Probing the Outskirts of Clusters with *Suzaku*, *Chandra*, and *XMM*

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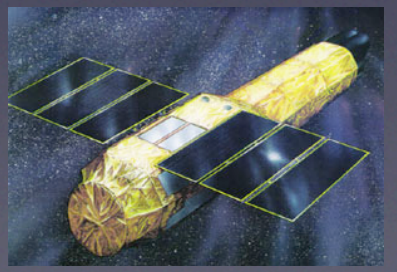
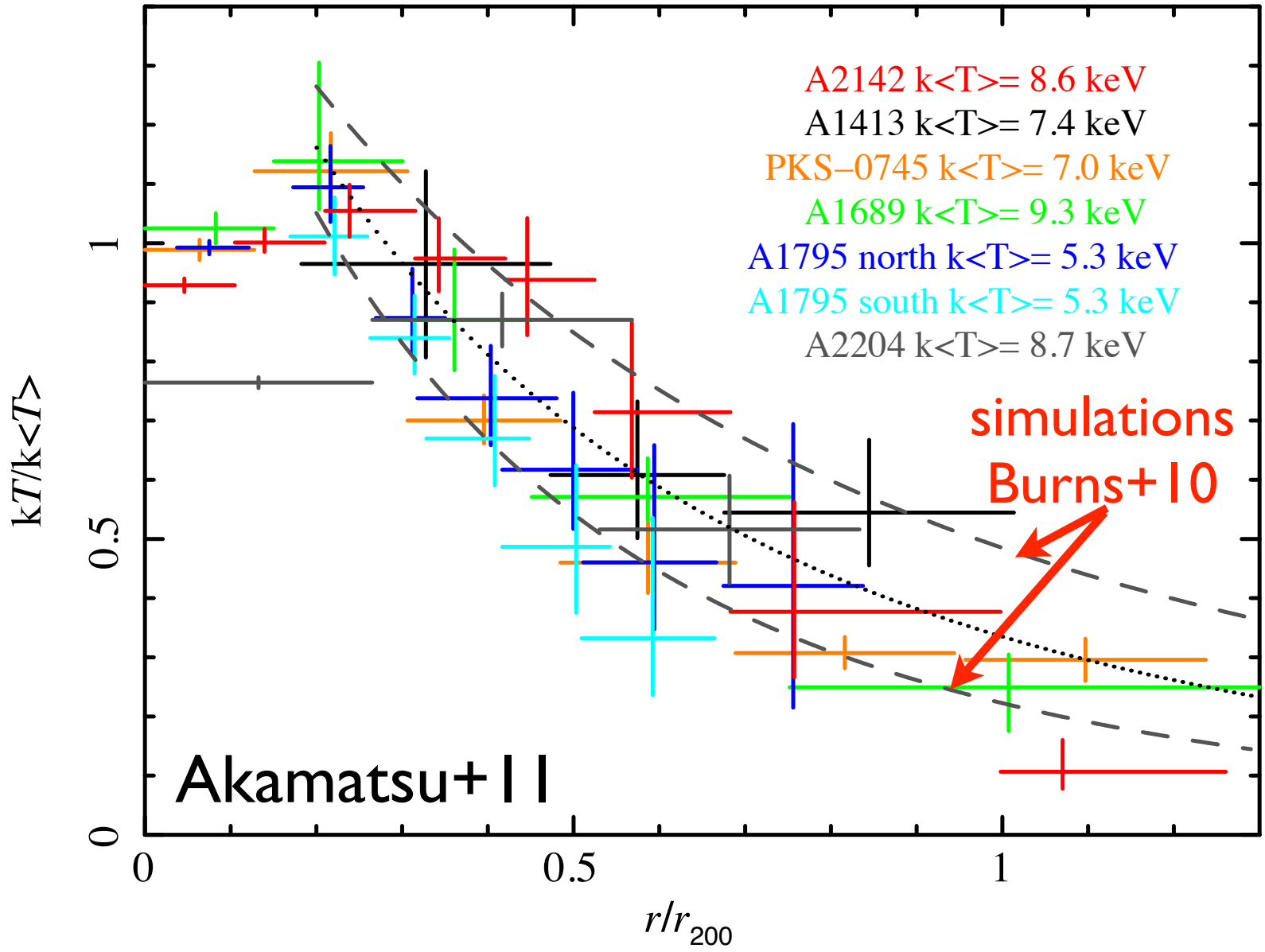


Why Study Cluster Outskirts?

