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Luminous red galaxies formation in the cluster and group environment

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cospar 10
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18 - 25 july 2010 | bremen . germany

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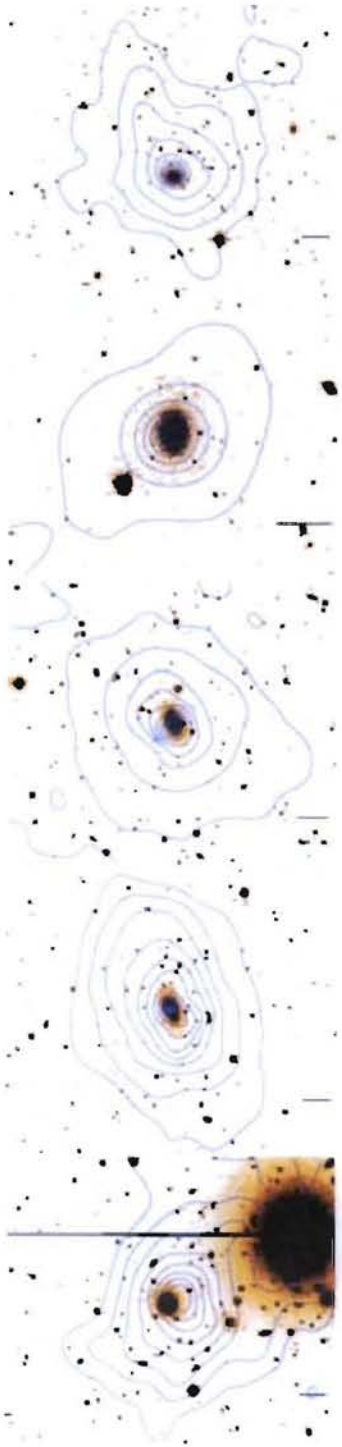
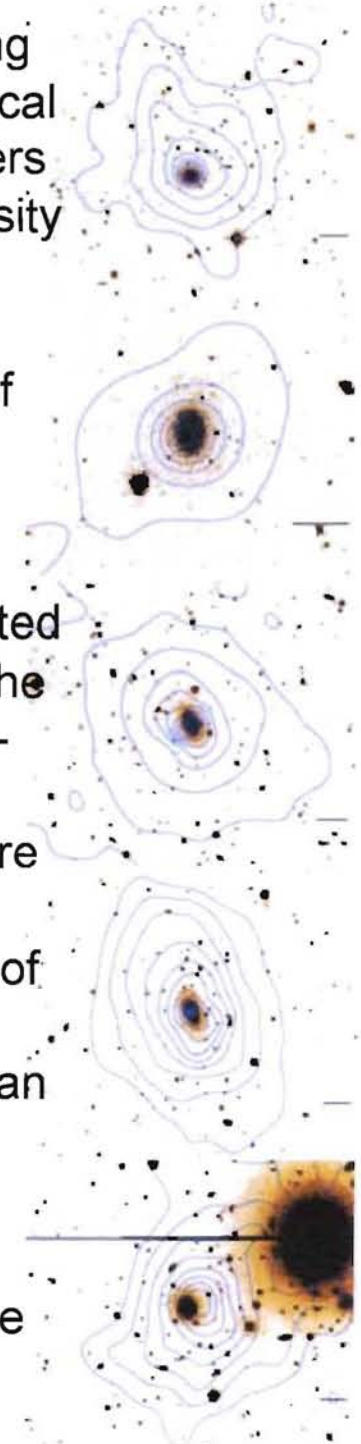


