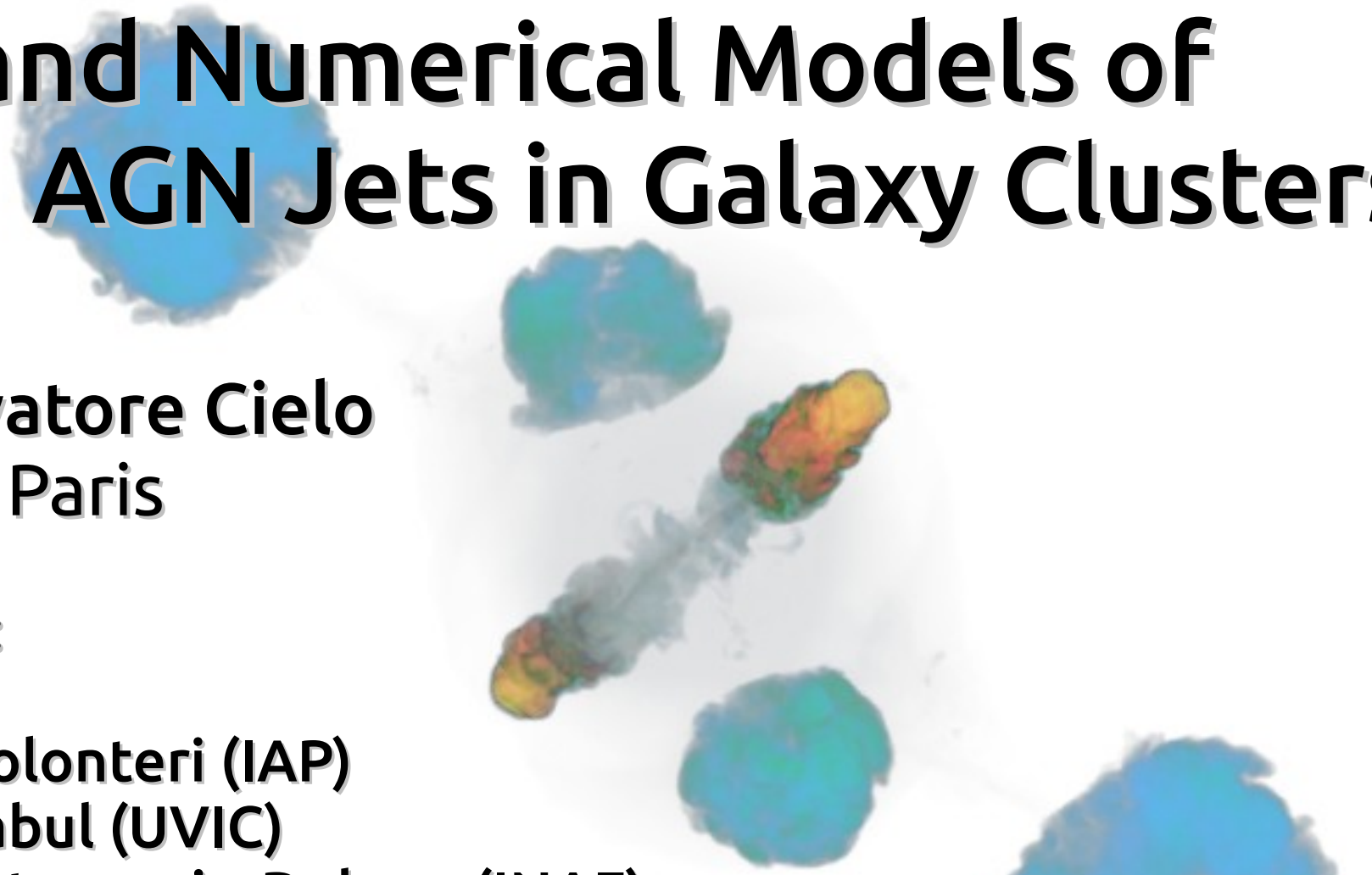
Xray and Numerical Models of AGN Jets in Galaxy Clusters



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with:

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A. Babul (UVIC)
V. Antonuccio-Delogu (INAF)
J. Silk (IAP|JHU)

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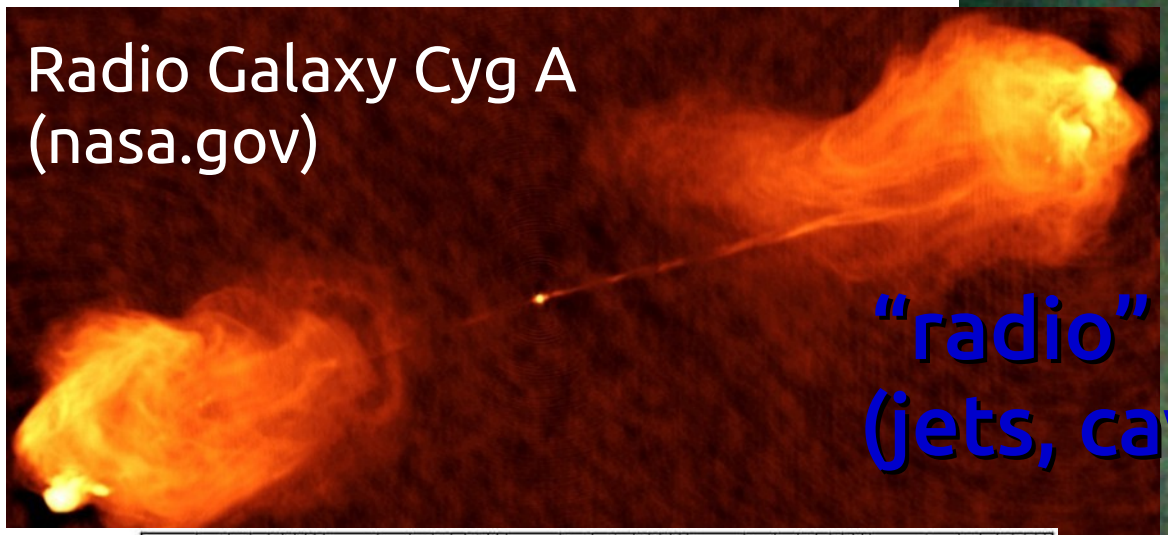
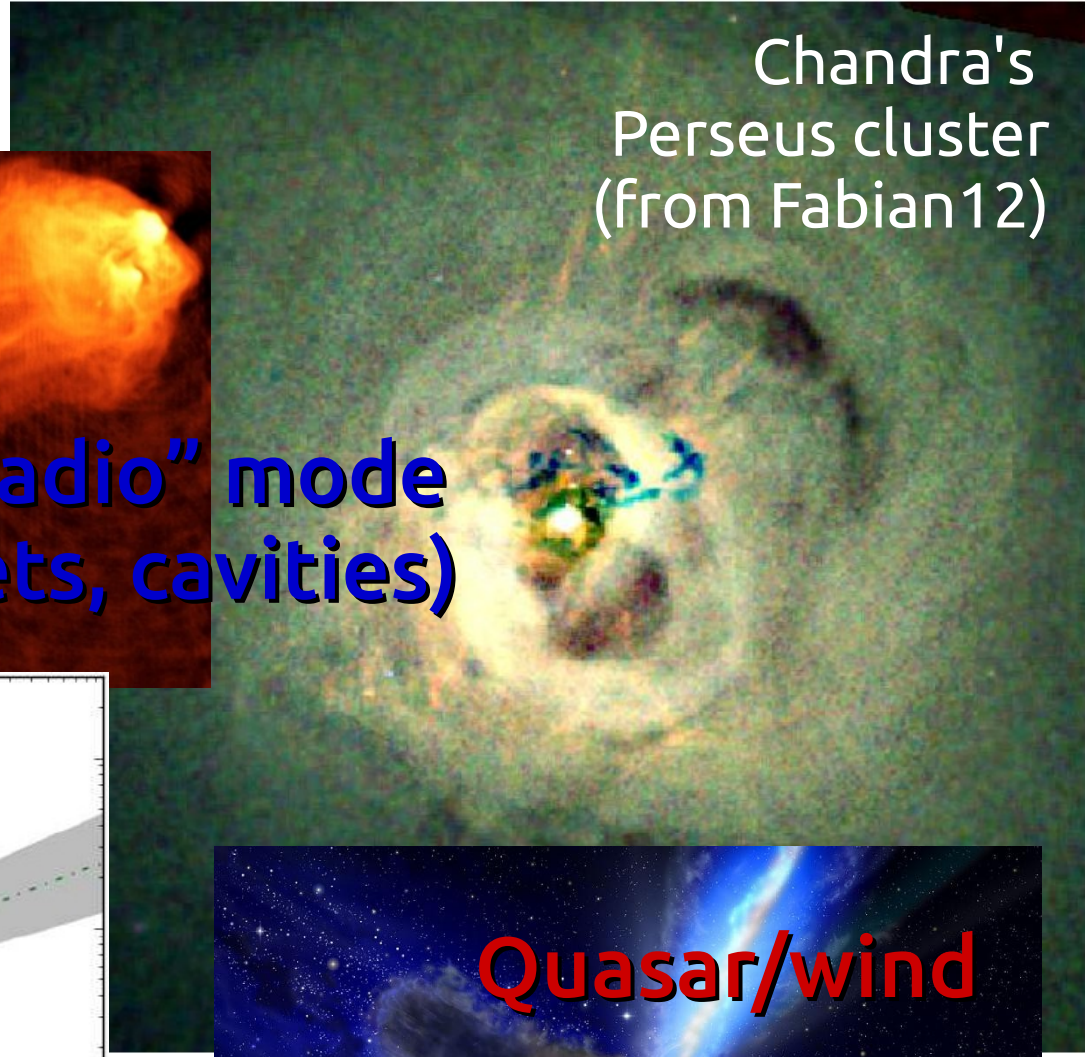
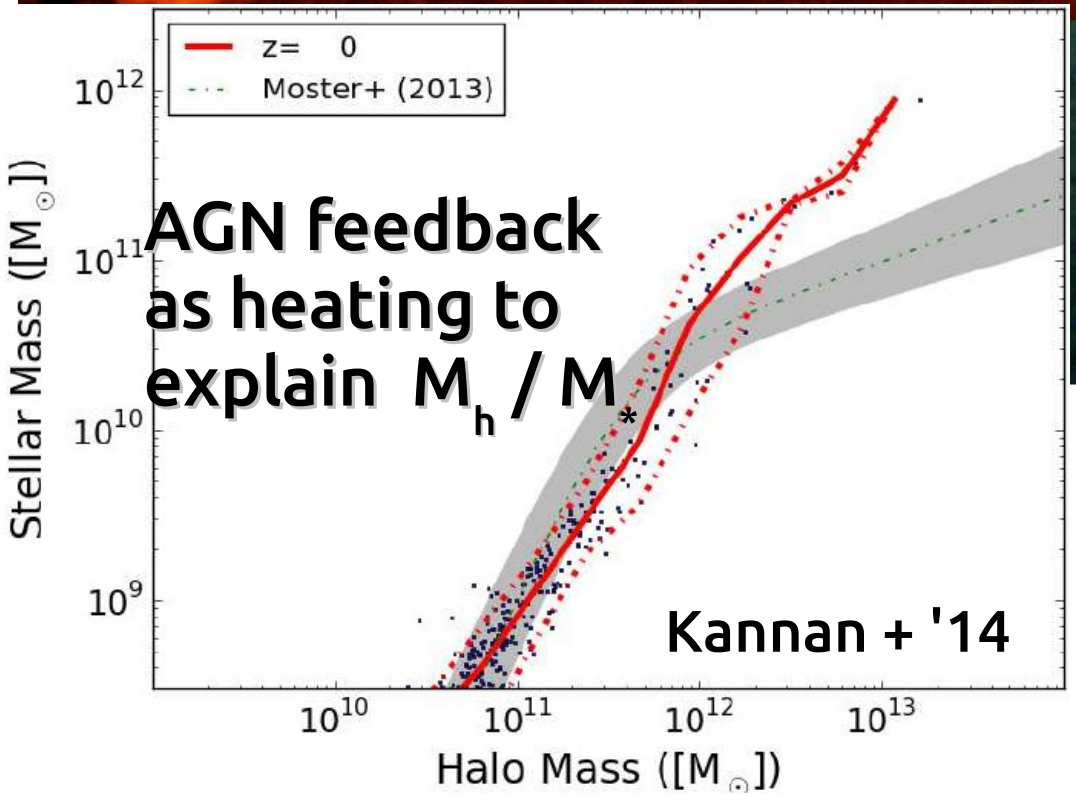
European Research Council
Established by the European Commission

