On mass-to-light ratios in fossil groups. Are they simply dark clusters?

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ABSTRACT:
Defined as X-ray bright galaxy groups, with large gap between the luminosities of their brightest and second brightest galaxies (Δm12), ``fossil groups'' are believed to be some of the oldest galaxy systems in the universe.

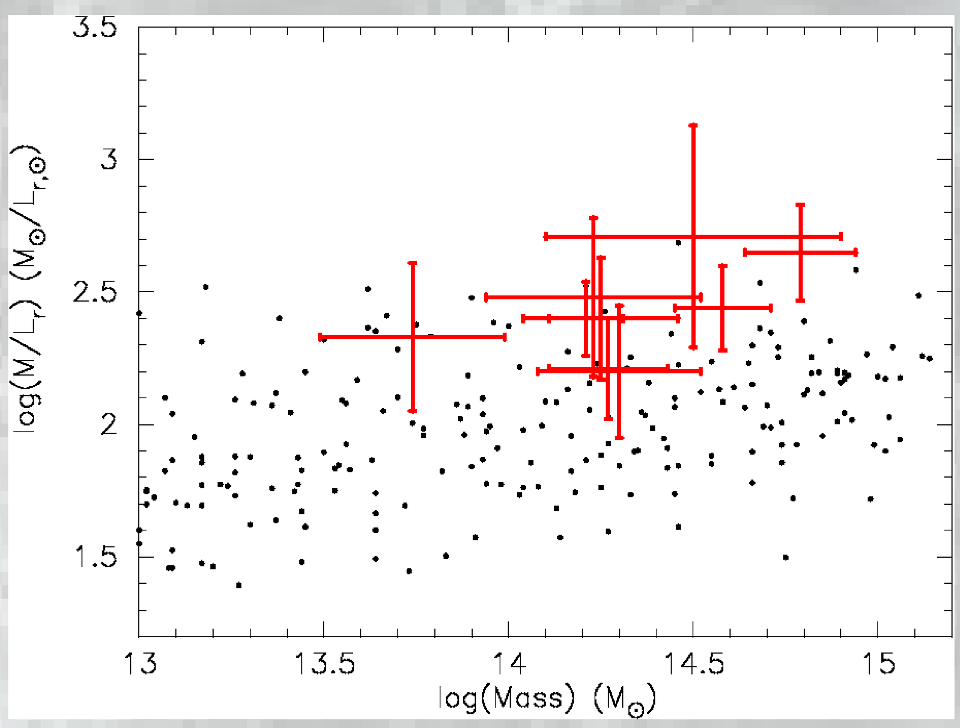
We report the results of the deepest spectroscopic study of fossil groups to-date. The study shows that many fossil groups can be characterised as relatively massive, with appropriately bright BCGs, but otherwise containing only ~25% of the non-BCG galaxies of "normal" systems (clusters) of the same mass. Consequently, the mass-to-light ratio of fossil groups are ~3 times higher than normal systems of the same mass. The luminosity of the missing 75% of non-BCG galaxies amounts to some 5 times the luminosity of the central BCGs and twice the total luminosity of the whole system. We show that the low richnesses, coupled with bright BCGs naturally result in large Δm12 gaps. Therefore, dynamical friction need not be invoked to explain large gaps in fossil groups.

1. BACKGROUND:

Fossil groups (FGs) are defined as X-ray bright systems that exhibit a 2 magnitude gap between the luminosities of the brightest cluster galaxy (BCG) and the second most luminous galaxy within half the virial radius.

While no consensus as yet exists, the most commonly quoted paradigm for the formation of FGs invokes the action of dynamical friction in ancient groups and clusters (i.e. systems that have remained relatively undisturbed for a significant fraction of a Hubble time). This results in bright central galaxies spiraling into the centre, to be "cannibalised" by the BCG. In this way the large gaps in luminosity between the brightest and second ranked galaxies are produced.