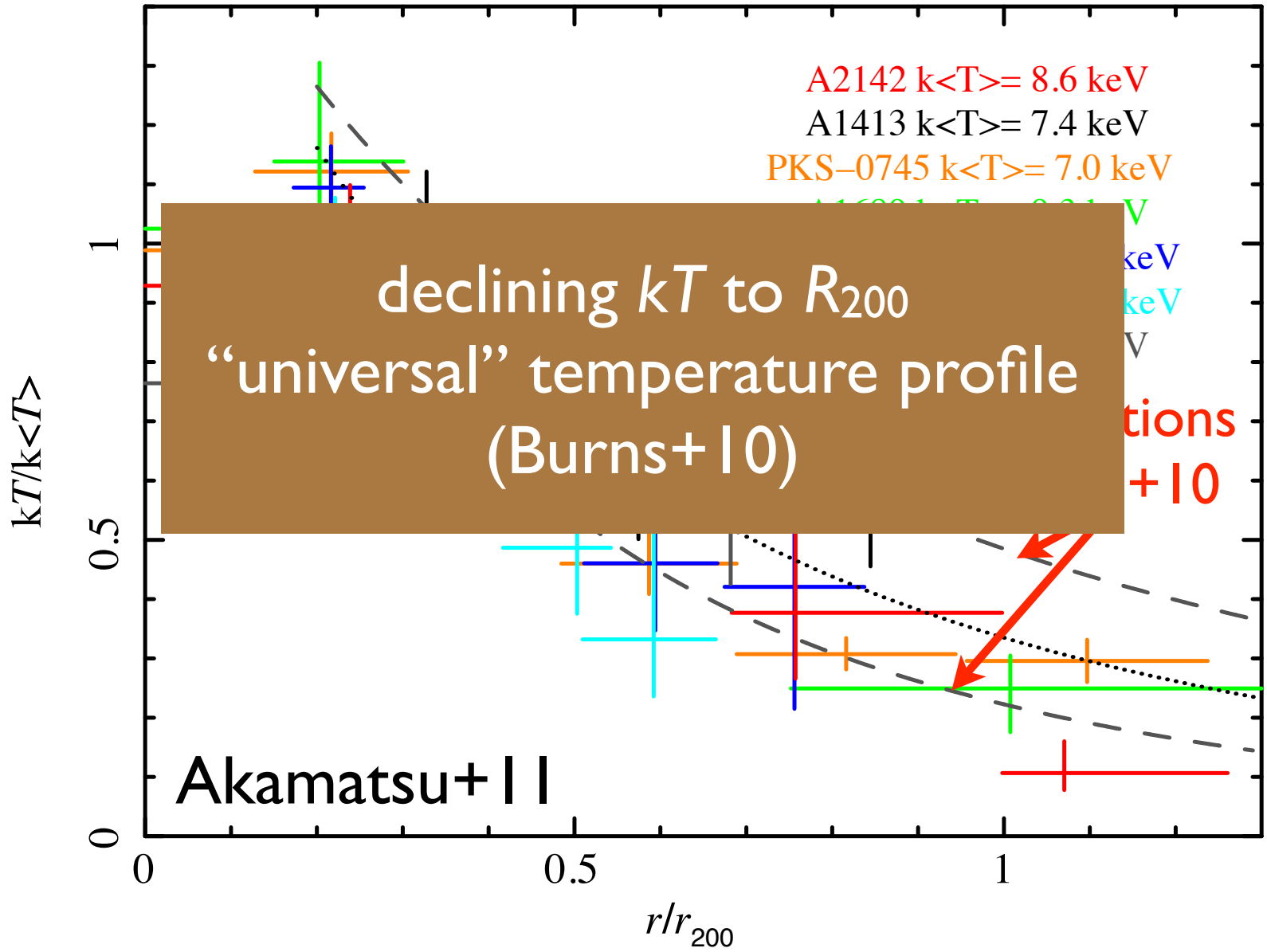
- majority of dark matter, baryons, metals in cluster
- clusters are still accreting at R_{vir}
  - constrain cluster formation models, assembly history
  - clumping, turbulence, electron-ion non-equilibrium
  - universal temperature, pressure profiles?
- clusters as cosmological tools via mass, baryon fraction
  - helpful to understand cluster physics to use them as cosmological probes

Abell 85: X-ray (NASA/CXC/SAO/A.Vikhlinin et al.); Optical (SDSS)