on AGN Feedback





**"radio" mode
(jets, cavities)**



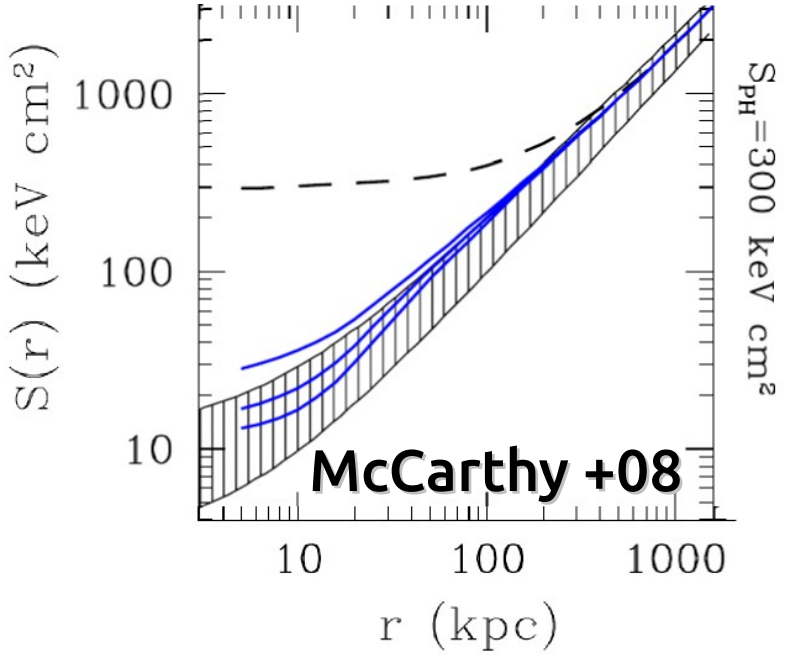
AGN jets models in CC clusters

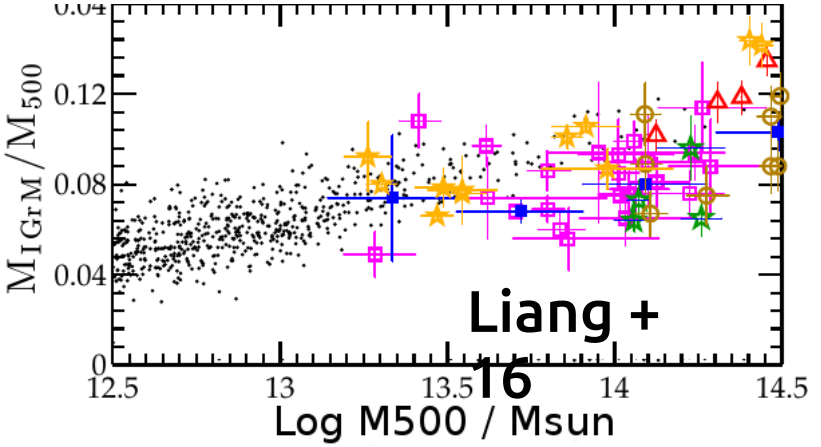
Cooling ↔ **feedback**
is shaping **Xray** gas

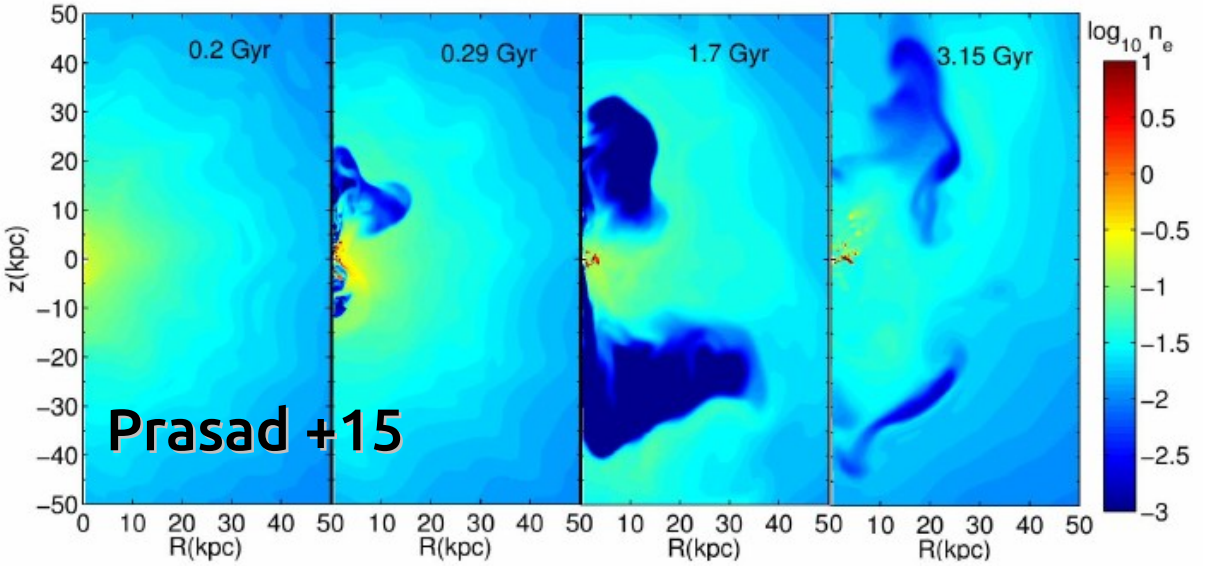
➡ $t^0_{cool} \sim 3x10^8$ y →
SFR >100 M_{sun}/y

heating at formation + **AGN**

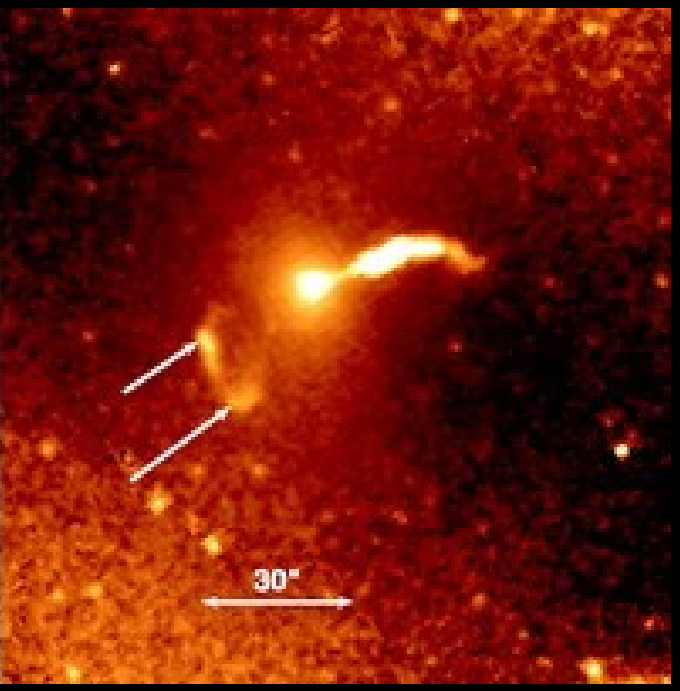
entropy (metals)
gas fraction **cavities**

