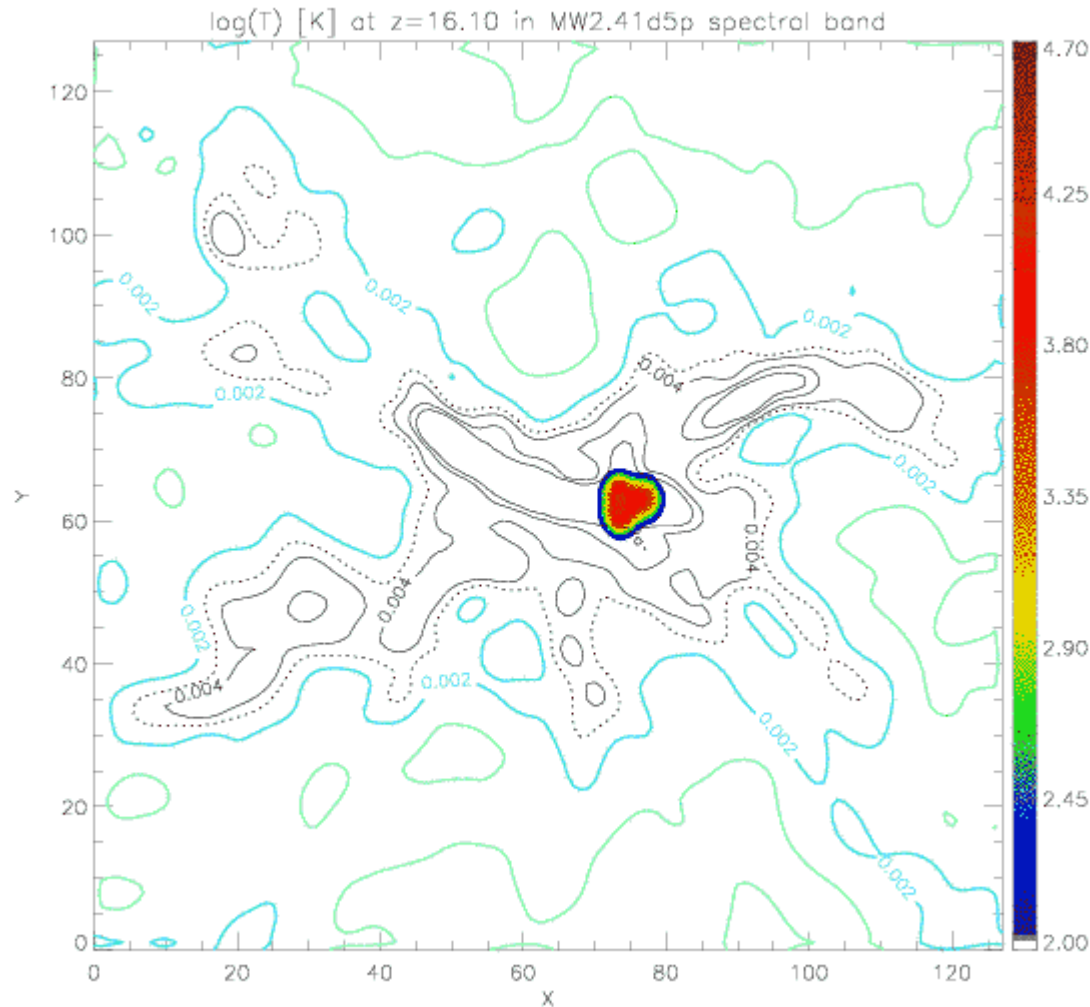


ERC_FIRST HPC-class Projects @ INAF- OAR

Luca Graziani



- RT, Gas Dynamics in Cosmology
- CRASH, GAMESH, dustyGadget



In collaboration with:



- S. Salvadori (Kaptein, Groningen)
- R. Schneider (INAF-OAR, Italy)
- D. Kawata (UCL, UK)
- B. Ciardi (MPA Garching, Germany)
- A. Ferrara (SNS, Italy)
- S. Bianchi (INAF-Arcetri, Italy)

