The CLEF-SSH simulation project:
Modeling the SZ cluster population with radiative gas cooling and energy feedback

António da Silva
CMBnet postdoc
IAS, Orsay, France

20th IAP colloquium, Paris, 2nd July 2004

The CLEF-SSH simulation project:

(CLuster Evolution & Formation using Supercomputer Simulations with Hydrodynamics)

- **CLEF collaboration**: IAS, Orsay (FR) - LA2T, Toulouse (FR) - Sussex (UK) using existing French computing facilities.

- **Objectives:**
  - Perform large hydro simulations of LSS that include models of radiative cooling and energy feedback to study:
    - Cluster physics & scaling laws
    - Map making (e.g. SZ effect)

The CLEF-SSH simulation project:

(CLuster Evolution & Formation using Supercomputer Simulations with Hydrodynamics)

- **CLEF collaboration**: IAS, Orsay (FR) - LA2T, Toulouse (FR) - Sussex (UK) using existing French computing facilities.
- **Core Members:**
  - Antonio da Silva, IAS, (PI)
  - Nabila Aghanim, IAS
  - Jean-Loup Puget, IAS
  - Alain Blanchard, Toulouse
  - Rachida Sadat, Toulouse
  - Scott Kay, Univ. Sussex
  - Peter Thomas, Univ. Sussex
  - Andrew Liddle, Univ. Sussex
- **First proposal**: To CINES, Montpelier (PI: Antonio da Silva).
  - Designed as part of our contribution to the PLANCK WG5 (clusters and secondary anisotropies) simulation effort

The Planck WG5 workpackage breakdown:

5.5 Physical Simulations

5.5.1
- 5.5.1.1 perform hydro- sim- ulations of individual clusters
- 5.5.1.2 perform hydro- sim- ulations of large volumes
- 5.5.1.3 simulate SZ maps at full numerical resolution
- 5.5.1.4 simulate Planck observations of SZ maps

5.5.2
- 5.5.2.1 model cluster dist. in semi- analytic way
- 5.5.2.2 evaluate SZ power spectrum using SZ maps
- 5.5.2.3 assess feasibility of cluster velocity studies

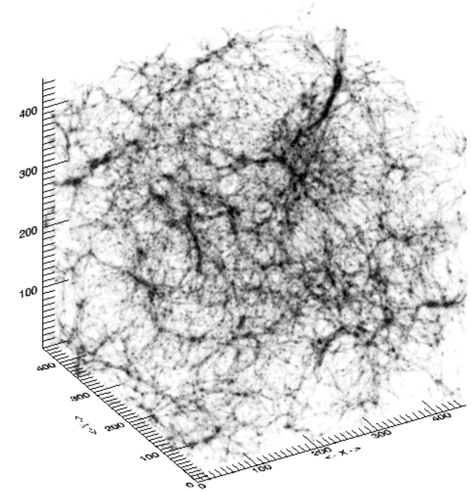
5.5.6
- 5.5.6.1 realistic modeling of ionisation history
- 5.5.6.2 simulate radiative transfer through IGM
- 5.5.6.3 simulate Planck observations in detail
- 5.5.6.4 investigate effect of systematics on science

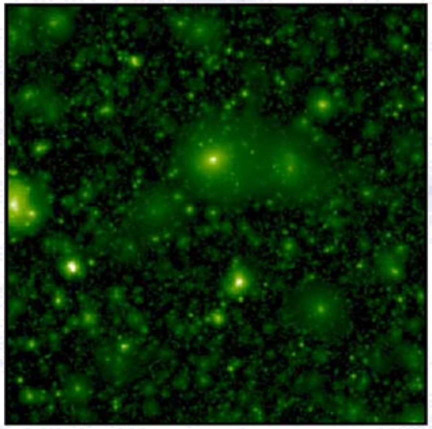
5.5.3
- 5.5.3.1 construct approx. template maps
- 5.5.3.2 update using large- scale N- body simulations
- 5.5.3.3 update using large- scale hydro simulations
- 5.5.3.4 include contamin- ating effects
- 5.5.3.5 simulate X- ray and optical cluster props.
- 5.5.3.6 model selection functions using observations
- 5.5.3.7 develop tools for cluster extraction from data

