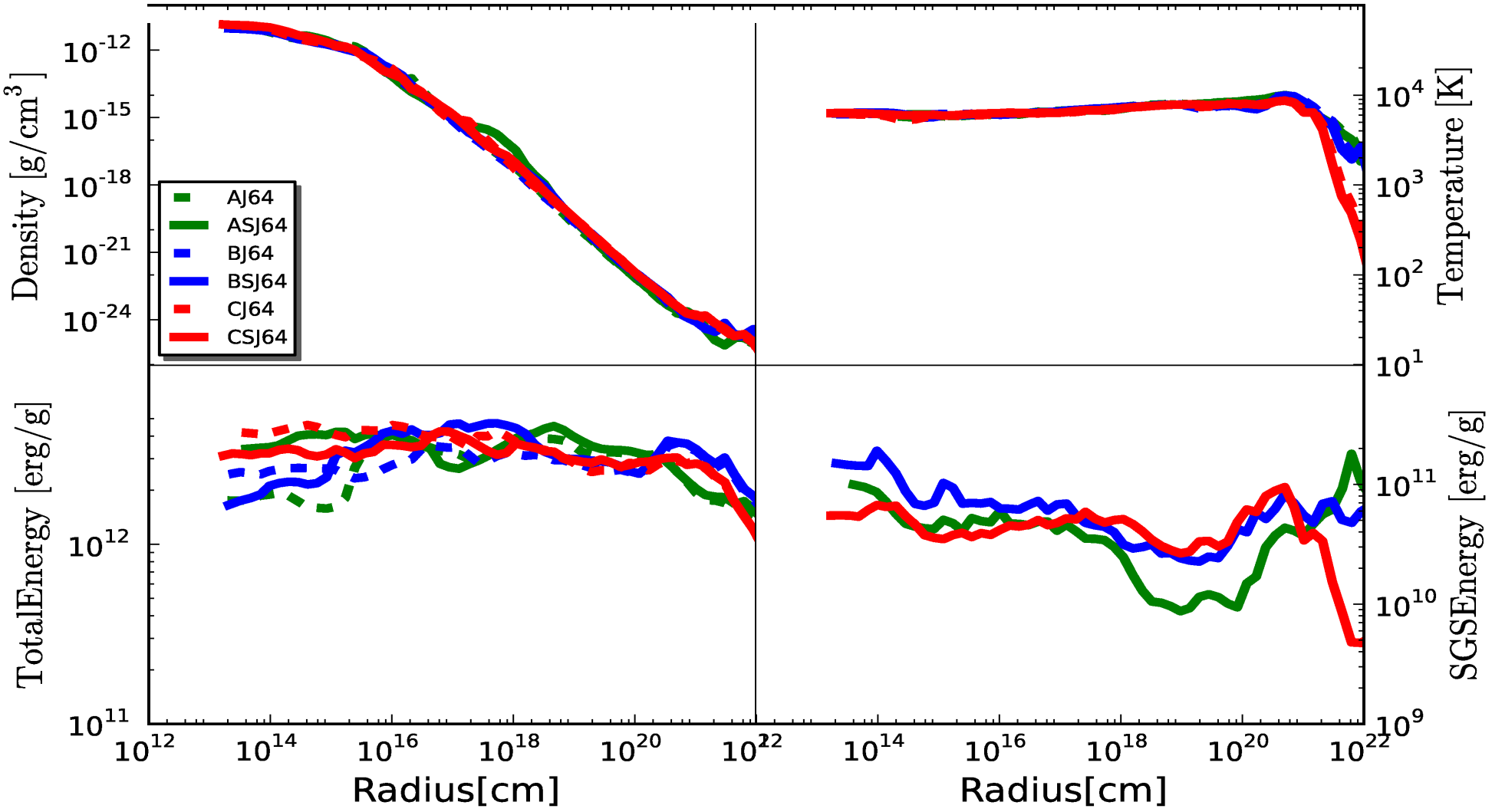
Density Projections

No SGS

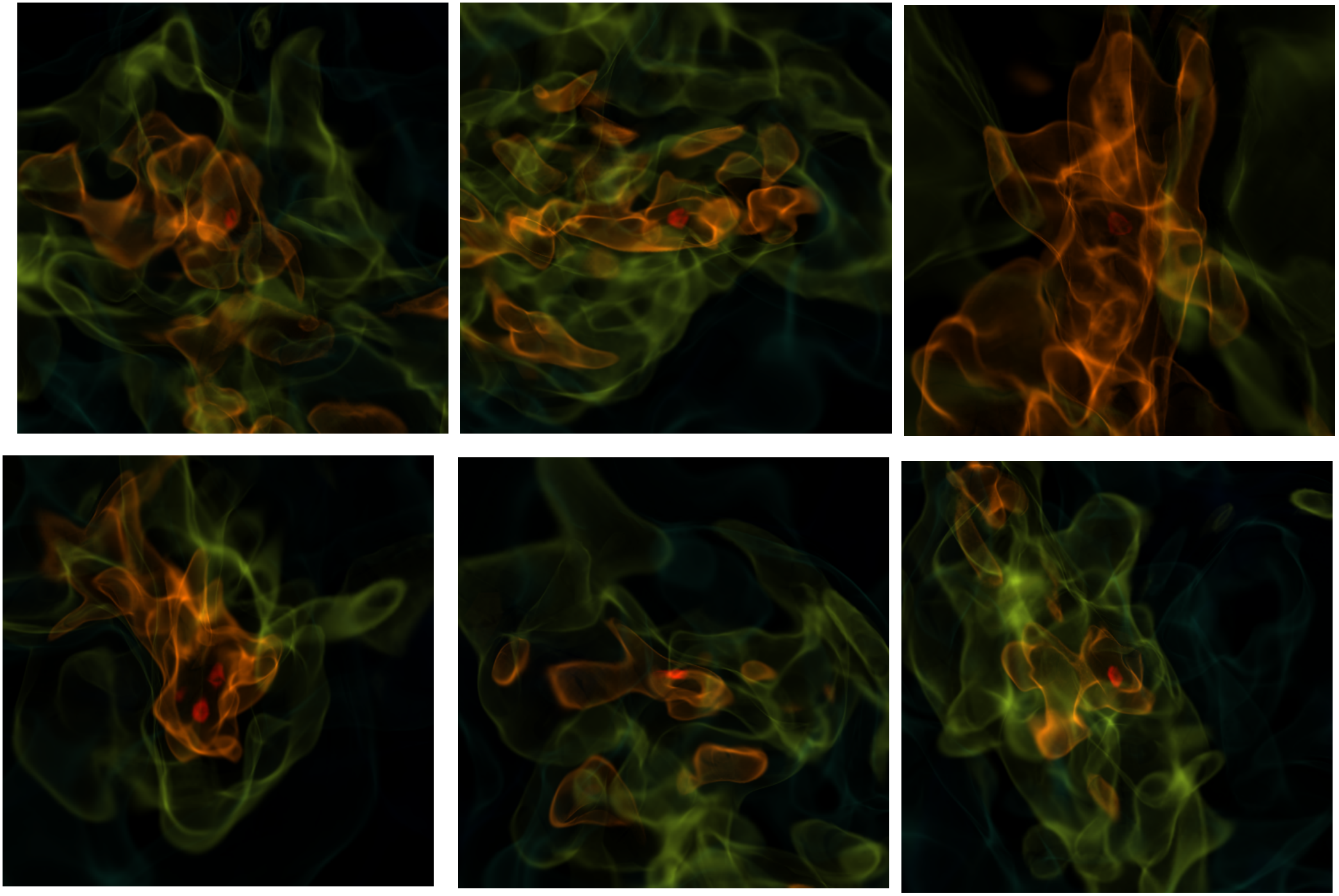


SGS