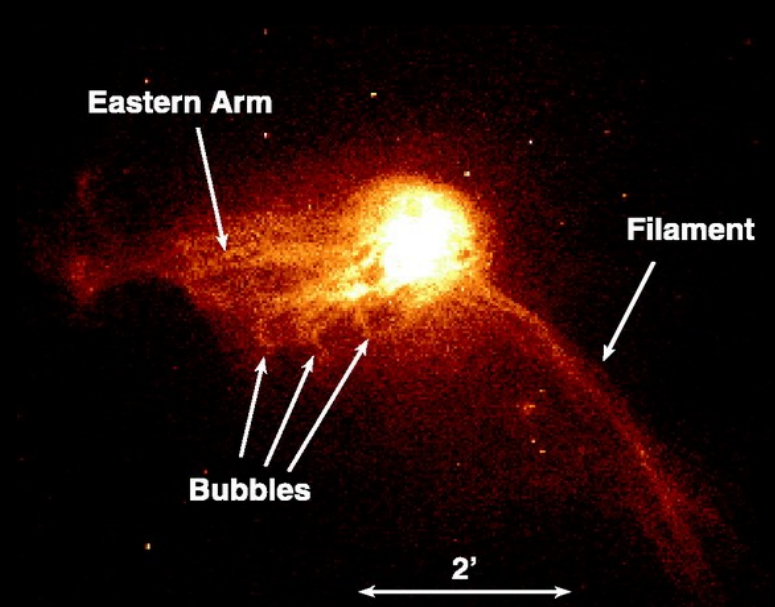


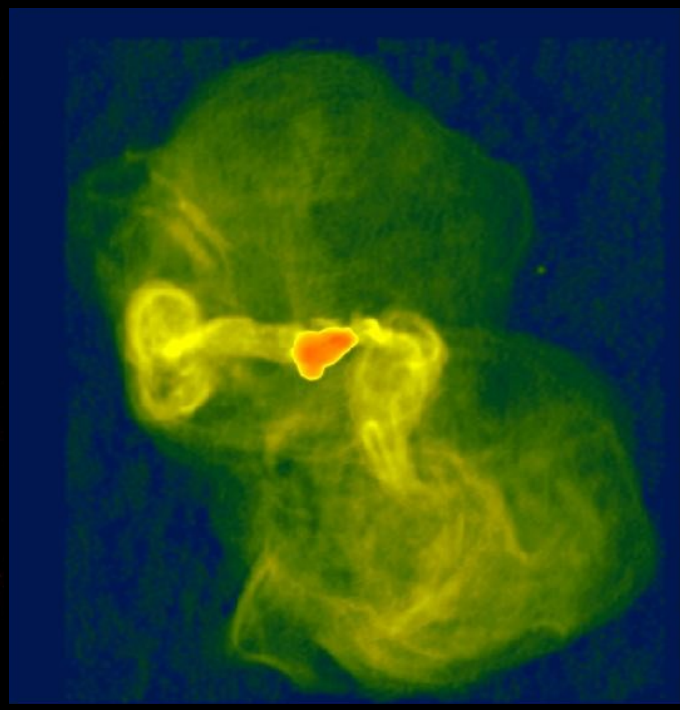




NATURE APPEARS TO HAVE SOLVED THE ISOTROPY PROBLEM





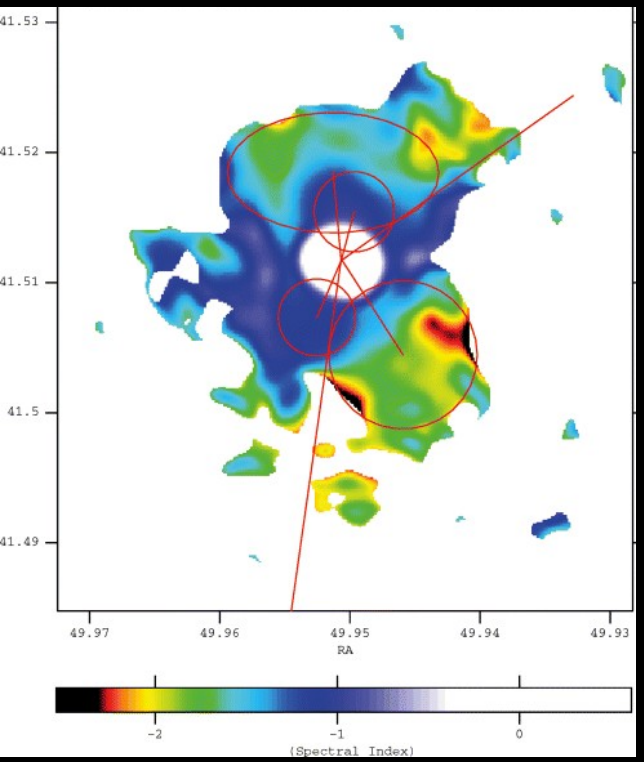


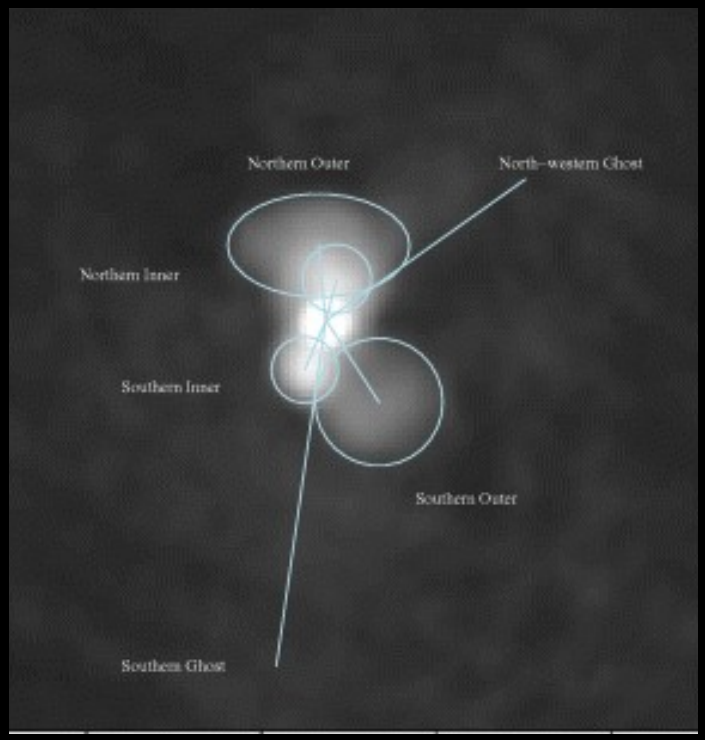
5 (8) directional changes: small-scale jet to radio bubbles .
ΔΘ between features: ~20-60^0 in plane of the sky
Δt between changes: ~20 Myrs (mean)

