SCIENCE ON GALAXY CLUSTERS WITH 4M CLASS TELESCOPES

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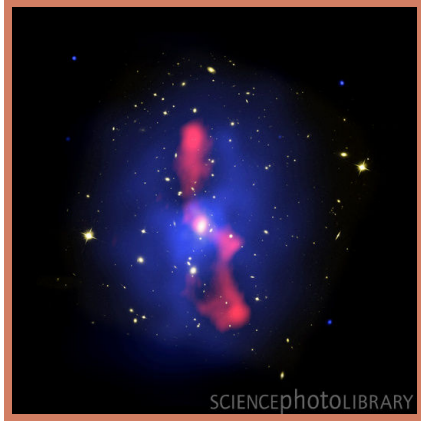
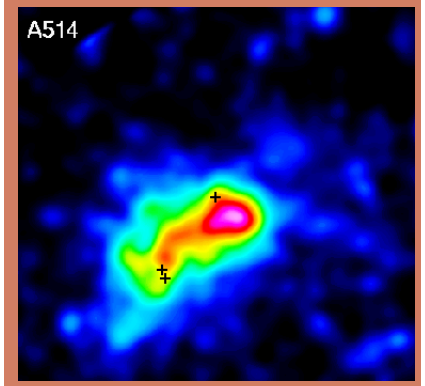
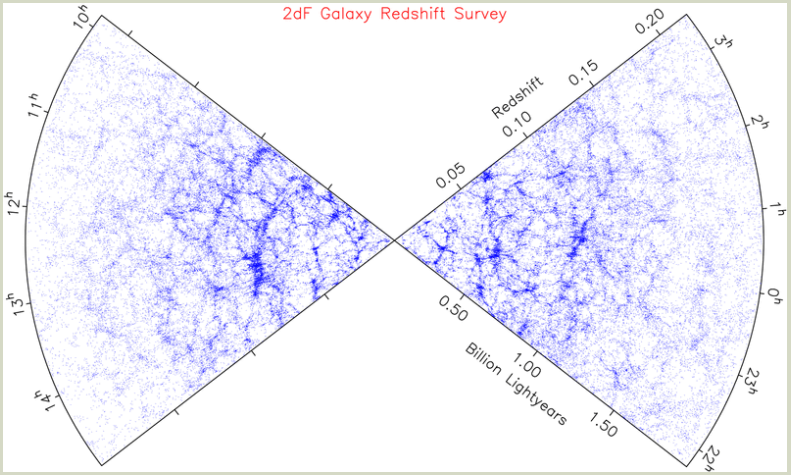
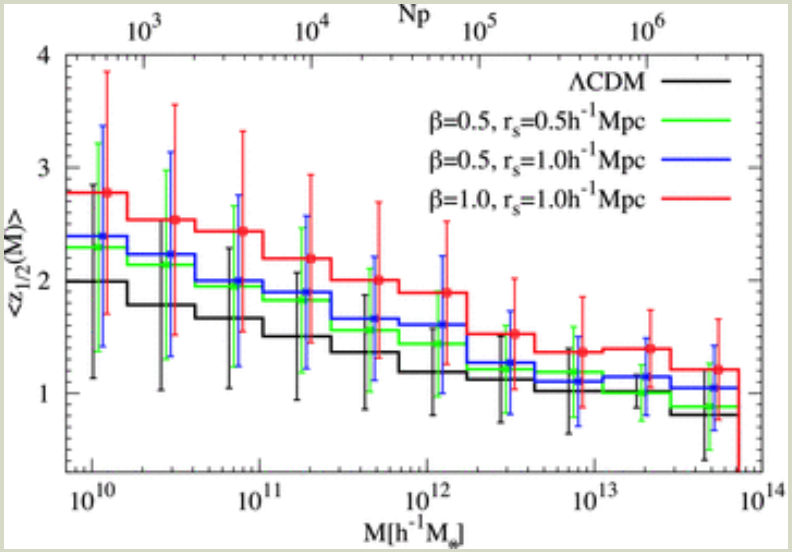




STRUCTURE FORMATION





- Galaxies are **not in an homogeneous distribution** in the Universe. In contrast, they are located in clusters or groups of galaxies with 10s-100s objects
- Structure formation models predict that this formation is **hierarchical and merger driven**

GALAXY CLUSTERS

Galaxy clusters provide a unique oportinity in order to study:

- ***Structure formation***: How do clusters form?; What are the mass observables and scaling relations that can be used for cosmology?.
- ***Feedback processes***: How does feddback from star, galaxy, and black hole formation impact cluster evolution?; Which is the main mechanism of metal enrichment of the ICM?
- ***Fundamental physics***: Does dark matter interact or is it collisionless?; Does DM annihilate?; How dark energy affects the formation and evolution of clusters?
- ***Plasma astrophysic***: What is the origin of large scale magnetic fields?
- ***Galaxy evolution vs environment***: How do galaxies evolve in galaxy clusters?; How are the properties of the galaxies affected by the cluster environment?

GALAXY CLUSTERS COMPONENTS

Image: Bullet cluster (Markevitch et al. 2004; Clowe et al. 2004)

- Massive virialized systems (10^14-10^15 M_sun).
- Systems with several components evolving at the same time.