2015 ICT workshop, Oct 06-09 2015, Cefalu', Italy





The FIRST team and collaborators



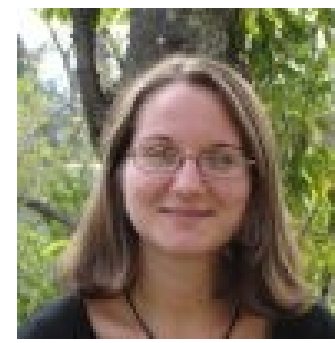
Matteo de Bennassuti, PhD
INAF/OAR



Stefania Marassi, Pdoc
INAF/OAR



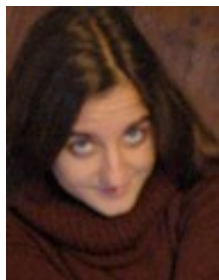
Raffaella Schneider, PI
INAF/OAR



Rosa Valiante, Pdoc
INAF/OAR



Marco Limongi
INAF/OAR



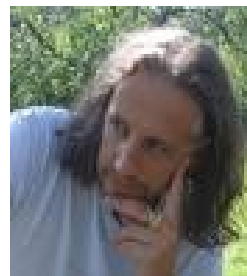
Stefania Salvadori
Kepteyn, Groningen



Simone Bianchi
INAF/OAA



Roberto Maiolino
Cambridge



Andrea Ferrara
Scuola Normale



Gen Chiaki
Tokyo University



Kazu Omukai
Tohoku University

Cosmology / Star formation / formation of the Milky Way

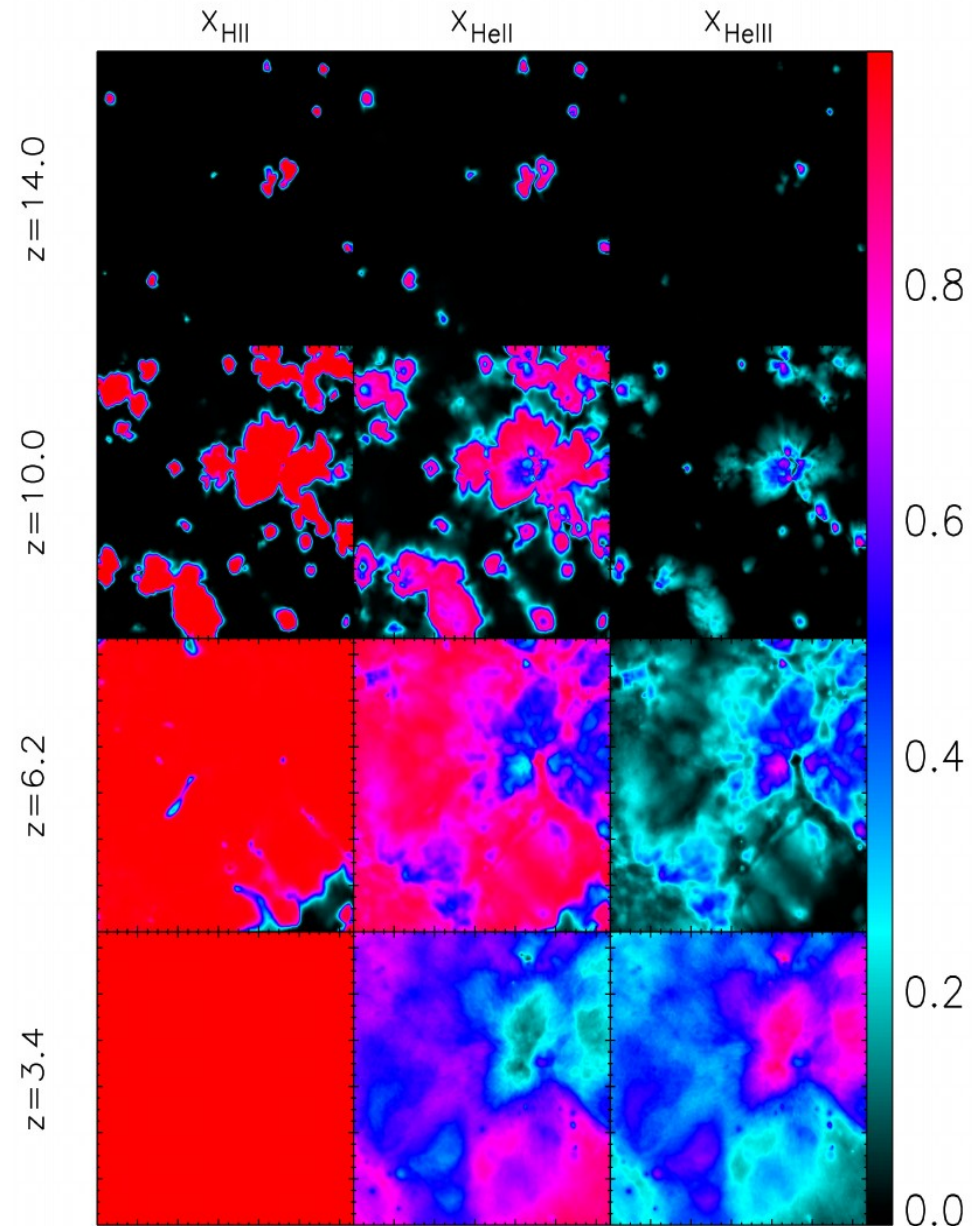
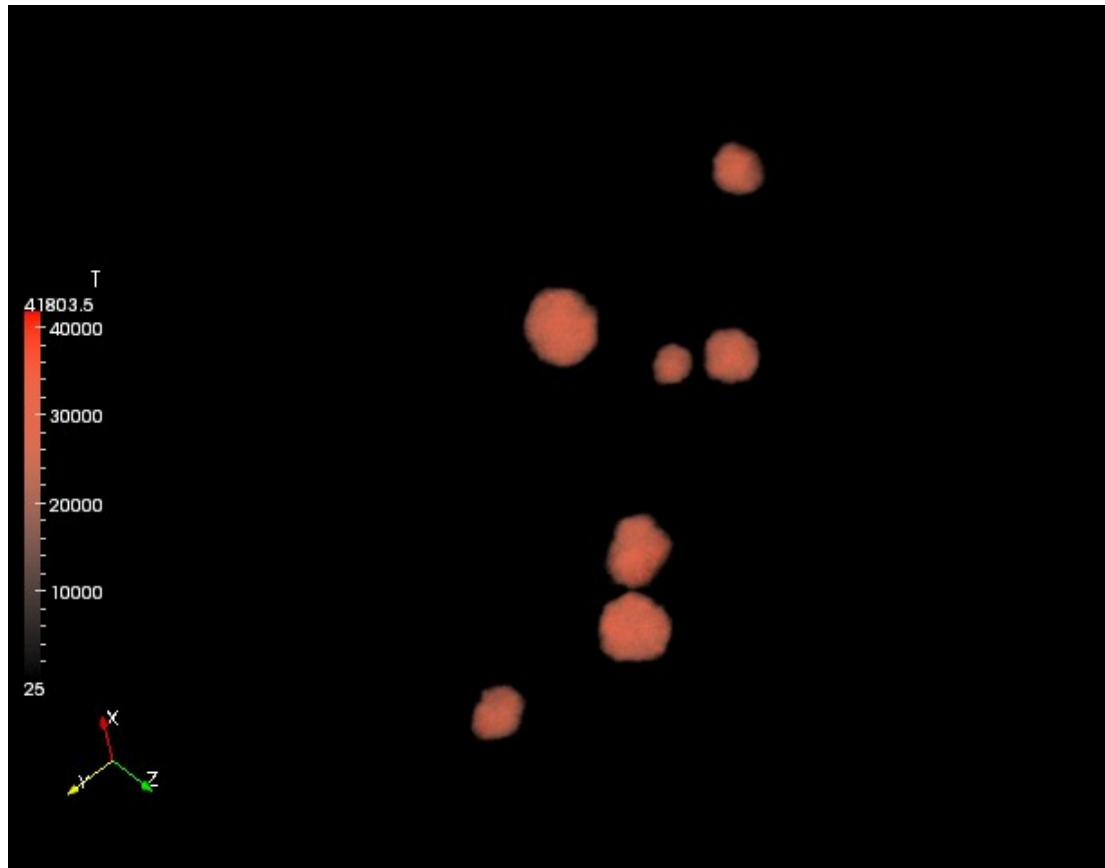


