LA-UR- 10-05049

Approved for public release; distribution is unlimited.

Title:	Fossil Groups: graveyards or cradles for the brightest galaxies?
Author(s):	Konstantin Borozdin, Salman Habib, Katrin Heitmann, Zarija Lukic, Alexey Voevodkin
Intended for:	Cosmology Clusters Conference, Garching, Germany, July 26-30 2010

Los Alamos
NATIONAL LABORATORY
EST. 1943

Los Alamos National Laboratory, an affirmative action/equal opportunity employer, is operated by the Los Alamos National Security, LLC for the National Nuclear Security Administration of the U.S. Department of Energy under contract DE-AC52-06NA25396. By acceptance of this article, the publisher recognizes that the U.S. Government retains a nonexclusive, royalty-free license to publish or reproduce the published form of this contribution, or to allow others to do so, for U.S. Government purposes. Los Alamos National Laboratory requests that the publisher identify this article as work performed under the auspices of the U.S. Department of Energy. Los Alamos National Laboratory strongly supports academic freedom and a researcher's right to publish; as an institution, however, the Laboratory does not endorse the viewpoint of a publication or guarantee its technical correctness.

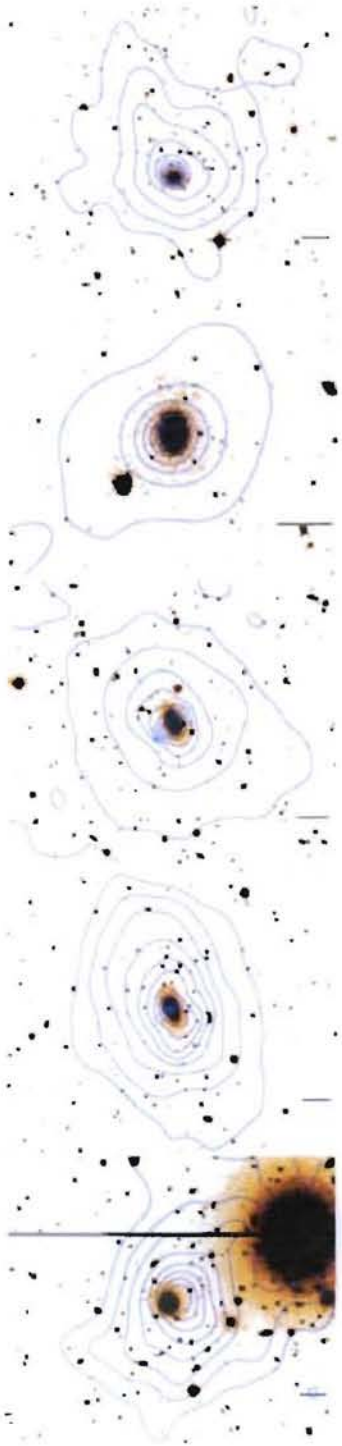
Form 836 (7/06)

Fossil Groups: graveyards or cradles for the brightest galaxies?

Konstantin Borozdin,
Salman Habib, Katrin Heitmann, Zarija Lukić
(Los Alamos National Laboratory)
Alexey Voevodkin
(Ludwig-Maximilians-Universität, München)