Clusters with *Suzaku*



Clusters with *Suzaku*



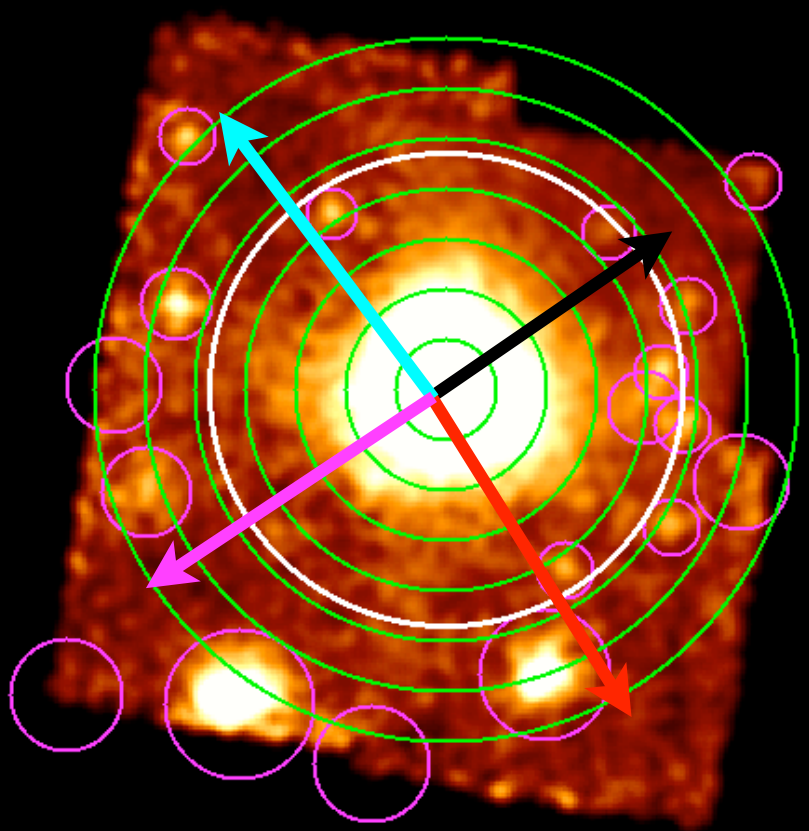
Suzaku Cluster Outskirts Project

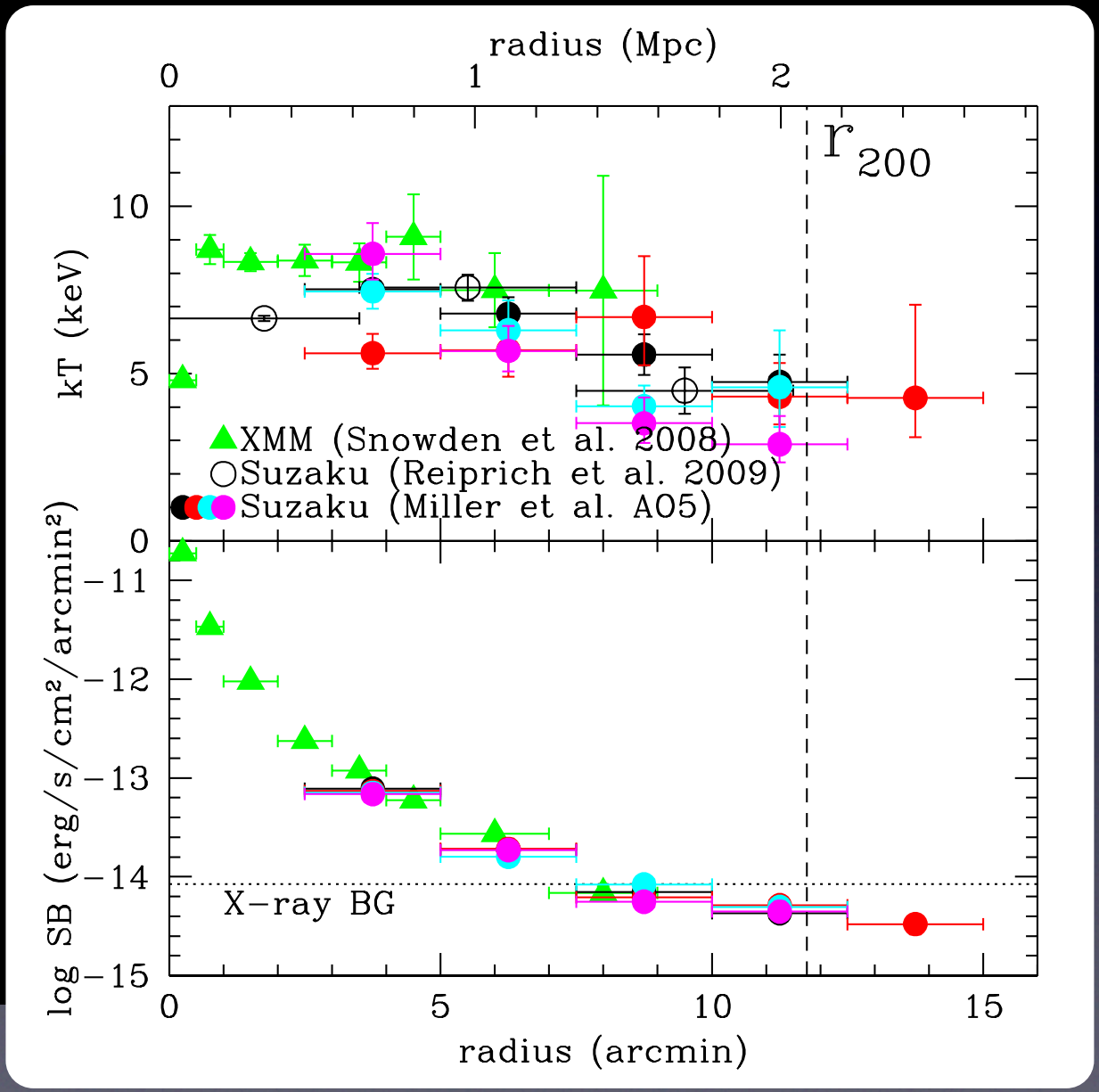
Cluster	z	R_{200}	ksec	date obs.
A383	0.187	9.3	110	July 2010
A1413	0.135	14.8	170	May 2010 + archive
A1795	0.063	26.0	260	June 2009 + archive
A1914	0.174	14.5	160	June 2010
A2204	0.151	11.8	140	Sep 2010 + archive
RXCJ0605	0.137	12.2	150	May 2010
A773	0.216	9.5	200	May 2011
A1068	0.147	10.8	200	>June 2011
A2667	0.221	10.0	200	June 2011

- selected from Snowden et al. 2008 XMM cluster catalog
- "relaxed", no substructure
- falling, flat, and rising *kT* profiles
- full azimuthal coverage out to R_{200}