5.5.5
- 5.5.5.1 perform N- body sim- ulations of large- scale struct.
- 5.5.5.2 construct 3- dim. cluster catalogues
- 5.5.5.3 simulate observable cluster signatures
- 5.5.5.4 apply and test cluster- detection algorithms
- 5.5.5.5 combine with high- res. hydro cluster sims.
- 5.5.5.6 select, develop, and supply required tools

First simulation: the CLEF run1

- **Cosmology:** Flat Lambda CDM model with:
  - $\Omega_m=0.3$; $\Omega_\Lambda=0.7$; $\Omega_b=0.0486$; $\sigma_8=0.9$; $h=0.7$
- **Simulation details:**
  - L=200 Mpc/h ; 2(428)^3 (156 Million) particles (mgas =7e9Msun/h; mdark=1.4e10Msun/h); Soft.= 20kpc/h
  - Radiative cooling and energy feedback (Kay 2004)
- **Simulation code:**
  - A parallel version of GADGET II (Springel, Yoshida & White, 2001), PM-Tree code with SPH.
- **System resouces:**
  - 66000 CPU hours (SGI R14K); 0.5 Tb of data
- **Permits to obtain:**
  - extensive cluster catalogues (4000 objects @ z=0 resolved with at least 1000 particles each).
  - Maps of 5 deg^2. In a second step: 10deg^2

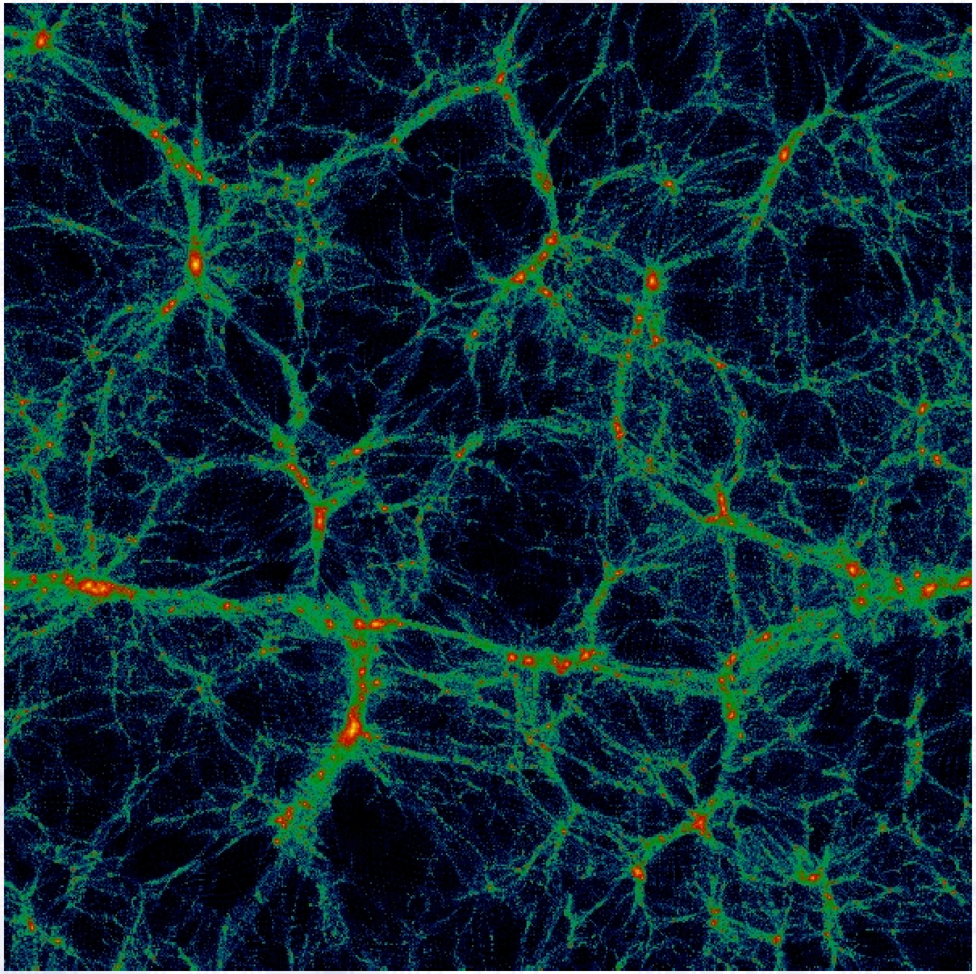




First glimpse at the CLEF run:

- **CLEF collaboration**: IAS (FR) - Toulouse (FR) - Sussex (UK) using French system CINES
- **Objectives:** Perform high resolution simulations to study:
  - Cluster physics & scaling laws
  - Map making (e.g. SZ effect)
- **First run:**
  - L=200 Mpc/h ; 2(428)^3 particles
  - Radiative cooling and energy feedback (Kay 2004)
  - GADGET (Springel, Yoshida & White, 2001). Tree-SPH code
- **Permitted to generate**:
  - extensive cluster catalogues (4000 objects @ z=0 resolved with at least 1000 particles each).
  - Maps of 5-10 deg^2

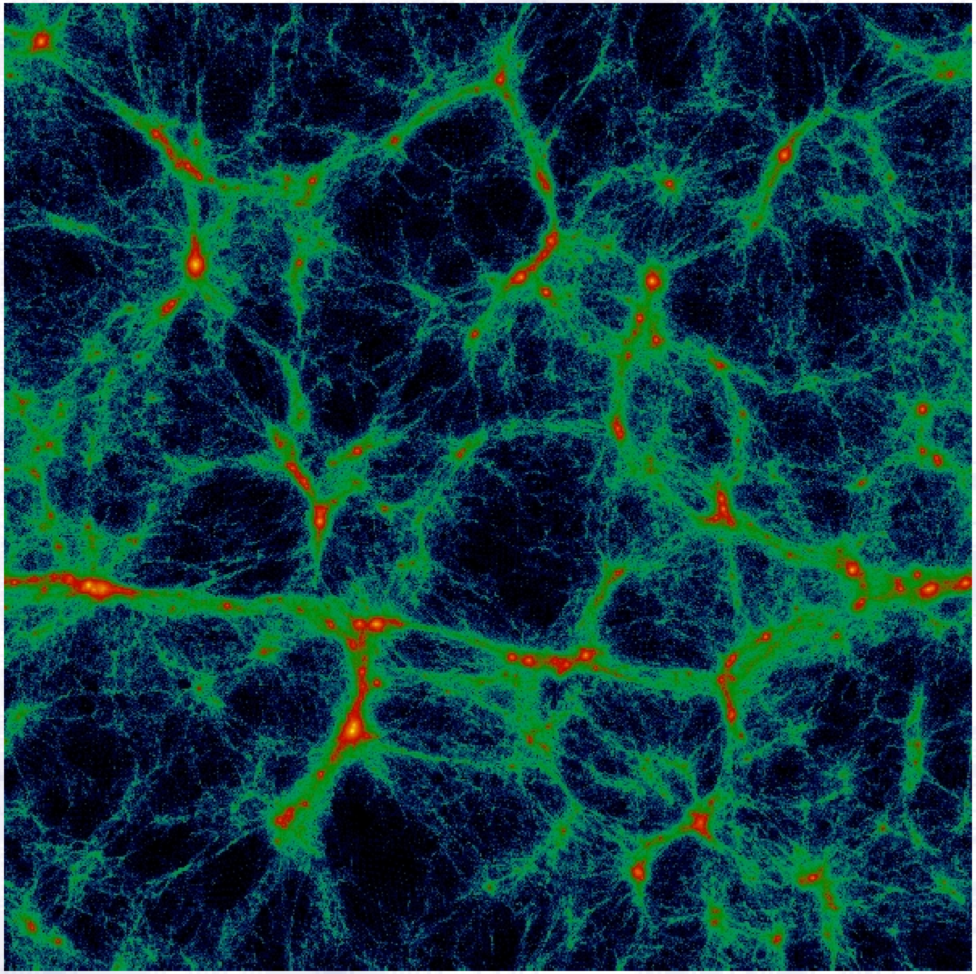
Dark matter



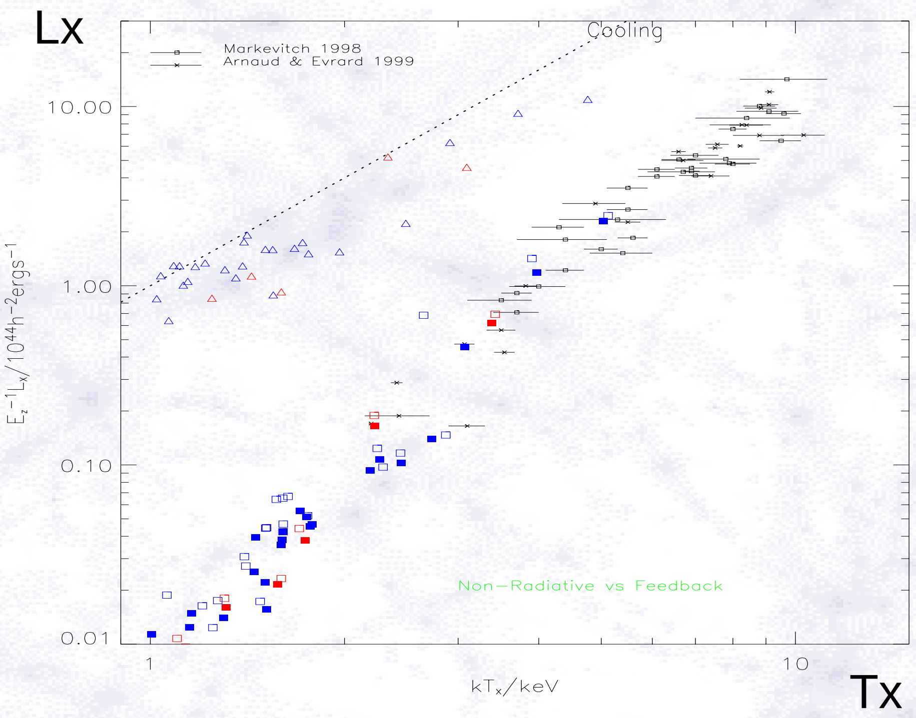