Feedback



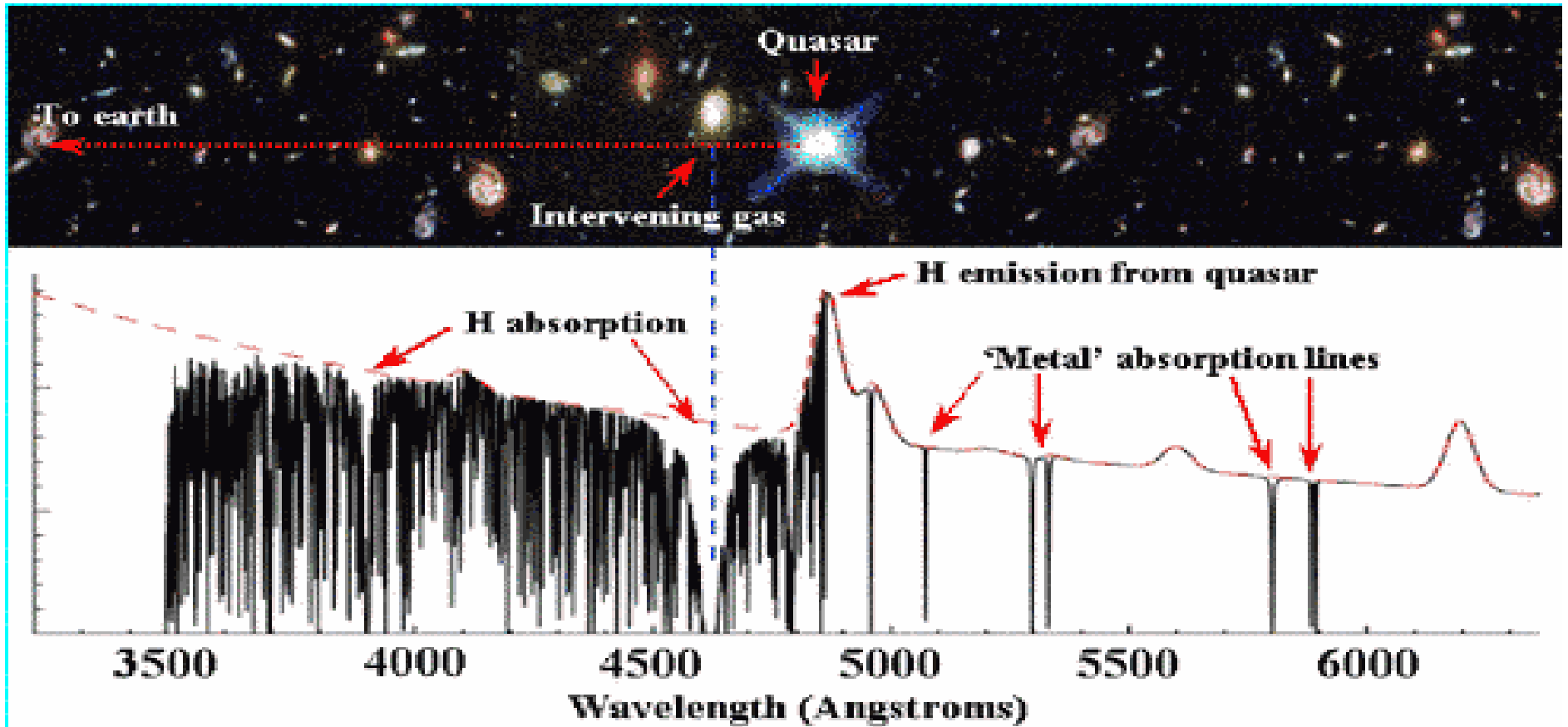
- **Mechanical** feedback: galaxy dynamical interactions.
- **Chemical** feedback: stellar evolution, chemical enrichment, interplay with CGM and IGM.
- **Radiative** feedback: IGM reionisation → Star formation.

Reionisation

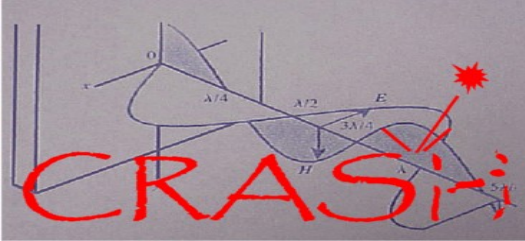


Scale of the problem? \rightarrow Universe
(> 100 cMpc ??)

Spectral lines of QSOs (OVI CIV CIII SiIII CII SiII FeII MgII)



