Literature on which the following results are based:

- Pfrommer, 2008, MNRAS, in print, ArXiv:0707.1693, *Simulating cosmic rays in clusters of galaxies – III. Non-thermal scaling relations and comparison to observations*
- Pfrommer, Enßlin, Springel, 2008, MNRAS, in print, ArXiv:0707.1707, *Simulating cosmic rays in clusters of galaxies – II. A unified scheme for radio halos and relics with predictions of the* γ*-ray emission*
- Pfrommer, Enßlin, Springel, Jubelgas, and Dolag, 2007, MNRAS, 378, 385, *Simulating cosmic rays in clusters of galaxies – I. Effects on the Sunyaev-Zel'dovich effect and the X-ray emission*
- Pfrommer, Springel, Enßlin, Jubelgas 2006, MNRAS, 367, 113, *Detecting shock waves in cosmological smoothed particle hydrodynamics simulations*
- Enßlin, Pfrommer, Springel, and Jubelgas, 2007, A&A, 473, 41, *Cosmic ray physics in calculations of cosmological structure formation*
- Jubelgas, Springel, Enßlin, and Pfrommer, A&A, in print, astro-ph/0603485, *Cosmic ray feedback in hydrodynamical simulations of galaxy formation*

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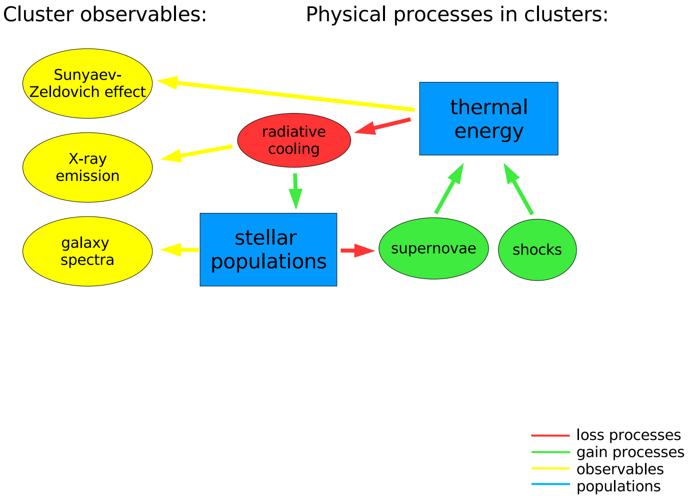
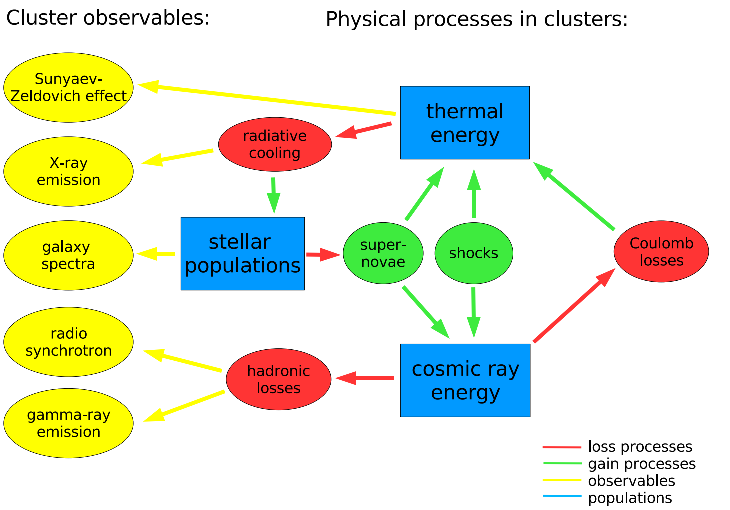
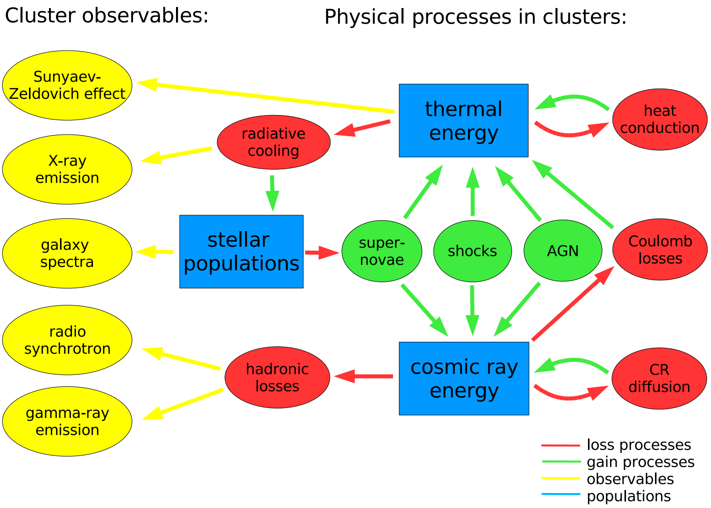
Radiative simulations – flowchart