Abell 2204
z = 0.151

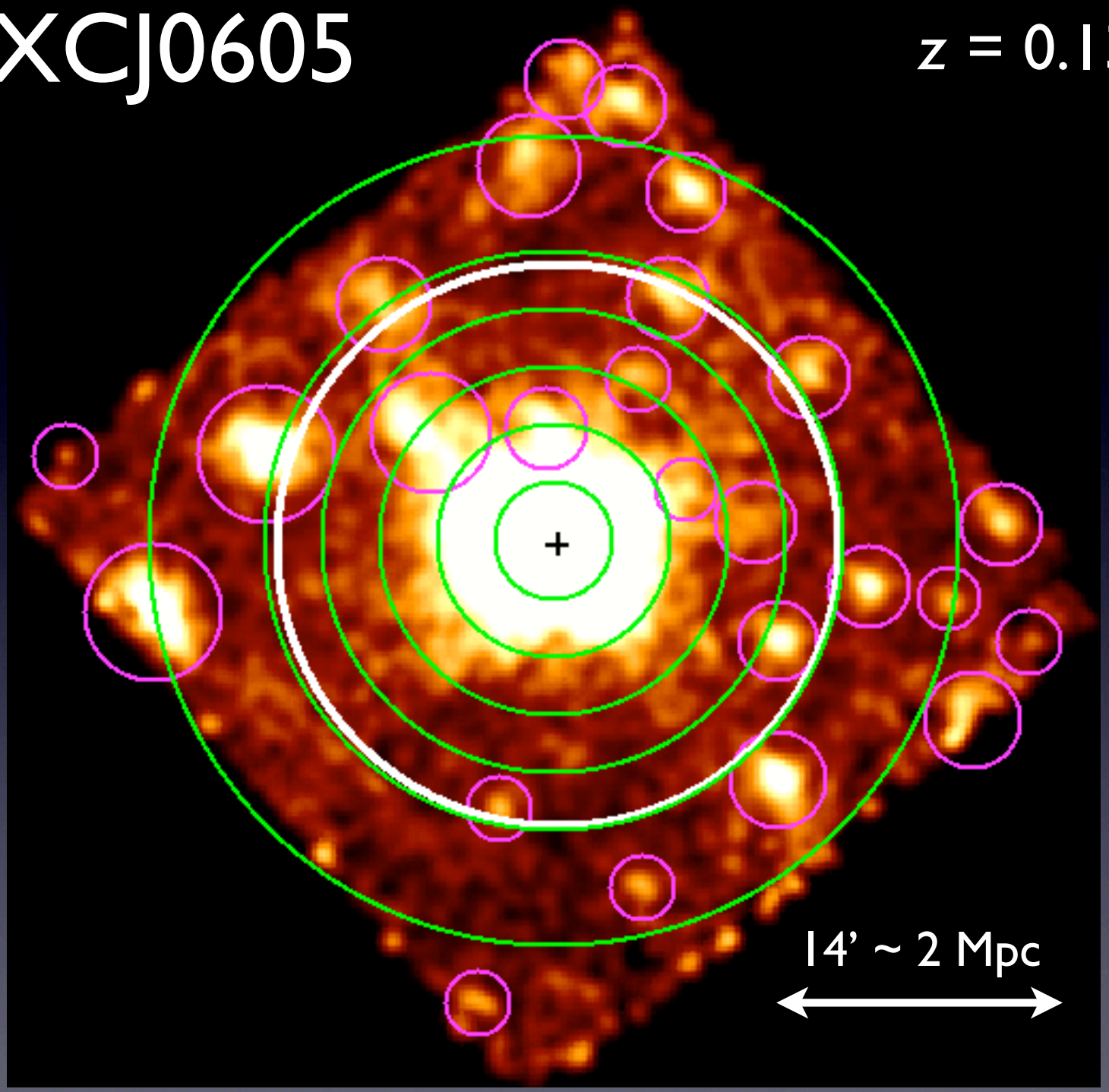
12' ~ 2 Mpc



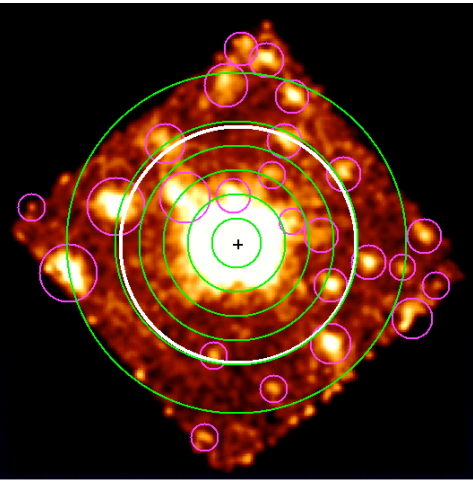


RXCJ0605

$z = 0.137$

