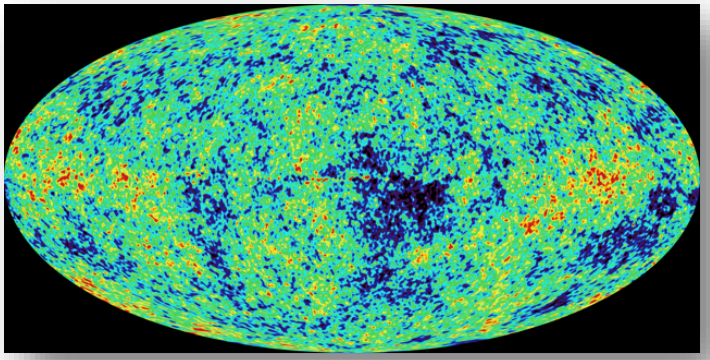
COSMOLOGICAL SIMULATIONS

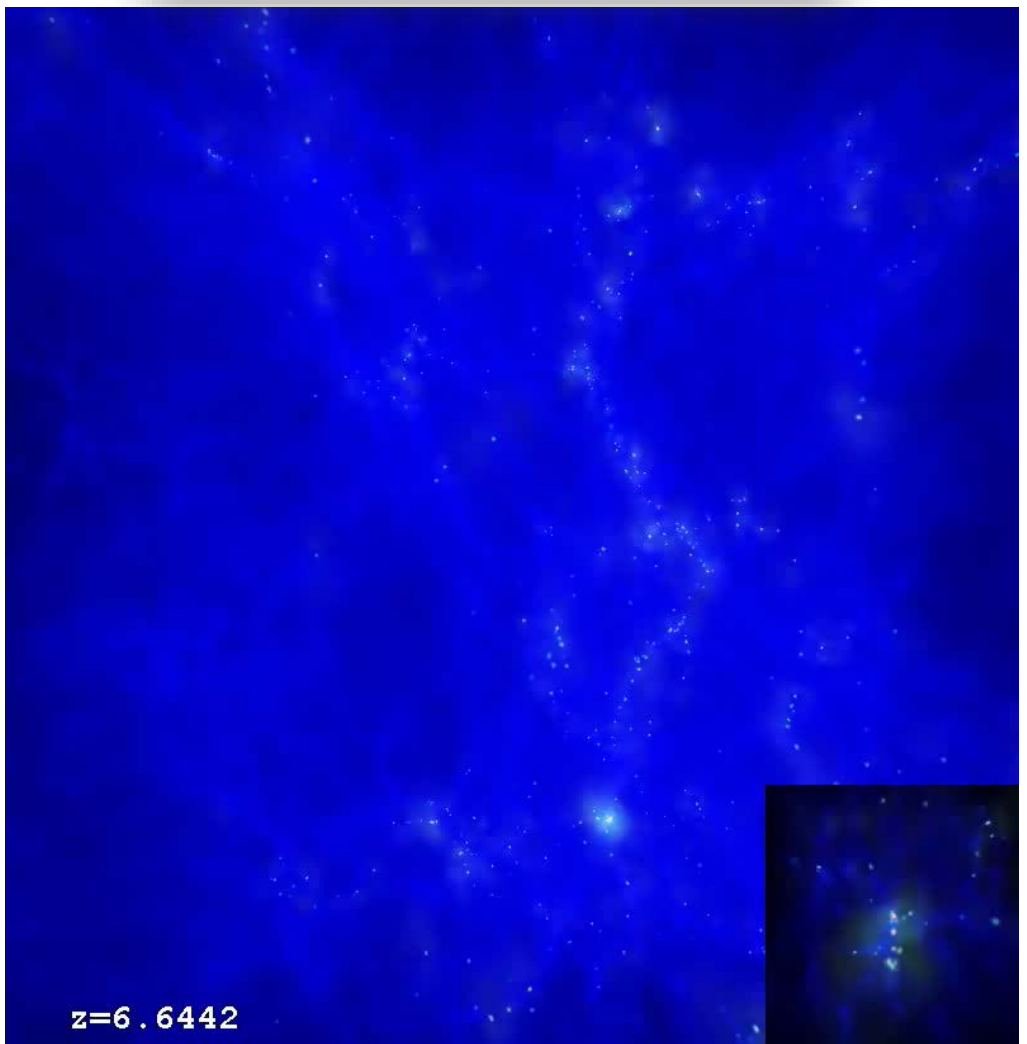
Stefano Borgani
(INAF-OATs & UNITs)