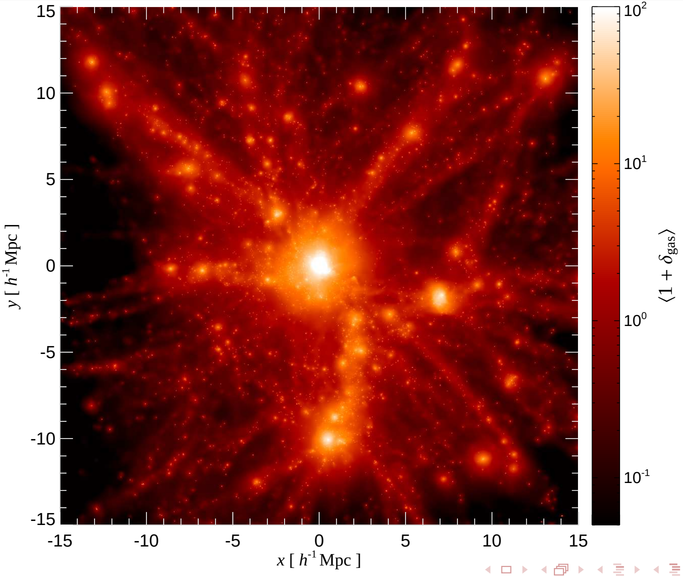
Radiative simulations with cosmic ray (CR) physics



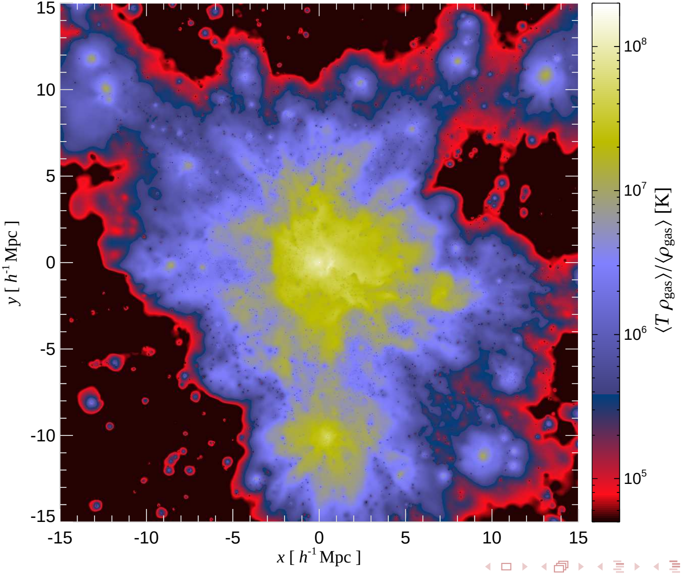
Radiative simulations with extended CR physics



Radiative cool core cluster simulation: gas density



Mass weighted temperature



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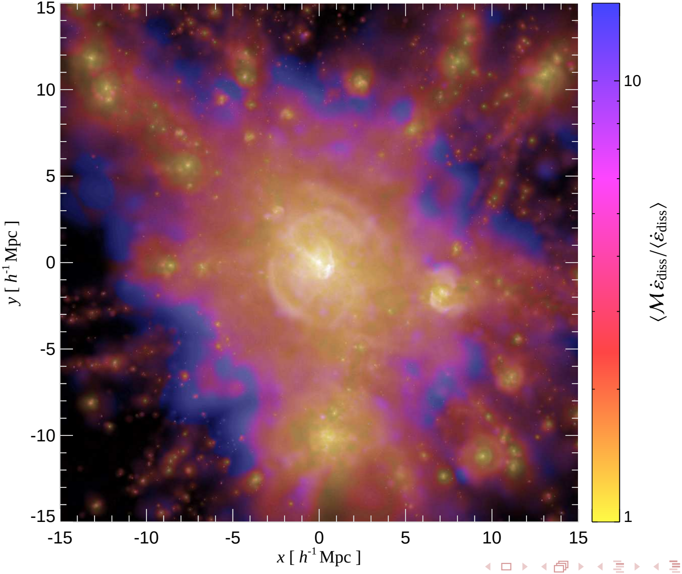
Mach number distribution weighted by $\varepsilon_{\rm diss}$



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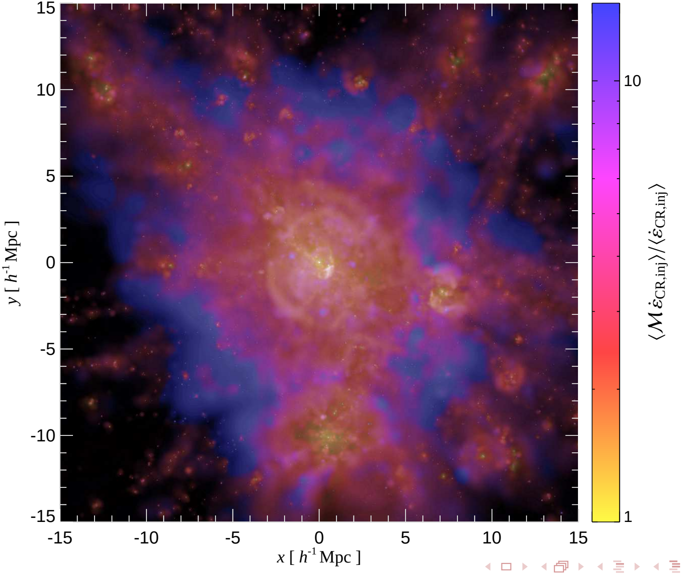
Mach number distribution weighted by $\varepsilon_{\mathrm{CR,inj}}$