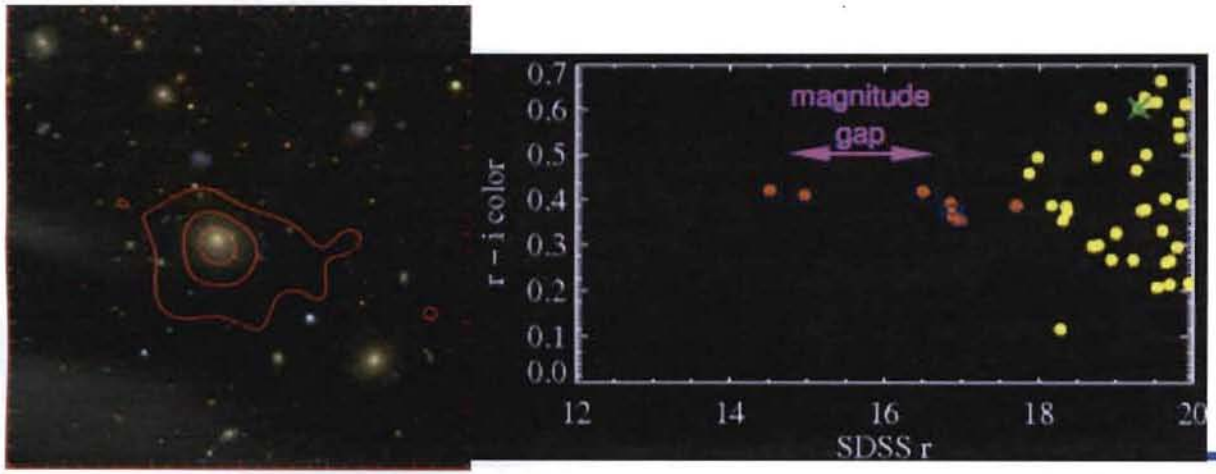
Luminous red galaxies are important for our understanding of the structure formation in the Universe. In the hierarchical structure formation model larger structures such as clusters evolve through series of mergers form the primordial density fluctuations. Still, the details of the galaxy formation and evolution are very uncertain. In particular, formation mechanism of the brightest cluster galaxies is a subject of active debate. Several suggested mechanisms, involving galactic cannibalism, cooling flows and mergers during cluster collapse, predict formation of the brightest cluster galaxies in situ. Galaxies forming this way should be located at the centre of the cluster gravitation potential, which is the most popular assumption for N-body modeling of the non-linear growth of the structure. Recent studies however demonstrate that large fraction of the brightest galaxies are offset from the centre of mass, therefore challenging the paradigm of in situ formation. Alternatively, the formation of luminous red galaxies may happen mostly in group environment, where dynamical friction is more efficient than in the clusters. A galaxy formed in a group may consequently be seeded into the larger gravitational potential of the cluster becoming the brightest cluster galaxy. These issues can be understood by comparing the observations with theory-based simulations.



Brightest Cluster Galaxies

- BCGs constitute the most massive and luminous galaxies in the Universe
- Most BCGs are giant elliptical galaxies, they also exhibit an extended diffuse envelope surrounding an elliptical-like nucleus akin to regular elliptical galaxies
- Multiple nuclei are common at low and moderate redshifts

Abell S0740 observed with Hubble Space Telescope

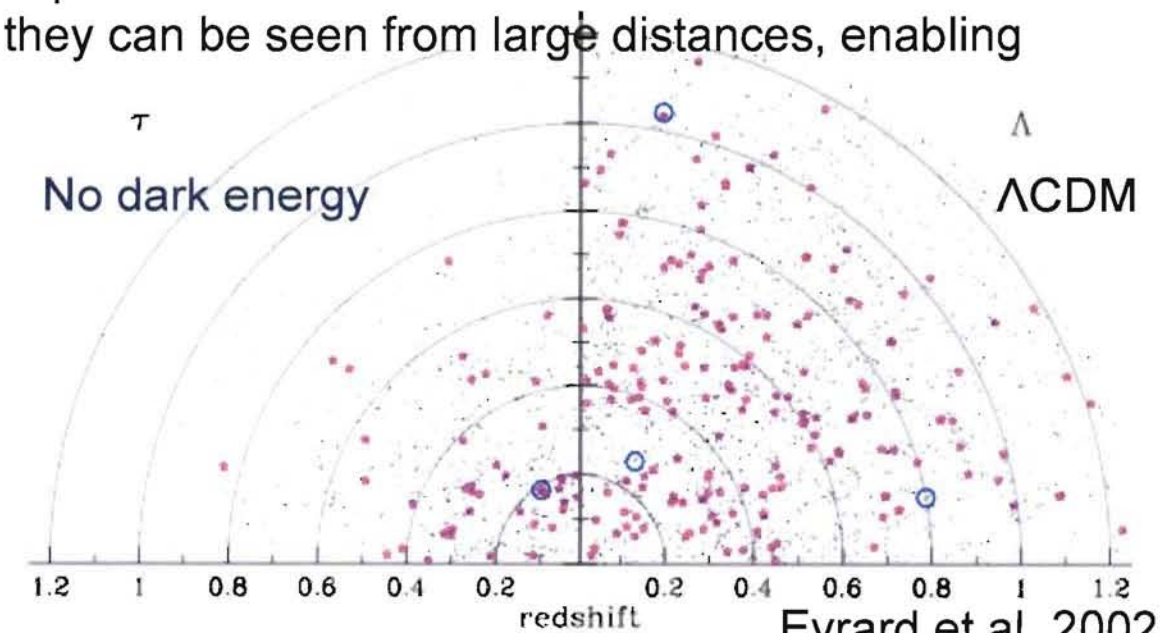


Fossil-like group with a double nucleus observed with DSS and XMM-Newton (contours)

