New constraints on large-scale thermal conductivity in galaxy clusters

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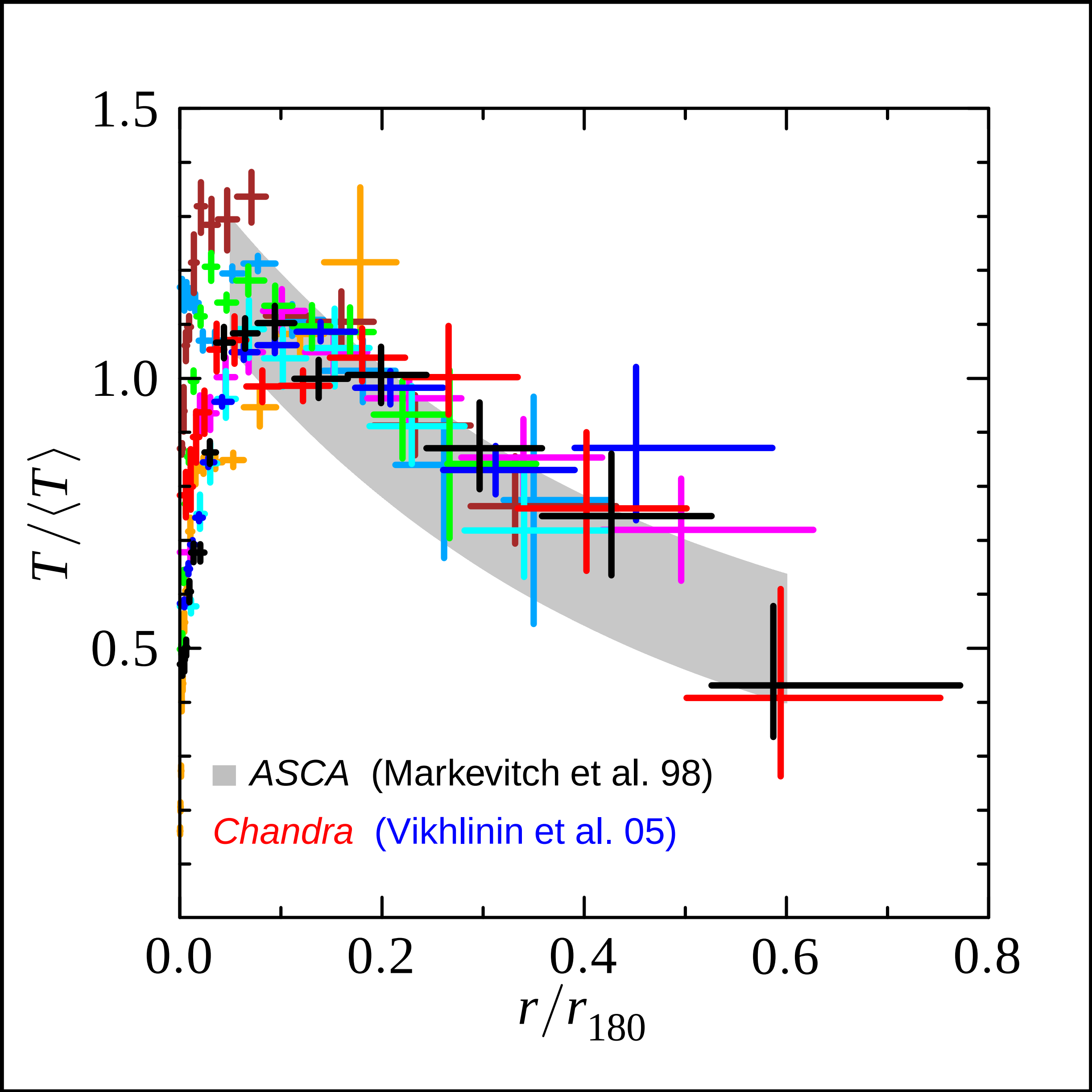
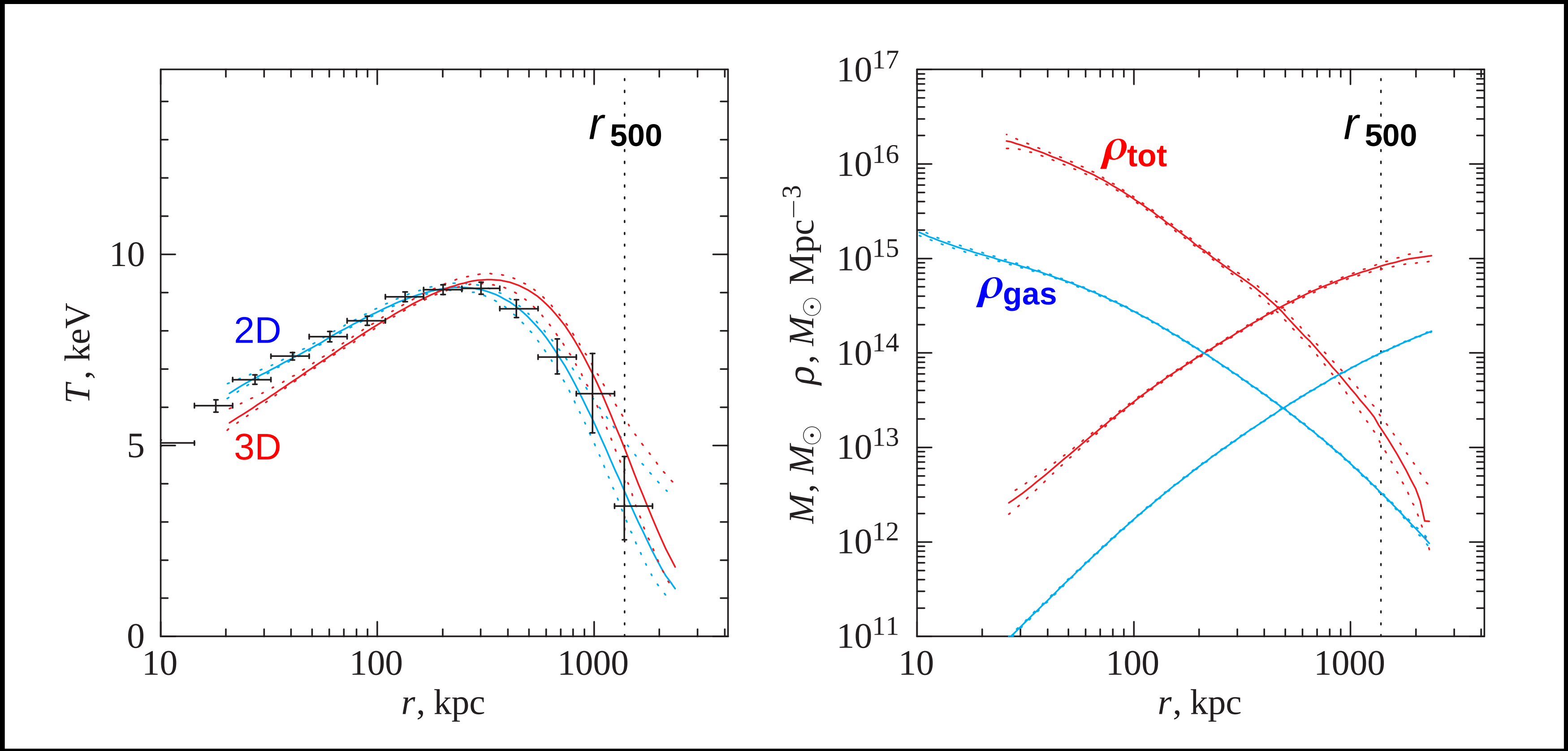
August 11, 2014

Cluster radial temperature profiles



- *XMM*, *Suzaku* results similar (Molendi & Leccardi 08; George et al. 09; ...)

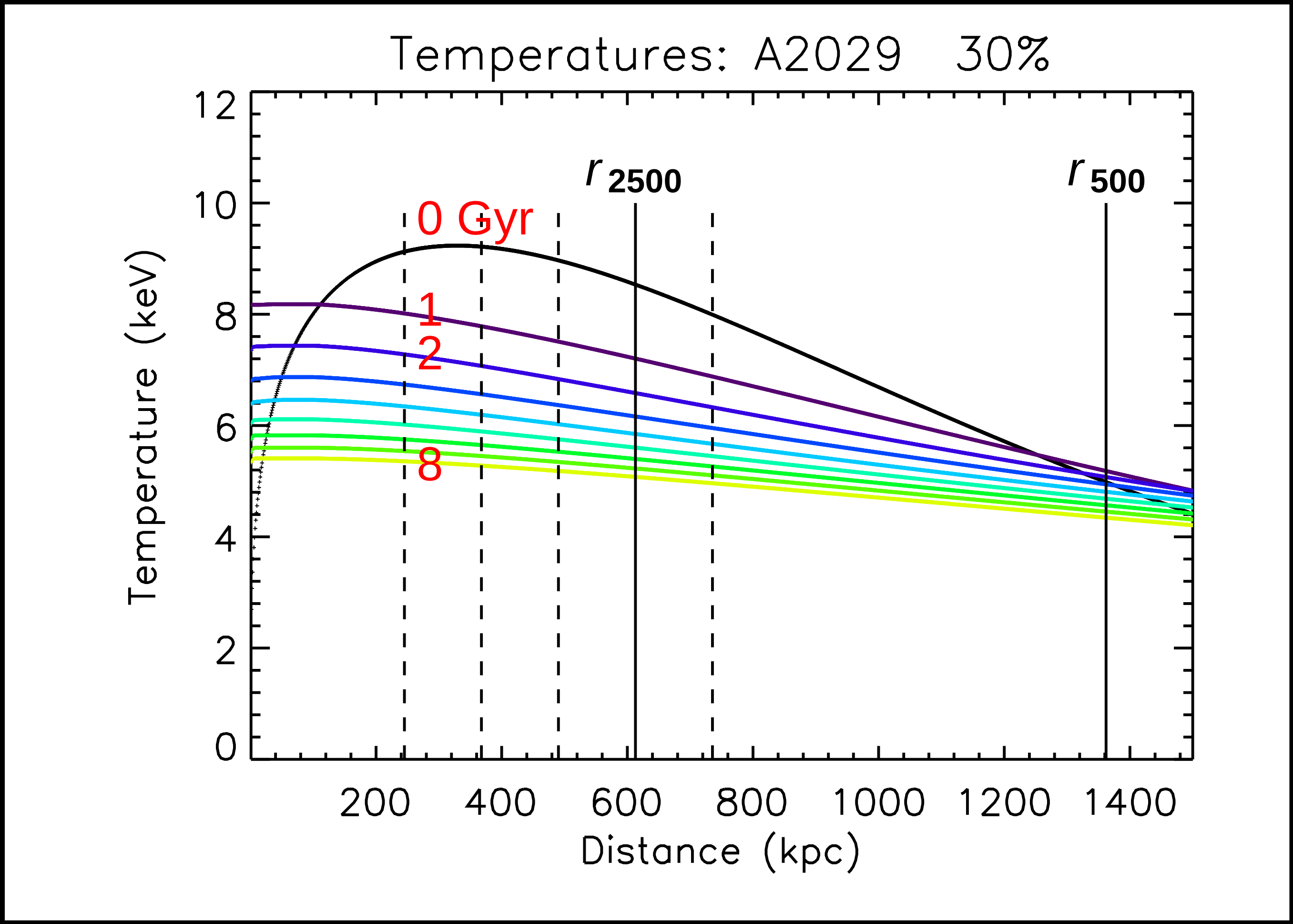
A2029, a prototypical hot relaxed cluster