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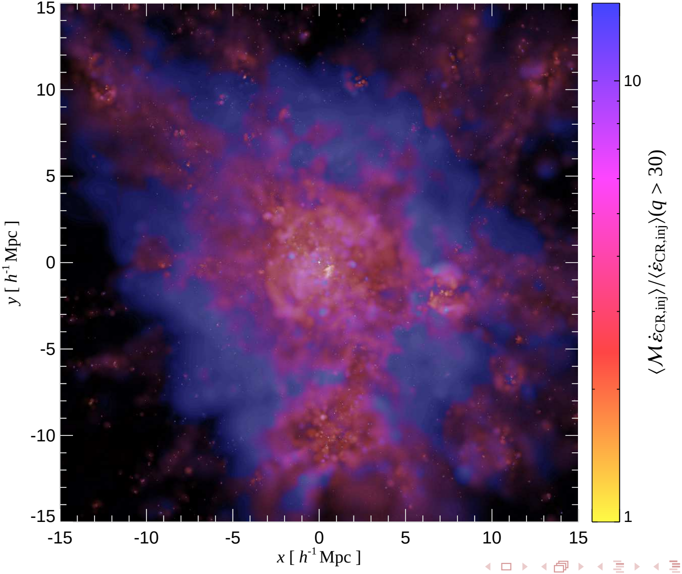
Mach number distribution weighted by $\varepsilon_{\mathrm{CR,inj}}(q > 30)$



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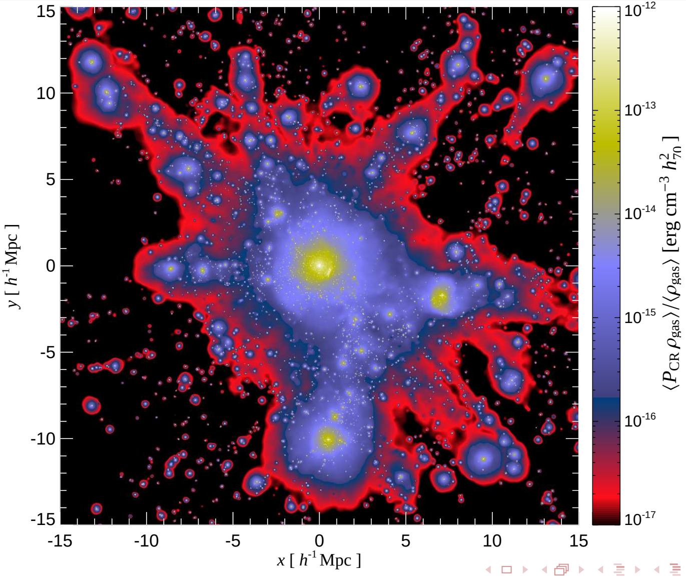
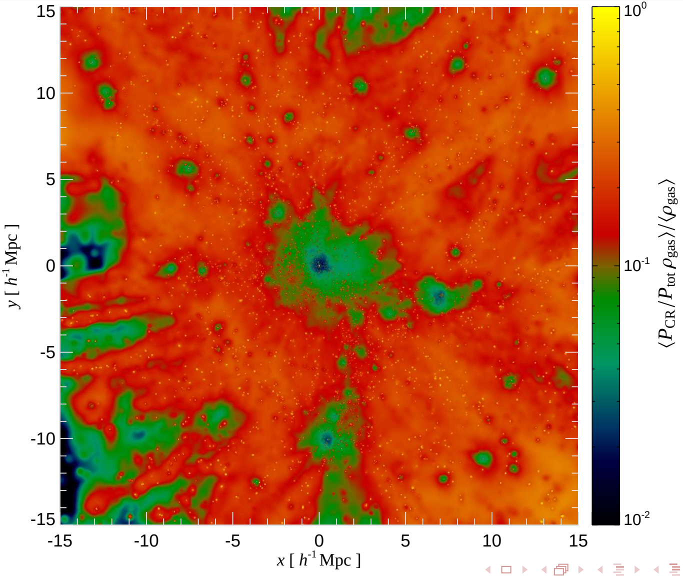
CR pressure P_{CR}



Relative CR pressure $P_{\mathrm{CR}}/P_{\mathrm{total}}$



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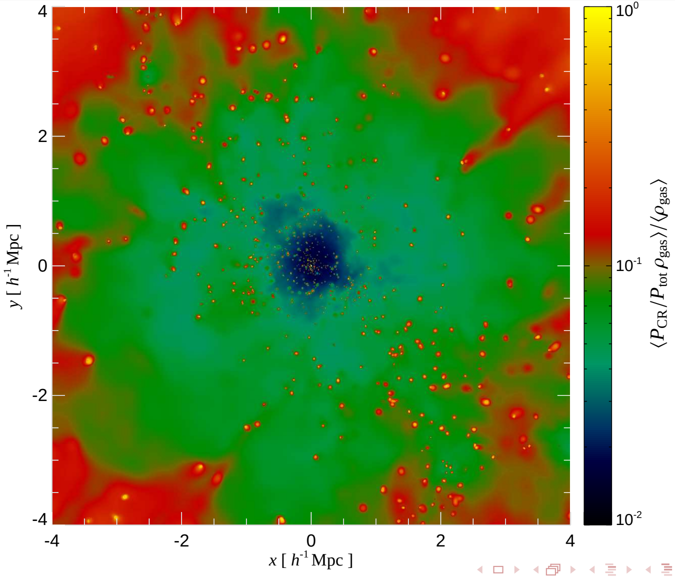
Relative CR pressure $P_{\rm CR}/P_{\rm total}$