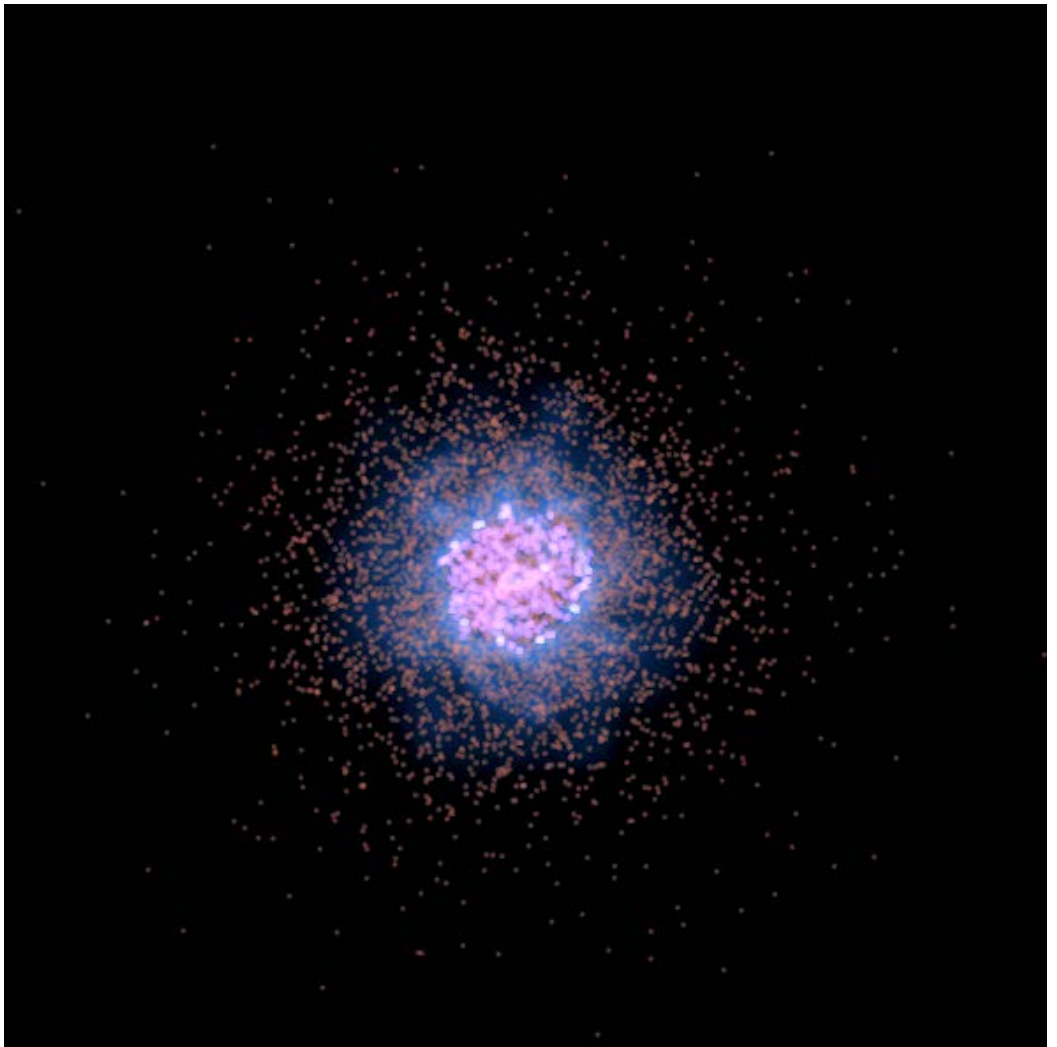
- What is a simulation of cosmic structure formation?
- What cosmological simulations are useful for?
- What is needed by our community?

What is a cosmological simulation?



