# RHAPSODY-G and MUSIC 2.0

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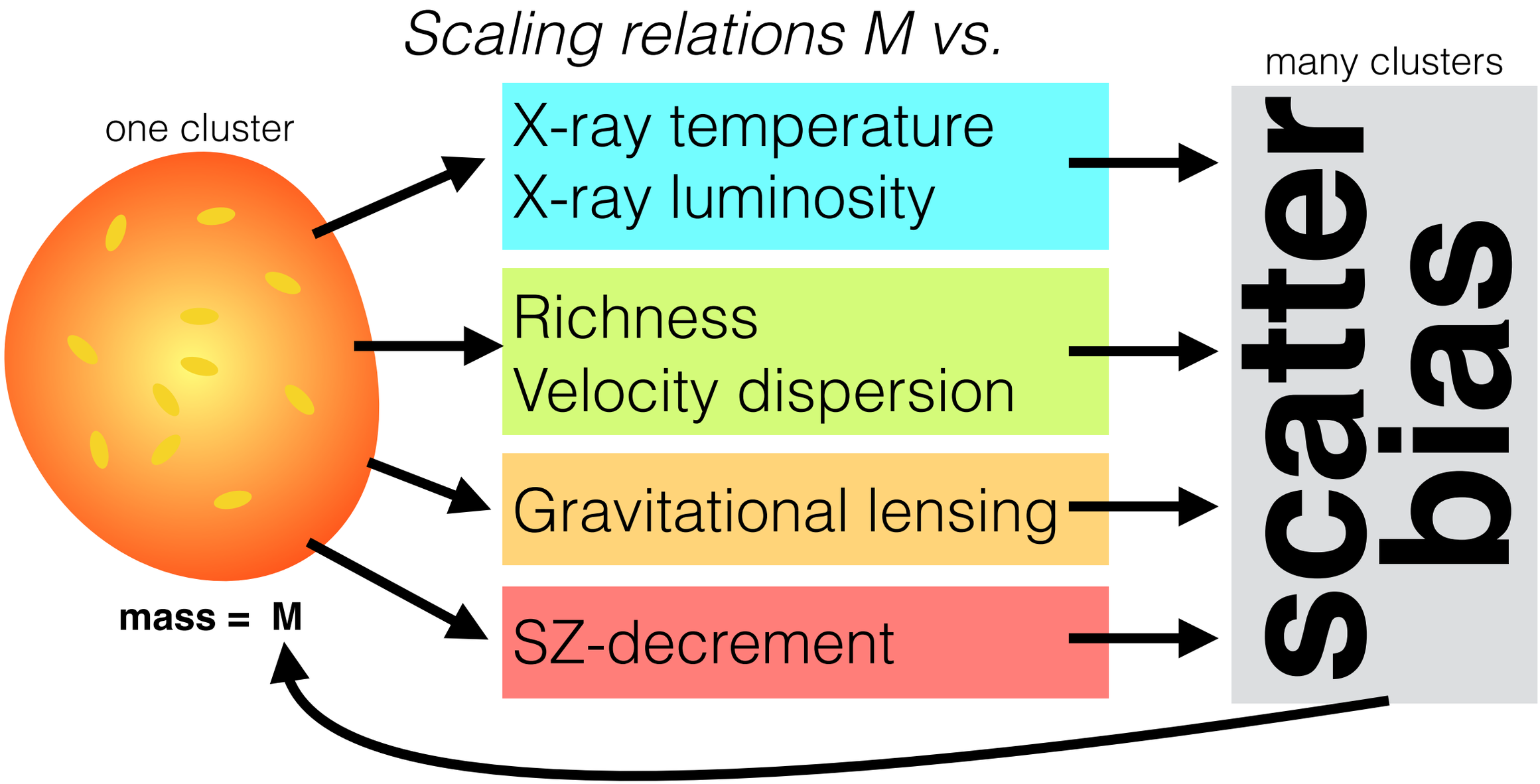
# Simulations for cluster cosmology



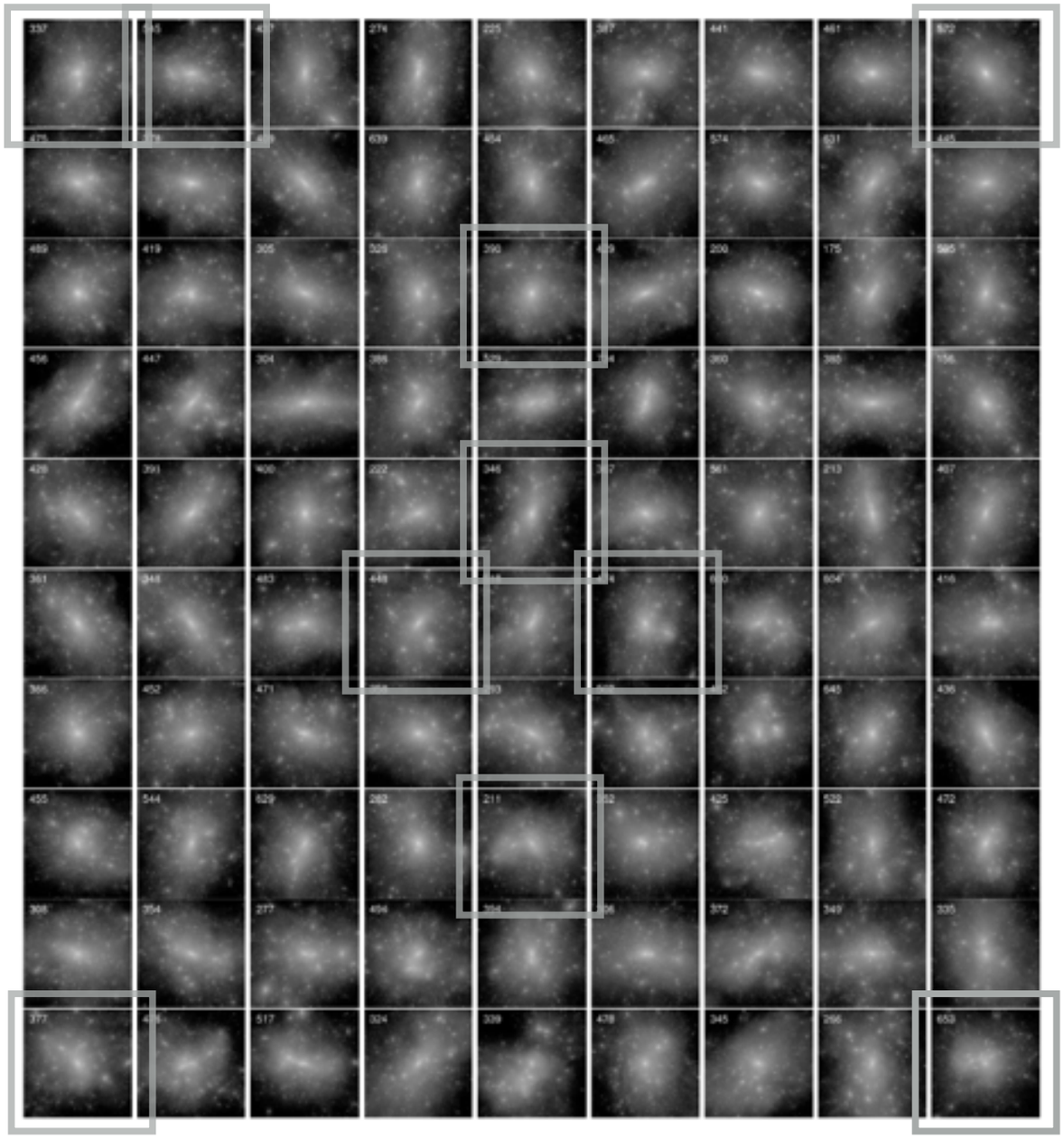

**Goal 1: use simulations to understand relation between proxies, mass and other properties!**

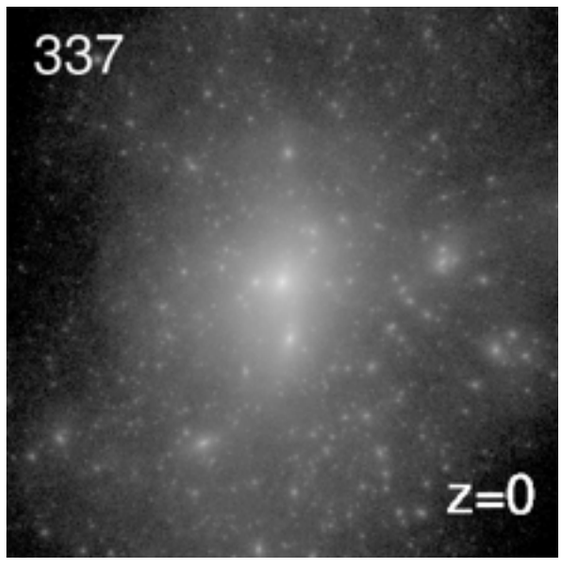
**Goal 2: learn about galaxy formation and ICM physics**