Cosmological Importance of BCGs

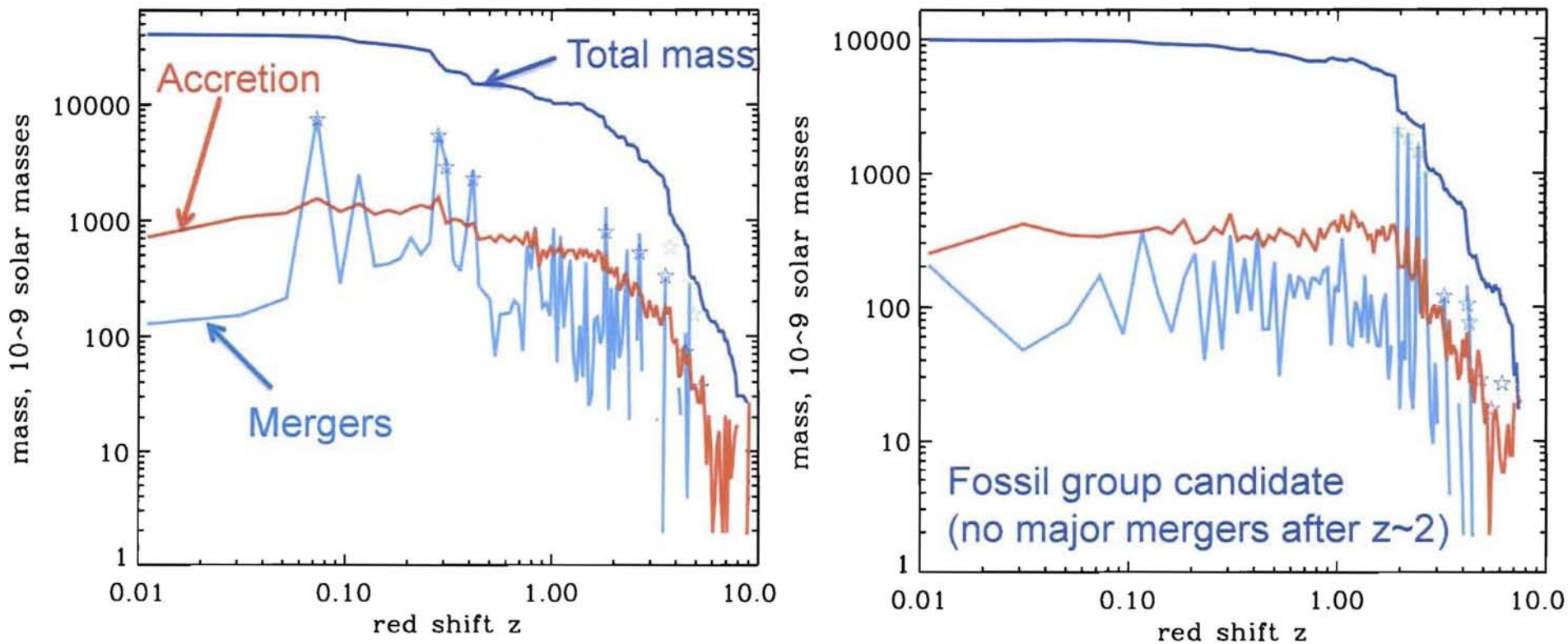
Galaxy evolution studies:
formation of massive galaxies
connection between properties of the galaxies and local environment
Large-scale structure:
halo occupation distribution (HOD) models
light-mass or richness-mass correlations
identification of clusters in optical observations
BCGs are big and bright, they can be seen from large distances, enabling evolution studies