Chandra data, Vikhlinin et al. 06

If the cluster were a solid body ...

no cooling, 0.3 Spitzer isotropic conduction

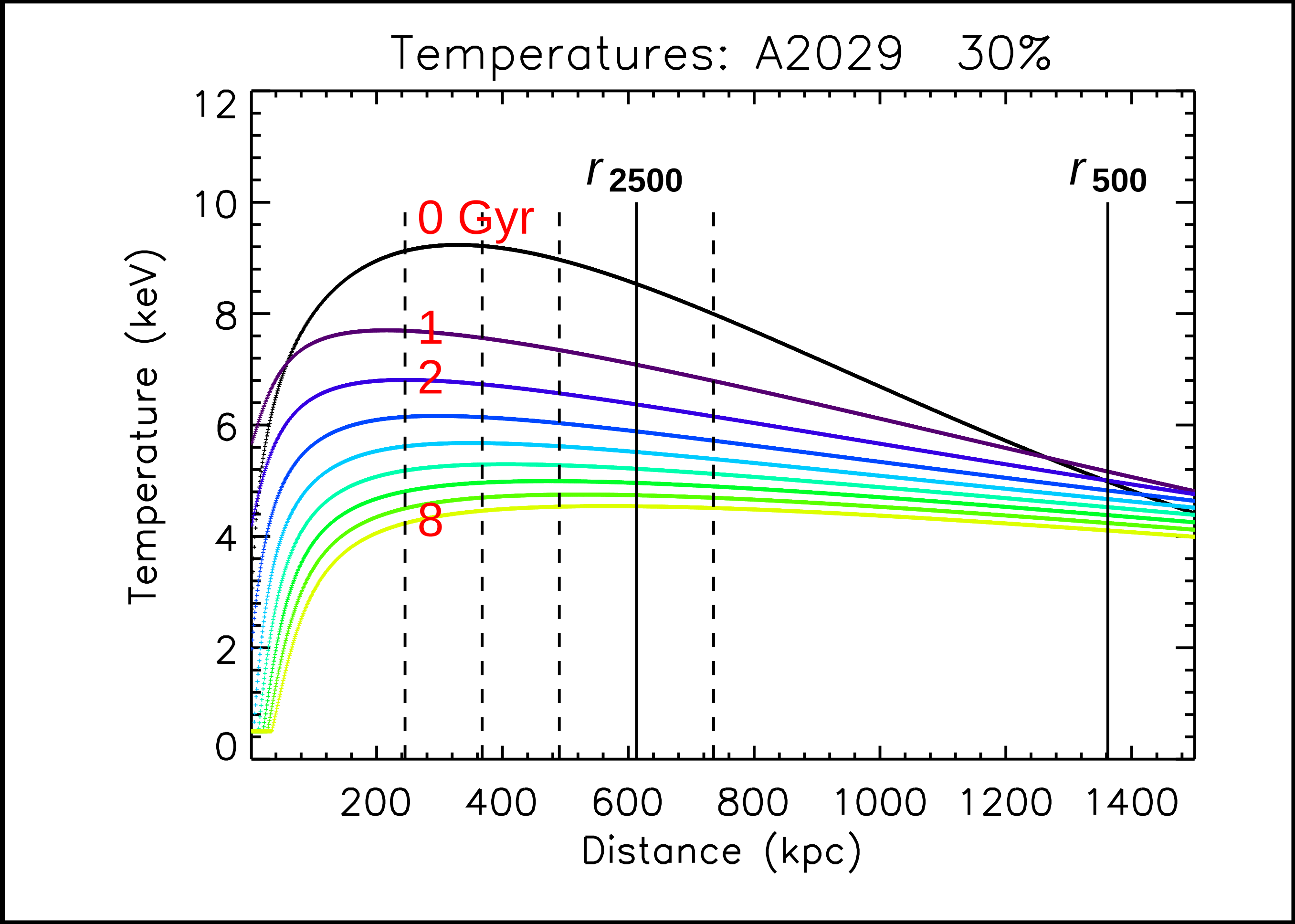


Russell et al. 14

- conduction erases *T* gradient

If the cluster were a solid body ...

cooling, 0.3 Spitzer isotropic conduction



Russell et al. 14

- conduction erases *T* gradient outside the cool core

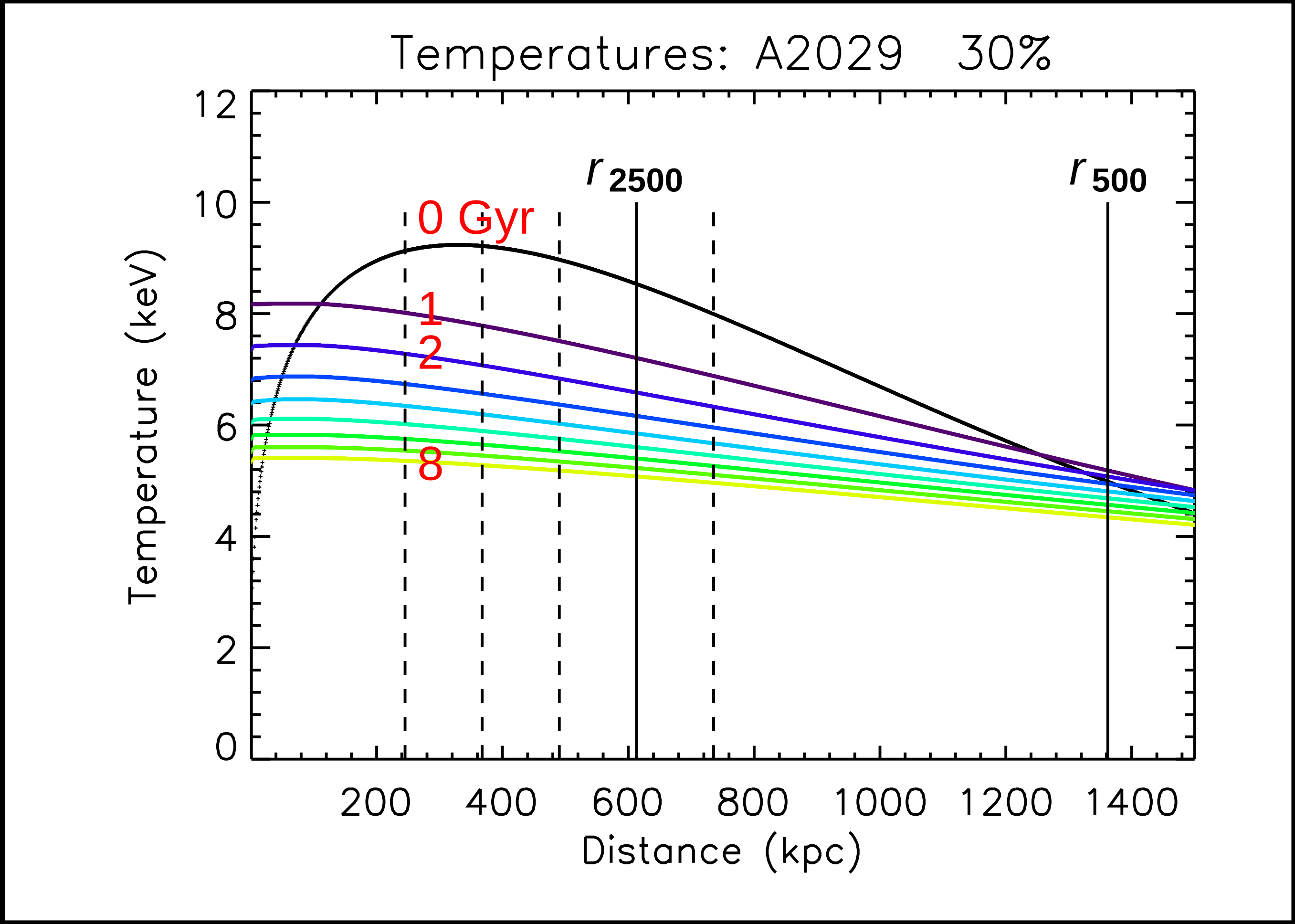
Allow the cluster to maintain hydrostatic equilibrium:

- Assume constant grav. potential
- Let the gas redistribute quasistatically
- Outer boundary (at $r \sim$ 3 Mpc) open for gas and heat flow

- simulation using Lagrangian shells (whose boundaries move with the gas)
- special treatment in central 10 kpc (smoothly suppressed cooling)

If the cluster is hydrostatic ...

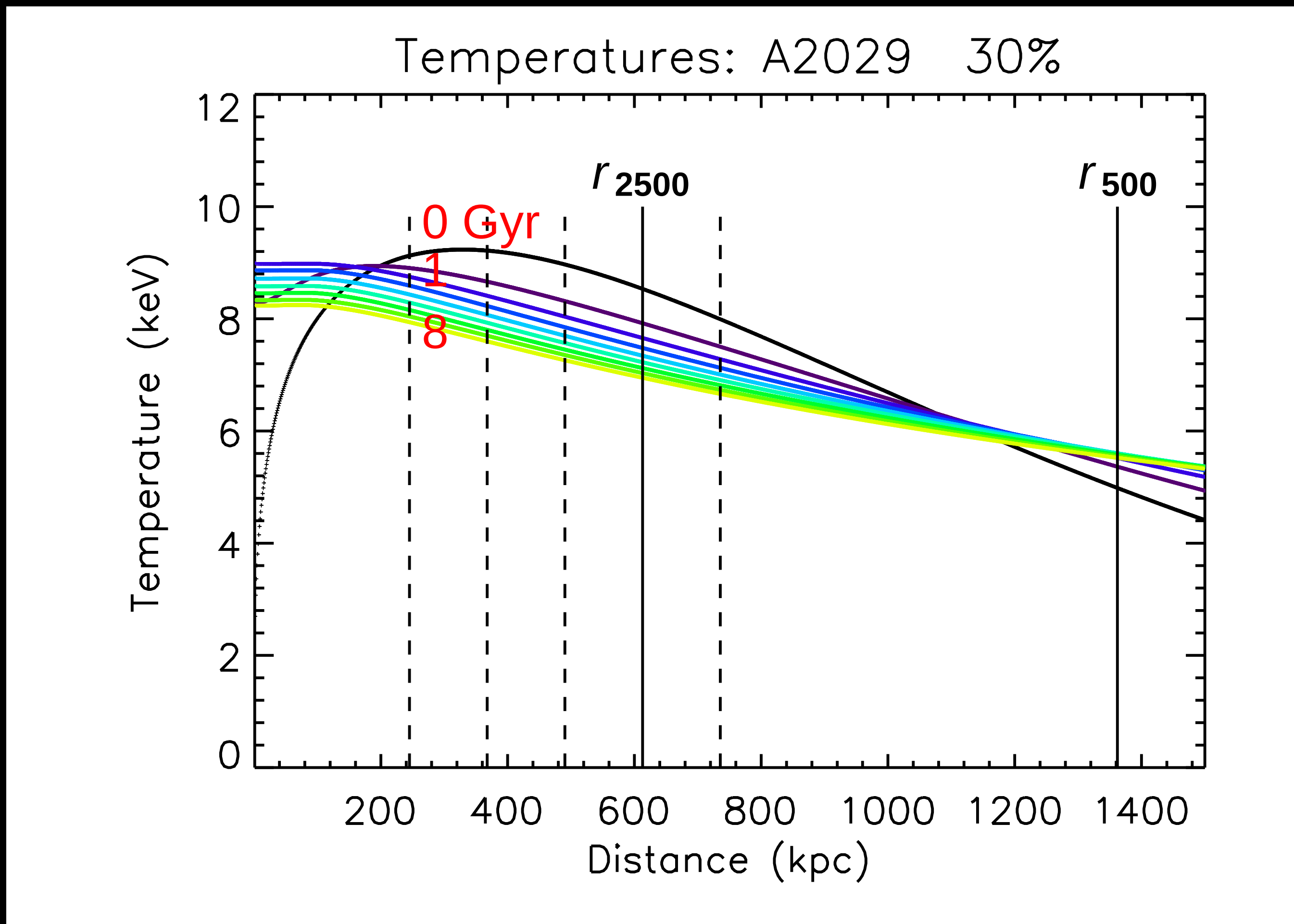
no cooling, 0.3 Spitzer isotropic conduction, no gas redistribution