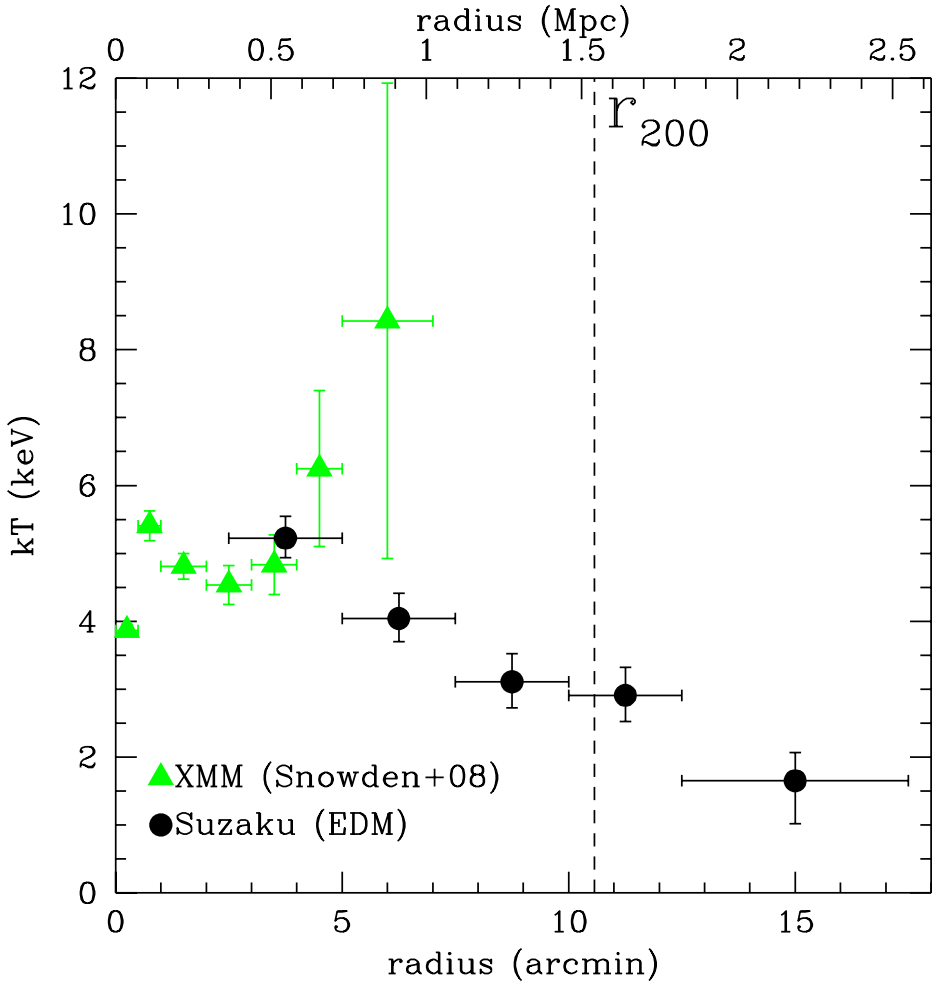


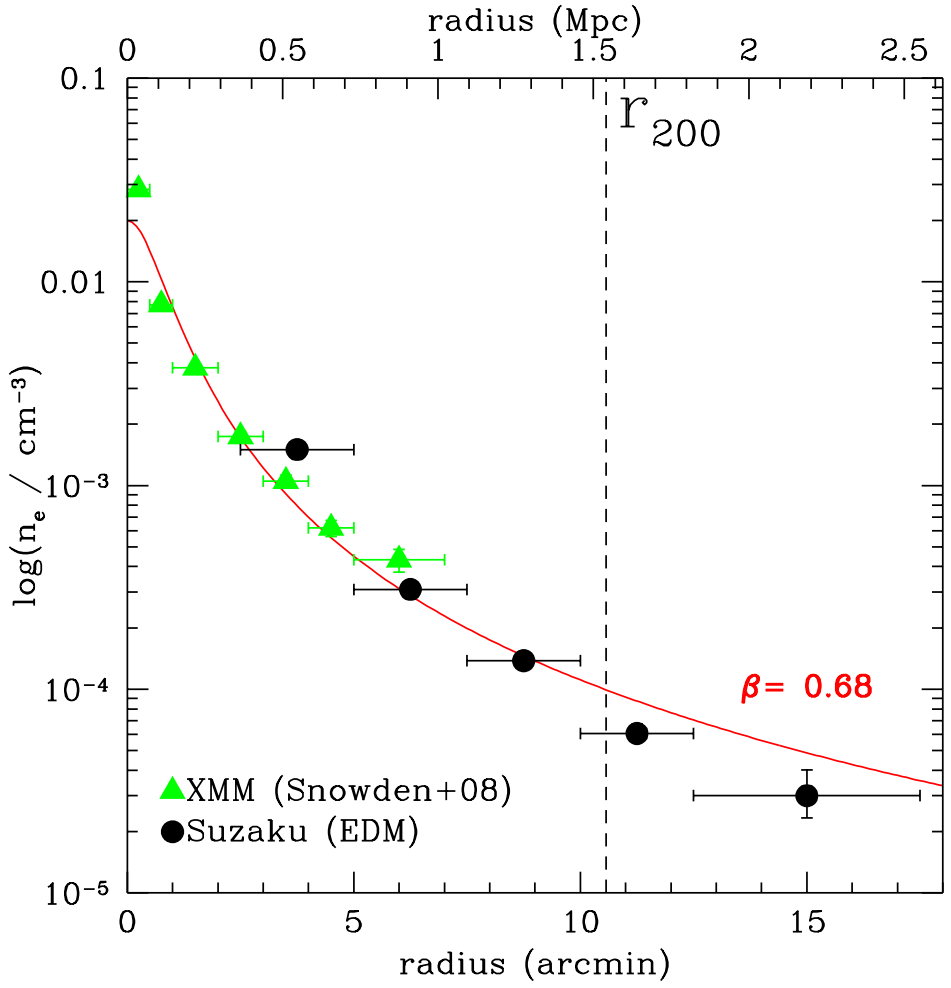
RXCJ0605



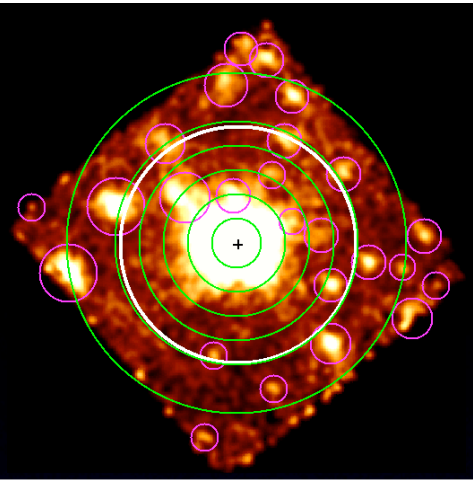
temperature