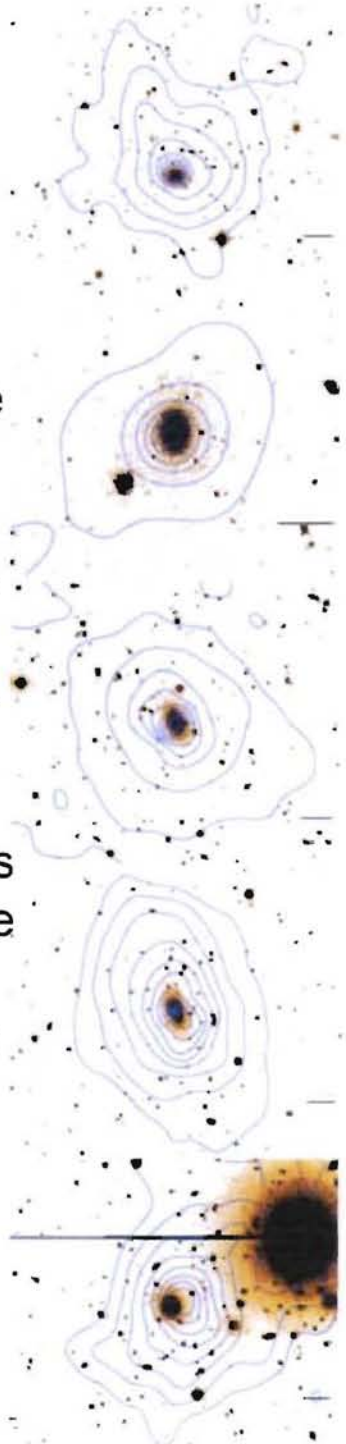
July 26-30, Garching

Los Alamos
NATIONAL LABORATORY
EST. 1943



Abstract

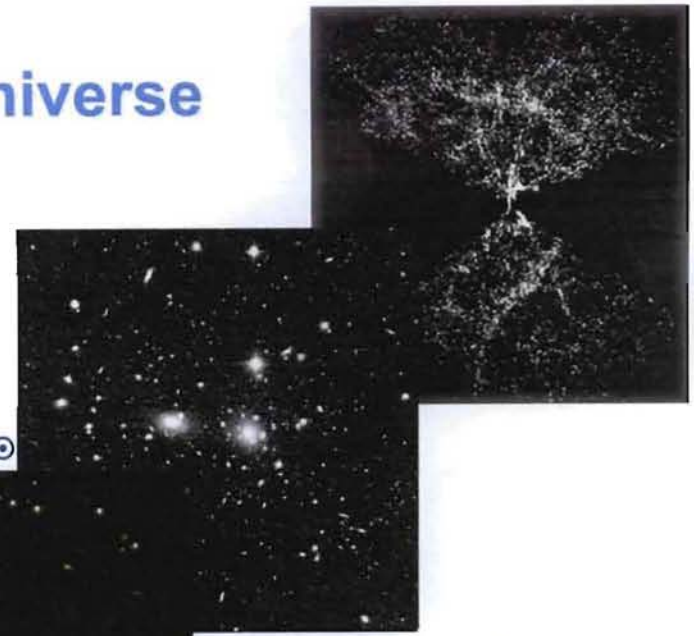
Fossil groups are relaxed, X-ray bright systems dominated by a giant elliptical galaxy at the centre. Though typically labeled "groups", they are often massive enough to be found in cluster catalogs. Properties of these systems are usually attributed to their dynamical history, including a lack of galaxy mergers for a long time prior to observation. They are often seen therefore as a final stage of galactic evolution in the group environment. More recently it was suggested however that these systems may represent a transient "fossil stage" in the evolution of clusters, ending with the infall of new galaxies from the environment. Properties of central galaxies in the fossil groups are very similar to those of the brightest cluster galaxies (BCGs). "Fossil phase" may therefore be important for the formation of the BCGs. New studies of fossil systems in observations and N-body simulations promise to answer this question.



Constituent Parts of the Universe

Age

Groups: - more numerous than clusters
- most galaxies are in groups
- galaxy evolution in groups



