X-ray observations of PKS 0745-191 at the virial radius:

Are we there yet?

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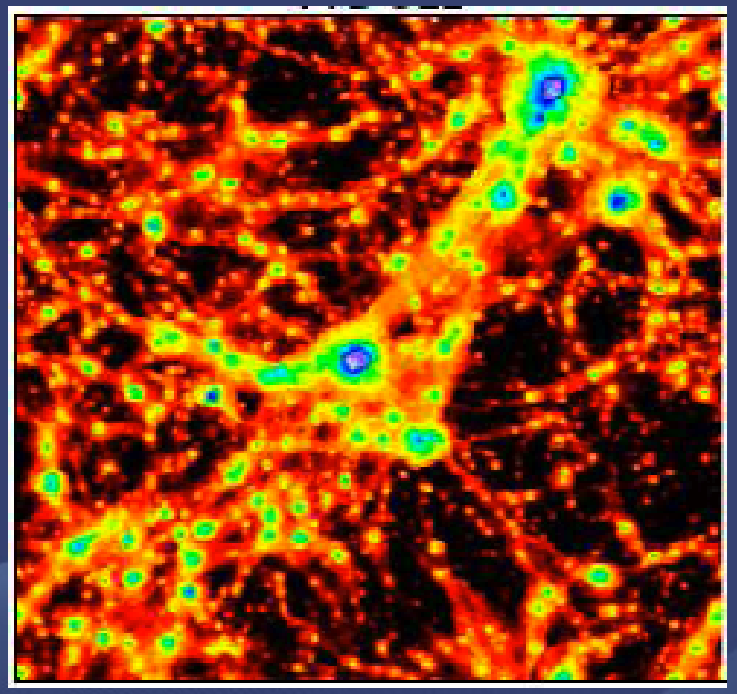
D. Eckert et al. 2011, A&A 529, 133

Why study cluster outskirts?

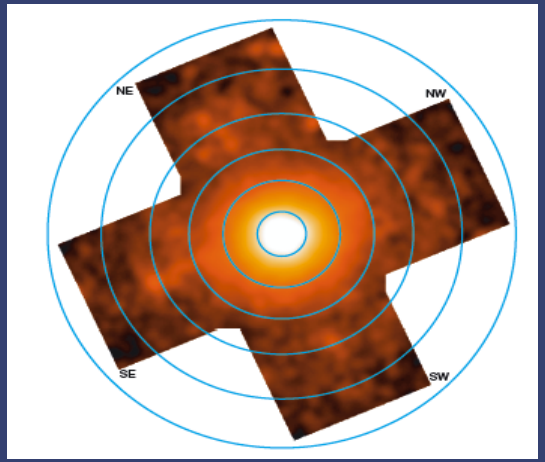
- Where the current activity of structure formation takes place
- Study the transition between virialized and infalling material
- Calibrate X-ray mass measurements