electron density





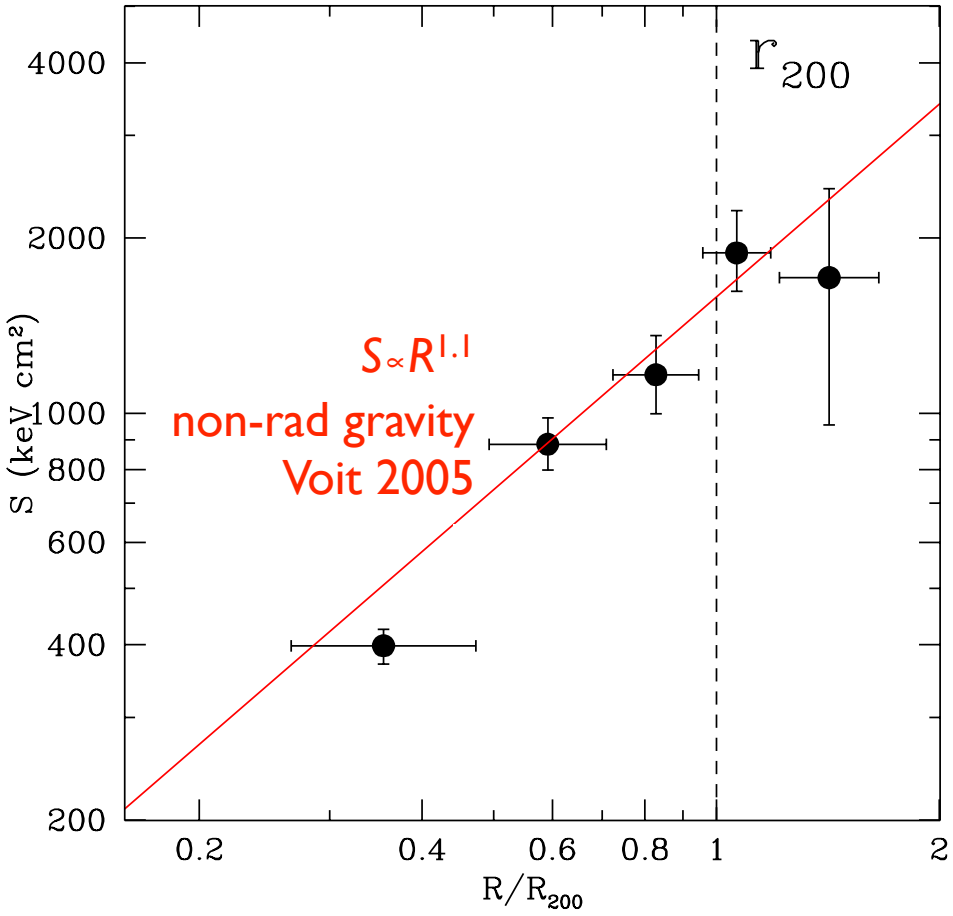
RXCJ0605



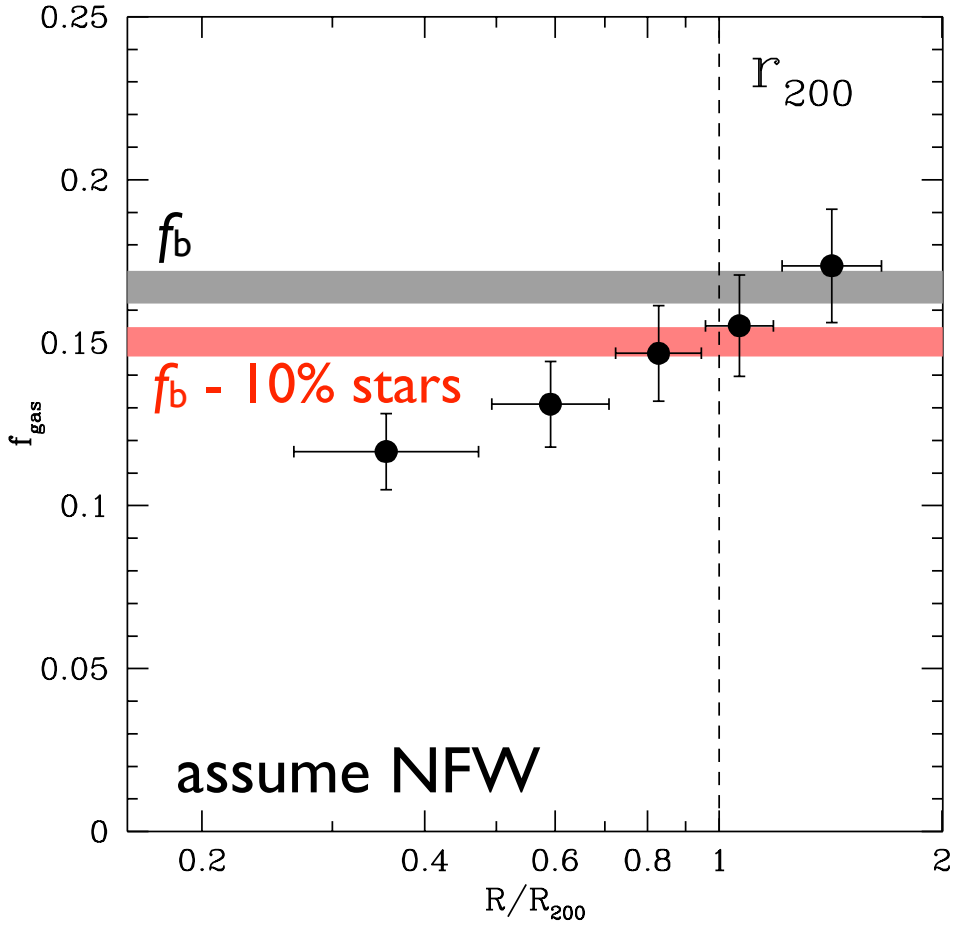
$M_{200} = 4.2 \times 10^{14}\ M_{\odot}$