$M \sim 10^{12} - 10^{14}\ M_\odot$

$M \sim 10^{14}\text{-}10^{15}\ M_\odot$

Numbers

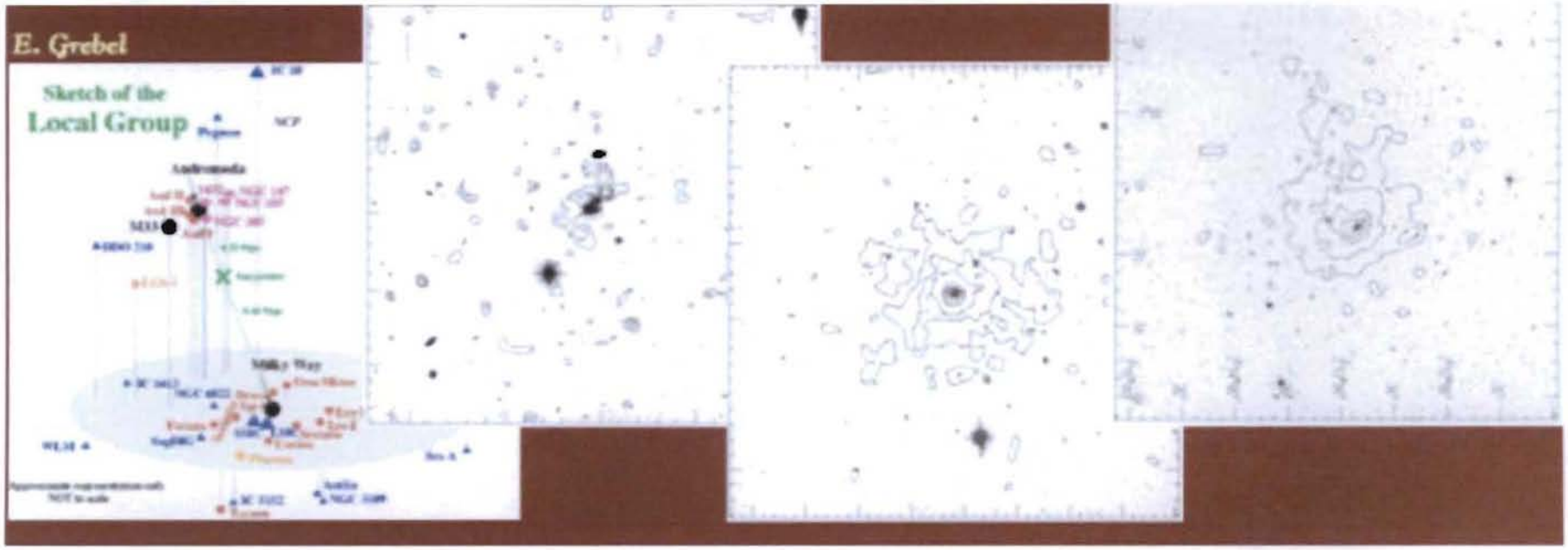
$M \sim 10^{9} - 10^{12}\ M_\odot$

$\sim 10^{4} - 10^{6}$ stars

$M \sim 0.1 - 100\ M_\odot$

Size Mass

Evolution of Groups



A schematic of the Local Group (E. Grebel), and the optical/X-ray images of HCG 90, NGC 2563, and NCG 1132, respectively, from left to right (Mulchaey & Zabludoff 1998). Do these four classes of groups represent one possible group evolutionary sequence? ⟹

