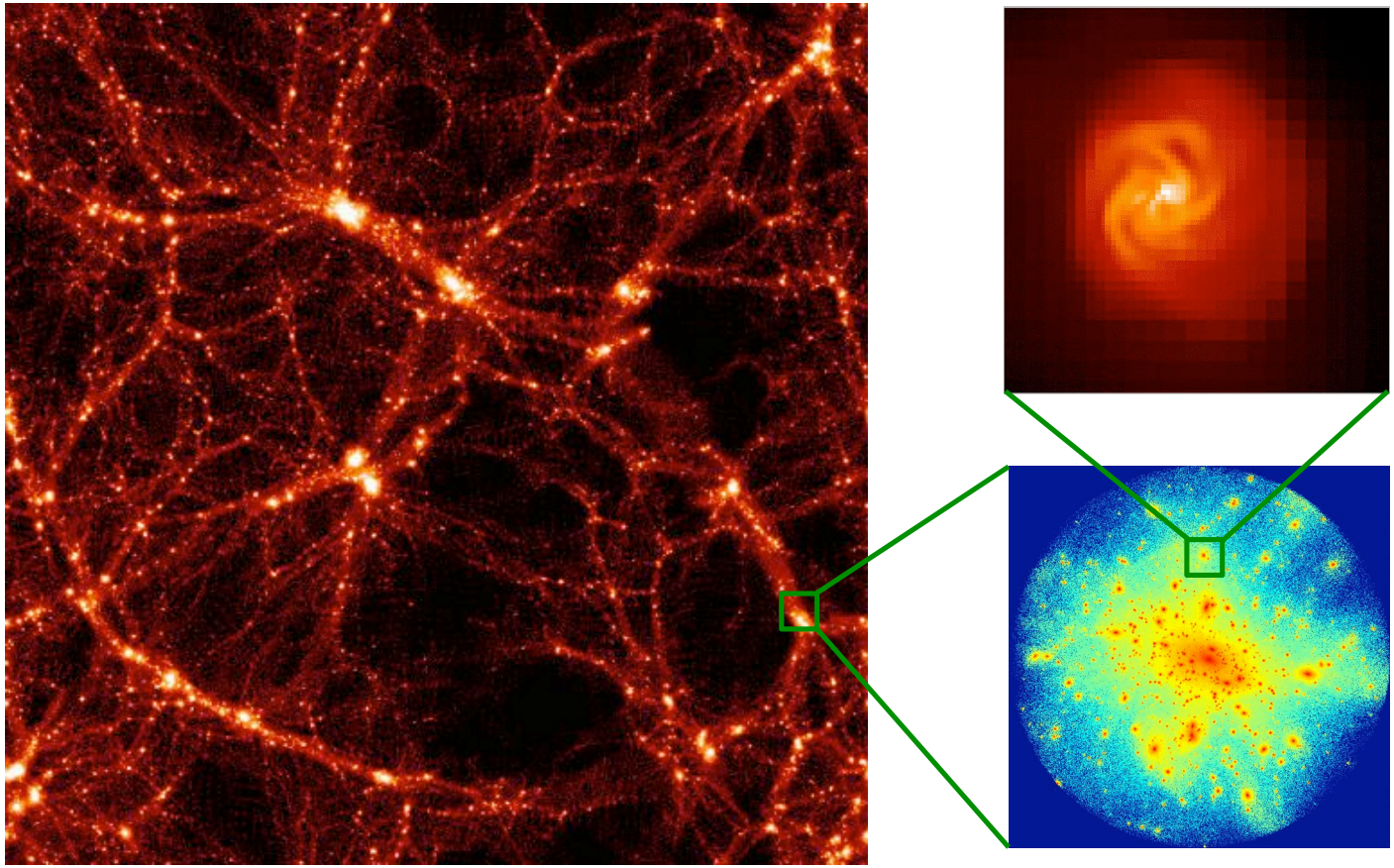
Extreme Computational Cosmology



Outline

- Horizon: what is it ?
- Initial conditions
- Physics
  - From pure N body to fully reactive radiation MHD ?
  - Star formation and supernovae driven winds
  - AGN driven outflows
- Supercomputers in Europe. Current and future projects
- Goal of this workshop

PROJET HORIZON

The Horizon Consortium

5 Partners

Labo	Co-I	Lieu
LUTH	J.-M. Alimi	Meudon
IAP	S. Colombi	Paris
LERMA	F. Combes	Paris
CRAL	B. Guiderdoni	Lyon
SAP	R. Teyssier **PI**	Saclay

Horizon Scientist: collaborator responsible of a work package under the supervision of a node leader
30 scientists and 10 students

Horizon Associate: collaborator without work package participating to Horizon on a short term basis.

