Interplay among Cooling, AGN Feedback and Anisotropic Conduction in the Cool Cores of Galaxy Clusters

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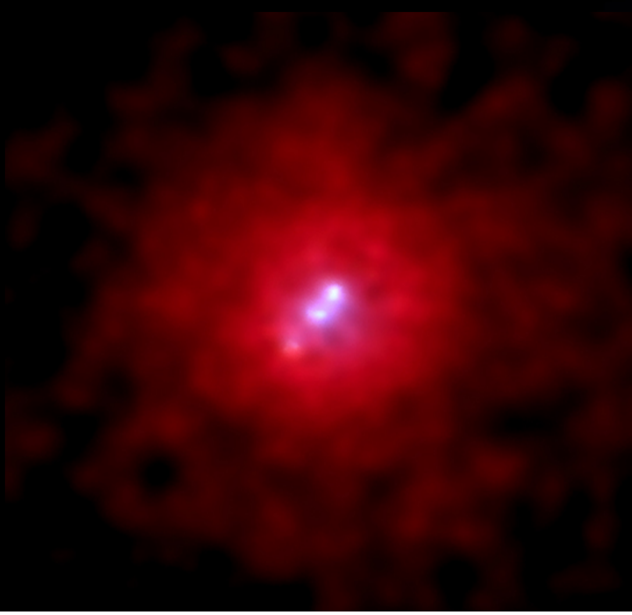
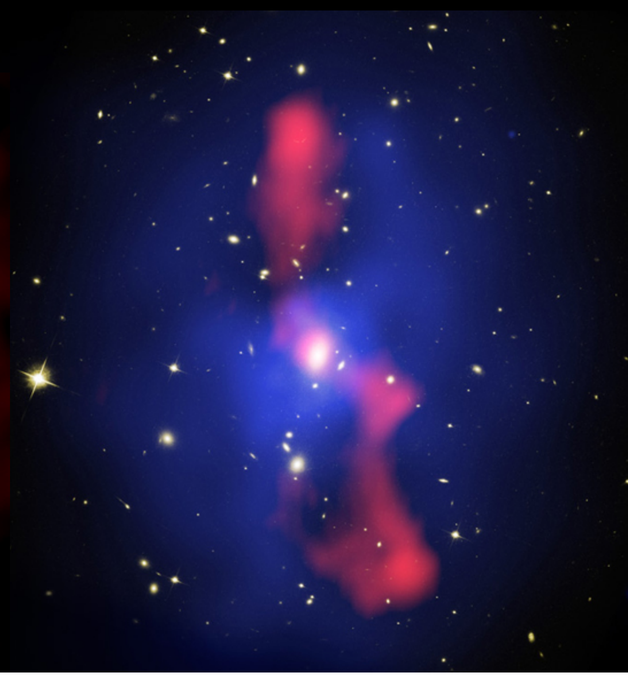
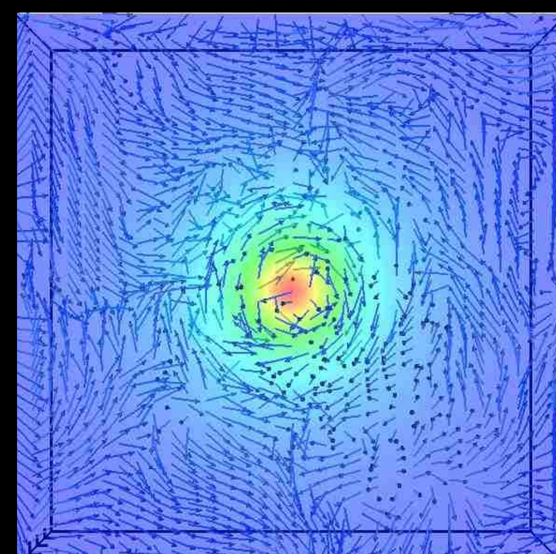
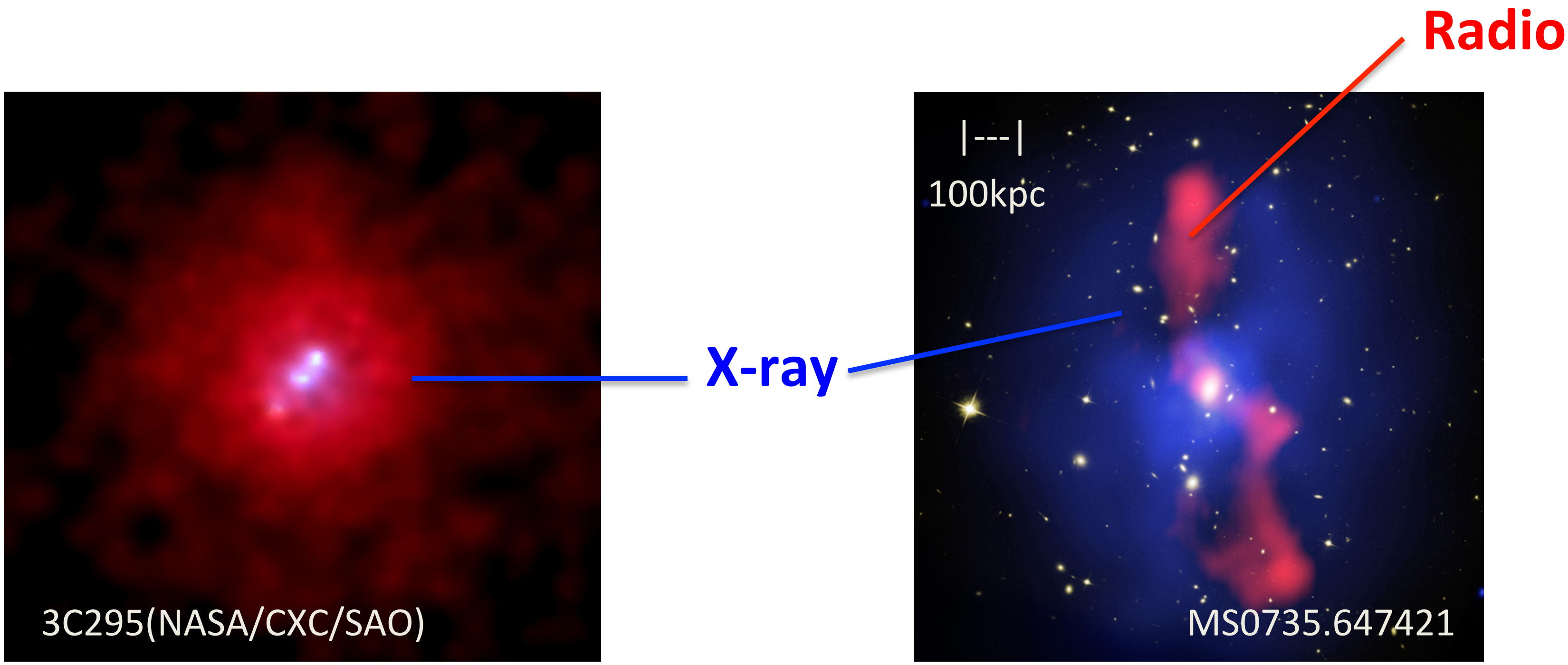
Yang & Reynolds, 2015, ApJ submitted