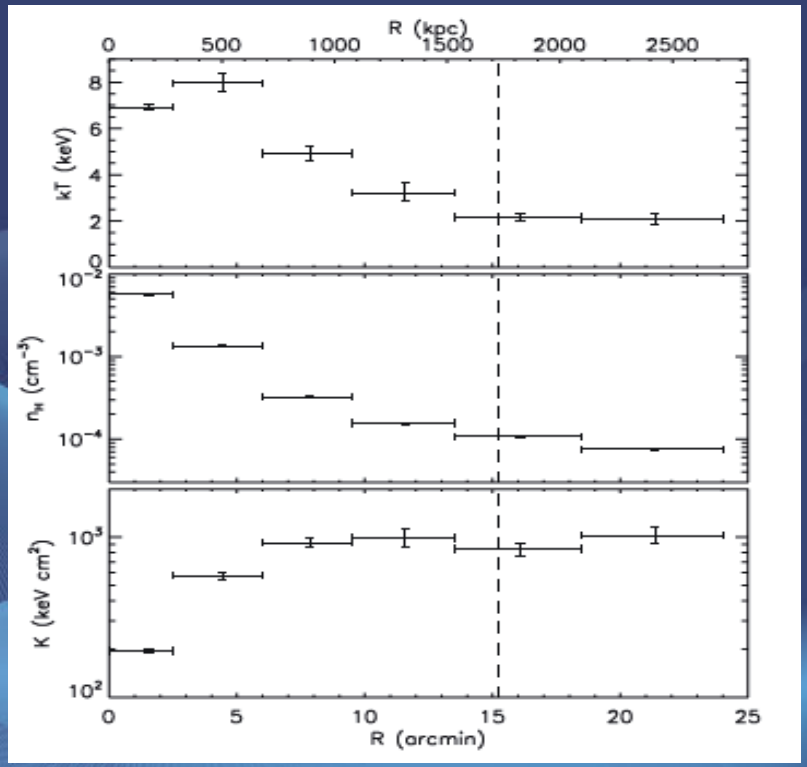


Vazza et al. 2011

Suzaku results on PKS 0745-191

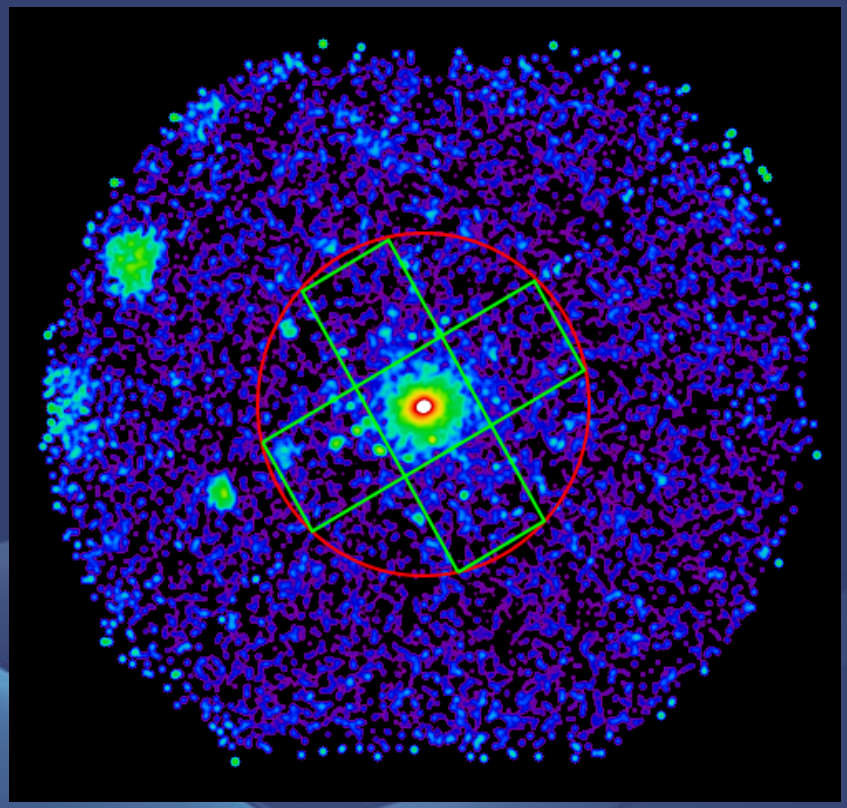
- PKS 0745-191 (z=0.1028) is a massive cool-core cluster located at low Galactic latitude (b=3°)
- Observed by Suzaku, 5 pointings of 30 ks
- Results presented in George et al. 09 (G09)
- ICM convectively unstable in cluster outskirts?
- **Needs confirmation from another instrument**





ROSAT/PSPC observation

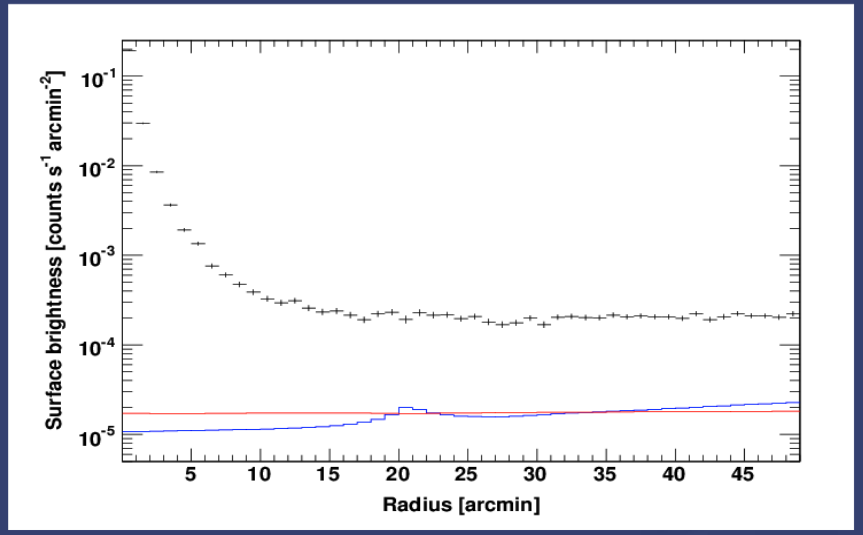
- Advantages of the PSPC:
  - Large FOV (25 times Suzaku)
  - Very low instrumental background
  - Good PSF (~25" on-axis, 4 times better than Suzaku)
- … But limited spectral capabilities