$c_{200} = 12$

entropy



gas fraction

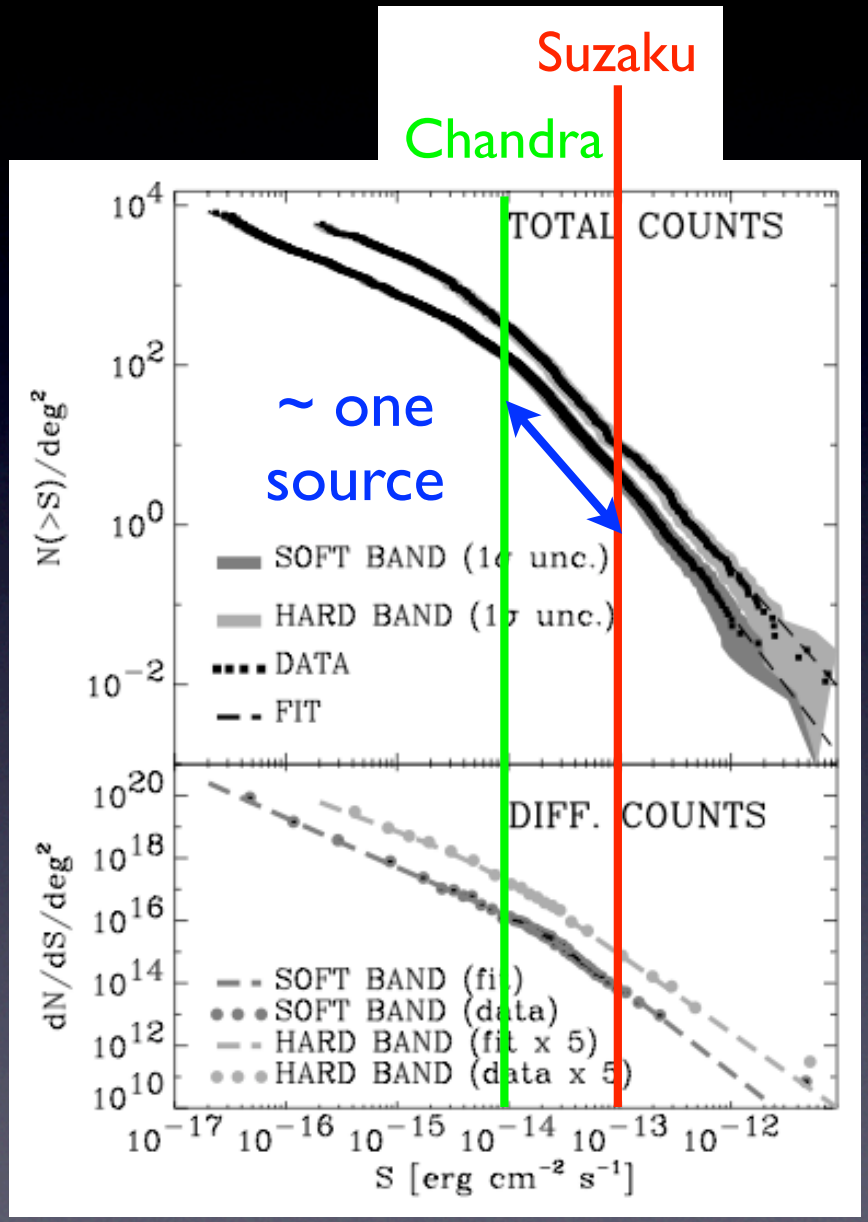


Systematics

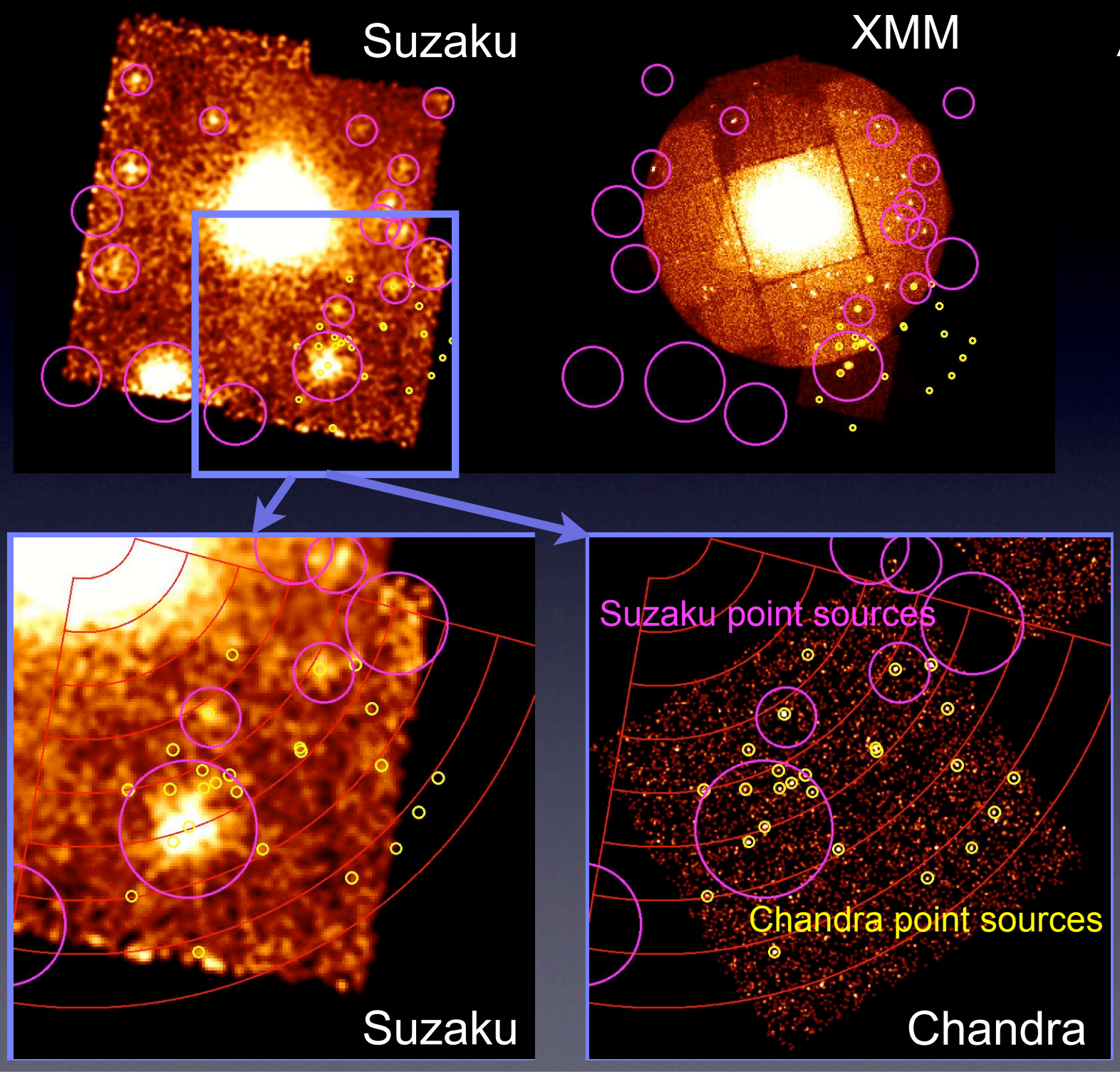
- at r_{vir} , cluster flux < 30% of background
- constraining the background is vital
- sources of background uncertainty
  - scattered X-ray flux from bright core (< 10%; simulations underway)
  - cosmic background variations (up to 40%) for small extraction regions (≤ 0.01 deg^2), background accuracy limited by Poisson statistics of point sources (AGN) just below threshold

