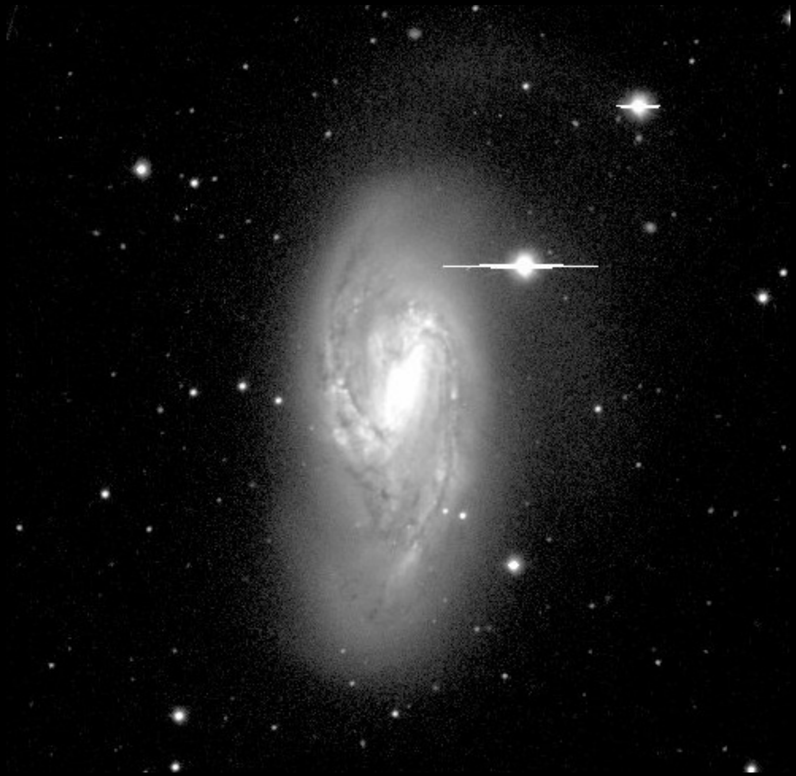
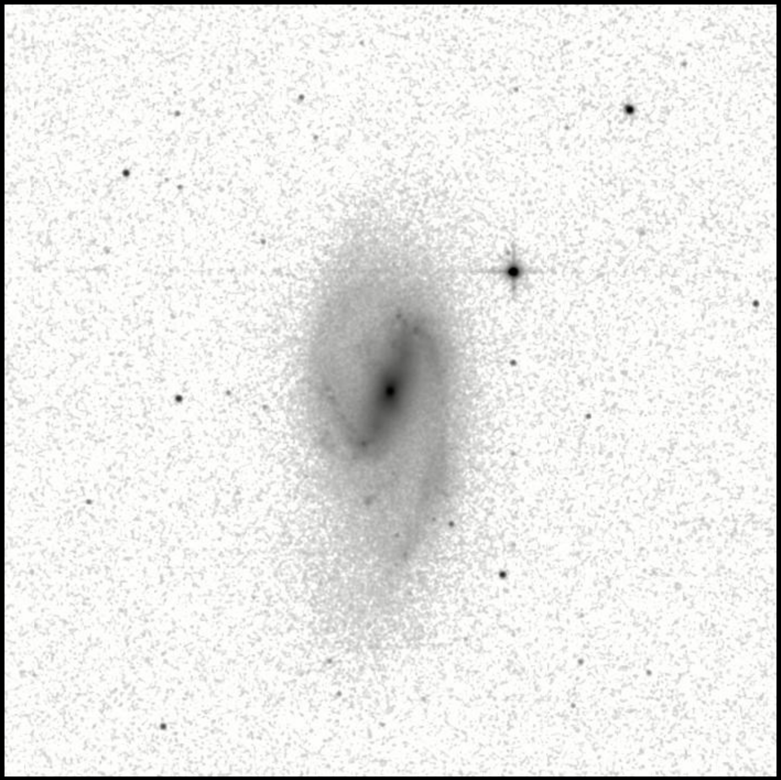
Measured galaxy properties

What can we measure from broadband galaxy images?



V band



K band

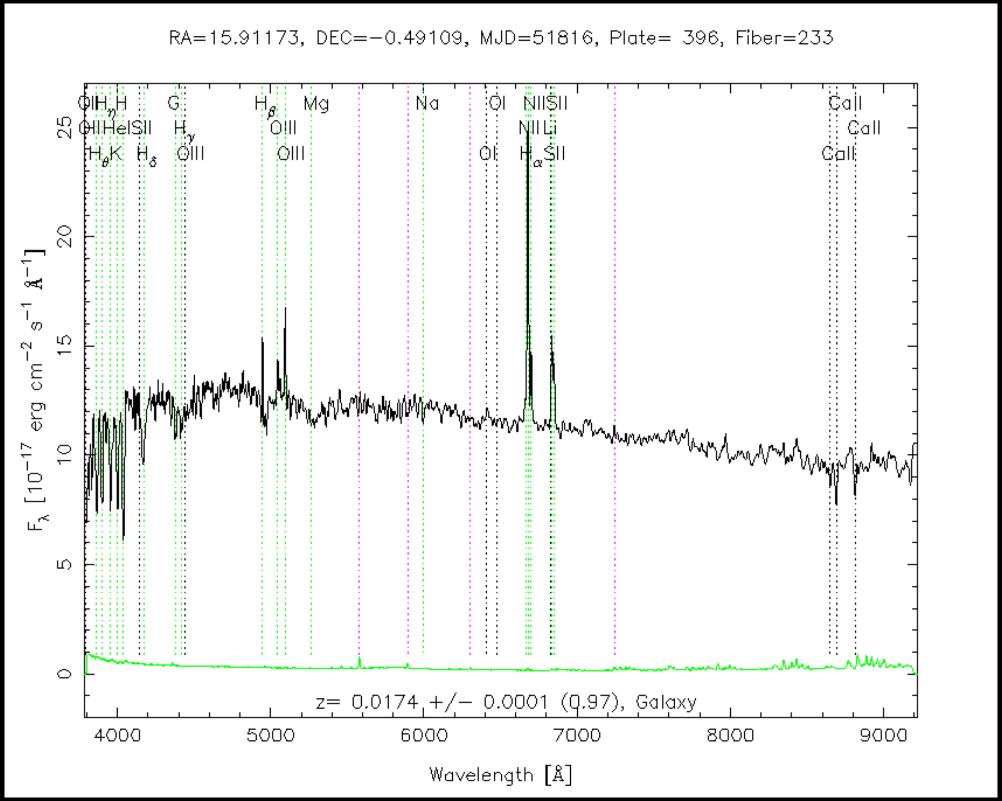
Measured galaxy properties

What can we measure from broadband galaxy images?

- magnitudes (e.g., m_r)
- colors (e.g., g-r)
- surface brightness
- angular size
- 1D radial light profile
- morphology
- photometric redshift

Measured galaxy properties

What can we measure from galaxy spectra?

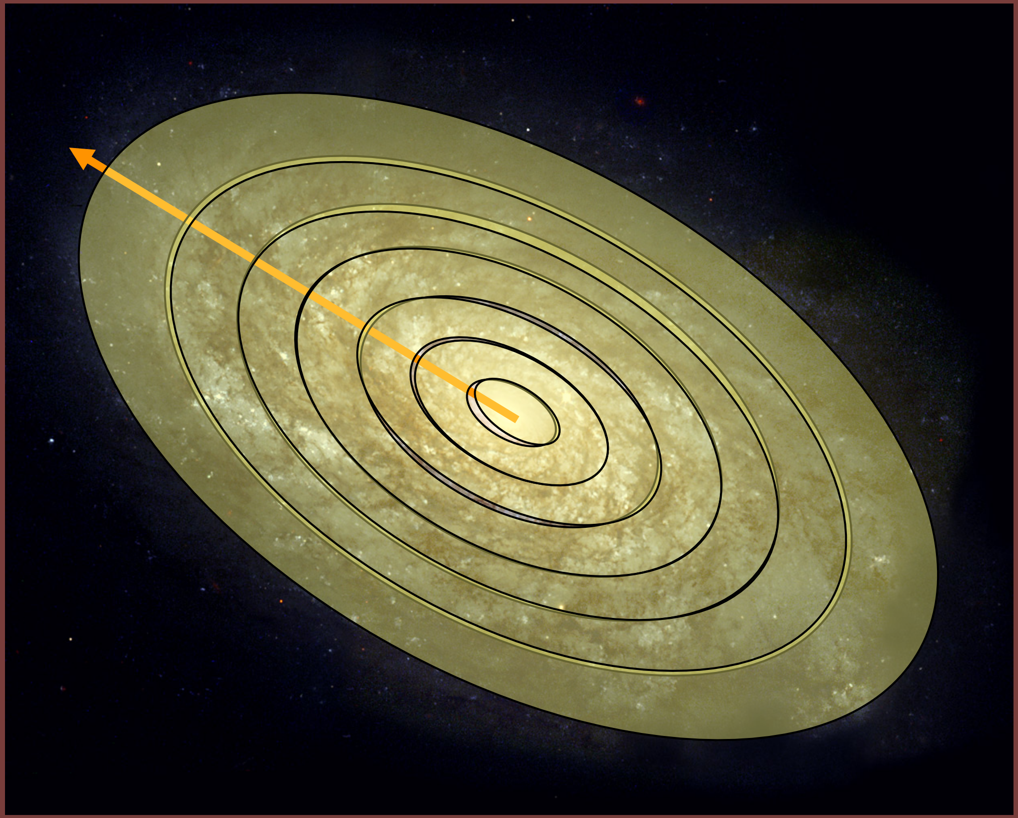


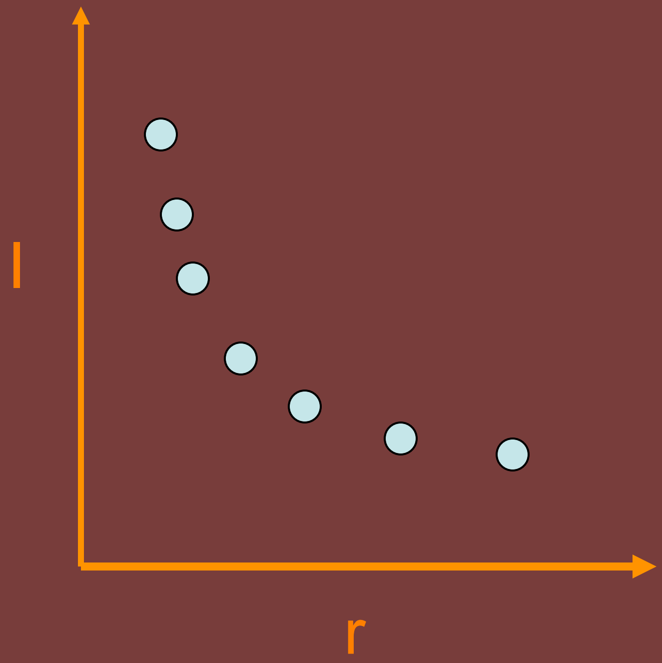
Measured galaxy properties

What can we measure from galaxy spectra?