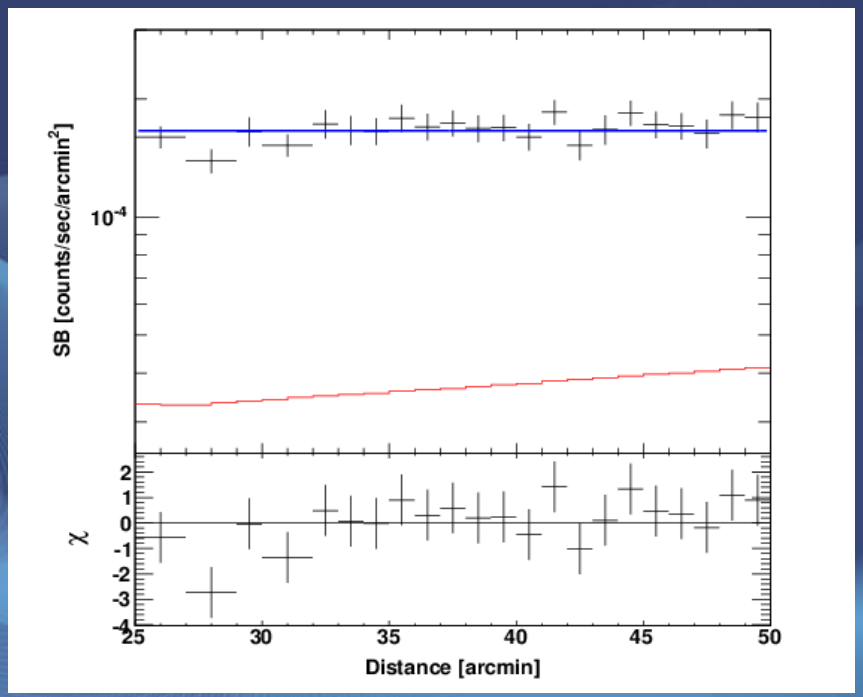


- PKS 0745-191 was observed by the PSPC for a total of 11 ksec

Data analysis

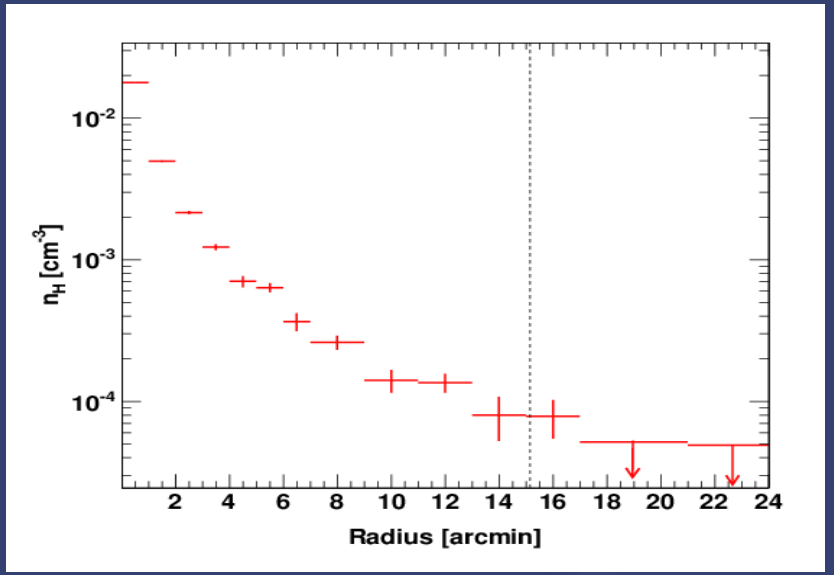
- We used the ROSAT ESAS software (Snowden et al. 1994)
- Various background components:
  - Particle background
  - Scattered solar X-rays
  - Sky background
- We used the source-free region (r>25') to measure the cosmic background

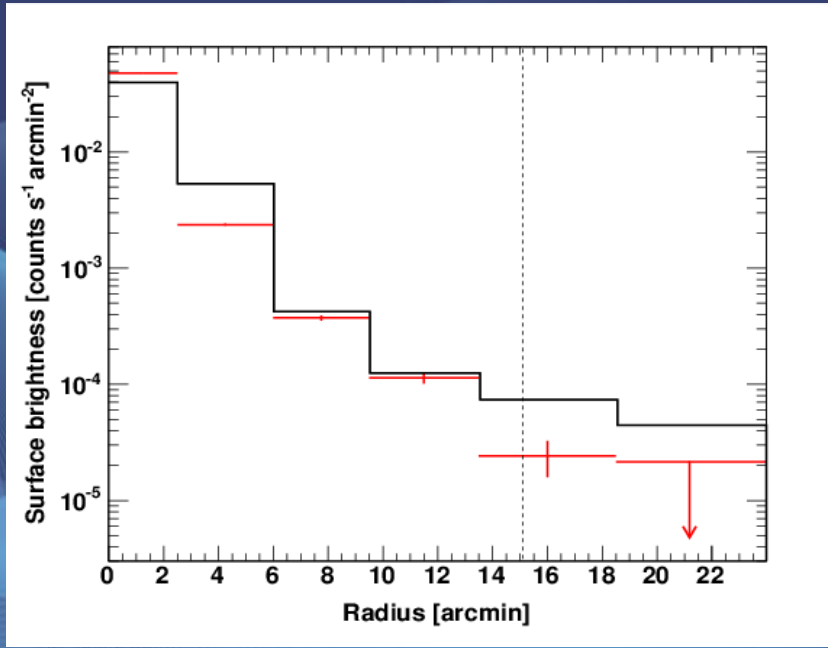




Results

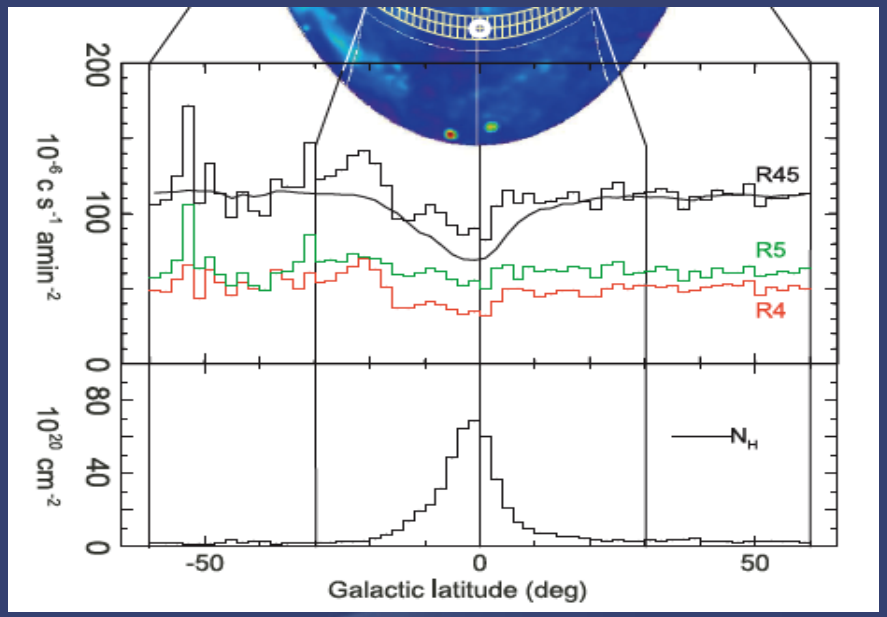
- No significant cluster emission is detected beyond r=17': $n_{17\text{-}25'} < 4.2 \times 10^{-5}$ cm^{-3} (90%)
- We folded the Suzaku data with the PSPC response and compared with our results
- ROSAT and Suzaku inconsistent at 7.7σ