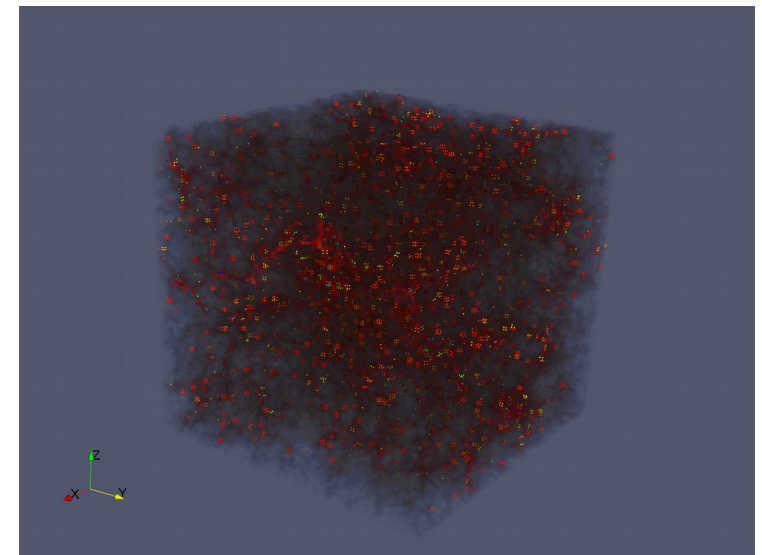
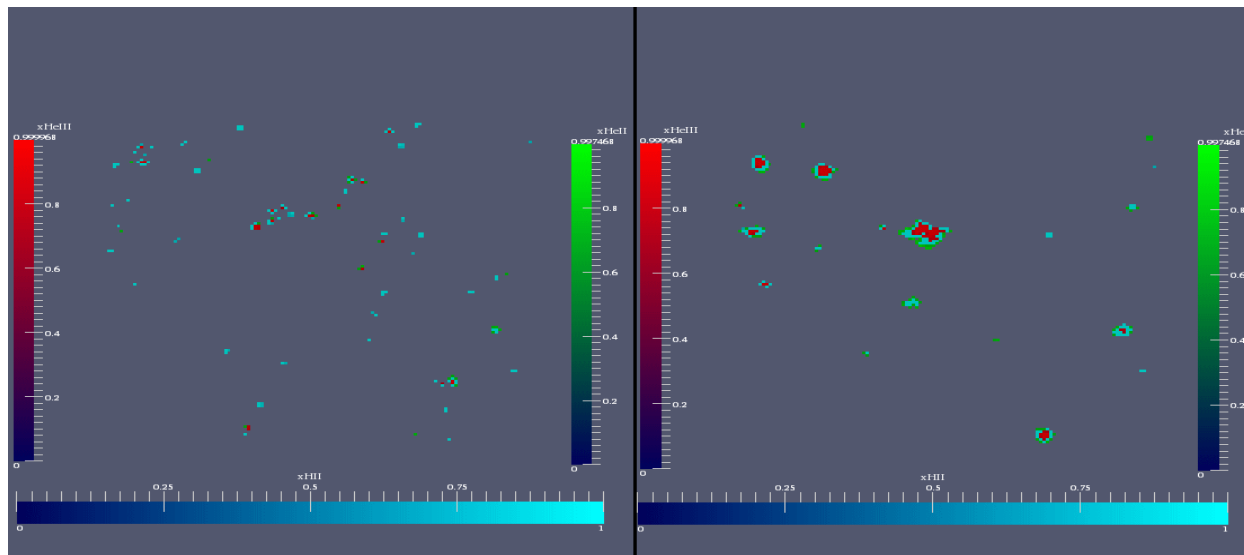
- **H, He, Metal atoms highly ionized:** Why?
- What radiation field at fixed z ?

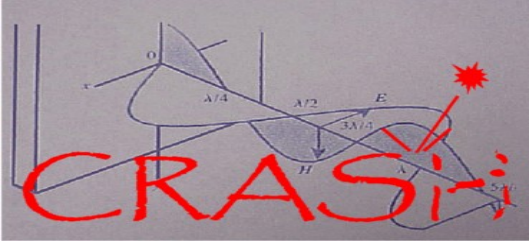


C.R.A.S.H.

Cosmological **RA**diative transfer **S**cheme
for **H**ydrodynamics

- RT code based on MC + Ray tracing.
- Describes **3D** RT cosmological scenarios.
- Solves **time dependent** RT on cosmological scales → **Cosmic Reionisation of H and He**.
- Implements **detailed H, He physics + metal ions (in pipeline with other codes)**.





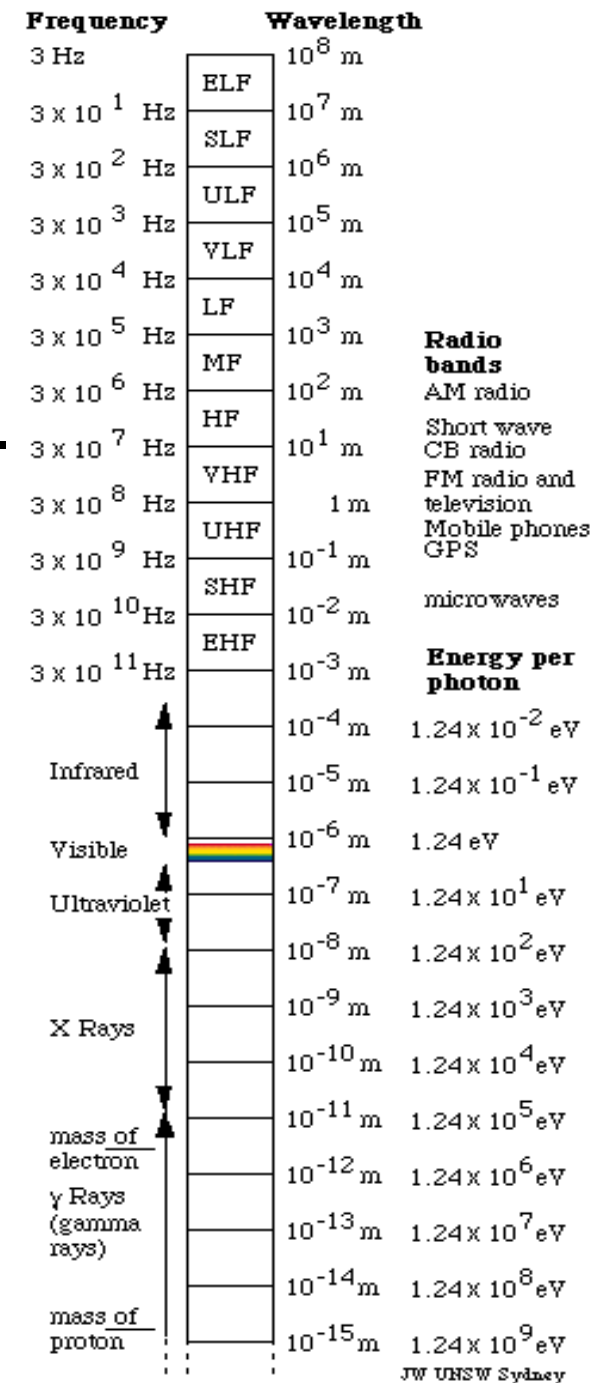
CRASH4

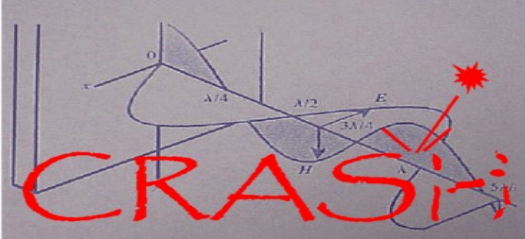
- **Multi-frequency band RT:**

- UV+ soft x-rays: 10 KeV.
- Include Ly α RT coupled with continuum.
- LW band and molecules: H $_2$, CO.
- Dust.