AGN feedback in CC clusters



- Radiative cooling: $L_X = \int n_e n_H \Lambda(T) d^3x$
- Cool-core (CC) clusters: $t_{cool} << t_H$
- Cooling-flow model predicts too much cool gas and stars

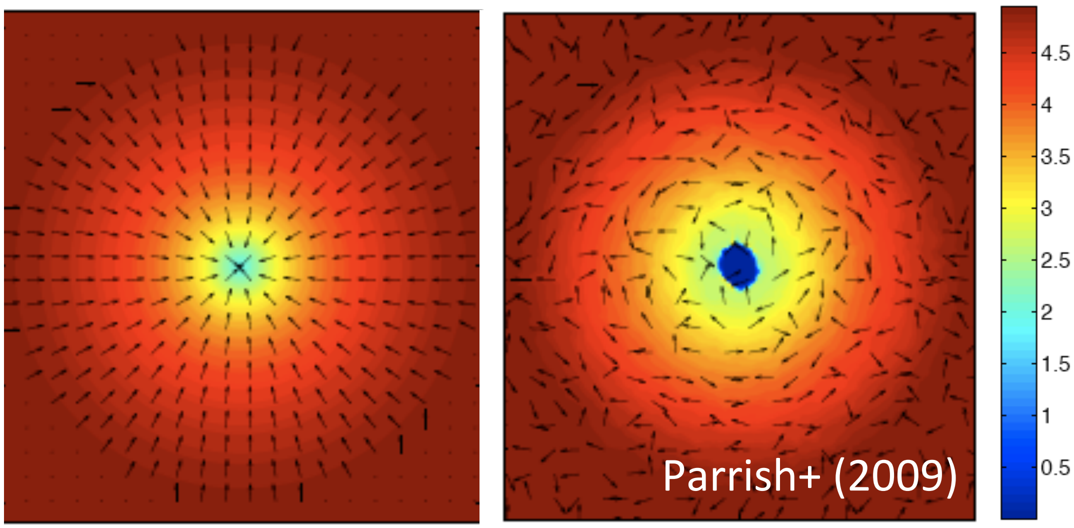
AGN feedback:

- Cluster radio bubbles
- $P_{bubble} \sim L_{cool}$

Roles of thermal conduction?

- Anisotropic conduction -> heat-flux driven buoyancy instability (HBI)