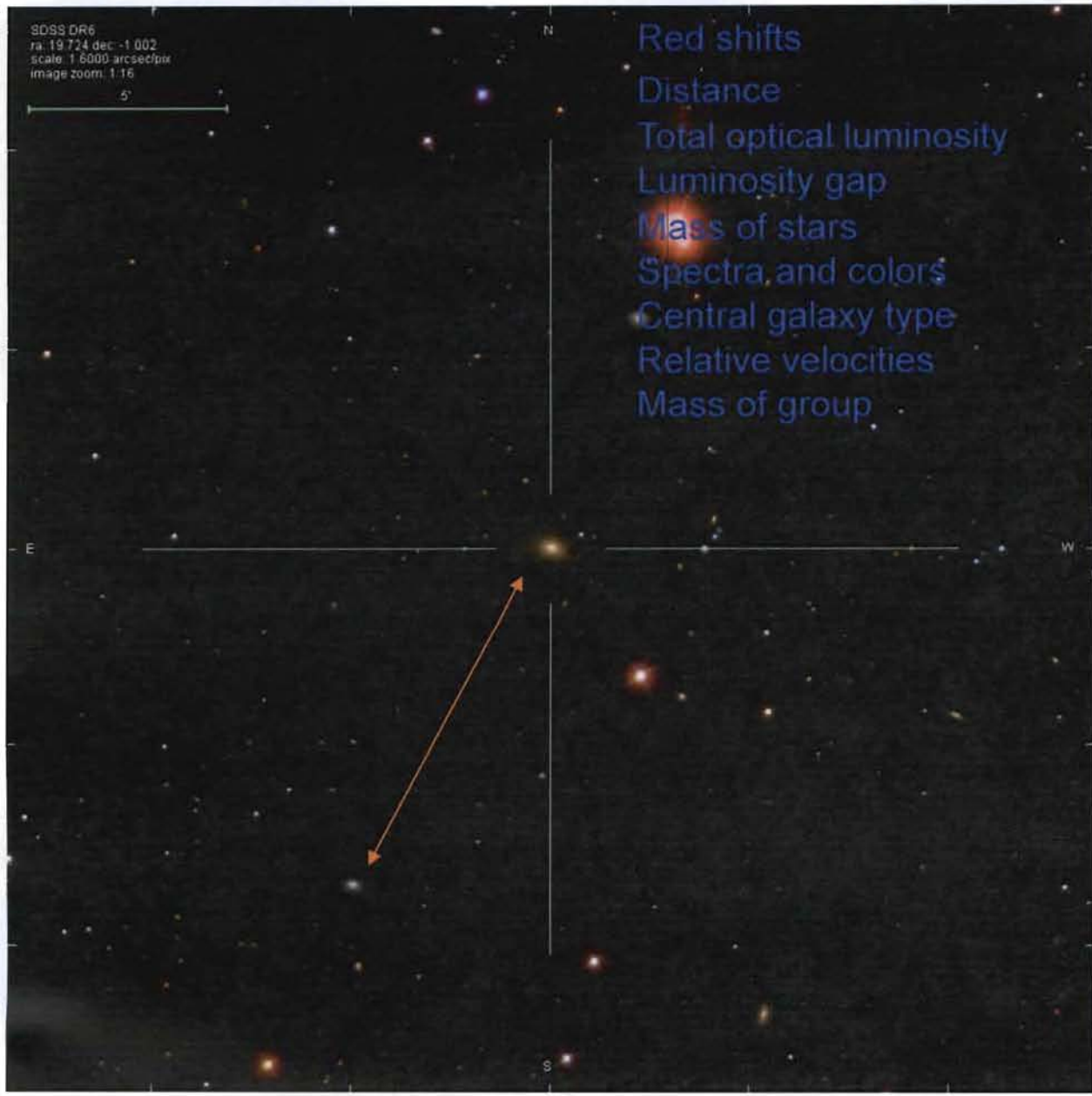
Fossil Groups

- ✓ luminous red elliptical in the center
- ✓ luminosity gap $m_{12} > 2$ (R band)
- ✓ bright extended X-ray emission

