Cool Core properties of Galaxy Groups- Outlook on AGN Feedback and Star Formation

by

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Today

- Introduction
- Sample and Methods
- Results
- Summary

Introduction

Galaxy groups

- As the name suggests, an ‘accumulation’ of a few galaxies.

- No strict definition, but generally collection of < 50 galaxies called a group and above 50, a cluster.

- Lie on the lower end of X-ray scaling relations with lower mass and luminosity as compared to clusters.

- Possible sub-classifications-loose groups, compact groups and fossil groups.

Why Study groups?

- Much more common than galaxy clusters.
- Matter distribution in ICM vs. galaxies is different from clusters; not scaled down versions of galaxy clusters!
- Cooler and less massive, thus, more prone to non-gravitational effects.
- Perfect locations to study effects like AGN heating.

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AGN heating/ICM cooling in clusters

- The gas in the ICM cools via X-ray emission. A central temperature drop in clusters shows that cool gas collects at the centre.

- Central Cooling Time (CCT) the best parameter to distinguish between clusters with and without a cool core (Hudson et al. 2010).

- Clusters can be classified as SCC (t_{cool} < 1 Gyr), WCC (1 < t_{cool} < 7.7 Gyr) and NCC (t_{cool} > 7.7 Gyr).

- All SCC clusters in the HIFLUGCS sample show a central temperature drop.

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AGN heating/ICM cooling in clusters

- Cool gas initially thought to fuel star formation but expected star formation rates not seen.

- Strong source of heating mooted for clusters with very short CCTs. AGN heating the best candidate (e.g. Voit & Donahue 2005, Roychowdury 2004, Mittal et al. 2009).

- Presence of a Central Radio Source (CRS) strongly correlated to the CCT (e.g. Mittal et al. 2009).

- Anti-correlation trend between CCT and integrated radio luminosity (e.g. Mittal et al. 2009).

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Sample and Methods

Sample and Methods

- Sample of 26 luminosity-limited, low redshift ($0.01 < z < 0.1$) galaxy groups from REFLEX, HIFLUGCS and NORAS X-ray catalogs.

- Chandra data used for analysis. Reduction carried out by Helen Eckmiller (Eckmiller et al. 2011).

- Radio data compiled from radio catalogs like NVSS, VLSS and SUMSS. Integrated radio luminosity calculated between 10 MHz and 15 GHz.

- BCG data obtained from the 2MASS XSC to study correlation between BCG and large scale host properties.

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Results-Core Properties

Observed Cool Core Fractions

	HIFLUGCS Sample	Group Sample
% of CC clusters/ groups (SCC+WCC)	72	80
% of SCC clusters/ groups	44	42
% of WCC clusters/ groups	28	38
% of NCC clusters/ groups	28	20