Final B perp to grad(T), shut off conduction



or

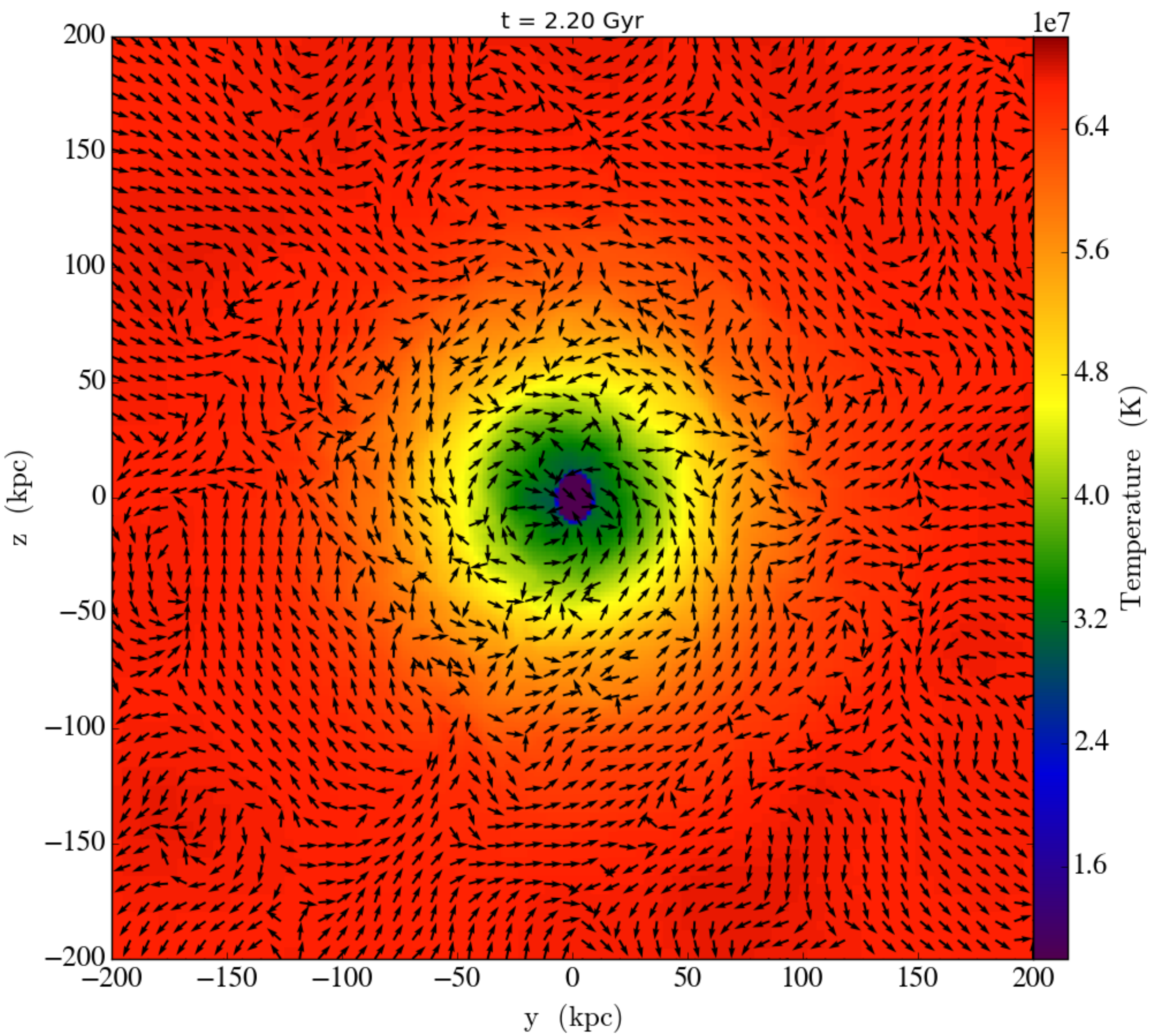
??

Q1: realistic B field strength (beta = P_{th} / P_B ~ 100)?

Q2: Does AGN-driven turbulence halt the HBI?

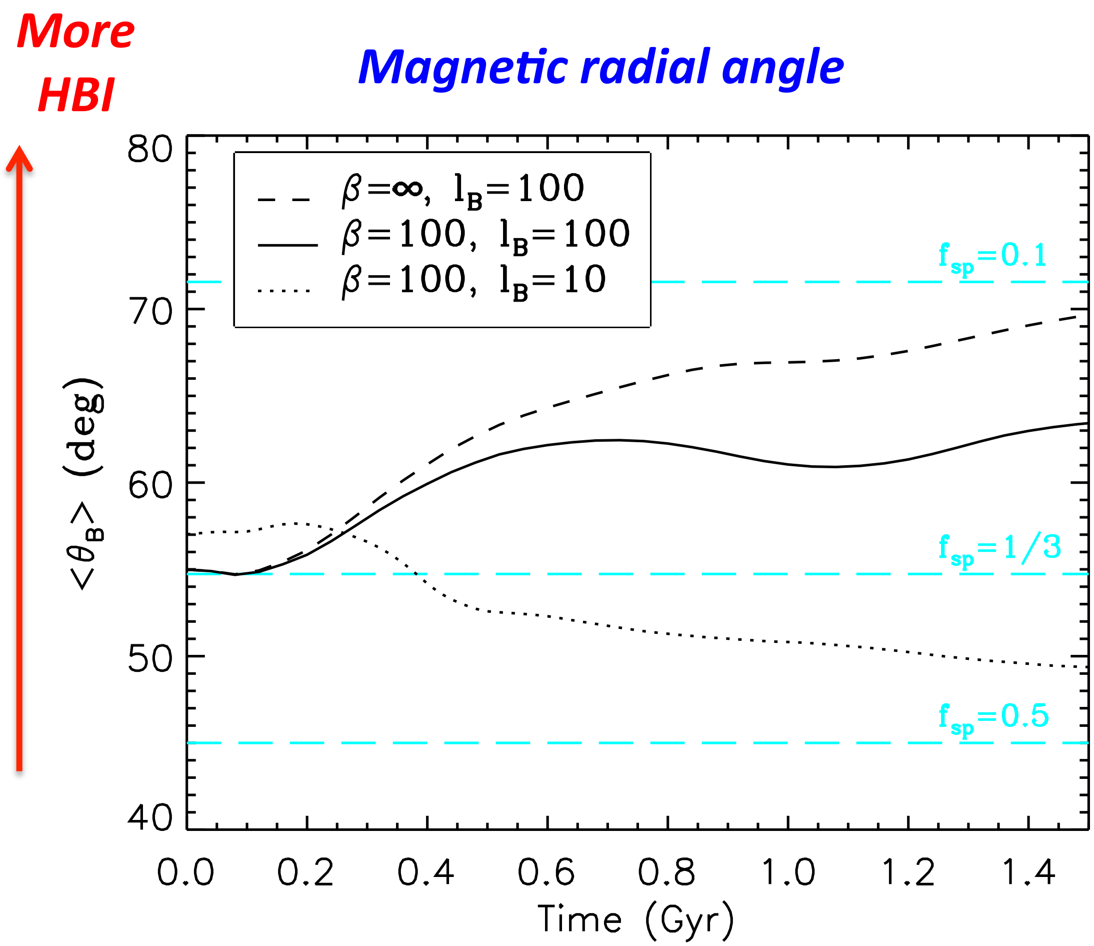
Q3: what is the relative importance of conductive and AGN heating?