Growth of the structure is very different in different universes



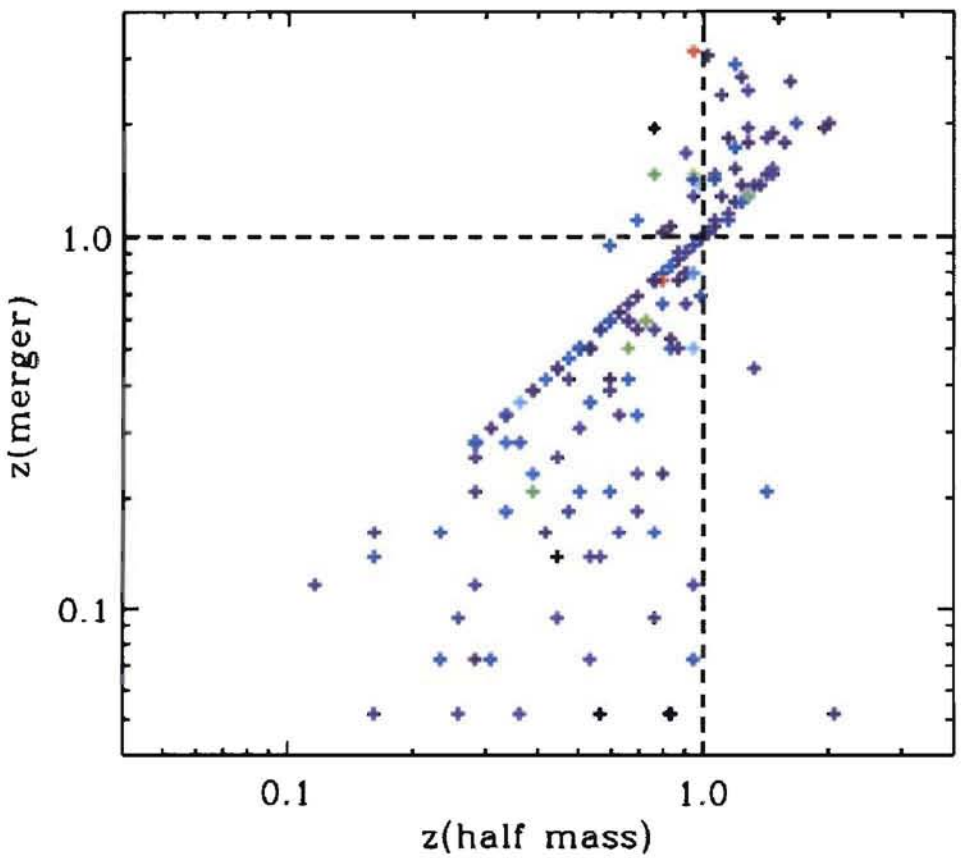
Evrard et al. 2002

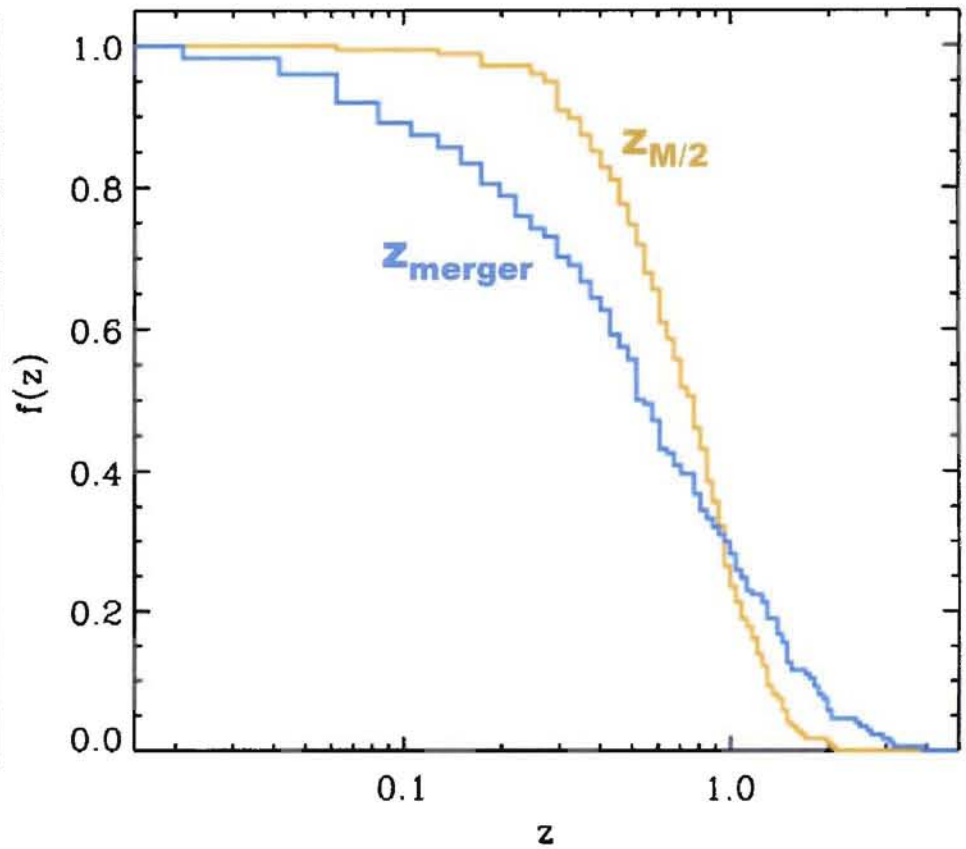
Mass Accumulation in Groups



Main contributions come from accretion and mergers. Fossil group candidates can be identified by the lack of major mergers for a long time (z < ~1).