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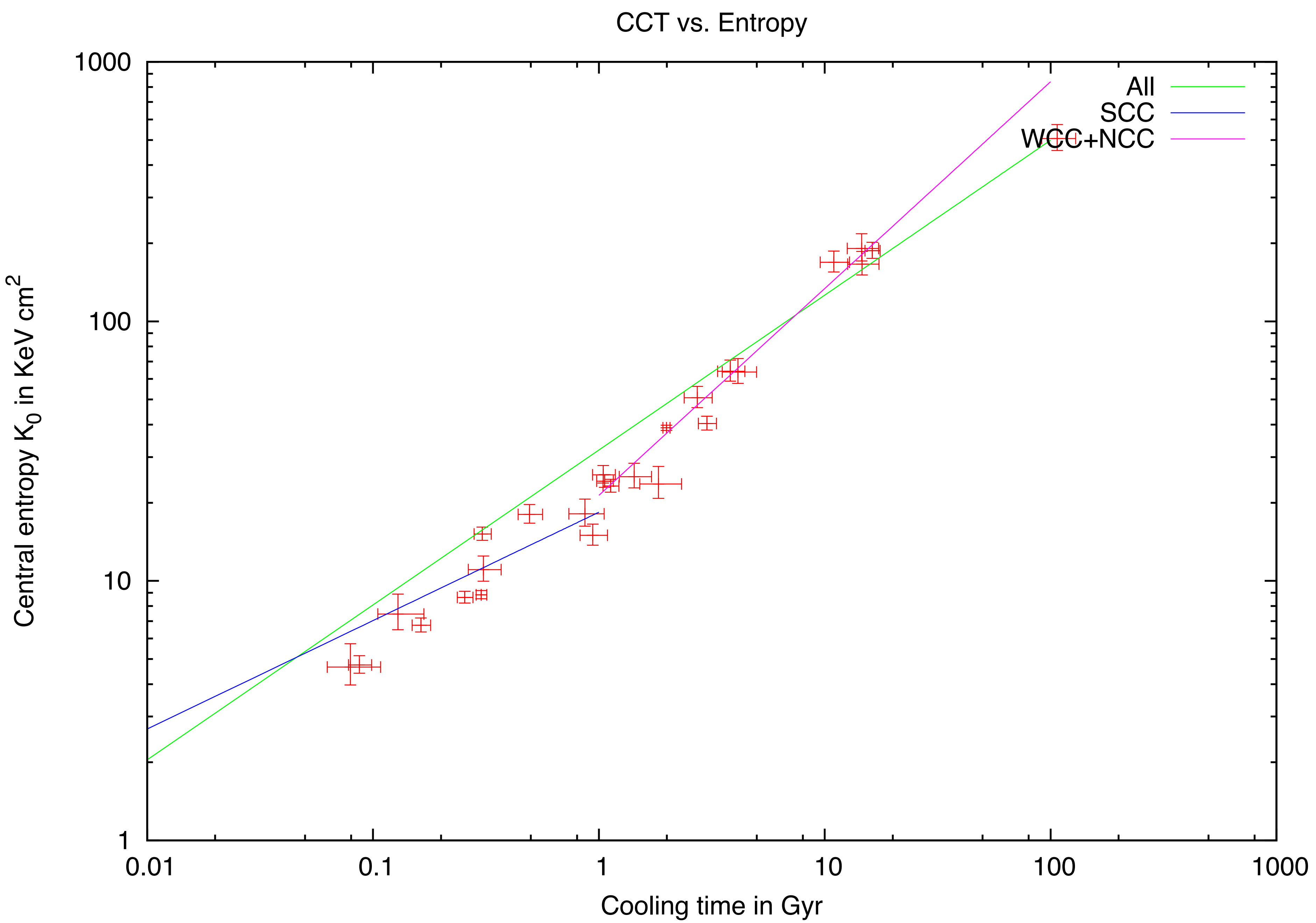
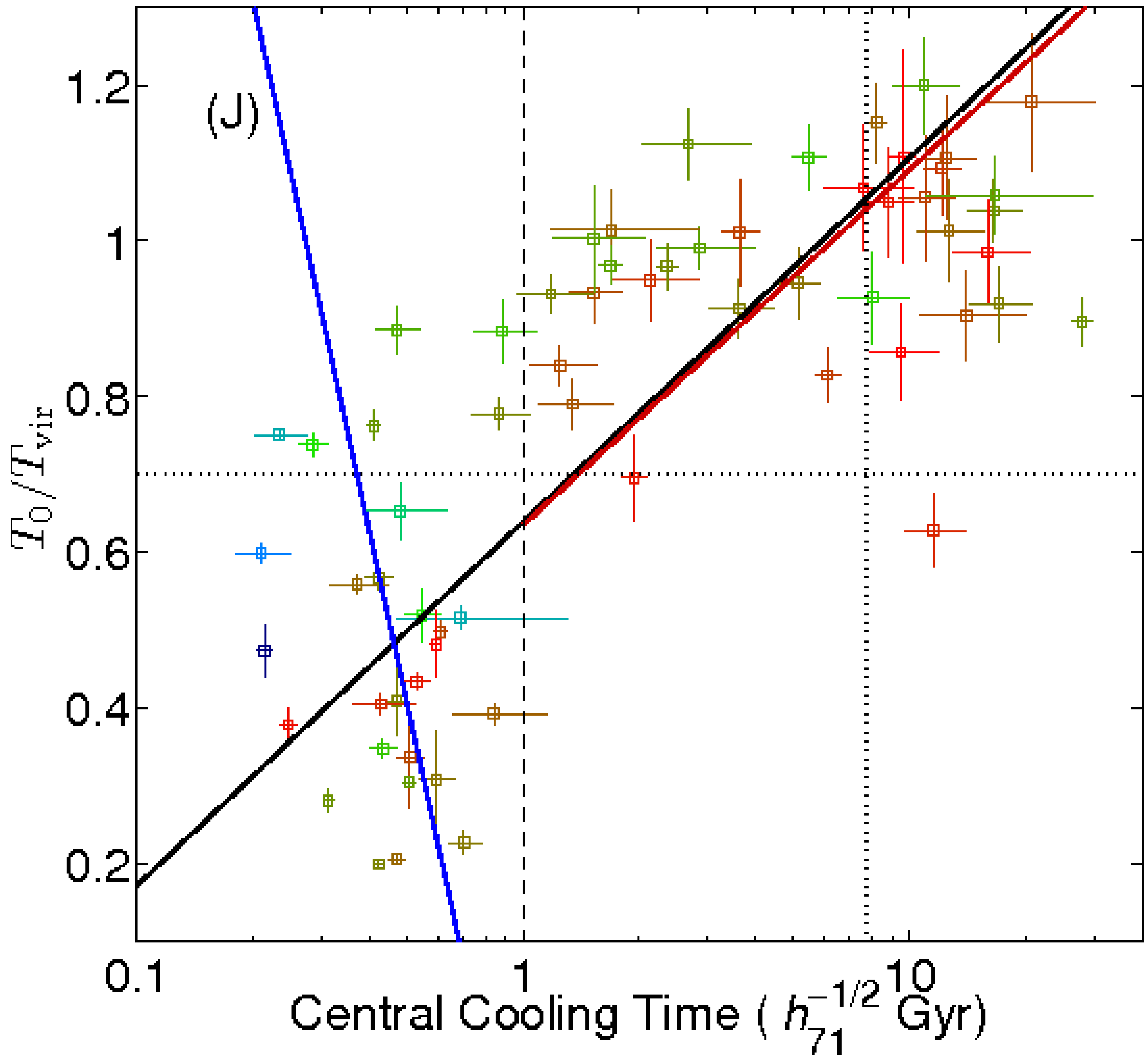
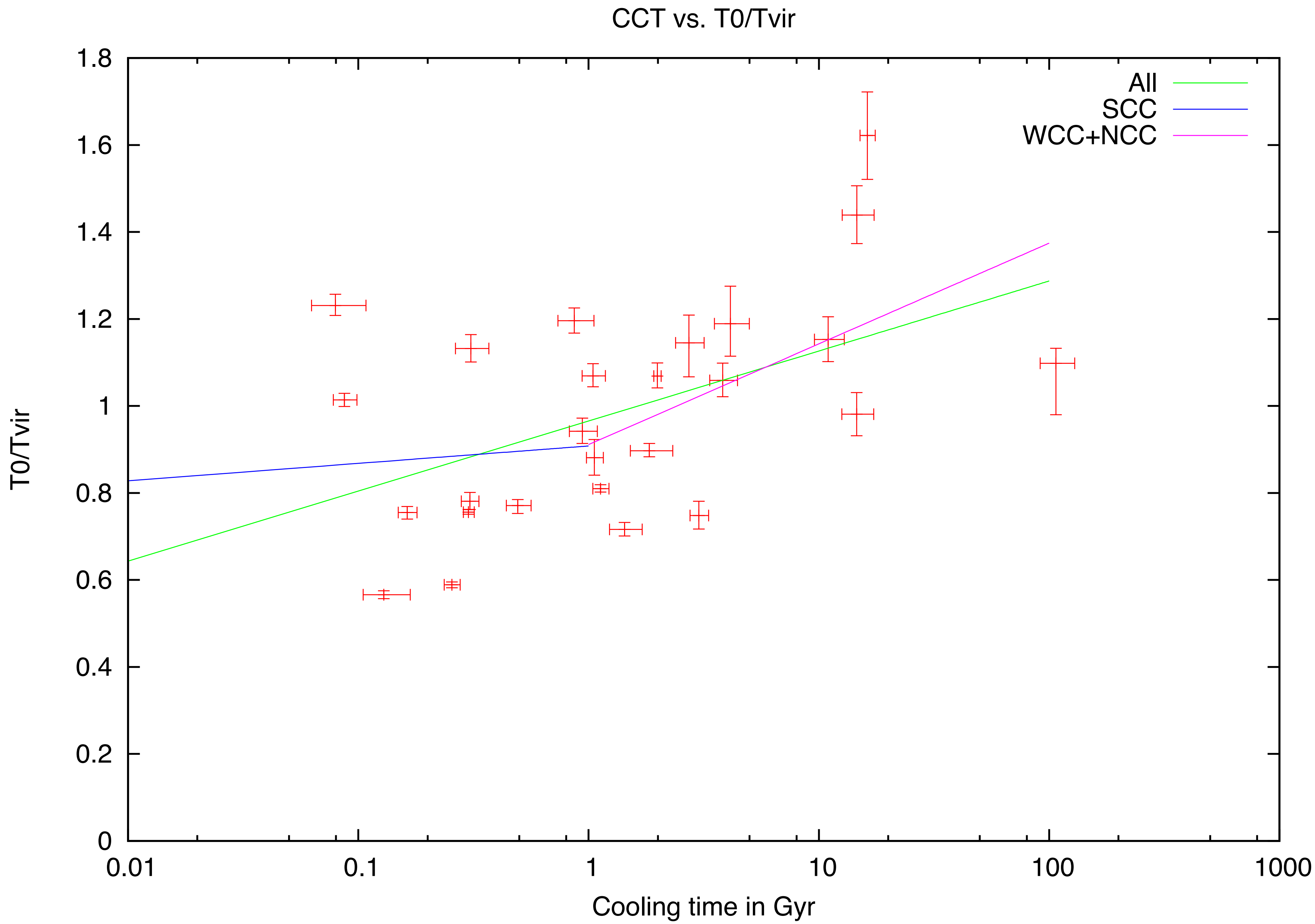