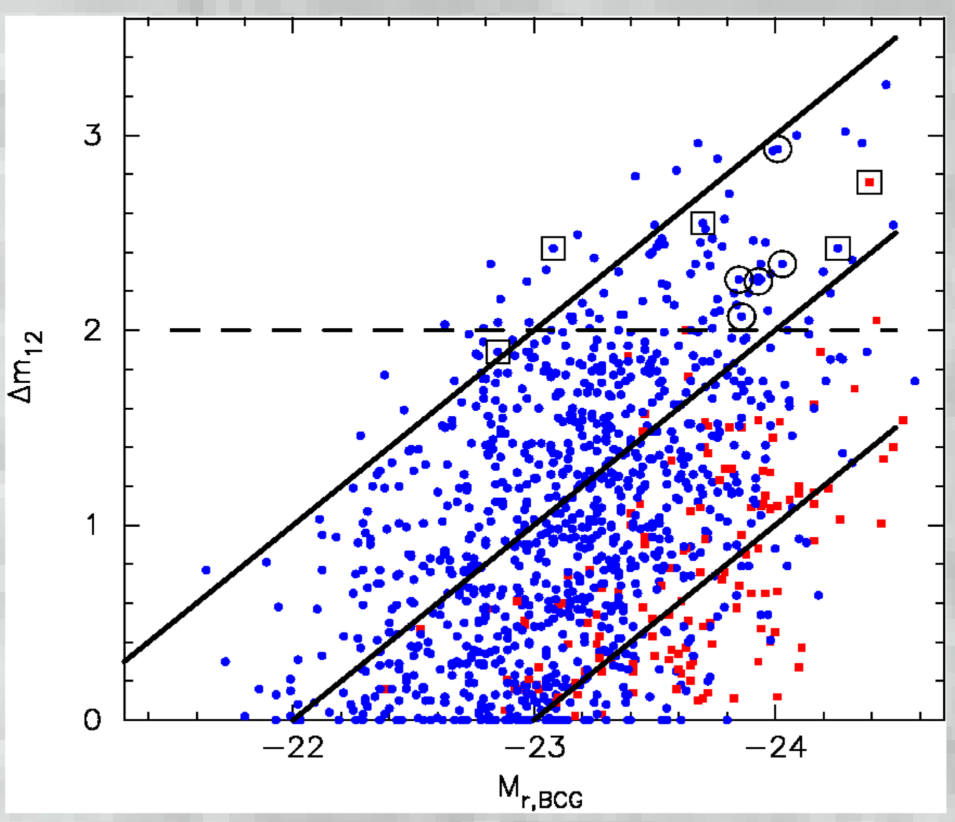
Previous observational studies suggest that FGs are `X-ray luminous´ for their optical luminosity, while others find high mass-to-light ratios. We therefore carried out a detailed study of the scaling relations between the optical and X-ray properties of fossil systems for comparison with those of "normal" systems. In panels 2 to 8 below we outline our findings.



4. Mass-to-light ratios (left):

The r band mass-to-light ratio of FGs are compared to values for "normal" systems from Girardi et al. 2002 (black dots).

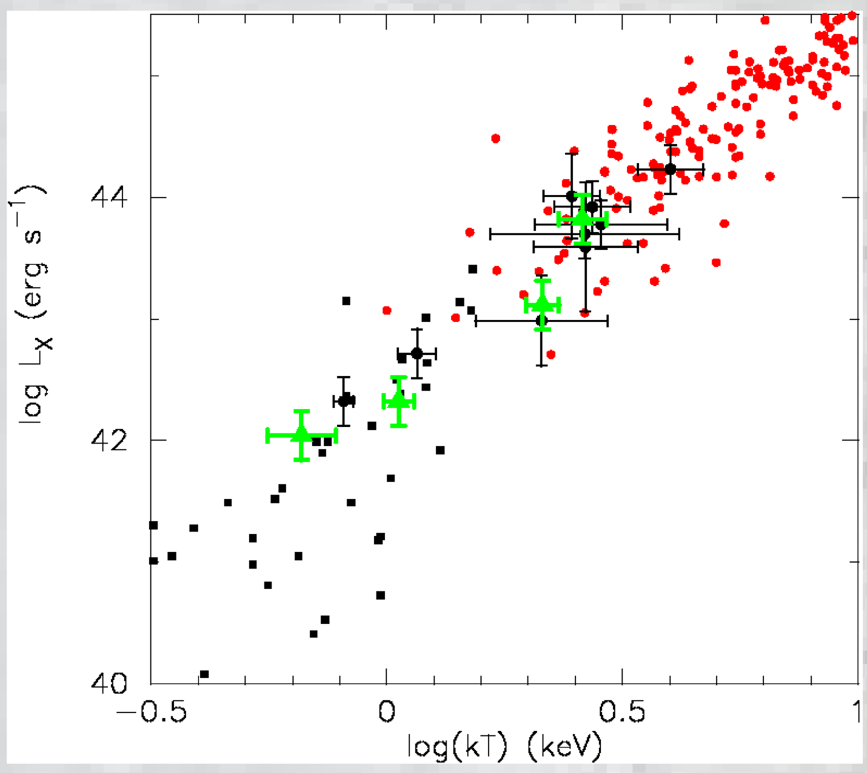
- Masses of the FGs in our sample are all ~10^{14} solar masses or greater.
- The mass-to-light ratio of fossil groups are approximately a factor of 3 higher than normal systems of the same mass.
- This suggests an under-abundance of non-BCG galaxies of approx. 75%