Times of Mergers and Half Mass Accumulation

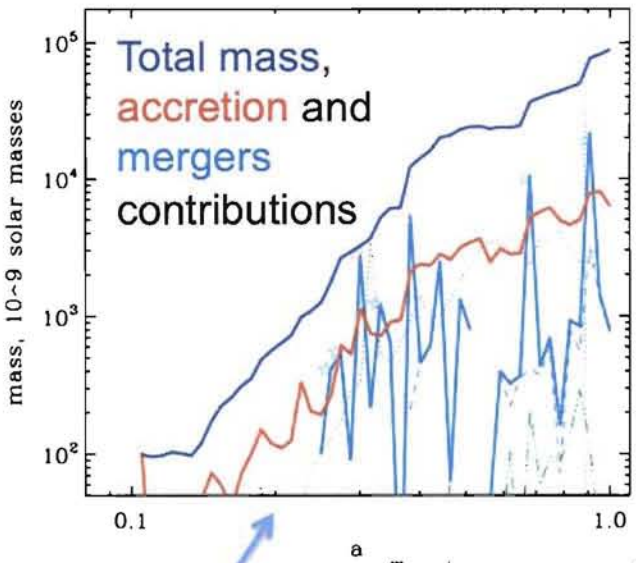


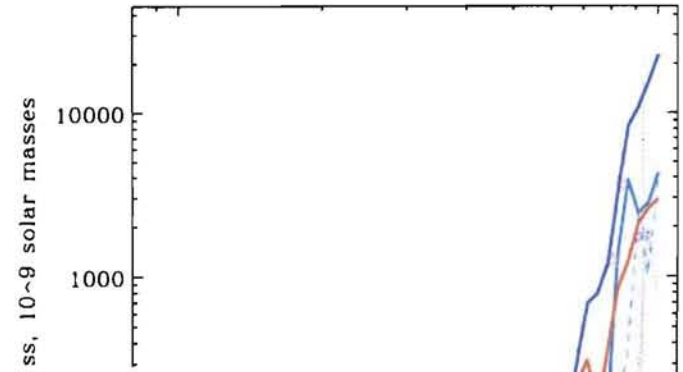


$z_{M/2}$ - redshift of half-mass accumulation

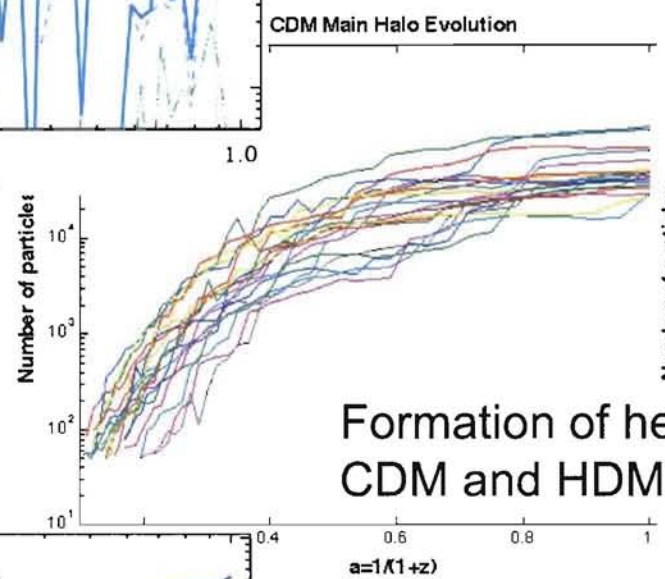
z_{merger} - redshift of last merger with $M_2/M_1>0.15$

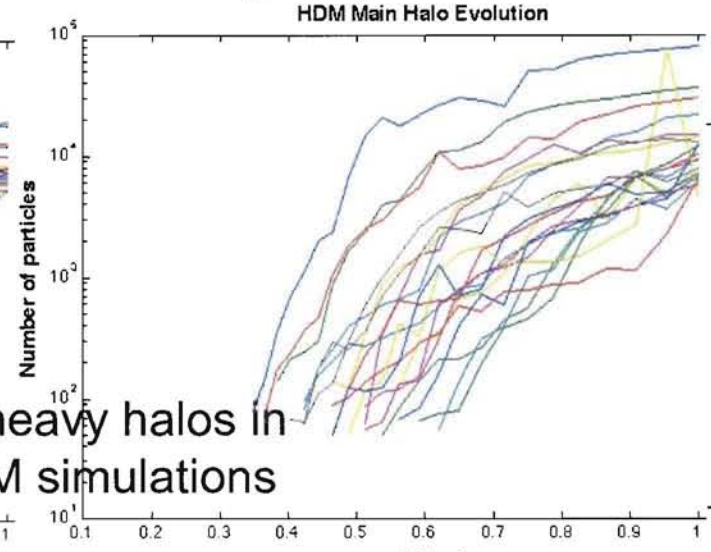
Structure Formation in Different Cosmologies