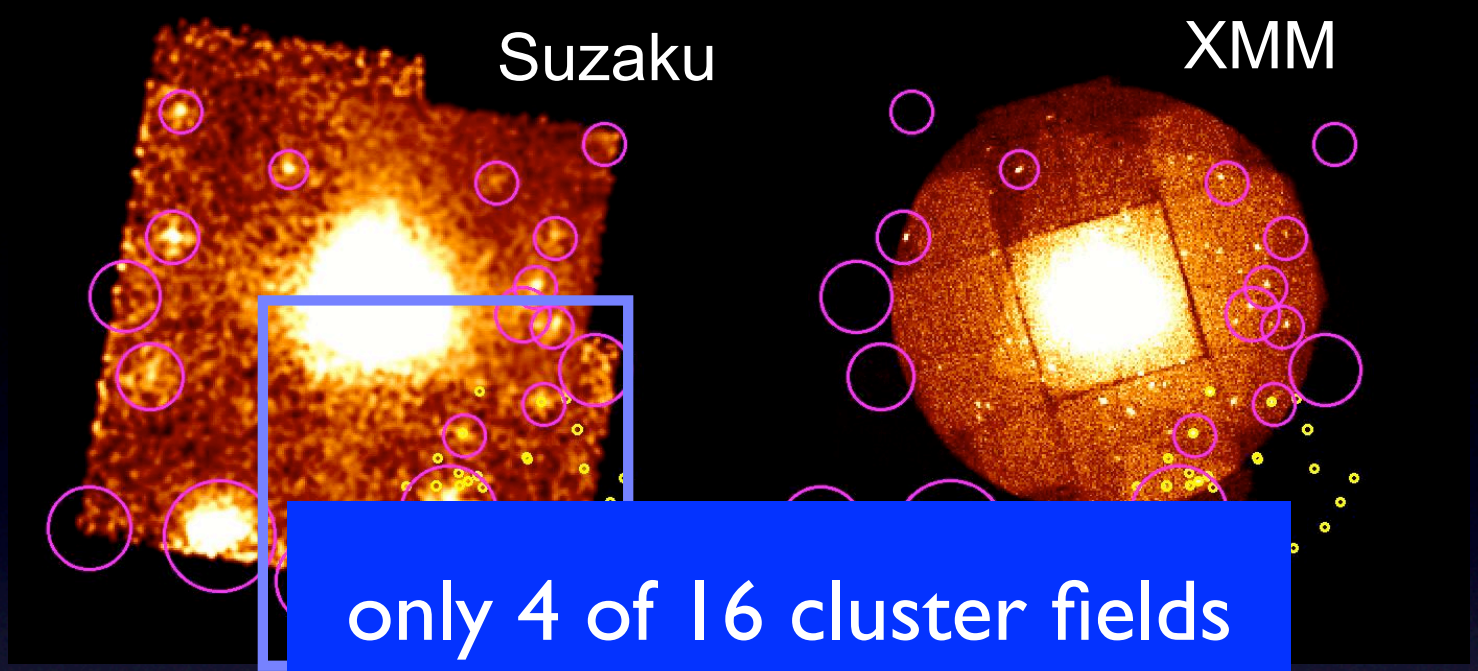
Cosmic Background Variations

- *Suzaku* detection limit
  ~ 10^{-13} erg/s/cm^2
- *Chandra* detection limit
  ~ 10^{-14} erg/s/cm^2
- expect ~ 1 source per region between *Suzaku, Chandra* limits
- *Suzaku* surf. brightness limit
  $\sigma_B \sim 4\times10^{-12}$ erg/s/cm^2/deg^2
  ~ 40% of soft BG!
- *Chandra* surf. brightness limit
  $\sigma_B \sim 1\times10^{-12}$ erg/s/cm^2/deg^2
  ~ 10% of soft BG!

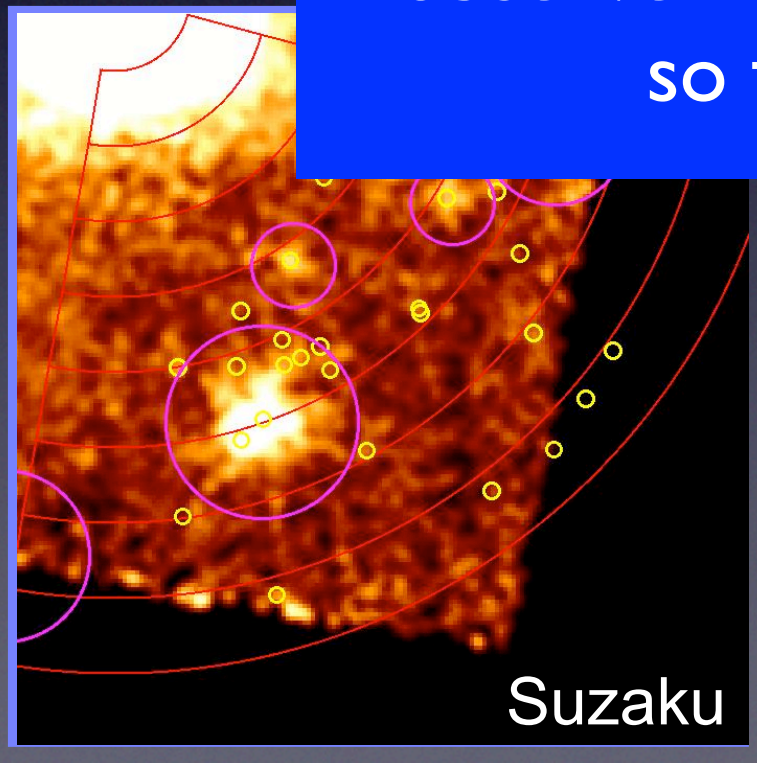


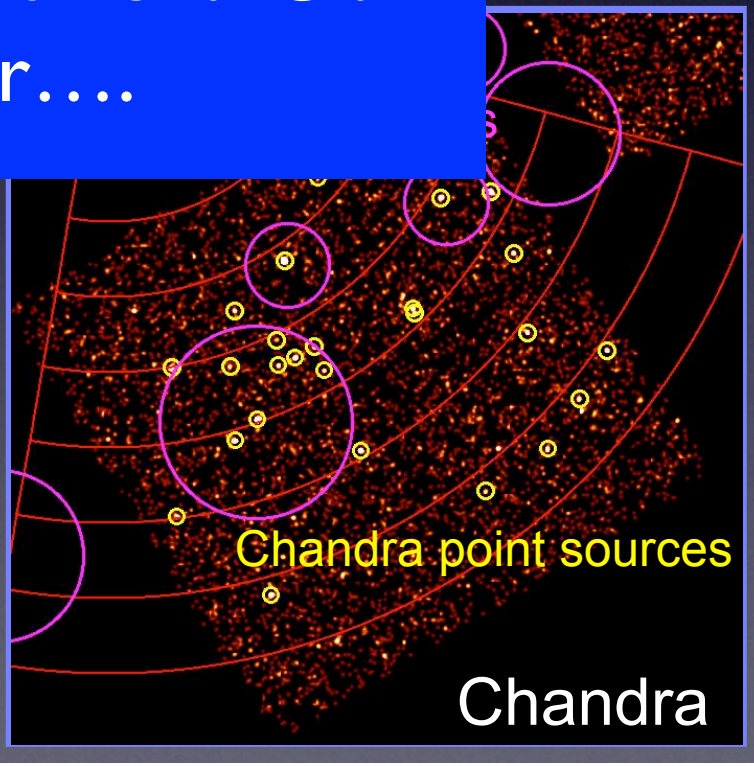
cumulative flux dist. Moretti et al. 2003


Suzaku
XMM
A2204
Suzaku point sources
Chandra point sources
Suzaku
Chandra



only 4 of 16 cluster fields observed with *Chandra* so far….





Summary

- 9 clusters selected from Snowden XMM catalog
- multiple directions probed to R_{200}
- average profiles to $R_{100} \sim R_{vir}$
- confirm falling kT profiles
- so far consistent with cosmic baryon fraction at R_{200}