  a) Dark matter haloes

  b) The instracluster medium

  c) Galaxies

GALAXY CLUSTERS COMPONENTS: DARK MATTER

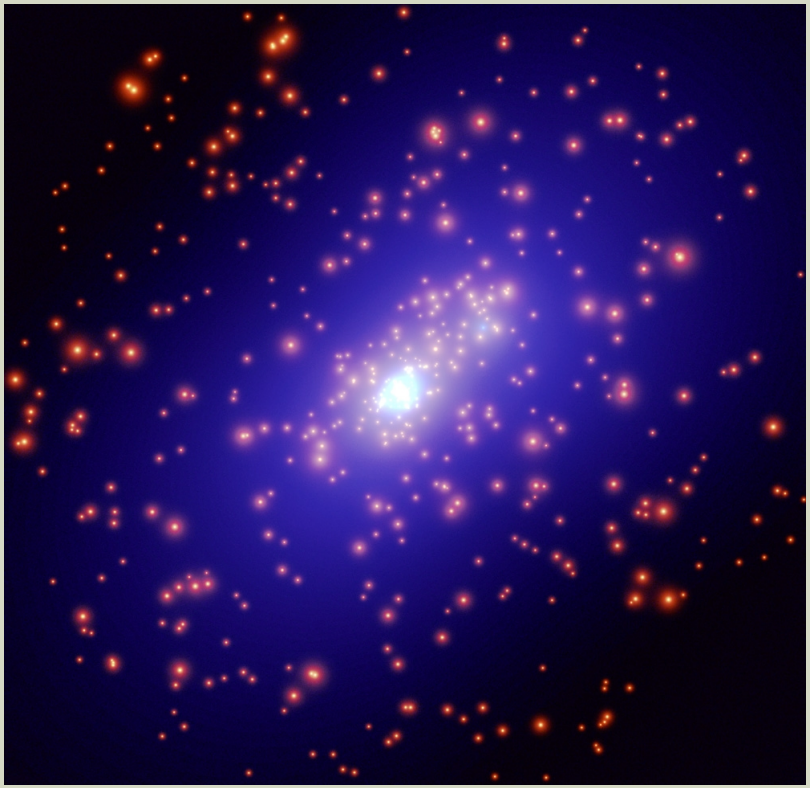
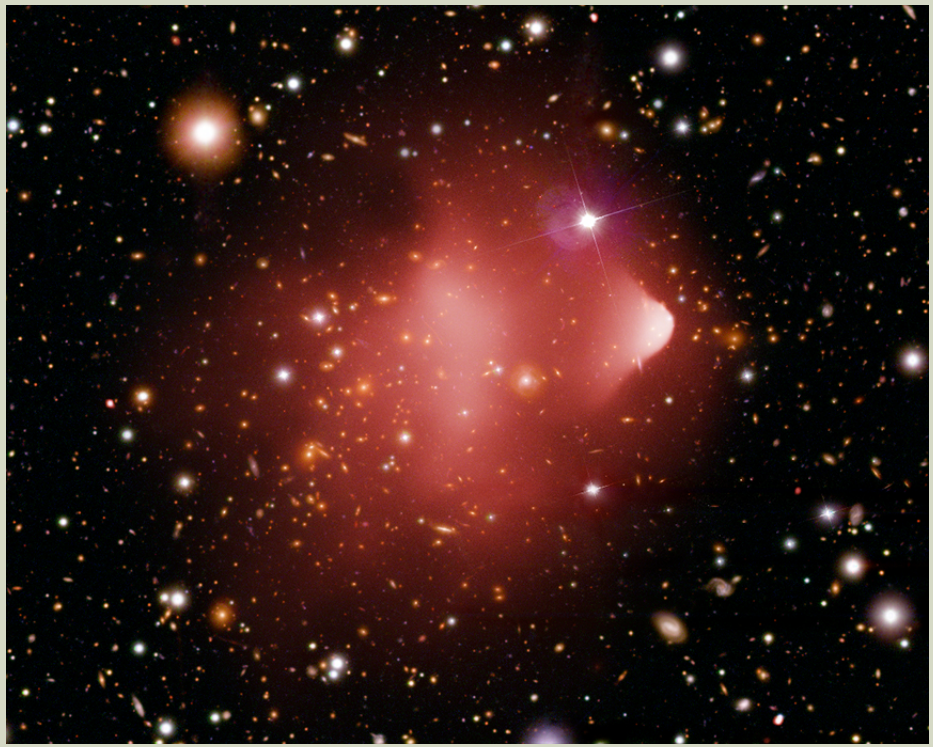


Image: Mass map of the cluster CL0024+1654

- Dominate the mass content (~85 %)
- Universal dark matter density profiles (NFW)
- Large amount of substructure.

GALAXY CLUSTERS COMPONENTS: INTRACLUSTER MEDIUM



Bullet cluster: Chandra RX (Markevitch et al. 2005)

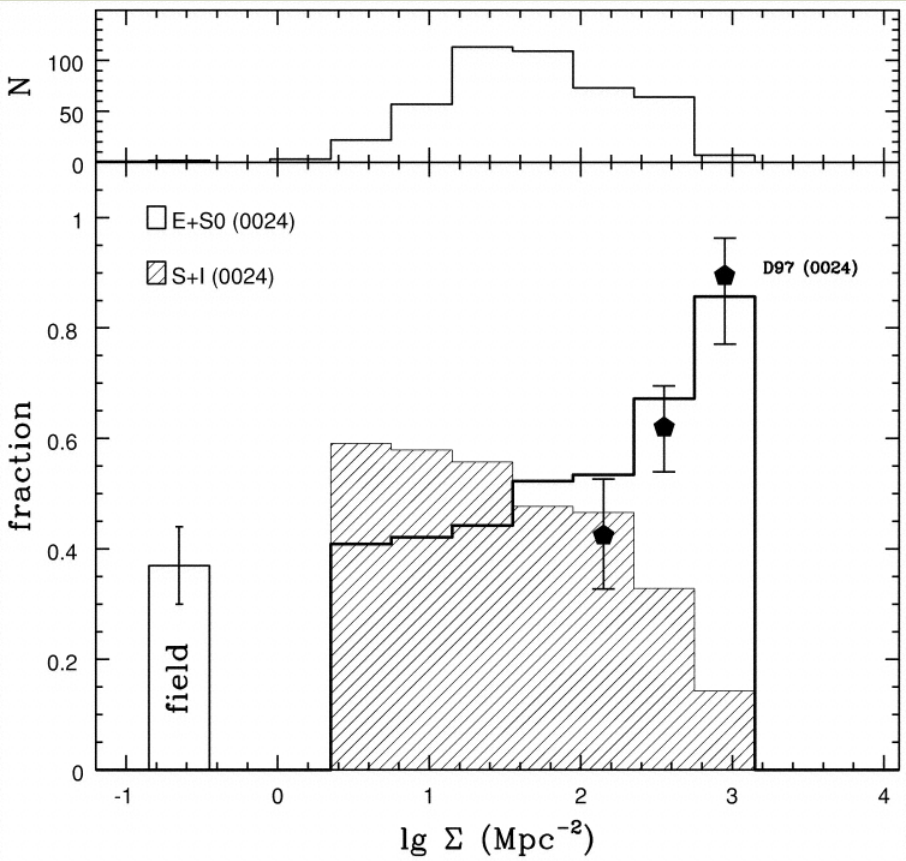
- Hot gas (T~10^6-10^8 K). Emitting in X-ray
- Dominates the barionic matter in clusters (M~10^14 M_sun)
- Low density medium in hydrostatic equilibrium in the virialized region.
- The intracluster medium is also formed by free-flying star forming a component of low surface brightness. This is called diffuse light. 5-10% of the total luminosity of the cluster (see Aguerri et al. 2005; Castro-Rodriguez et al. 2009)

GALAXY CLUSTERS COMPONENTS: THE GALAXIES

Abell 1689 (Broadhurst et al. 2005)

- Visible component of the clusters.
- Small barionic fraction (~5-15 %).
- The number of galaxies goes from 10s to 100s in the most rich clusters.
- Galaxies in clusters show different properties than in field.