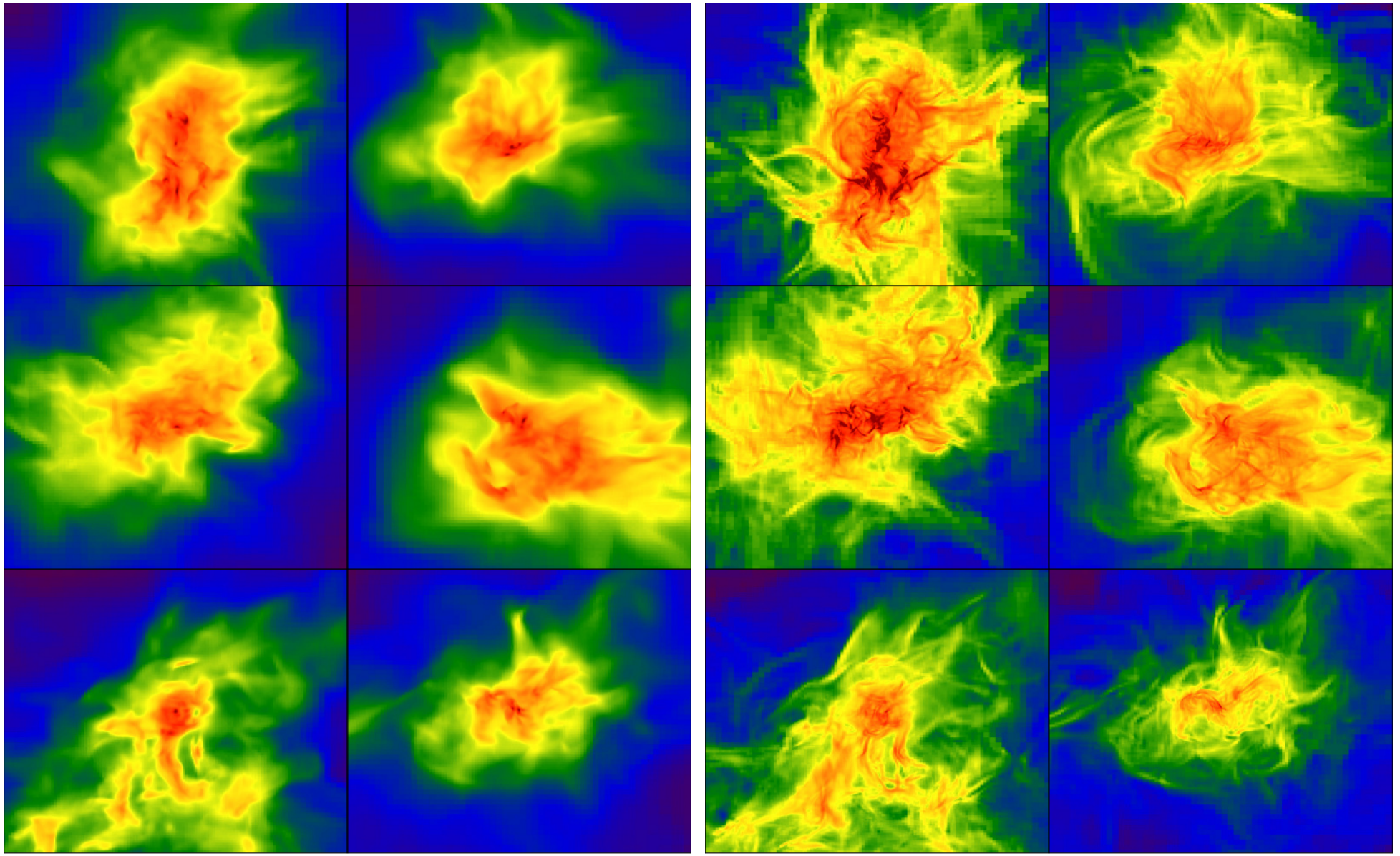
Comparison of different haloes



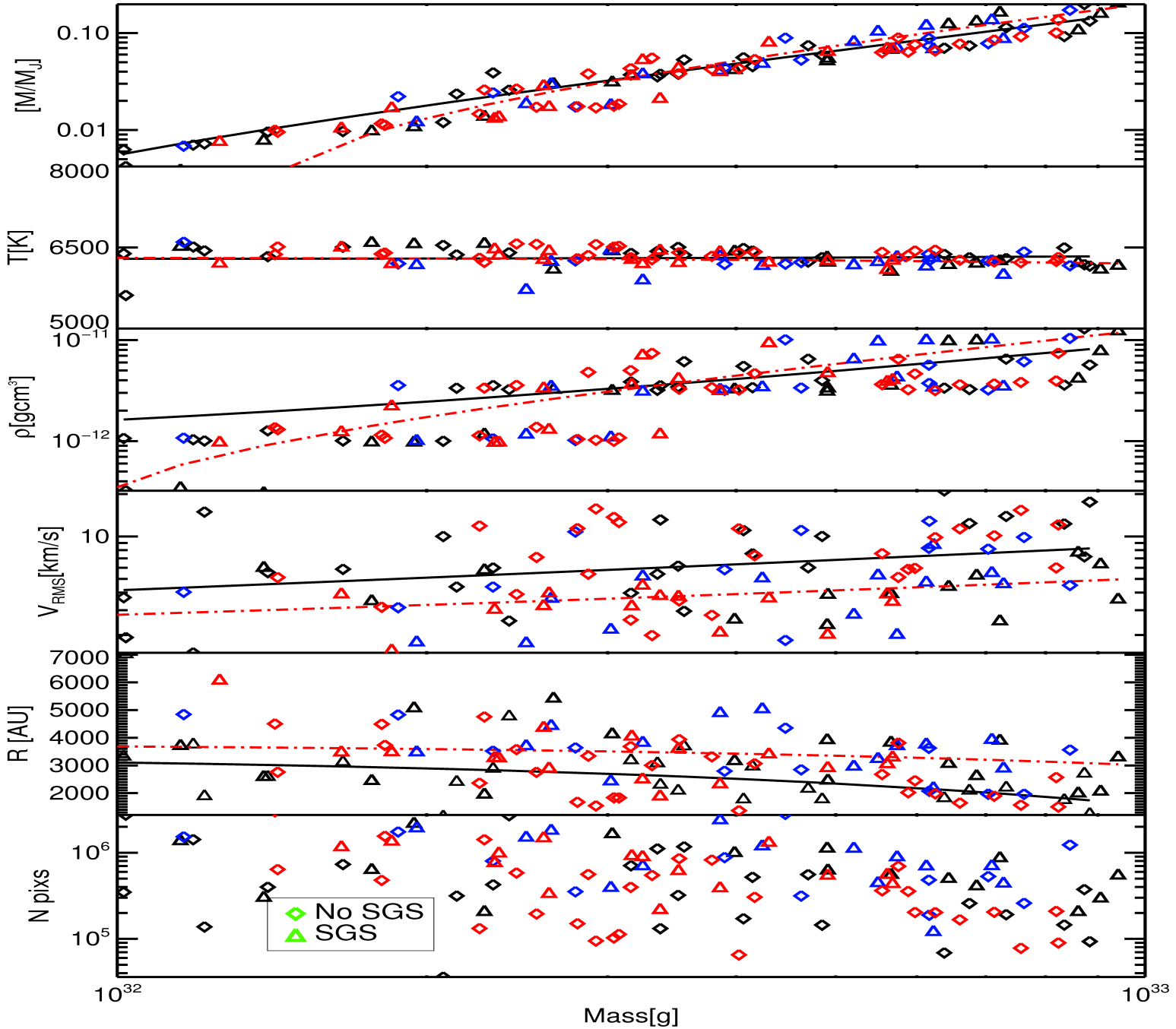
State of the simulations at collapse redshift



Vorticity


10^{-14} 10^{-13} 10^{-12}
Density (g cm^{-3})
10^{-14} 10^{-13} 10^{-12}
Density (g cm^{-3})
10^{-18} 10^{-17} 10^{-16}
VorticitySquared [cm^{-2}]
10^{-18} 10^{-17}
VorticitySquared [cm^{-2}]