Russell et al. 14

If the cluster is hydrostatic ...

no cooling, 0.3 Spitzer isotropic conduction, gas redistribution



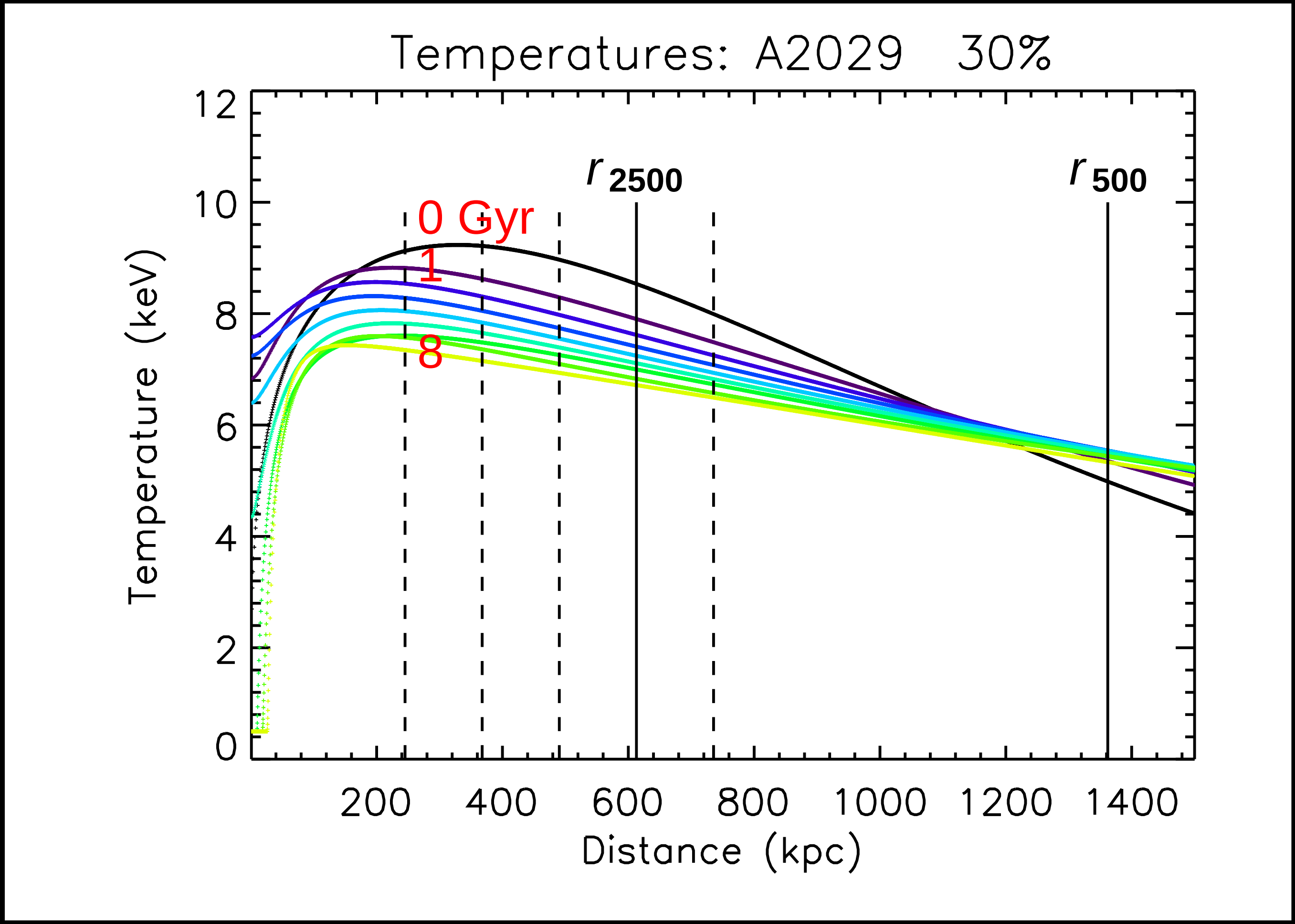
Russell et al. 14

- T gradient maintained because of cluster compression

(result very similar to McCourt, Quataert & Parrish 13)

If the cluster is hydrostatic ...

cooling, 0.3 Spitzer isotropic conduction, gas redistribution

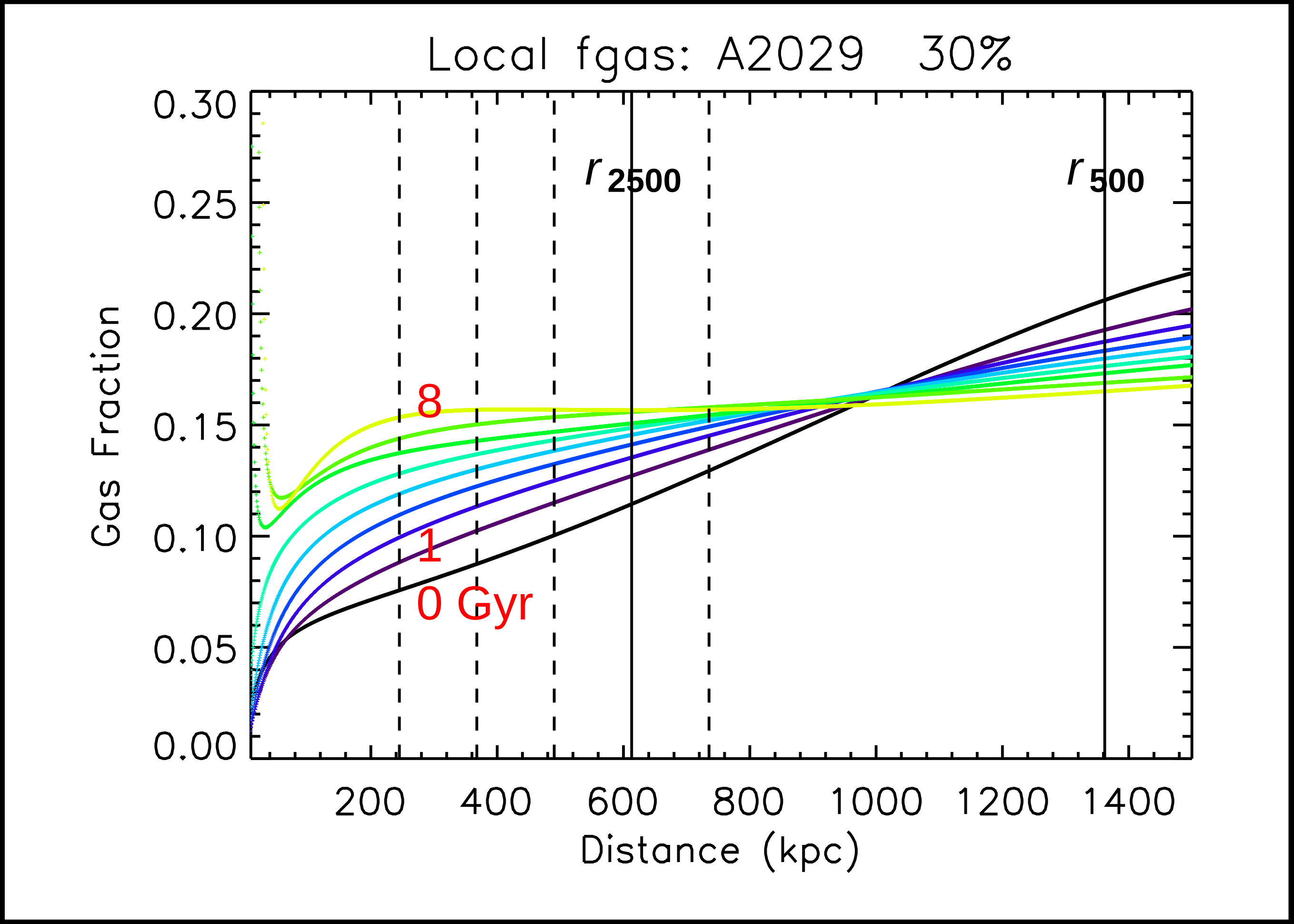


Russell et al. 14

- *T* gradient (mostly) maintained because of cluster compression

Evolution of gas density profile

cooling, 0.3 Spitzer isotropic conduction



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Evolution of gas density profile