Executive committee: 5 co-I meeting every month

Scientific committee: 10 members meeting every year (in preparation)

Horizon Web Site: with separate private and public parts (1 technical and 3 editorial supervisors)
http://www.projet-horizon.fr

Horizon Mini-Grid: 6 quad AMD64 16 Gb servers located in each lab and interconnected as a grid (3 system managers)

Horizon Meso-Machine: 3 quad AMD64 64 Gb servers located in HPC1 and 250 000 additional "on demand" hours

Supercomputing Centers: combined proposals in France (IDRIS, CINES et CCRT) and in Europe (DEISA initiative)
http://www.deisa.org

Horizon Hardware

Centres de calcul

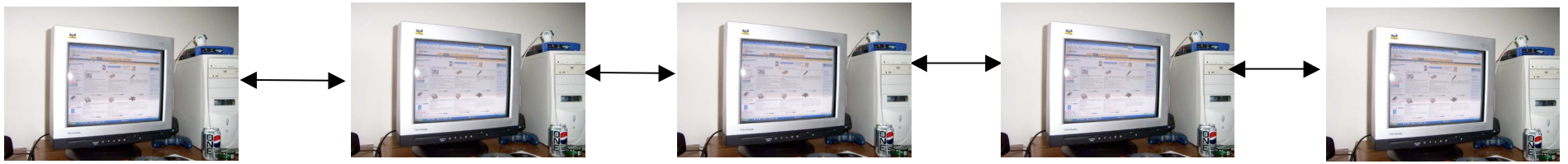
Méso-machine

Post-traitement et
Archivage lourds

Soumission de jobs

Visualisation,
Post-traitement et
Archivage légers

Mini-grille



Paris Meudon Saclay Lyon Marseille

PROJET HORIZON

Projet Horizon: history

Fév. 2004: support from the French Galaxy and Cosmology Programs.

Avr. 2004: support from the French Astroparticle Program
Funding of the mini-grid 105 k€ (INSU + IN2P3)

Juin 2004: Support from Paris University (Paris 6)
100 k€ grants for travel and equipment up to 2008

Sep. 2004: Kick-Off Meeting: 1st Horizon Workshop

Fév. 2005: support from the French Astronomy Program (INSU)
Funding of the meso machine 120 k€ (INSU) + 30 k€ (CEA)

Sep. 2005: HP provides the meso machine as "on demand computing" HPC1

Oct. 2005: 2 post-docs are funded from CNRS (Saclay, Obs. Paris)

Oct. 2005: support from the French Science Foundation (ANR)
500 k€ grants up to 2008 (including 3 post-docs)

Oct. 2005: Horizon is selected by DEISA with 27 other European projects
Mare Nostrum computer in the Barcelona Supercomputing Centre

Nov. 2005: 2nd Horizon Workshop

Projet Horizon: products

3 box sizes: **500, 100 and 20 h^{-1} Mpc**
Unique set of initial conditions: **4096^3, 2048^3, 1024^3, 512^3…**

3 types of simulations
- "periodic box"
- "zoom" on pre-identified halos
- "idealized" on pre-identified halos

Several types of models
- Pure N body + semi-analytics post-processing
- N body and gas dynamics "The Works"
- Isolated halo with prescribed boundary conditions