HBI simulations (no AGN)



- Perseus, r_c~100kpc, tangled B field with l_B = 100 kpc
- FLASH AMR
- Full Spitzer conductivity along B field
- Collapse @ t~0.3Gyr

HBI simulations (no AGN)

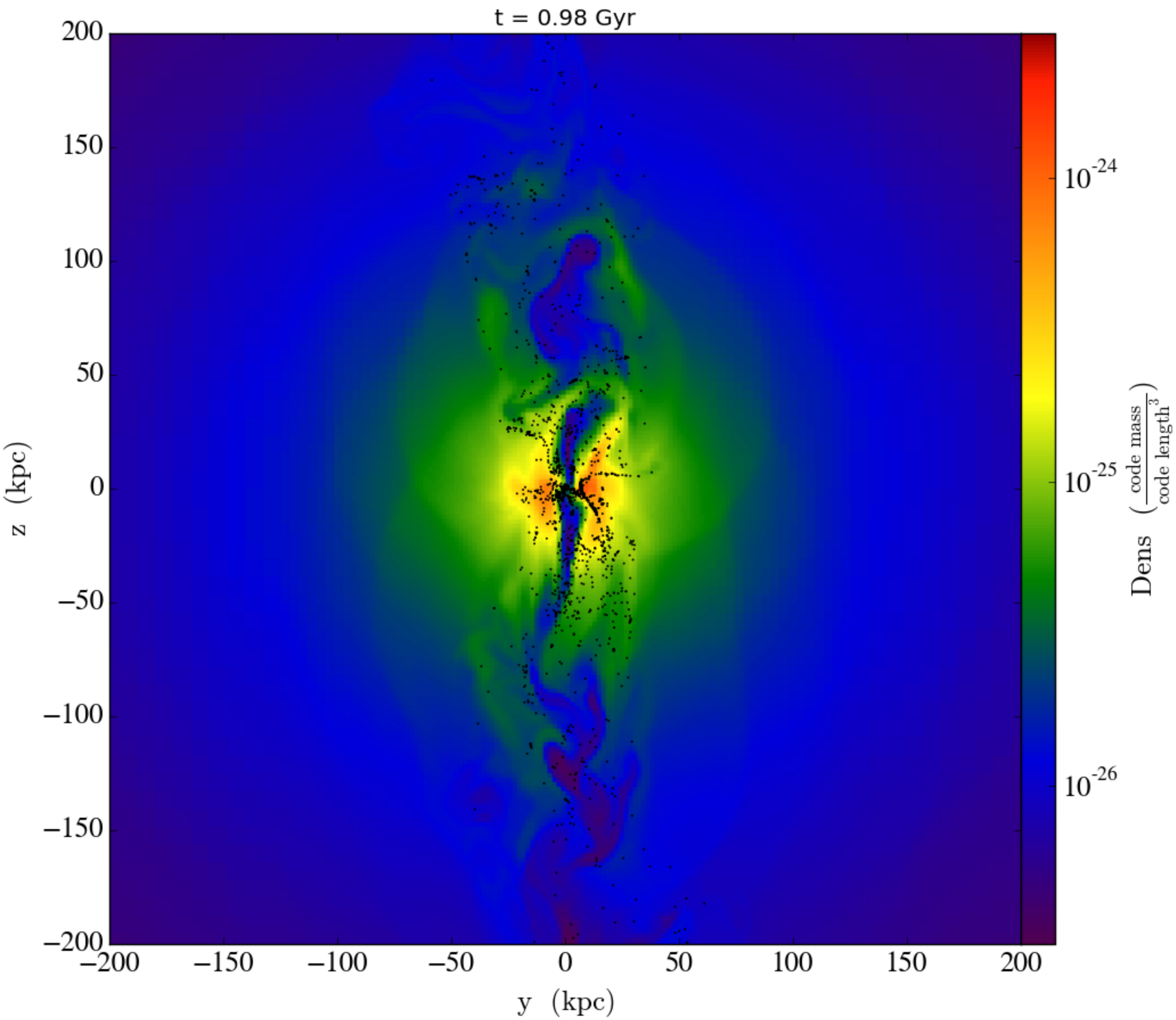


Perturbations are stable to HBI if:

$$-\frac{1}{2}\frac{g}{T^2}\frac{dT}{dr}+\frac{k_B}{\mu m_p}\frac{k^2}{\beta}>0,$$