CCT vs. Entropy
All
SCC
WCC+NCC
1000
100
10
1
0.01
0.1
1
10
100
1000
Central entropy K_0 in KeV cm^2
Cooling time in Gyr



From Hudson et al. (2010)



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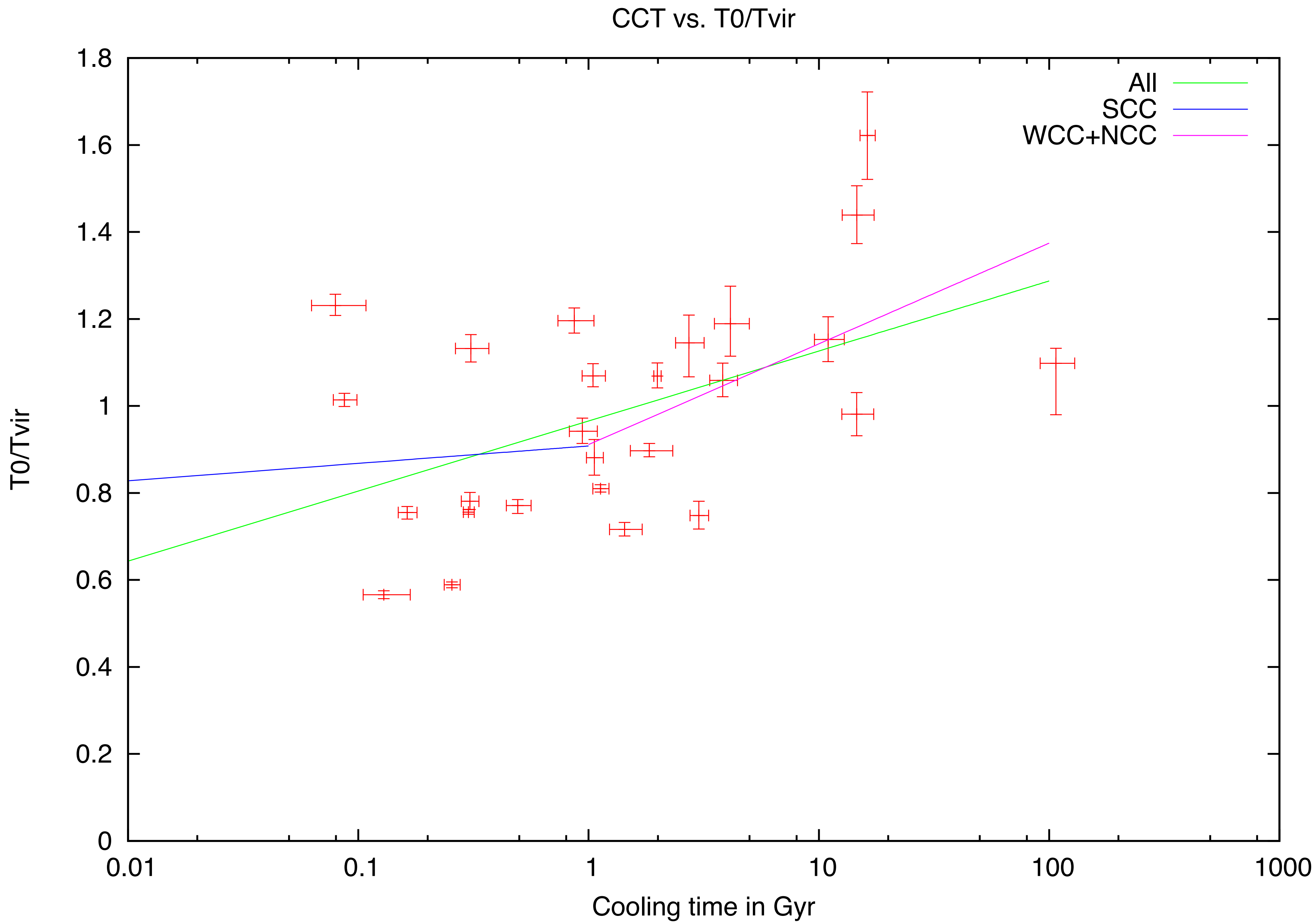
Do all fossil groups show this feature? Very preliminary investigations with a complete sample of fossil groups seems to suggest they show a rising central temperature profile!