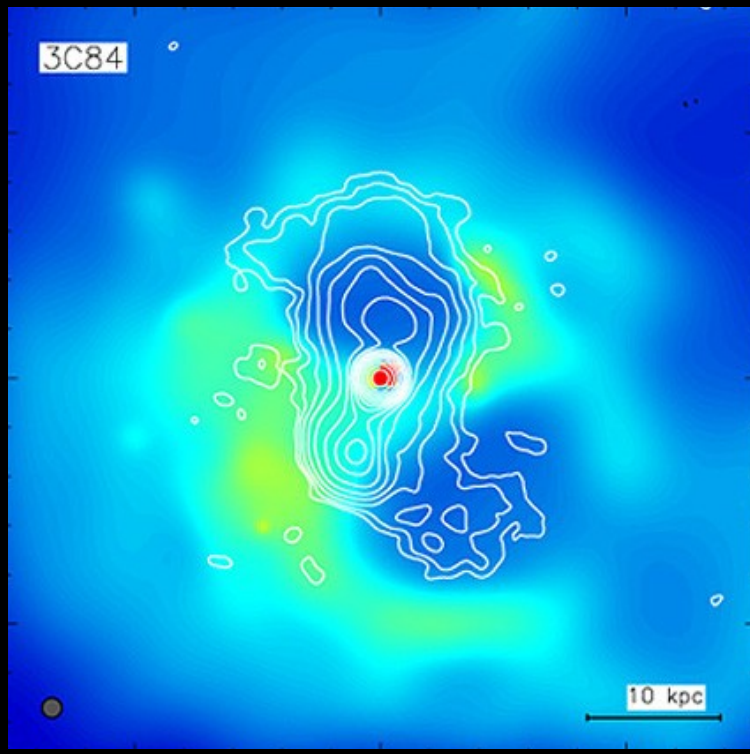
M87

Courtesy of A. Babul

NATURE APPEARS TO HAVE SOLVED THE ISOTROPY PROBLEM





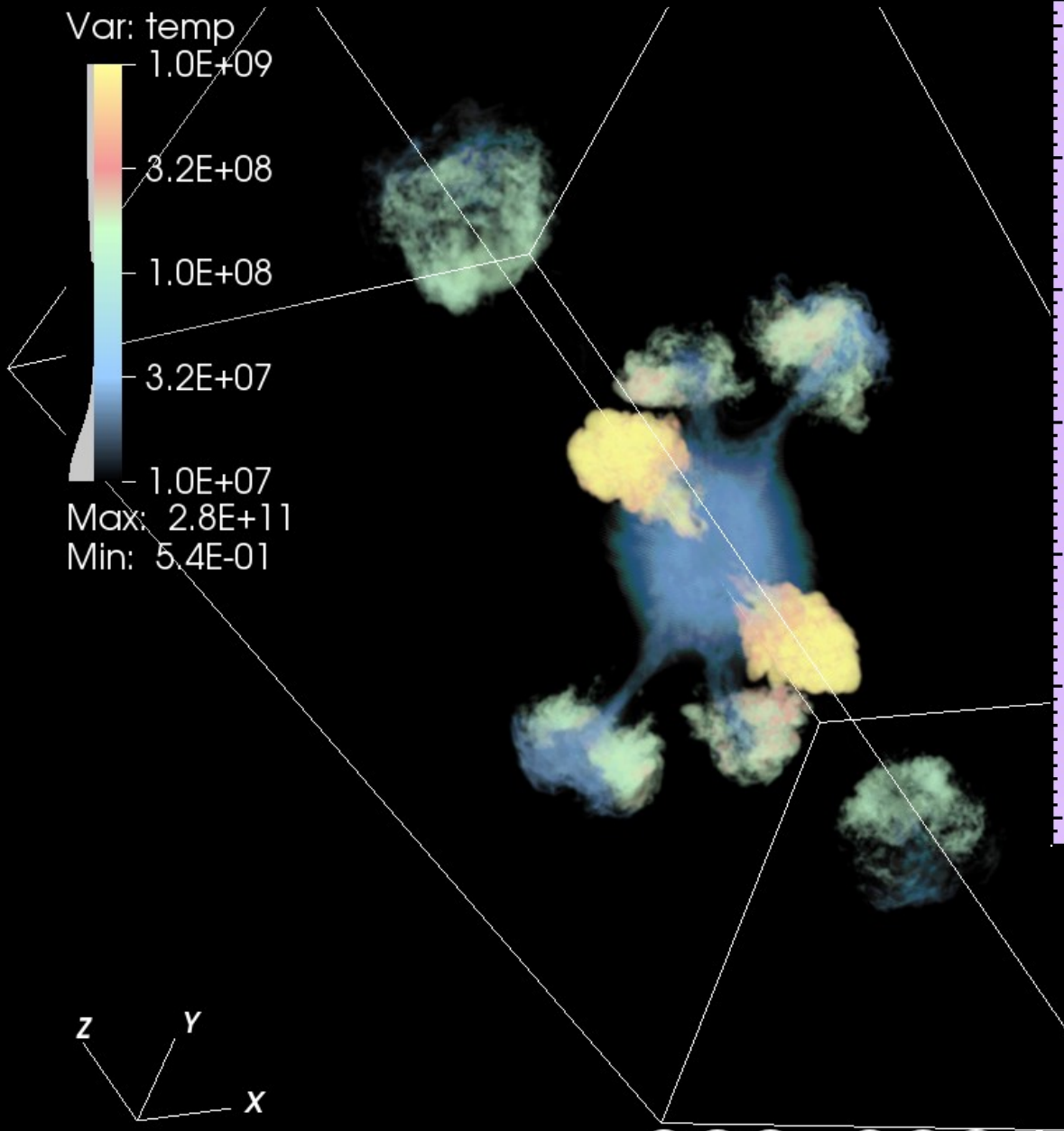


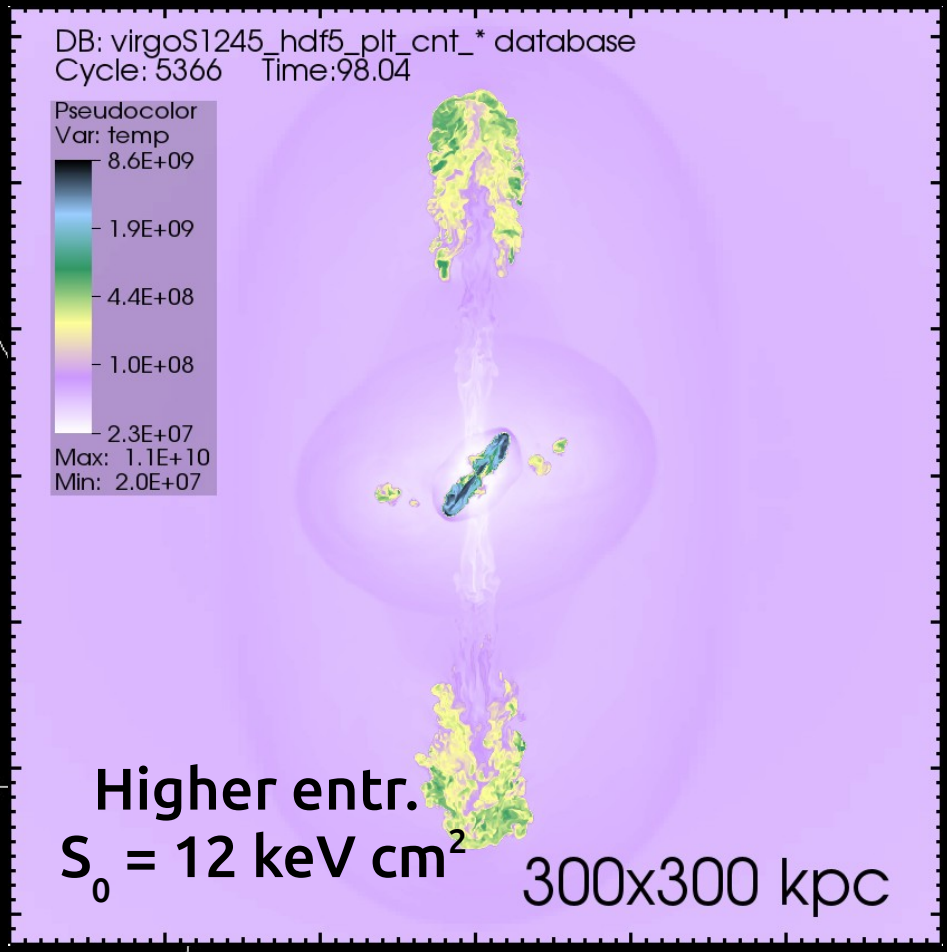
7 directional changes: From mas jets to ghost bubble.
Consecutive features: ~20-45^0 in plane of the sky
Δt between changes: ~typically 20 Myrs

PERSEUS

Courtesy of A. Babul

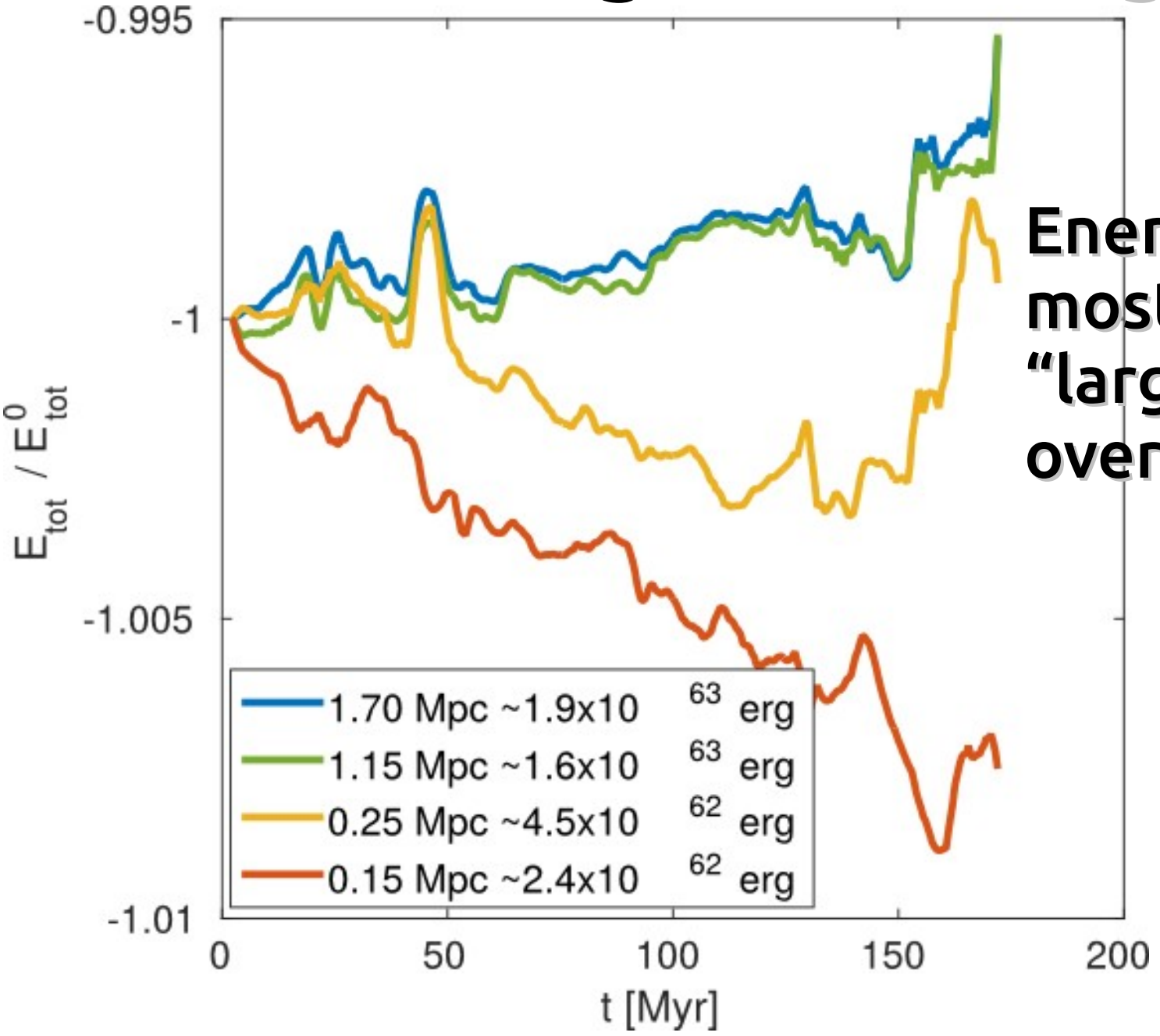
Bubbles and re-orienting jets





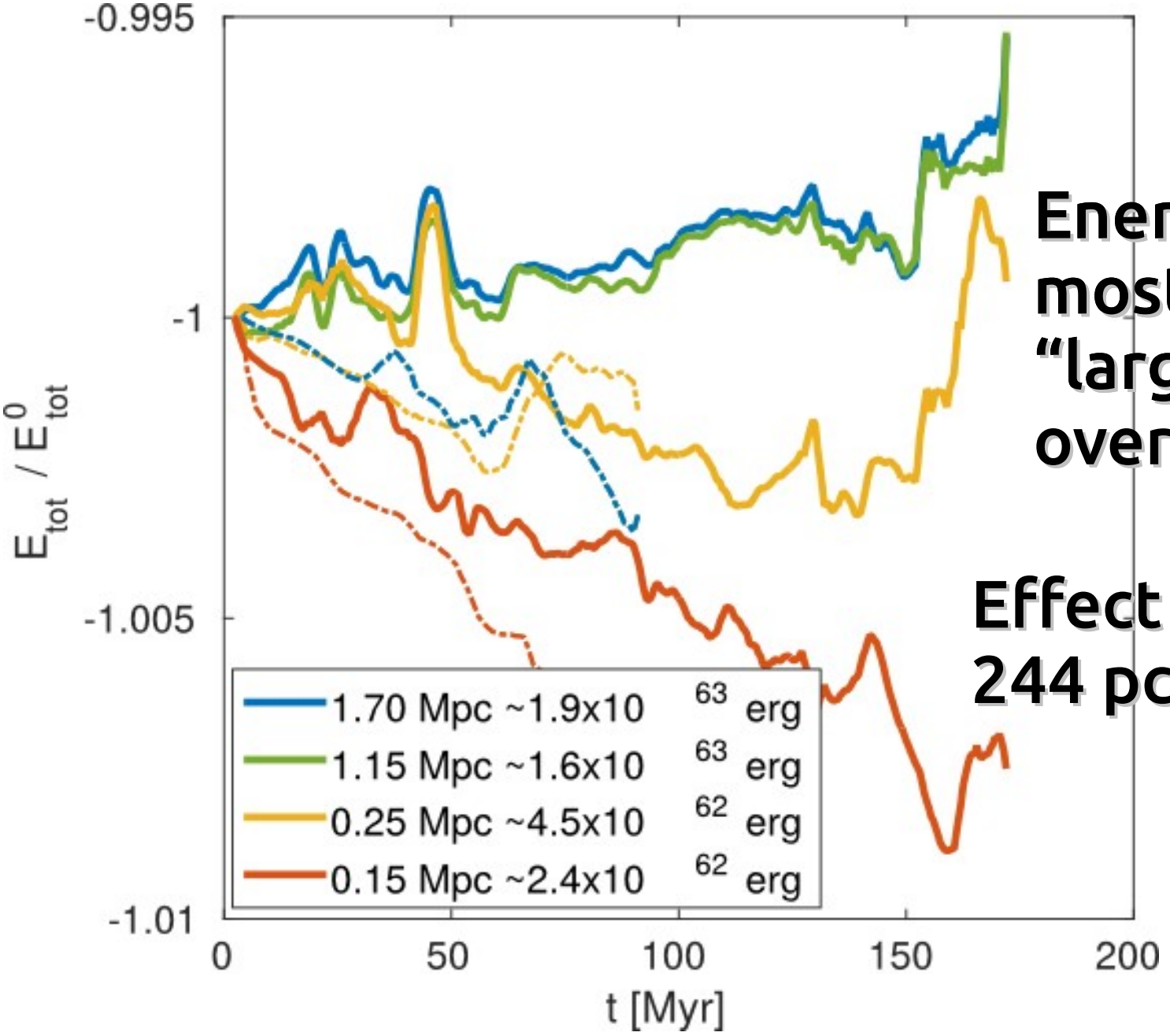
Supersonic, light jets
vortex-ring cavities

AGN vs cooling: total energy



Energy deposition most effective at "large" scale, overall cooling.