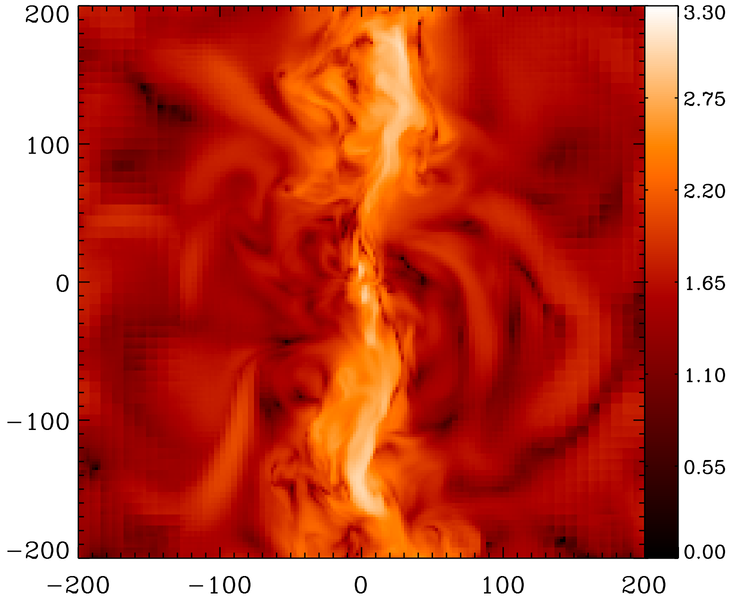
$$l < l_{\rm crit} \simeq 84 \text{ kpc}$$

HBI + AGN

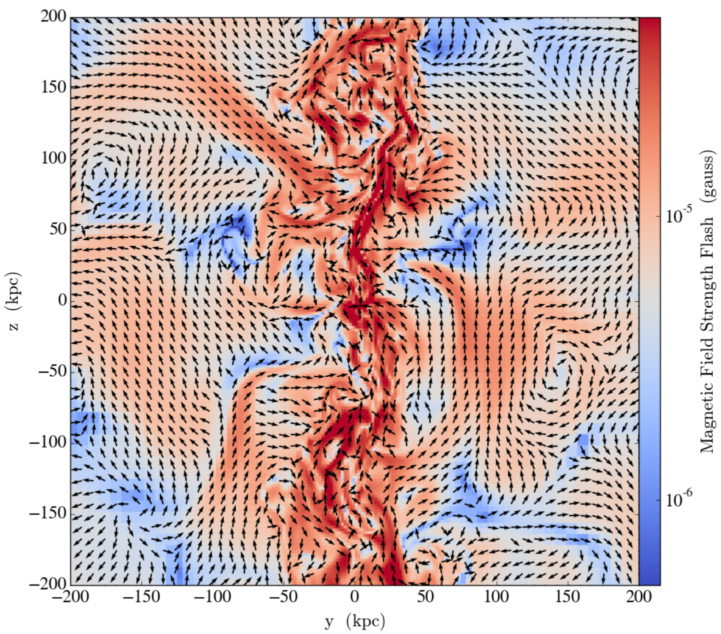


t = 0.98 Gyr
200
150
100
50
0
−50
−100
−150
−200
z (kpc)
−200
−150
−100
−50
0
50
100
150
200
y (kpc)
10^-24
10^-25
10^-26
Dens (code mass / code length^3)

Turbulent velocity



B field

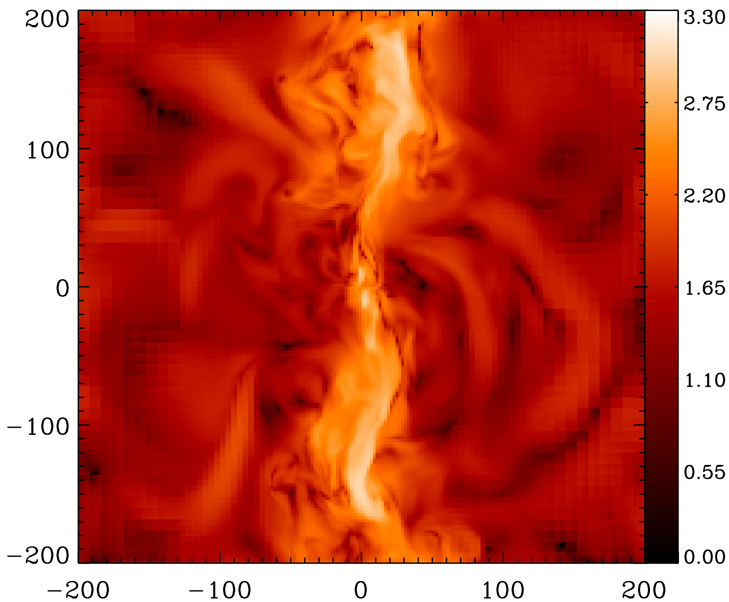


HBI + AGN

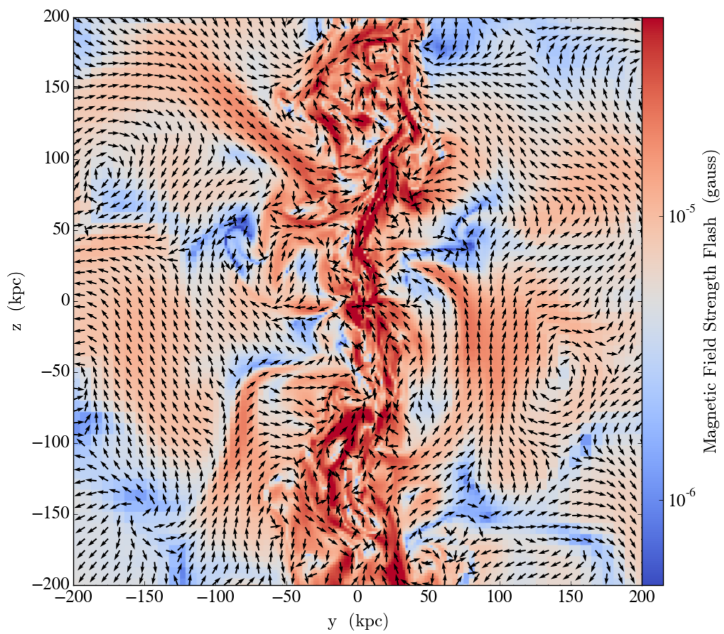
- AGN-driven turbulence randomizes field lines and counteract the HBI
- Effects primarily along the jet axis