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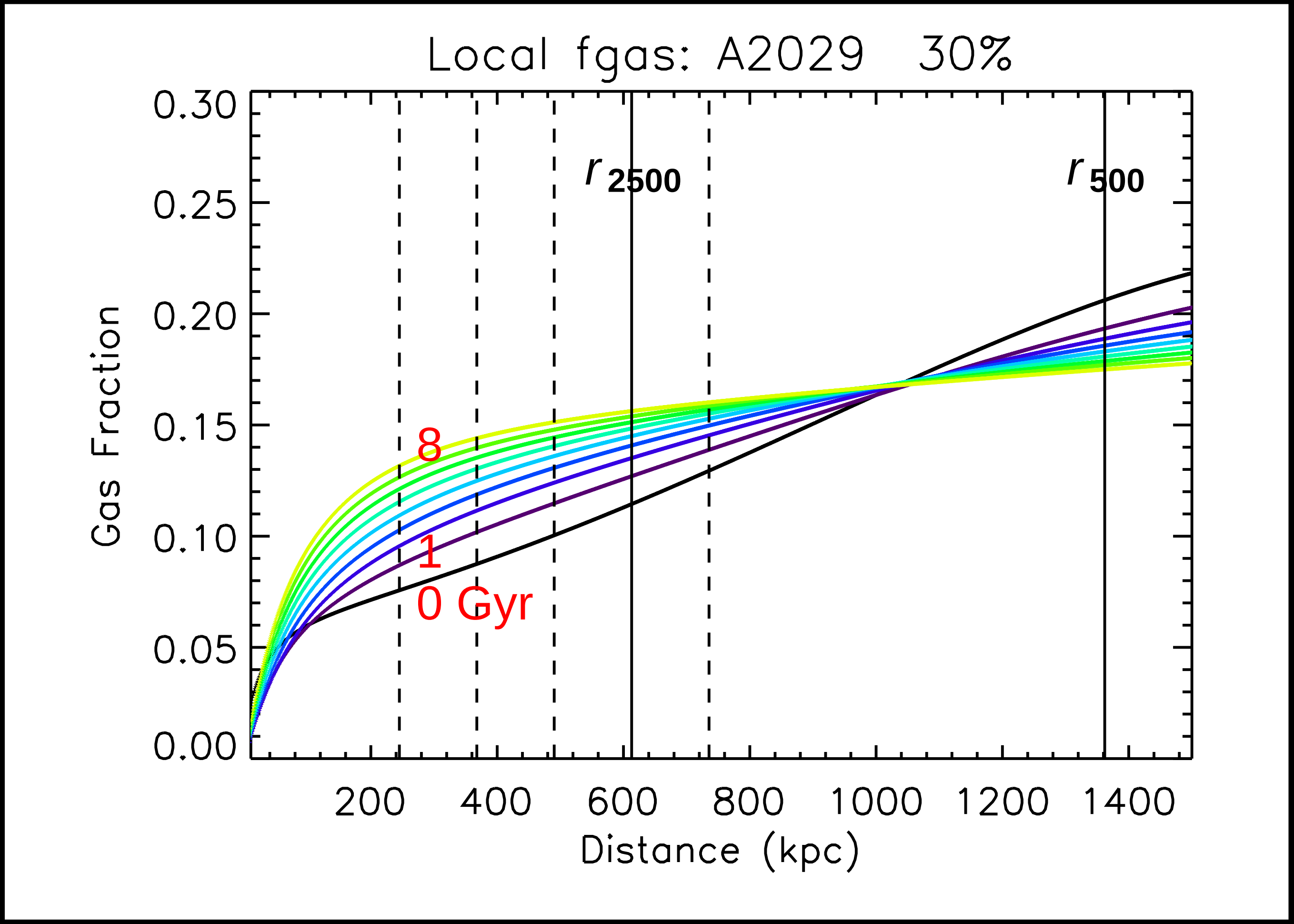
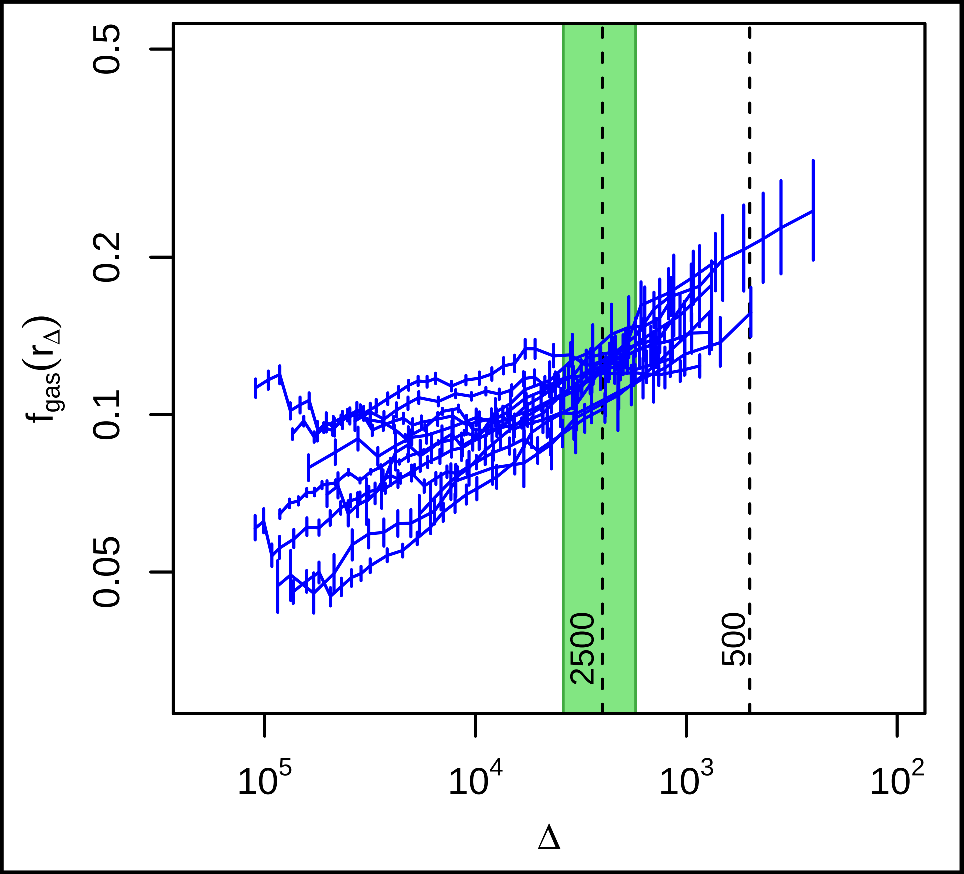


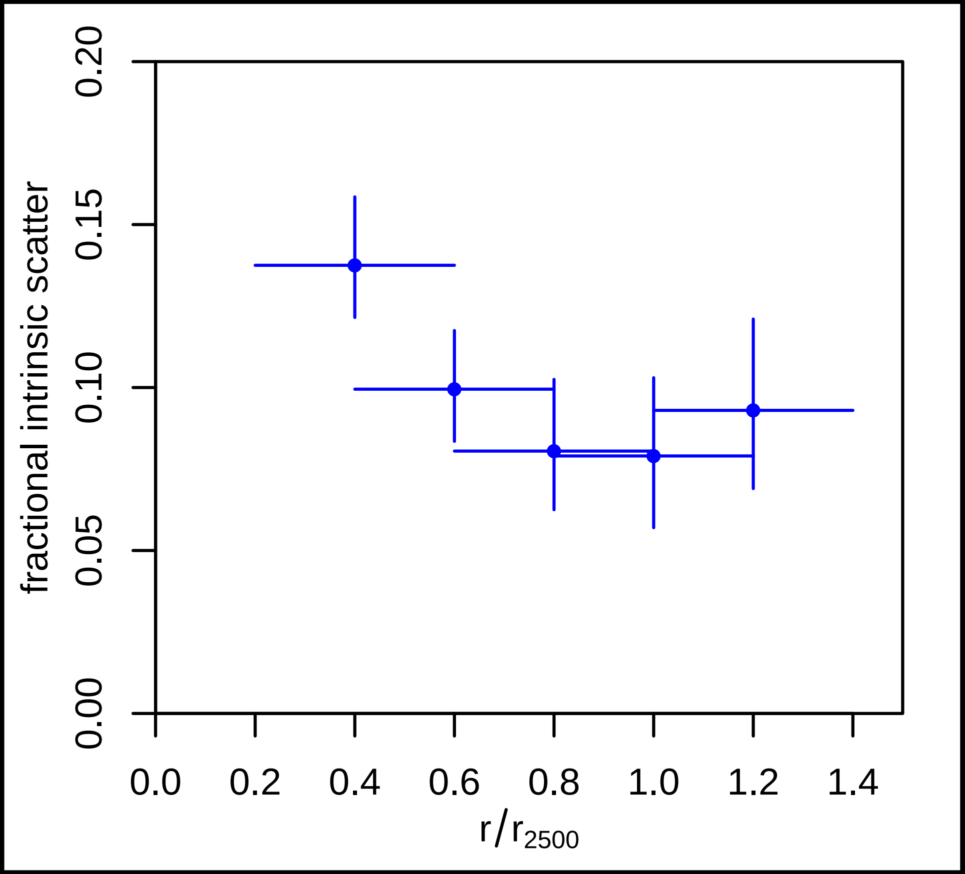
Russell et al. 14

- for $r > 0.5\, r_{2500}$, result doesn't depend on details of heating and feedback in cool core