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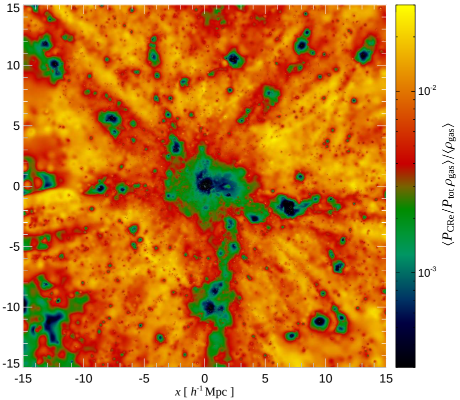
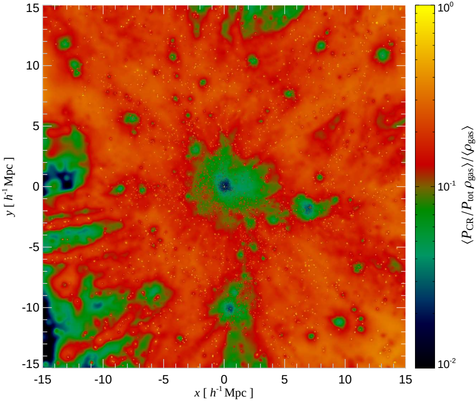
CR electron versus CR proton pressure



Relative pressure of primary CR electrons.



Relative pressure of CR protons.

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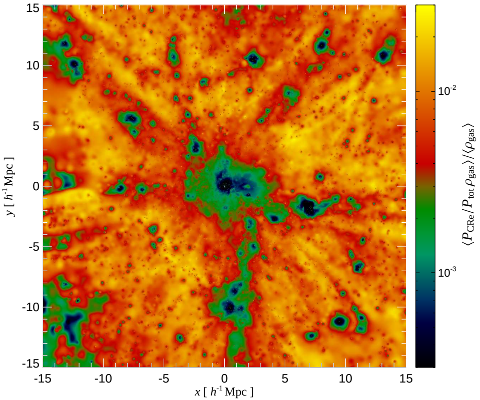
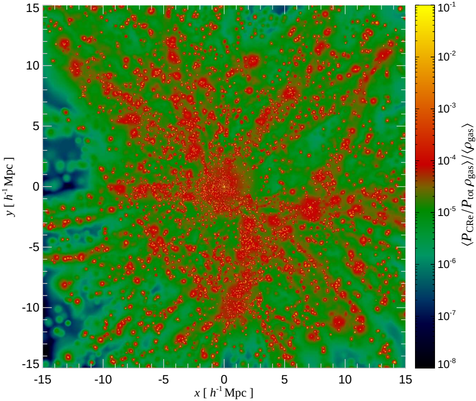
Primary versus secondary CR electrons



Relative pressure of *primary* CR electrons.



Rel. pressure of *secondary* CR electrons.

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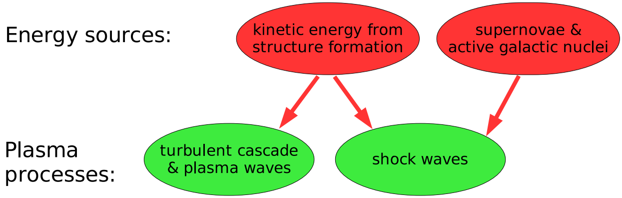
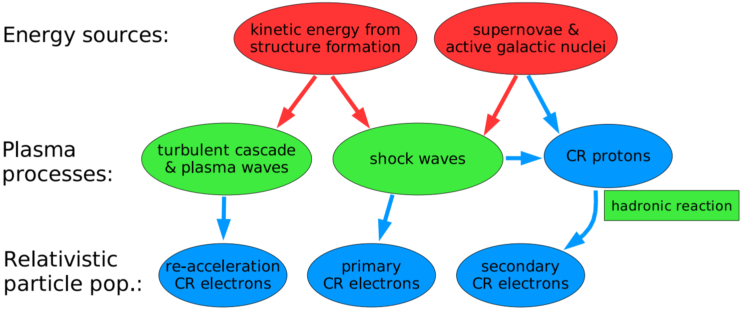
Cosmic rays and radiative processes

Relativistic populations and radiative processes in clusters:



Cosmic rays and radiative processes

Relativistic populations and radiative processes in clusters:



Cosmic rays and radiative processes

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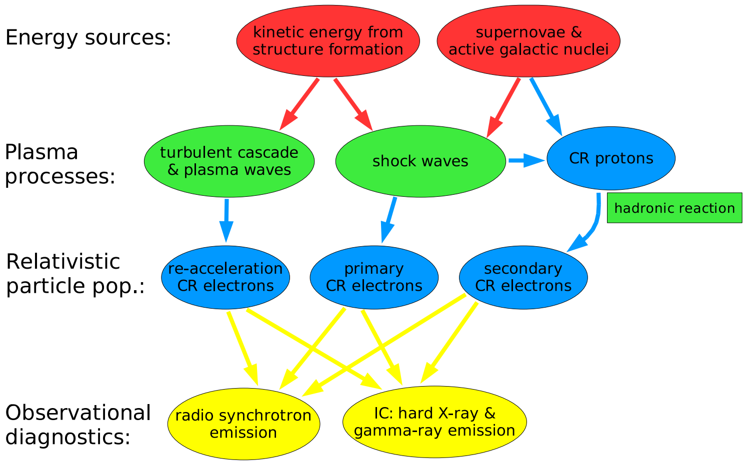