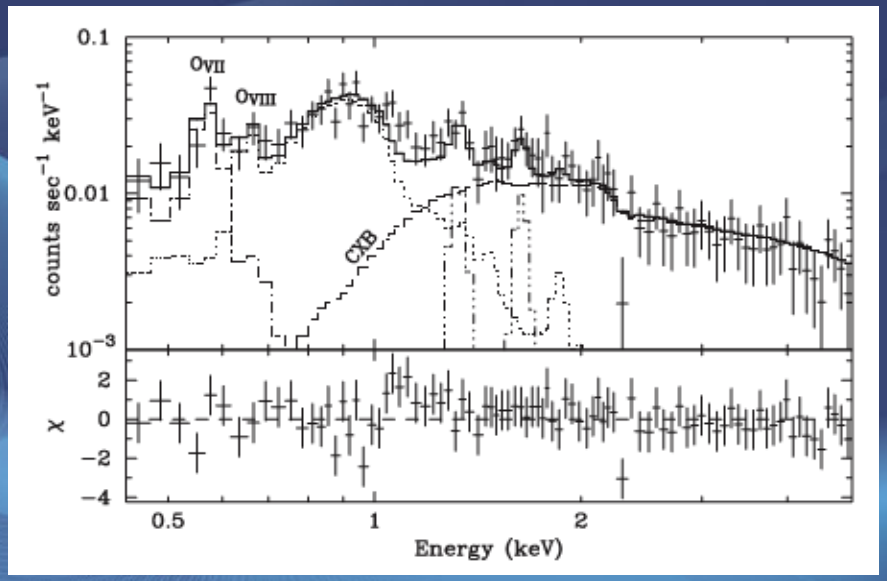




Sky background

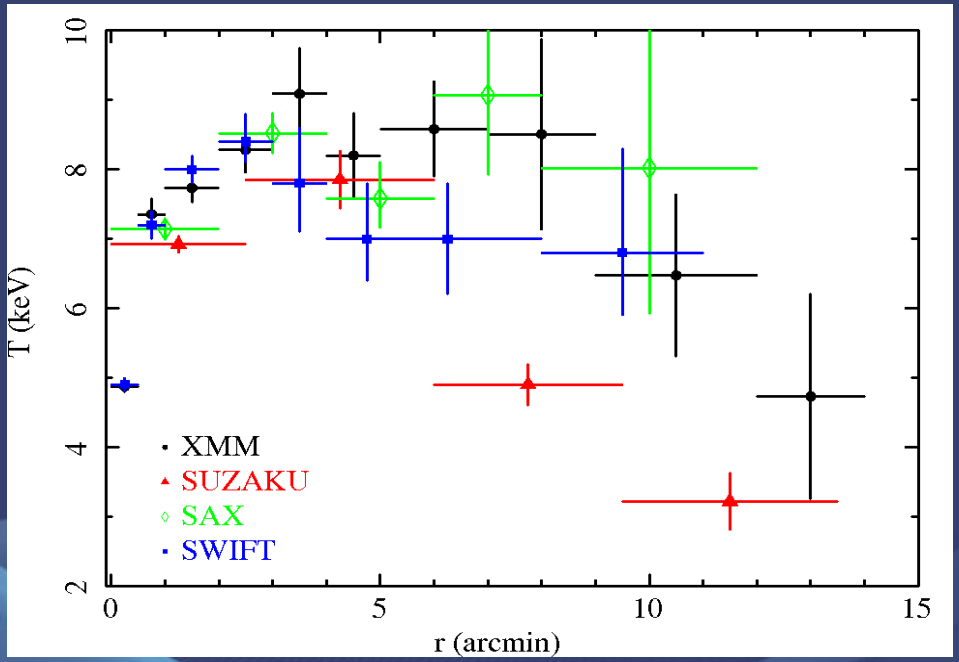
- G09 used the Lockman hole as bkg for the observation
- There is foreground emission in the mid-plane (e.g., McCammon 90)
- Masui et al. 09: presence of hot components (0.5-1.5 keV)
- **"This strong feature makes the b=0 spectrum qualitatively unlike empty-field spectra at other latitudes."**





Temperature profile

- G09 found a very steep temperature gradient (PL slope -0.94)
- Tension with other results (XMM, Swift, SAX) beyond r=6'
- **Leads to an indetermination of 25% in r_{200} and a factor of 2 in M_{200}**