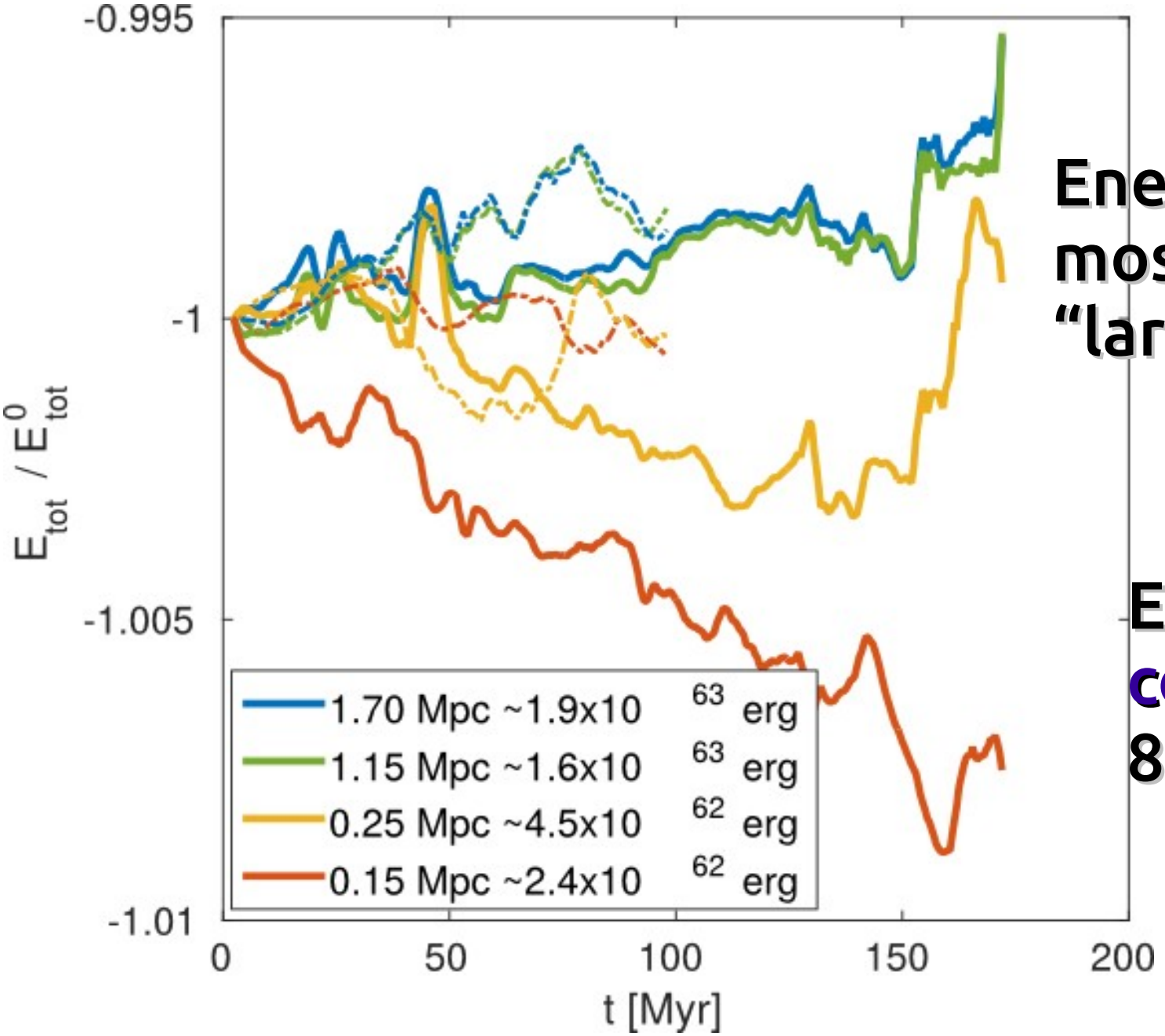
AGN vs cooling: total energy



Energy deposition most effective at "large" scale, overall cooling.

Effect of resolution: 244 pc VS 488pc.

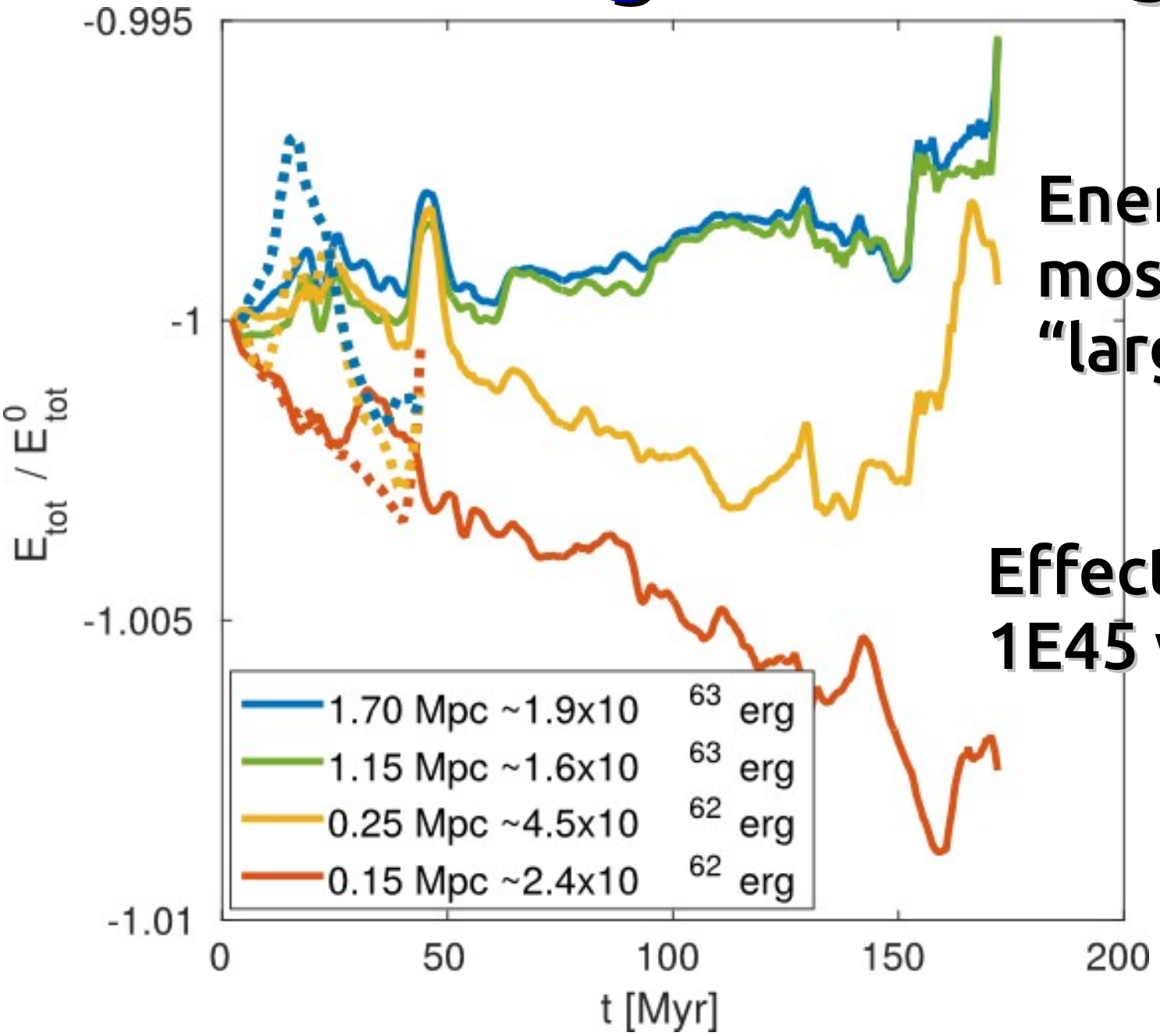
AGN vs cooling: total energy



Energy deposition most effective at "large" scale.