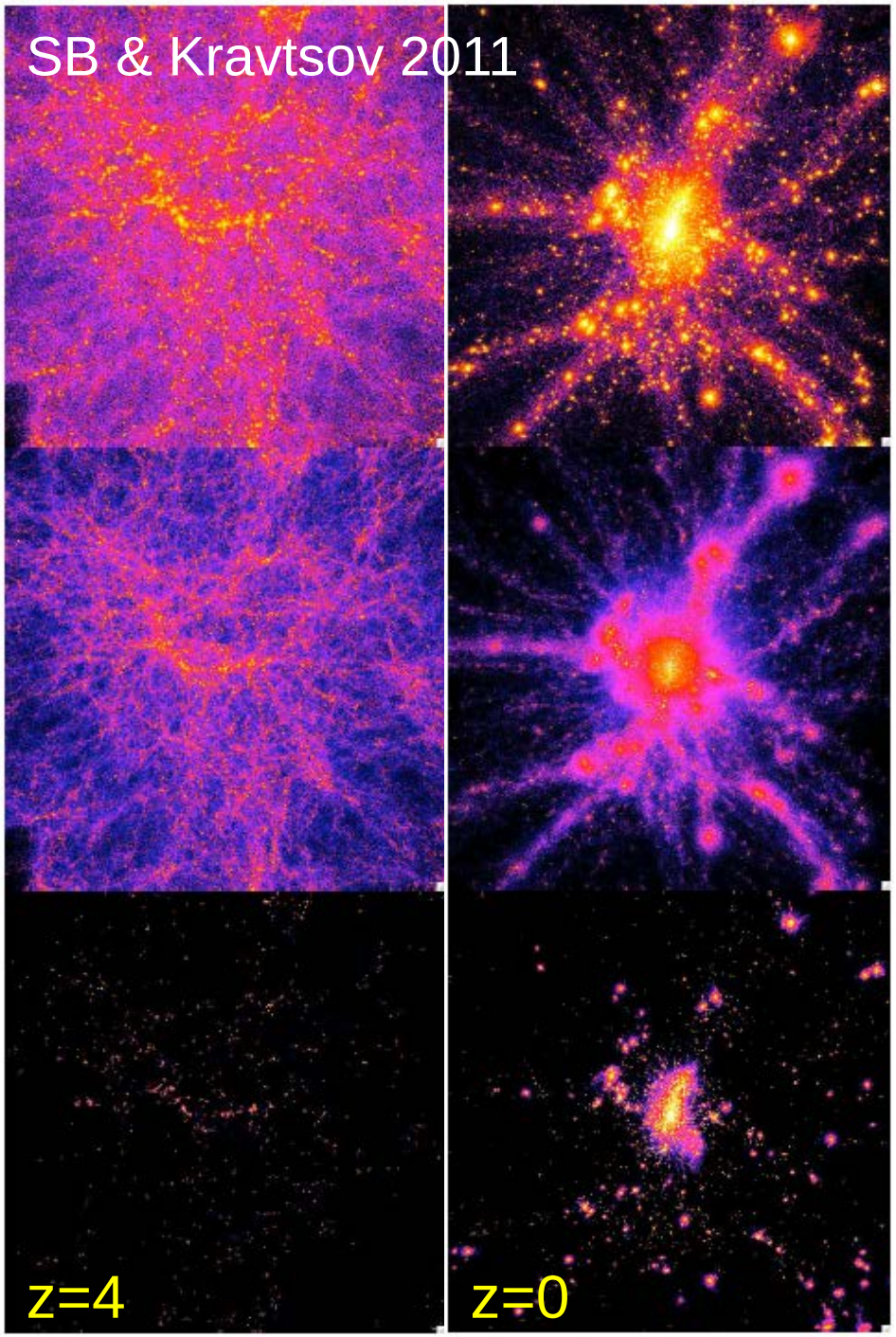
See talk by G. Murante





What are they useful for?

- To study gravitational instability of DM cosmic density perturbations in the strongly non-linear regime
- Observational signatures of non-standard cosmological models (massive ν's, WDM, non-standard quintessence, modified gravity, ...)
- To study astrophysics of cosmic structure formation
- Mocking surveys to develop analysis pipeline
- Mocking observations of specific objects to define scientific requirements on instruments