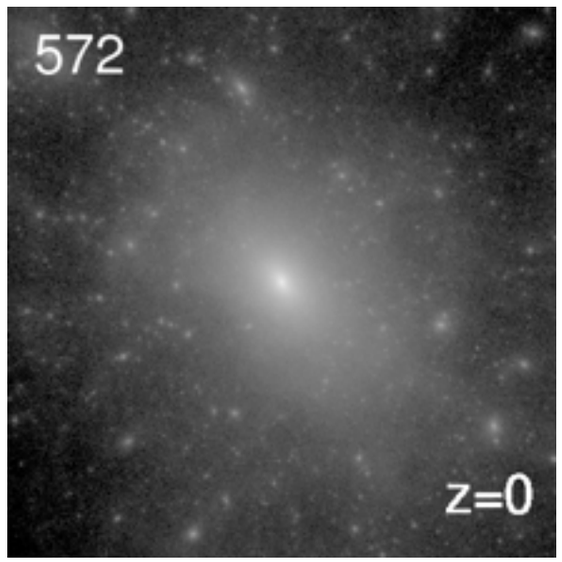
# The RHAPSODY simulation suite - difference at fixed M

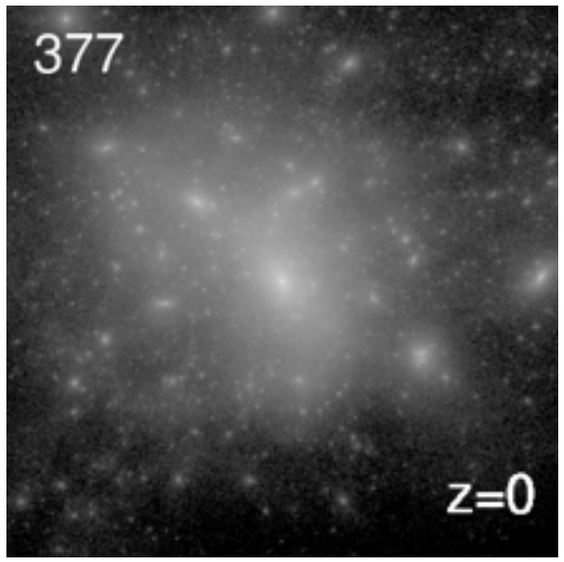
100 high-res N-body simulations of massive clusters
all of the same mass$10^{15}$ $M_\odot$ at z=0
from as big as possible box

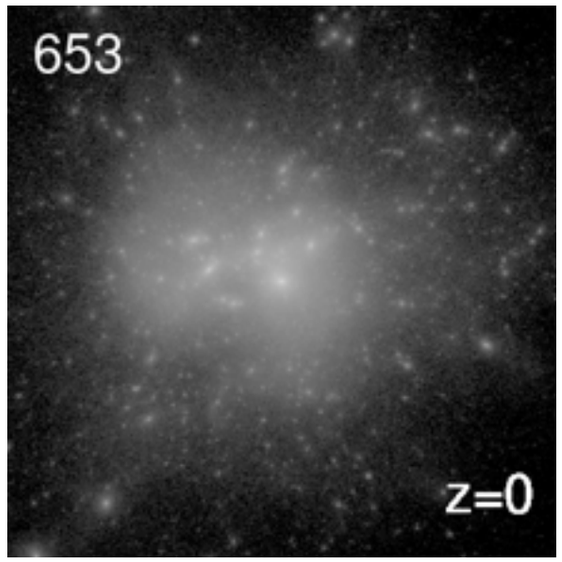
Wu+(2012a,b)