- redshift
- absolute magnitude (e.g., M_r)
- physical size
- elemental abundances
- velocity dispersion / rotation
- stellar population
- star formation indicators

Galaxy light profiles





Disk galaxies: Exponential disk

$$I(r) = I_0 \exp(-r/r_0)$$

Galaxy light profiles

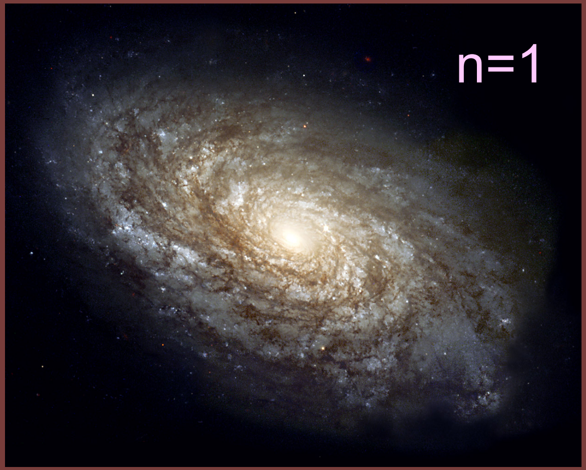
Elliptical galaxies: de Vaucouleurs profile

$$I(r) = I_0 \exp\left(-\left(r/r_0\right)^{\frac{1}{4}} \right)$$

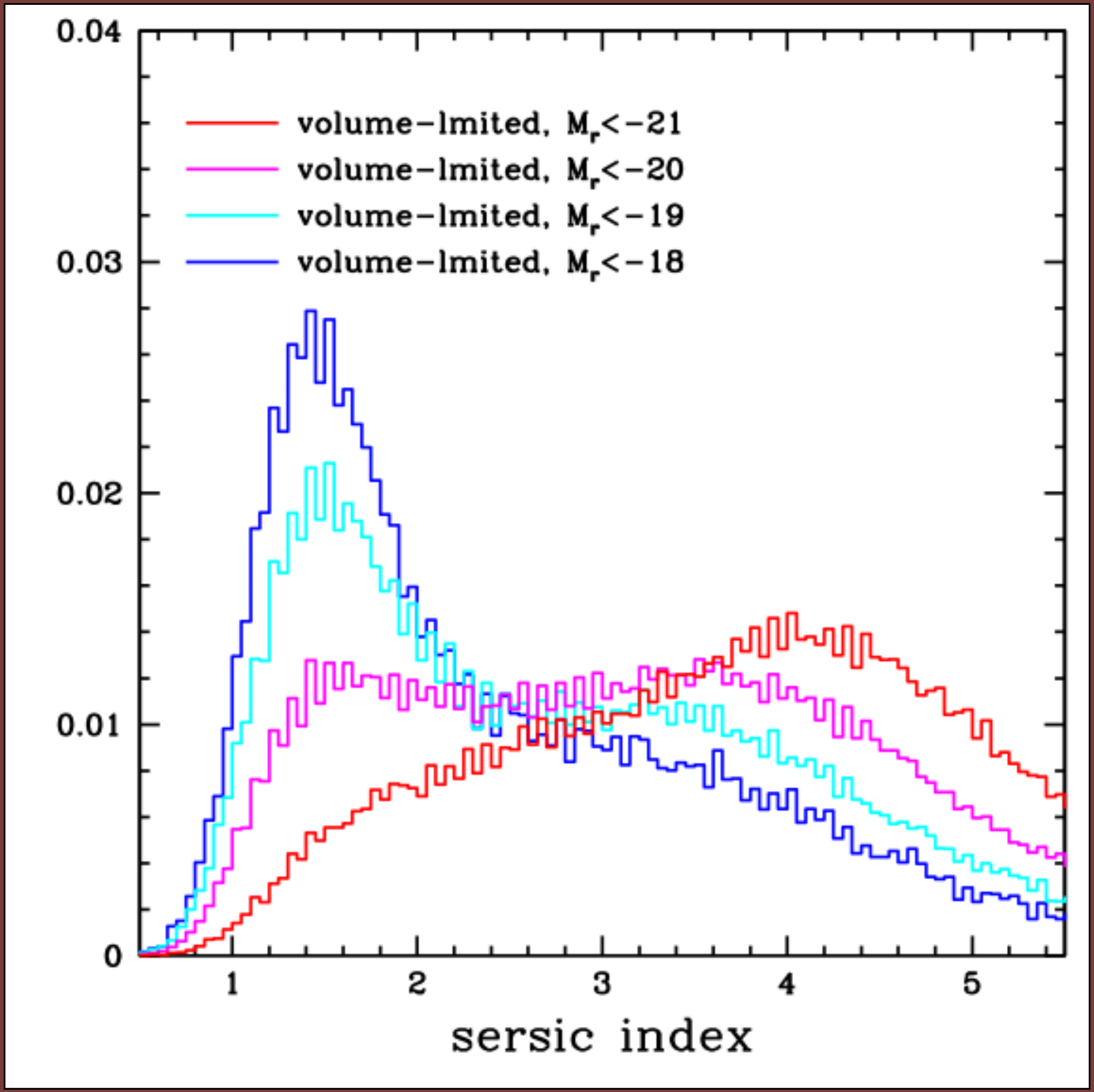
Galaxy light profiles

More general: Sersic profile

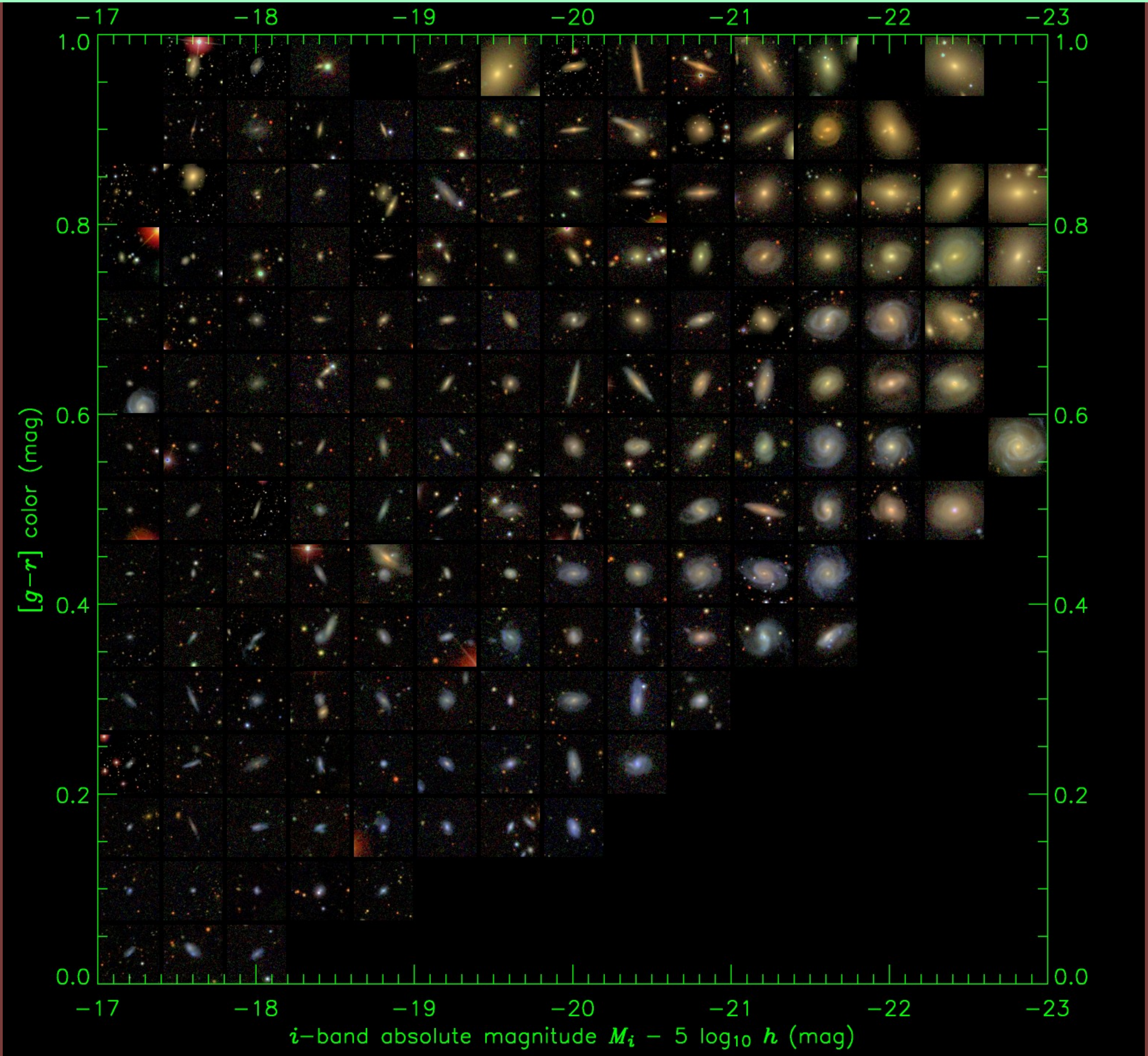
$$I(r) = I_0 \exp\left(-(r/r_0)^{\frac{1}{n}} \right)$$



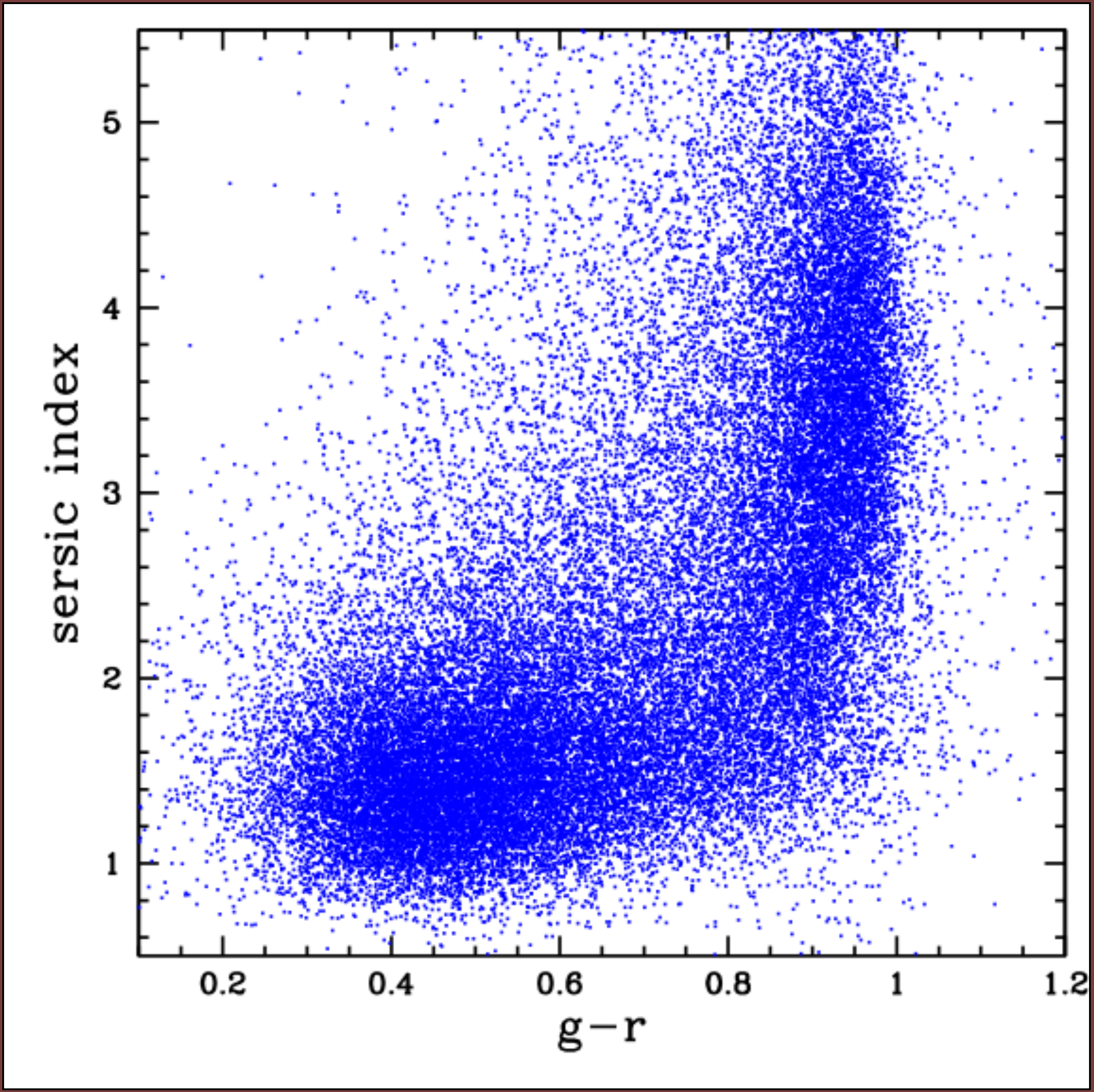
Galaxy light profiles



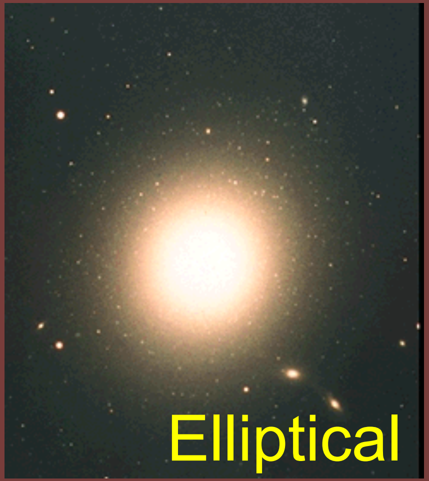
Galaxy light profiles



Galaxy light profiles



Galaxy morphology



Galaxy morphology








Galaxy morphology

<u>Types</u>

- Spiral structure
- Bars vs. no bars
- Disk vs. bulge
- Smooth vs. clumpy
- Tidal features