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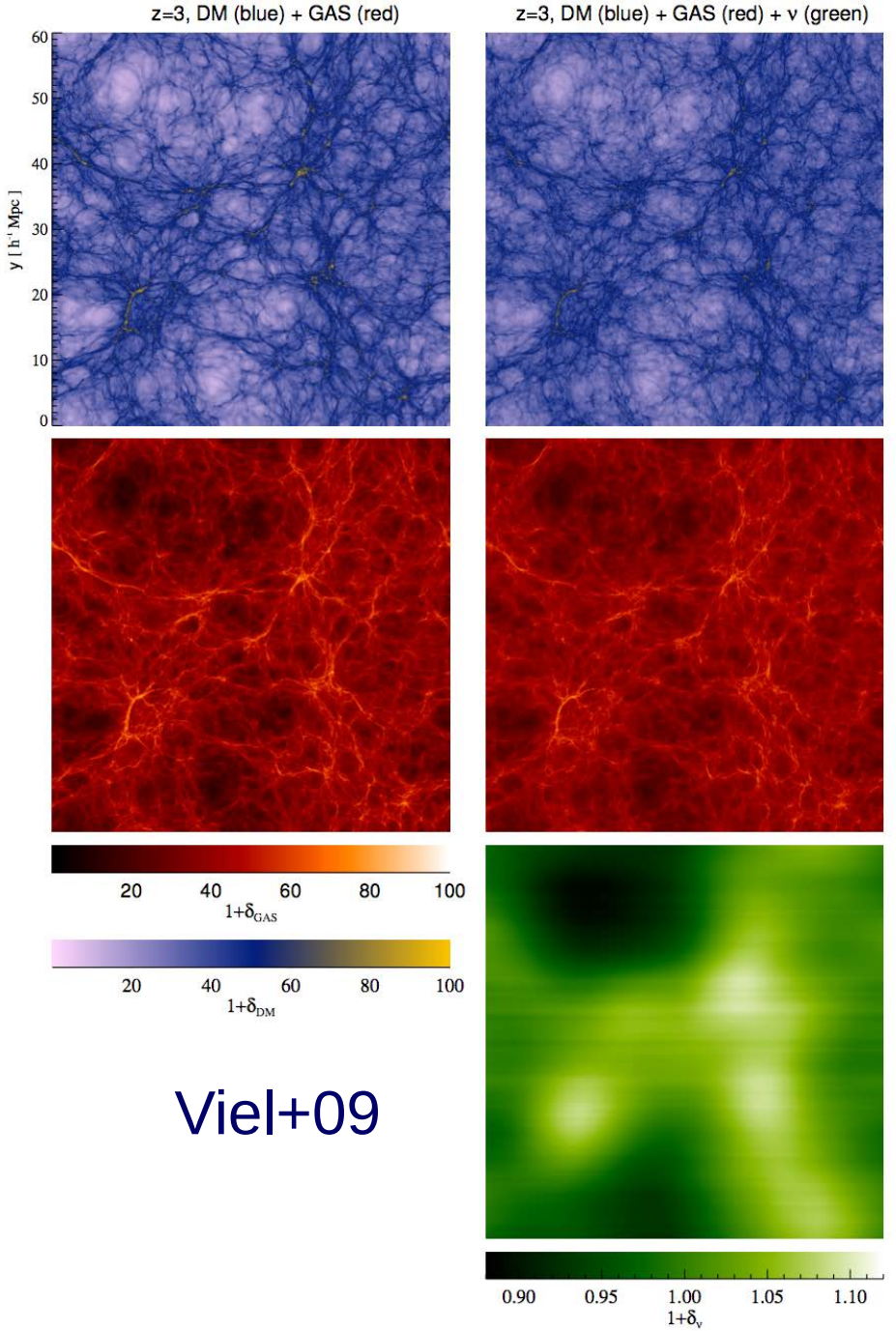

Viel+09

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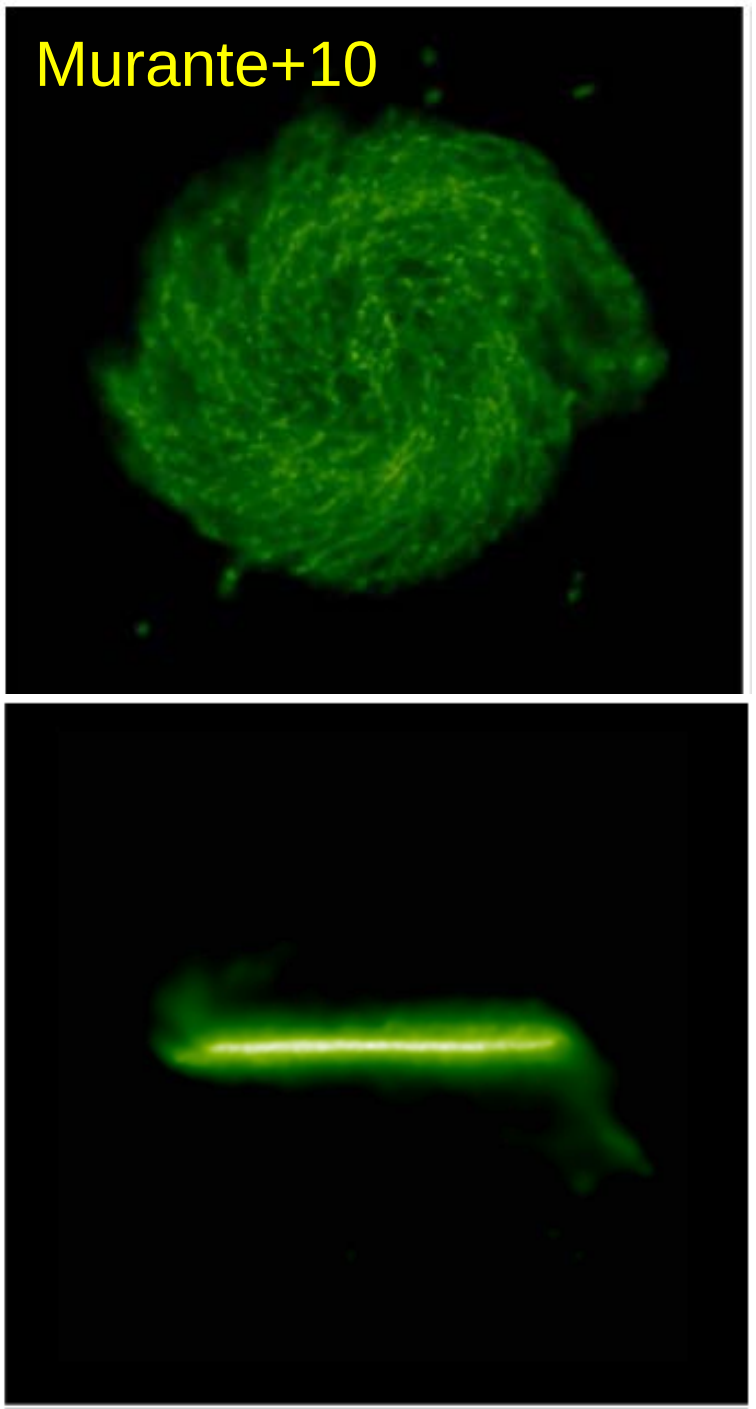