Observed differential f_{gas} profiles in hot relaxed clusters

T > 5 keV, z < 0.25 relaxed clusters

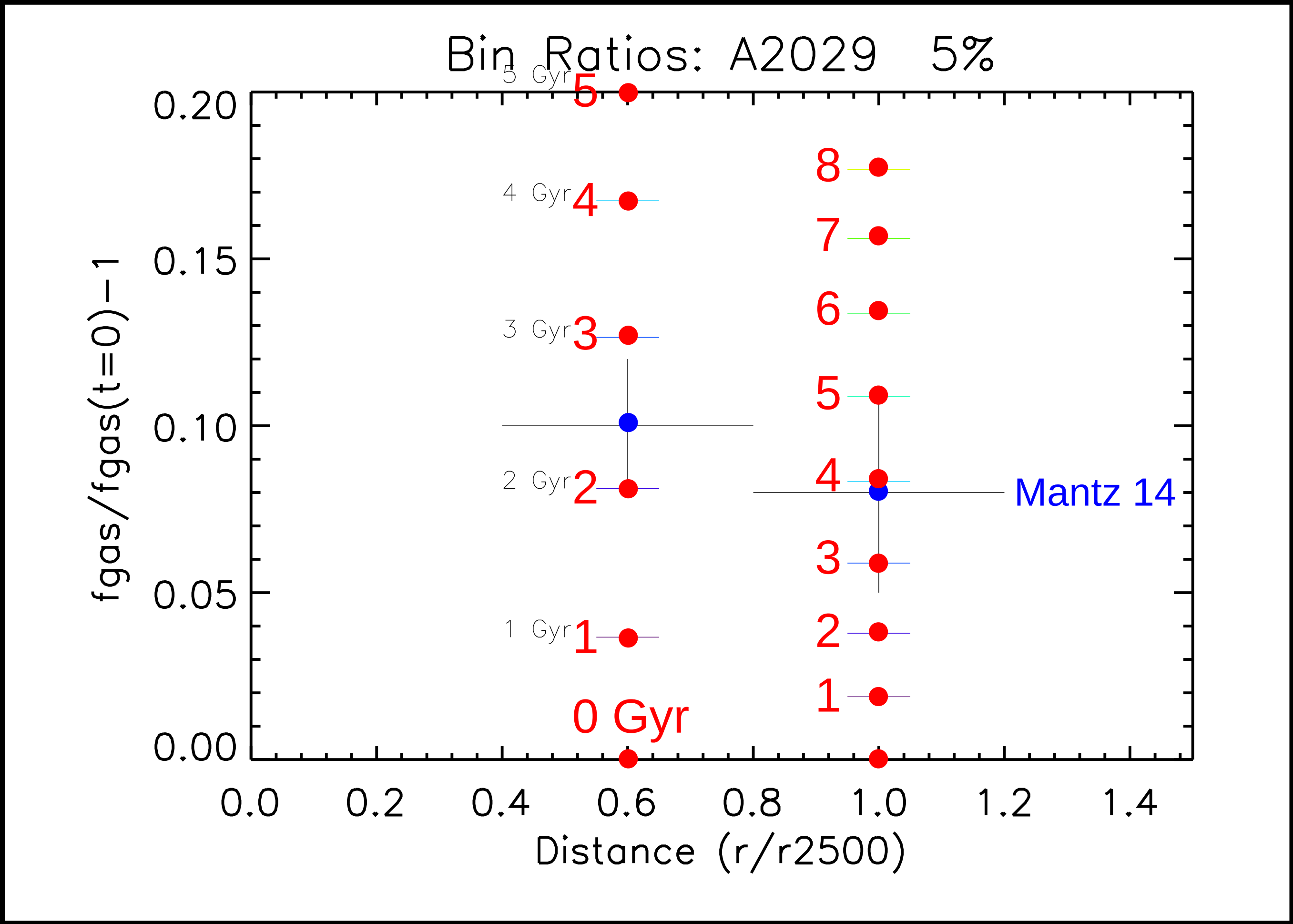




Mantz et al. 14

Evolution of differential f_{gas} profile with conduction

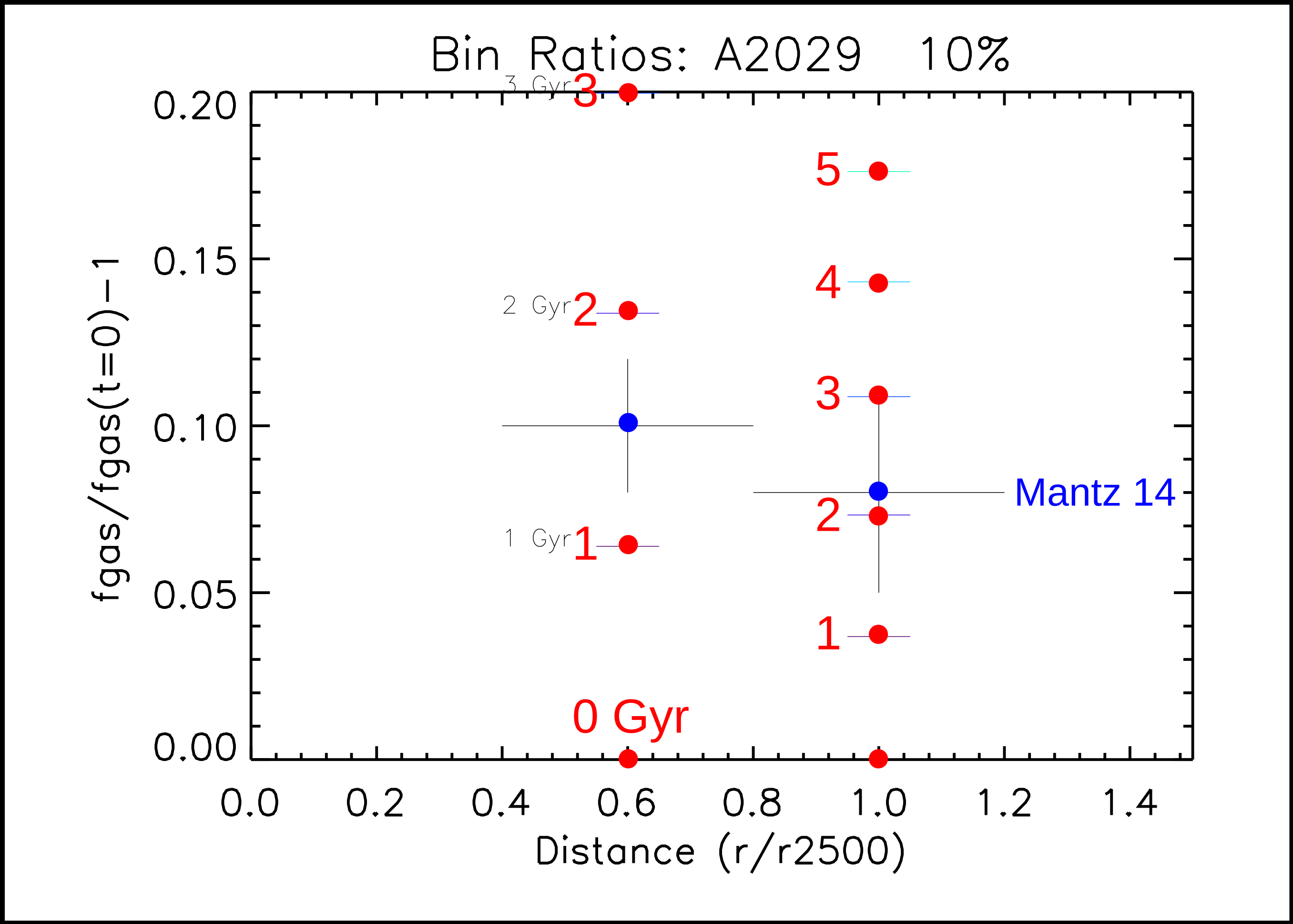
5% Spitzer



Russell et al. 14

Evolution of differential f_{gas} profile with conduction

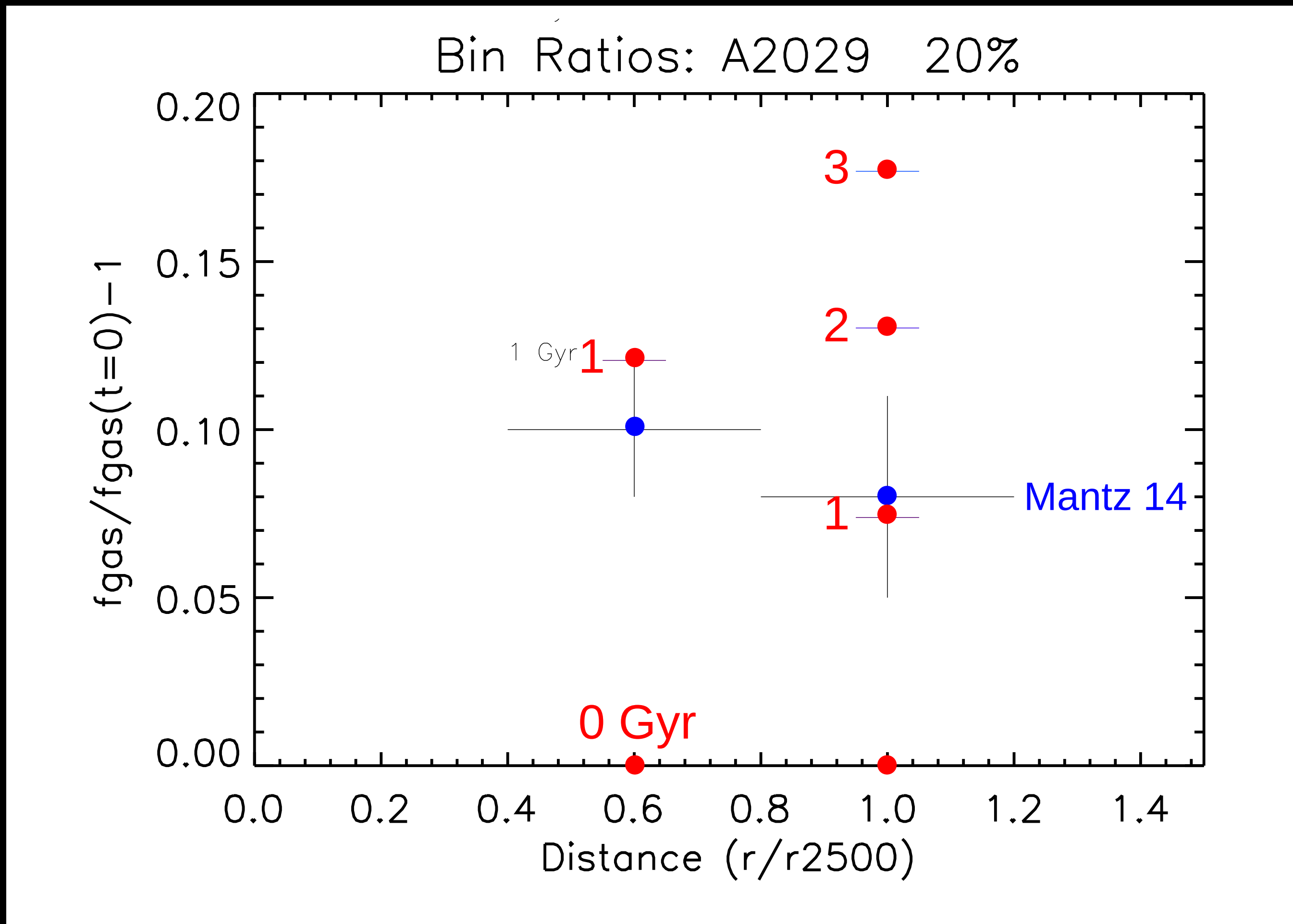
10% Spitzer



Russell et al. 14

Evolution of differential f_{gas} profile with conduction

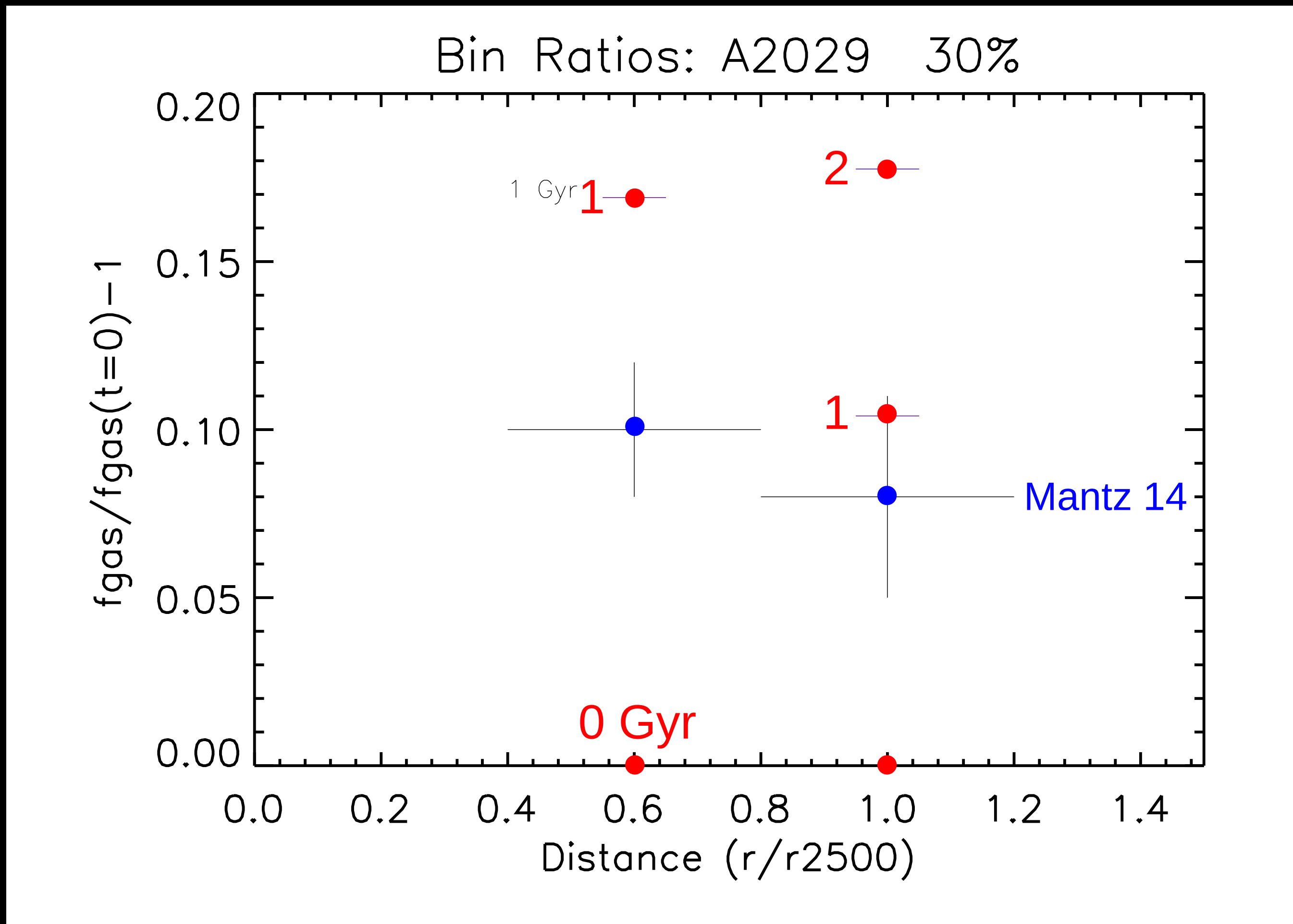
20% Spitzer



Russell et al. 14

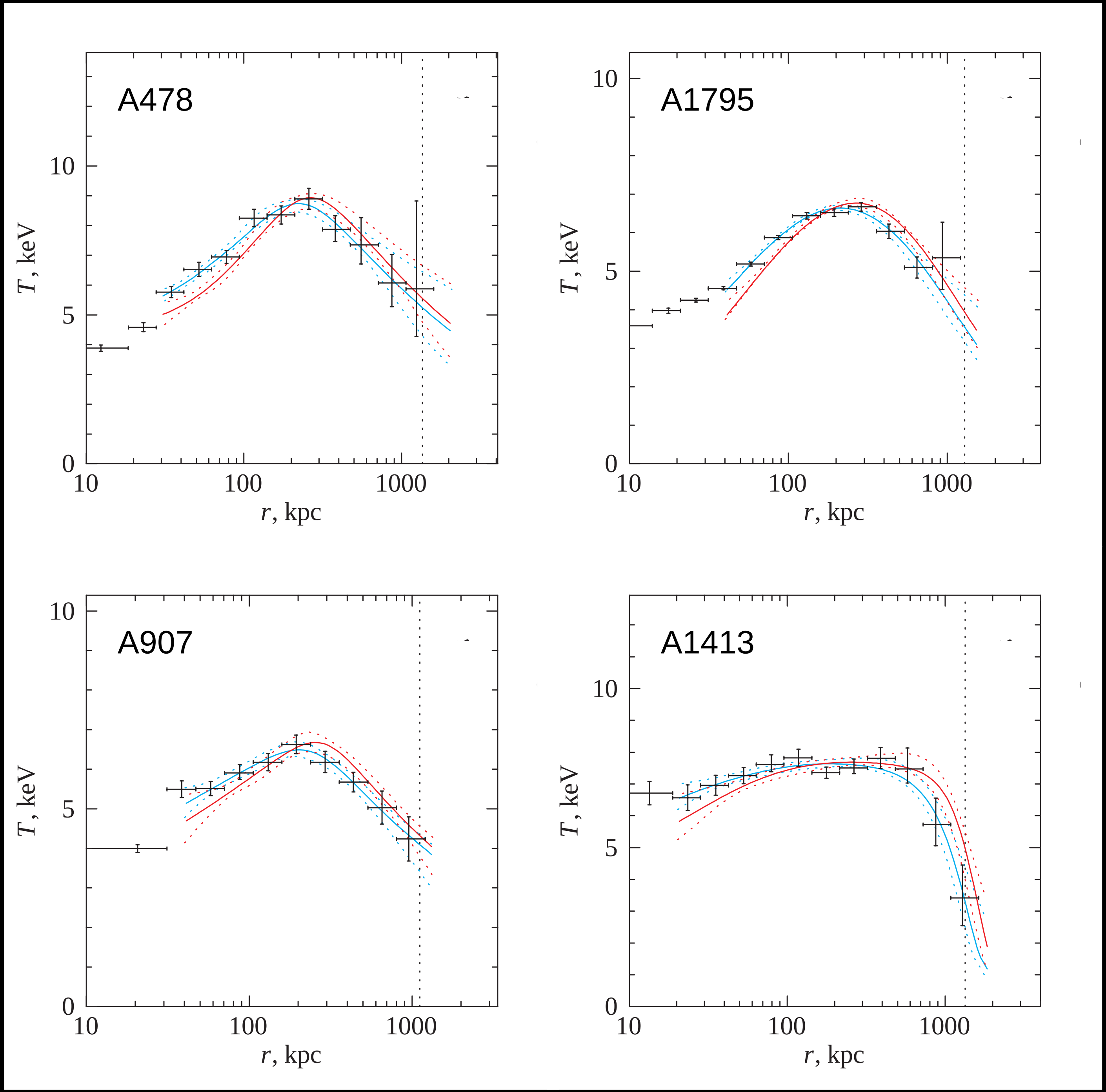