<u>Method</u>

- By eye
- 1D light profile fitting
- 2D light profile fitting
- Disk/bulge decomposition
- Spectro-Photometrically

Galaxy morphology

THE ASTROPHYSICAL JOURNAL, 754:68 (3pp), 2012 July 20
doi:10.1088/0004-637X/754/1/68

LUMINOSITIES OF BARRED AND UNBARRED S0 GALAXIES

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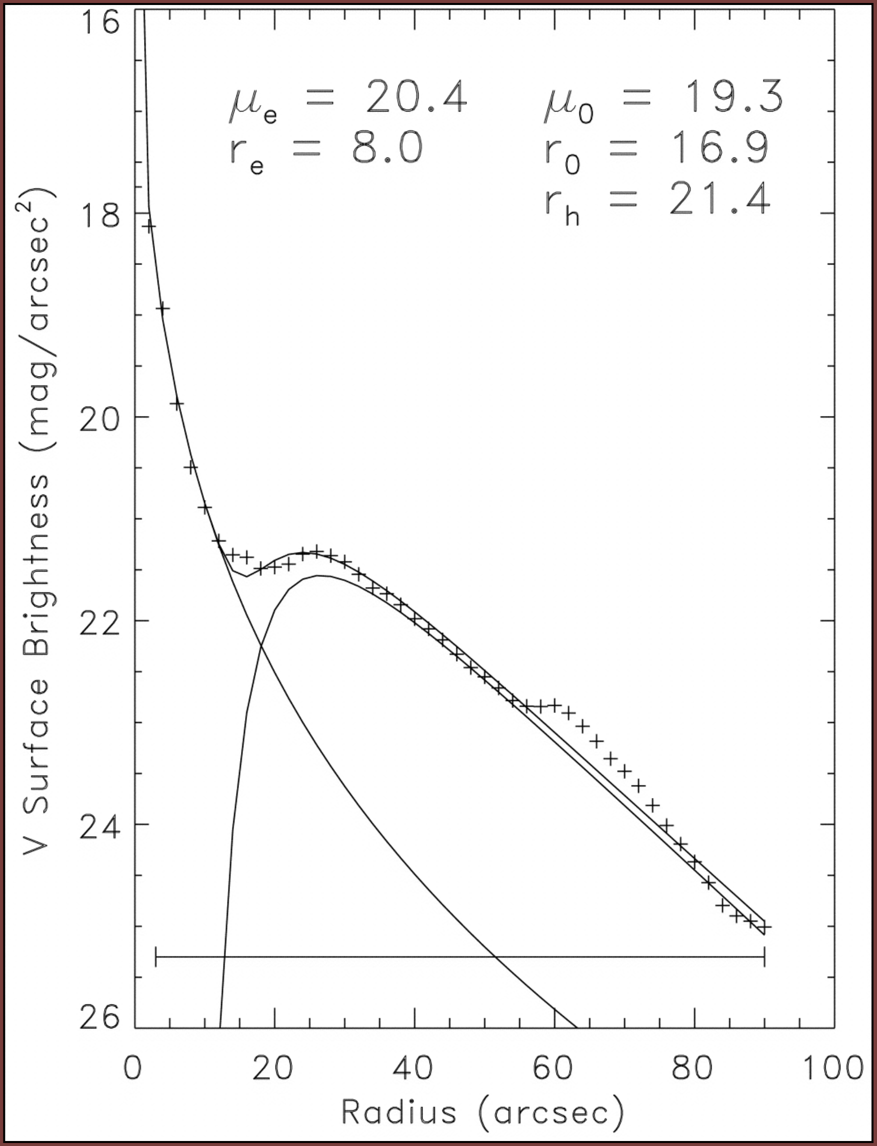
ABSTRACT

Lenticular galaxies with $M_B < -21.5$ are almost exclusively unbarred, whereas both barred and unbarred objects occur at fainter luminosity levels. This effect is observed both for objects classified in blue light, and for those that were classified in the infrared. This result suggests that the most luminous (massive) S0 galaxies find it difficult to form bars. As a result, the mean luminosity of unbarred lenticular galaxies in both B and IR light is observed to be ~0.4 mag brighter than that of barred lenticulars. A small contribution to the observed luminosity difference that is found between SA0 and SB0 galaxies may also be due to the fact that there is an asymmetry between the effects of small classification errors on SA0 and SB0 galaxies. An elliptical (E) galaxy might be misclassified as a lenticular (S0) or an S0 as an E. However, an E will never be misclassified as an SB0, nor will an SB0 ever be called an E. This asymmetry is important because E galaxies are typically twice as luminous as S0 galaxies. The present results suggest that the evolution of luminous lenticular galaxies may be closely linked to that of elliptical galaxies, whereas fainter lenticulars might be more closely associated with ram-pressure stripped spiral galaxies. Finally, it is pointed out that fine details of the galaxy formation process might account for some of the differences between the classifications of the same galaxy by individual competent morphologists.

Key word: galaxies: elliptical and lenticular, cD

Galaxy morphology

1D fitting



de Souza (2004)

2D fitting

de Souza (2004)

Galaxy morphology

Galaxy morphology

GALAXY ZOO 2

- 150,000 people
- 50 million galaxy classifications

Galaxy Zoo: Morphologies derived from visual inspection of galaxies from the Sloan Digital Sky Survey*

Chris J. Lintott[1]†, Kevin Schawinski[1]‡, Anže Slosar[1,2], Kate Land[1], Steven Bamford[3], Daniel Thomas[3], M. Jordan Raddick[4], Robert C. Nichol[3], Alex Szalay[4], Dan Andreescu[5], Phil Murray[6], Jan van den Berg[4]

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[3] *Institute of Cosmology and Gravitation, University of Portsmouth, Mercantile House, Hampshire Terrace, Portsmouth, PO1 2EG, UK*
[4] *Department of Physics and Astronomy, Johns Hopkins University, 3400 N. Charles St., Baltimore, MD 21218, USA*
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[6] *Fingerprint Digital Media, 9 Victoria Close, Newtownards, Co. Down, Northern Ireland, BT23 7GY, UK*

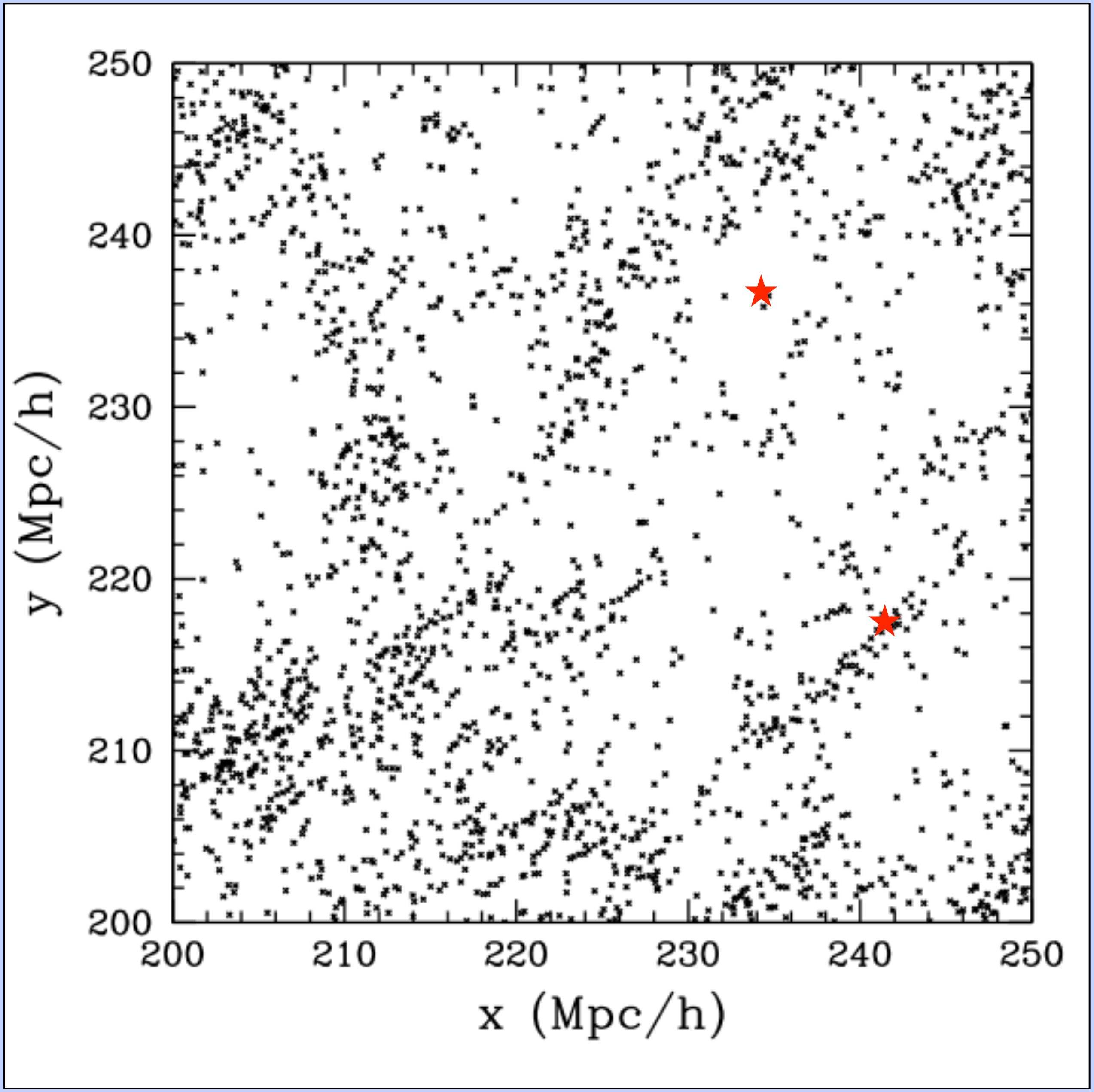
Galaxy environments

The “environment” of a galaxy is a general term that has many different specific definitions, but is usually related to the local mass density.