Results-CRS and AGN Heating

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Presence of Central Radio Sources (CRS)

	HIFLUGCS Sample	Group Sample
% of CC systems with CRS	75	77
% of NCCs with CRS	45	100
% of WCCs with CRS	67	80
% of SCCs with CRS	100	72

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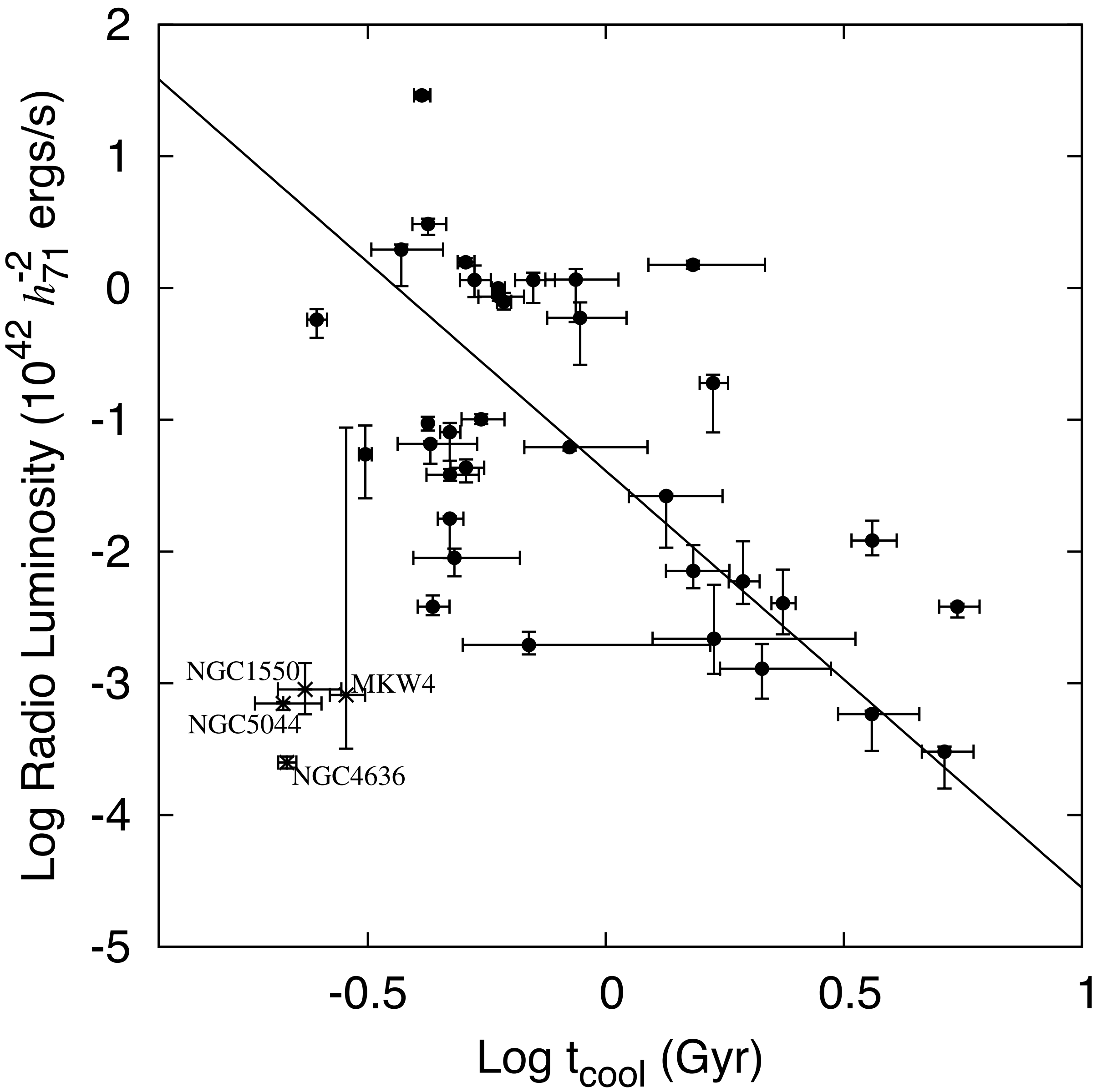
