The structure of the ICM in cosmological simulations

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Hutt (High resolution Cluster set)

48 Haloes ($> 0.7 \times 10^{14} M_{\text{sol}}$), up to $4 \times 10^6$ Particles in $R_{\text{vir}}$

- DM-only (dm)
- none radiative gas (gas)
- cooling+starformation+winds (csf)
- no/week/strong winds (csfnw, csf, csfsw)
- thermal conduction (csfc)
- new scheme to avoid damping of turbulence (gas_nv)
- Metals and chemical enrichment
  ⇒ talk of Luca Tornatore on "chemical enrichment"
The revenge of the ICM

The presence of gas changes dynamics and profiles!

- Strong lensing cross section decreases for none radiative gas with strong turbulence (e.g. none thermal pressure)
- Increases strongly for cooling and star formation.

Structure of the ICM

Mass weighted temperature vs. emission weighted temperature! 
⇒ Predicted calibration depends on physics included!
Structure of the ICM

Emission is complex, mixture of dynamic & physical processes!
Shape crucial for interpretation of global quantities!

Dolag et al. (in prep.)
Structure of the ICM

Mass weighted temperature vs. with of the gaussian fit!
⇒ Correlated, but physics, e.g. thermal conduction!
Diagnostic of a Merger

Deviation from gaussianity contain information about dynamics!
Single and double gaussian fit to the emission distribution.
⇒ with of gaussian not necessarily related to with of distribution!
Diagnostic of a Merger

Time evolution of Mass, Temperature and Mach-number.

⇒ High Mach number related to outgoing shock!

(Mach number by Pfrommer et al, in prep.)
Evolution of single and double Gaussian fit during merger. ⇒ no clear signal for high temperature tail in gas!
Diagnoistic of a Merger

Evolution of single and double Gaussian fit during merger.
⇒ double gaussian fit reveals substructure activity!
Turbulence in the ICM

Old viscosity scheme

New viscosity scheme

Artificial viscosity completely switched off outside of shocks!

- Instabilities less damped (e.g. Kelvin-Helmholtz).

⇒ Inset of turbulence

⇒ Enlarged energy-fraction in gas velocity

Turbulence in the ICM

Turbulence can leave to significant pressure support! 
⇒ Can change $L_x$ up to a factor of 2!
Turbulence in the ICM

Unsharpened masked: image - smoothed(image, 200kpc)
2Mpc x 2Mpc x-ray emission of $gI$ comparing the two viscosity schemes.
Turbulence in the ICM

Unsharpened masked: image - smoothed(image, 200kpc) 2Mpc x 2Mpc pressure map (e.g. SZ) of $gI$ comparing the two viscosity schemes.
Turbulence in the ICM

Due to large contribution of bulk motions and beam smearing, the imprint of "true" turbulence will be hard to detect, even resolution like Astro-E2!
Leia (Large filament Simulation)

27 Haloes ($> 0.7 \times 10^{14} M_{\odot}$), same resolution than Hutt

- DM-only (dm)
- none radiative gas (svisc)

Dolag et al. 2005, submitted
Density dominates over sheets till $\approx 5$ Mpc.
Higher temperature in the outskirts / towards voids.
The Filament
The Filament

Radial density profile along the filament.
Filament \( \propto r^{-2} \), Cluster \( \propto r^{-3} \), Outskirts steeper (\( \propto r^{-4} \)?)
The Filament

Radii for different density thresholds along the filament. ⇒ Cluster felt at ≈ 15 Mpc, region of influence 3-5 $R_{vir}$ !?
Conclusions

**Emission distribution**

- ICM in Complex state, depend on dynamics and physics
- Diagnostic by modelling reveals interesting details

**Turbulence**

- Modelling needs sub grid physics
- Potentially very interesting ($L_x, \kappa, \vec{B}, CR, \ldots$)

**Filaments**

- Direct detection only by over-density of haloes (4-6)
- Total contribution can change $L_x$ ($\approx 10\%$) and $SZ$ ($\approx 30\%$)
- Cluster environment starts at $3-5 R_{vir}$
- Density within filament $\propto r^{-2}$
Galaxy clusters as physics laboratory:

- Lots of Dark Energy?
- Stars
- WHIM
- EUV excess?
- Radio Emission
- Thermal Emission
- Lots of Dark Matter
- Radio Ghosts
- hard/soft X-Ray
- Turbulence
- Some Baryonic Matter
- Sharp Edges (cold fronts!)
- Thermal Conduction
- Cooling

Do we understand our "world"!?
Dark Energy, observed $c$
Dark Energy, observed $c$

Comparison with results obtained from numerical simulations within different cosmologies (from Dolag et al. 2004).