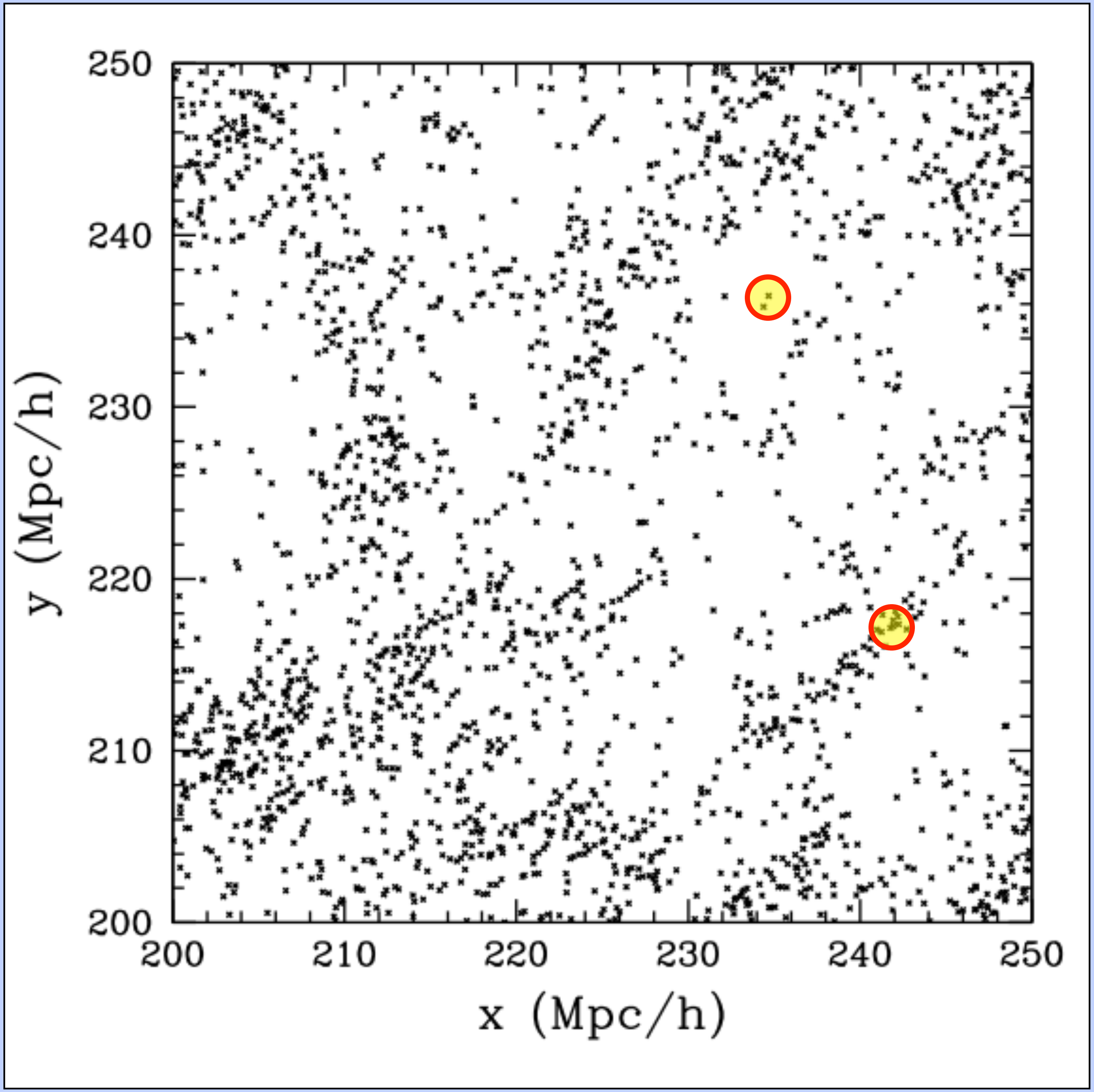
Environment measures

- galaxy density on a scale *r*
- distance to N^{th} nearest neighbor
- group or cluster membership
- distance to nearest cluster
- filament/void membership

Galaxy environments

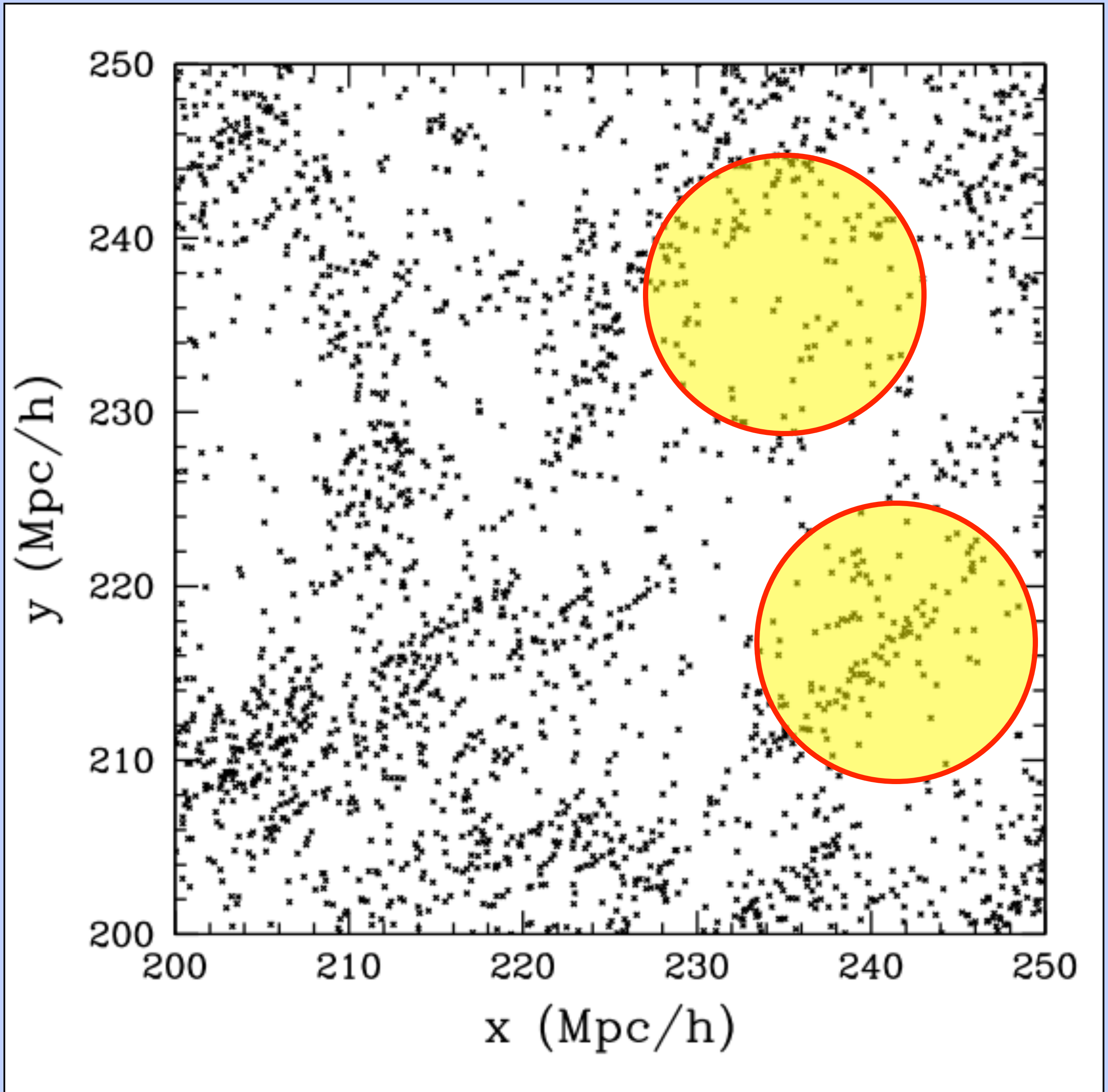


Galaxy environments



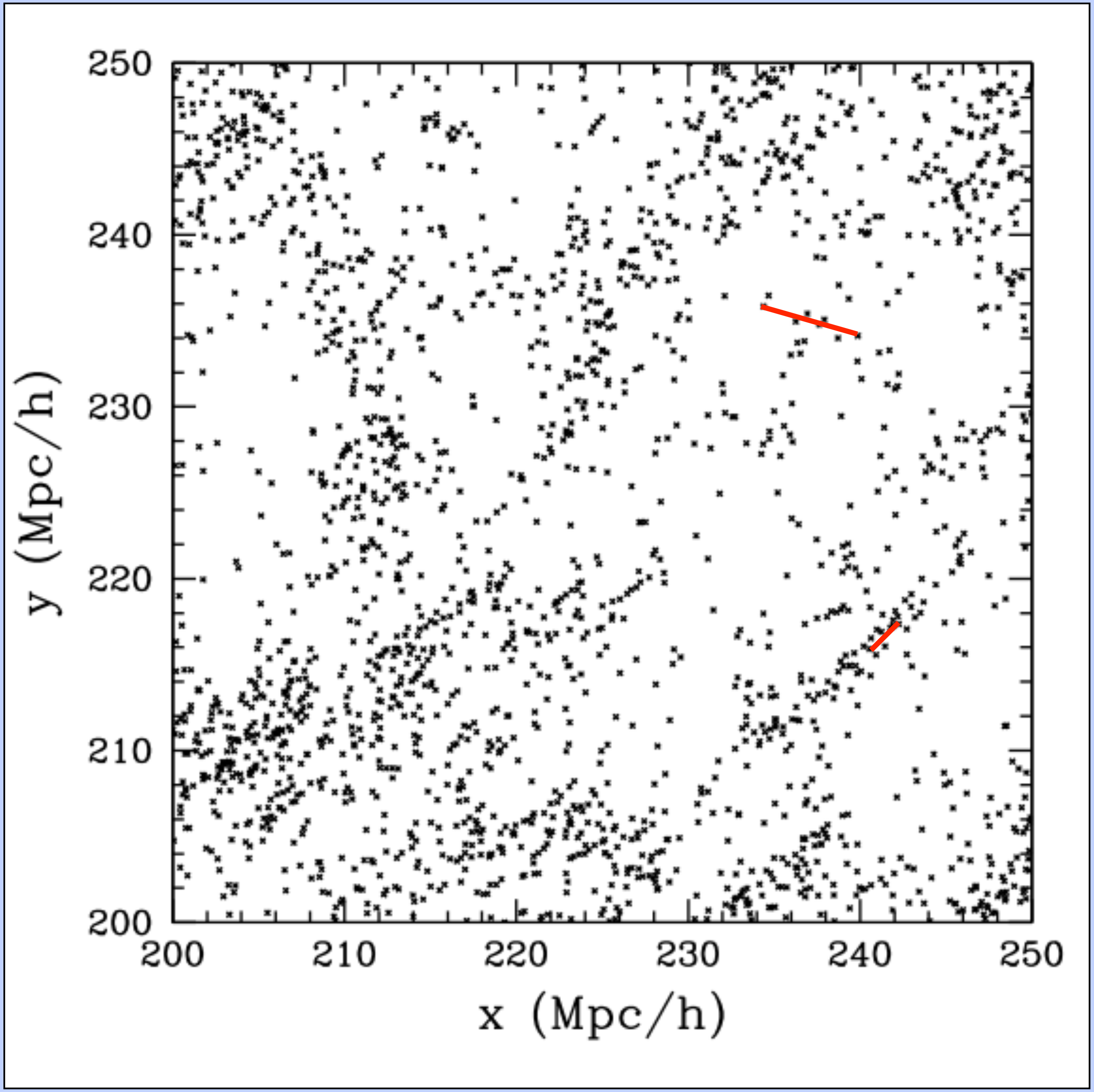
- Galaxy density on small scale (1 Mpc/h)