Cosmic rays and radiative processes

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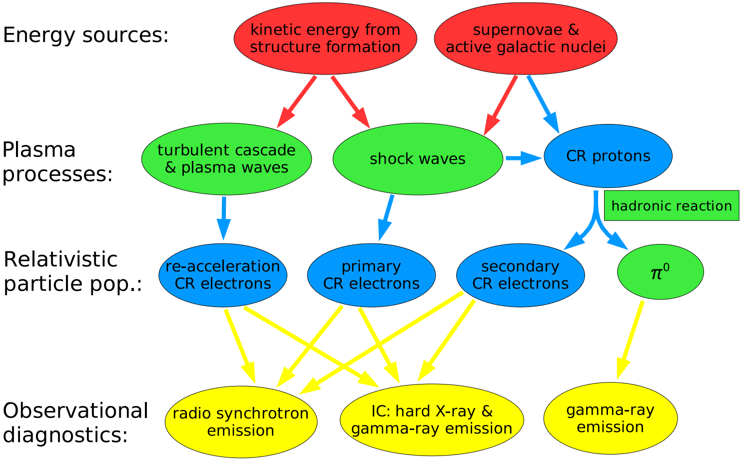

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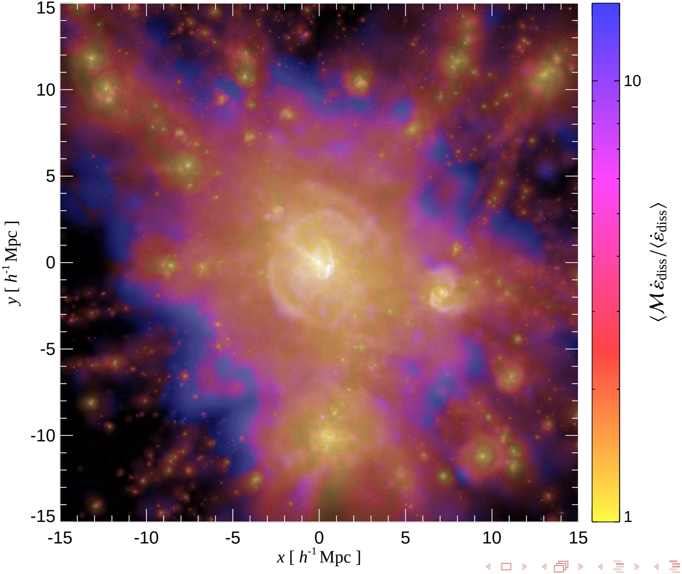
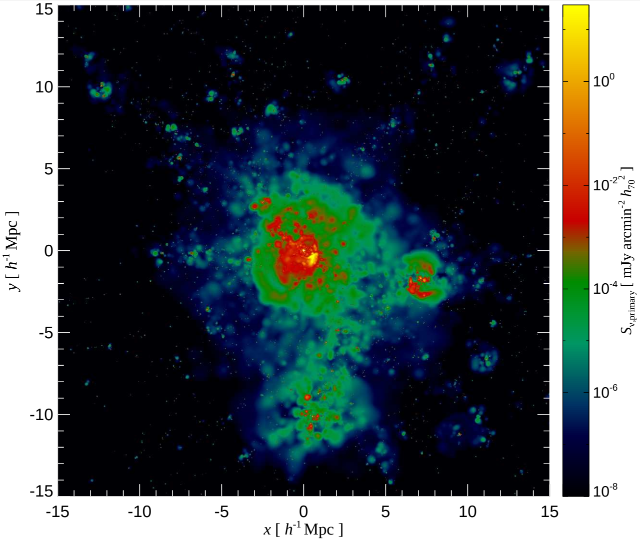
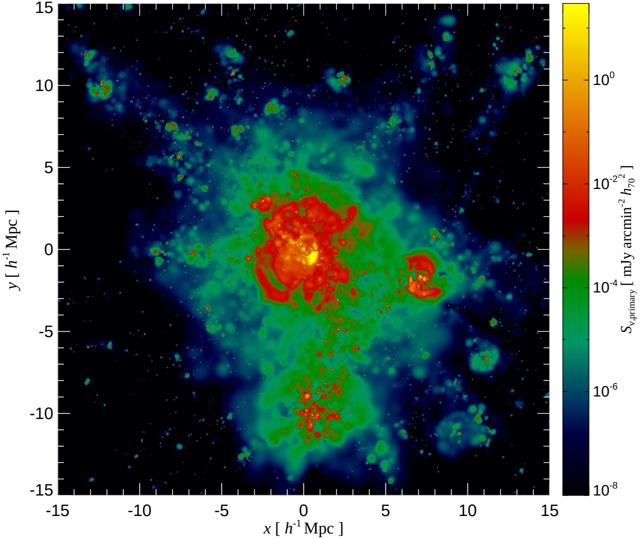
Cosmic web: Mach number