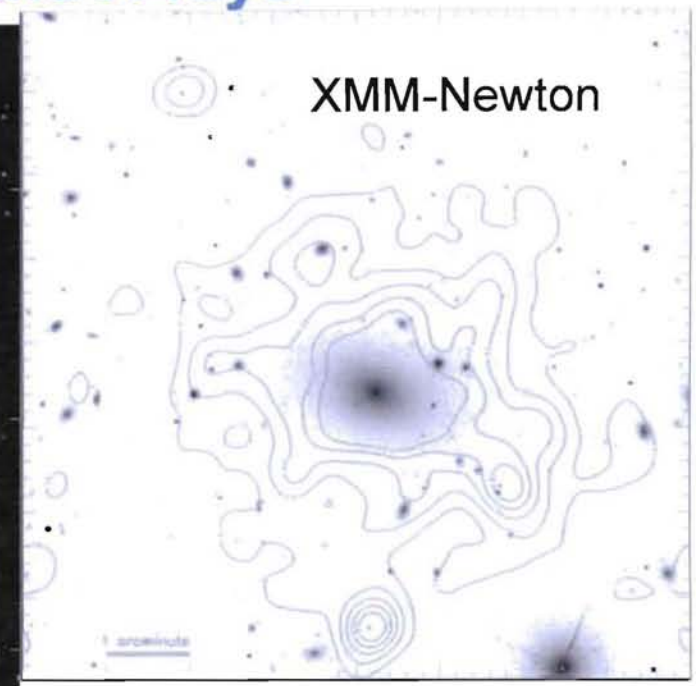
$L_x > 10^{42}$ erg/s

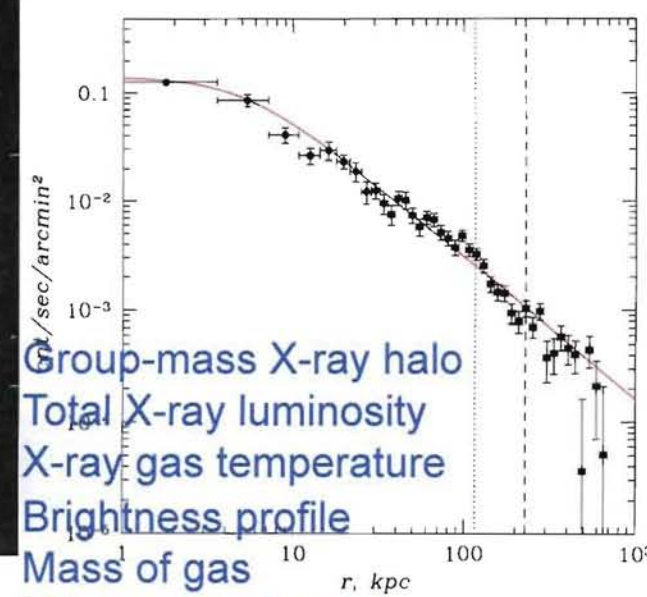
(Jones et al. 2003)

Fossil Groups Observations in Optical and X-rays



Red shifts
Distance
Total optical luminosity
Luminosity gap
Mass of stars
Spectra and colors
Central galaxy type
Relative velocities
Mass of group





Group-mass X-ray halo
Total X-ray luminosity
X-ray gas temperature
Brightness profile
Mass of gas
Total mass of group

UGC0042 (Voevodkin, Miller, Borozdin et al. 2008)