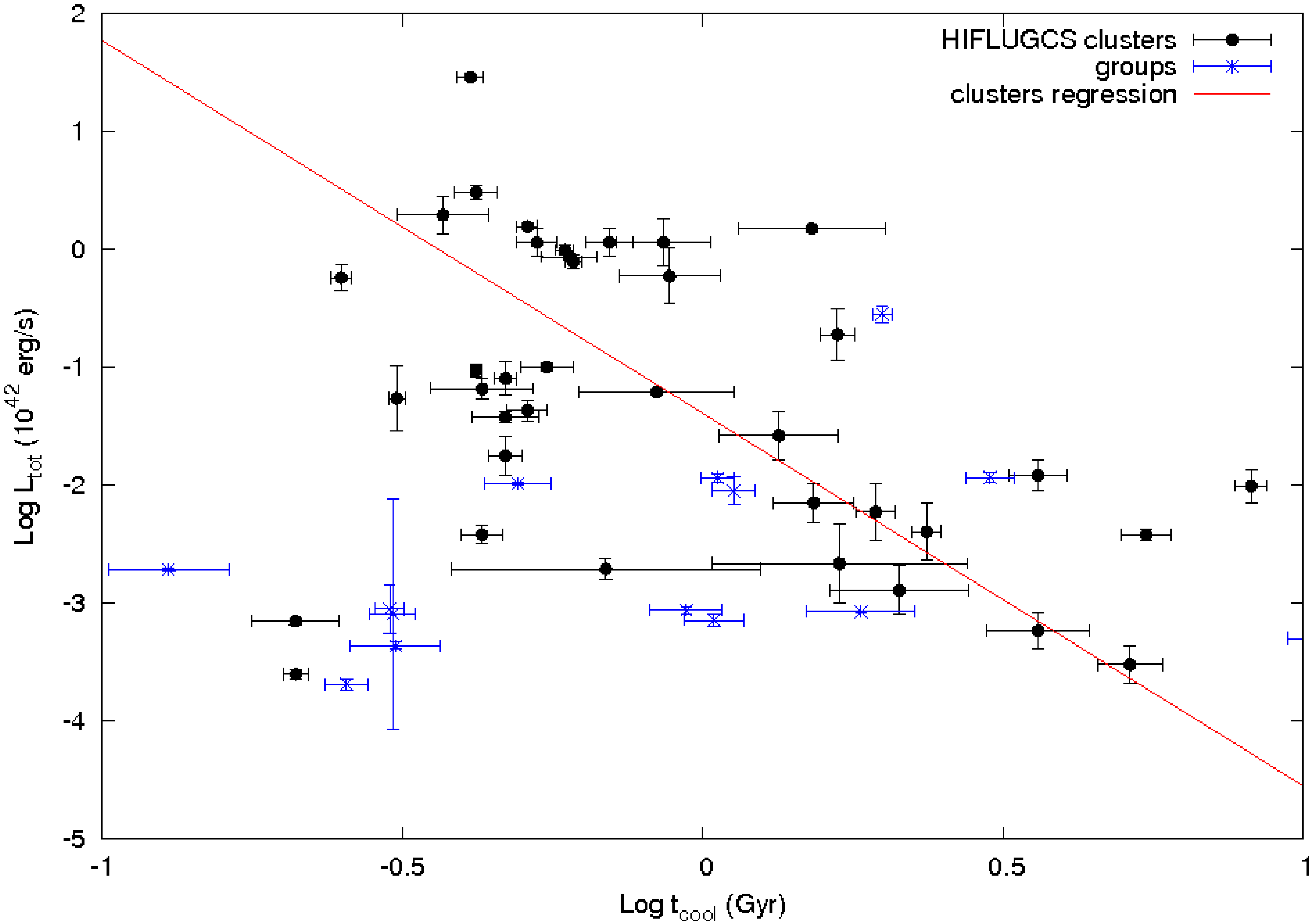
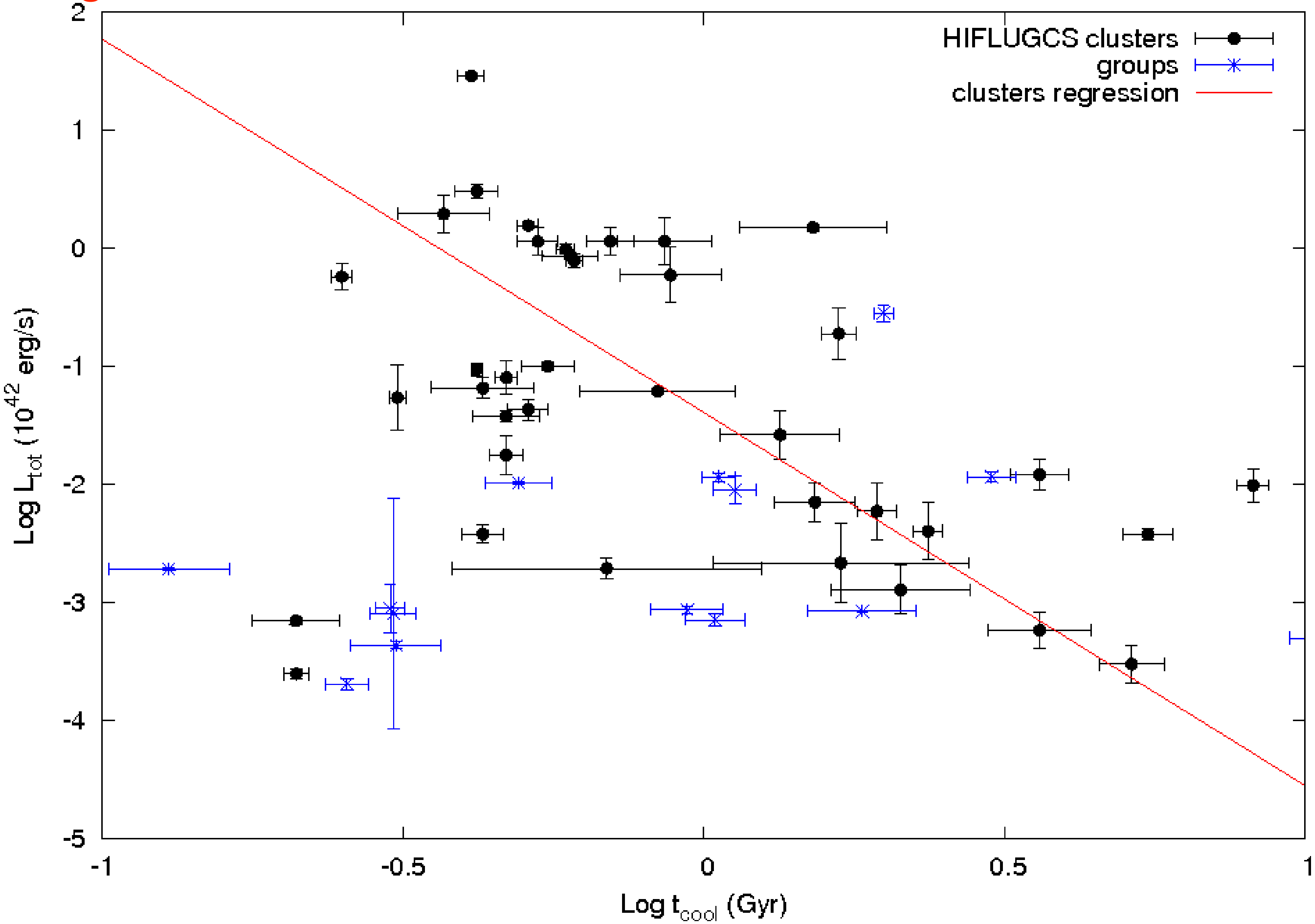


From Mittal et al. (2009)


HIFLUGCS clusters
groups
clusters regression
Log L_{tot} (10^{42} erg/s)
Log t_{cool} (Gyr)
2
1
0
-1
-2
-3
-4
-5
-1
-0.5
0
0.5
1

CC groups have a median radio luminosity an order of magnitude lesser than CC clusters!