Radio web: primary CRe (1.4 GHz)



Radio web: primary CRe (150 MHz)



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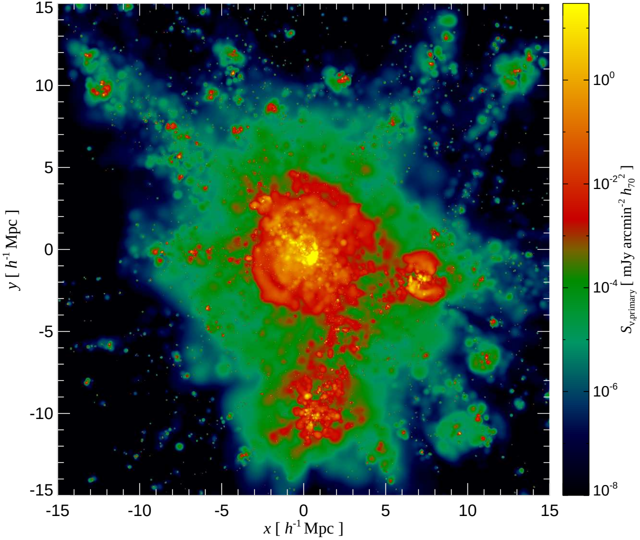
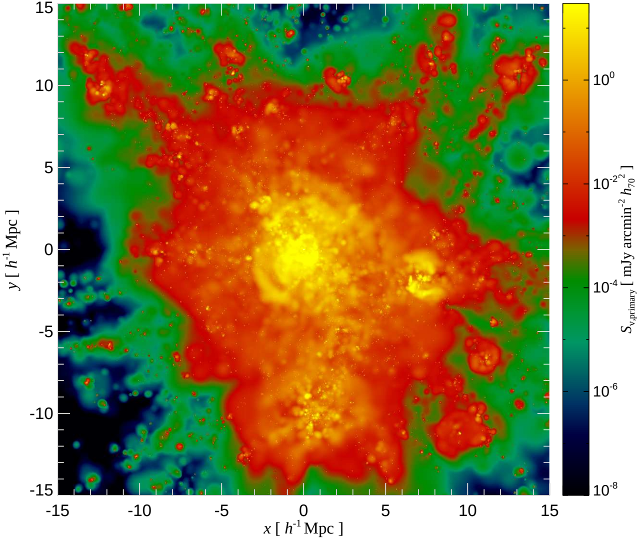
Radio web: primary CRe (15 MHz)



Radio web: primary CRe (15 MHz), slower magnetic decline



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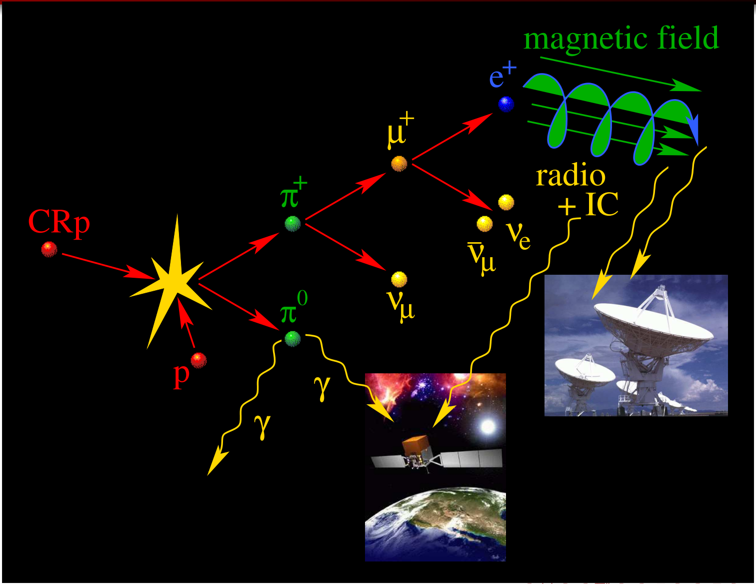
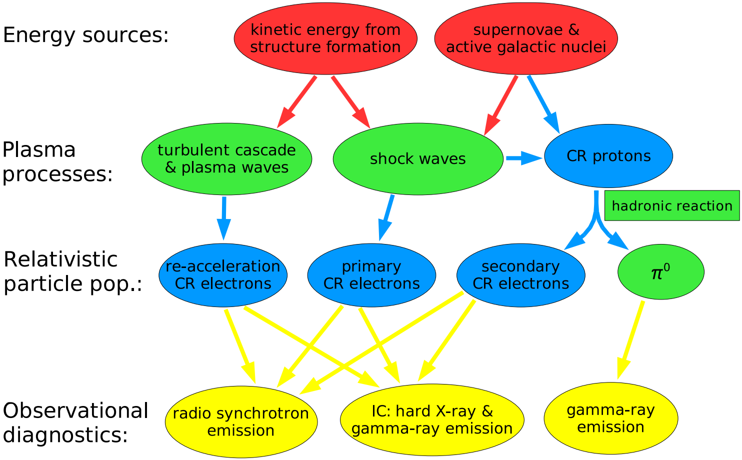
Hadronic cosmic ray proton interaction