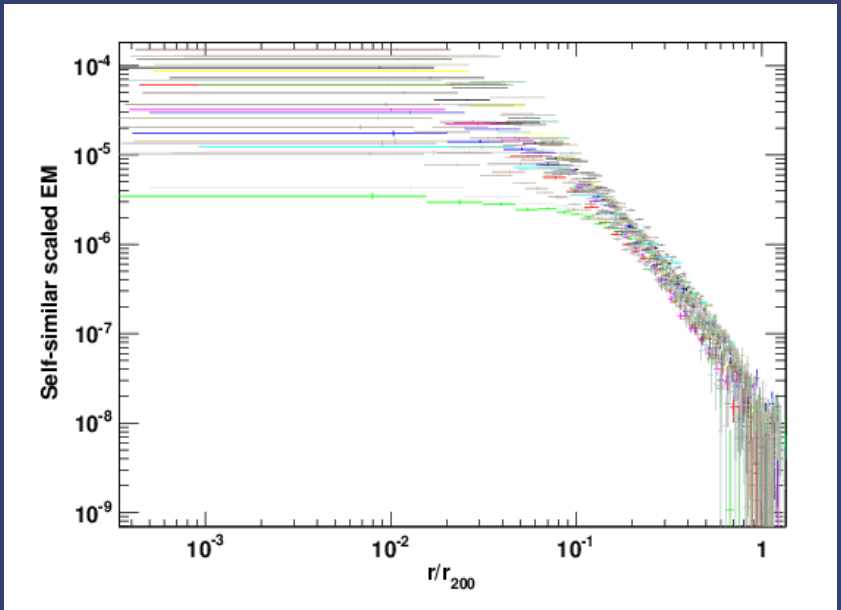
Summary

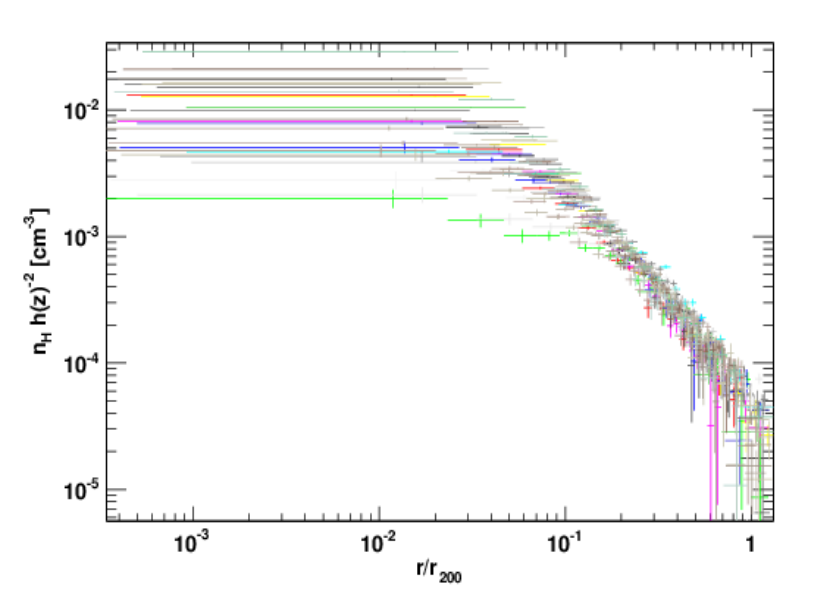
- ROSAT/PSPC has clear advantages with respect to Suzaku in low-SB regions (large FOV, better PSF)
- The PSPC SB profile is inconsistent with Suzaku at 7.7σ beyond r=13.5'
- Result explained by an improper modeling of the galactic foreground emission at low galactic latitude
- The improper background modeling biases the measured temperatures low, inconsistent with 3 other satellites

We are not there yet

Cluster sample

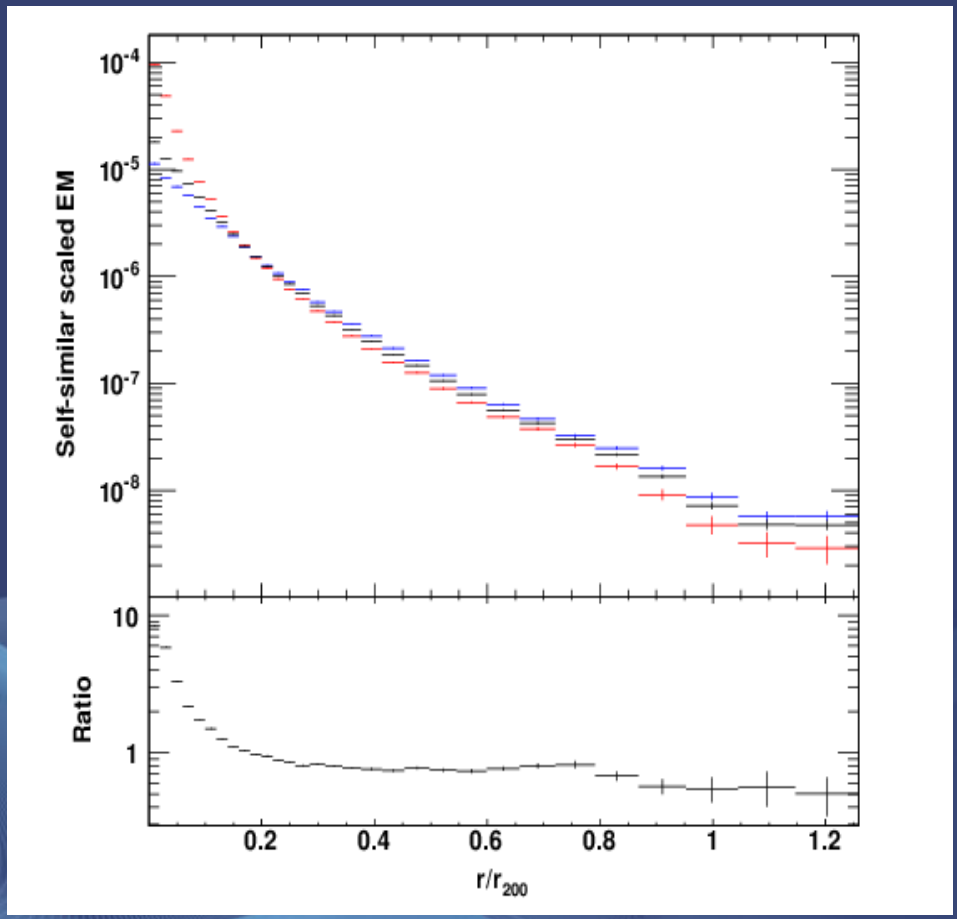
- We analyzed a sample of 31 clusters observed with ROSAT/PSPC in the redshift range 0.04-0.2
- Aim: compute mean density and EM profiles, constrain azimuthal variations
- We computed r_{200} from scaling relations and performed self-similar scaling (Arnaud et al. 02)