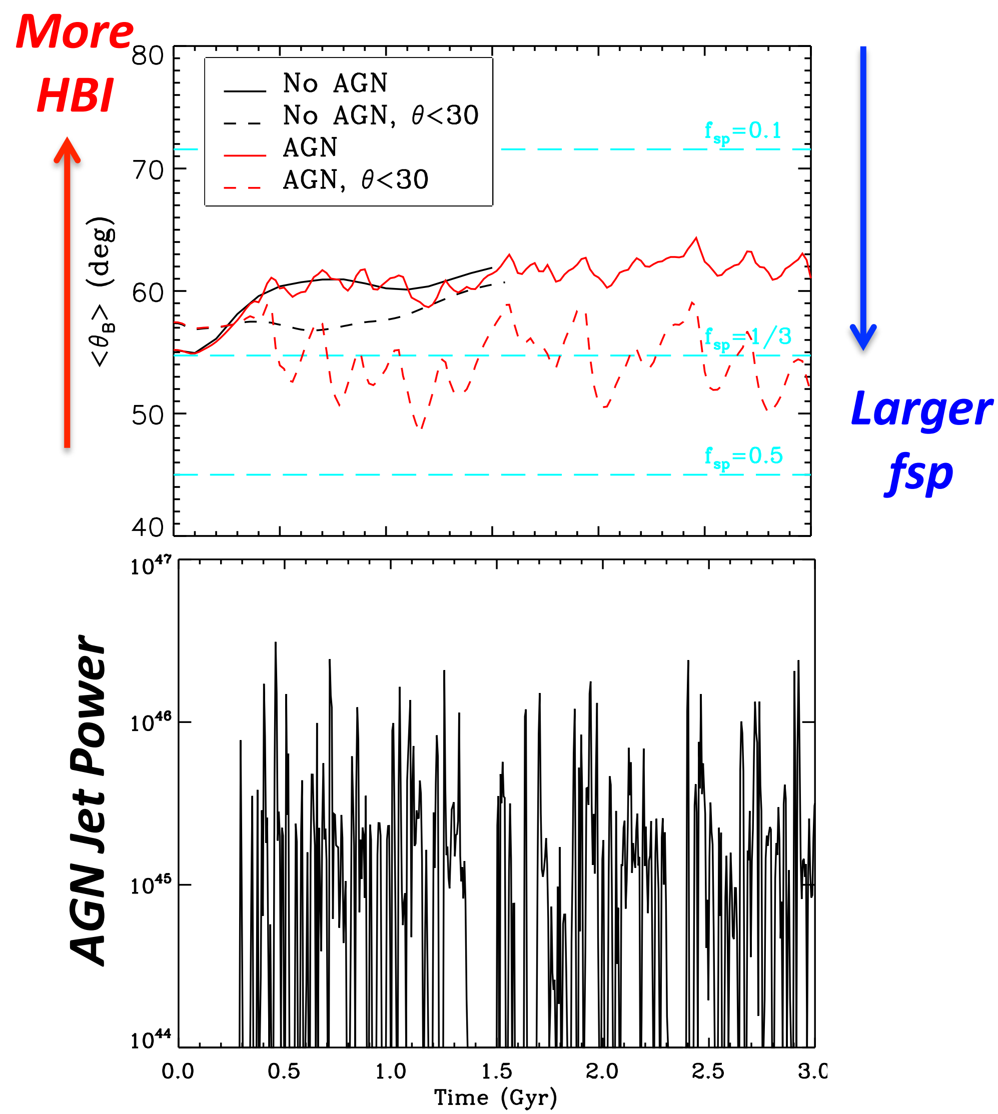
HBI + AGN

Turbulent velocity



B field





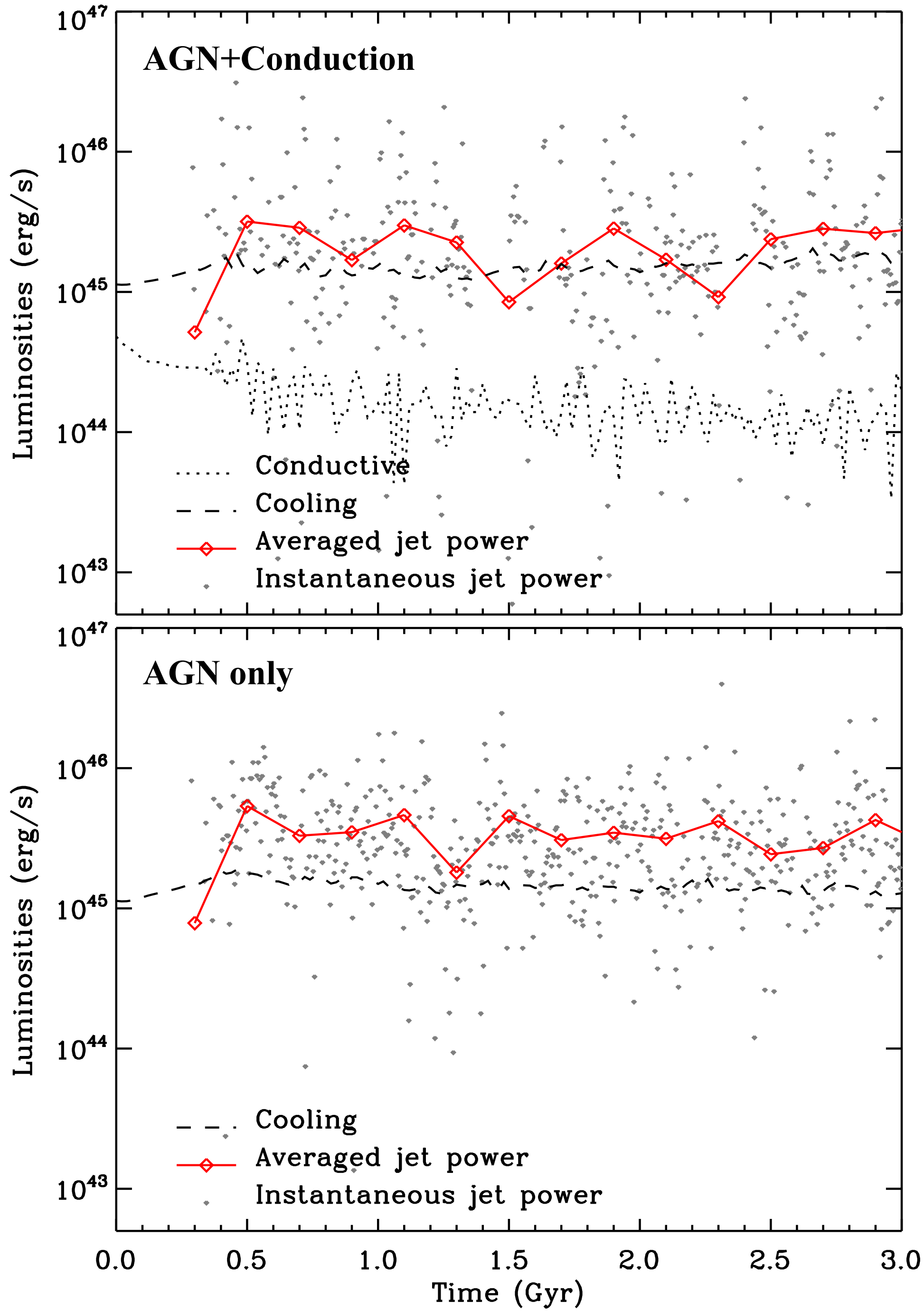
Conductive vs. AGN heating (Perseus-like)