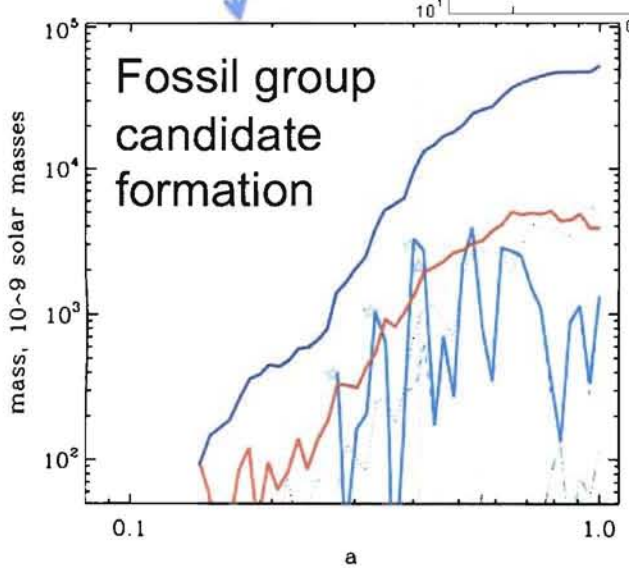


Individual halos

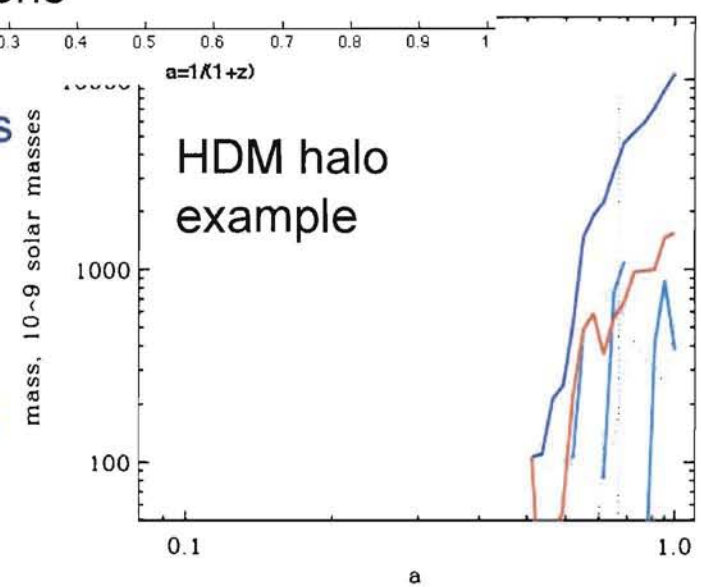




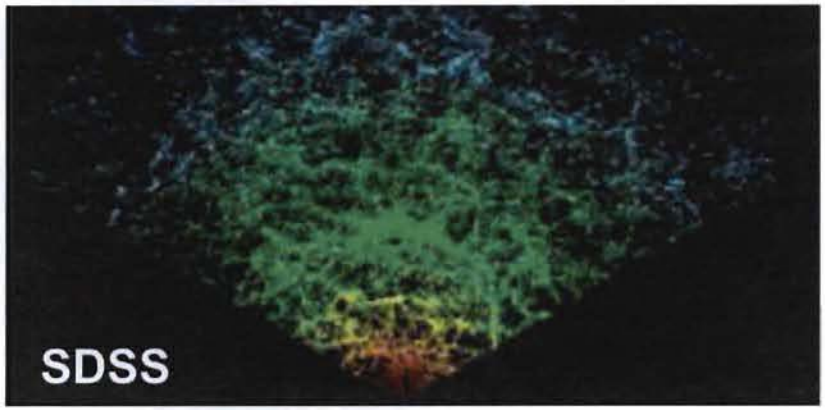
Formation of heavy halos in CDM and HDM simulations



Structure formation process strongly depend on dark matter parameters. Structure forms much later and grows much faster in hot dark matter simulations



Comparing theory with observations

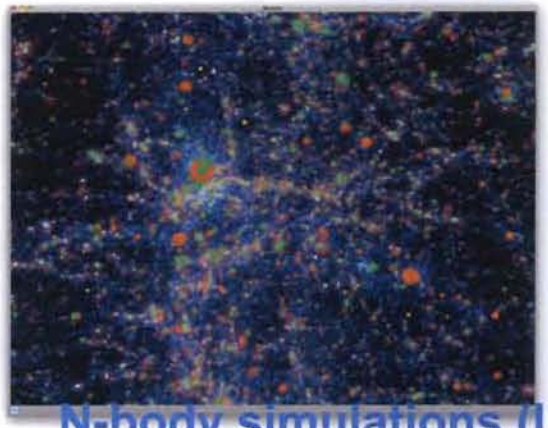


Detect Luminous Red Galaxies (potential BCGs)

Identify BCGs spectroscopically and clusters by density of the galaxies

Measure richness and luminosity of clusters

Get mass of the clusters



N-body simulations (LANL)