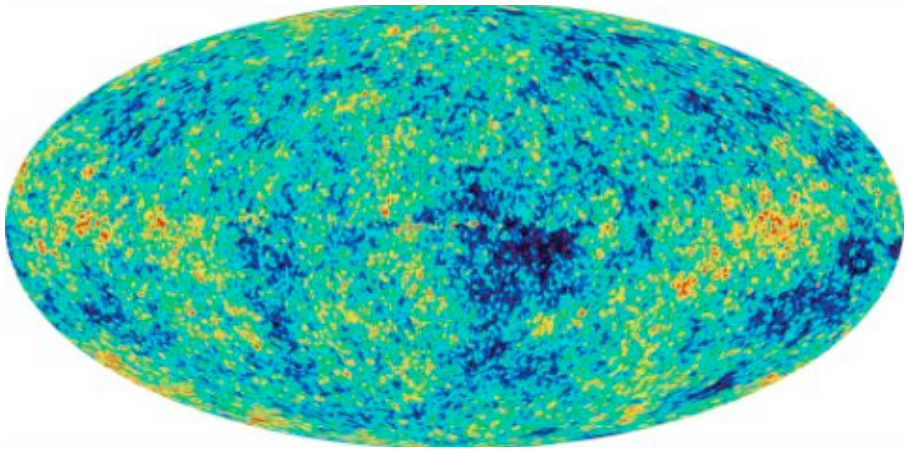
Several types of codes
- PM-AMR (RAMSES, ENZO, PMCOLL…)
- TREE-SPH (GADGET, MULTIZOOM…)
- …

Several "on line" outputs
- halos (sub-halos) and galaxy catalogs, merging trees
- "all-sky" or "patch" virtual images (γ, X, visible, IR, mm, radio)
- mock spectra and spectro- images
- "raw data", with images and movies

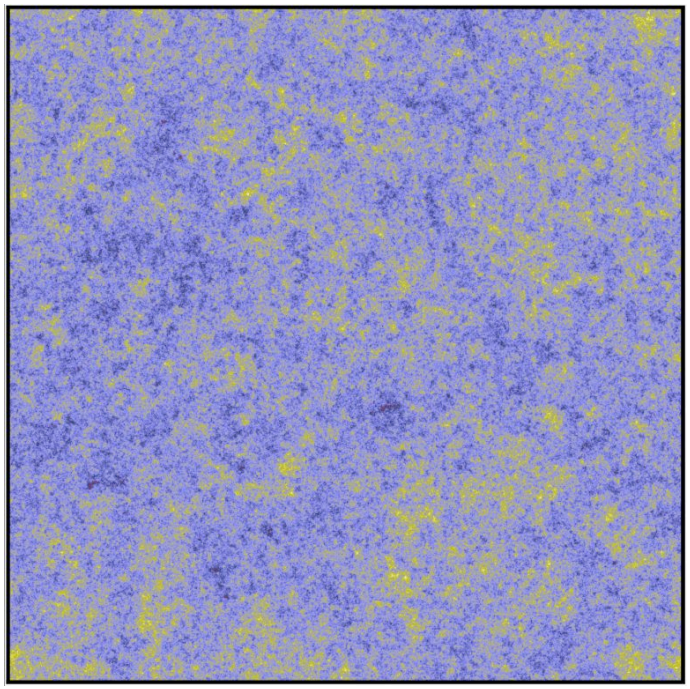
Initial conditions

From current cosmological constraints, generate density and 3-velocity (3-displacement) fluctuations. Analytical transfer function with “baryons wiggles”. 2 fluids ?

Standard procedure:
- generate white noise array in real space
- convolve by $\sqrt{P(k)}$ using FFTW