5. Luminosity gap Δm12 (left):

The luminosity gaps between the brightest (BCG) and second brightest galaxy within half the virial radius (Δm12) are plotted against BCG luminosity. Diagonal lines mark loci of second ranked galaxies of constant luminosity (increasing to the lower right) Blue (red) points show a sample of systems of low (high) richness from the maxBCG catalogue . Our sample are identified by open squares and circles. It is evident that FGs (i.e. Δm12>2.0) show:

- High BCG luminosities, with values generally more similar to those in clusters than those in groups .
- Low second ranked galaxy luminosities.
- Low richnesses.



2. The Lx--Tx relation (left):

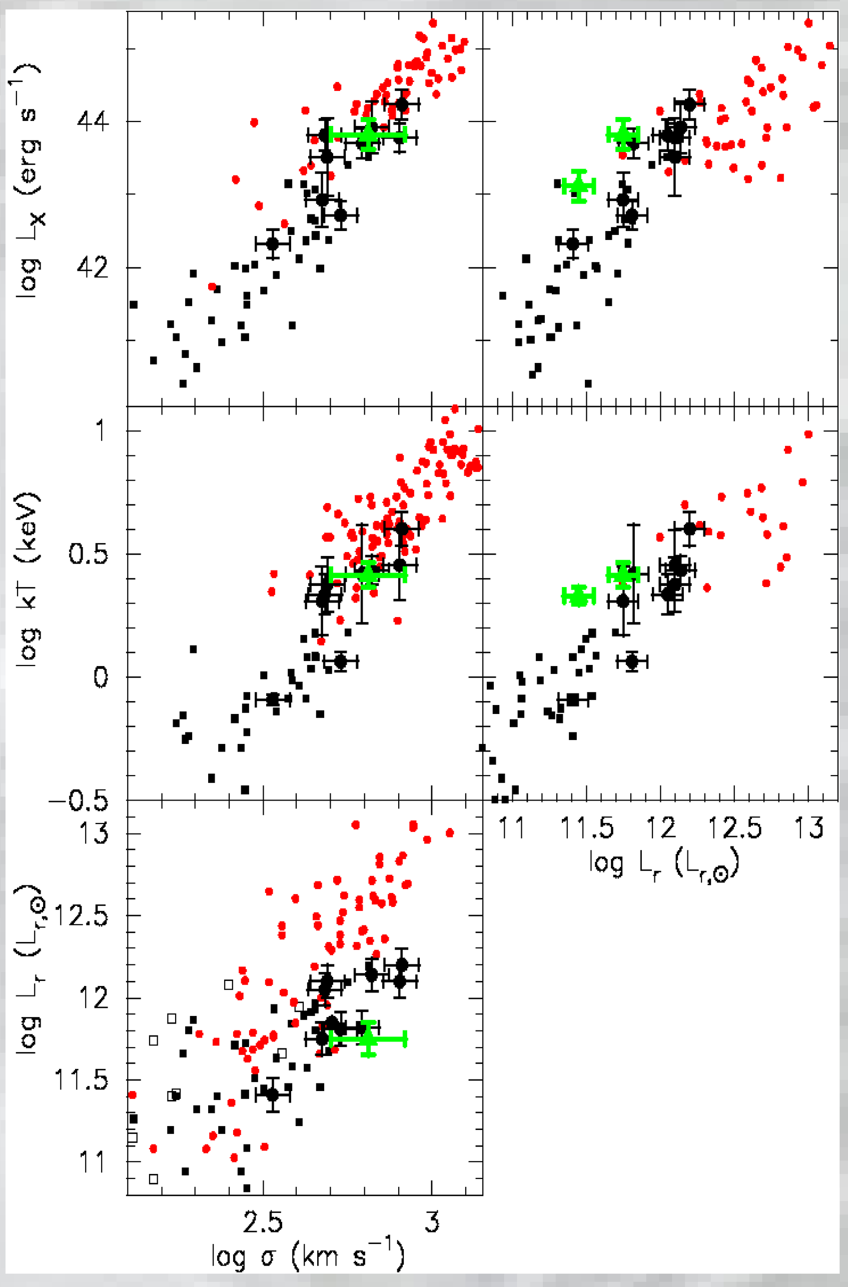
FG data are shown with error bars (black; our data, green from Khosroshahi et al 2007). Data for "normal" systems are black squares (groups; Osmond & Ponman 2004) and red dots (clusters; Wu et al. 1999).