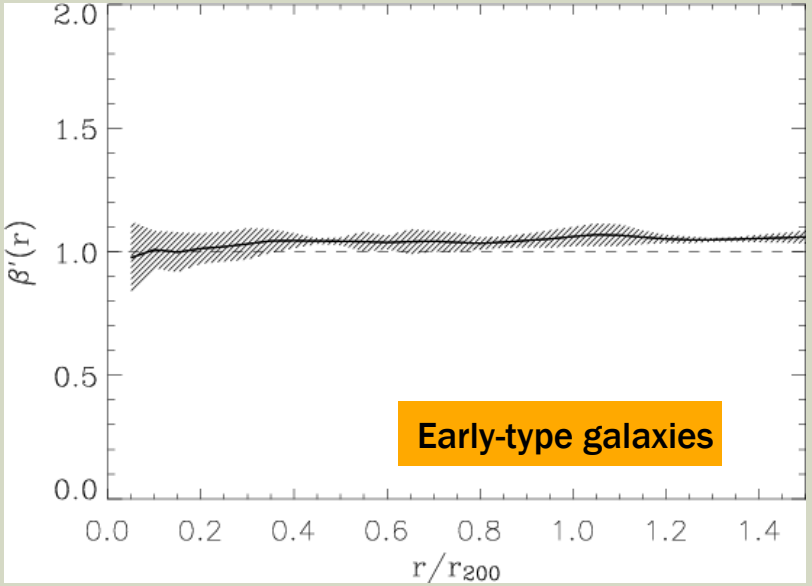
MORPHOLOGY-DENSITY RELATION

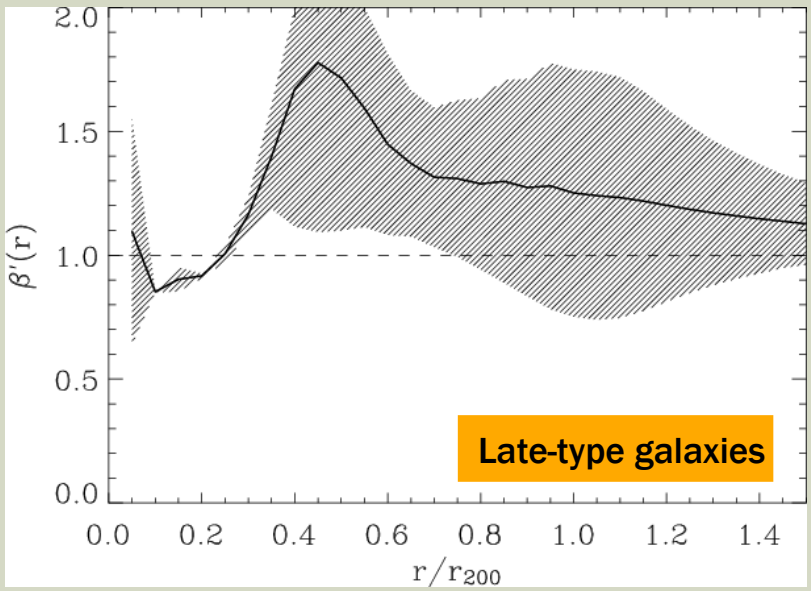


- Dressler (1980) studied a sample of 55 nearby clusters. He discovered a gradient in the galaxy population in clusters.
- E/S0 dominate the central regions of the clusters
- In contrast, spiral galaxies and Irr are located in the less dense cluster regions.

Treu et al. 2003

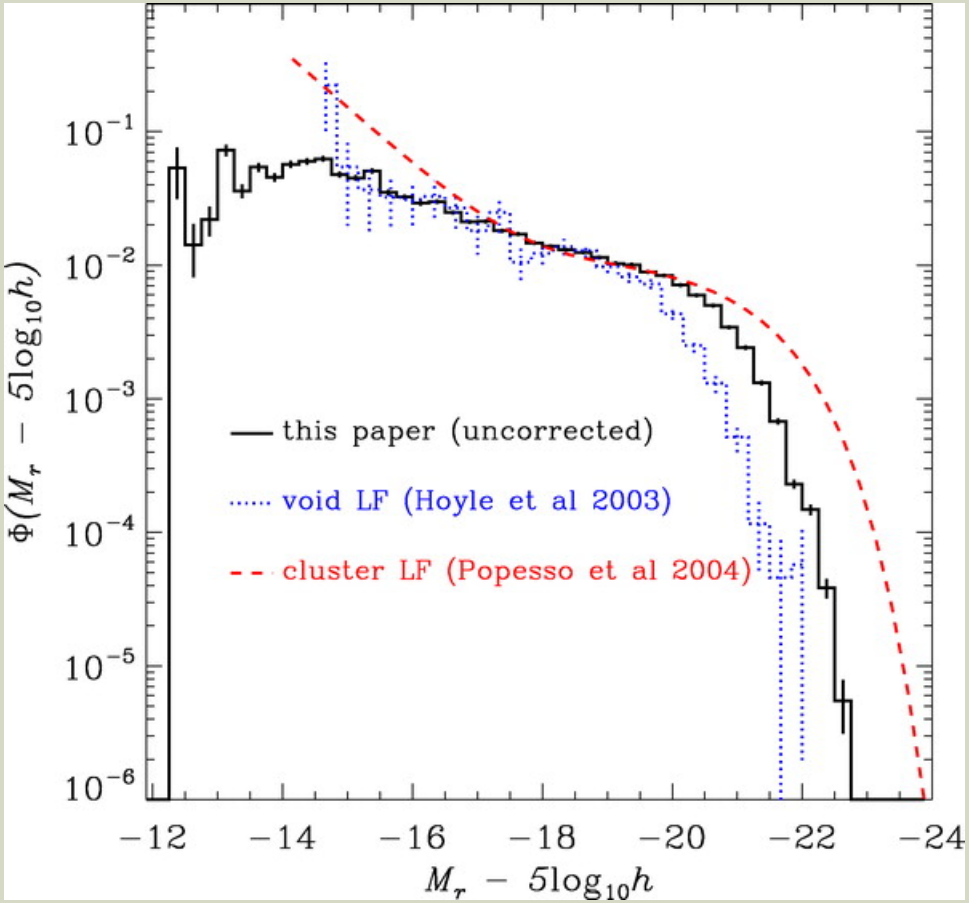
KINEMATIC DECOUPLING OF GALAXIES IN CLUSTERS.





- Different orbits: Early-type galaxies are located in more isotropic orbits than lat-type spirals. (Adami et al. 1998; Biviano & Katgert 2004)
- Possible different arrival to the clusters?. (see goto et al. 2008)

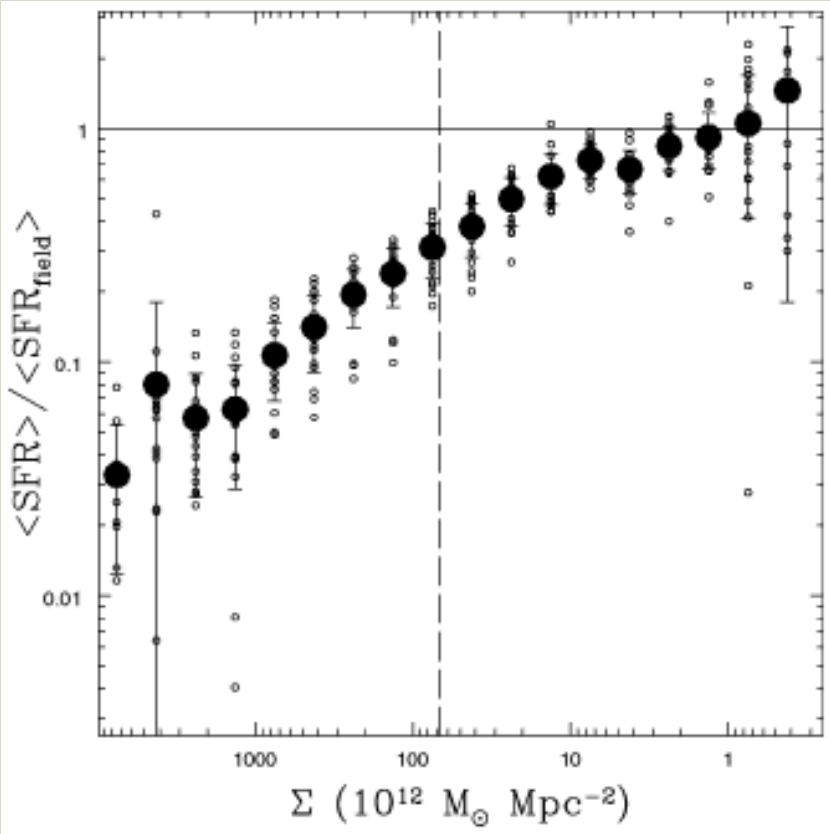
GALAXY POPULATION IN CLUSTERS.