Effect of **core entropy:** 8 vs 12 keVcm^2

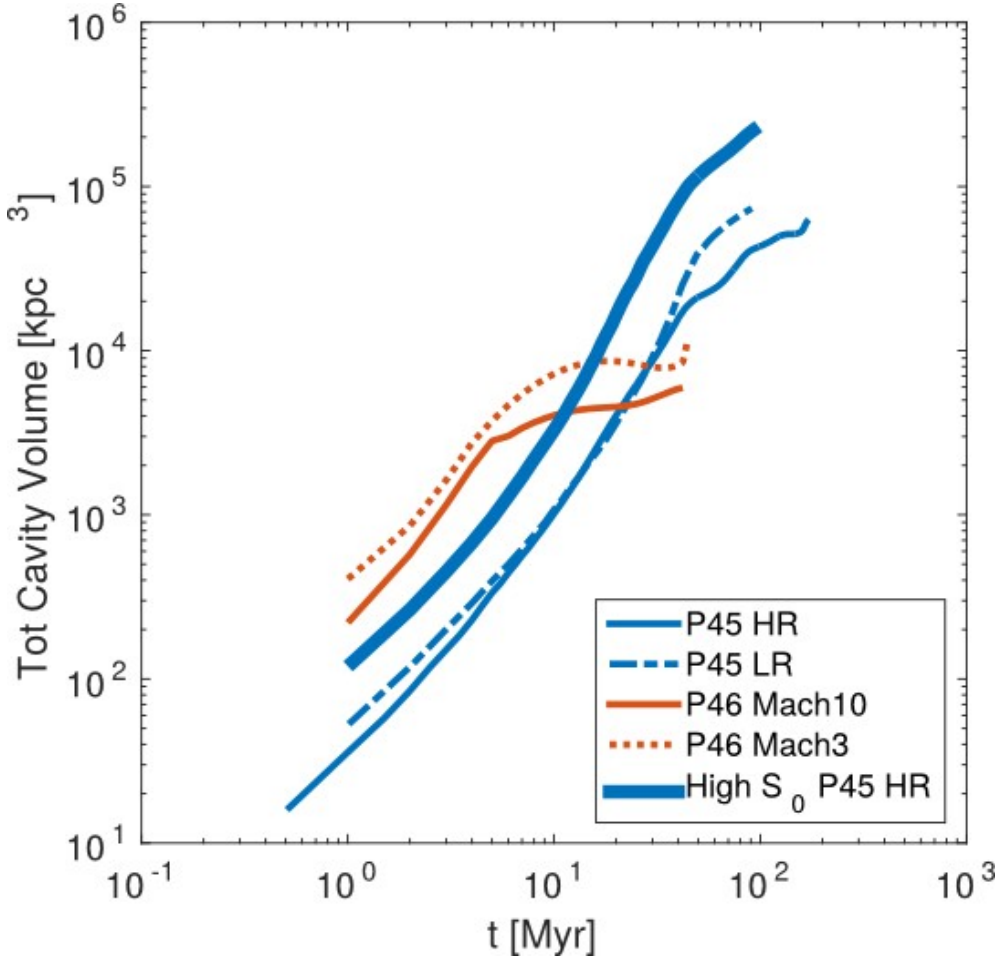
AGN vs cooling: total energy

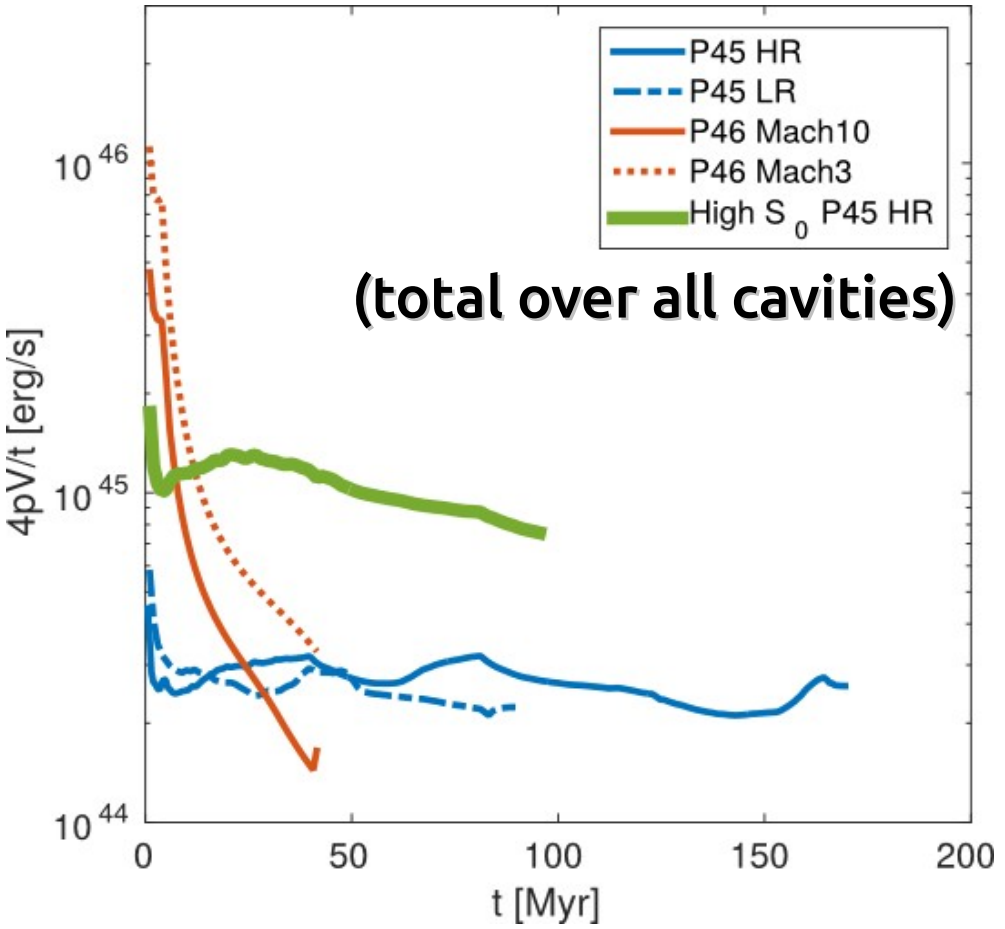


Energy deposition most effective at "large" scale.

Effect of jet power: 1E45 vs 1E46 erg/s

Cavities and mechanical work





Coupling depends on environment and power.
Instantly ~100%, later **30-50%**.

Forward modeling: Xray imaging

Using yt photon simulator: (Zuhone'14, from Biffi, Dolag '12, '13)

http://yt-project.org/doc/analyzing/analysis_modules/photon_simulator.html

Simulation
ρ T (Z)

+

AtomDB
spectral model

thermal photon model
(UV-Xray, thermal brehms. + em. lines)