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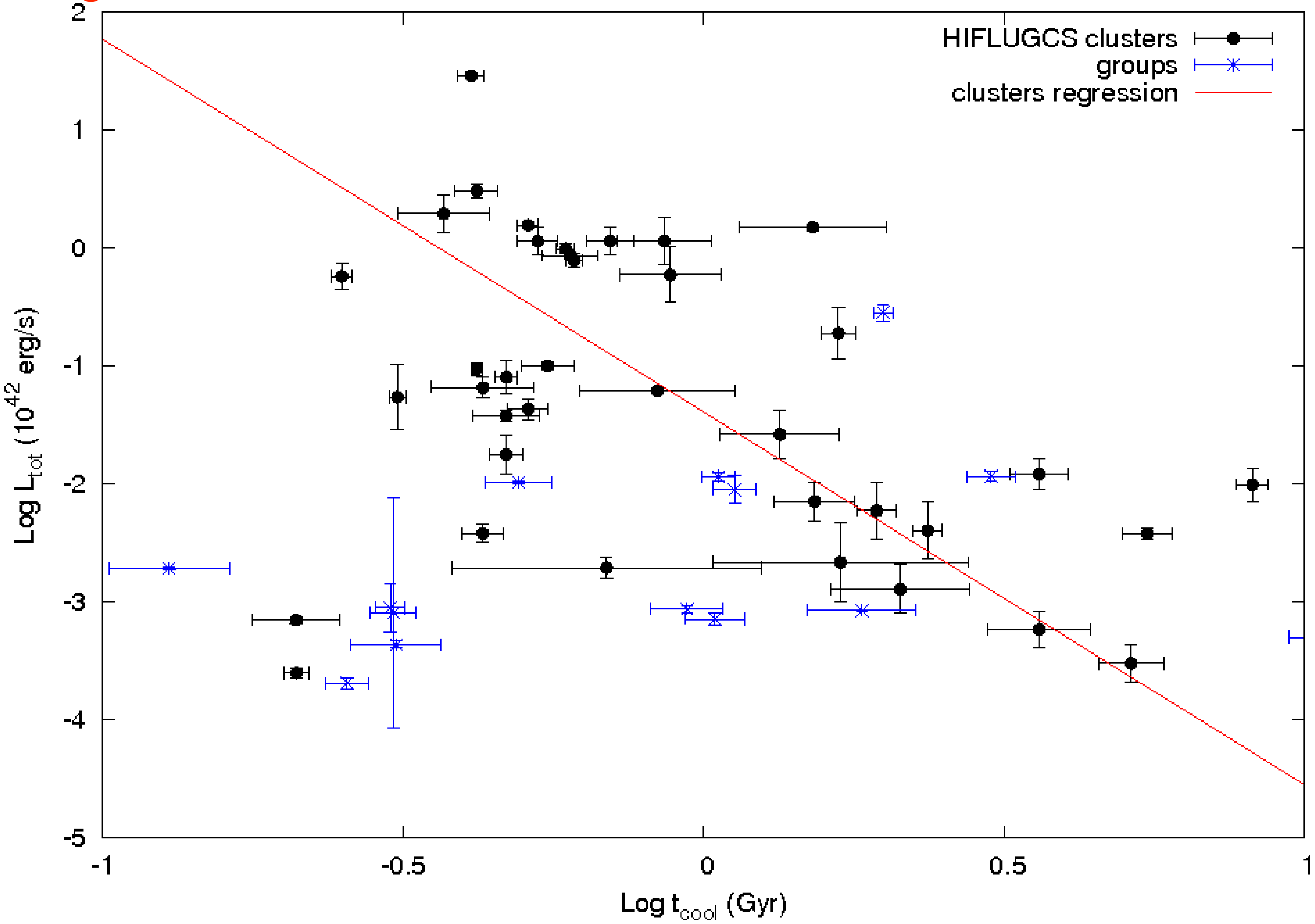
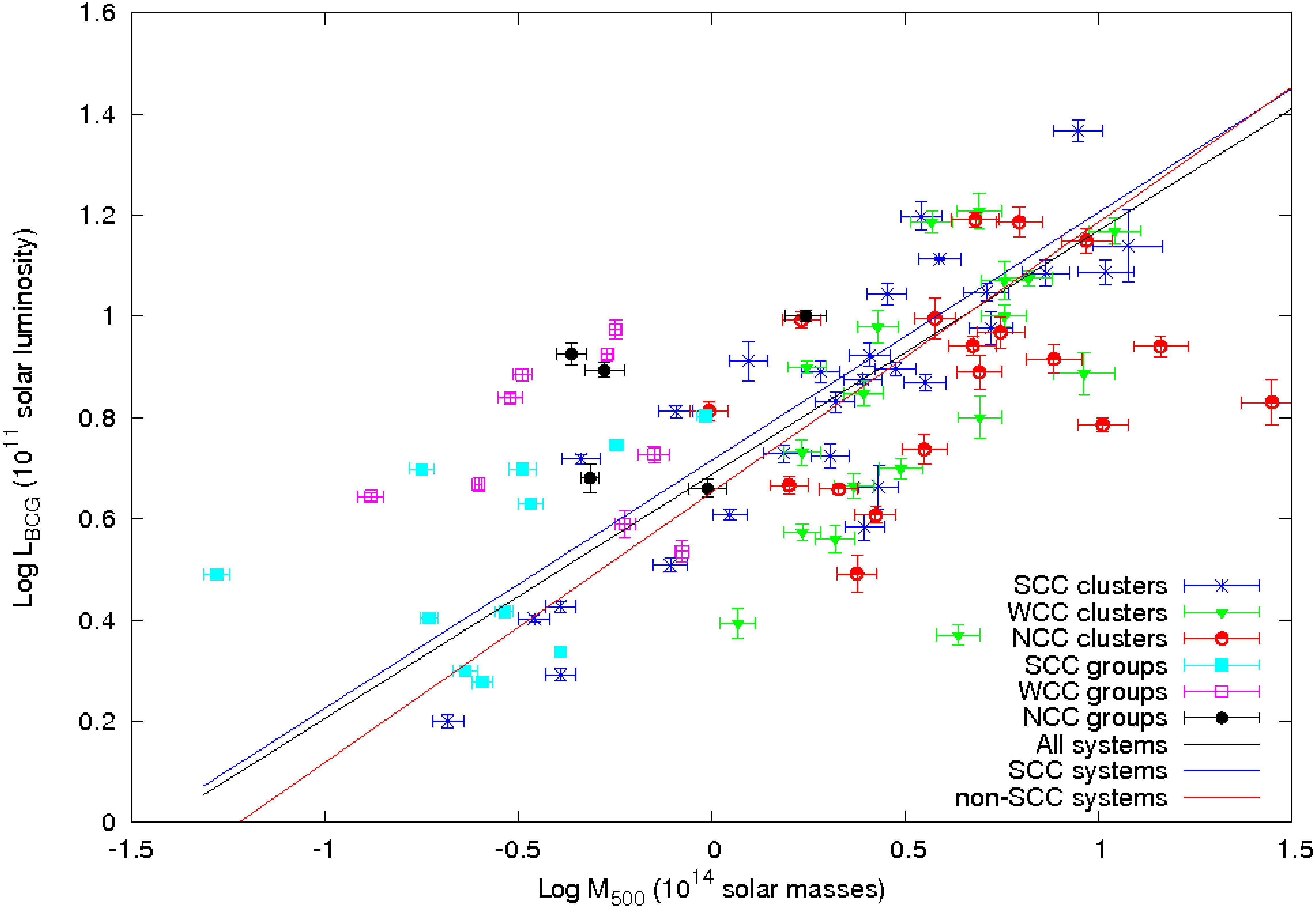