- Luminosity functions (LF) of galaxies in clusters are different for the brightest and low-mass systems.
- Galaxy clusters show an excess of bright (Mr<-22) and dwarf (Mr>-17) galaxies.

Popesso et al. 2004;
Blanton et al. 2005

STAR FORMATION IN GALAXY CLUSTERS.



- **SDSS+2dF:** Lewis et al (2002), Gómez et al (2003), Balogh et al. (2004): Star formation depends on the cluster environment. In particular, star formation is lower in clusters than in field.
- Poggianti et al (1999) found that **post-starburst** galaxies are more abundant in clusters than in the field.
- Strangulation of the star formation for galaxies falling into the cluster.
- **Gas anemy of spiral galaxies located in the central regions of the clusters.**

Lewis et al. 2002

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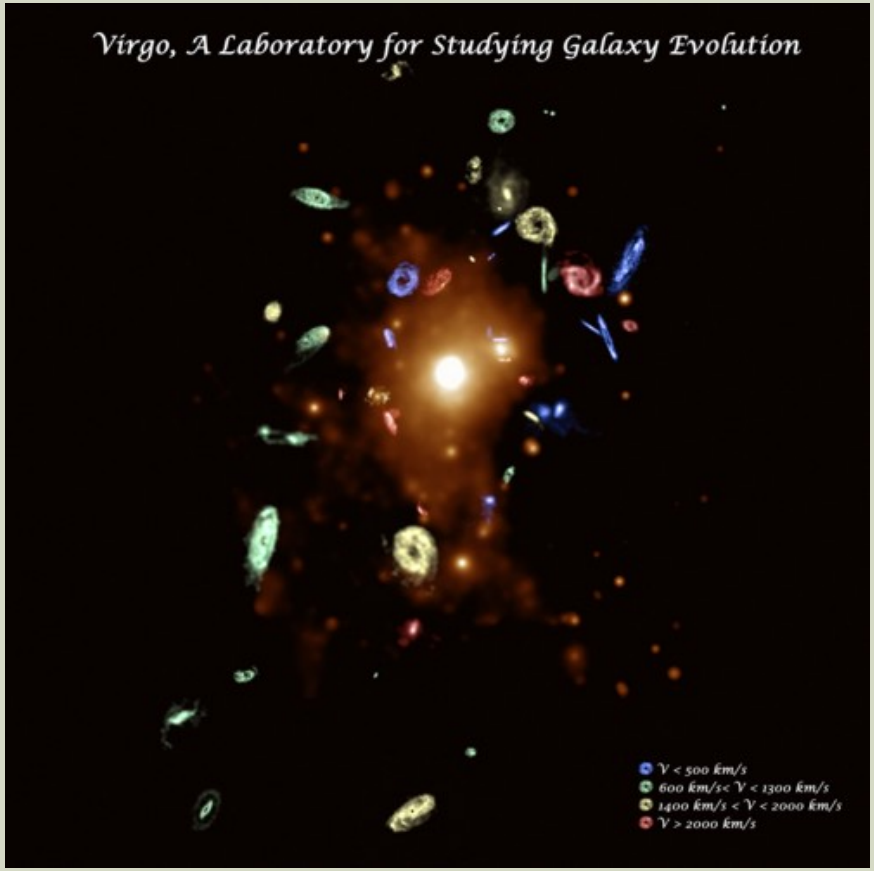

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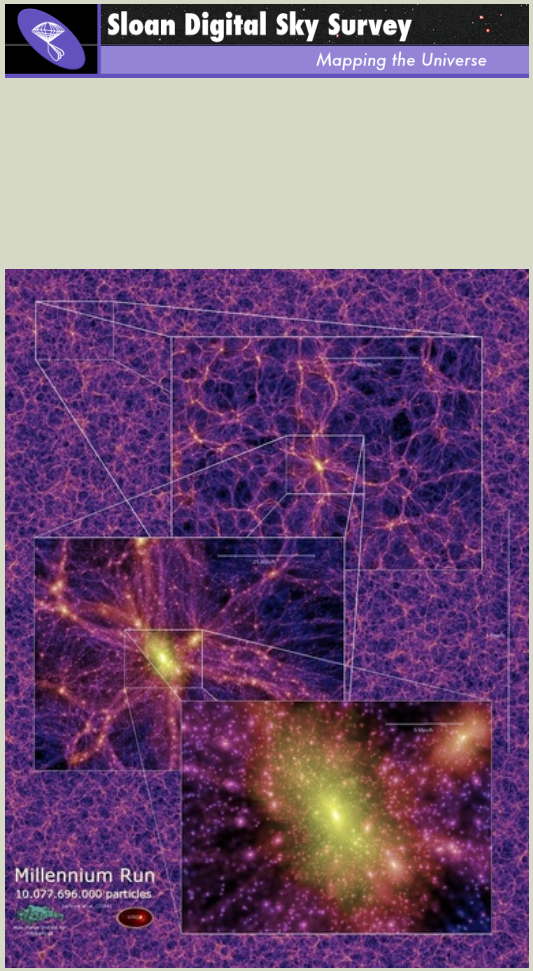
VIVA Survey: Kenney et al. 2008

CLUSTER ASTROPHYSICS NOW

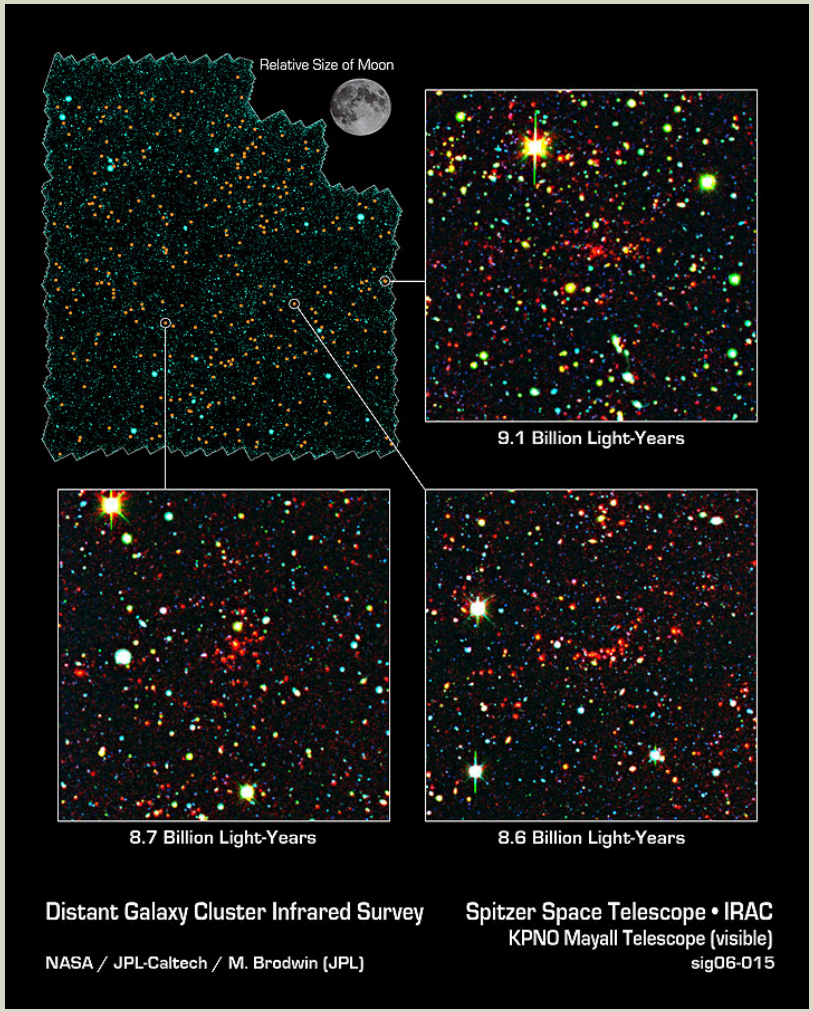


In the past decade, important advances in our understanding of clusters of galaxies, from the standpoint of their internal structure and evolution to their place in the larger scale structure of the Universe. Two main reasons

1.-Explosion of cluster observations: Large optical surveys as SDSS or 2dF have Given new candidates. The ROSAT satellite provided the best all-sky X-ray sample up to now CHANDRA and XMM give spectacular images of X-ray of clusters.