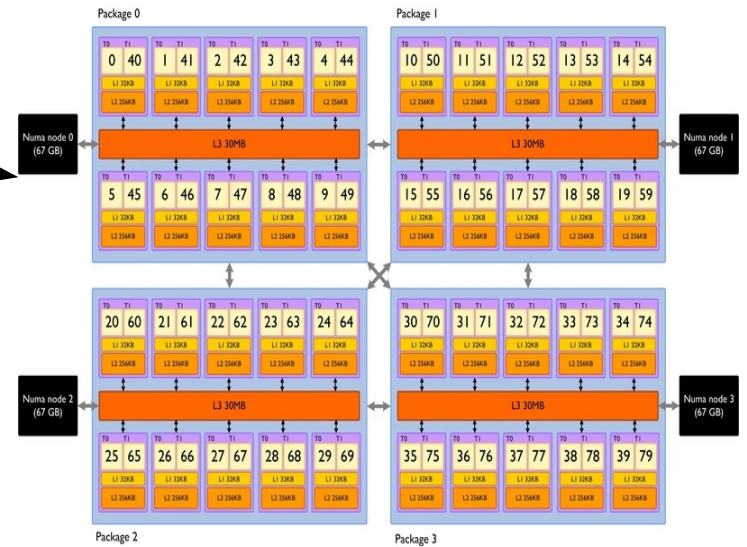
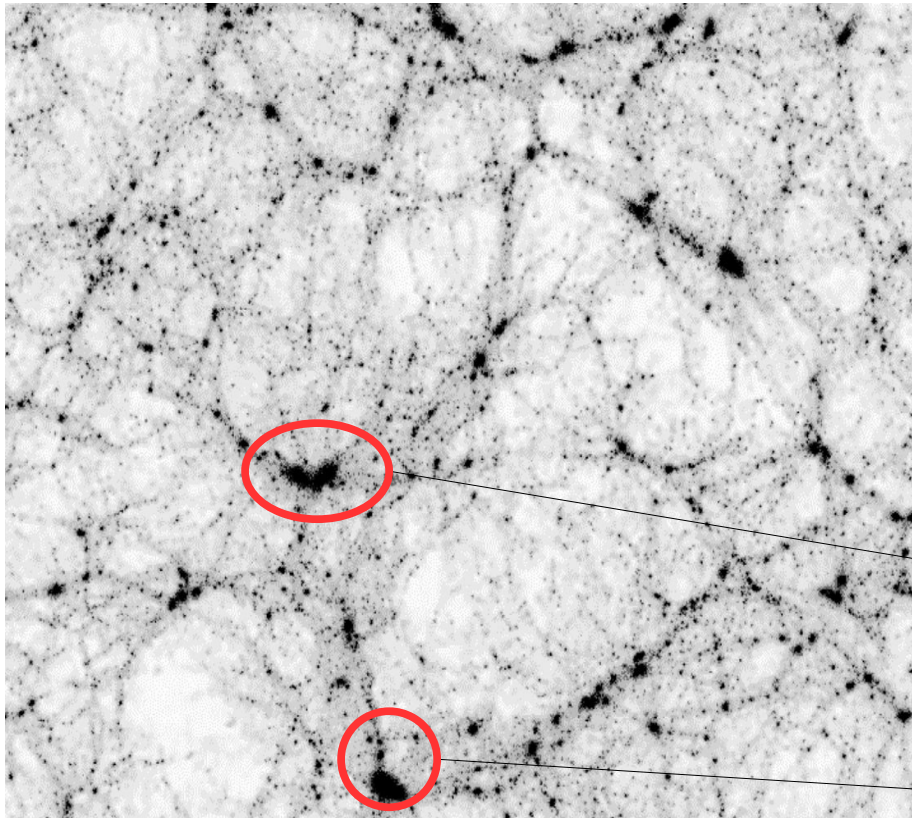
- **Intrinsic Parallel framework:**

- OpenMP for ray tracing and Chemistry.
- MPI to map the topology of the Cosmic Web.