Galaxy environments



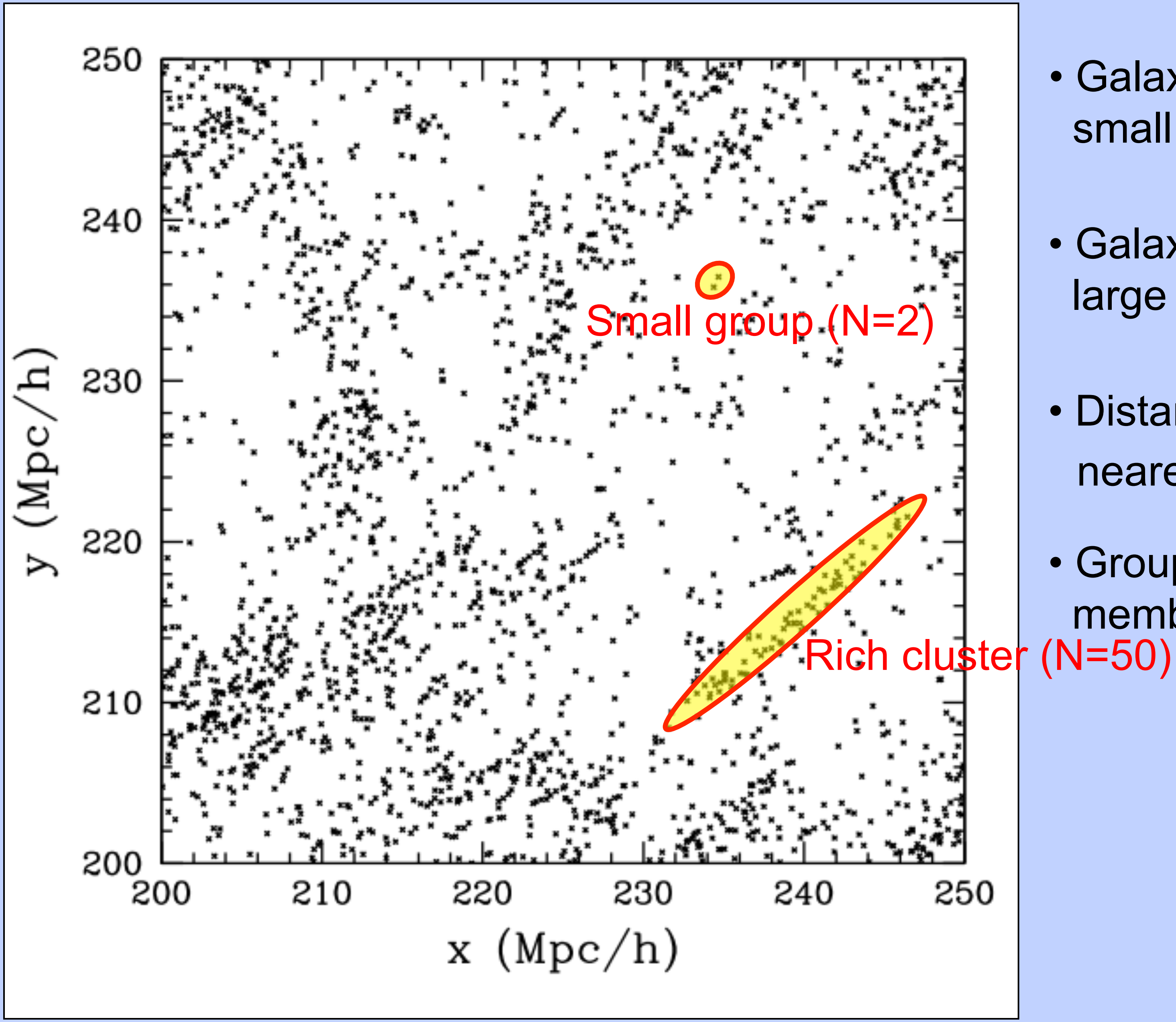
- Galaxy density on small scale (1 Mpc/h)
- Galaxy density on large scale (8 Mpc/h)

Galaxy environments



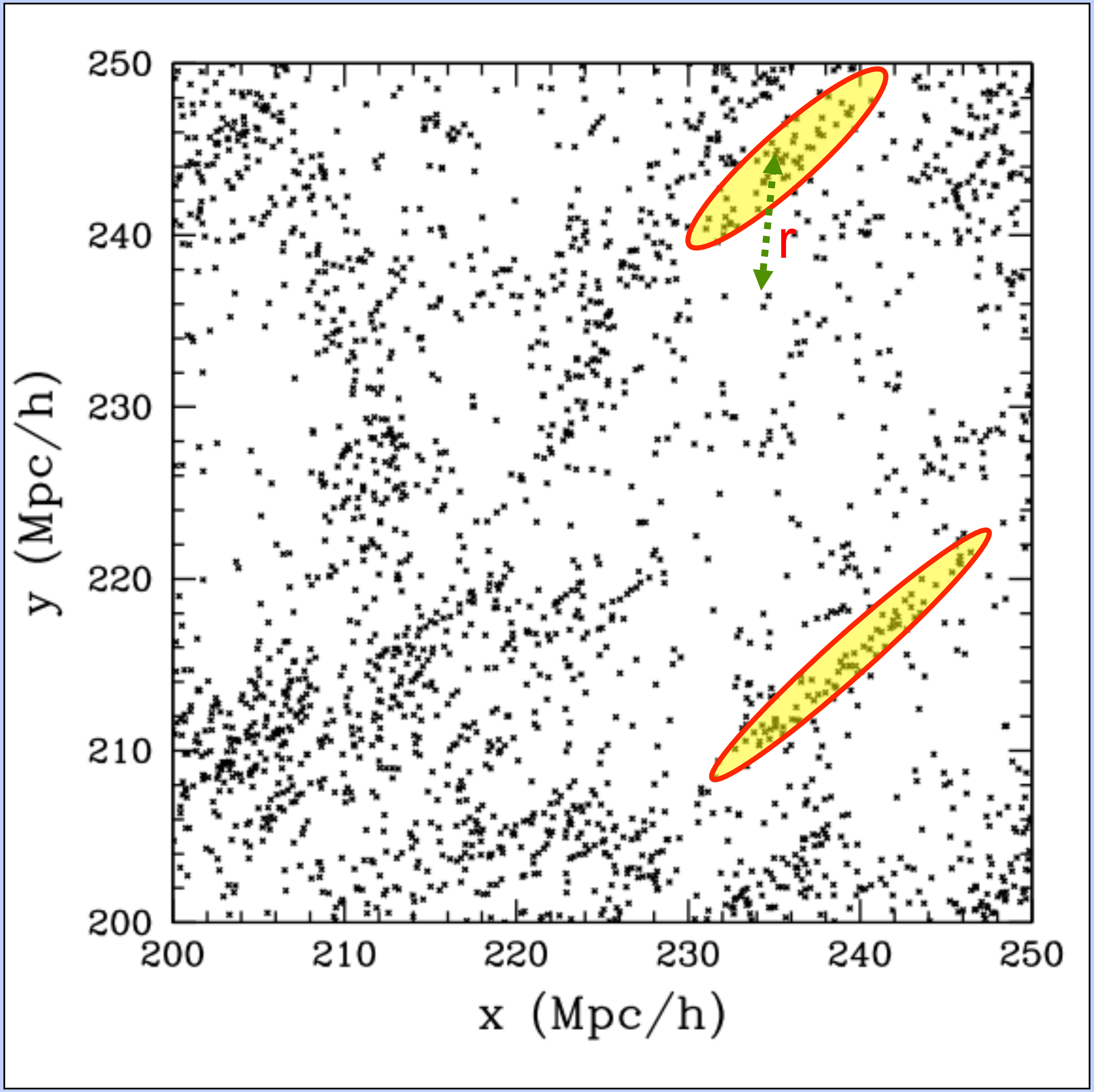
- Galaxy density on small scale (1 Mpc/h)
- Galaxy density on large scale (8 Mpc/h)
- Distance to Nth nearest neighbor

Galaxy environments



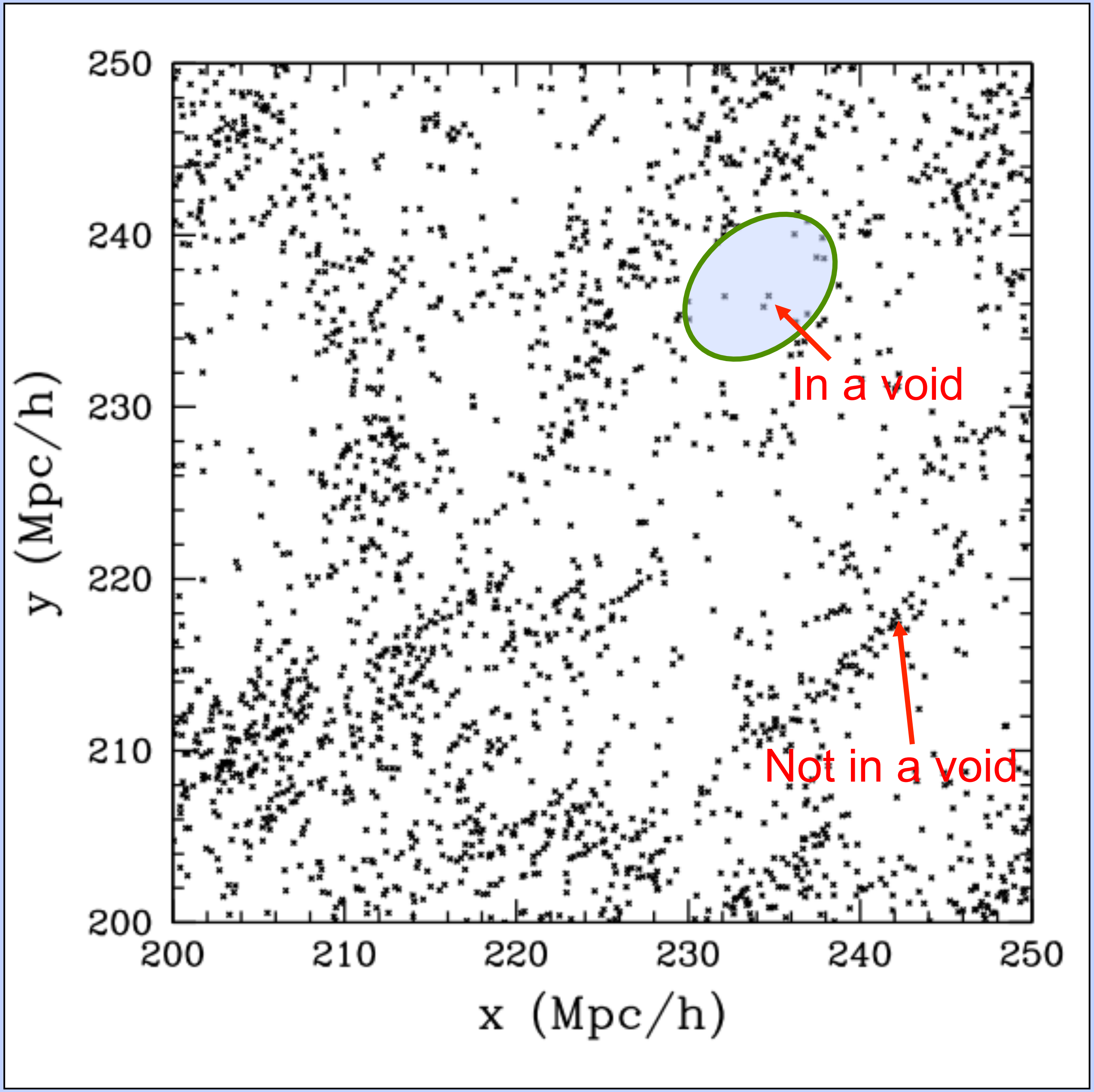
- Galaxy density on small scale (1 Mpc/h)
- Galaxy density on large scale (8 Mpc/h)
- Distance to N^{th} nearest neighbor
- Group or cluster membership

Galaxy environments



- Galaxy density on small scale (1 Mpc/h)
- Galaxy density on large scale (8 Mpc/h)
- Distance to Nth nearest neighbor
- Group or cluster membership
- Distance to nearest cluster

Galaxy environments



- Galaxy density on small scale (1 Mpc/h)
- Galaxy density on large scale (8 Mpc/h)
- Distance to N^{th} nearest neighbor
- Group or cluster membership
- Distance to nearest cluster
- Void membership