2.- New simulations: New N-body and hydrodynamic simulation codes. The Millennium Simulations has provided theoretical information to observers.

MAIN QUESTIONS ON GALAXY CLUSTERS



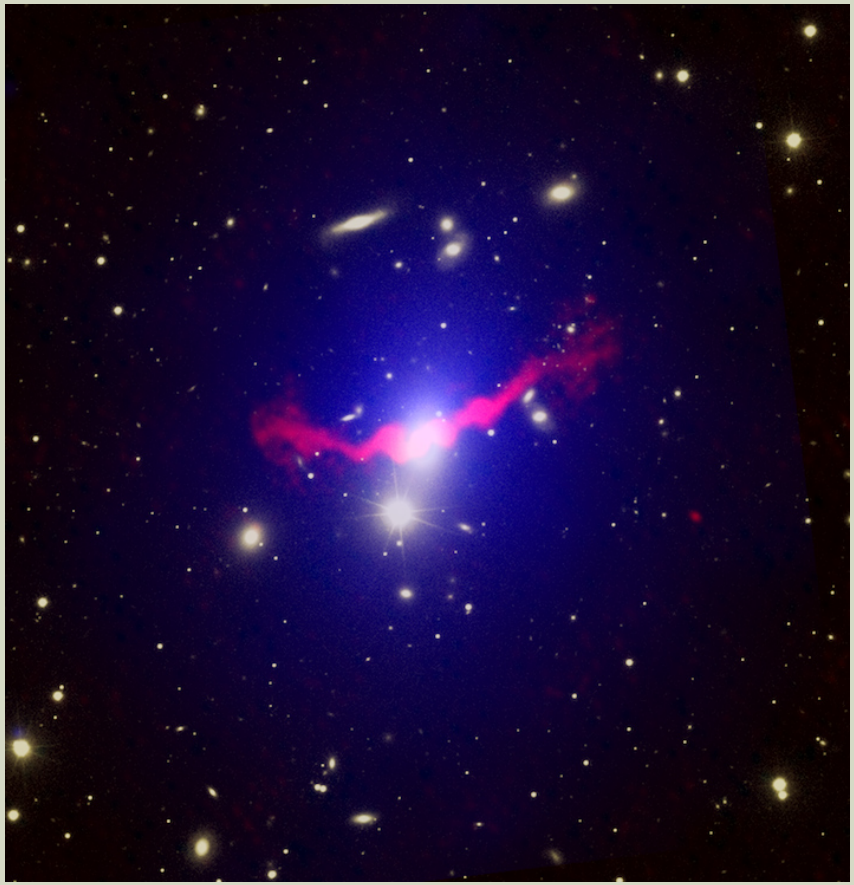
Three main questions on galaxy clusters today

1.- How and when do clusters form?; How different are proto-clusters and today clusters?

2.- How do the cluster medium evolve?; Which is the main enrichment physical mechanism of the intracluster medium?; Conexion between AGN and metal enrichment.

3.- How do galaxies evolved in galaxy clusters?; Which is the main formation mechanism of bright and dwarf galaxies?; Any mass segregation?

MAIN QUESTIONS ON GALAXY CLUSTERS



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CLUSTERS IN 4M TELESCOPES

- Programs of **multi-wavelength surveys**

Radio facilities: active and relic regions of clusters

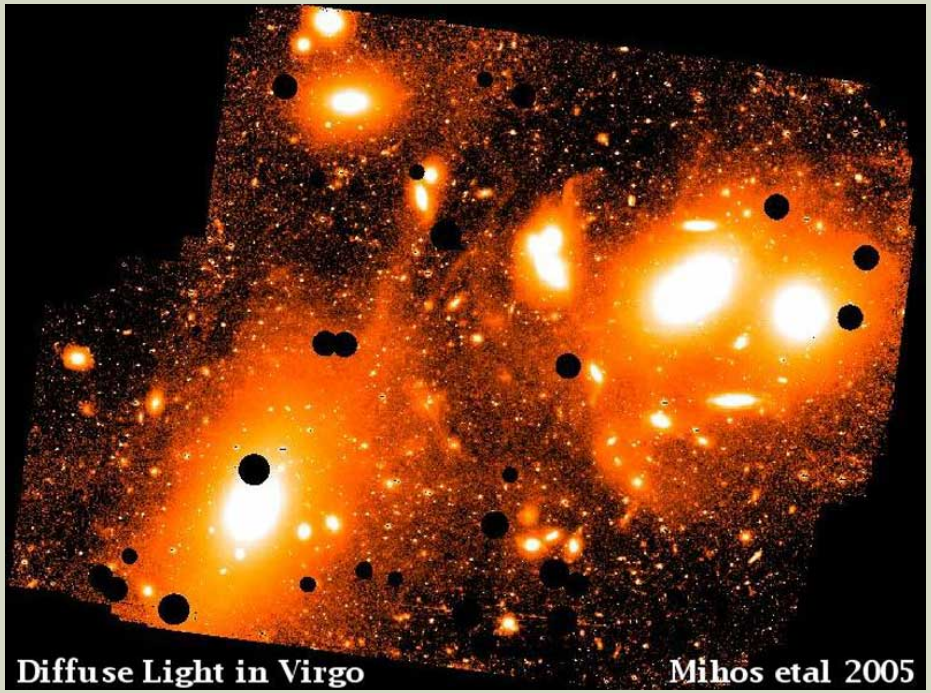
Millimeter and Submillimiter: active star formation

Optical and near-IR: stellar and dark-matter content through imaging and MOS spectroscopy

X-ray: structure, shocks, feedback of the ICM

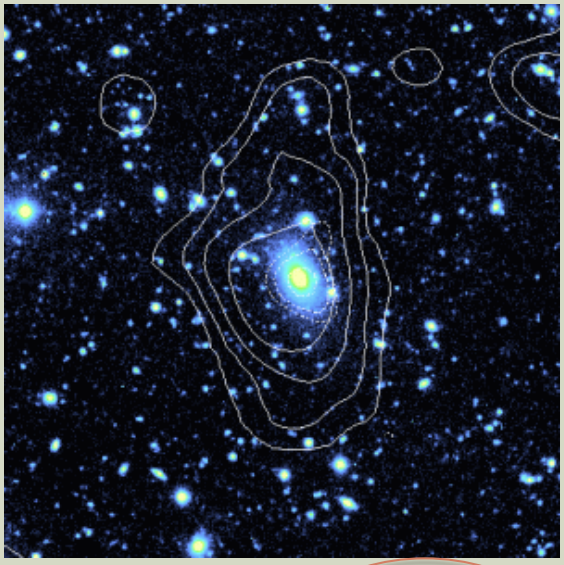
- 4m class telescopes can be part of these multi-wavelength surveys and produce important science in the galaxy evolution in nearby and high redshift clusters.
- This can be done by running deep spectroscopic surveys: Dedicated instruments and Large amount of telescope time