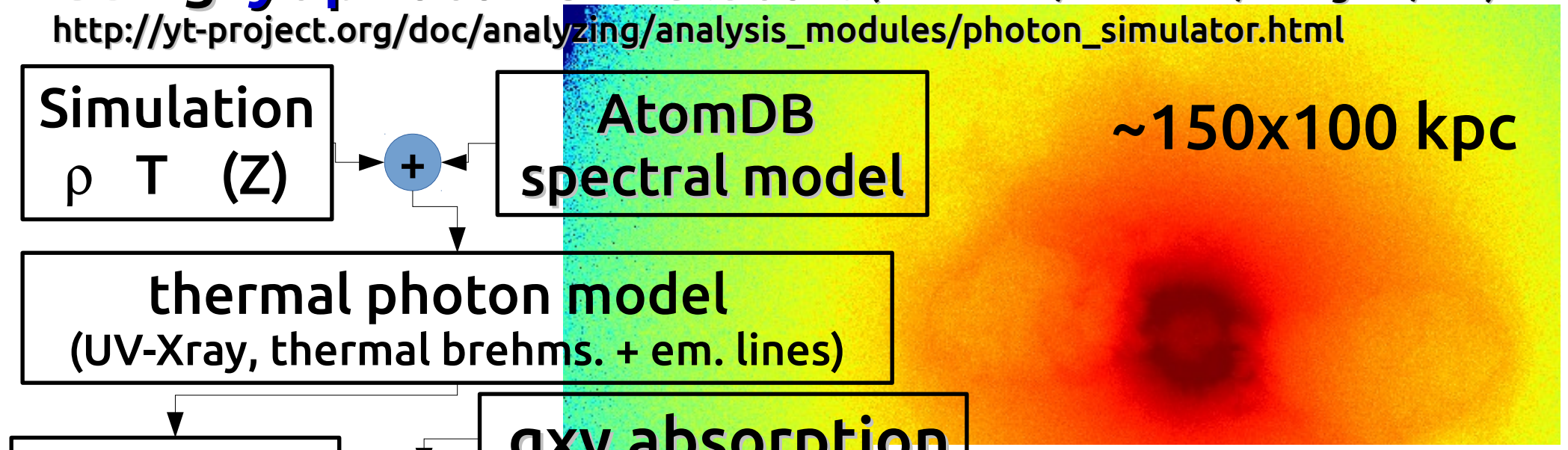
photon list

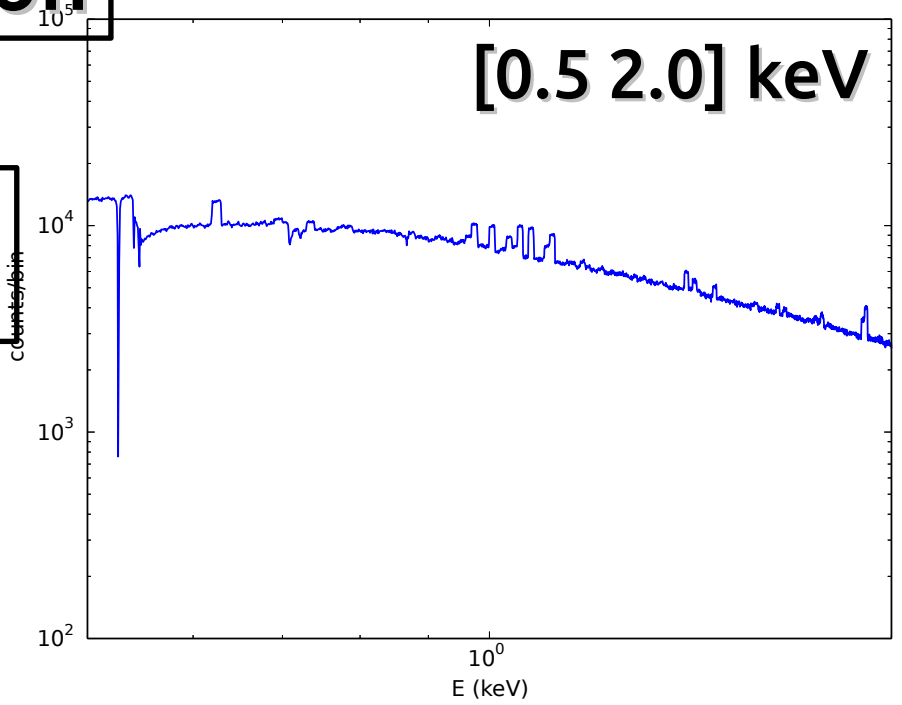
+

gxy absorption

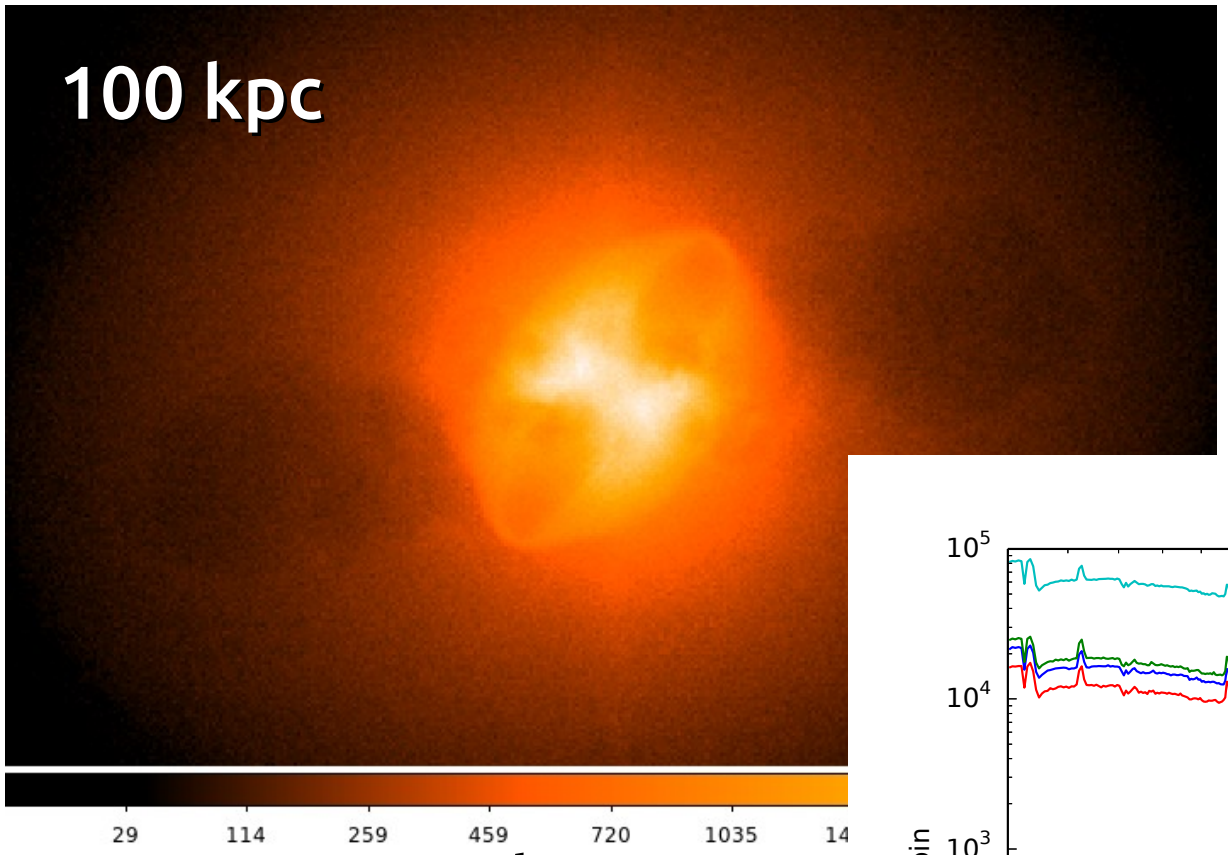
instrumental ARF/RMF
(XMM, Chadra, AstroH)

Events in simulated telescope





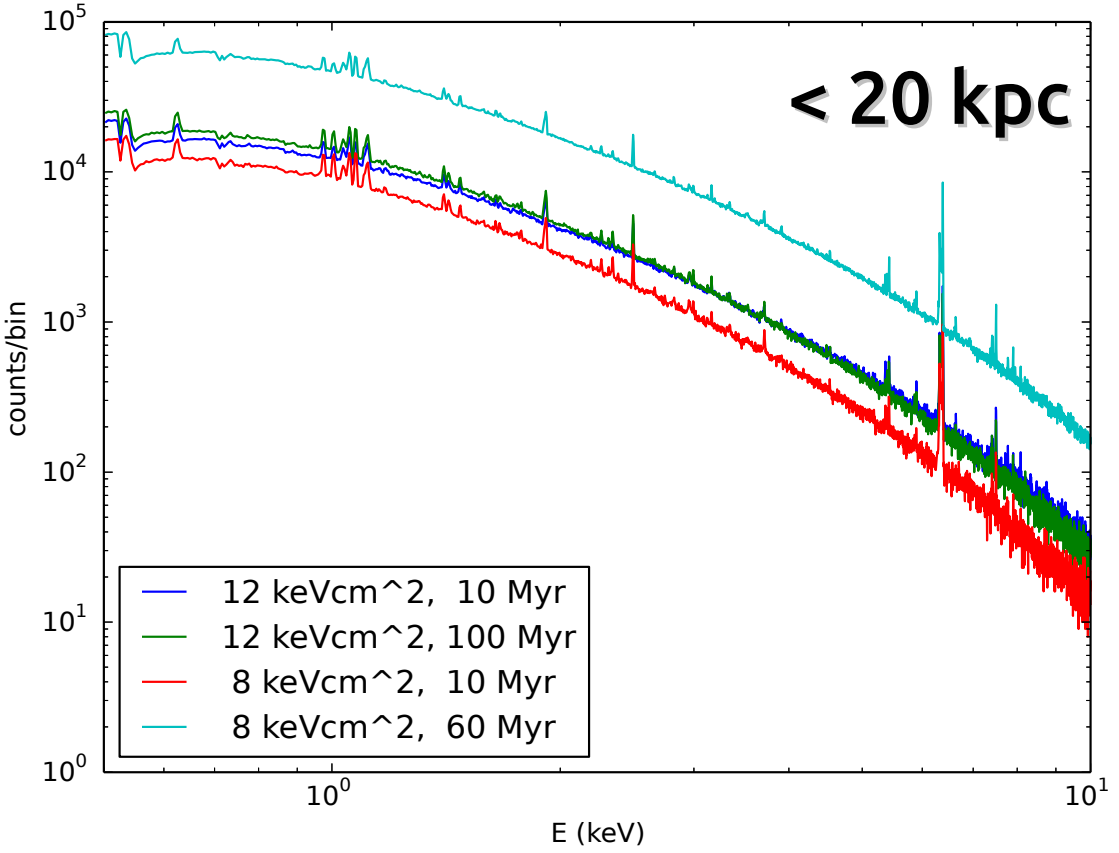
Mock Xray Imaging and Spectra



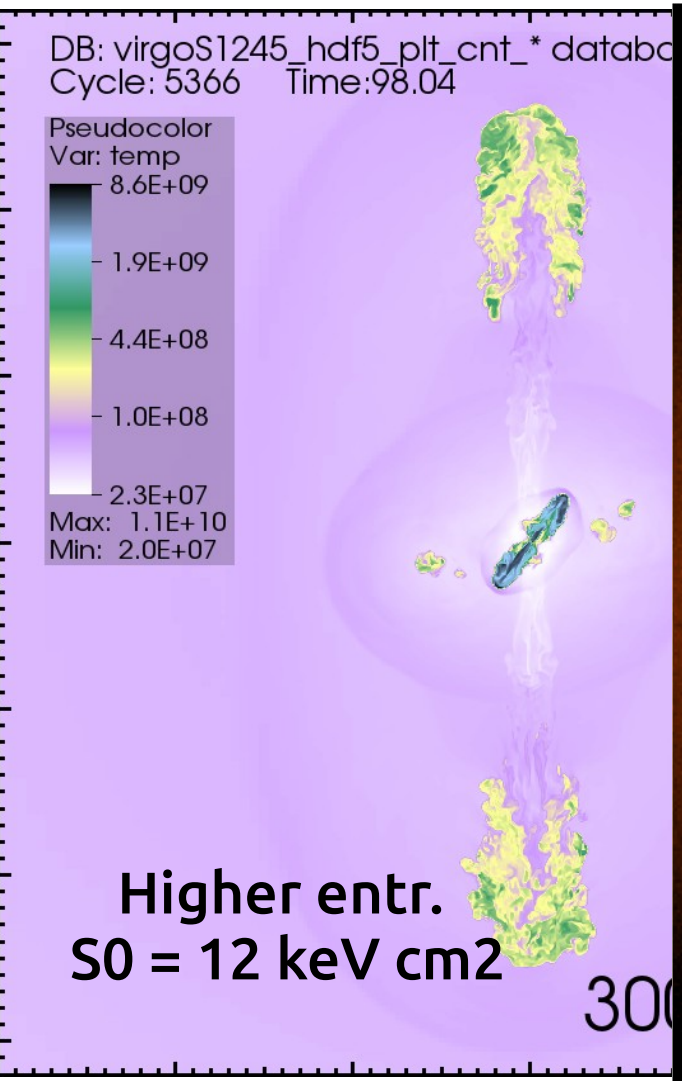
XMM 0.2-10 keV,
2000 channels
200 ks exp

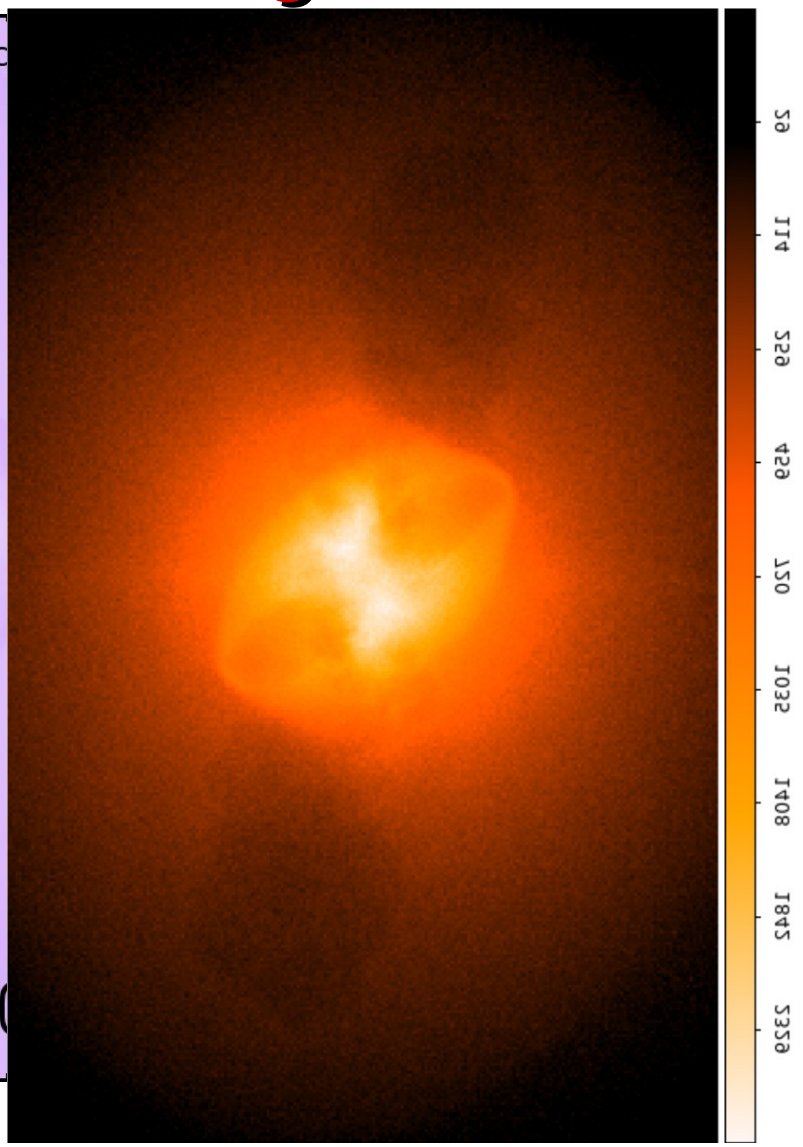
redshift 0.05
metallicity 0.1 Solar

Spectral evolution:
[1,3] keV line variation;
outshined by continuum.