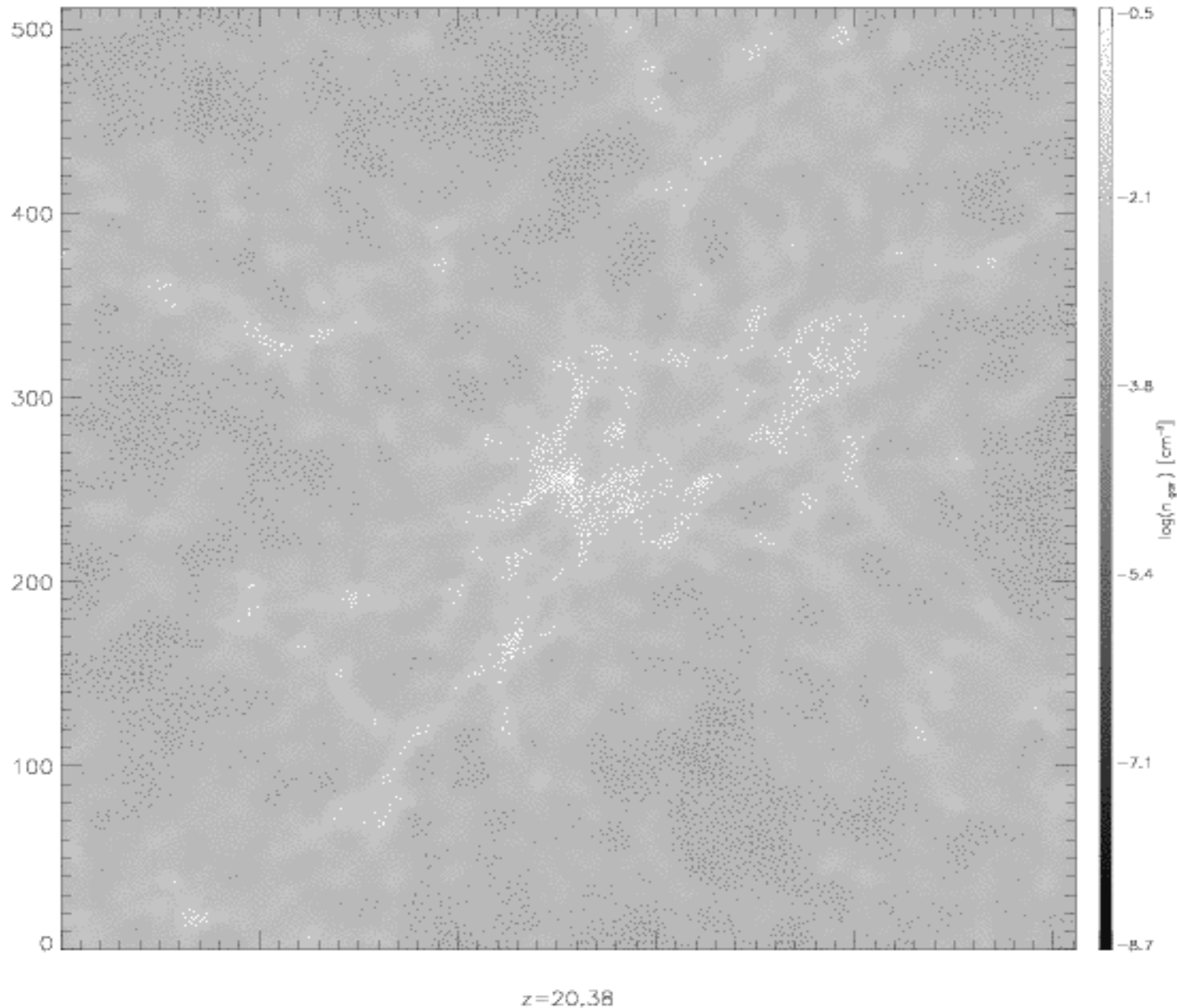


Parallelism in CRASH4

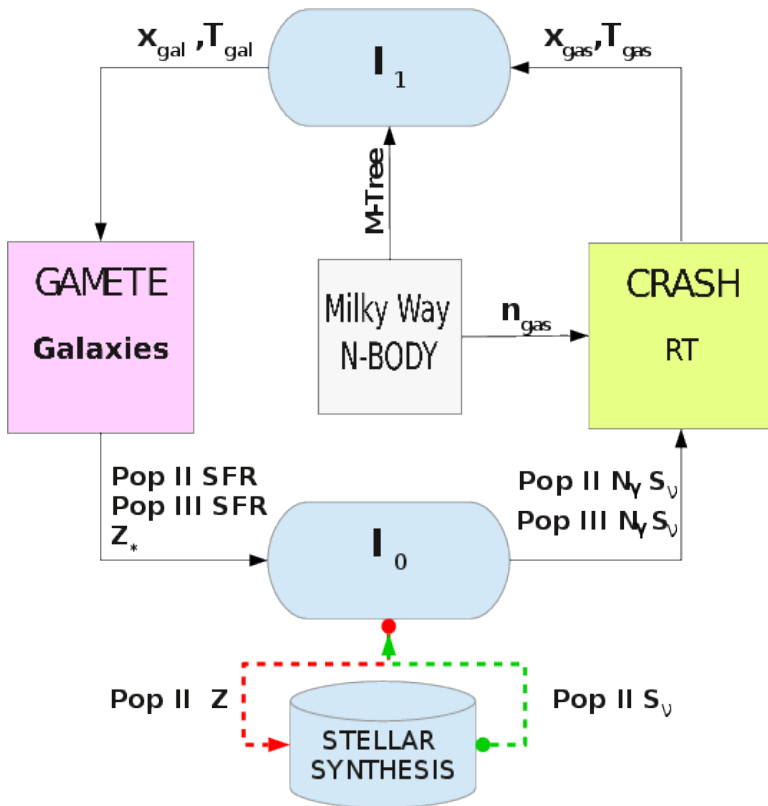
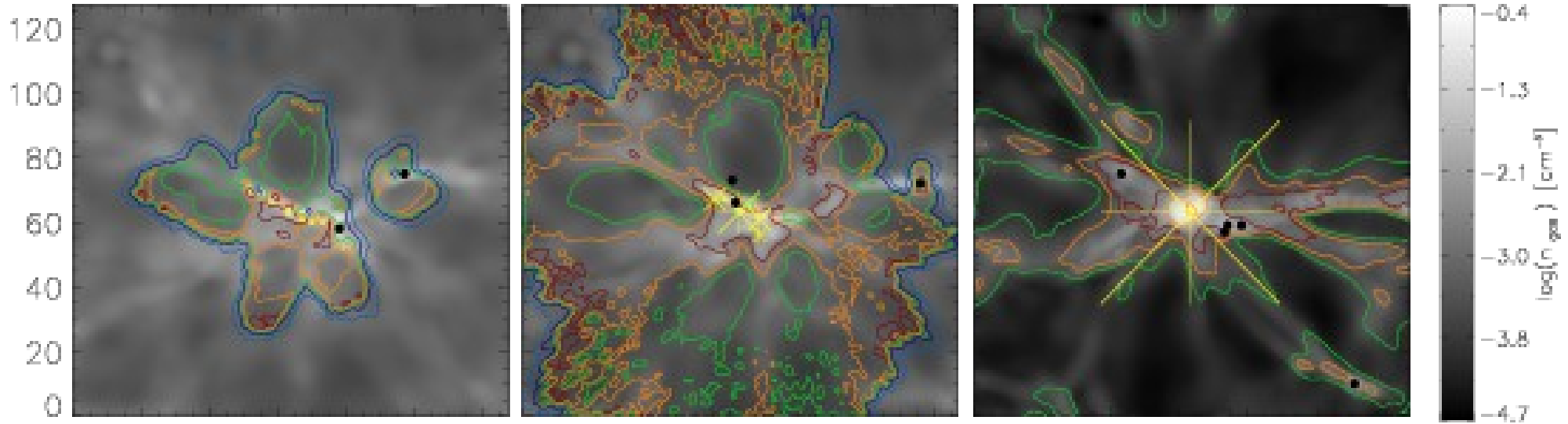


GALAXY FORMATION WITH N-BODY SIMULATIONS

Scale? (< 4 cMpc ??)