First glimpse at the CLEF run:

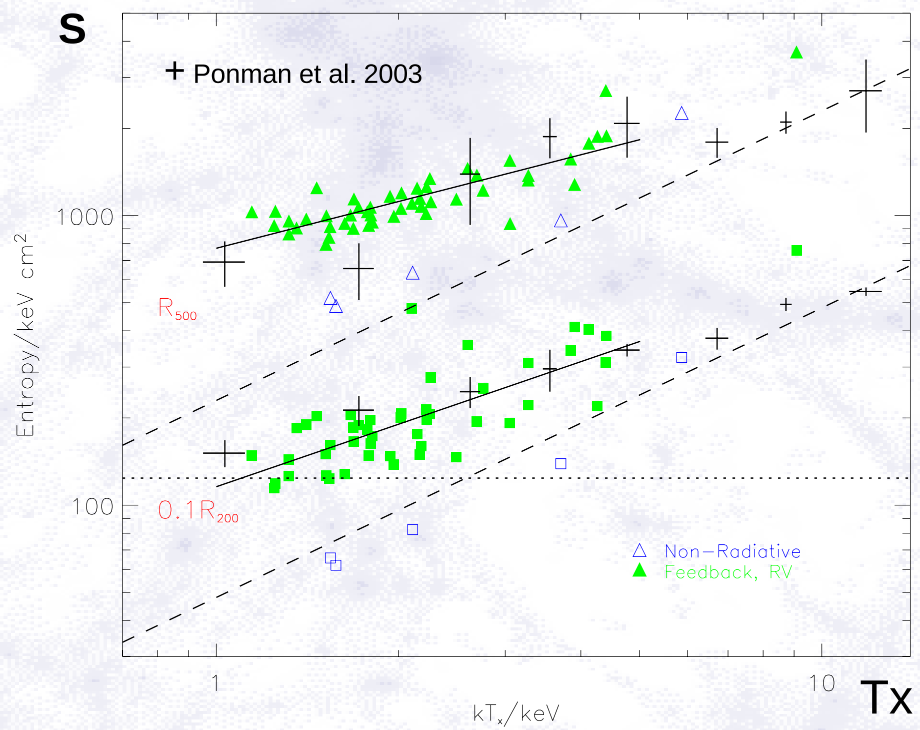
- **CLEF collaboration**: IAS (FR) - Toulouse (FR) - Sussex (UK) using French system CINES
- **Objectives:** Perform high resolution simulations to study:
    - Cluster physics & scaling laws
    - Map making (e.g. SZ effect)
- **First run:**
    - L=200 Mpc/h ; 2(428)^3 particles
    - Radiative cooling and energy feedback (Kay 2004)
    - GADGET (Springel, Yoshida & White, 2001). Tree-SPH code
- **Permitted to generate**:
    - extensive cluster catalogues (4000 objects @ z=0 resolved with at least 1000 particles each).
    - Maps of 5-10 deg^2