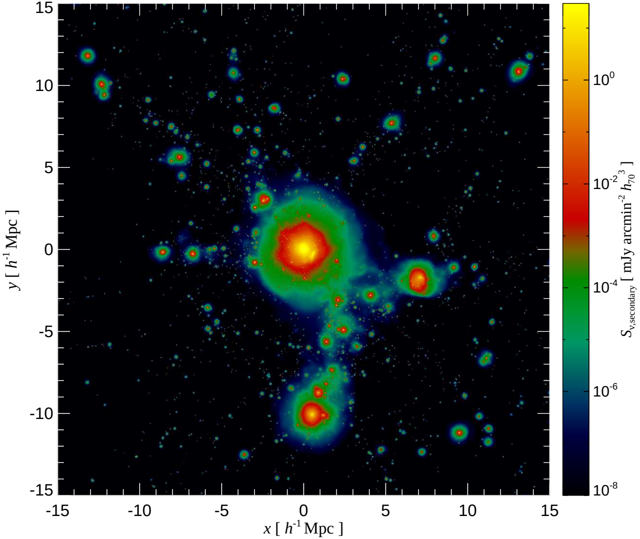


Cosmic rays and radiative processes

Relativistic populations and radiative processes in clusters:



Radio halos: secondary CRe (150 MHz)



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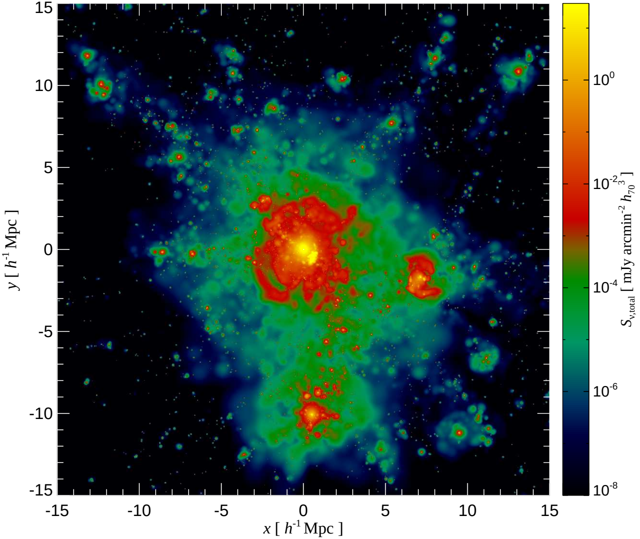
Radio relics + halos 150 MHz



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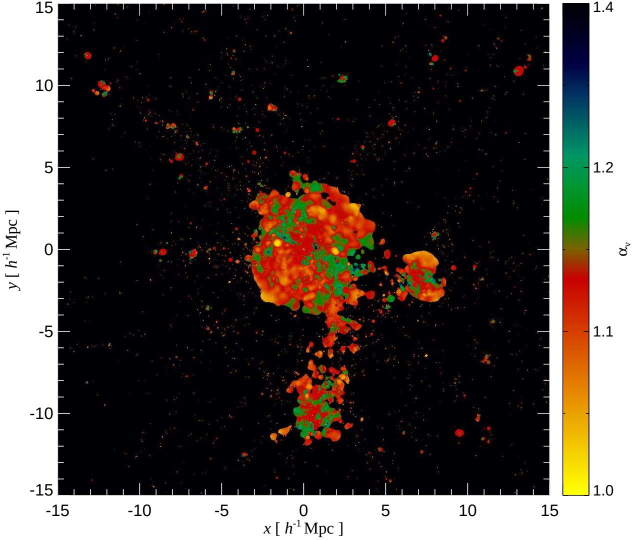
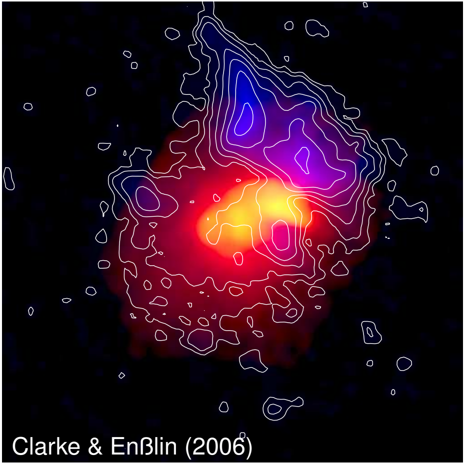
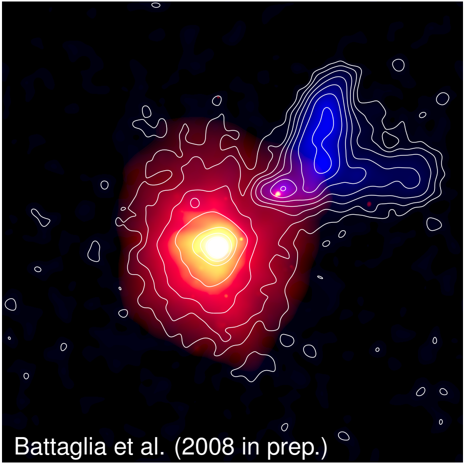
Radio relics + halos: spectral index



Comparison of simulation vs. observation of A2256





red/yellow: thermal X-ray emission,
blue/contours: 1.4 GHz radio emission with giant radio halo and relic