Evolution of differential f_{gas} profile with conduction

30% Spitzer



Russell et al. 14

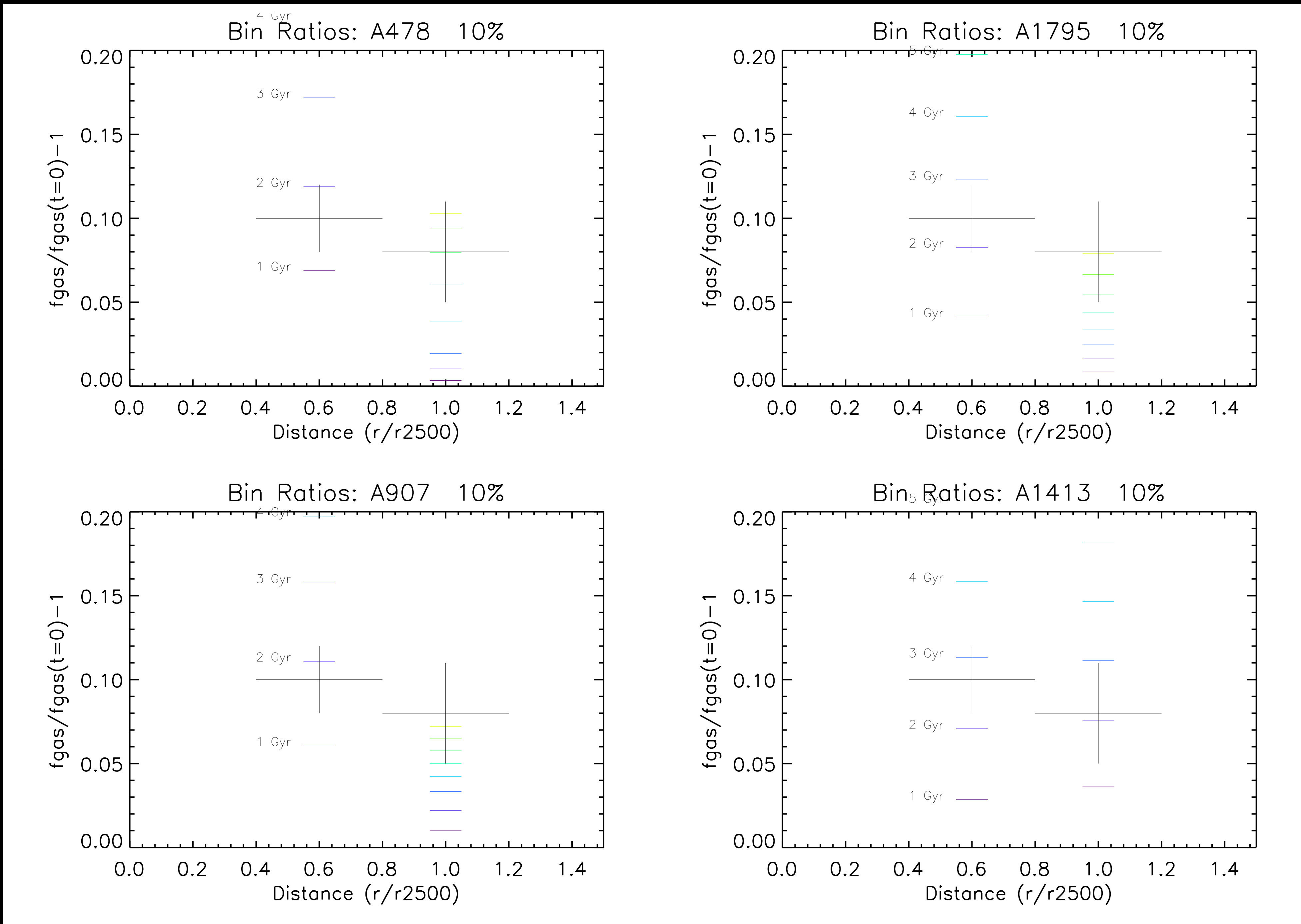
Other hot relaxed clusters



Chandra data, Vikhlinin et al. 06

Other hot relaxed clusters

10% Spitzer



Russell et al. 14

Conclusions

- Large-scale heat conduction does not erase the cluster radial temperature gradients (as shown before)
- What it does change is $f_{\mathbf{gas}}$ profile
- Under simple assumptions, $\kappa > 5$ – 10% Spitzer (in the cluster radial direction) contradicts the observed small scatter in $f_{\mathbf{gas}}$ at $r \sim r_{\mathbf{2500}}$ in hot, relaxed clusters