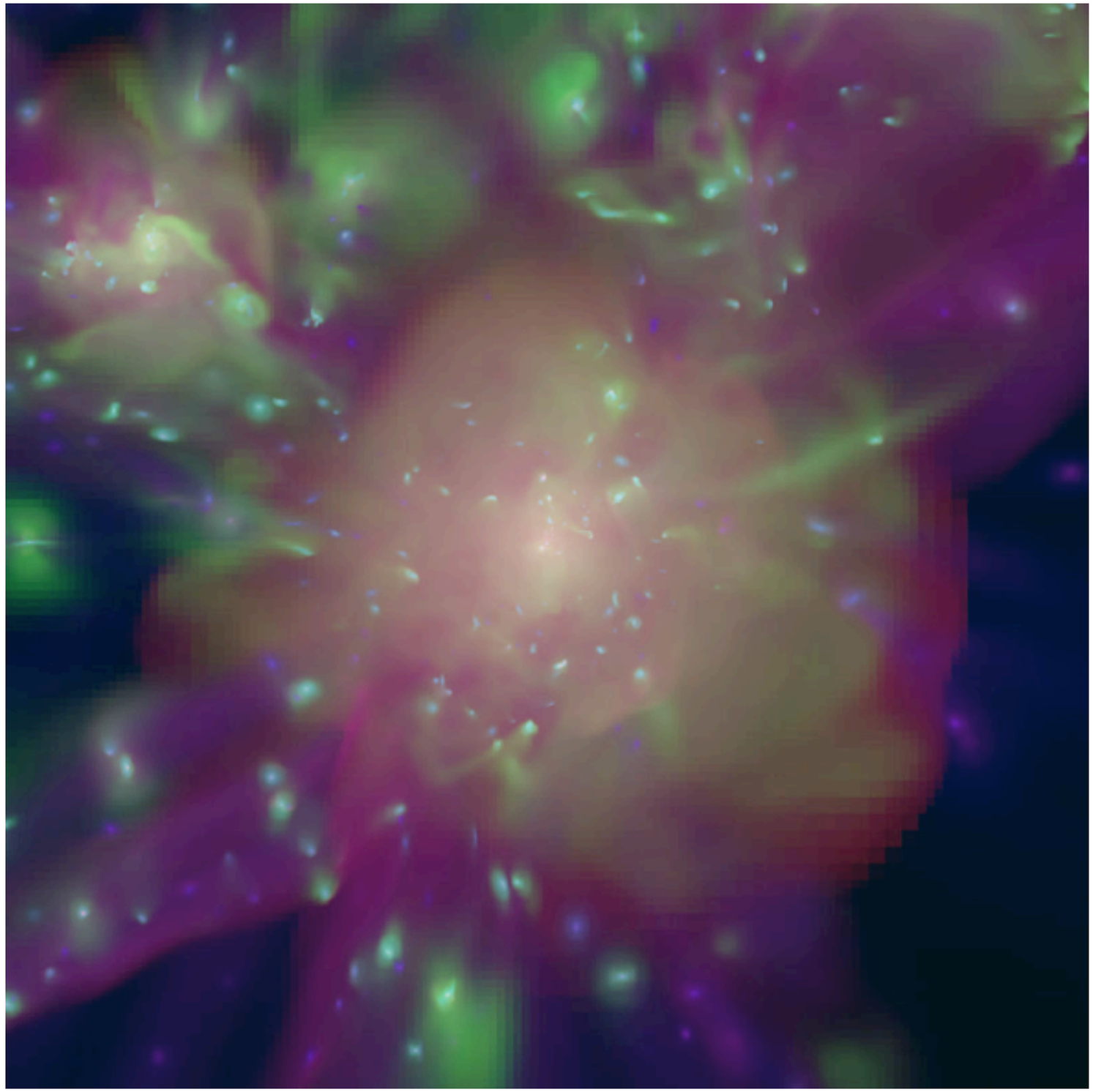




**At fixed mass, large differences in assembly history, profile, number of massive substructure …**

# The RHAPSODY-G simulations

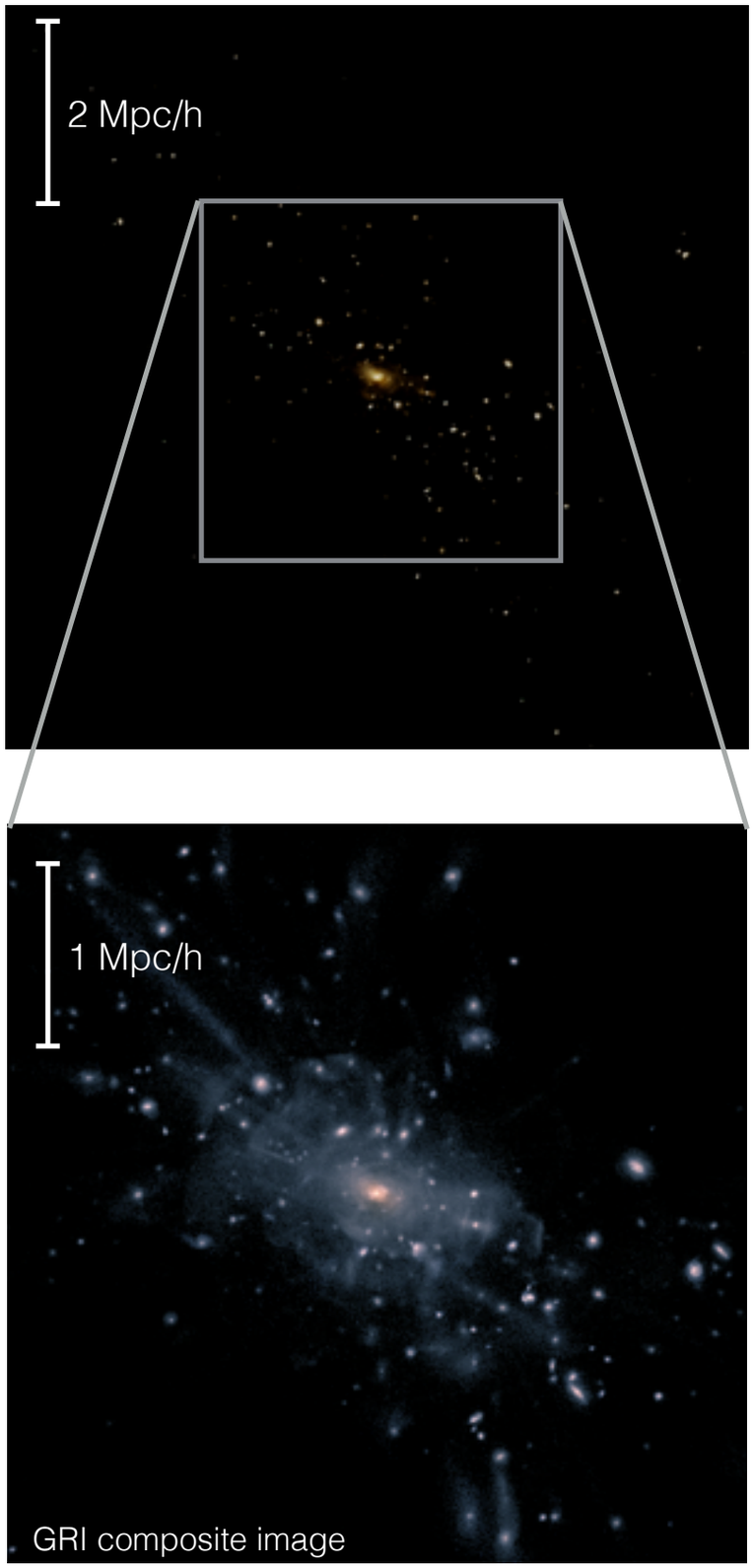


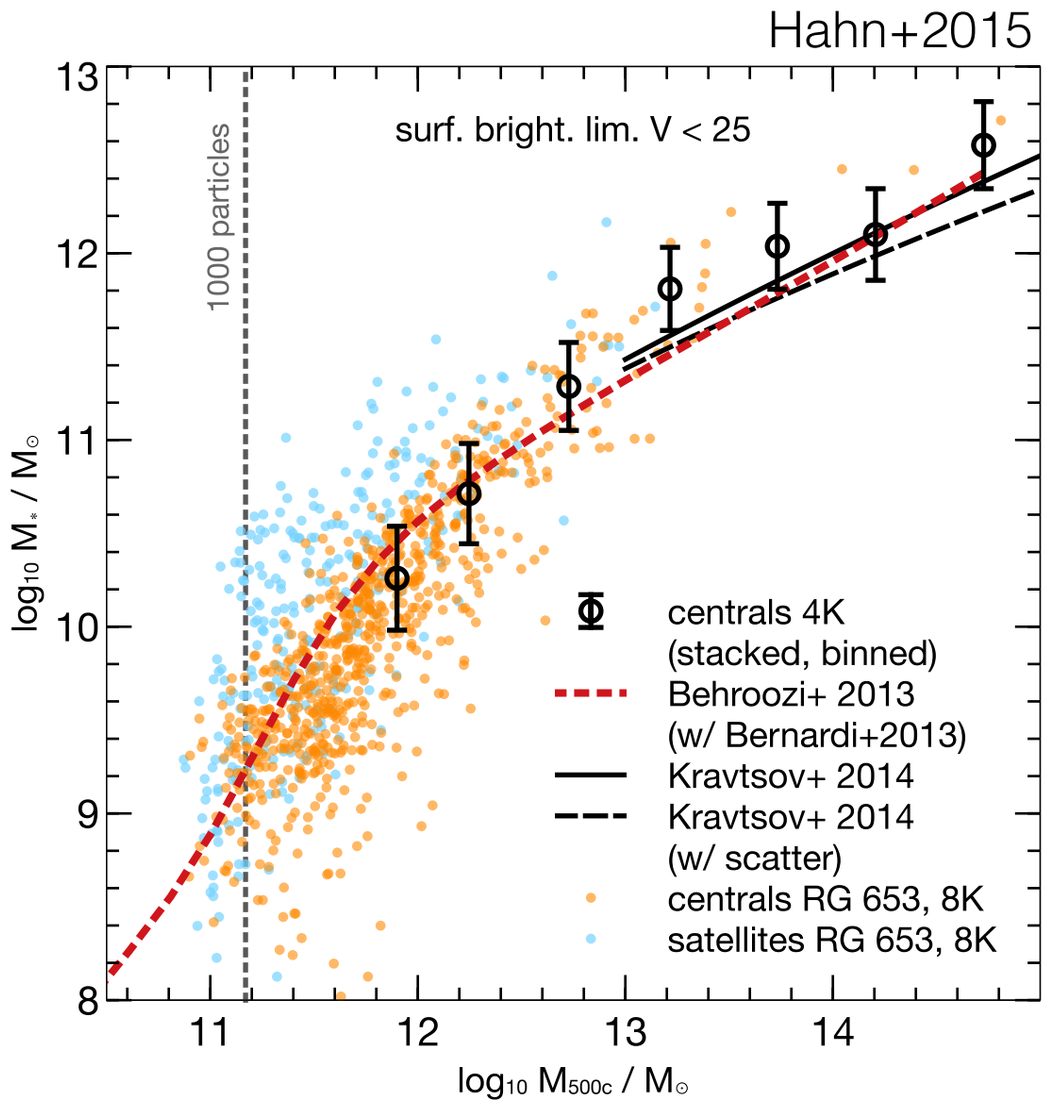
- 8 Mpc/h region around cluster
- 3.8 kpc/h (lowres)
  1.9 kpc/h (hires runs)
- star formation
- SN feedback
  (Dubois&Teyssier 2008)
- AGN feedback
  (Booth&Schaye 2009,
  but implemented as Martizzi+ 2015)
- metal enrichment and metal cooling
- analysis with Rockstar-galaxies

# The RHAPSODY-G simulations

gas density and temperature evolution

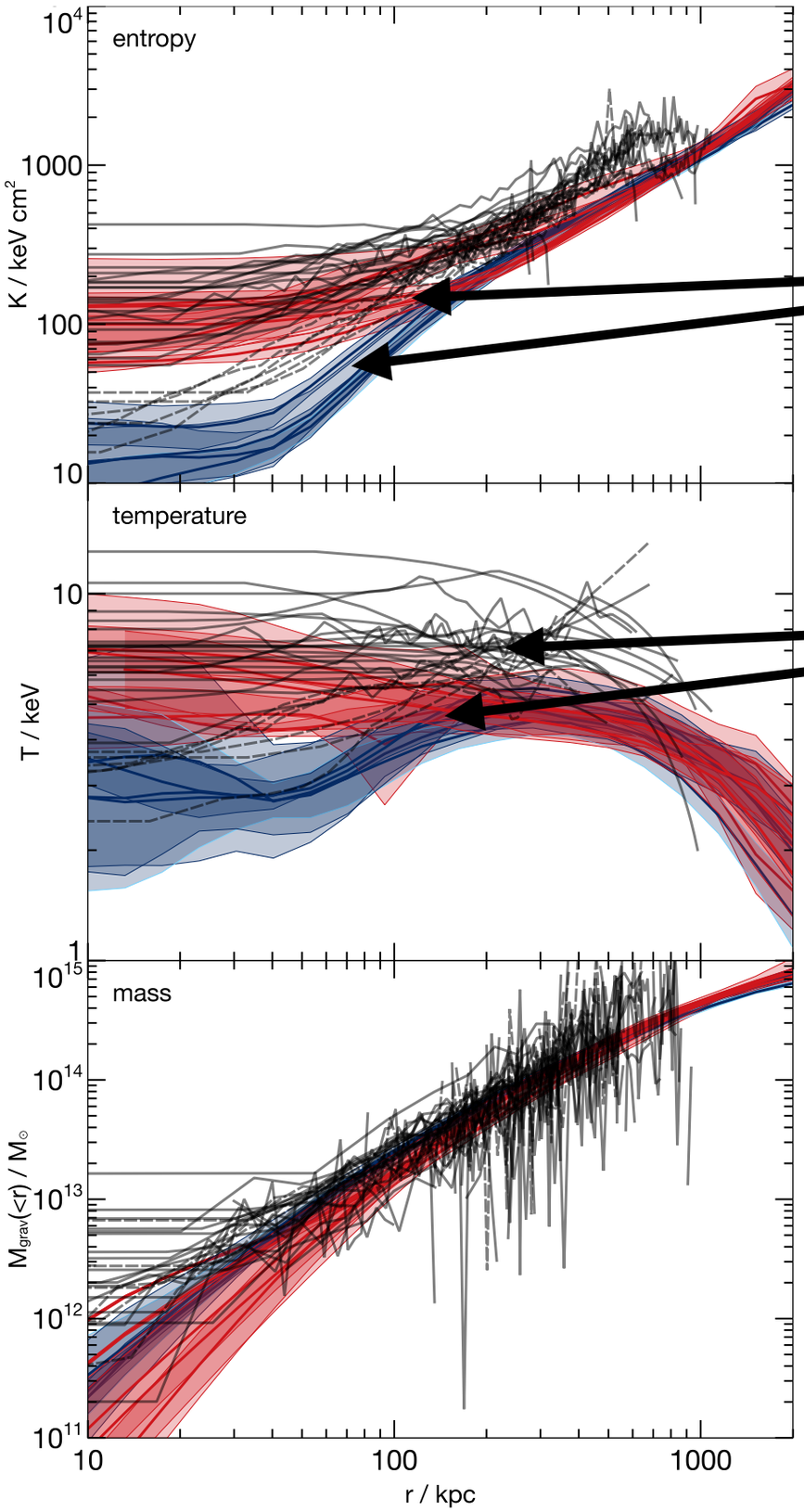

# Reproducing (realistic) galaxies




Ratio of galaxy stellar mass to total mass (including DM) is a sensitive indicator if galaxy formation physics is ok