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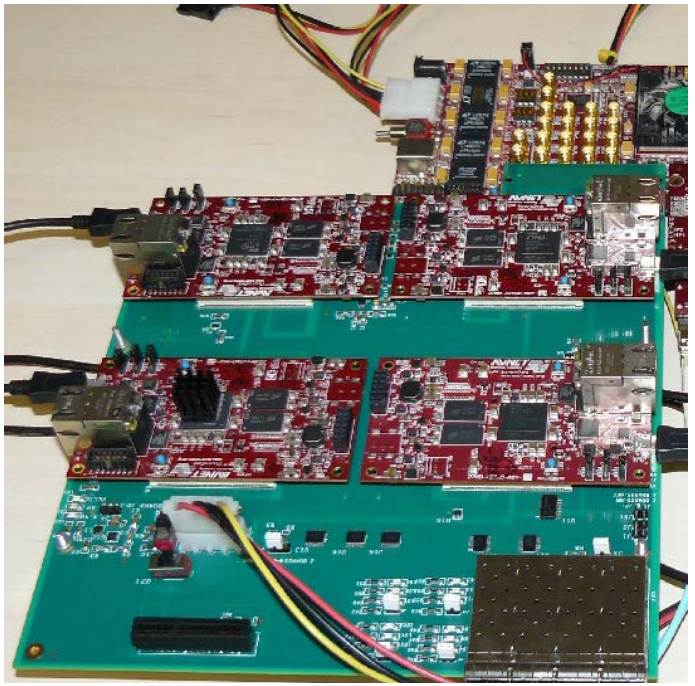