Baryonic gas



Results from test runs: (fheat=0.1, Sheat=1000 keV cm2)





•2 parameter energy feedback model (S. Kay 2004) : fheat, Sheat

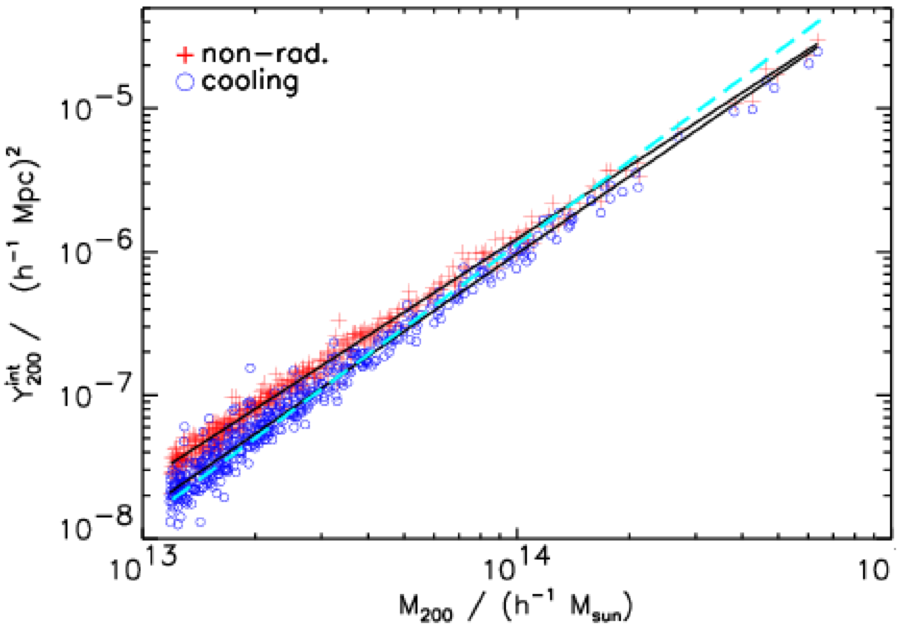
Cold dense gas particles (T<1e5, n>1e-3 cm^-3) have fheat probability of being heated up with an entropy Sheat.

- Draw random 0<r<1 (uniform dist.) for each gas particles with T<1e5, n>1e-3 cm^-3
- If r<fheat then reheat particle by the fixed entropy Sheat
- If r>fheat then convert particle to colisionless baryonic material