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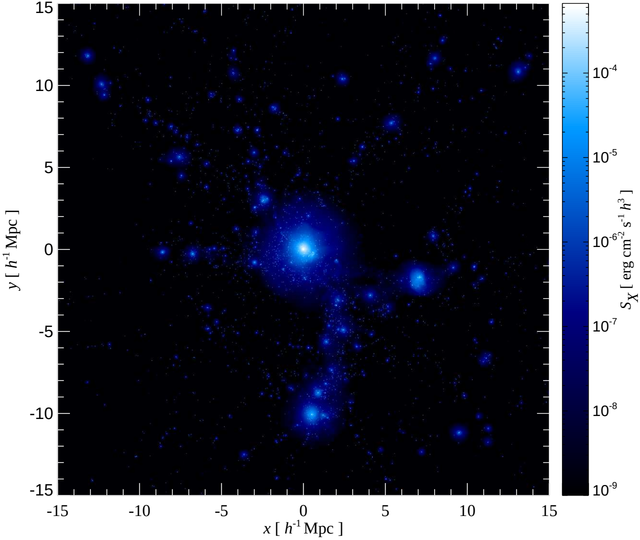
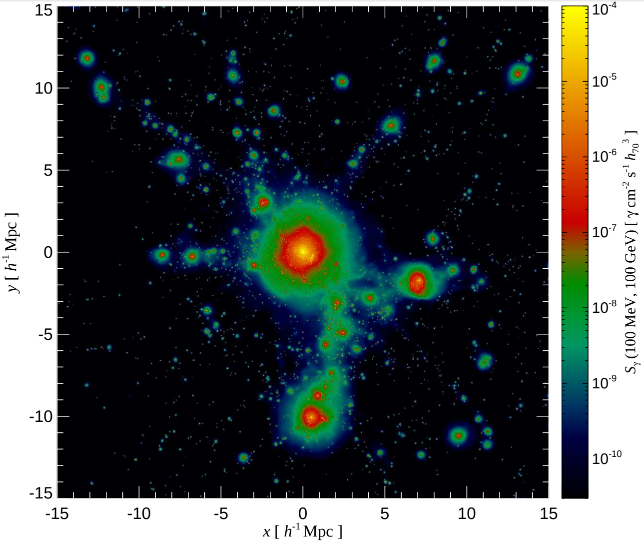
Thermal X-ray emission



Hadronic γ-ray emission, $E_\gamma > 100$ MeV



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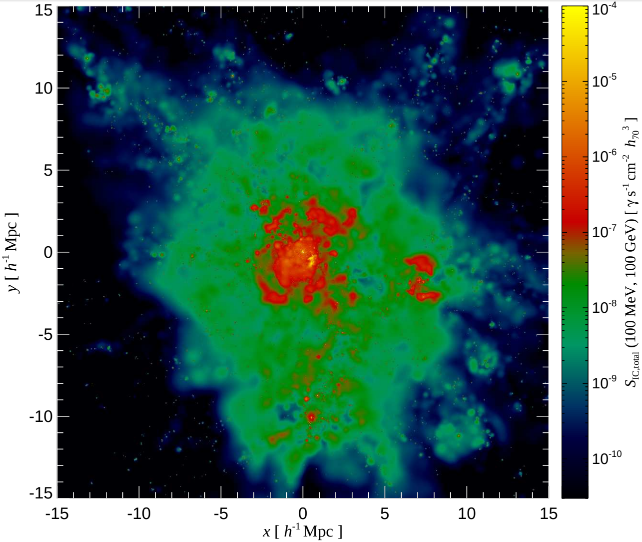
Inverse Compton emission, $E_{\mathrm{IC}} > 100$ MeV



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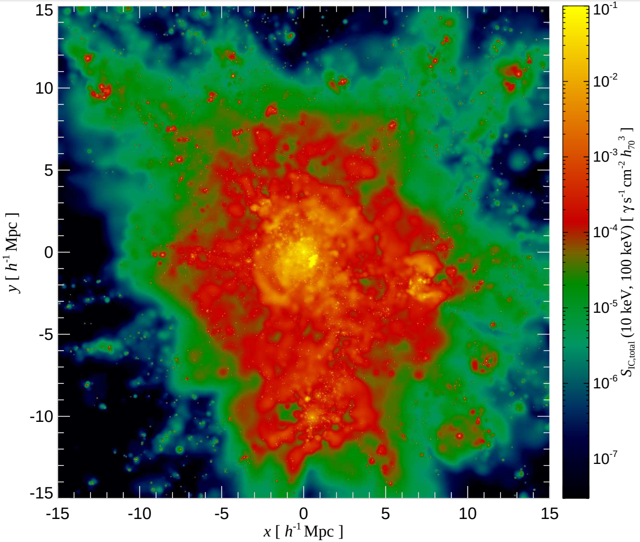
Inverse Compton emission, $E_{\mathrm{IC}} > 10$ keV



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Summary

1. Characteristics of the CRs in clusters:
   - CR proton pressure: time integrated non-equilibrium activities of clusters, modulated by recent mergers.
   - Primary CR electron pressure: resembles current accretion and merging shocks in the virial regions.
2. Non-thermal cluster emission
   - Unified model for the generation of giant radio halos, radio mini-halos, and relics
   - We predict GLAST to detect $\sim$ ten γ-ray clusters: test of the presented scenario

$\rightarrow$ exciting experiments allow a complementary view on structure formation as well as fundamental plasma physics!

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