$$Q_{\rm cond} = -f_{\rm sp}\chi\partial T/\partial r$$

❖ Conductive heating ~ 10% of cooling losses

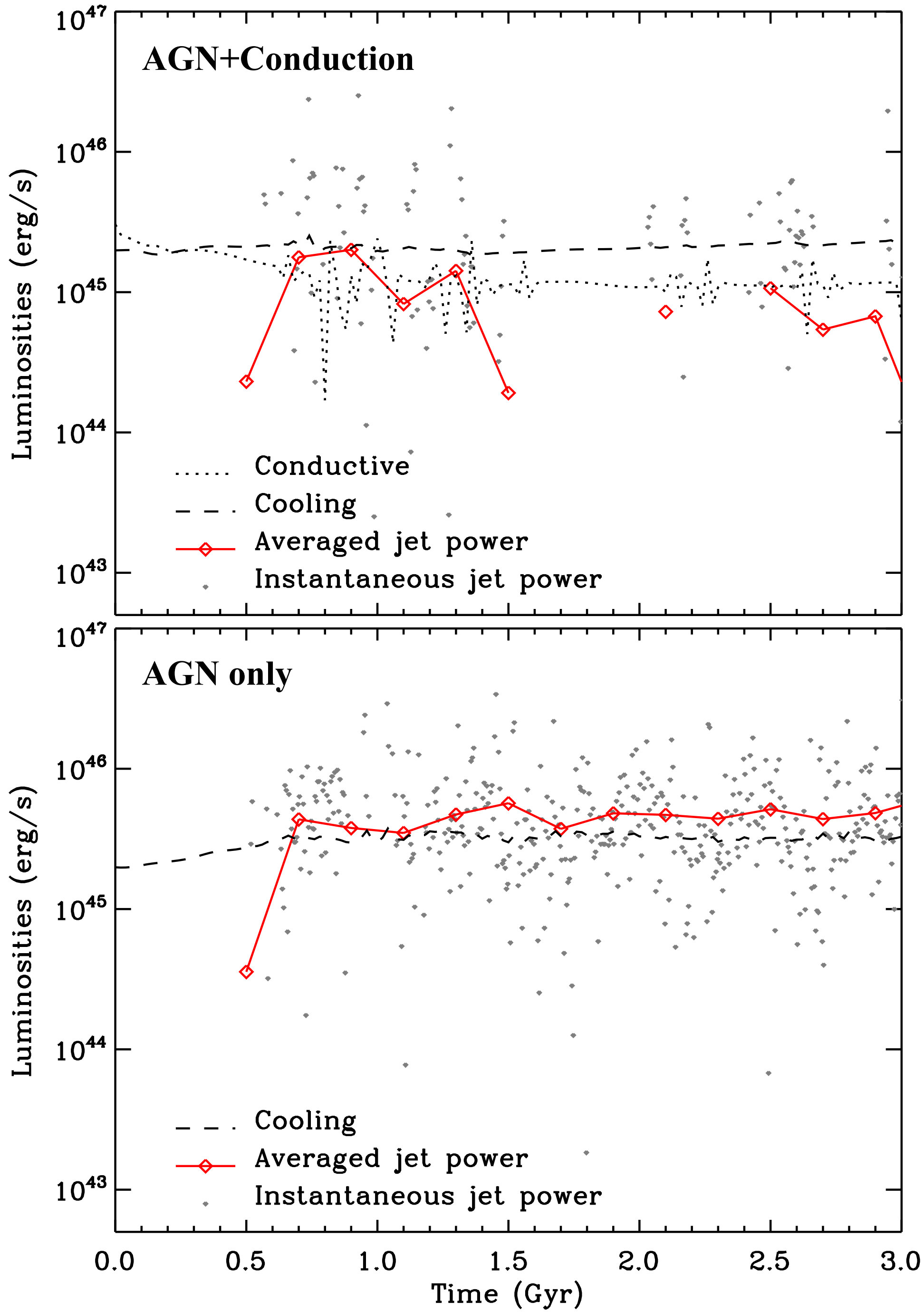
❖ Conductive heating decreases with time due to HBI and reduced grad(T)