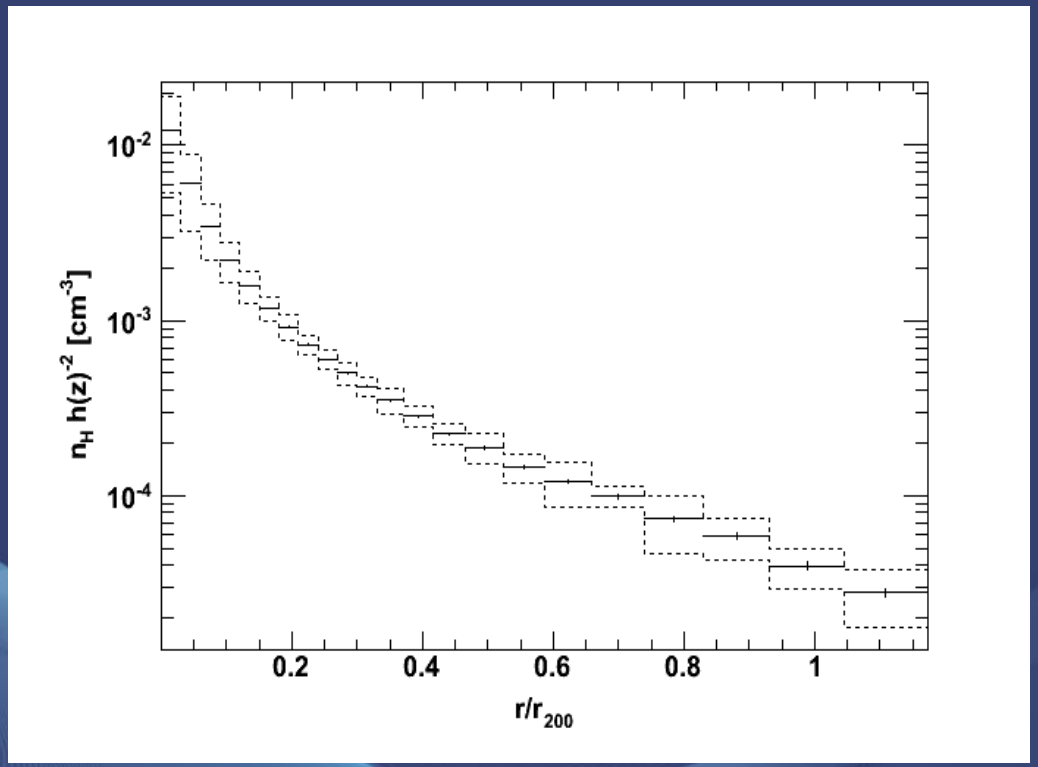
Mean emission measure profiles

- Stacked EM profiles for the total sample, and for NCC and CC classes
- Mean profiles steepen beyond $0.7r_{200} \sim r_{500}$
  Agreement with previous ROSAT results (Vikhlinin et al. 99, Neumann 05)
- NCC profiles exceed CC beyond $\sim 0.3r_{200}$



Average density profile

- We computed the average deprojected density profile
- Scatter 10-20% in density in 0.3-0.7r_{200}, good agreement with previous results (e.g. Croston et al. 08)



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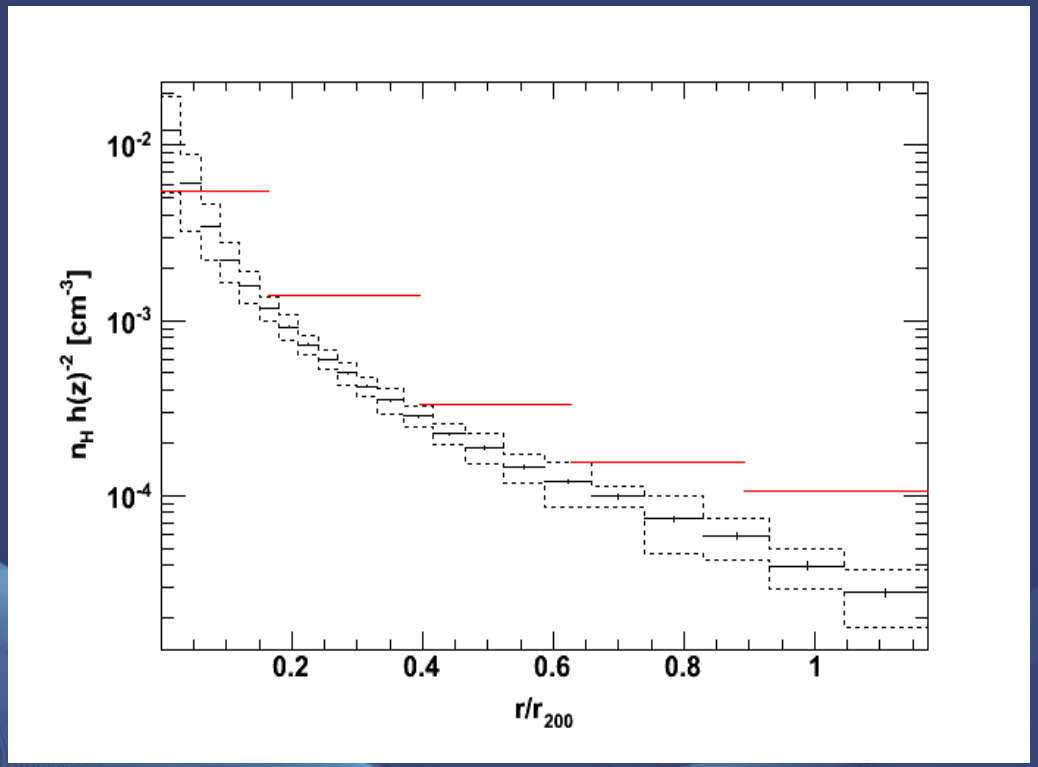
- G09 density profile strongly deviant from the mean