GAMESH = GAMETE + CRASH + N-Body



N-Body simulation: dynamical evolution of DM halos

GAMETE simulation: Star formation, metal production

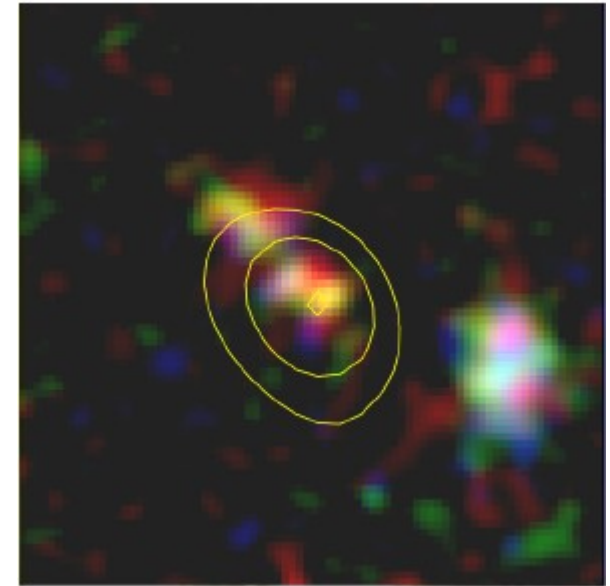
CRASH simulation: RT, gas ionisation heating

High redshift ($6.5 < z < 7.5$) dusty galaxies ???

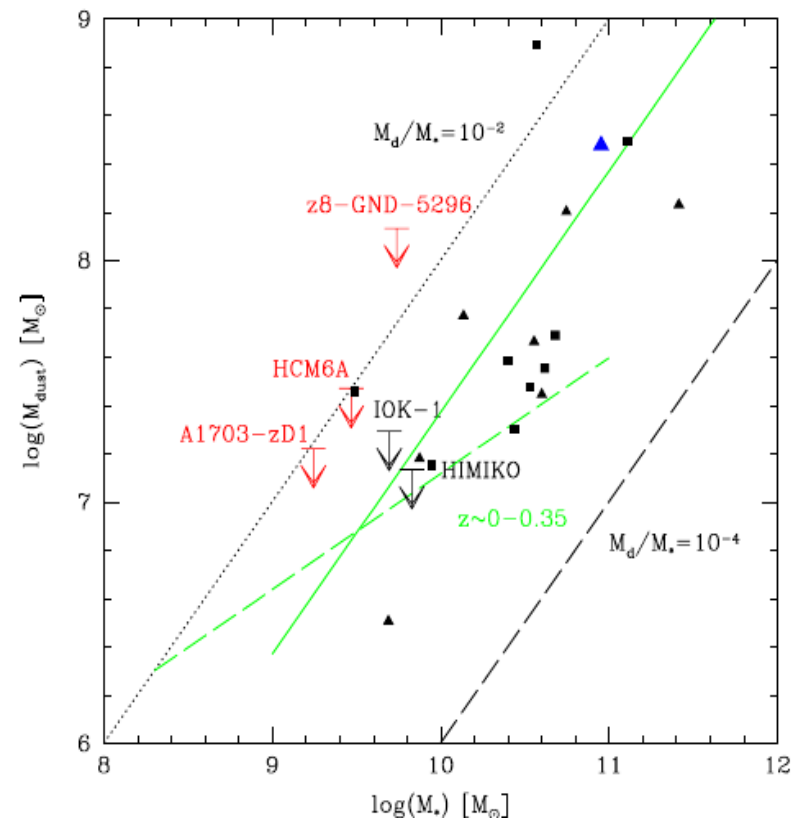
- Watson et al., 2015: Direct detection of dust emission!
- Schaerer et al., 2015: Sample of five high-z, star-forming galaxies: estimates for dust properties, stellar emission, star formation rates, dust masses, [C II] luminosity, UV attenuation, stellar masses.
- Maiolino et al., 2015: three spectroscopically confirmed Lyman Break Galaxies at $6.8 < z < 67.1$. CII line detection (also see Gallerani et al. 2012, Williams et al., 2014)



- Access the properties of the ISM of high-z Galaxies.
- Disentangle the role of various feedback Processes in place
- Estimate of the evolutionary status of the galaxy by both SFR, atomic metals and dust.
- Interplay between ISM and IGM -> Escape fraction in many spectral bands → Reionisation



Watson et al. Nature 2015



Schaerer et al. A&A 2015

Need to **update theoretical models of galaxy formation** (both semi-analytical and numerical):

feedback (**chemical**), feedback (**radiative**), feedback (**mechanical**) !!

Chemical

- Improve chemo-dynamical existing schemes:
 - updated metal yields.
 - Improve schemes of metal spreading.
- Extend with dust production and spreading:
 - Updated dust production yields.
 - Detailed study of AGB vs SNIa impact on total dust.
- Molecules (H₂) and grain growth in molecular clouds.

Radiative

- H-ionising UV and x-rays are not sufficient!
- Self consistent photo-ionisation of metals requires to follow Photons with energies well below 8eV (SiI).
- Molecules and Dust require to account for LW and Ly α

Mechanical

- Galactic and Extra-galactic winds.
- Interplay between radiation and dust!