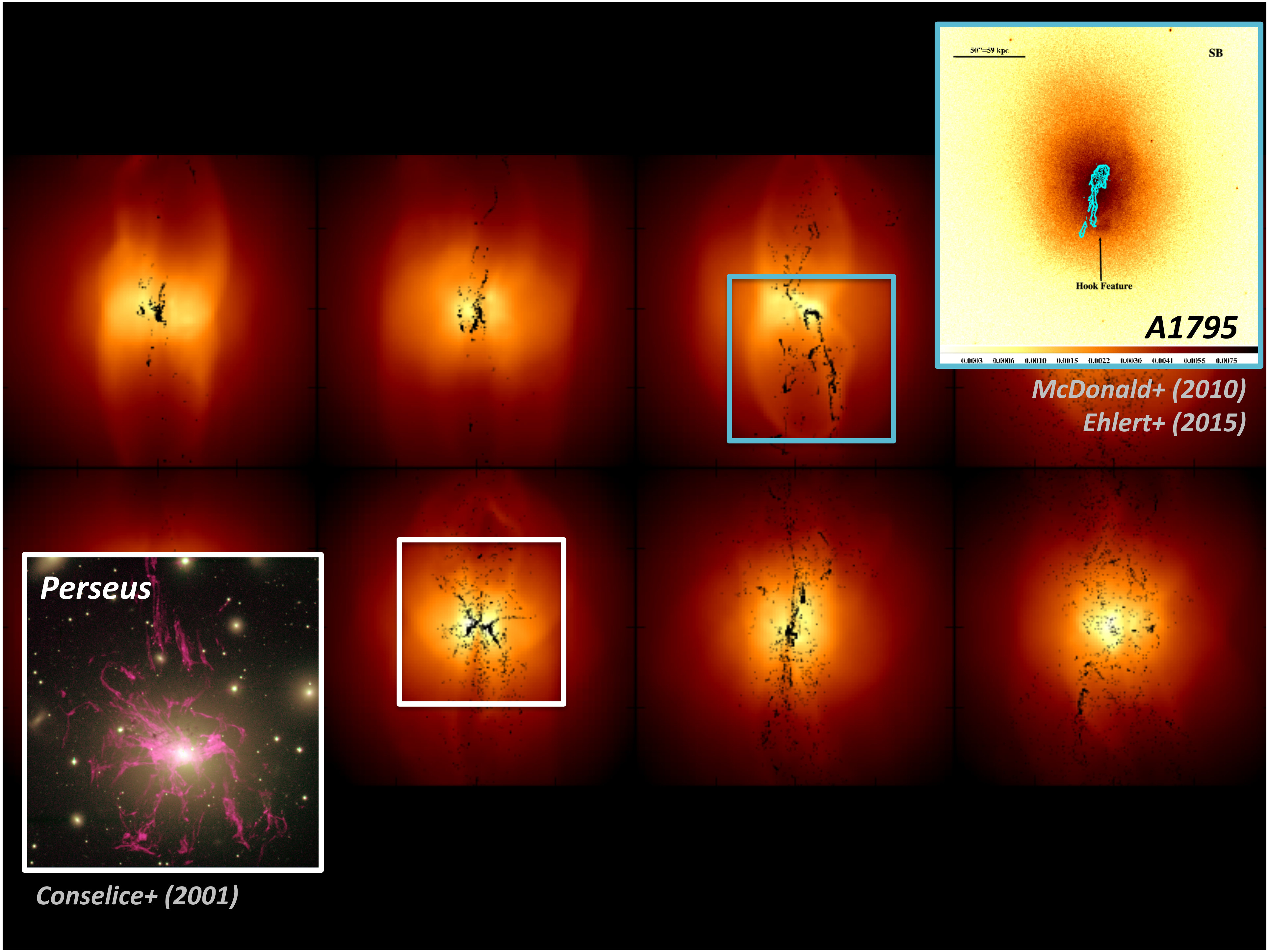
❖ Effect of AGN is temporary



Conductive vs. AGN heating (*2 x Perseus ~ 1.7e15 Msun*)

- Conductive heating ~ 50% of cooling losses
- With conduction: weaker jets, less frequent activity, suppressed cold gas formation





50"=59 kpc
SB
Hook Feature
A1795
McDonald+ (2010)
Ehlert+ (2015)
Perseus
Conselice+ (2001)

Summary

1. In realistic cluster conditions, ***HBI should be completely or significantly suppressed by magnetic tension***, depending on l_B

2. ***AGN-jet driven turbulence can randomize field lines and counteract the HBI***, but only in regions directly influenced by the jets

3. ***Conductive heating contributes to 10%~50% of radiative losses***, depending on the cluster mass. Possible signatures in hottest clusters.