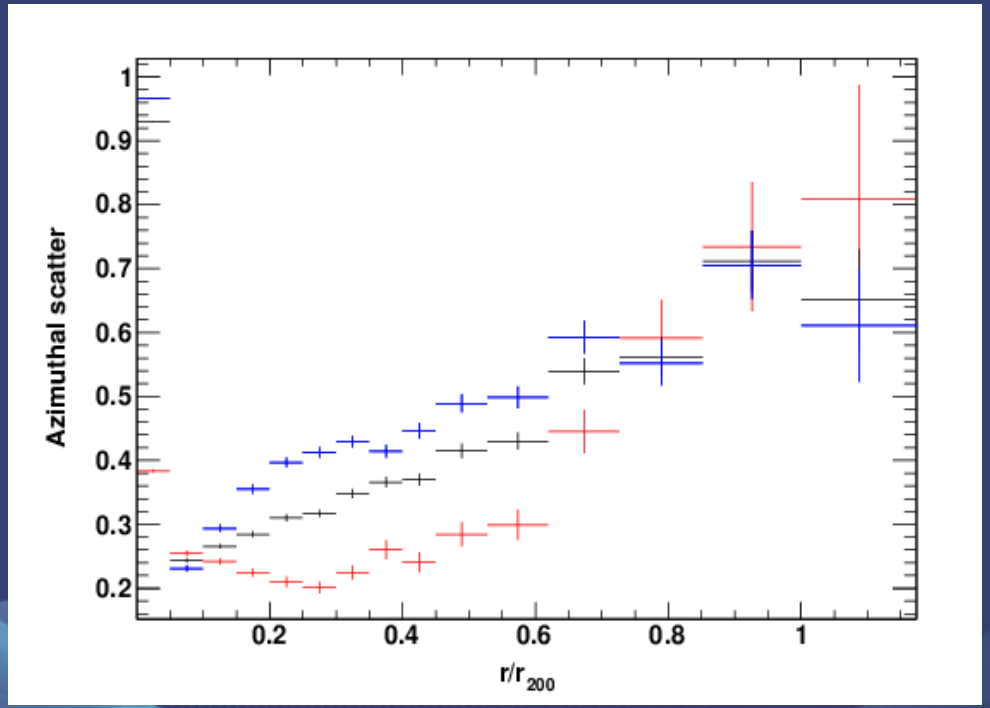


Azimuthal scatter

- Azimuthal scatter in 12 sectors using the definition of Vazza et al. 2011:

$$\sigma^2 = \sum_{i=1}^{12} \frac{(S_i - \langle S \rangle)^2}{\langle S \rangle^2}$$

- The profiles were stacked to obtain a mean scatter profile
- Around r_{200} even CC clusters are strongly asymmetric



Summary

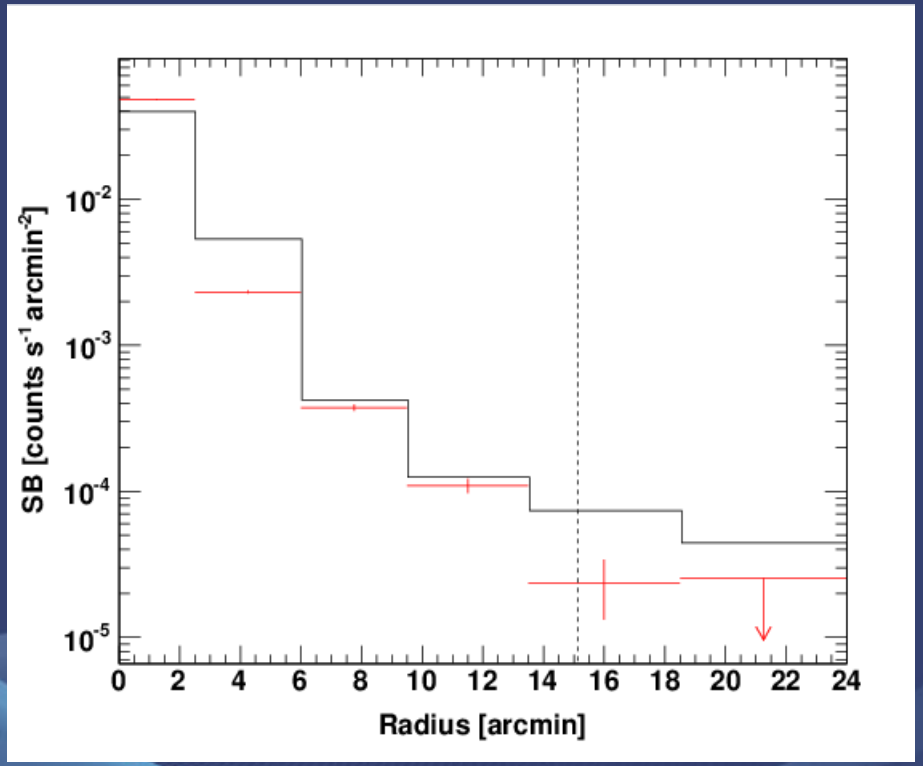
- In average, density profiles *steepen* beyond r_{500}
- Profiles are highly self-similar outside the core, *but* we observe in average steeper profiles for CC than for NCC clusters
- Even clusters which exhibit relaxed morphologies inside r_{500} are highly asymmetric around r_{200}

→ A sufficient azimuthal coverage is necessary to study the behavior of the gas around r_{200}