2D temperature map of the CMB observed by WMAP



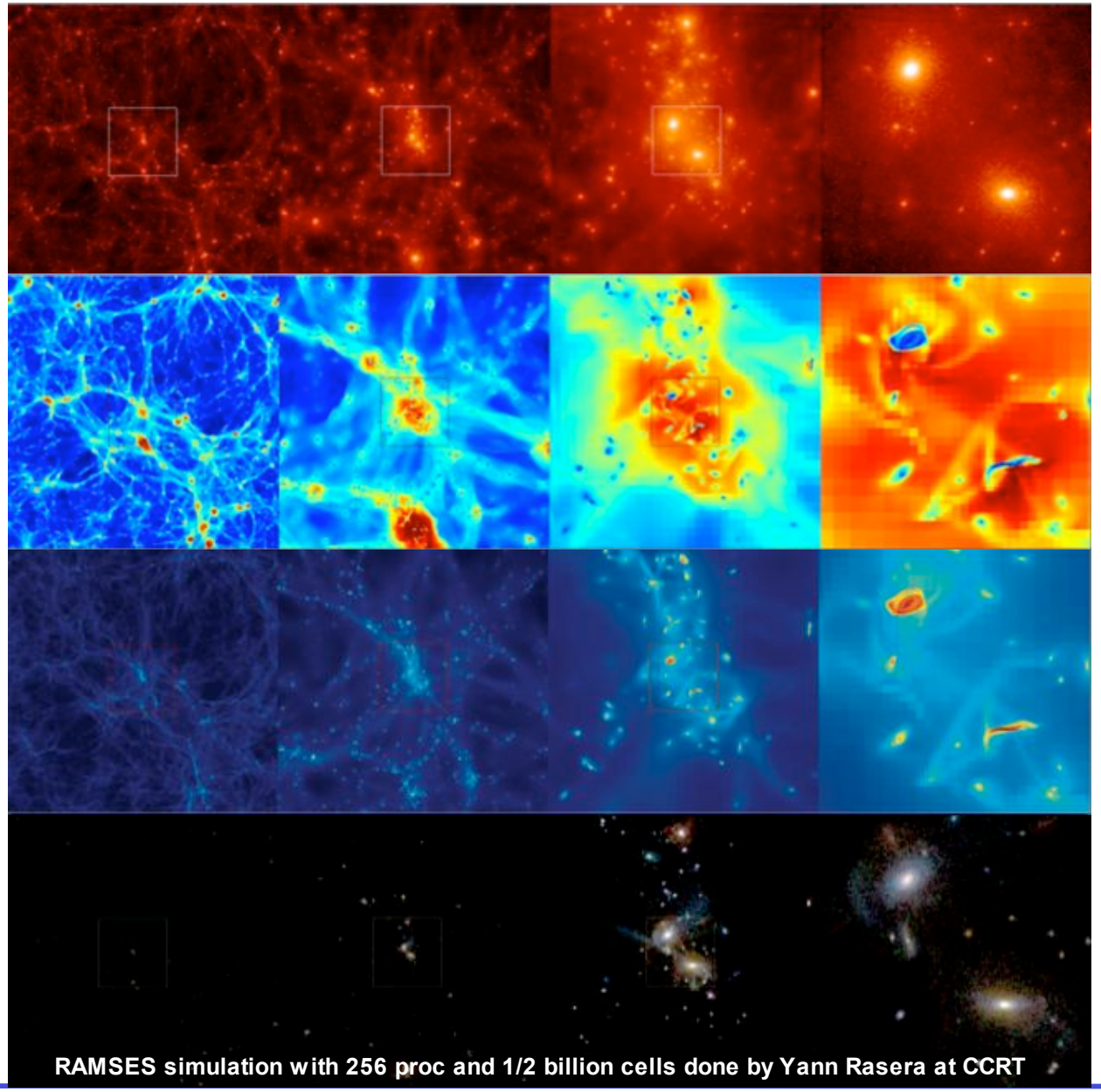
3D density field 2048^3 generated by MPgrafic
Aubert, Pichon, Prunet

Mare Nostrum IC from Yepes, Hoeft & Gottloeber
50 h^{-1} Mpc 2048^3 : 32 Gb per field

Horizon: 100 h^{-1} Mpc 4096^3: 256 Gb per field
Same white noise for 500 and 20 h^{-1} Mpc

Zoom initial conditions will be extracted from these 3 reference sets

Galaxy Formation in a 10 h^{-1} Mpc box @ z=3

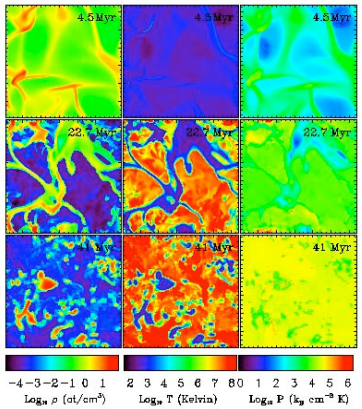


RAMSES simulation with 256 proc and 1/2 billion cells done by Yann Rasera at CCRT

Minimal physical model ?