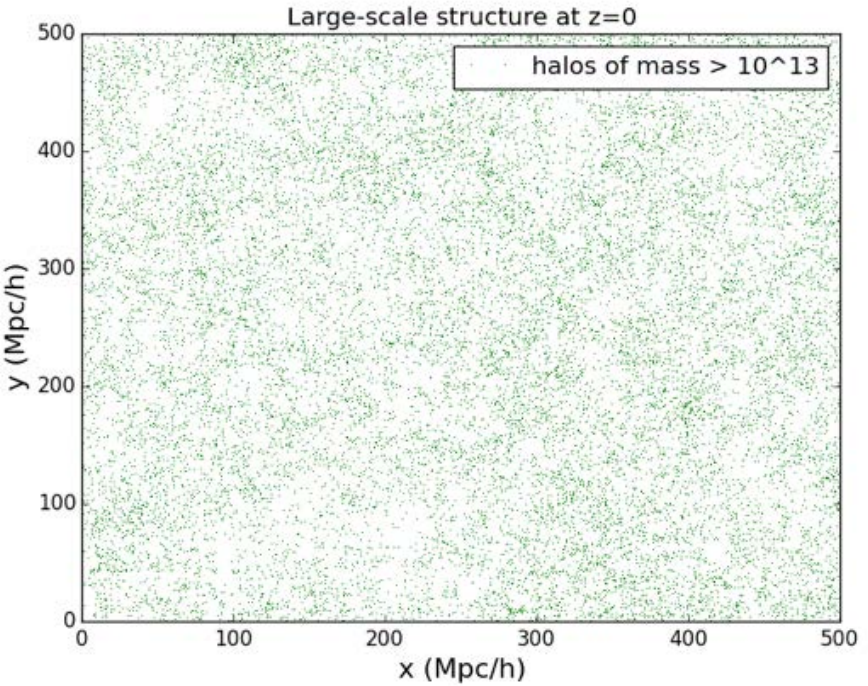

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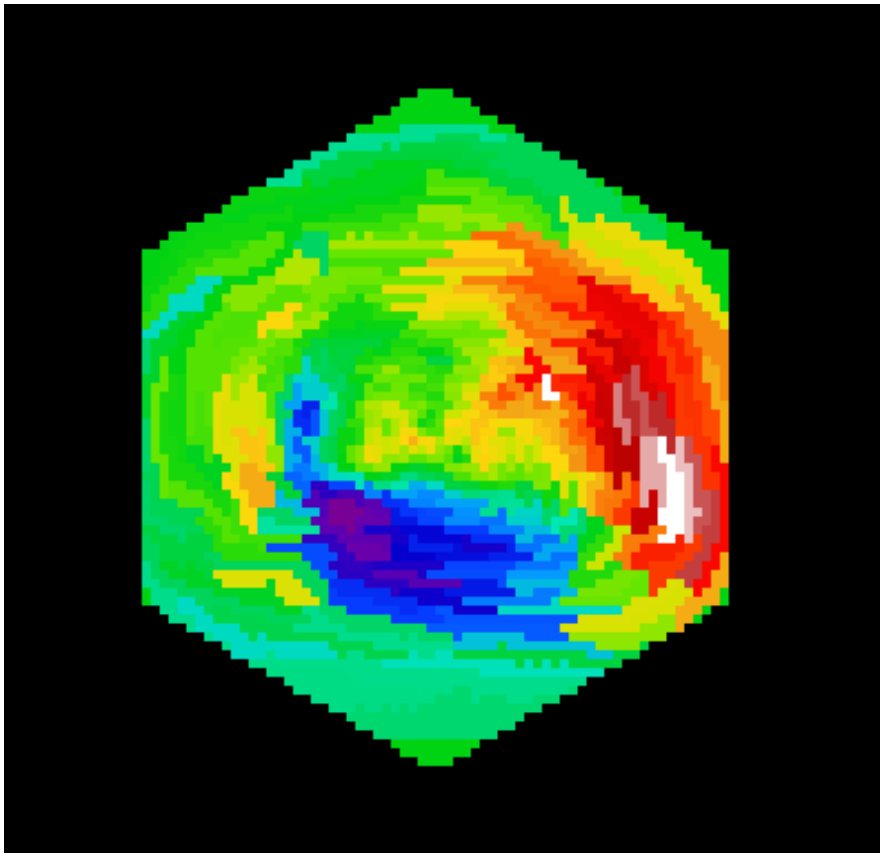
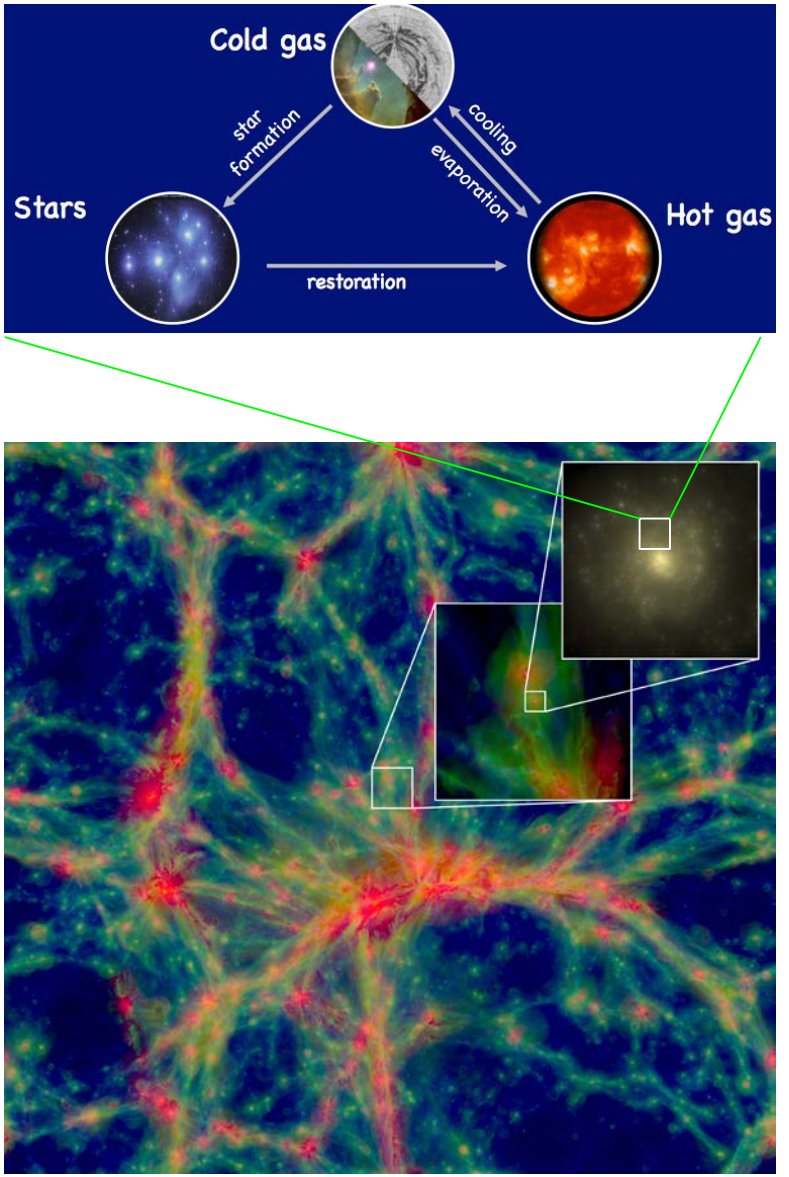


ICM bulk velocities of a simulated Perseus-like clusters with a 100 ksec exposure with Athena

Why are they so complex?