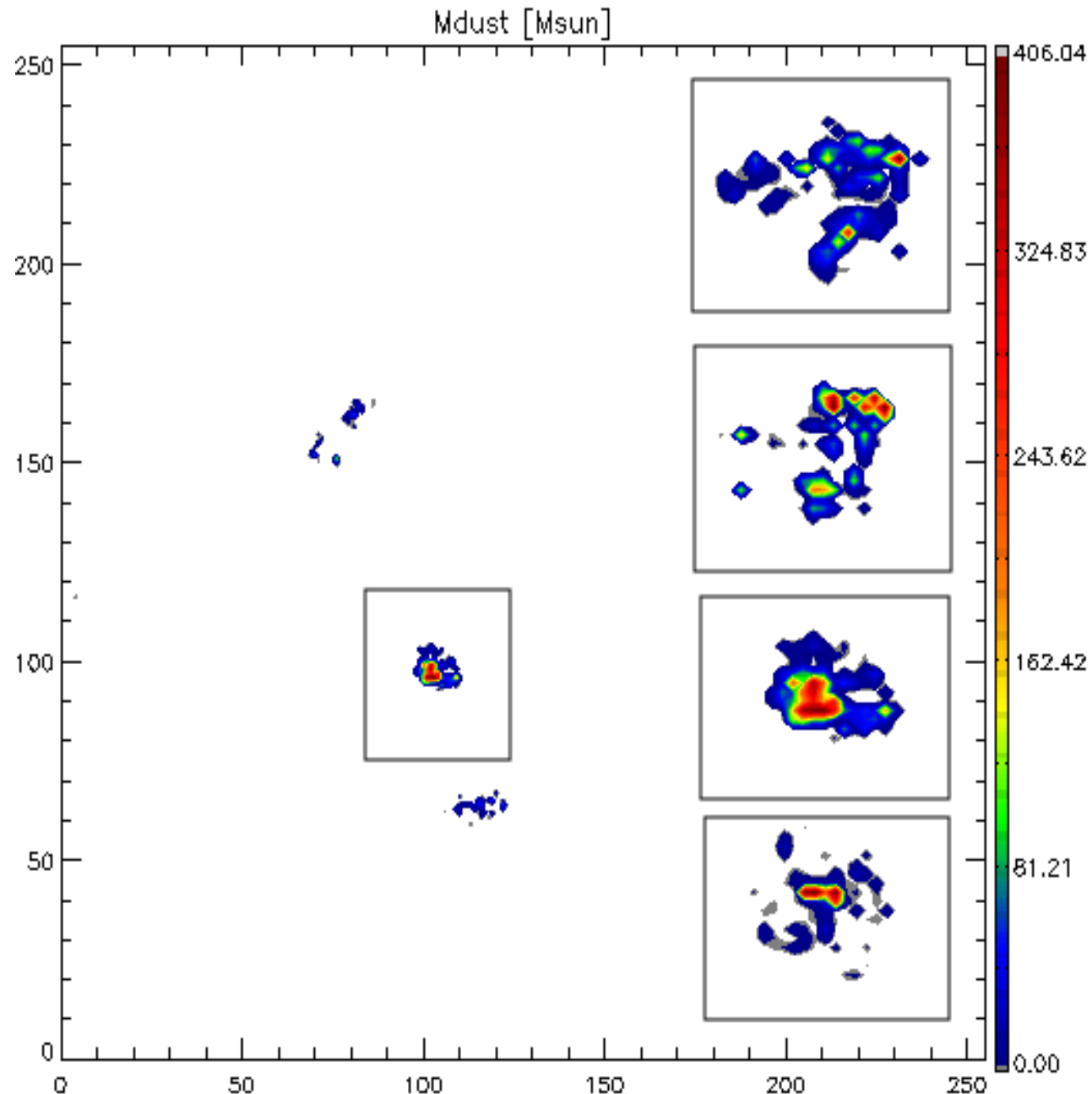


Multi-phase ISM

DustyGadget : Dust inside and around Galaxies

Simulation with dust.

- $z = 5.67$
- Box size: 10 cMpc/h
- Dust follows the same metal patterns.
- Spreading: dust distribution highly In-homogeneous
- Huge gradients in the enriched regions of the box

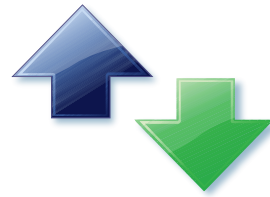


What is needed to do RT, Nbody, Gas dynamics??

- **Supercomputers:** capacity&capability → **PRACE ??**



- **Parallel/Distributed technologies** → Open source / Industry



- **Human resources** → Post-docs + Students (MSC+PhD)



- **Skills** → Transfer of knowledge

Supercomputers in Europe → PRACE ??



CURIE: French Tier-0 supercomputer



FERMI: Italian Tier-0 supercomputer



SuperMUC: German Tier-0 supercomputer



Huge facilities → code ready?

Huge facilities → competitive access



Competitive for production runs

??? DEVELOPMENT ??

Parallel/Distributed technologies → too many ...

CURIE: French Tier-0 supercomputer



FERMI: Italian Tier-0 supercomputer



SuperMUC: German Tier-0 supercomputer



OMP → Algorithm ready?

MPI → scaling with problem

Native threads → difficult

Functional Parallelisation

→ time !!!

Optimisation libs →

Implementor dependent

PRACE is necessary but not so easy..



CURIE: French Tier-0 supercomputer



FERMI: Italian Tier-0 supercomputer



SuperMUC: German Tier-0 supercomputer



**Necessary on global HPC ✓
competition**

Requires time&commitment! ✗

**Requires Skills& code Pre-
development and scaling ✗**

Human resources.....

Research in Astronomy is based on : permanent staff → well established research field



Post-docs → Innovation required → International competition

PhD students → 3-4 yrs to learn both astronomy and HPC

Compare time scales of HPC with lifetime of people in Astronomy → do we need a national HPC facility ??



We do not need to replicate PRACE but complement PRACE.