Backup slides

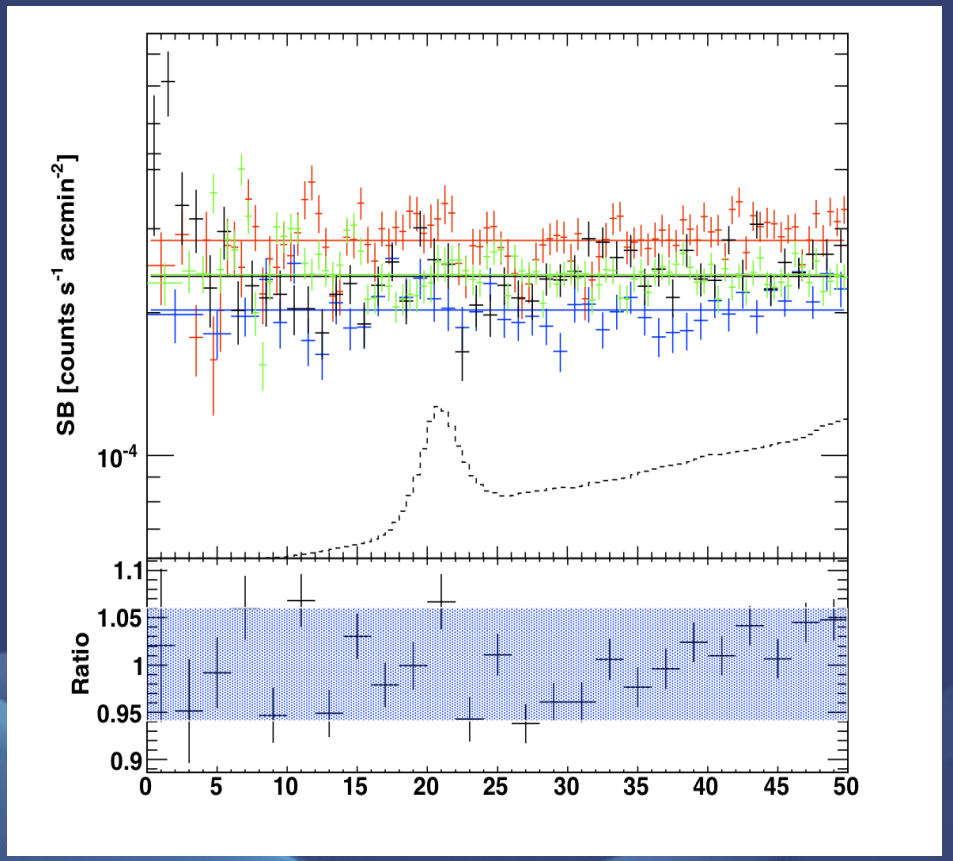
PKS azimuthal variations

- Surface brightness profile in exactly the same regions as G09
- ROSAT still inconsistent with Suzaku at 5.2σ



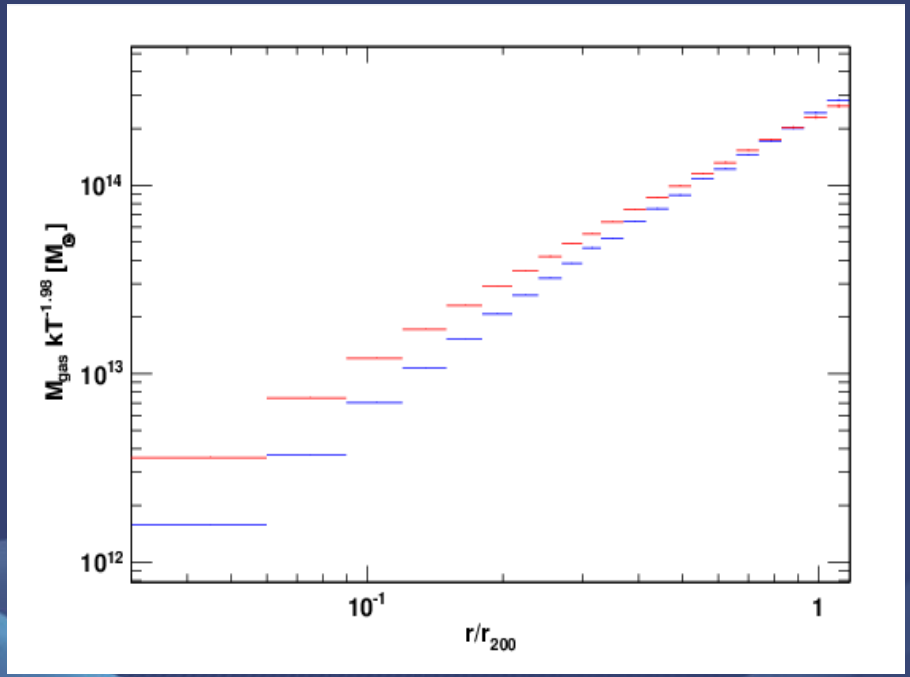
Systematic uncertainties in bkg

- We extracted SB profiles for 4 different blank fields
- Profiles from the center of the FOV fitted with a constant
- Systematic error ~6% of the CXB, including cosmic variance
- Added in quadrature to SB profiles



Gas mass

- Enclosed gas mass profiles for CC and NCC
- Once the appropriate scaling is applied, the profiles converge to the same gas mass within r_{200}
- The same gas mass is distributed in a different way in CC and NCC



Statistical scatter

- The total scatter computed using the formula of Vazza et al. is the sum of statistical and intrinsic scatter:

$$\sigma^2 = \sigma^2_{stat} + \sigma^2_{intr}$$

- The statistical scatter is given by the mean error in each bin:

$$\sigma^2_{stat} = \frac{1}{N} \sum_{i=1}^{12} \frac{\sigma_i^2}{\langle S \rangle^2}$$

- It is then subtracted from the total scatter to estimate the intrinsic scatter
- Errors from MC simulations