# The cool-core non-cool-core dichotomy




Like cluster X-ray observations, we find a dichotomy

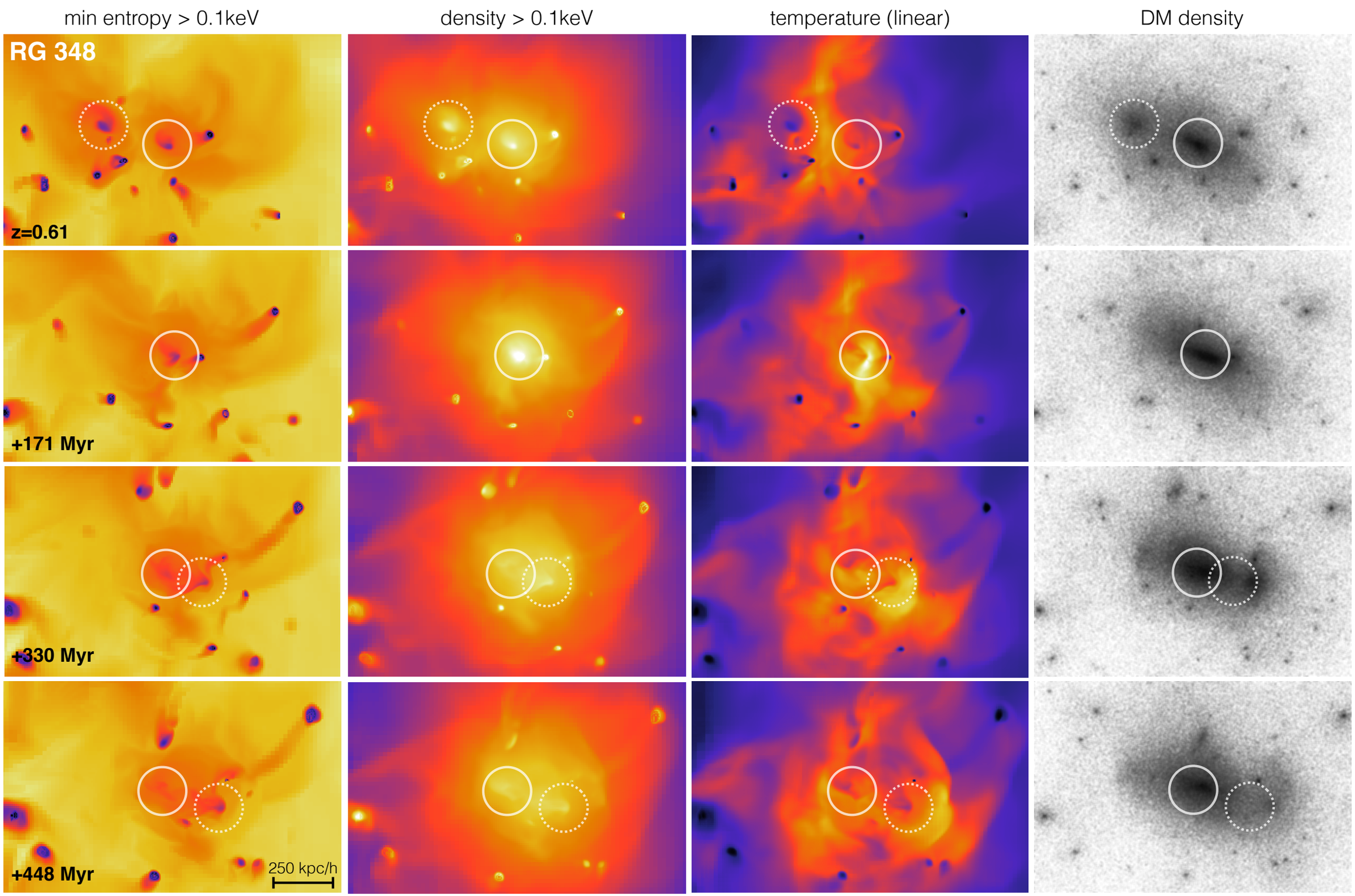
present also (weaker) in temperature

-> clusters too compact (see X-ray lum. later)

**still overcooling, despite AGN, but we can explain the dichotomy of clusters**

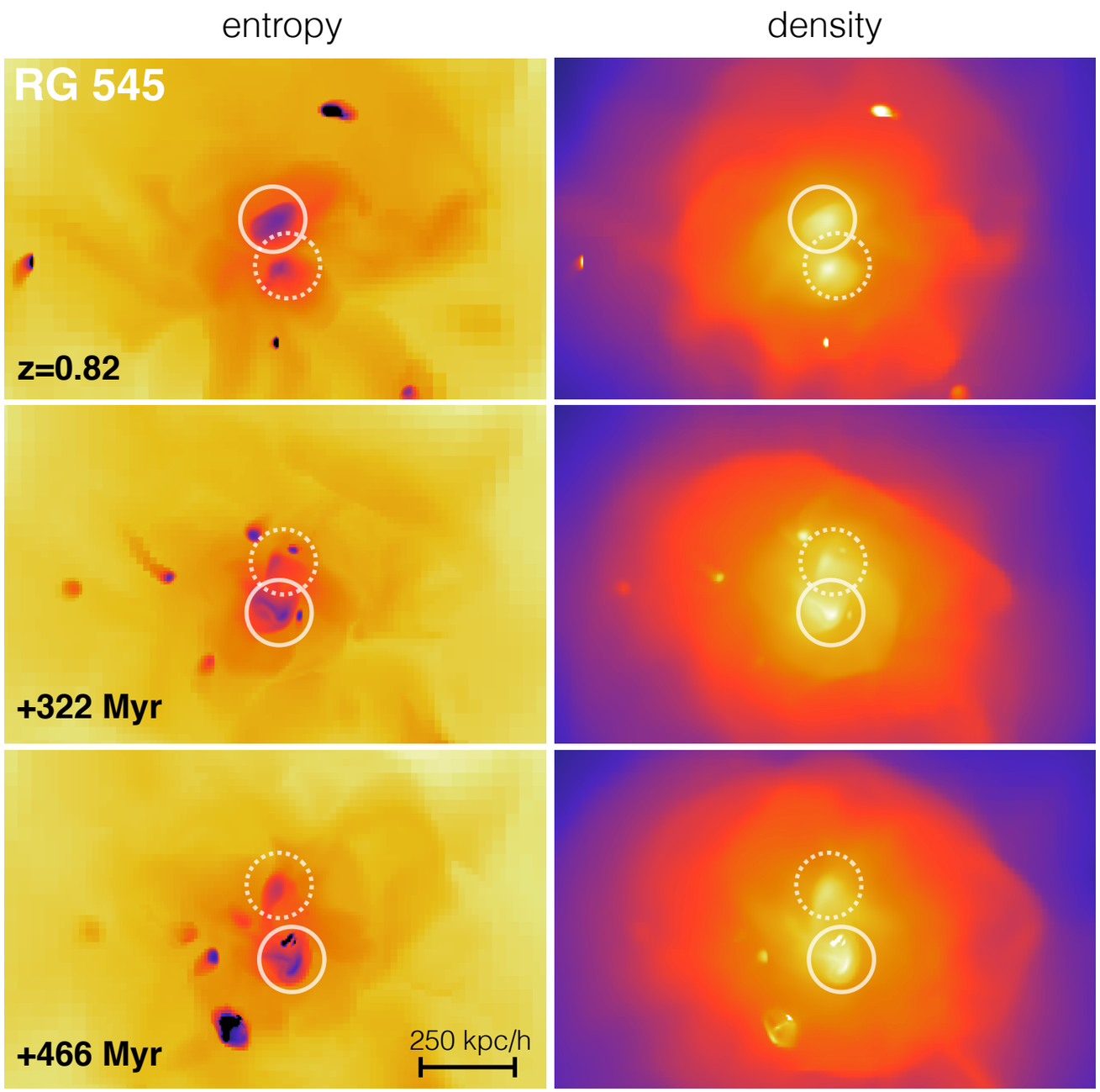
Hahn+2015
obs. data ACCEPT
Cavagnolo+2009