Model structure formation

Identify halos

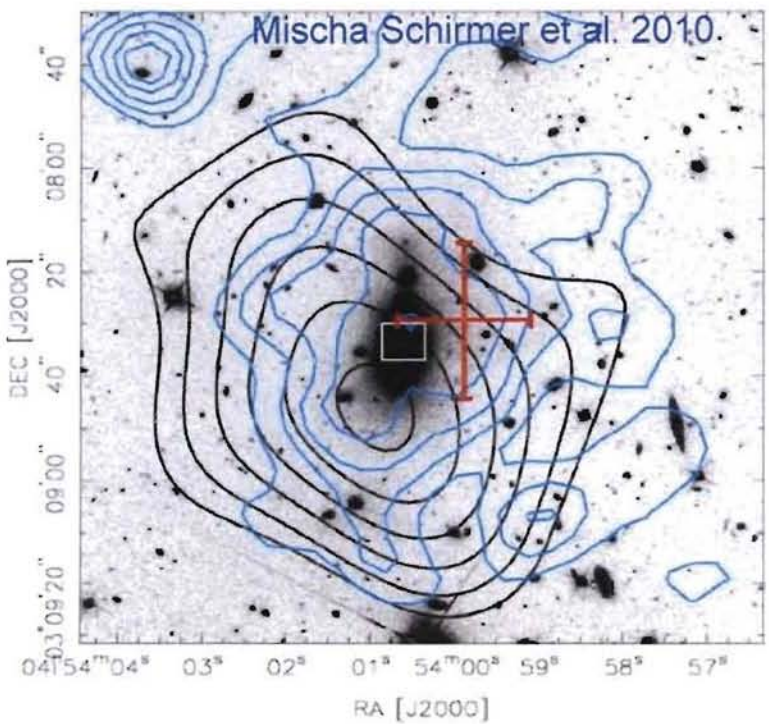
Measure masses of clusters

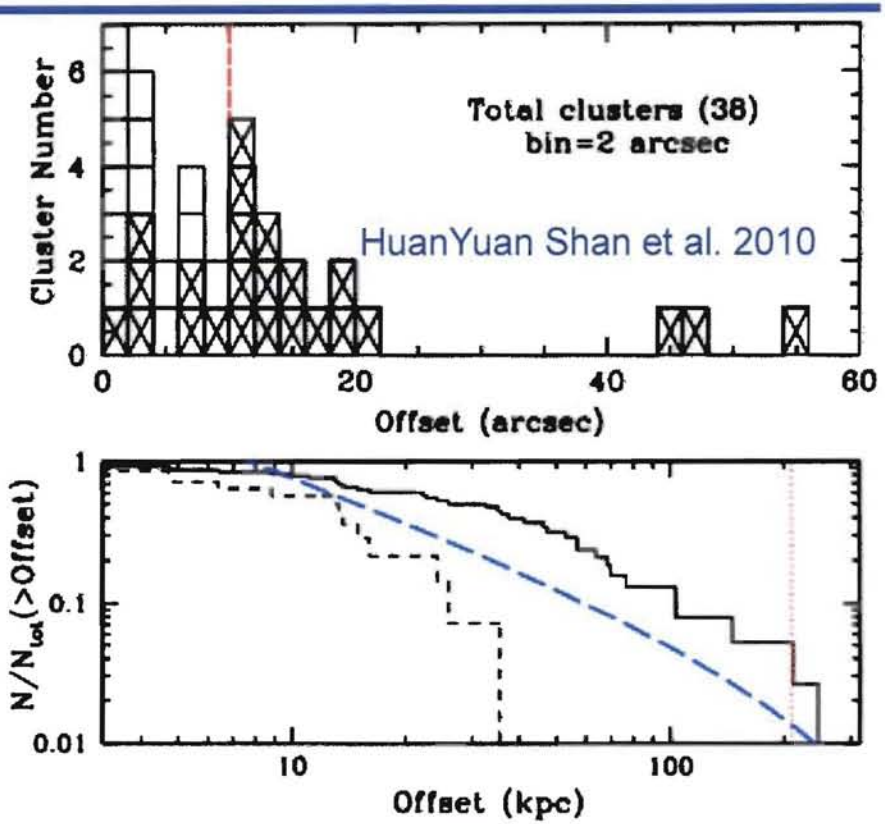
Populate halos with galaxies (HOD), starting from BCGs