- Gravity: long range interaction, no screening
- Large (spatial and temporal) dynamic ranges:
  - ➔ From ~100 Mpc of cosmological environment to sub-pc scale, relevant for astrophysical processes: > 8 decades
- Resolve down to ~100 pc scales and describe the rest through sub-resolution models
- Cross-talk between resolved and unresolved scales



➔ Codes for computational cosmology: intensive and tough to parallelize

➔ Apps well suited for for co-design of exascale-oriented architectures (**ExaNeSt**; see talk by G. Taffoni)

Who's doing what in INAF?

- Trieste (INAF-OATs, UNITS, SISSA): N-body + hydrodynamics
  - Galaxies, clusters, IGM, SAMs,
  - LPT-based methods;
  - non-standard DM models (massive neutrinos, WDM)

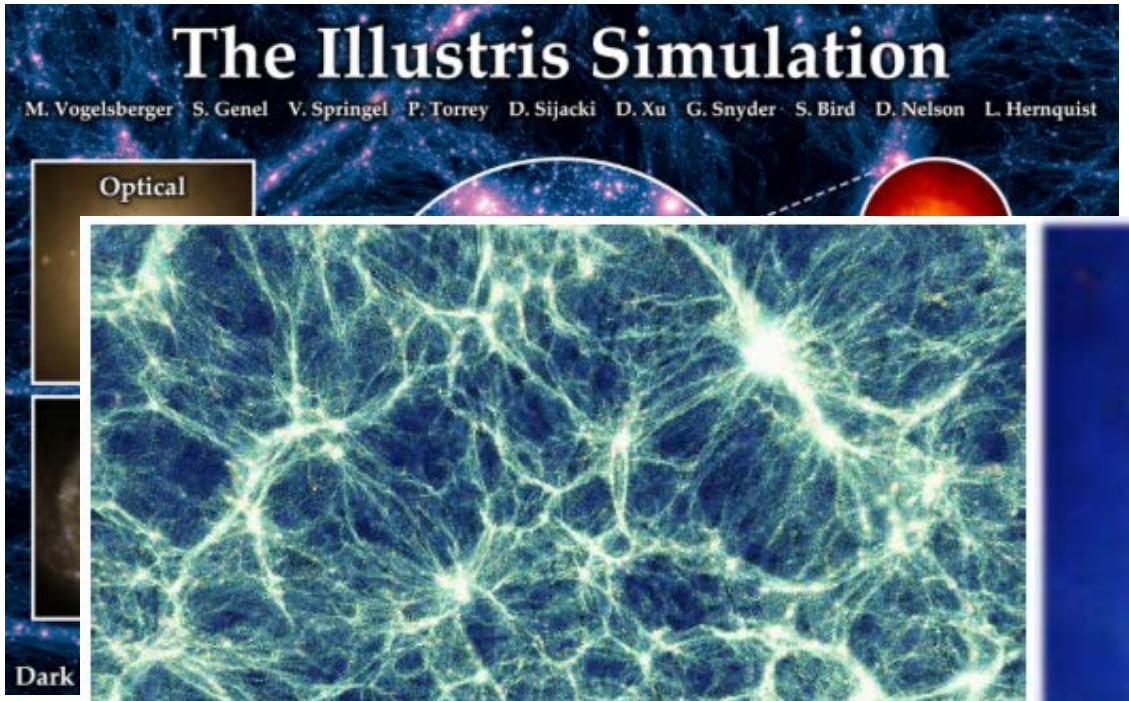
- Bologna (INAF-OABo, UNIBO):
  - non-standard cosmologies (Dark Energy & Modified Gravity)
  - AGN feedback (w/out cosmology)

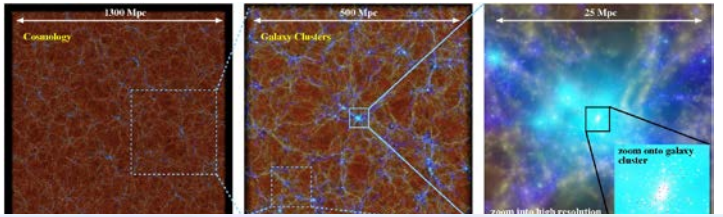
- Milano (INAF-OAB):
  - N-body with massive neutrinos