# The destruction of cool cores by mergers

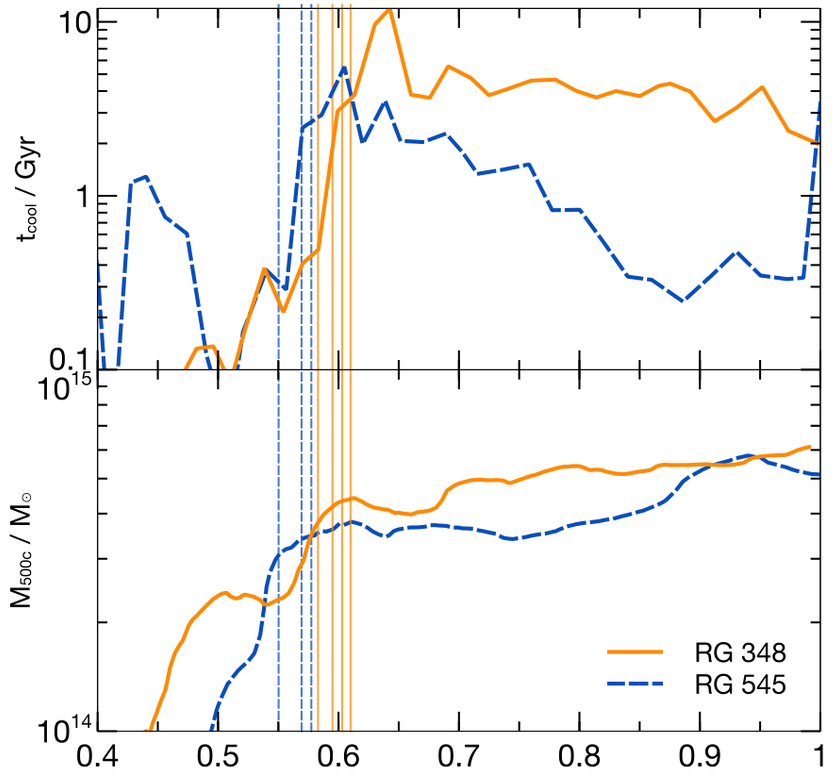


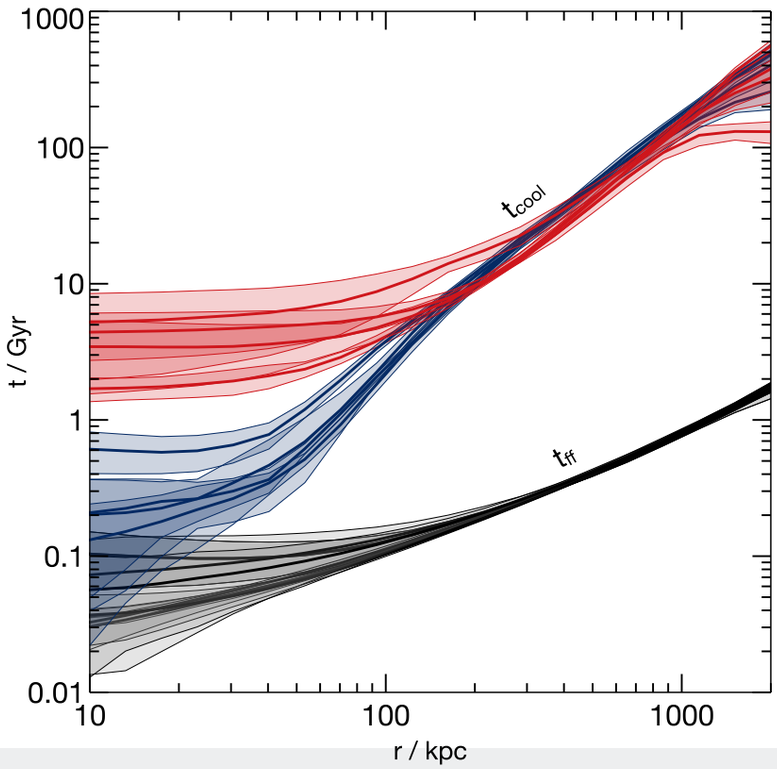

Hahn+2015

# The survival of cool cores in some mergers




Hahn+2015



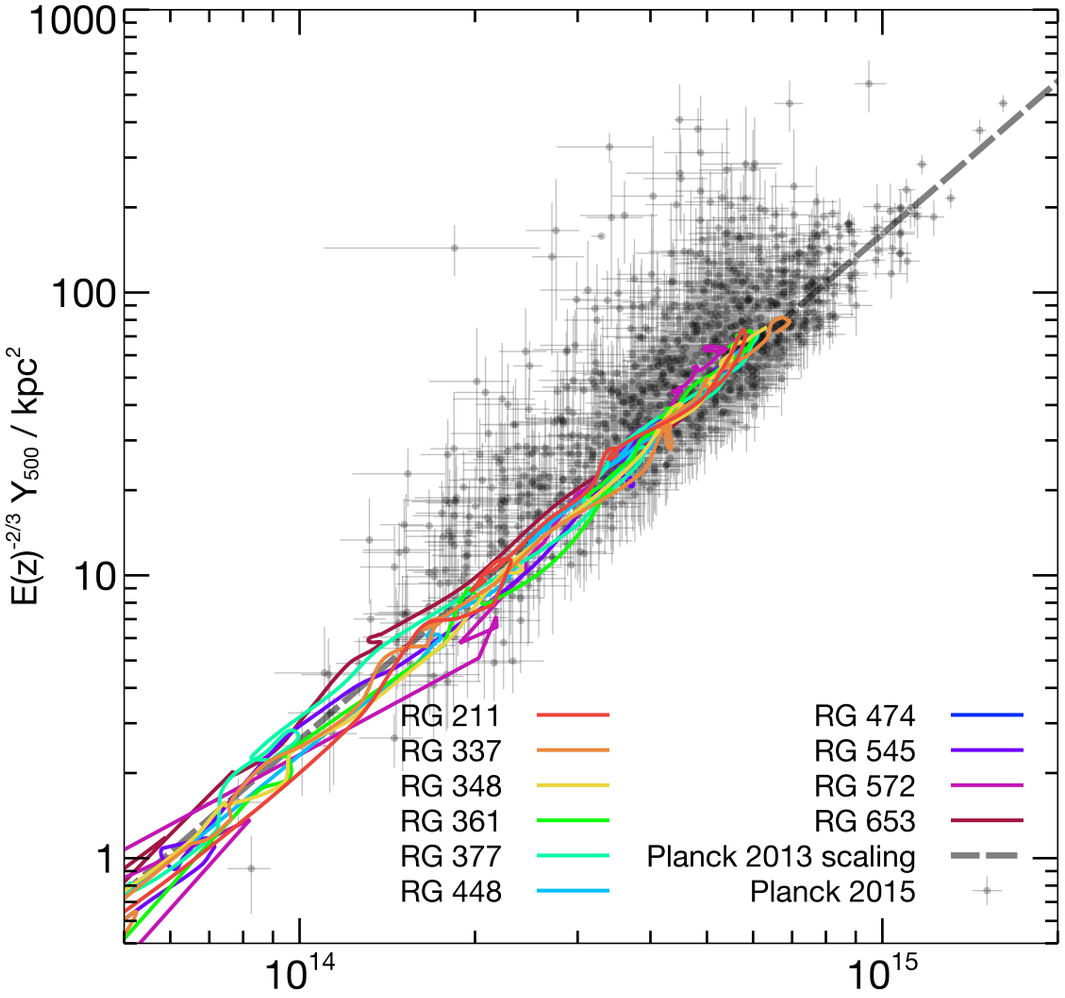




**Head on mergers can destroy cores, others not**

(cf. also Poole+2008, Burns+2008)