Morphology-density relations

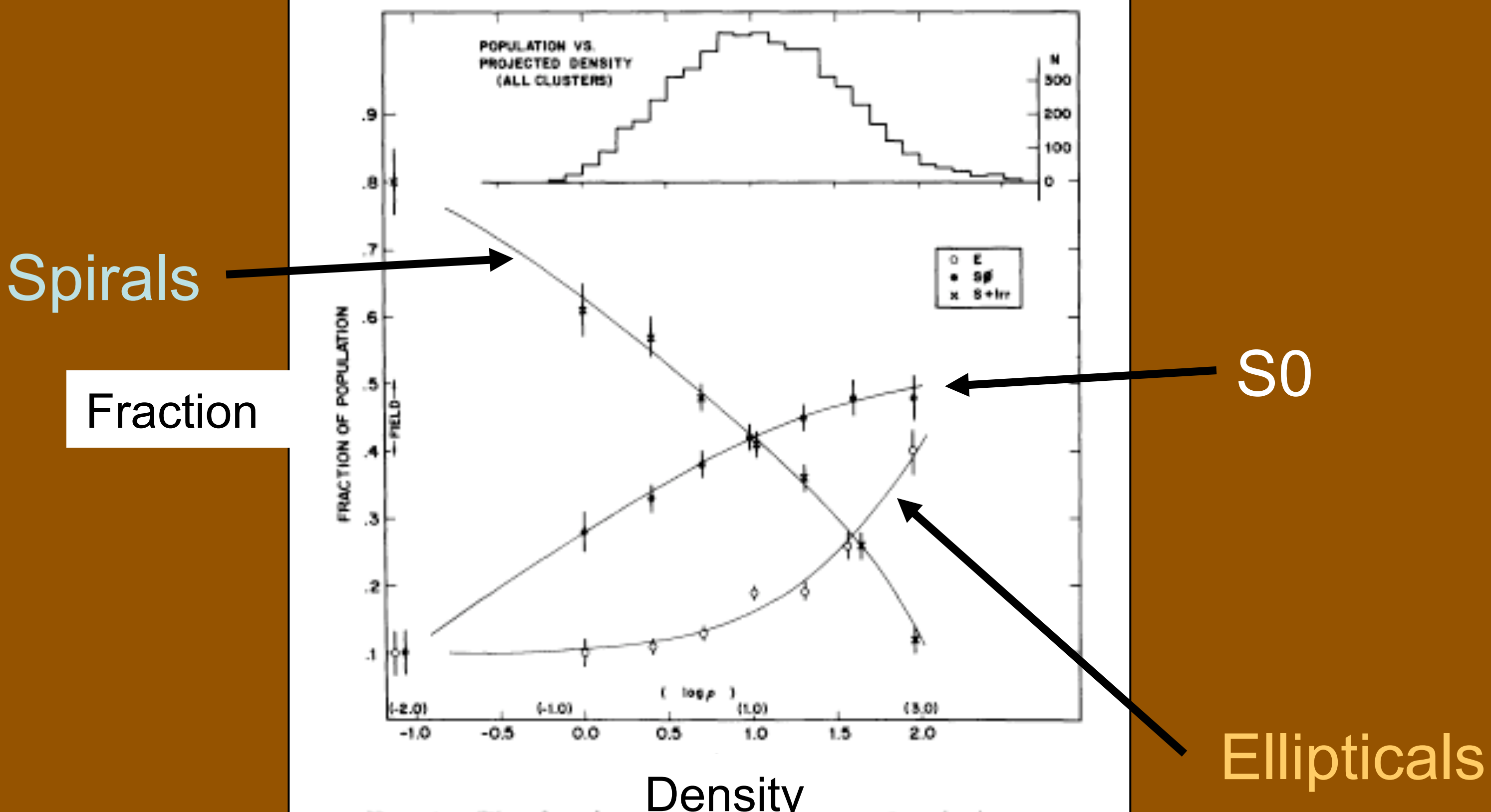
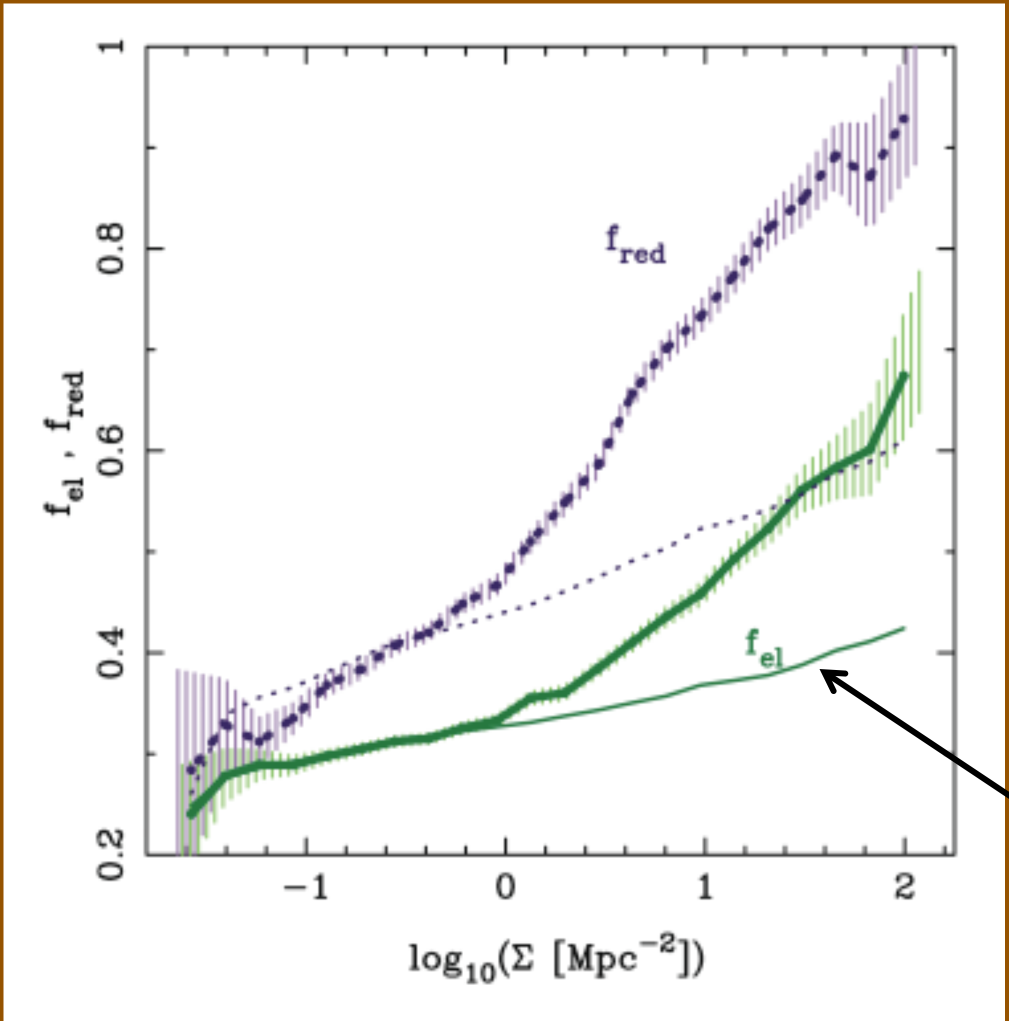


FIG. 4.—The fraction [illegible] -I galaxies as a function of the log of the projected density, in galaxies Mpc^{-2}. The data shown are for all cluster galaxies in the sample and for the field. Also shown is an estimated scale of true space density in galaxies Mpc^{-3}. The upper histogram shows the number distribution of the galaxies over the bins of projected density.

Dressler 1980

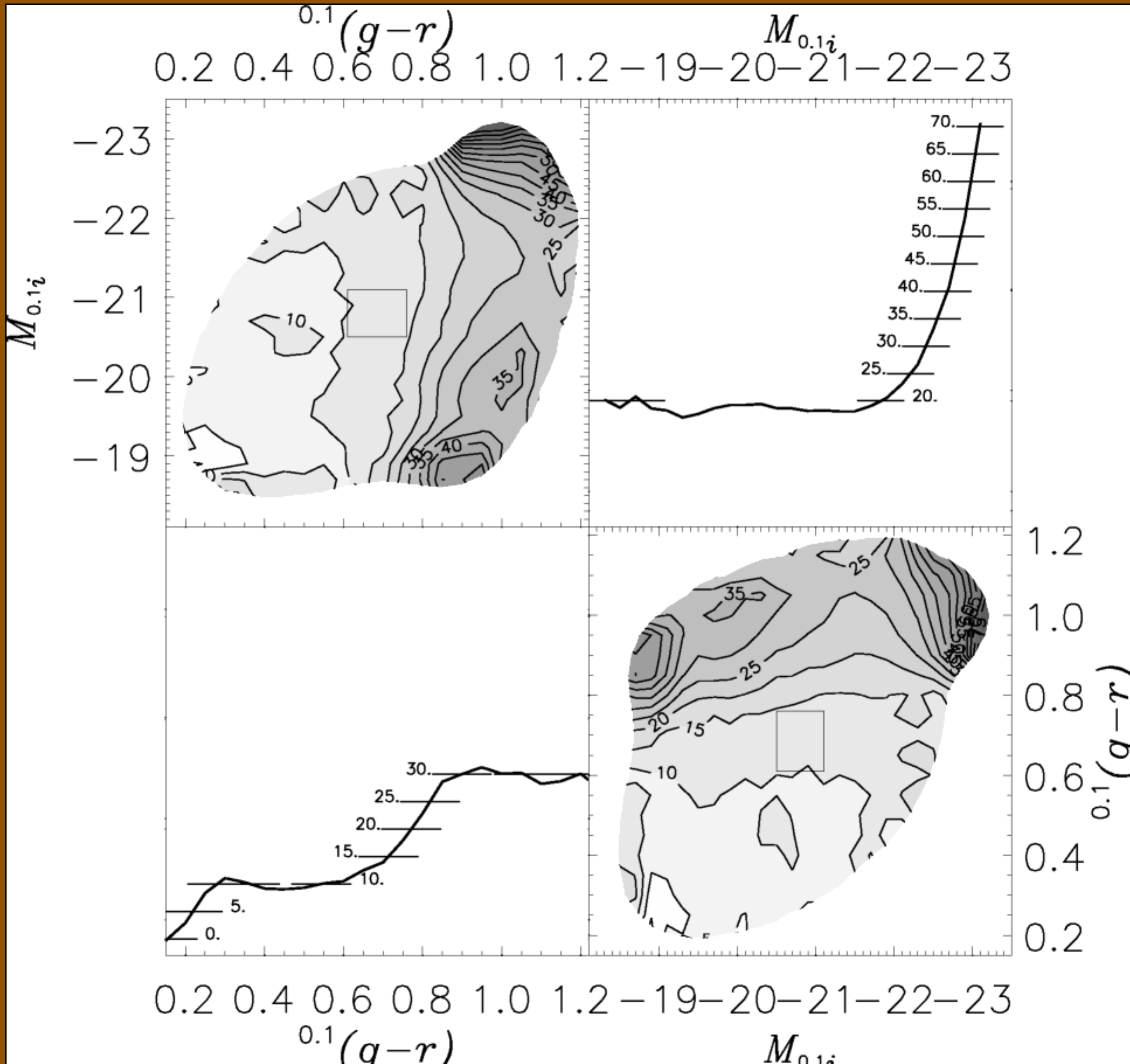
Morphology-density relations



Trend due to correlation between stellar mass and environment.

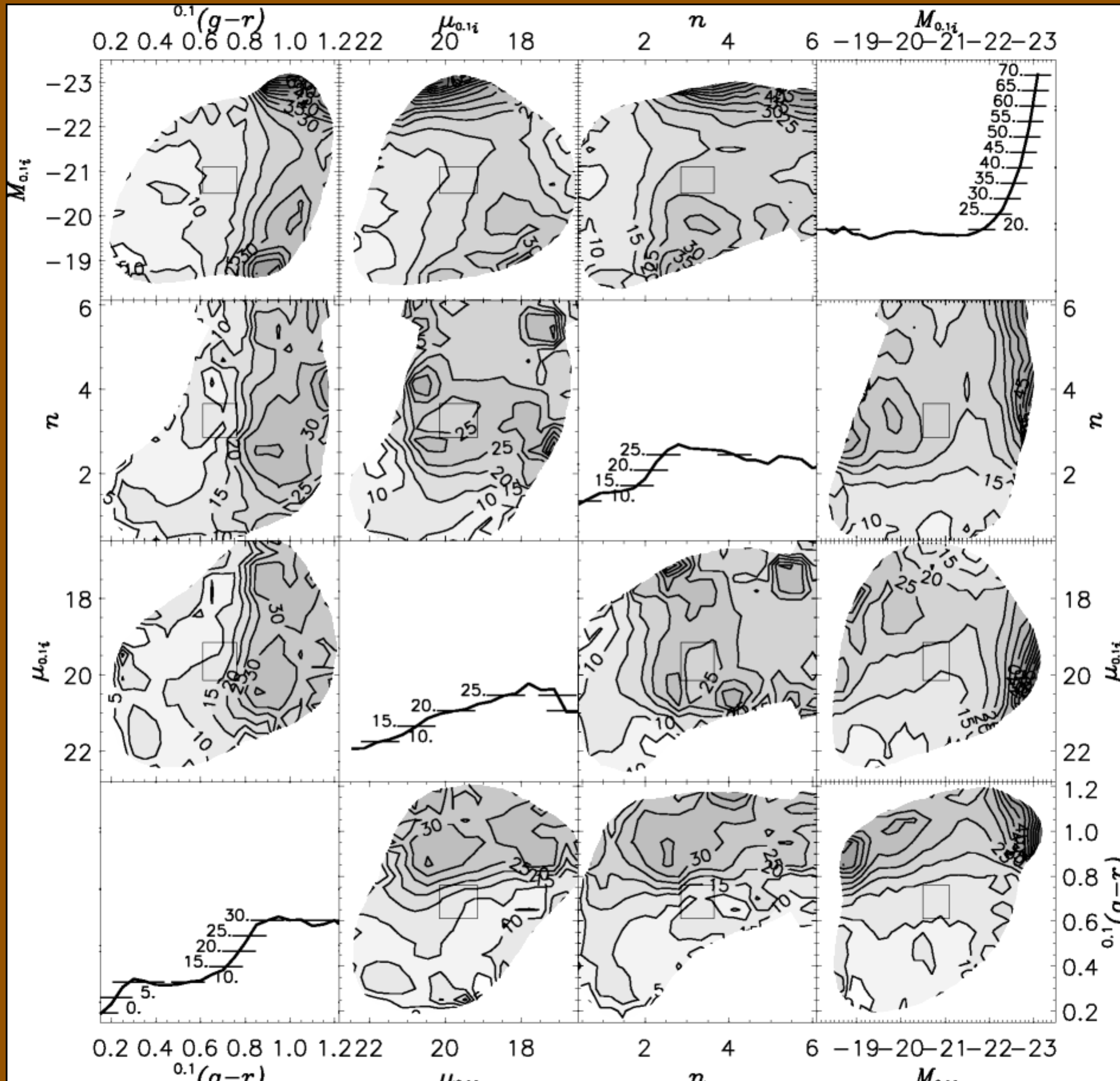
Bamford et al. 2009

Correlations of galaxy properties with environment



Blanton et al. (2005)