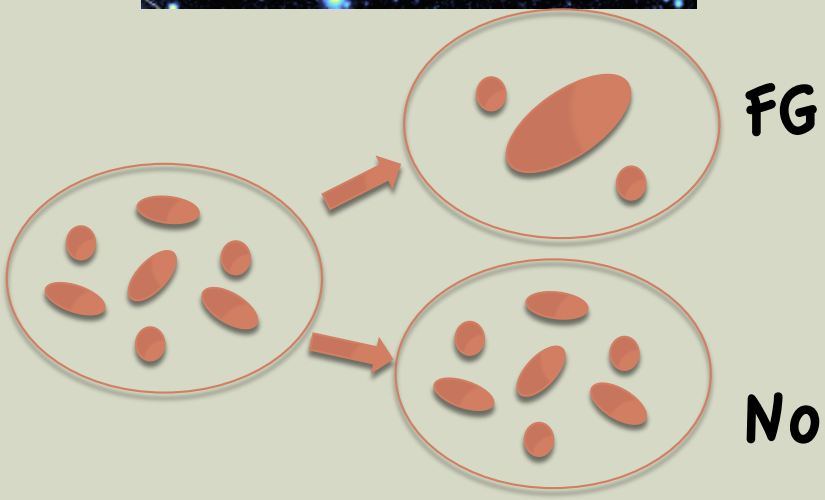
BRIGHTEST CLUSTER GALAXIES



- How do the BCGs form and evolve?
- Their evolution could be different than other giant ellipticals: Scaling relations (e.g., Ascaso et al. 2011); Numerical simulations (De Lucia & Blaitzot 2007)
- Deep spectroscopical surveys can follow their evolution up to z=1.

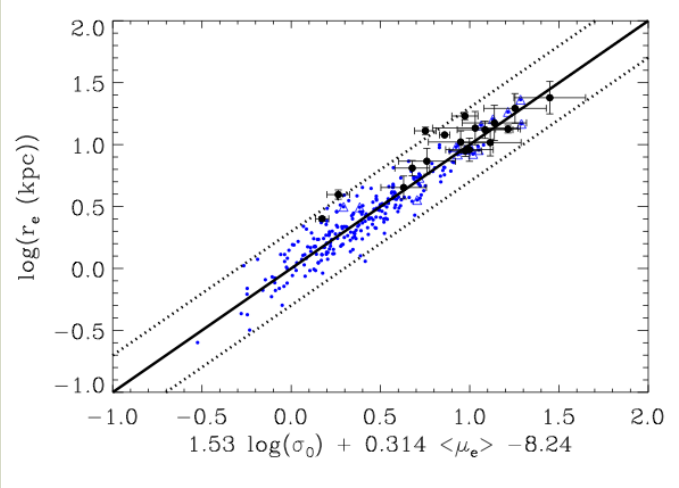
BRIGHTEST CLUSTER GALAXIES: FOSSIL SYSTEMS



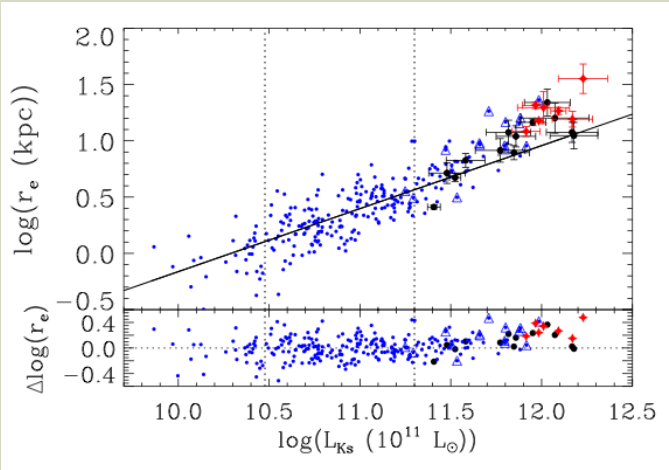


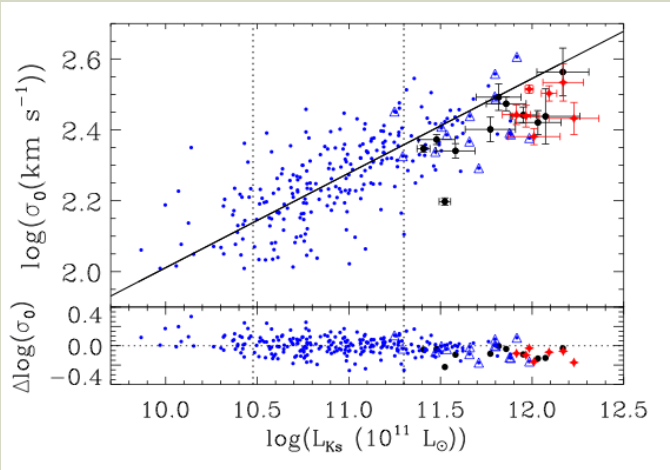
- Ponman et al (1994) discovered the galaxy RX J1340.6+4018 an elliptical galaxy dominated system.
- The elliptical galaxy was surrounded by an X-ray emitting halo of hot gas suggesting a large amount of dark matter
- This was interpreted as an evolved group of galaxies. The central galaxy has eaten all L* galaxies arround.

BRIGHTEST CLUSTER GALAXIES: FOSSIL SYSTEMS



- BGGs in FGs follow the **same FP** as bright elliptical galaxies.
- BGGs in FGs show a bend in the FJ and luminosity-size relations as other bright elliptical galaxies.
- **Formation** as other bright elliptical galaxies **by dry mergers** (see Bernardi et al 2011; Mendez-Abreu et al. 2012).