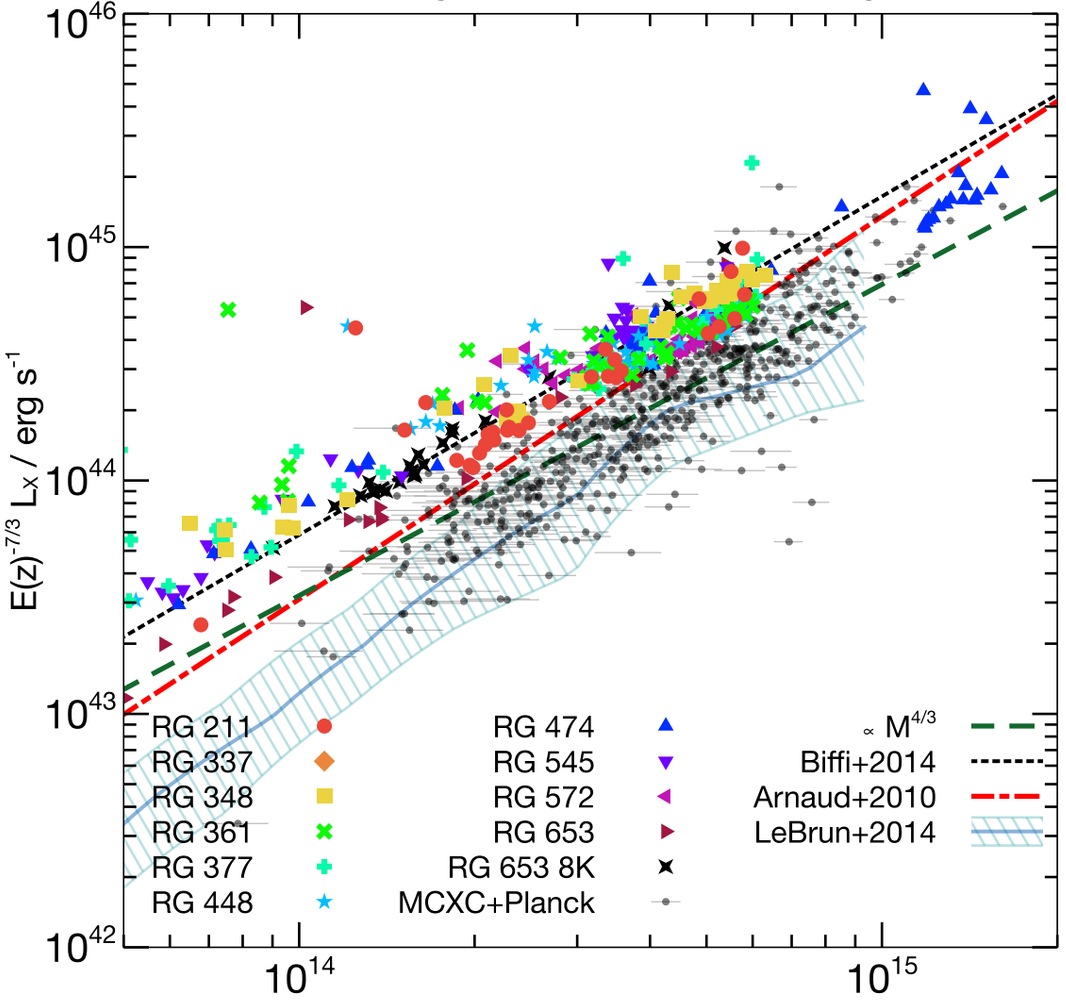
# Some scaling relations

SZ




Hahn+2015

X-ray luminosity

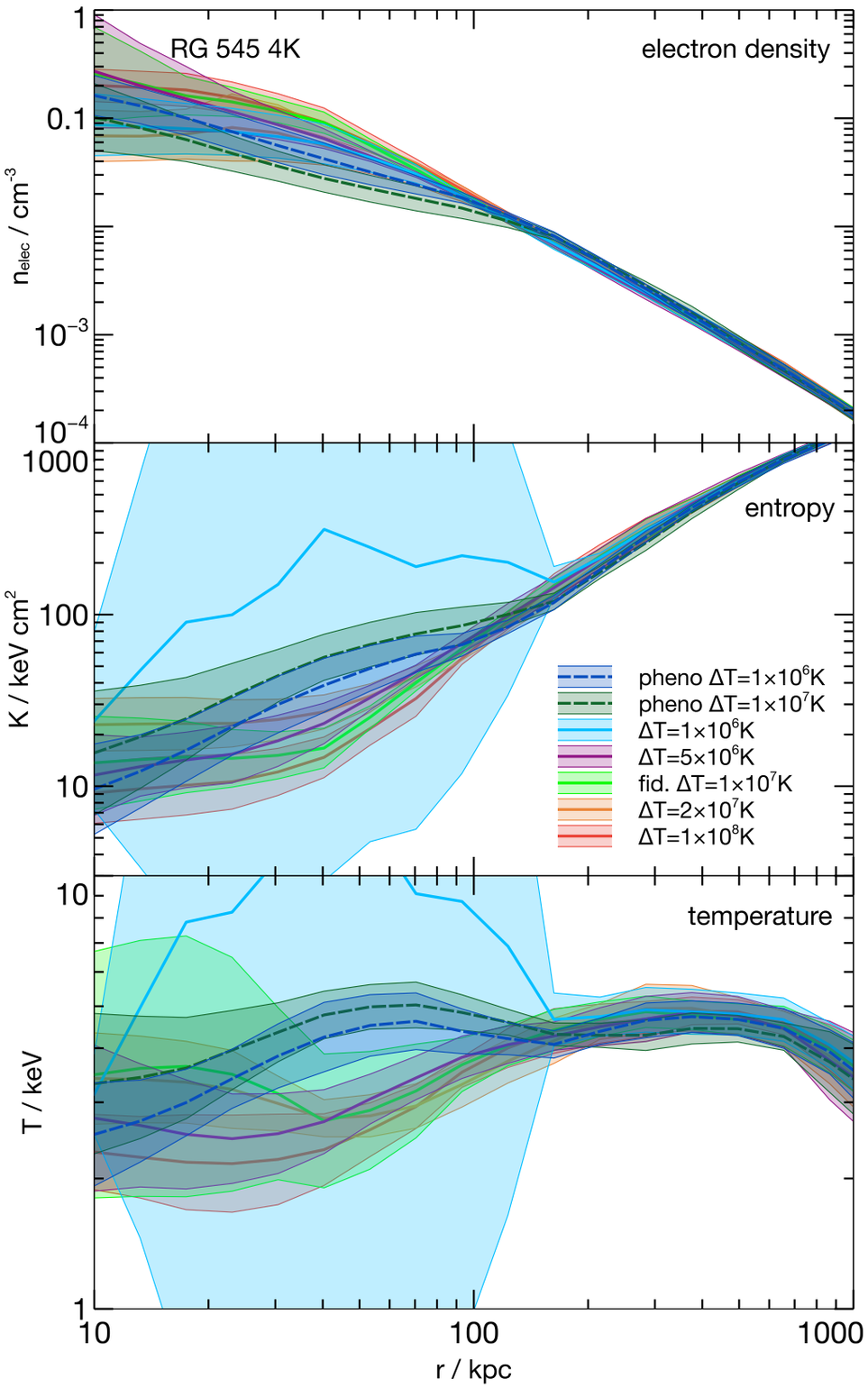


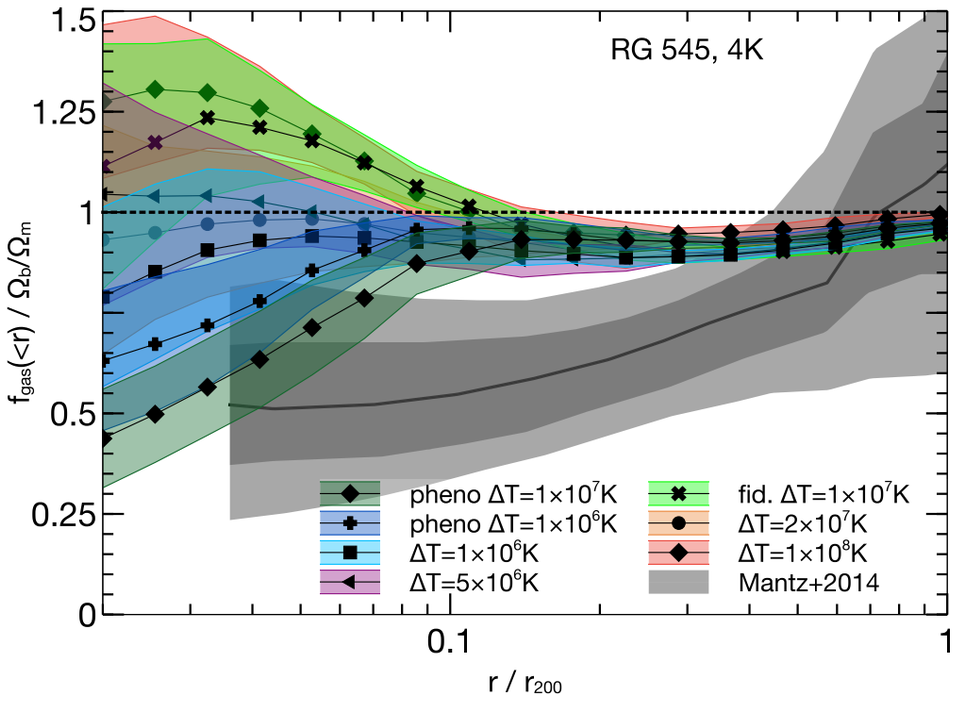

**too X-ray bright (and somewhat too cold)**

*solution*: likely refined black hole feedback, or additional physics (conduction)…

unclear: same AGN feedback works in Gadget (see LeBrun+2014)