- FGs follow the same relation as "normal" systems.
- However, many have properties more similar to clusters than groups and suggest high masses.

3. Scaling Relations (right):

Symbols are as in the Lx-log(kT) plot. Normal group data are from Osmond & Ponman (2004) and Girardi et al (2002), cluster data are from Wu et al. (1999), Zhang et al. (2011) and Girardi et al. (2002) . The scaling relations clearly show that:

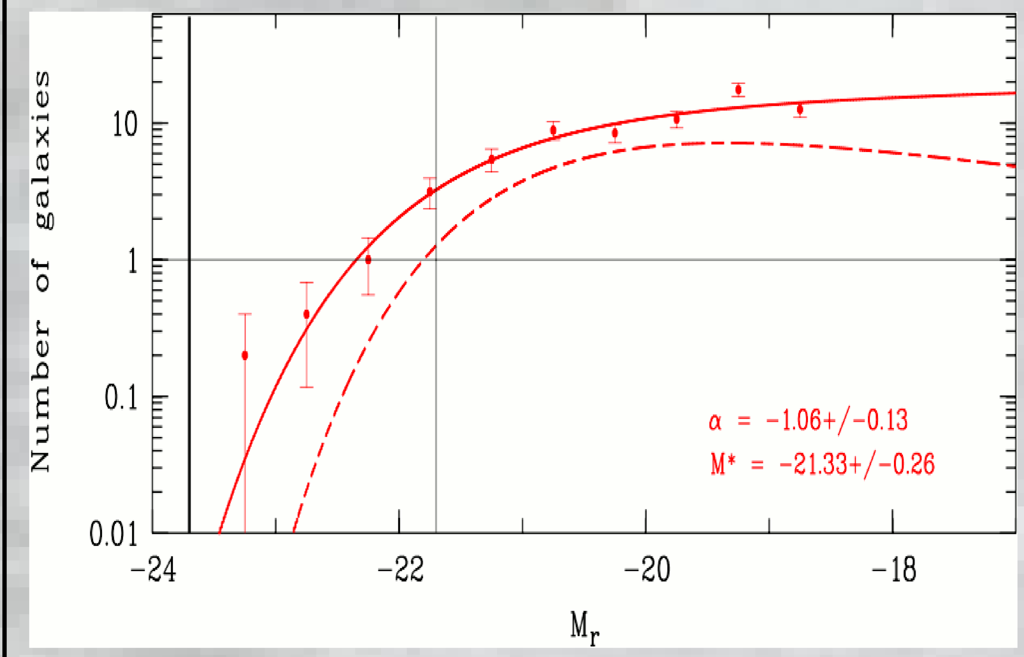
- Velocity dispersions (σ) confirm high masses found in Lx-kT (panel 2 above).
- σ in FGs generally following normal cluster relations with X-ray properties.
- However, optically, FGs are SIGNIFICANTLY under-luminous compared to normal systems (i.e low L_r for their σ).
- Cluster-like FGs are under-luminous with respect to X-ray properties.
- Scaling relations therefore indicate high mass-to-light ratios.



6. Luminosity Function (right)

The luminosity function within the virial radius (solid line) and half the virial radius (dashed line) of an *average* FG is shown. The dark vertical line marks BCG luminosity.

- FGs well fit by Schechter function, but low richness causes low normalisation.
- Low richness ***and*** bright BCG (panel 5) often causes large Δm12 gaps due to the sparseness of the Schechter function at high luminosities, i.e. within 0.5Rvir of the average group, the number of galaxies expected above M_r~-21.75 mag is <1.



7. Summary:

We have shown that fossil systems exhibit normal luminosity functions with richnesses appropriate to poor groups, but that they possess masses and BCG luminosities more similar to clusters. We show that, with these properties, all of the important characteristics of fossil systems can be explained:

- Low richnesses, coupled with bright BCGs naturally result in the large Δm12 gaps
- Low richnesses, coupled with high masses, result in high mass-to-light ratios (despite the bright BCGs).

It is interesting to note that, although we can not rule it out, dynamical friction is not called upon by this description to explain large Δm12 gaps (indeed it is disfavoured by the LF).

8. Open Questions:

A number of questions arise:
- Where are all the missing bright baryons?
- Are fossils really fossils? I.e. are they truly old?
- What do our results mean for studies that utilise cosmological N-body/semi-analytic modeling to address issues surrounding fossil groups?
- By what mechanism can the BCGs in the low richness systems of fossil groups achieve the same mass as those in much richer systems?

All of these issues clearly need addressing if we are to establish a coherent picture of how the formation of fossil systems differs from normal systems.

References:
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