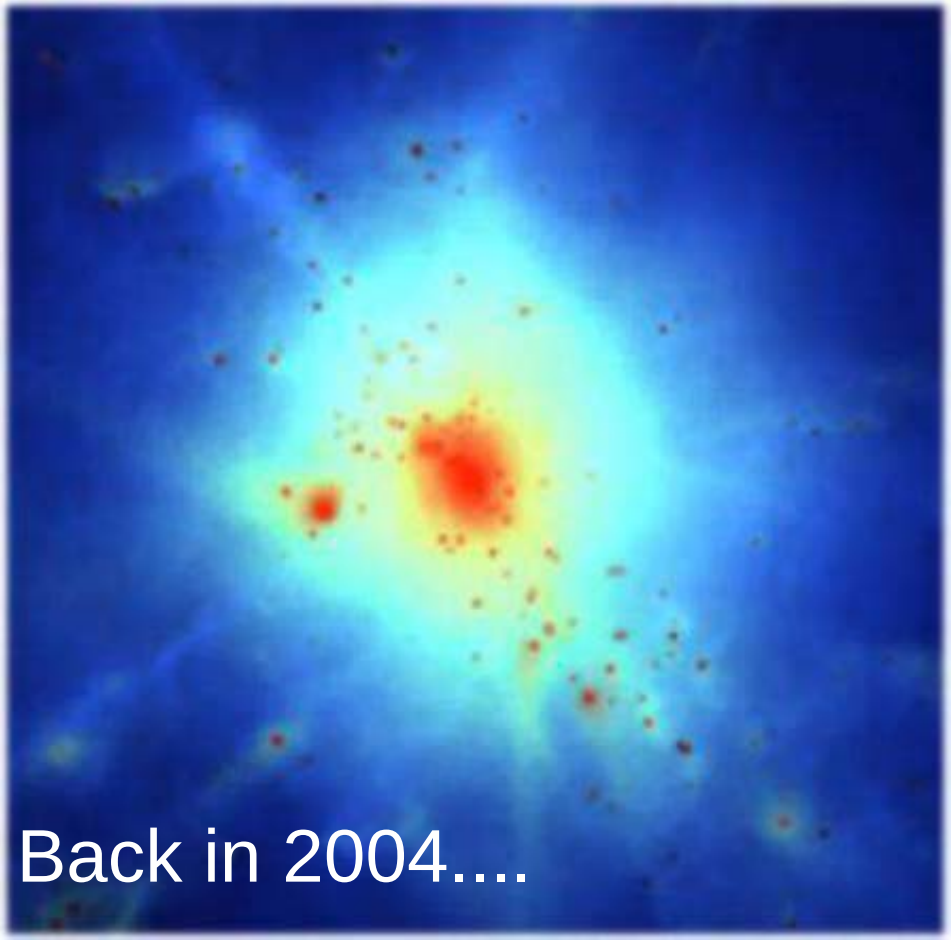
- Pisa (INAF-SNS) + Roma (INAF-OAR & "La Sapienza"):
  - N-body + hydrodynamics + RT
  - High-z galaxies and reionization

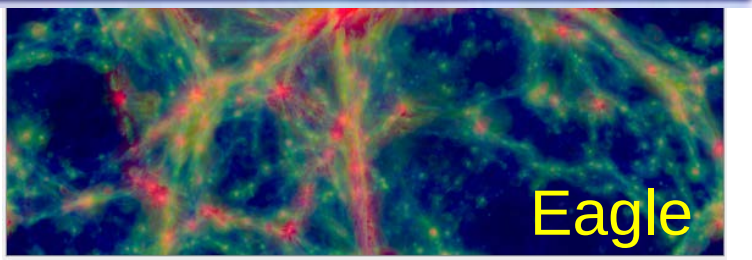
- Catania (INAF-OACt):
  - N-body for LSS
  - AGN feedback (w/out cosmology)

The “big splashes”









Facilities are not only telescopes

A policy of INAF is needed (and long overdue !) for:

- High-performance computing (HPC)
- High-throughput computing (HTC)
- Ultra-wide band connectivity

Crucial for scientific exploitation
of a variety of observational data !!!!!

Data storage and preservation infrastructure in place (IA2 service), BUT:

➔INAF doesn't even have a Tier-2.5 machine !

➔Fragmentation in a number of (often obsolete) small clusters

➔No expertise on HW configuration & middleware

➔No collaboration with HW companies to develop HPC/HTC facilities tailored on our needs

Which solution for INAF

A INAF computing center needs far more than "just" a Tier-N machine:

- A hosting infrastructure
- Mid- and long-term data storage (~1/2 of the cost)
- Personnel
- Commitment for a long-term policy: a machine becomes obsolete in 4 years!
- Shall we rather make a deal with other institutes or HPC centre?

Big splash simulation: apply to PRACE or make special deals with a national supercomputing centre

Development phase (including development of a "culture of computing"): flexible and continuous access to a Tier-2/2.5 INAF machine

What is NOT a solution for our simulations: grid/cloud computing