# Biggest Problem is AGN feedback

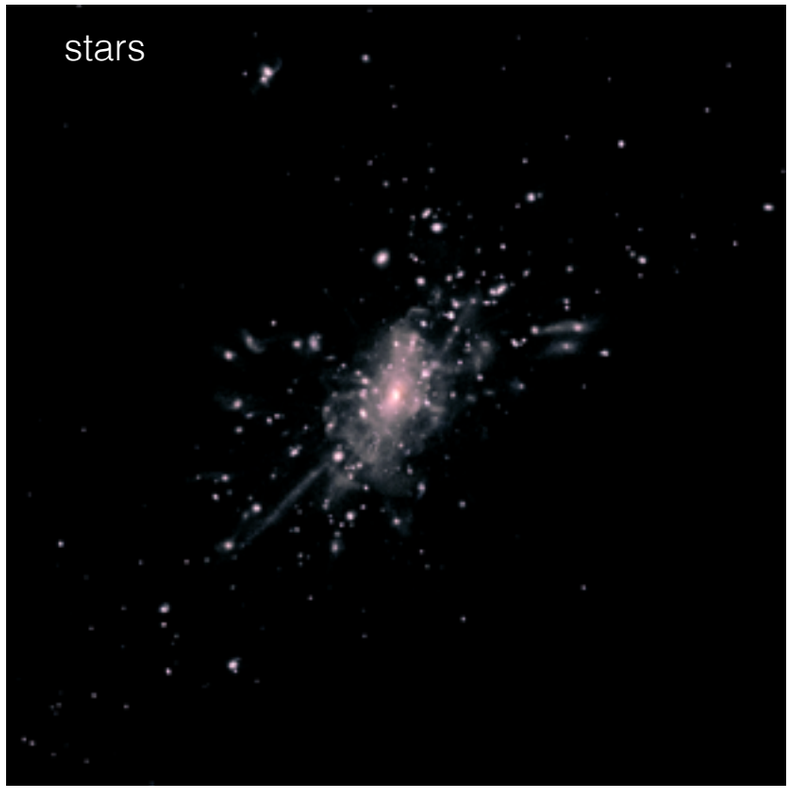


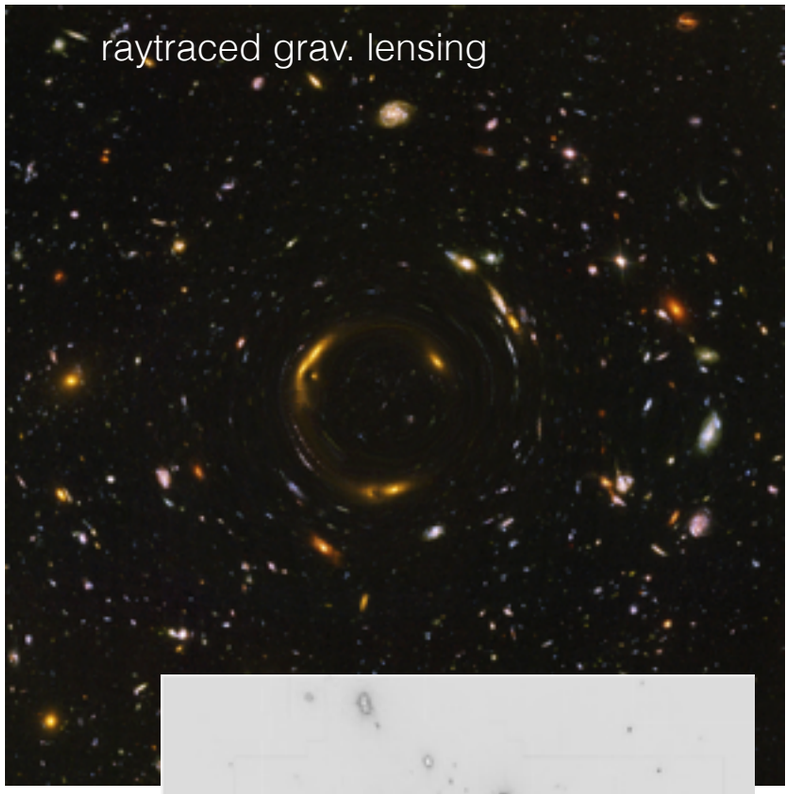

Booth&Schaye model doesn't seem to work in RAMSES

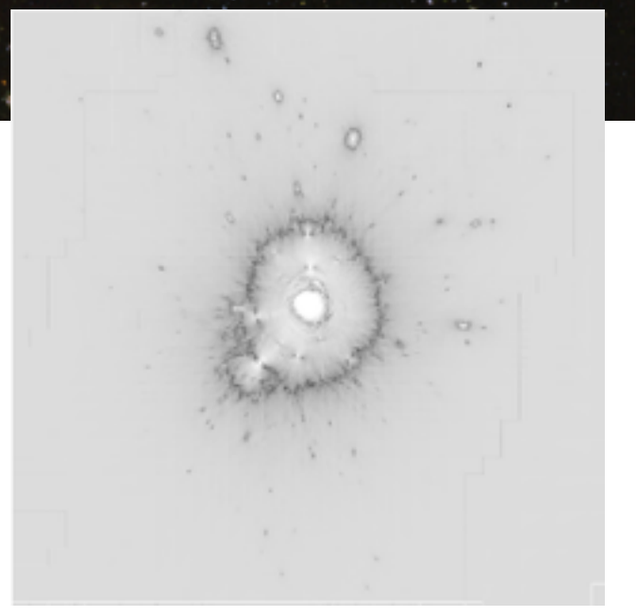
new AGNs…work in progress w/ Pawel Biernacki, kinetic feedback helps, also seeding matters…

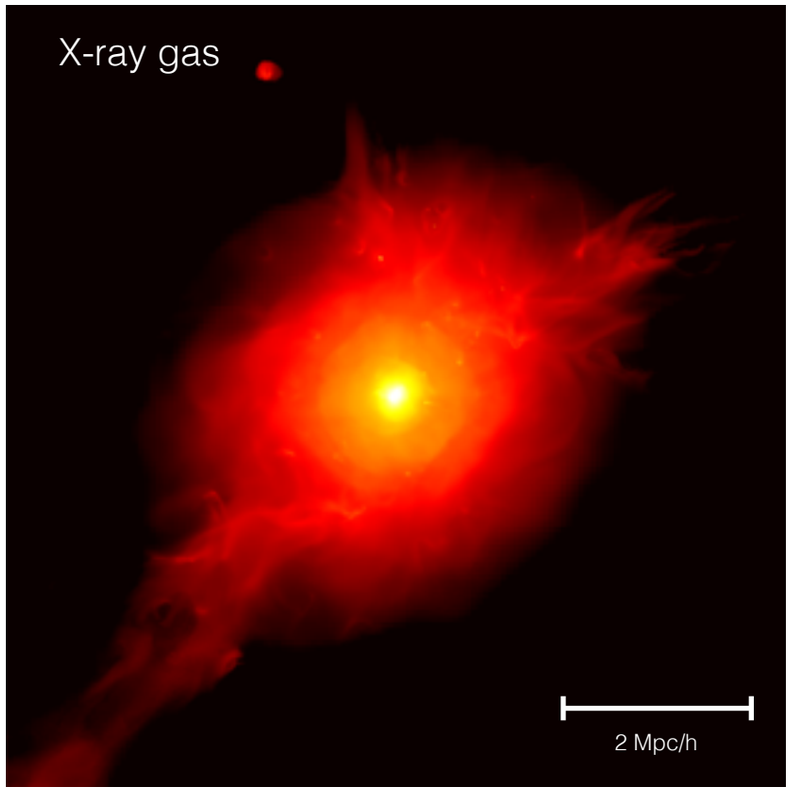
# Towards mock observation pipelines for clusters…