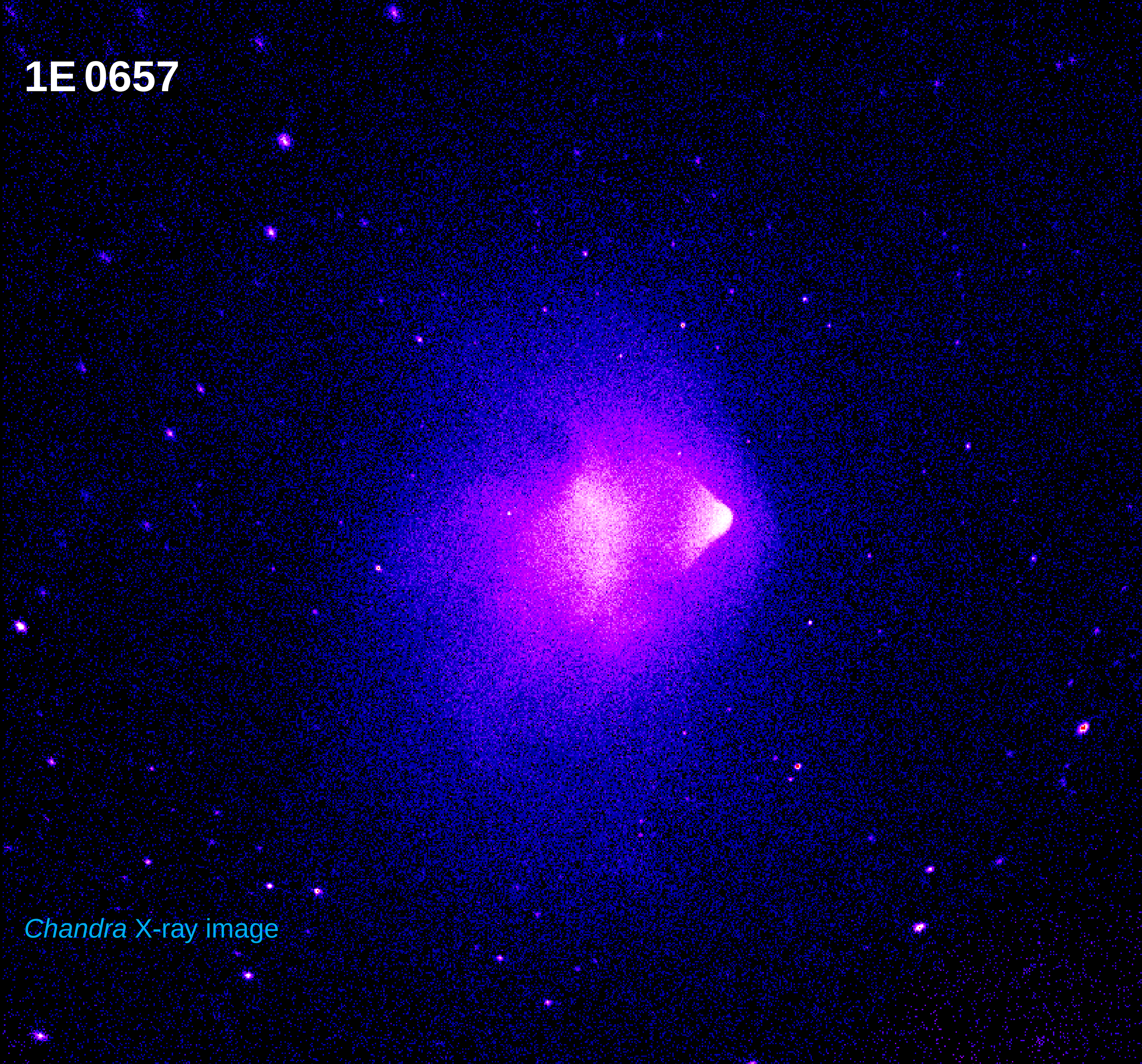
(e.g., *B* stretched in radial direction by MTI and full conduction along the field lines is excluded)

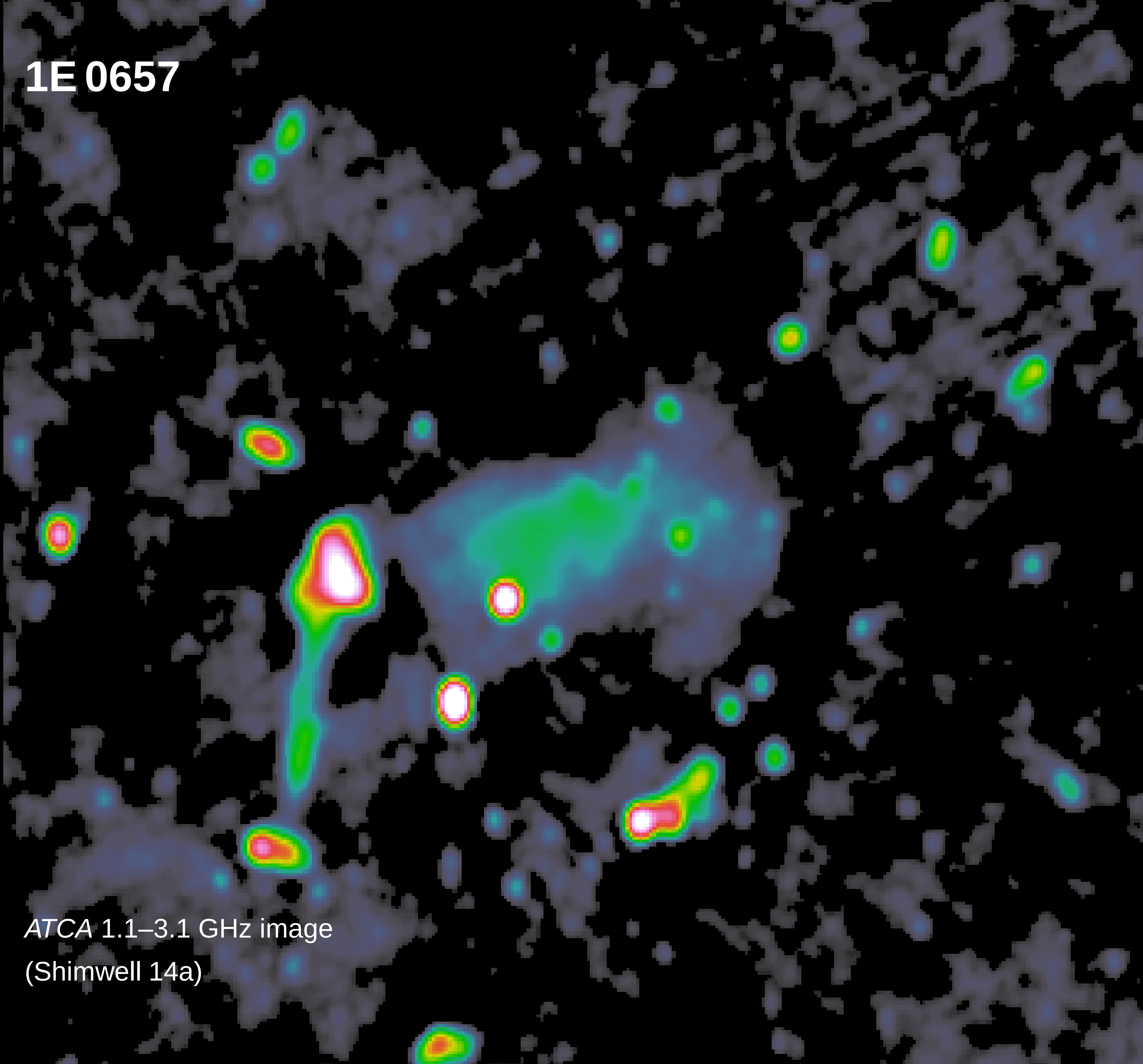
- Cosmological simulations including heat conduction and cooling, and the relaxed cluster selection as in Mantz 14, may place stronger constraints

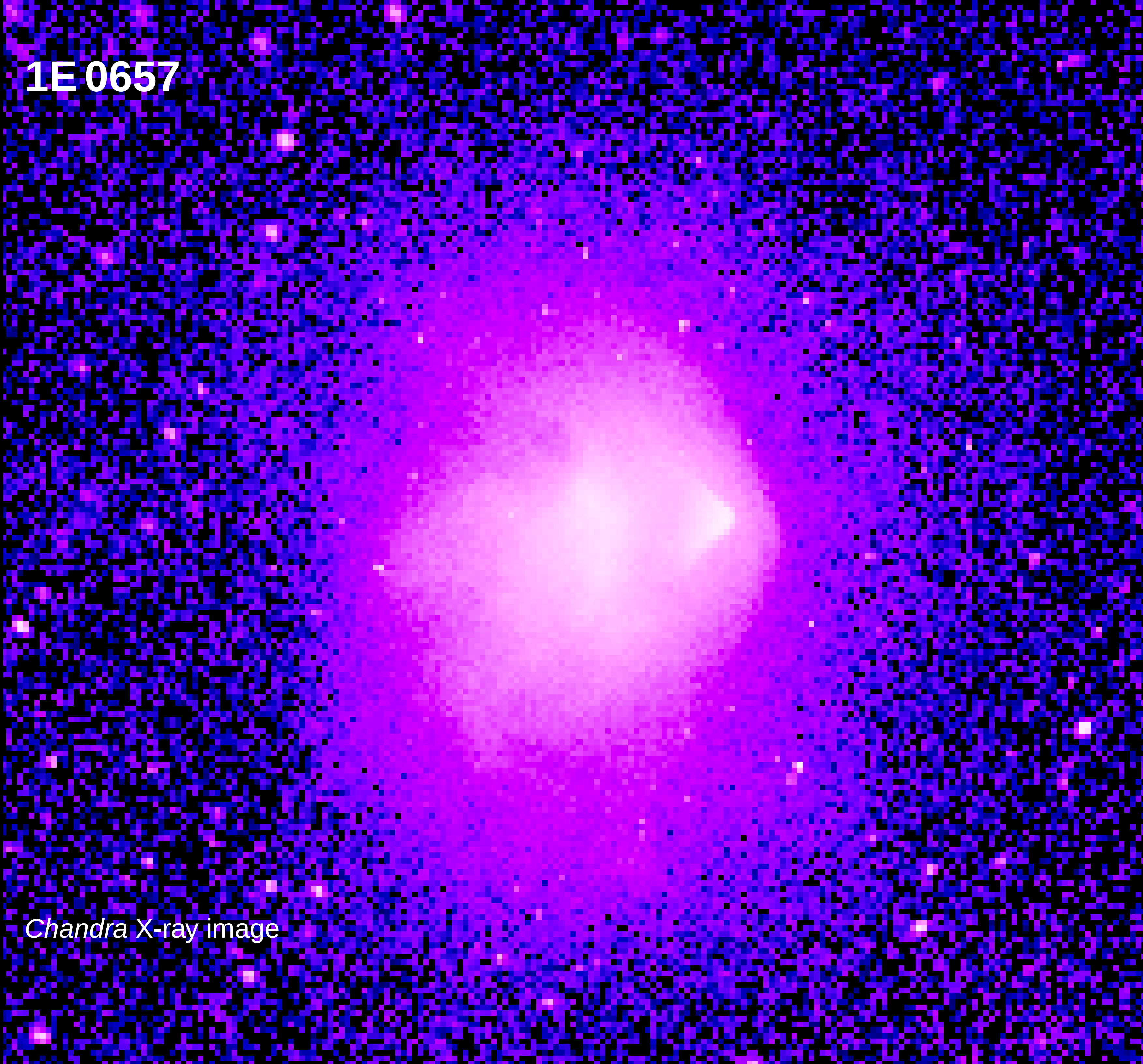
Another shock for the Bullet Cluster
and a smoking-gun model for radio relics

Tim Shimwell (Leiden), Maxim Markevitch (GSFC)