Halo Evolution and Fossil Groups in Dark Matter Simulations

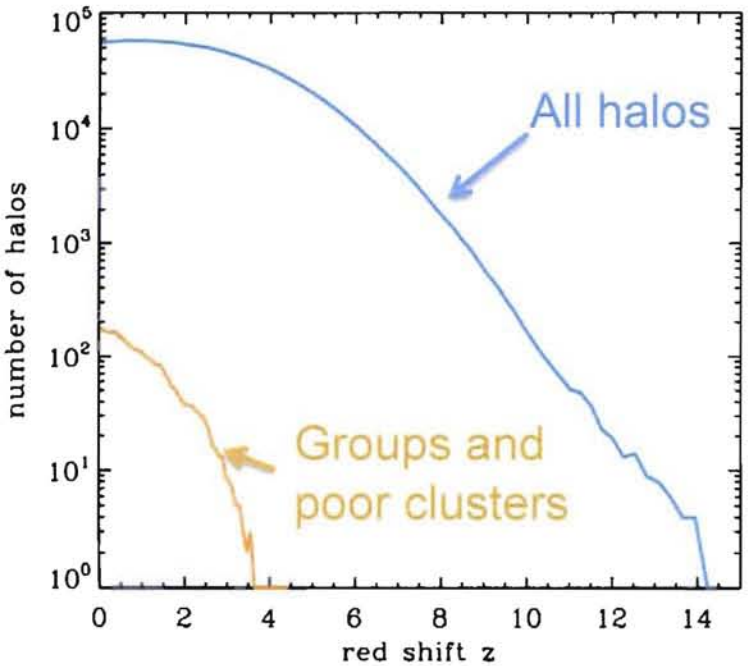
Mass range selection for fossil groups

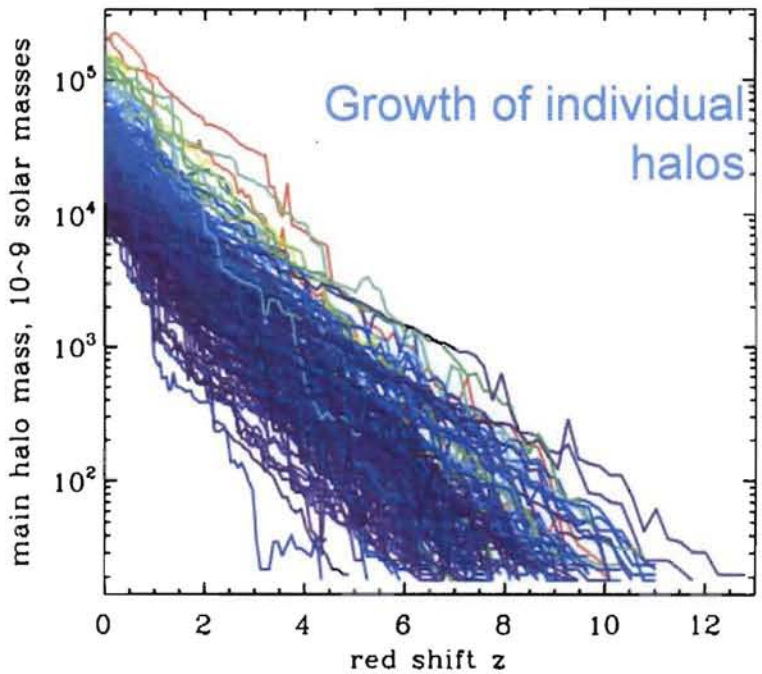
$10^{13} - 3*10^{14}\ M_{\odot}$

Identification in merger trees from the time of last merger

Halo substructure, velocities

Statistical studies



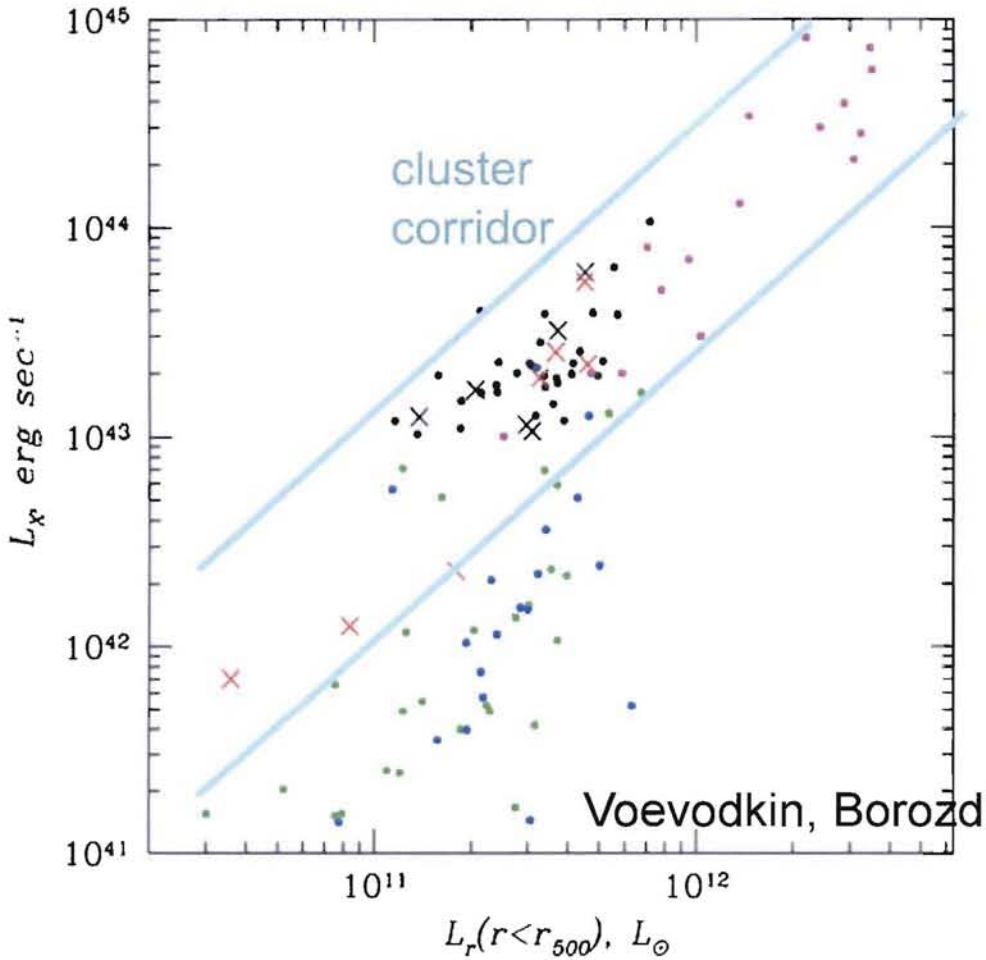


Missing Satellites in Fossil Groups

Cold dark matter simulations tend to predict a lot of substructure on all mass scales.