Get distribution of galaxies

Assuming BCGs are in centers of the halos

Dark matter and baryonic matter offsets

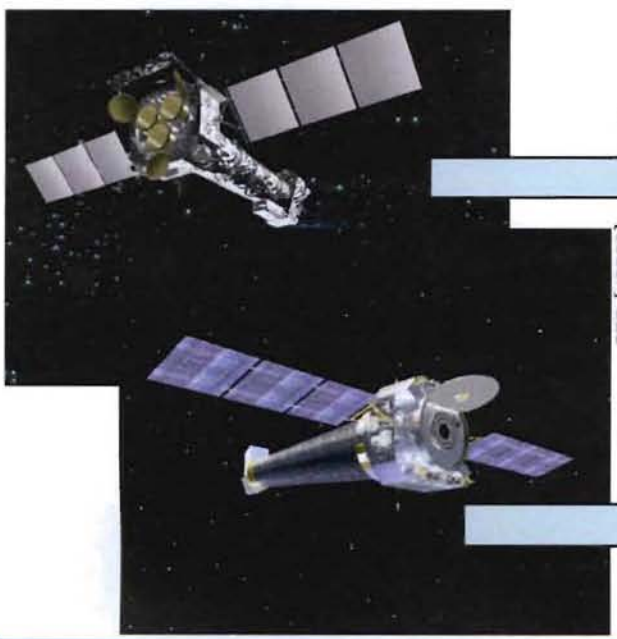


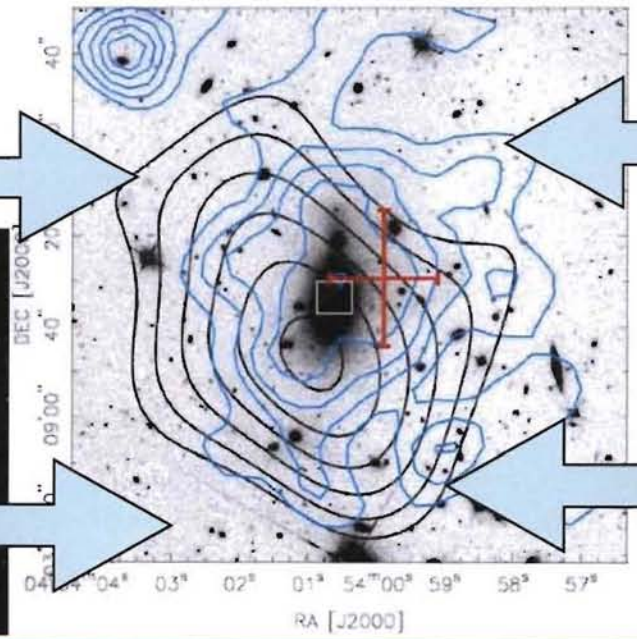


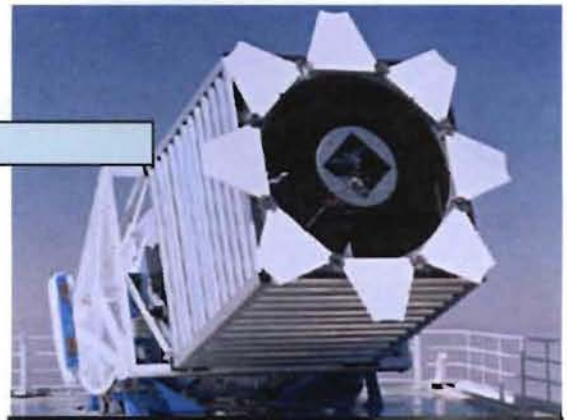
Observations show that center of mass, X-ray emission and BCG location do not necessarily coincide.

Large offsets indicate recent major mergers in the cluster (empty boxes represent cooling flow clusters, crossed boxed non-cooling flow clusters in the right panel).

- Understanding BCGs is important for galaxy evolution, structure formation studies and studying clusters
- BCG formation is poorly understood, there is a number of competing theories, and new observational studies will help a lot
- We can advance our understanding significantly using a combination of X-ray data, optical data and high-resolution large-box modeling



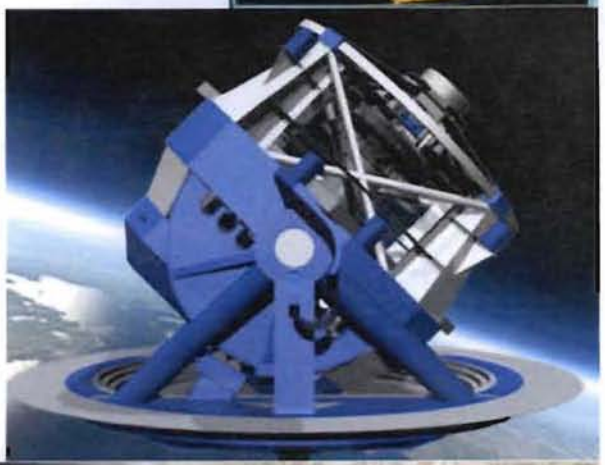


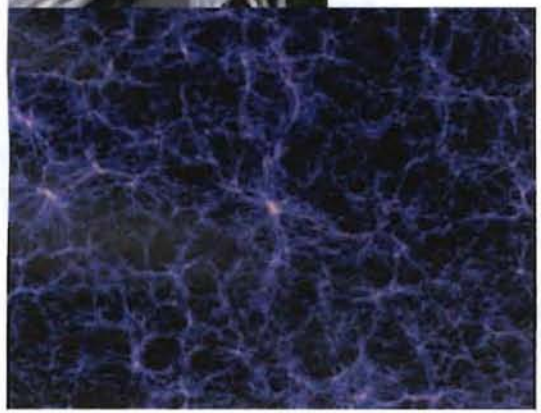
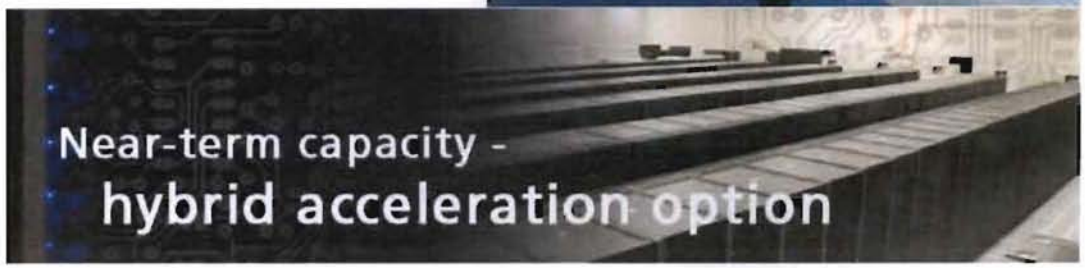


Present and Future Capabilities

X-ray: from Chandra and XMM to
Constellation-X and eRosita

Optical: from SDSS
to SDSS-III and LSST





Simulations: from Millenium
to Roadrunner