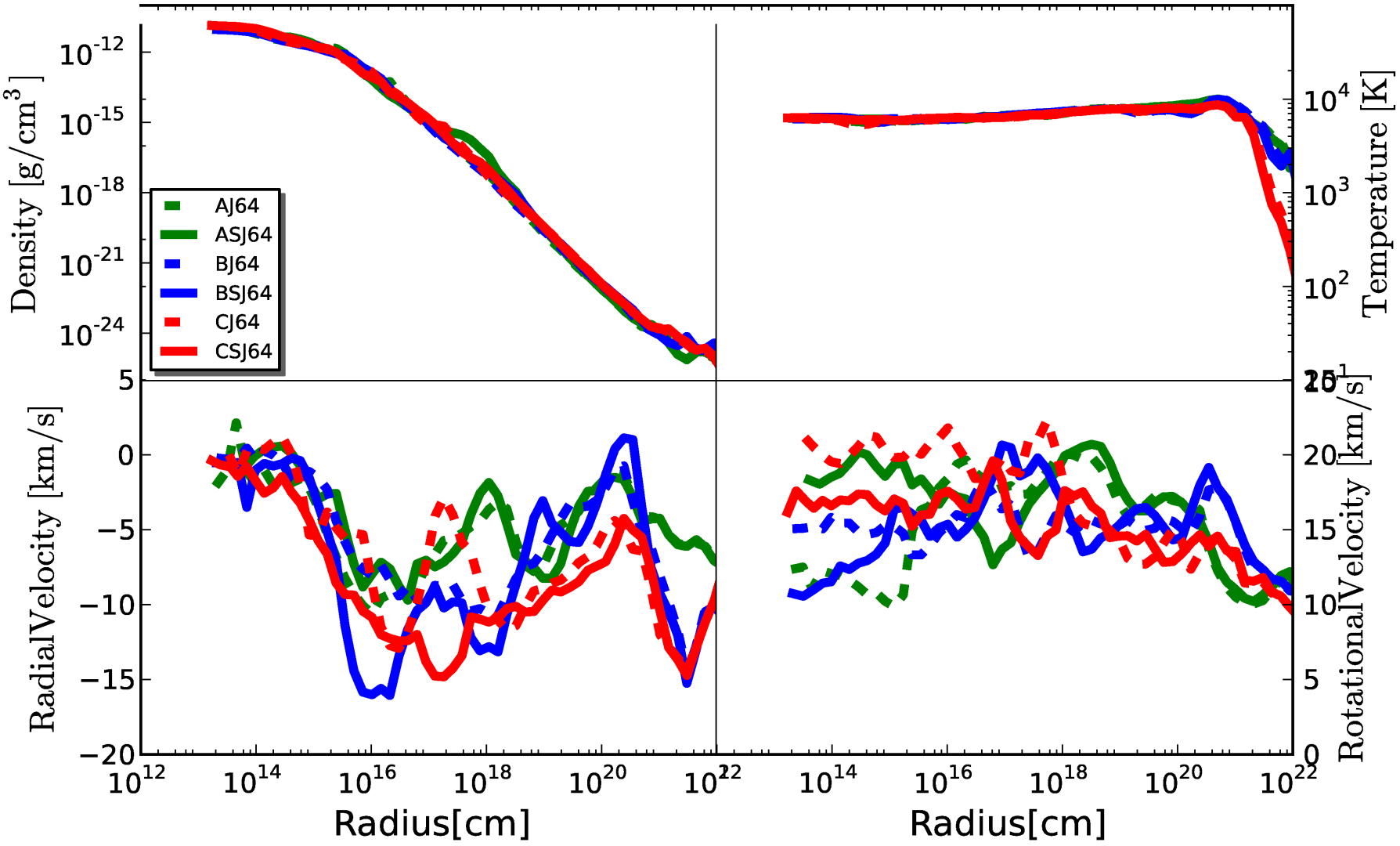
Properties of the clumps



Summary

- Gas in halos with $T_{vir} \geq 10^4$ K collapses almost isothermally in the presence of a constant UV field of strength 10^3 .
- Atomic cooling haloes become highly turbulent down to 100 AU scales provided that the Jeans length is resolved by ≥ 32 cells.
- Taking into account the unresolved SGS turbulence significantly influences the morphology of the halo.
- Clumps are generally more massive and dense in the presence of SGS turbulence compared to their counterparts.
- Morphology varies for different resolutions but average halo profiles roughly agree with each other.
- Halos with $T_{vir} \geq 10^4$ K are the potential site for the formation of SMBHS.

Extras


Density [g/cm^3]
10^{-12}
10^{-15}
10^{-18}
10^{-21}
10^{-24}
AJ64
ASJ64
BJ64
BSJ64
CJ64
CSJ64
Temperature [K]
10^4
10^3
10^2
RadialVelocity [km/s]
5
0
−5
−10
−15
−20
RotationalVelocity [km/s]
25
20
15
10
5
0
10^{12}
10^{14}
10^{16}
10^{18}
10^{20}
10^{22}
Radius[cm]
Radius[cm]