As fossil groups lack bright (L_*) galaxies, mass function of galaxies in these groups presents a challenge to CDM structure formation.

X-ray and Optical Luminosities



Crosses represent fossil groups
Pink and black dots are clusters
Green and blue dots are X-ray bright groups

Voevodkin, Borozdin, Heitmann et al. 2010

Fossil groups are similar to clusters in some respects.
They are exceptionally X-ray bright comparing to other groups of the same optical luminosity.
Central galaxies of fossil groups are very similar to BCGs

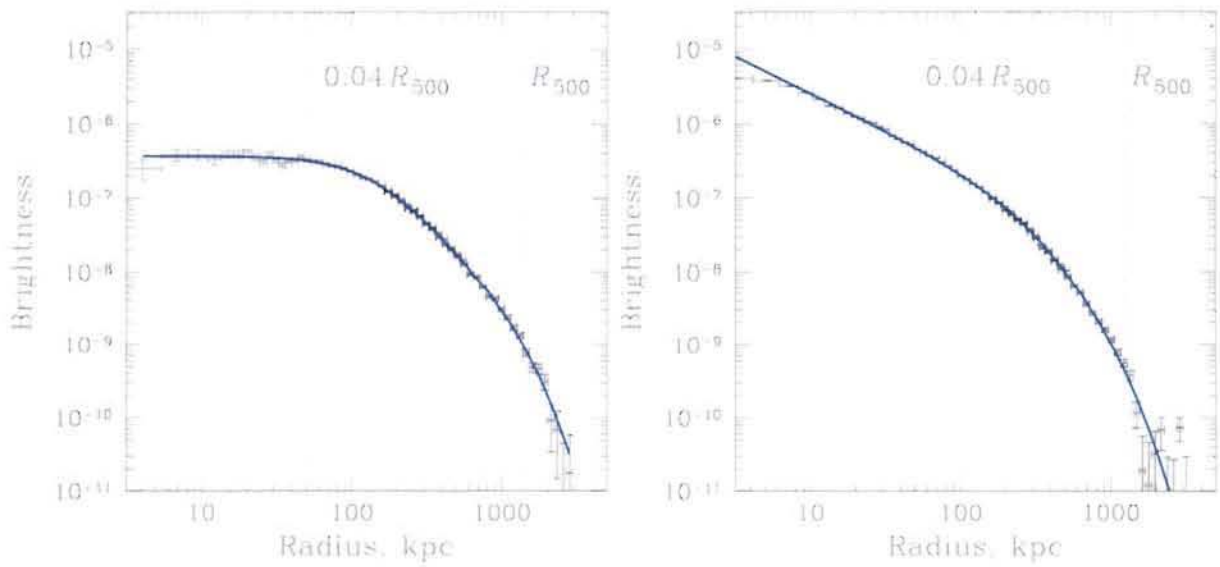
Cooling Flows

Dense internal regions of clusters lose energy by X-ray emission and cool down

Observed in as many as ~70% of relaxed clusters

Could be disrupted by mergers, AGN activity;
absent in higher-z clusters

Not reported in fossil groups



Vikhlinin et al. arXiv:astro-ph/0611438

A sharply peaked X-ray surface brightness distribution is indicative of a cooling flow, because it shows that the gas density is rising steeply towards the center of the cluster or group.

Galaxy mergers and dynamical friction in groups and clusters

$$t_{\rm inf} = r_0/(dr/dt) = 12.4\,\frac{r_0}{100\ \rm kpc}\left(\frac{V_H}{700\ \rm km\ s^{-1}}\right)^2 \times \left(\frac{V_s}{250\ \rm km\ s^{-1}}\right)^{-3}\ \rm Gyr$$

D'Onghia et al. 2005

V_H is main halo rotational velocity, V_s is satellite's rotational velocity and r_0 is the impact parameter

$t_{\rm Hubble}$ = 14 Gyr

More massive galaxies have shorter lifetimes in a less massive halos, so BCGs are more likely to form in a group environment making fossil groups

The Mice (NGC 4676A and B).
Credit: NASA, H. Ford (JHU), G. Illingworth (UCSC/LO), M.Clampin and G. Hartig (STScI), ACS Science Team, and ESA