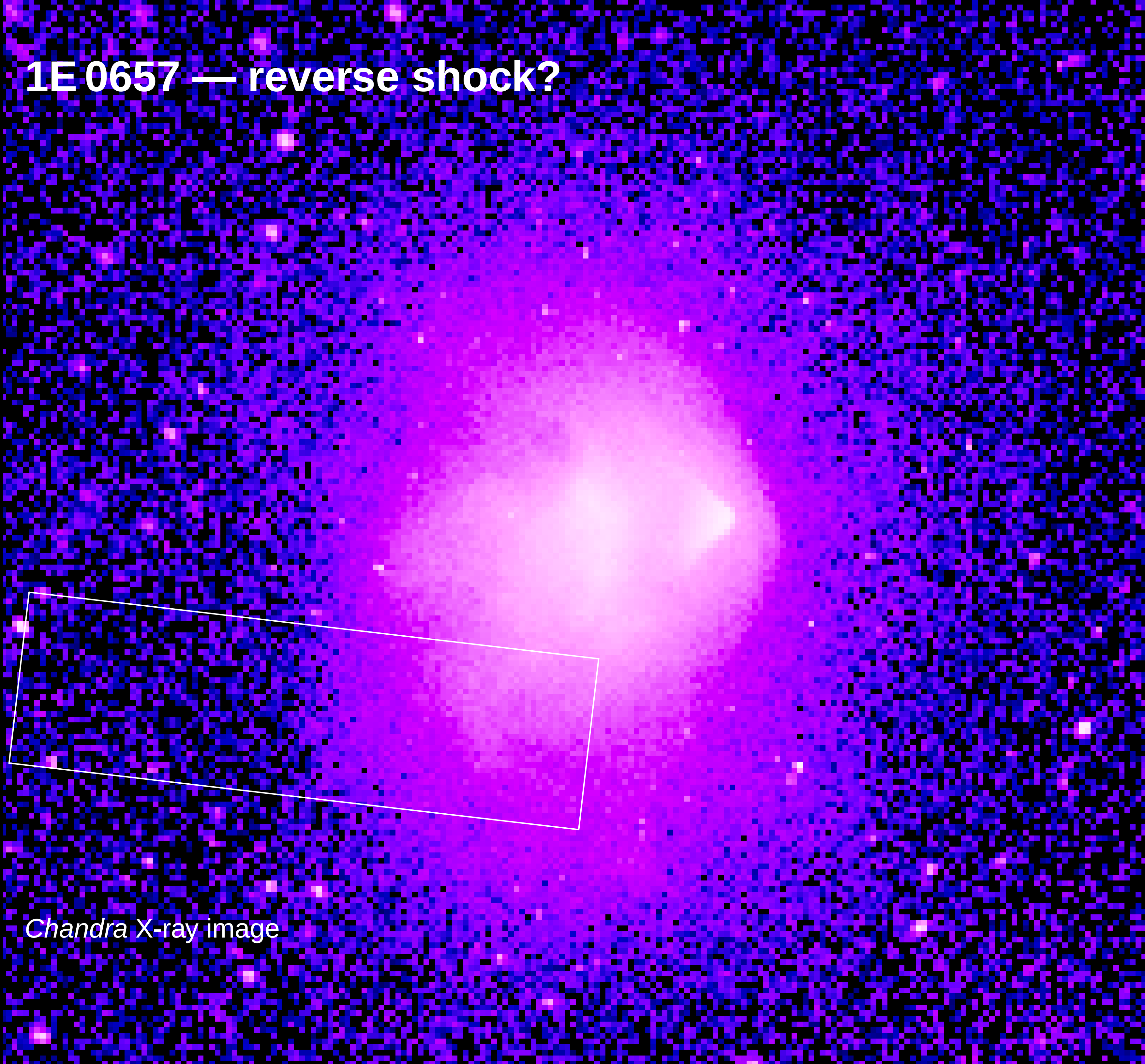
August 11, 2014


1E 0657
Chandra X-ray image


1E 0657
ATCA 1.1–3.1 GHz image
(Shimwell 14a)


1E 0657
Chandra X-ray image

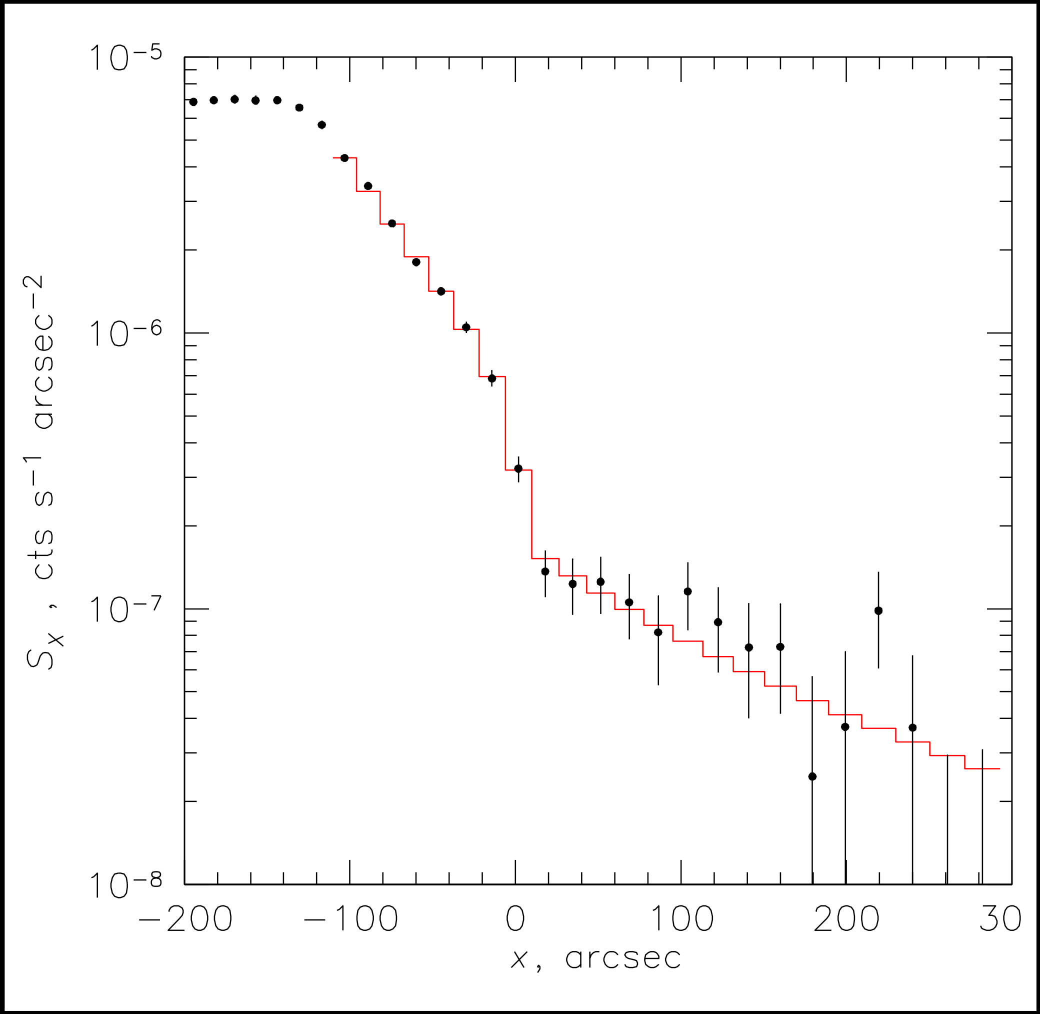
1E 0657 — reverse shock?



Chandra X-ray image

1E 0657 — reverse shock?

X-ray brightness across relic

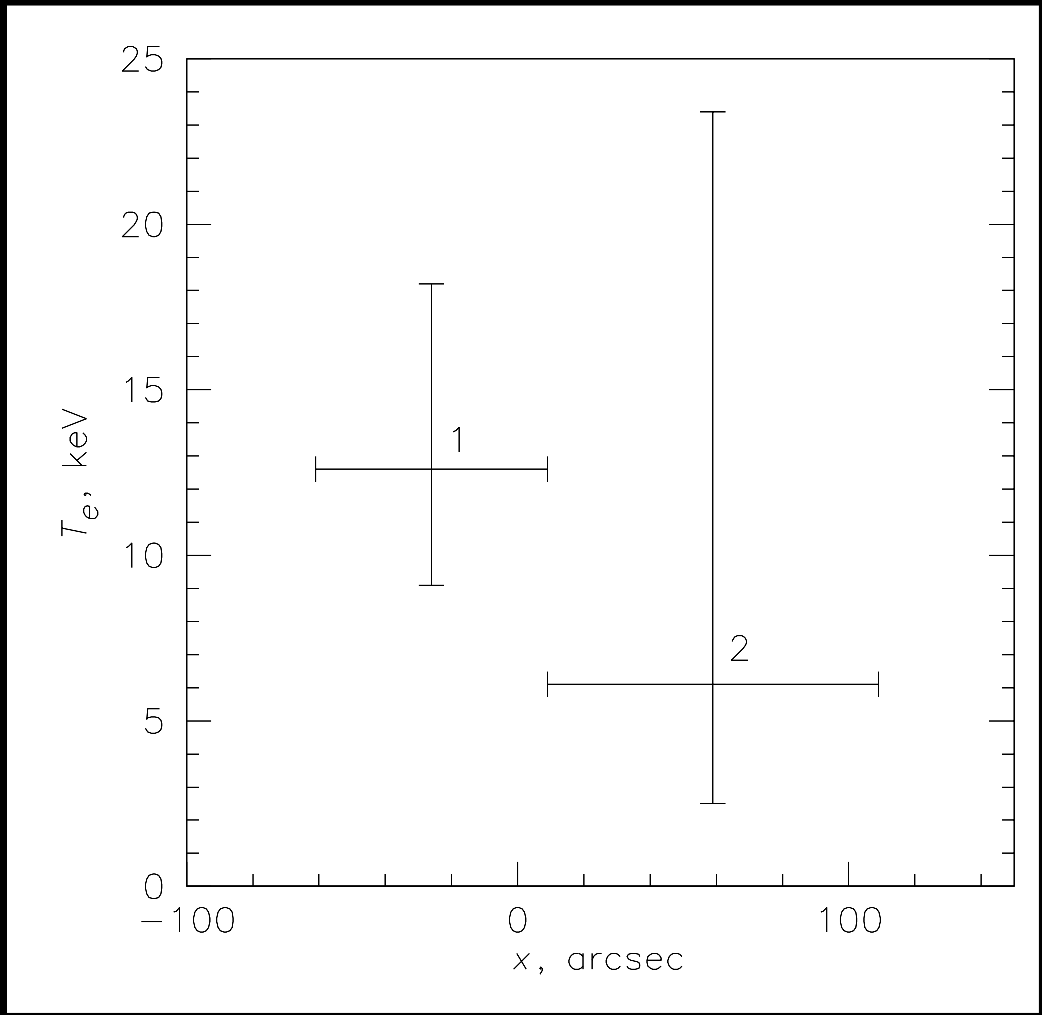


Fit corresponds to shock with *M* = 1.7 – 5.5 (uncertain 3D geometry)

(Shimwell 14b)

1E 0657 — reverse shock?

Gas temperature across relic



90% error bars (Shimwell 14b). Shock front “suggested” but not unambiguously confirmed

A "reverse shock" to the famous western shock

- Although T jump inconclusive, unlikely to be anything else
- X-ray M = $\mathbf{2.5^{+1.3}_{-0.8}}$
- Radio slope of tail region of relic + Fermi type I acceleration $\rightarrow$ M = 1.9 – 2.2
- Tail is connected to a bright "bulb", which looks like a just-died radio galaxy

  — source of aged electrons (a smoking gun) for re-acceleration?

- Conjecture: ICM polluted by a radio galaxy stays in the periphery, forming a pancake (or sausage) along the equipotential surface, waiting for a shock passage