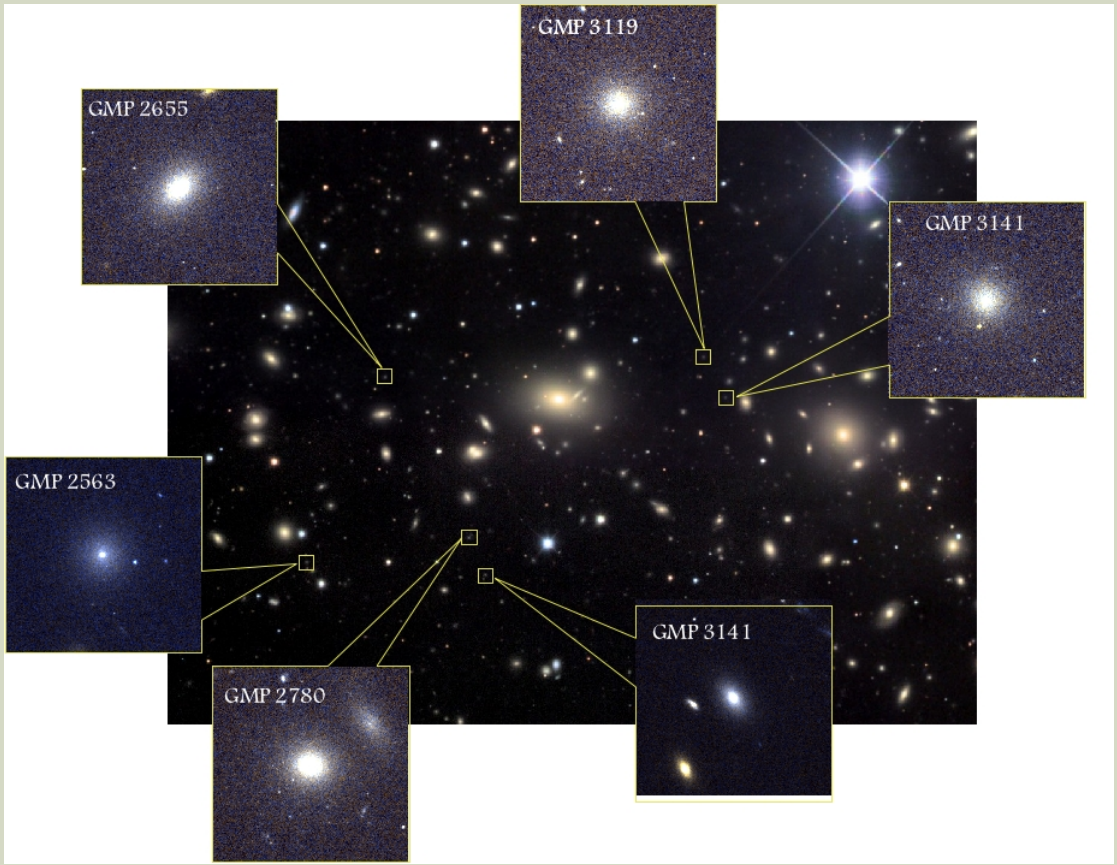




Confirm this with tests in order wavelengths.

Other diagrams: Sigma-z evolution

LOW-MASS GALAXIES IN CLUSTERS



- The origin of low-mass galaxies in clusters: are they **primordial systems or the end-products of galaxy transformations**?
- Several observational evindences are against the former scenario
  - Large scatter in Z and ages (Chilingarian 2009)
  - Different faint-end slope of LF in clusters and field Popesso et al. 2004)
  - Variation of the DGR as function of distance to the cluster center (Sanchez-Janssen et al. 2008; Aguerri et al. 2007)
  - Build-up of the red sequence at low masses (de Lucia et al. 2006)

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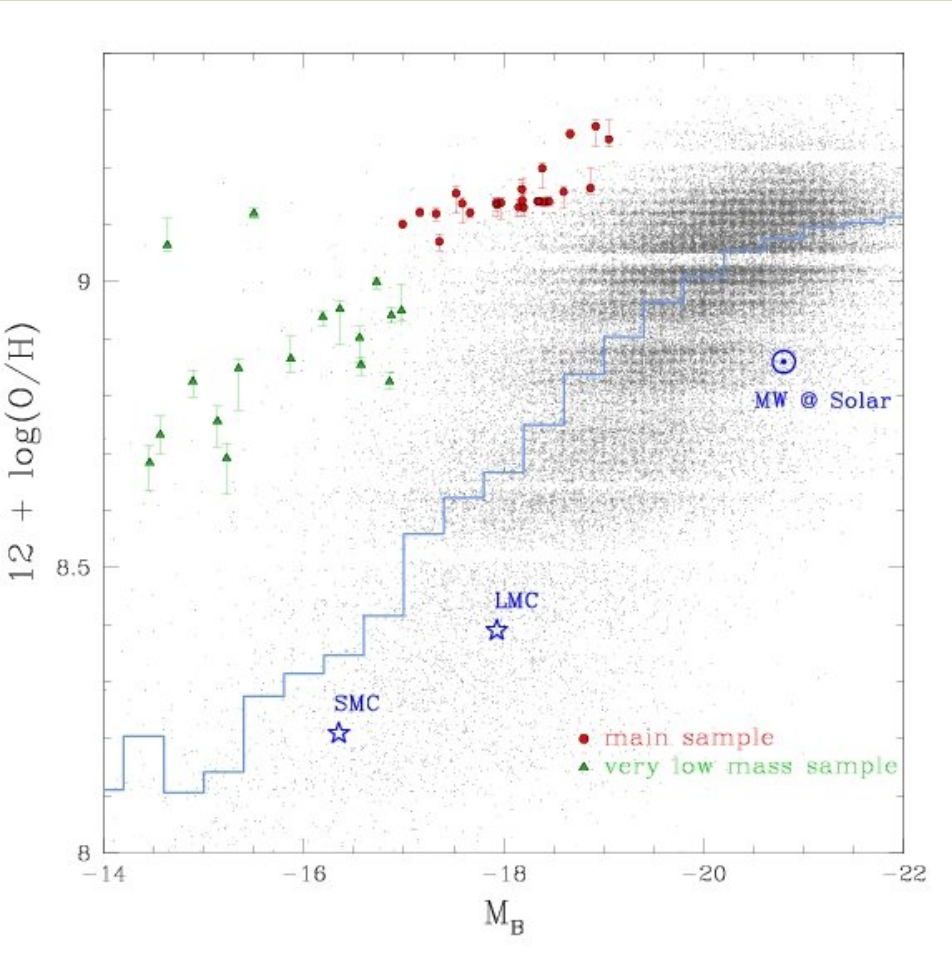

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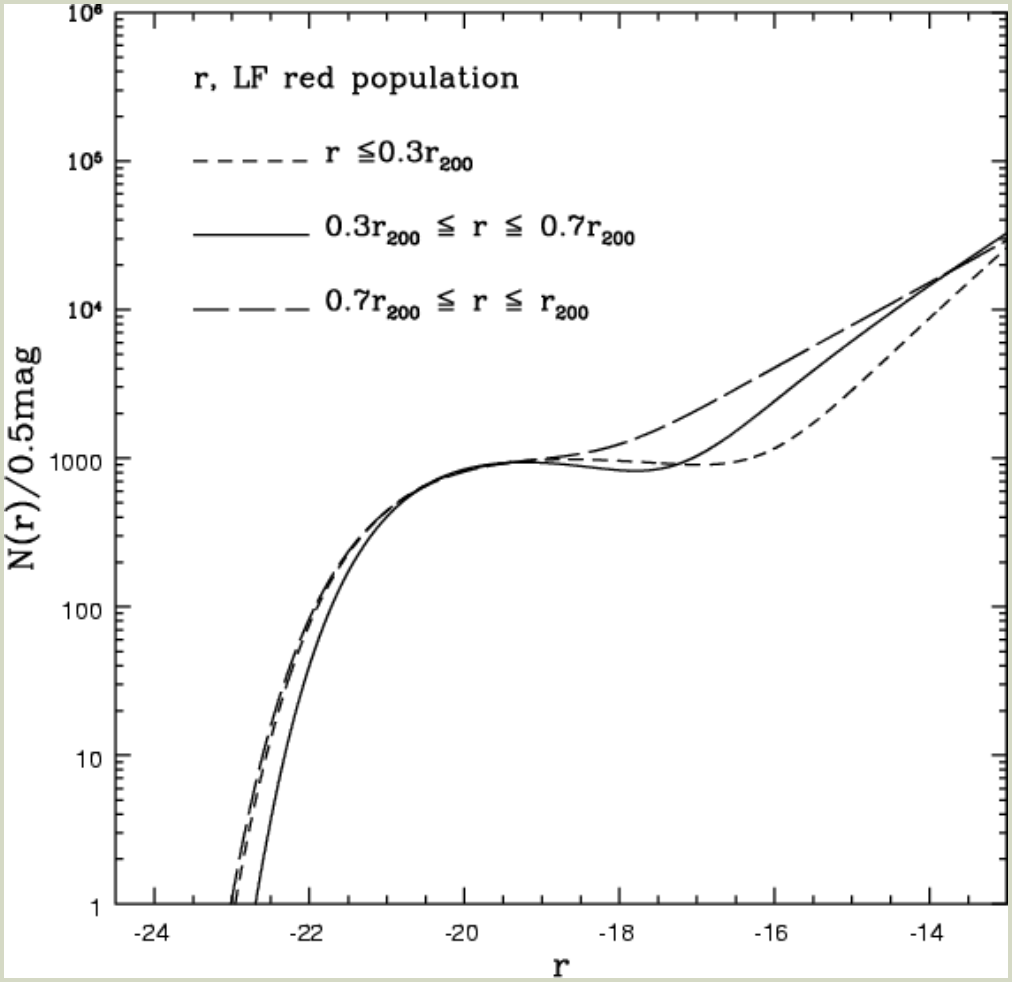