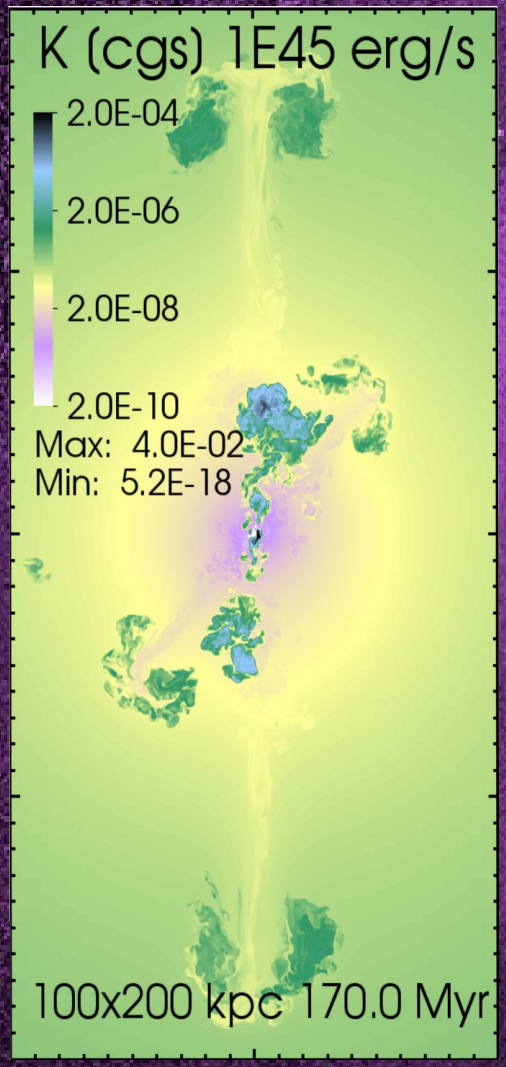
Slice VS Emissiviy VS Photon Sim.





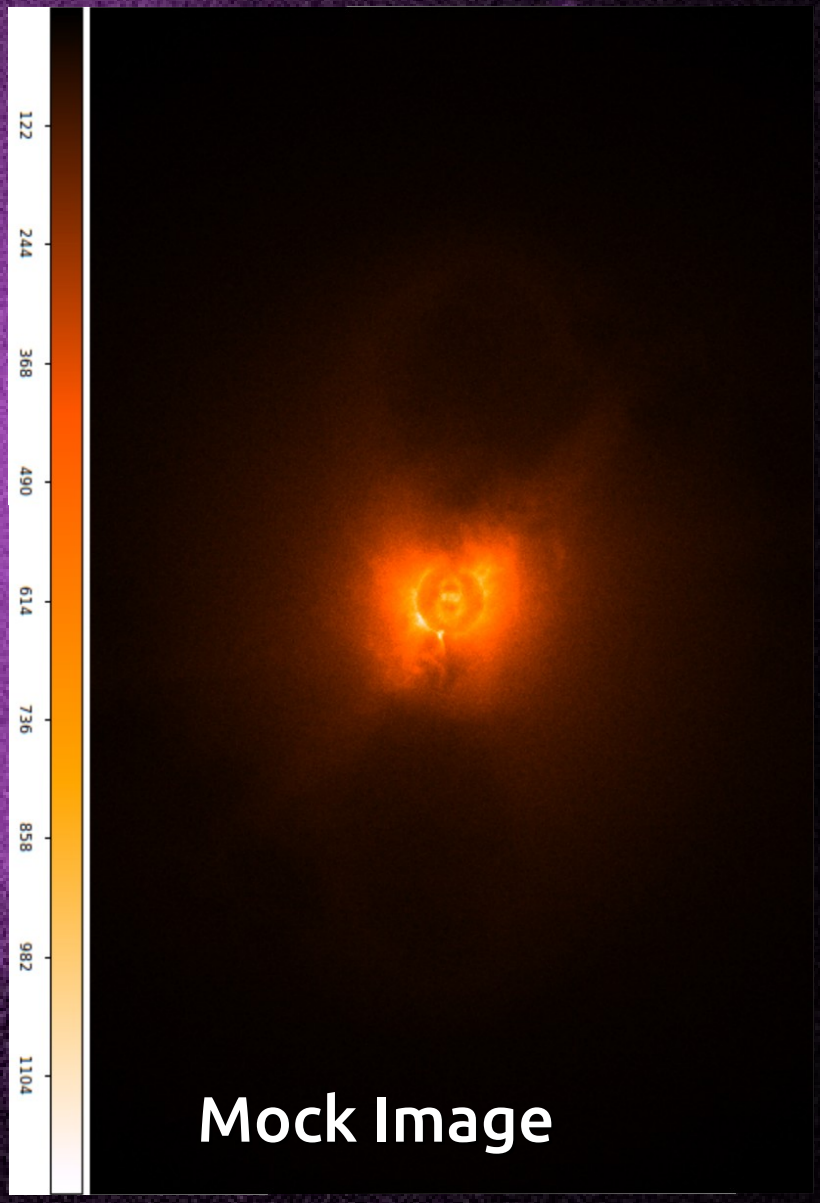
Predict cavity shapes and timing from physics:
e.g. “mushroom cap” VS “vortex ring”

Observed cavities



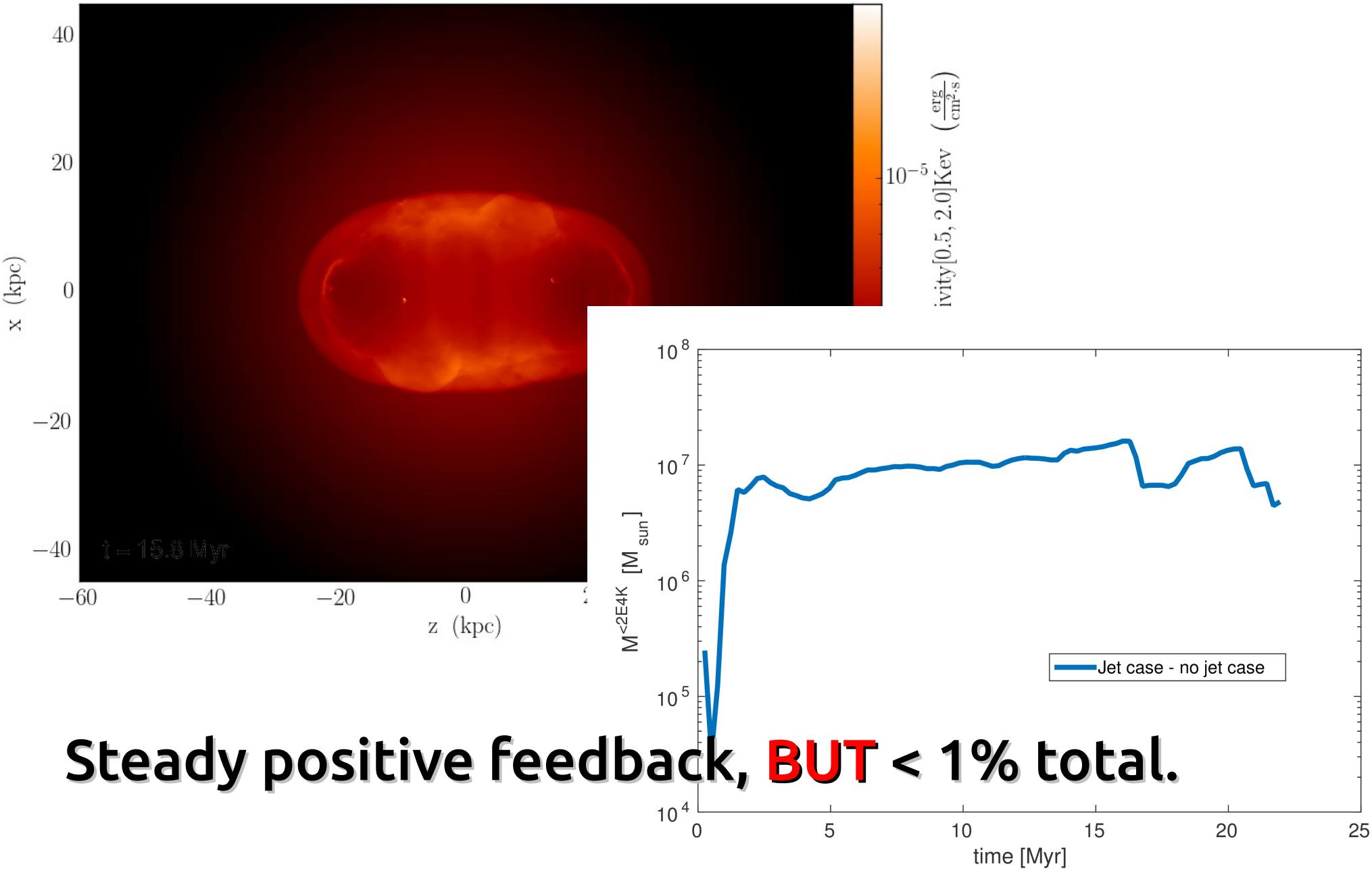
Entropy slice

Chandra's Perseus
~ 500 kpc c
Zhuraleva+ '14



Mock Image

Briefly, on “quasar mode”



Steady positive feedback, BUT < 1% total.

Conclusions

Radio mode AGN in clusters

- Those same jets that explain observed cavities may provide effective **feedback against cooling.**
- **Isotropy** is key
- Cavities teach us about jet parameters, **detailed forward modeling** very important.

AGN jets and cold gas (“quasar mode”)

- +/- feedback depends on ISM model

Thank you!