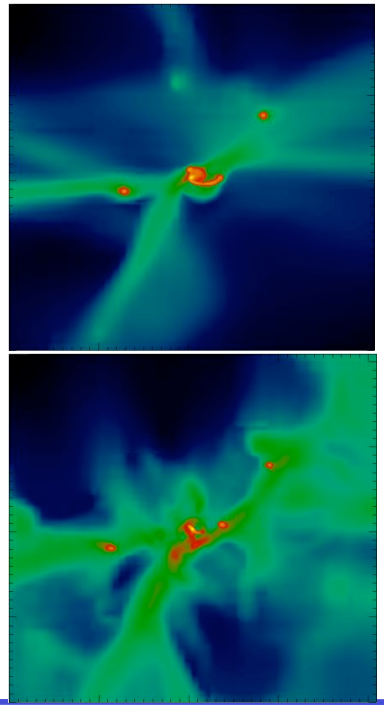
Metal dependant cooling and heating. **Radiative transfer ?**

Star formation within a multiphase/turbulent medium
$t_*=t_0(\rho/\rho_0)^{-1/2}$ for $\rho>\rho_0$ with t_0 =1-10 Gyr and n_0=0.01-0.1 cm^{-3}
Yepes et al., Springel & Hernquist
MHD ?
Supernovae heating: effective (polytropic) equation of state
$P_*=P_0(\rho/\rho_0)^{\gamma}$ for $\rho>\rho_0$ with T_0 =1-5x10^4 K. **Starburst ?**

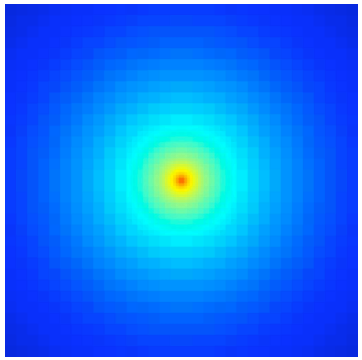


BGK simulation A. Slyz et al.

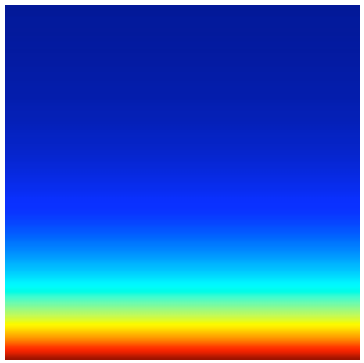
ENZO simulation
J. Devriendt



RAMSES simulation
Y. Dubois



AGN model and feedback ?
RAMSES simulation
A. Cattaneo



Galactic winds by supernovae kinetic feedback
- cooling delayed during t_d=10-100 Myr
- shrapnel (mass loading) deposited a few cells away
Superwinds ?

Massively parallel system in Europe

Clusters: Mare Nostrum (5th in Top500 list)

- 4 Gb nodes with 2 processors (IBM blades)
- Fast interconnect with Myrinet
- up to 2400 nodes !

Blue Gene: LoFar (6th in Top500 list)

- 2000 PowerPC 440 per rack and 6 racks (64 racks in the US !!)
- ultra-fast interconnect (tore 3D + fat tree)

Technical issues and constraints

- Parallel I/O and robustness
- Load balancing
- Data retrieval (internet access up to 20 Gb/s ?)

Prospectives

- PITAC report: **http://www.nitrd.gov/pitac/reports**
- Sartorius report:**http://www.recherche.gouv.fr/rapport/calcul/2005-017.pdf**
- European “Extreme Computing Initiative” and beyond…

Conclusion

Horizon: a 3-year computational project to study large scale structure and galaxy formation

Extreme computing in Europe: http://www.deisa.org 27 projects selected
1/2 of them are astronomy and 1/4 of them are computational cosmology
Mare Nostrum: Yepes *et al.*
Mare Nostrum: Horizon
Millenium: White *et al.*
…
LoFar: Joop Shaye *et al.*
Coordination-comparison-competition ?

Goal of this workshop: *set up the run parameter file !*
What are the current *outstanding* questions in galaxy formation ?
What physics need to be simulated ? **Minimum and Goal**
What simulations need to be performed ? **Minimum and Goal**

Agenda:
1. Mare Nostrum run before summer 2006: 10^{10} AMR cells
2. Other runs to come (winter 2006 and beyond)

End