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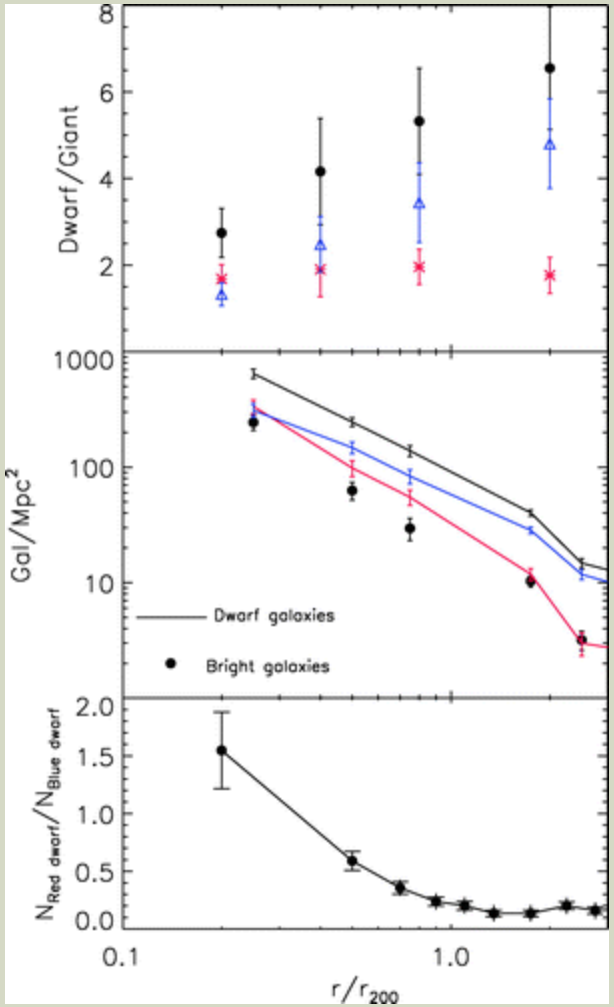

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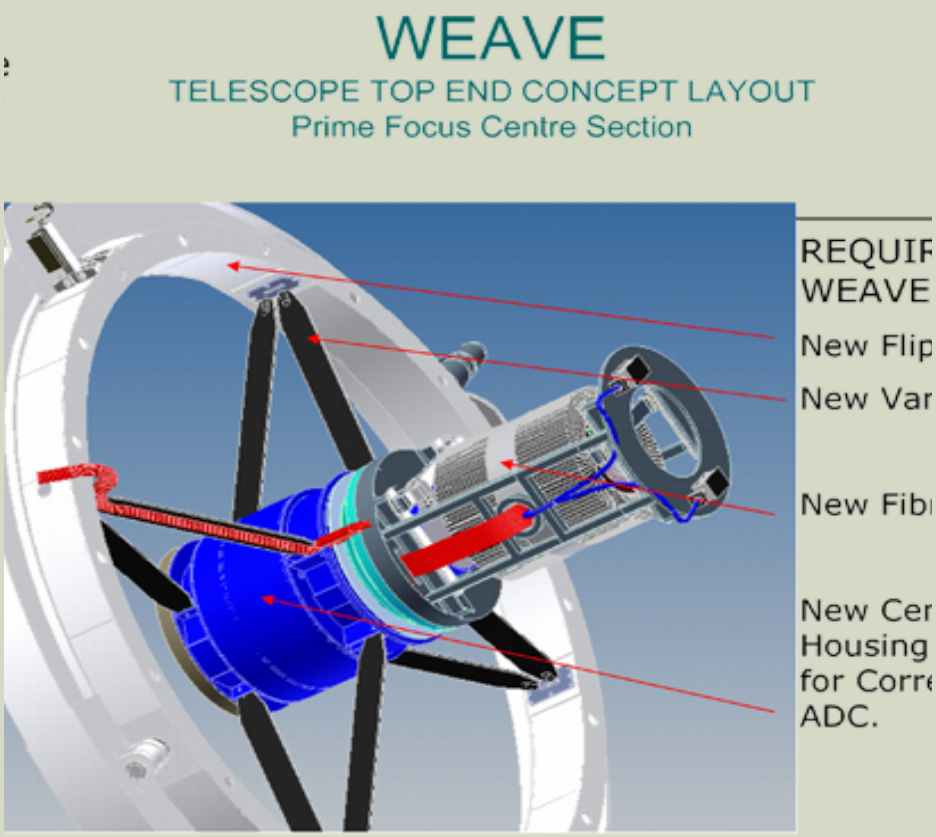

- Wide-field and multiobject spectrsographs in 4m telescopes like WEAVE can produce important results on dwarf galaxies in clusters.
- Deep spectroscopic surveys can observe dwarf galaxies (Mr<-16.) in the nearby Universe (D<40 Mpc)
- Other past and present surveys do not reach the dwarf regime.
  - ENACS (Katgert et al. 1996)
  - NOAO-FPS (Smith et al. 2004)
  - WINGS (Fasano et al. 2006)
  - HeCs (Rines et al.)
  - HectoMAP (Geller et al.)
  - NGVCS (Ferrarese et al.)
  - HST Coma treasury survey (Carter et al.)

LOW-MASS GALAXIES IN CLUSTERS

- The dynamical status of low-mass systems. Radial vs circular orbits for dwarf galaxies
- Spectroscopic LFs. Confirmation of the excess of dwarf galaxies showed by photometrical LFs
- Scaling relations of dwarf galaxies
- Stellar population and the star formation history of dwarf galaxies in clusters

CONCLUSSIONS

- Studies of galaxy clusters are important for several aspect in astrophysics and physics
- We have a unique opportunity in the field of galaxy clusters in 4m class telescopes in the next decade
- Dedicated instrument with large FOV and spectral capability
- Large amount of time for deep spectroscopic surveys