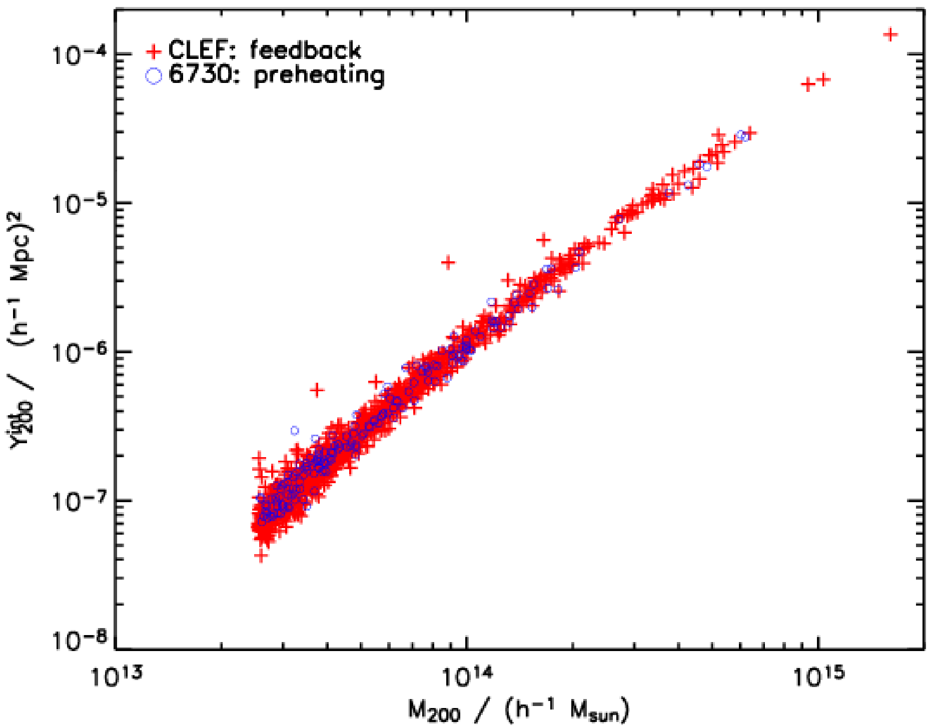
- **fheat**: Largely controls the amount of cooled gas fraction
- **Sheat**: determines de amount of energy feedback

Preliminar results: SZ scaling laws @ z=0

da Silva et al 2003



CLEF Y-M results



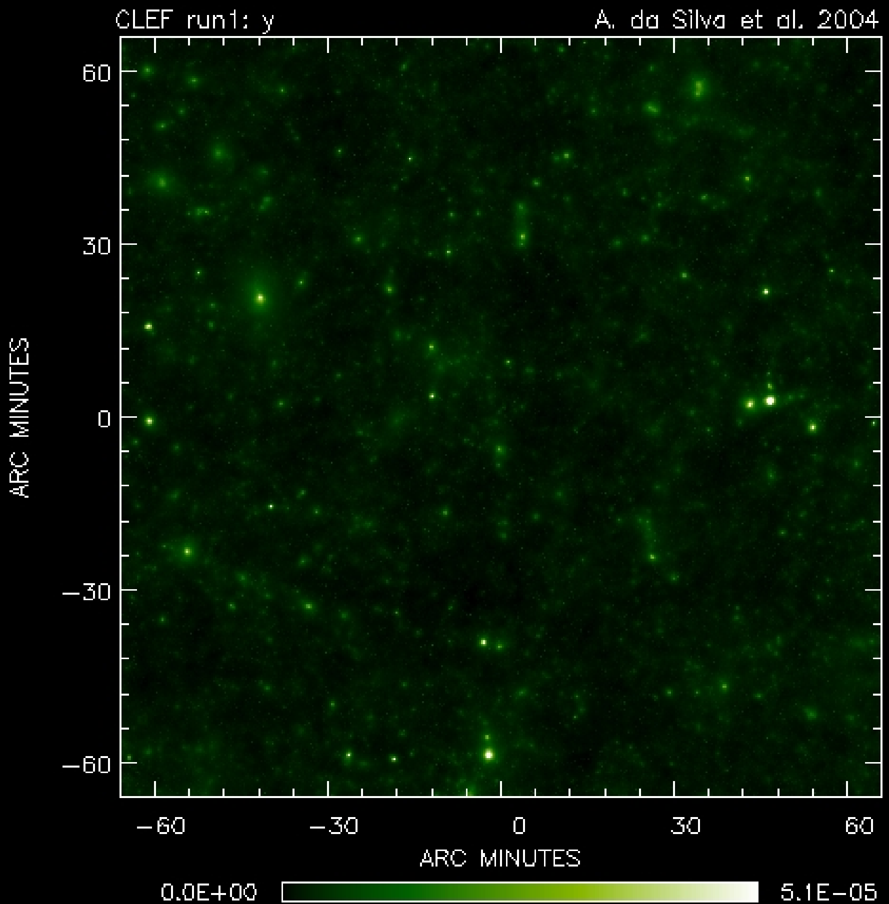
$$Y \propto f_{\rm gas} M\, T_{\rm mw}\, d_A^{-2} \propto f_{\rm gas} M^{5/3}\, d_A^{-2}(1+z)$$