Naive conclusion-Not enough gas accreting onto the SMBH.

Results-BCG Properties



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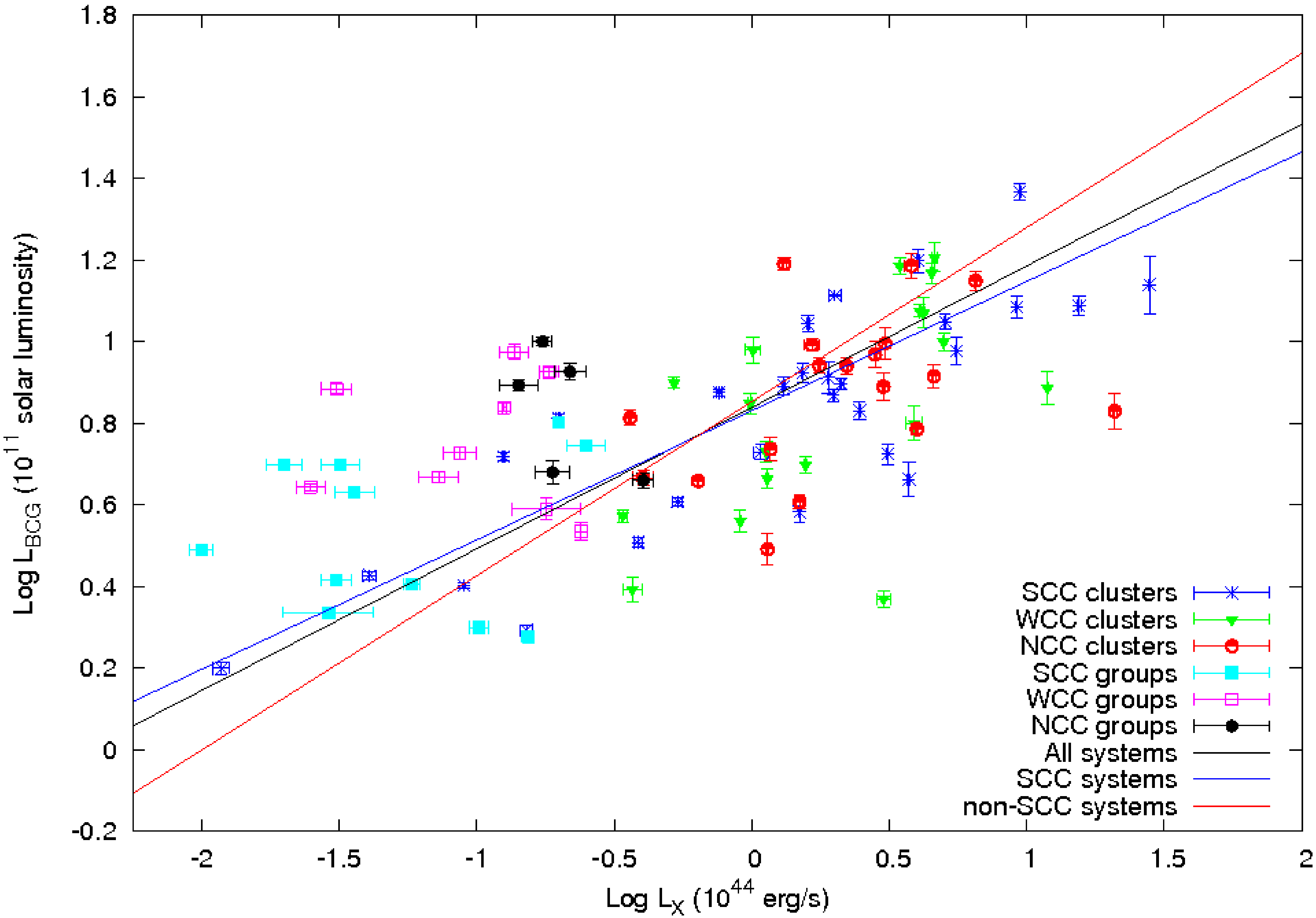

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BCG Scaling Relations

- Combining both samples, largest ever BCG-host scaling relations with CC/NCC distinction.