+crude color/luminosities directly in rockstar

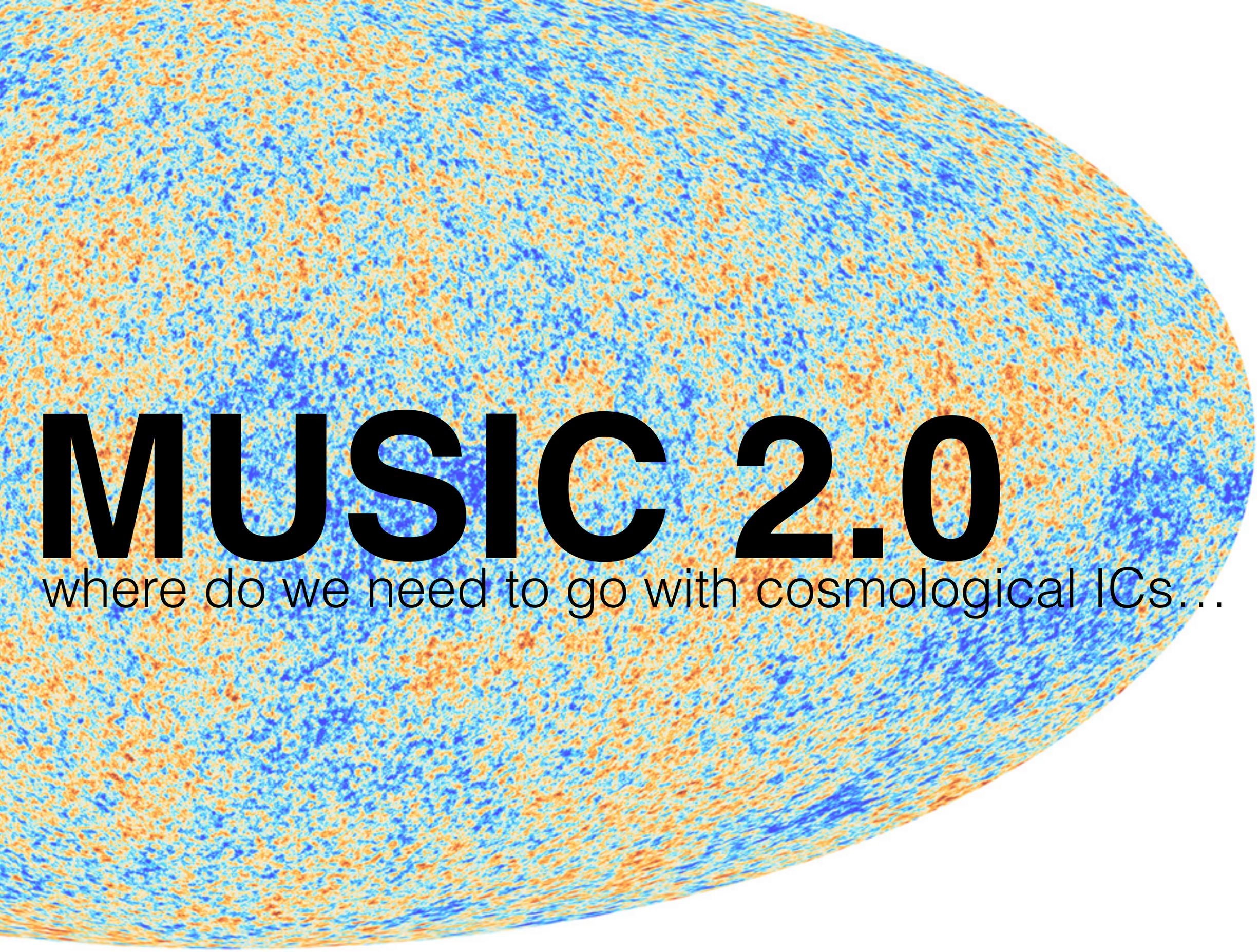




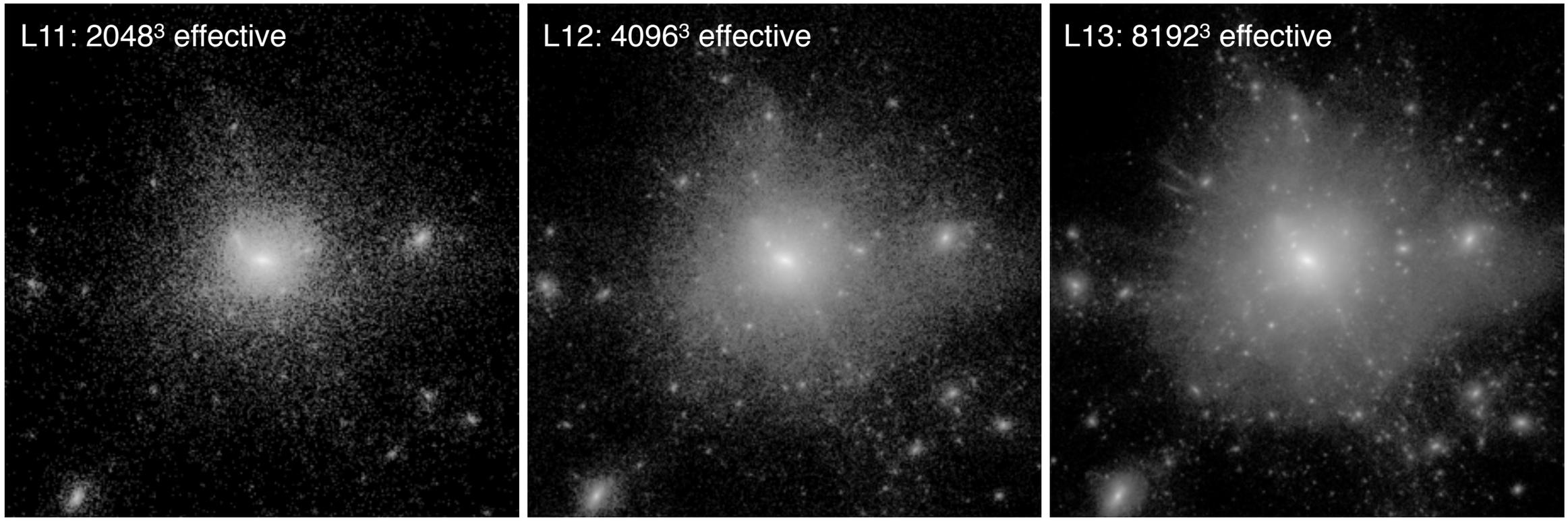

+SZ maps

Does it make sense to unify analysis tools in the RAMSES community?



# MUSIC 2.0

where do we need to go with cosmological ICs…

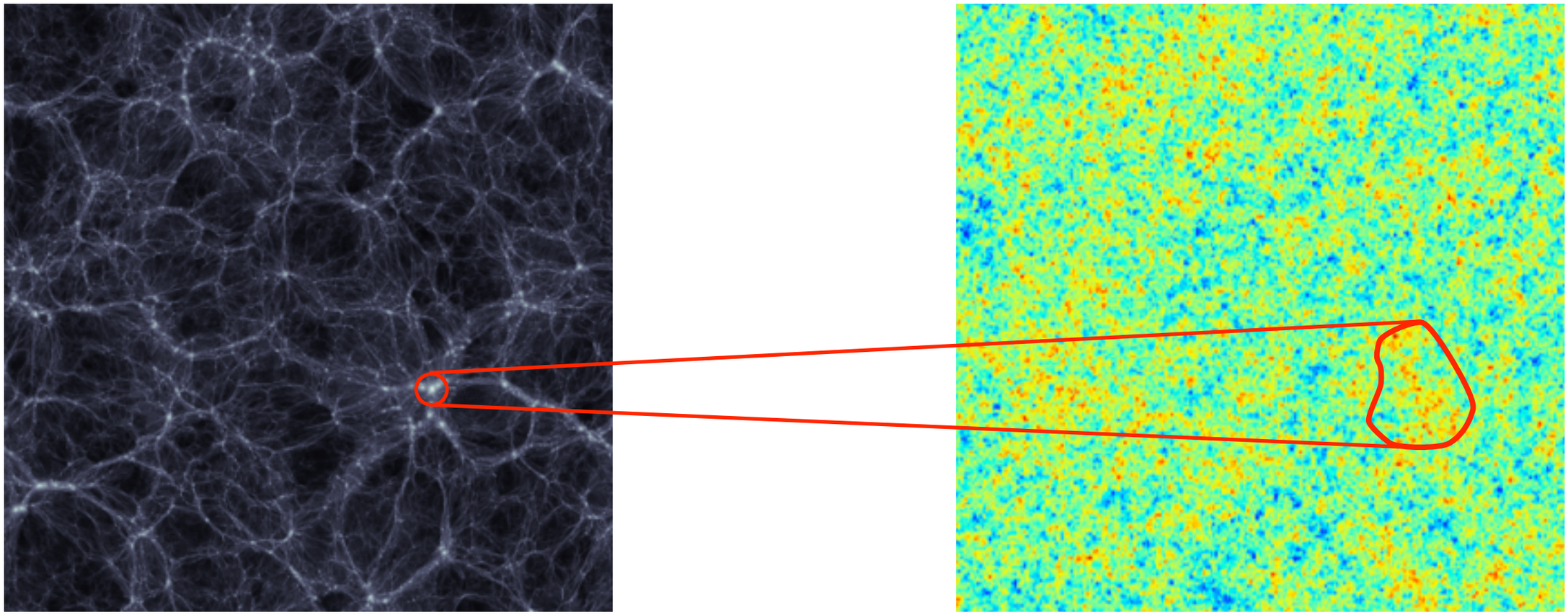



AGORA 1e11 halo (Kim et al. 2013)

# Current Status

- very widely adopted in the community for zooms
- virtually all codes supported now
- modular structure for transfer functions and I/O
- 2nd order PT, standard cosmologies,…
- stable random number field

# Challenges ahead



- bigger simulations (larger volume, higher res)
- bigger samples (stat. samples of zooms?)
- more physics

## Where to move next

- MPI (for memory and speed)
- better random numbers (and also add PANPHASIA)

- more cosmology (B-fields, neutrinos?)
- more accurate baryon PT

- better community integration (database/cloud)
  [avoid everybody running their own boxes, selecting their own haloes for resim, -> towards SIMBAD for sims]
- quicker assembly of statistical samples (database)
- multiple zooms in one run?

## What do you miss? don't like? could imagine?