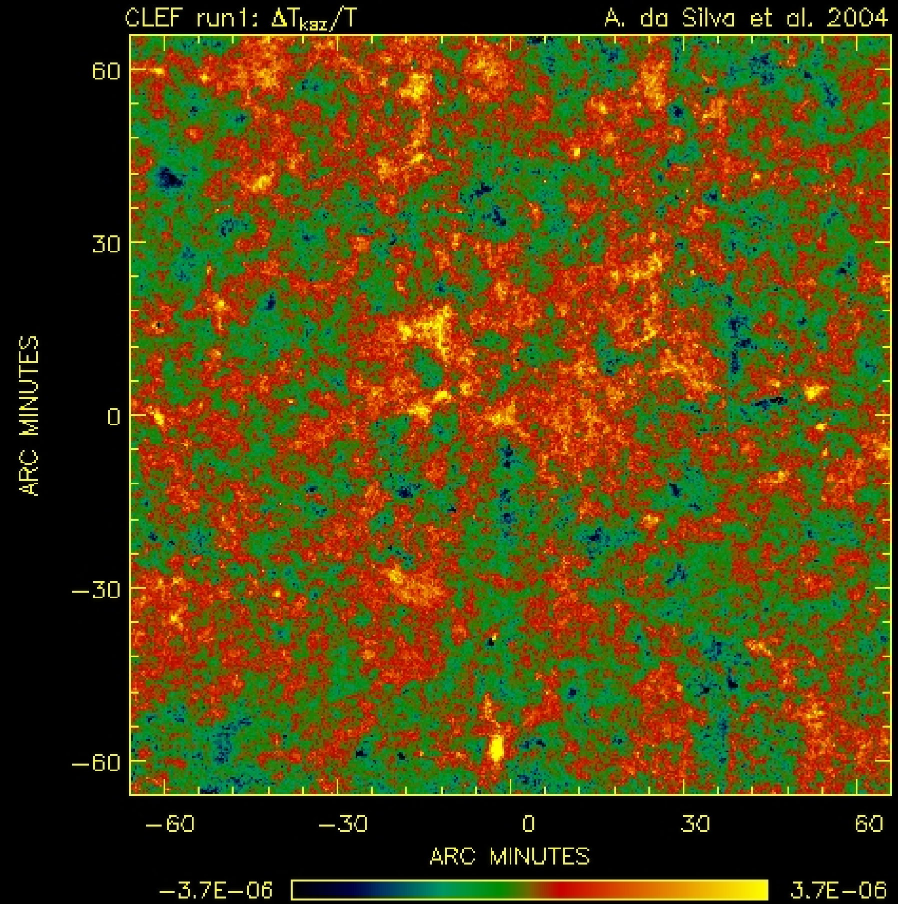
$$Y \propto M^{5/3} \propto T^{5/2} \propto L_X^{5/4}$$

Non_radiative	slope = 1.69
Radiative	slope = 1.79
Preheating	slope = 1.93

Energy feedback slope = 1.95

Preliminar results: 5 deg^2 SZ maps





ymean = 3.23 E-6; Sigma_y = 1.96 E-6

Sigma_k = 9.65 E-7

Concluding remarks:

Cluster scaling laws from hydrodynamical simulations:

- Radiative gas physics (Cooling and energy feedback) has non negligible impact in cluster scaling relations and the SZ effect.
- The magnitude of these effects is not yet well understood and need to be properly assessed with hydro sims. for preparing and interpreting future SZ/CMB observations, such as PLANCK .
- Larger simulations with high-resolution are most welcome! They permit to derive cluster scaling laws in wider mass ranges, with improved statistics.

Hydro maps:

- High-resolution SZ hydro maps are the most powerful tool for studying selection effects of deep surveys (high-angular resolution), complementarity between different observational strategies,…
- So far these maps have been limited to small sky areas (1 deg), which are too small for large beam experiments as PLANCK
- The CLEF run will permit to obtain a maximum 10deg^2 (unprecedented for hydro simulations with cooling and energy feedback)!