- Scaling relations show that BCG grows with host mass and luminosity.

- SCC systems have statistically significant different slopes and normalizations compared to non-SCC systems.

- Could indicate different growth histories for SCC BCGs as compared to other BCGs.

- Most group BCGs lie above the best fit.

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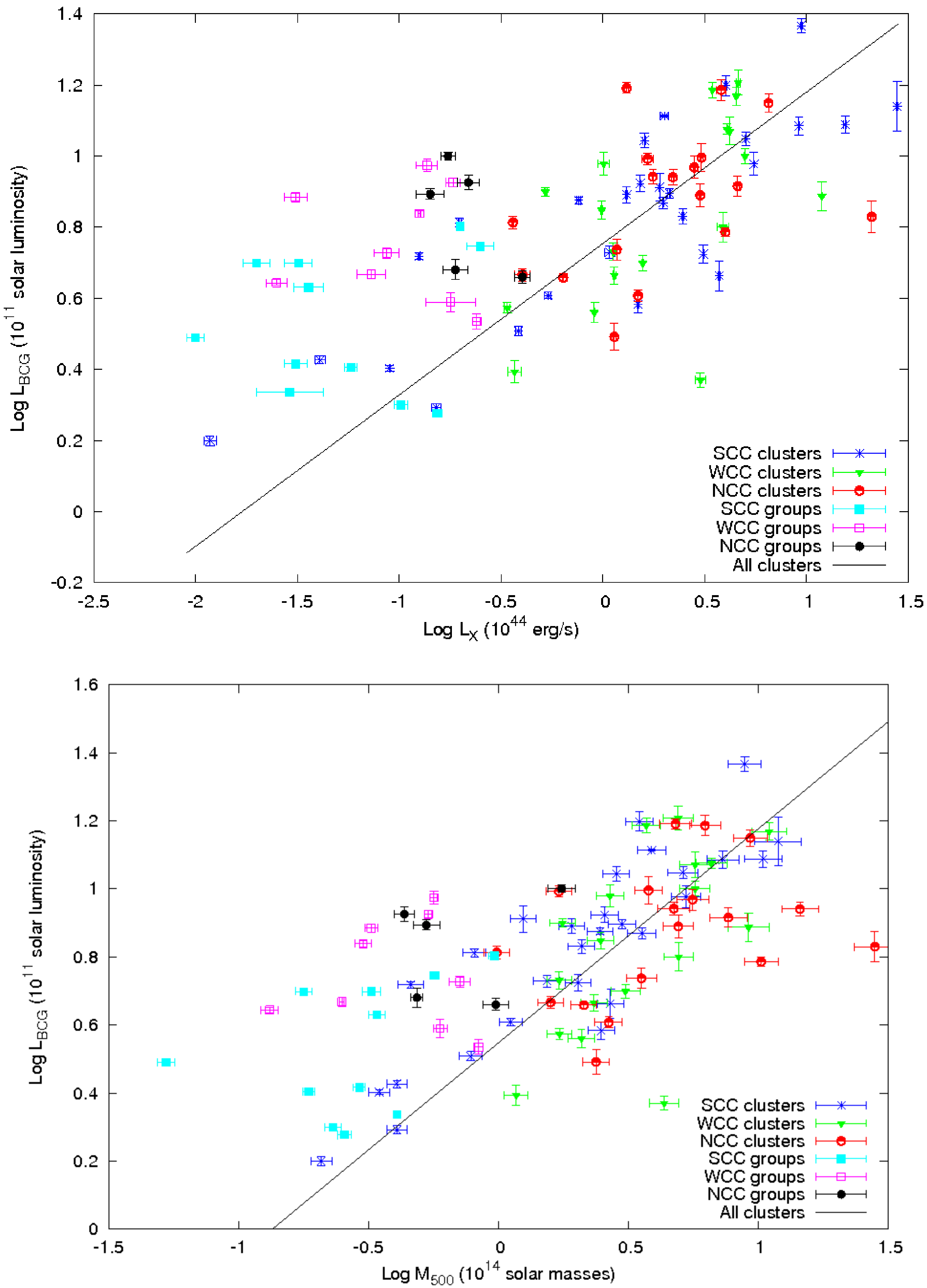

Log L_BCG (10^11 solar luminosity)
Log L_X (10^44 erg/s)
SCC clusters
WCC clusters
NCC clusters
SCC groups
WCC groups
NCC groups
All clusters
Log L_BCG (10^11 solar luminosity)
Log M_500 (10^14 solar masses)

Star Formation-The Missing Link

The Case for Star Formation

- Groups, being lower mass systems, are much more prolific star forming systems (e.g. Lin et al. 2003, Lagana et al. 2011)

- All SCC groups have central entropy well below 30 keV cm^2, fulfilling the condition for star formation (e.g. Rafferty et al. 2008).

- Star Formation Rate (SFR) increases as cooling time decreases (Hicks et al. 2010). Most SCC systems show SFR between 1 and 10 solar masses per year.

- Median classical mass deposition rates for our SCC groups 3.8 solar masses per year (6.1 for all CC groups).

- Gas in CC groups mostly fueling star formation?

- Observational evidence needed from other wavelengths.

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Star Formation

- H-alpha emission could indicate star formation.
- 18 of 26 group BCGs observed using the SOAR telescope to investigate H-alpha emission.
- Observations conducted in end 2011 and spring 2012 by Megan Donahue and Malanka Riabokin.
- Data currently being analysed and results to be compared to the cool core properties of groups.

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Summary

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Summary

- CC/NCC fractions comparable to clusters.

- Distribution of CRS fractions in groups much different than clusters.

- Group CRSs have much lower radio luminosity than cluster CRSs.

- Indications that fossil groups might be unique compared to other clusters/groups.

- BCG-cluster scaling relations extended to the group regime. Most group BCG luminosities well above the best fit for clusters.

- The role of star formation to be investigated in the near future.

- Groups different from galaxy clusters in trying to understand the ICM cooling/AGN feedback paradigm!

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Thank You!

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