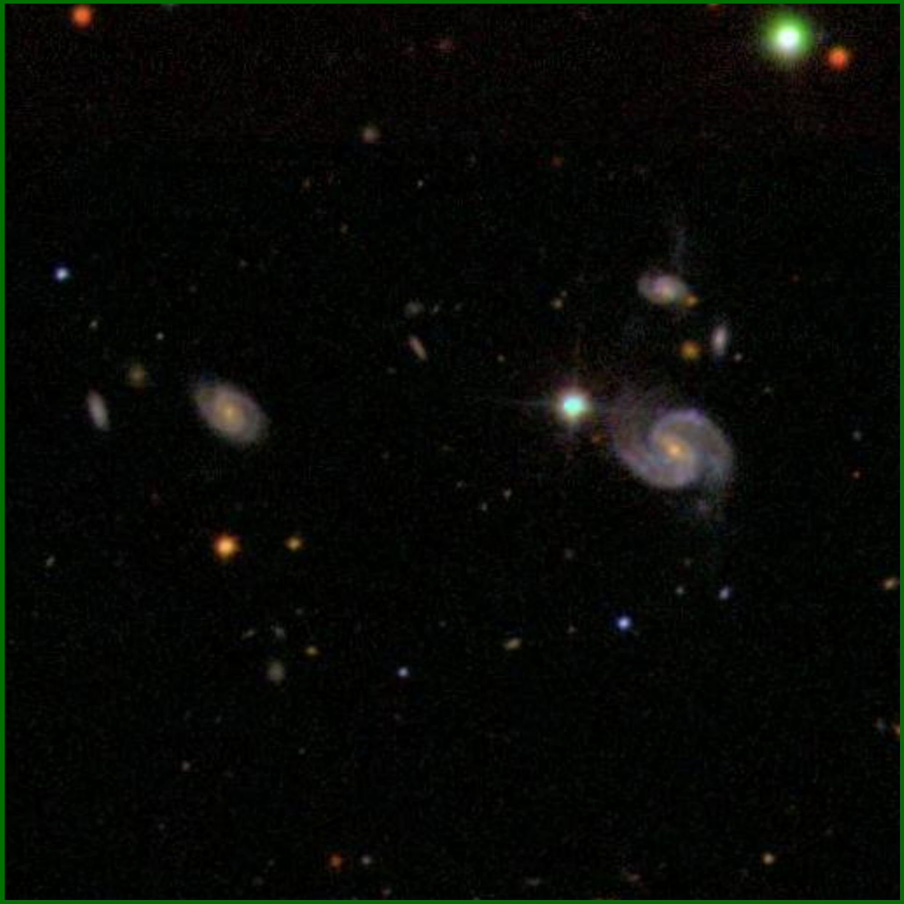
Correlations of galaxy properties with environment

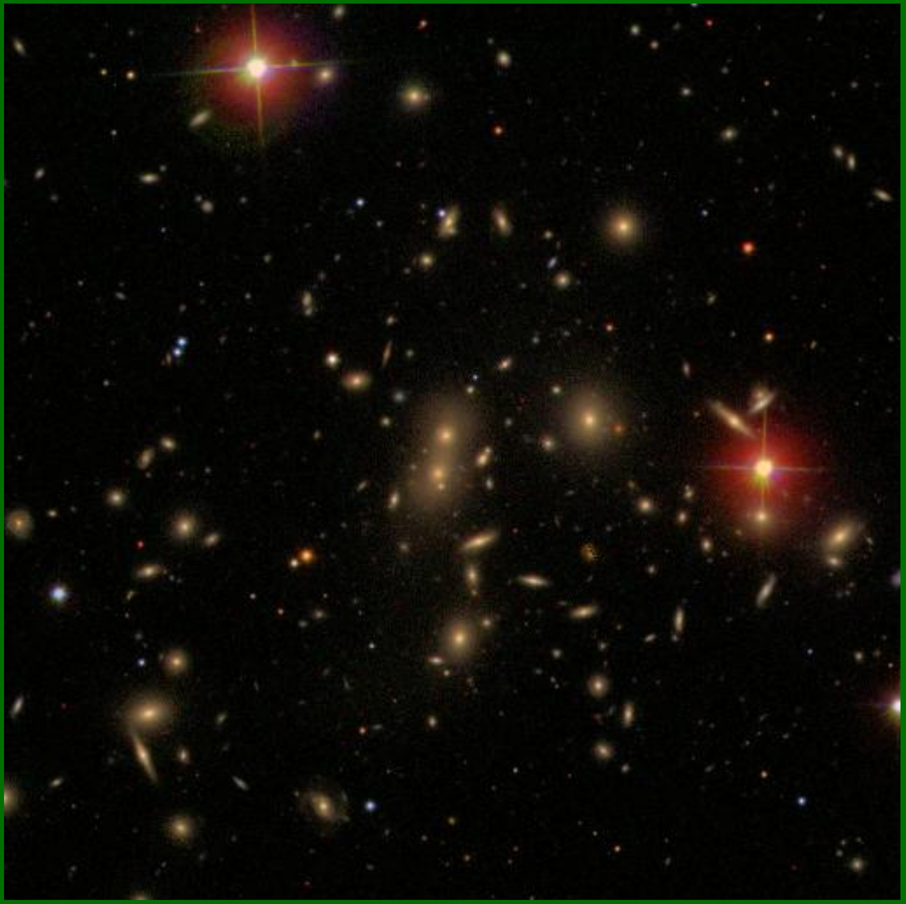


Blanton et al. (2005)

Galaxy groups and clusters

Galaxies congregate on small scales to form groups and clusters.





Galaxy groups and clusters

What defines a group or cluster?

In theory…

- Gravitationally bound system of galaxies
- System of galaxies in virial equilibrium
- Galaxies that live in the same dark matter halo

In practice…

- Whatever group-finding algorithm is used

Galaxy groups and clusters

There are as many algorithms as group/cluster catalogs

Three broad sets of classes:

- 2D vs. 3D
- purely geometric vs. spectro-photometric
- galaxies vs. gas vs. dark matter

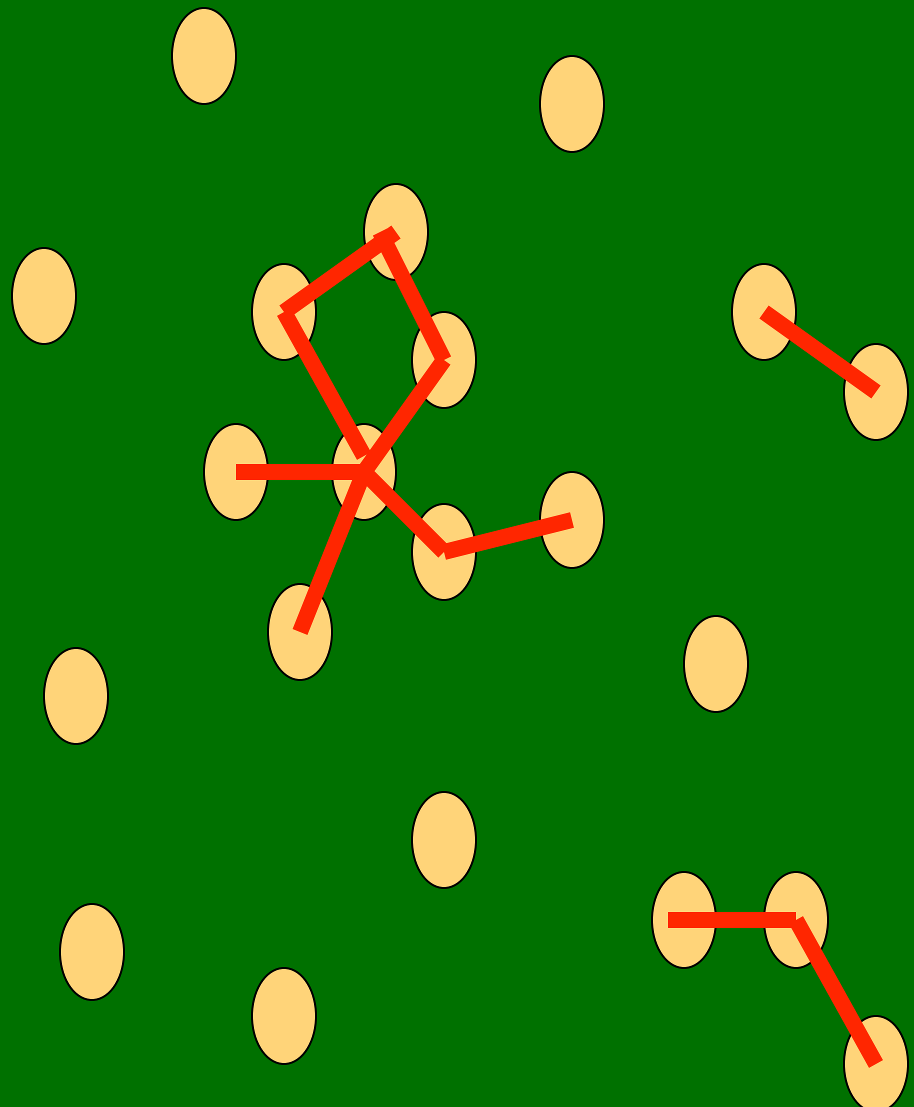
All must deal with:

- incompleteness (missing galaxies that should be included)
- contamination (including galaxies that should not be)

