

## Questions:

- What is the current status of the field (state of the art)?
- What are the **major** unsolved questions?
- What would be transformational observations, simulations or theoretical developments?
- What can be done in the near future (also as a collaboration)?
- Will it be helpful to summarise our opinions on the above question in a form of a White Paper?



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⇒ **restrict my 7-min part to theory and simulation**



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  - Braginskii MHD; anisotropic conduction: MTI, HBI, ...
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$\Rightarrow$  **how much physics do we need to include?**

$\Rightarrow$  **what are the correct descriptions/transport coefficients for CRs, heat, viscosity, ... ?**

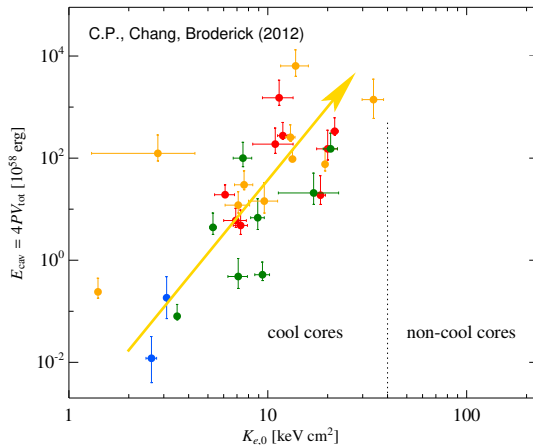
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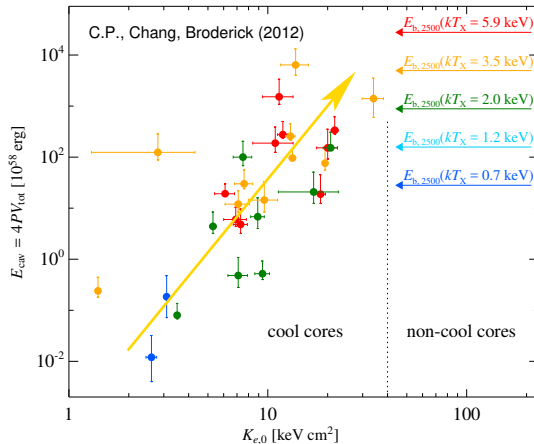
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- **cool core vs. non-cool core dichotomy**: origin, two separate populations or cycling between states?

# How efficient is heating by AGN feedback?

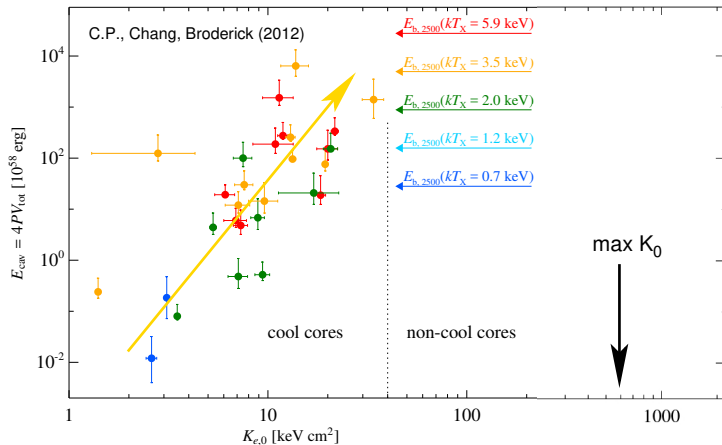




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**AGNs cannot transform CC to NCC clusters** (on a buoyancy timescale)

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# ICM Physics: **major** unsolved questions

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⇒ **minimal necessary physics to model ICM?**



# ICM Physics: breakthroughs

Transformational observations, simulations or theoretical developments

## breakthroughs anticipated: pinpoint role of ...

- **turbulent velocities?**  $\Rightarrow$  direct measurements of line broadening in outskirts (X-rays), clusters other than Perseus
- **cosmic rays?**  $\Rightarrow$  bubble content (SZE), heating rate, transport scheme (radio, gamma rays)
- **kinetic physics?**  $\Rightarrow$  connection to solar wind (local probes)



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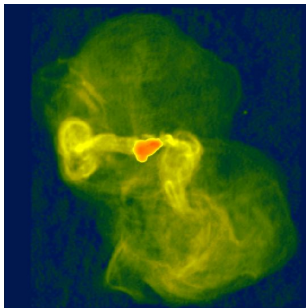
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$\Rightarrow$  **need a proper prediction ...**



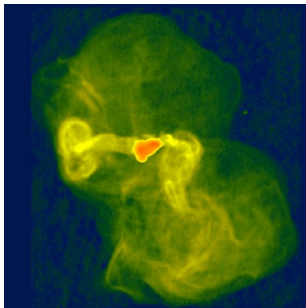
# Feedback heating: M87 at radio wavelengths



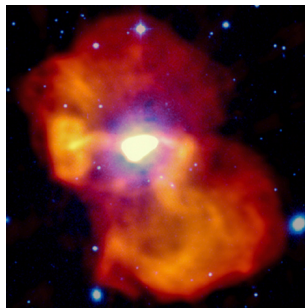
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low- $\nu$ : fossil CR electrons  $\rightarrow$  time-integrated AGN feedback!

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$\nu = 140$  MHz (LOFAR/de Gasperin+ 2012)

- high- $\nu$ : freshly accelerated CR electrons  
low- $\nu$ : fossil CR electrons  $\rightarrow$  time-integrated AGN feedback!
- LOFAR: same picture  $\rightarrow$  puzzle of “missing fossil electrons”
- solution: electrons are fully mixed with the dense cluster gas and cooled through Coulomb interactions  $\Rightarrow$   $\gamma$ -ray emission

# AGN feedback = cosmic ray heating (?)

hypothesis: low state  $\gamma$ -ray emission traces  $\pi^0$  decay within cluster

- cosmic rays excite Alfvén waves that dissipate the energy  $\rightarrow$  heating rate

$$\mathcal{H}_{\text{CR}} = -\mathbf{v}_A \cdot \nabla P_{\text{CR}}$$

- calibrate  $P_{\text{CR}}$  to  $\gamma$ -ray emission and  $\mathbf{v}_A$  to radio and X-ray emission  
 $\rightarrow$  spatial heating profile



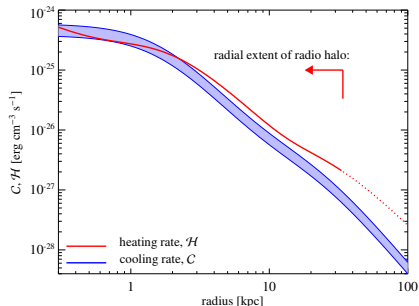
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C.P. (2013)

$\rightarrow$  cosmic-ray heating matches radiative cooling (observed in X-rays) and may solve the famous “cooling flow problem” in galaxy clusters?



# ICM Physics: necessity of a White Paper?

mainly political question: what are we aiming for?

- transformative telescope (X-rays, SZE, radio)?
- collaborative efforts: funding agencies?



# ICM Physics: necessity of a White Paper?

mainly political question: what are we aiming for?

- transformative telescope (X-rays, SZE, radio)?
- collaborative efforts: funding agencies?
- if there is a really good motivation: do it
- if there is no clear goal: not sure it is worth the effort