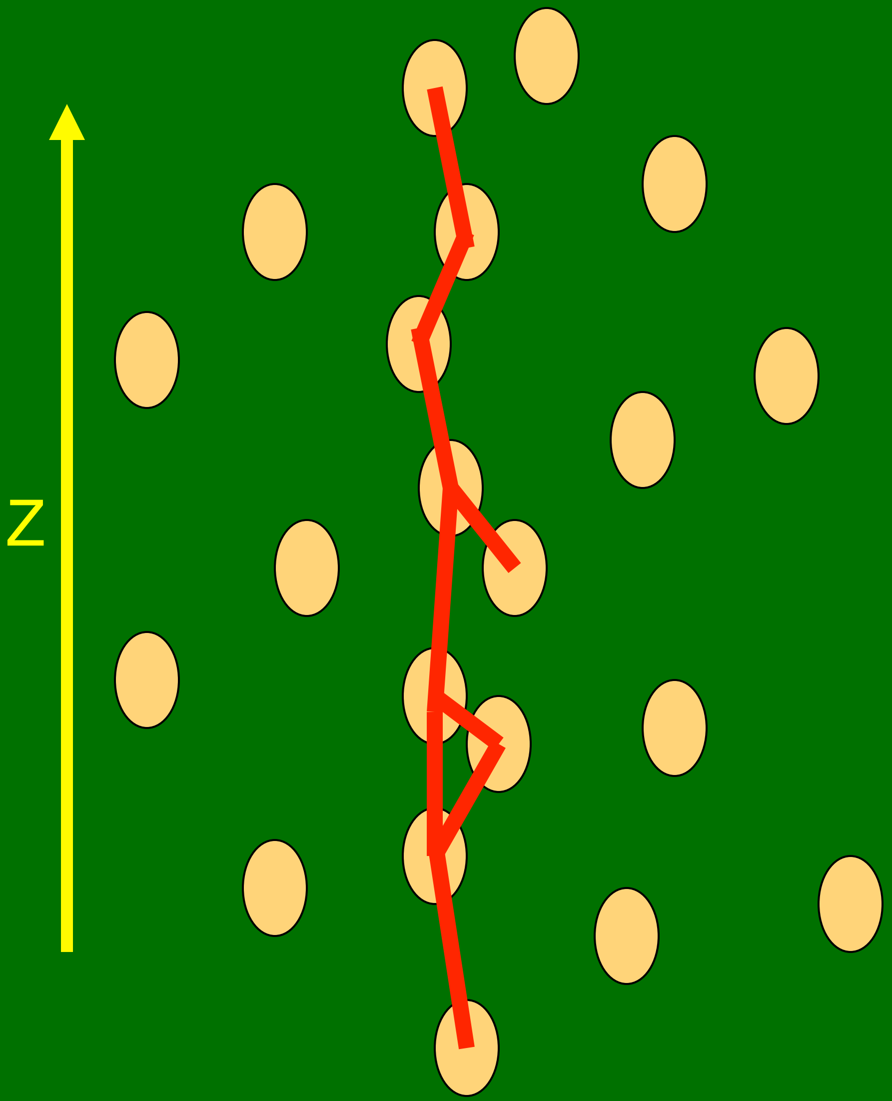
Galaxy groups and clusters

Geometric method: friends-of-friends

Linking length:



Geometric method: friends-of-friends



X-Y linking length:

Z linking length:

Galaxy groups and clusters

The Astrophysical Journal Supplement Series, 167:1–25, 2006 November

PERCOLATION GALAXY GROUPS AND CLUSTERS IN THE SDSS REDSHIFT SURVEY: IDENTIFICATION, CATALOGS, AND THE MULTIPLICITY FUNCTION

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Kevork Abazajian,[4] Ryan Scranton,[5] David W. Hogg,[1] Roman Scoccimarro,[1] Neta A. Bahcall,[6]
J. Brinkmann,[7] J. Richard Gott III,[6] S. J. Kleinman,[7] J. Krzesinski,[8,9] Brian C. Lee,[10]
Christopher J. Miller,[11] Atsuko Nitta,[7] Donald P. Schneider,[12]
Douglas L. Tucker,[13] and Idit Zehavi[14,15]
(for The SDSS Collaboration)
Received 2006 January 13; accepted 2006 July 26

ABSTRACT

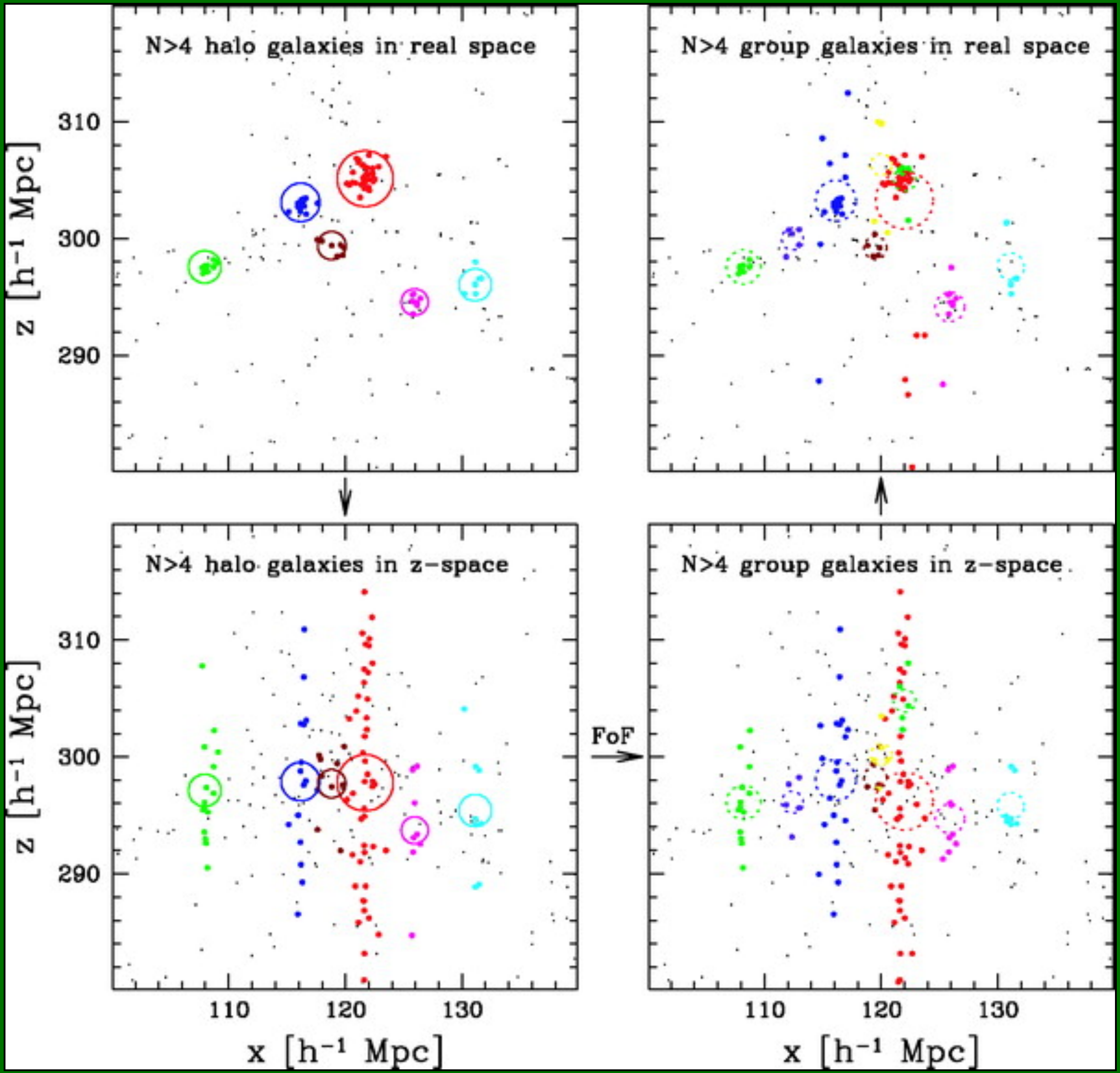
We identify galaxy groups and clusters in volume-limited samples of the Sloan Digital Sky Survey (SDSS) redshift survey, using a redshift-space friends-of-friends algorithm. We optimize the friends-of-friends linking lengths to recover galaxy systems that occupy the same dark matter halos, using a set of mock catalogs created by populating halos of *N*-body simulations with galaxies. Extensive tests with these mock catalogs show that no combination of perpendicular and line-of-sight linking lengths is able to yield groups and clusters that simultaneously recover the true halo multiplicity function, projected size distribution, and velocity dispersion. We adopt a linking length combination that yields, for galaxy groups with 10 or more members: a group multiplicity function that is unbiased with respect to the true halo multiplicity function; an unbiased median relation between the multiplicities of groups and their associated halos; a spurious group fraction of less than ∼1%; a halo completeness of more than ∼97%; the correct projected size distribution as a function of multiplicity; and a velocity dispersion distribution that is ∼20% too low at all multiplicities. These results hold over a range of mock catalogs that use different input recipes of populating halos with galaxies. We apply our group-finding algorithm to the SDSS data and obtain three group and cluster catalogs for three volume-limited samples that cover 3495.1 deg^2 on the sky, go out to redshifts of 0.1, 0.068, and 0.045, and contain 57,138, 37,820, and 18,895 galaxies, respectively. We correct for incompleteness caused by fiber collisions and survey edges and obtain measurements of the group multiplicity function, with errors calculated from realistic mock catalogs. These multiplicity function measurements provide a key constraint on the relation between galaxy populations and dark matter halos.

Subject headings: galaxies: clusters: general — large-scale structure of universe

Online material: color figures, machine-readable tables

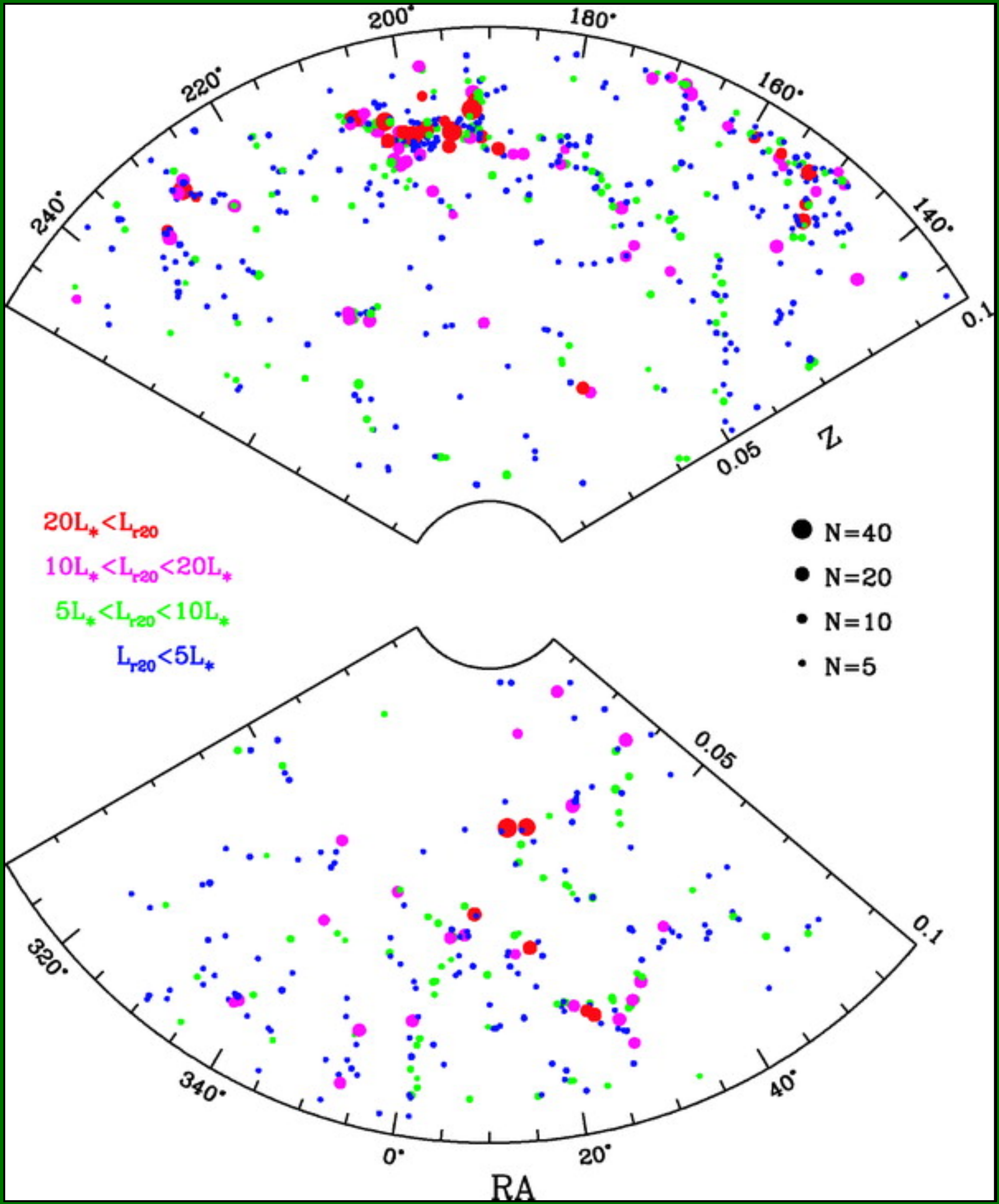
Berlind et al. (2006)

Galaxy groups and clusters



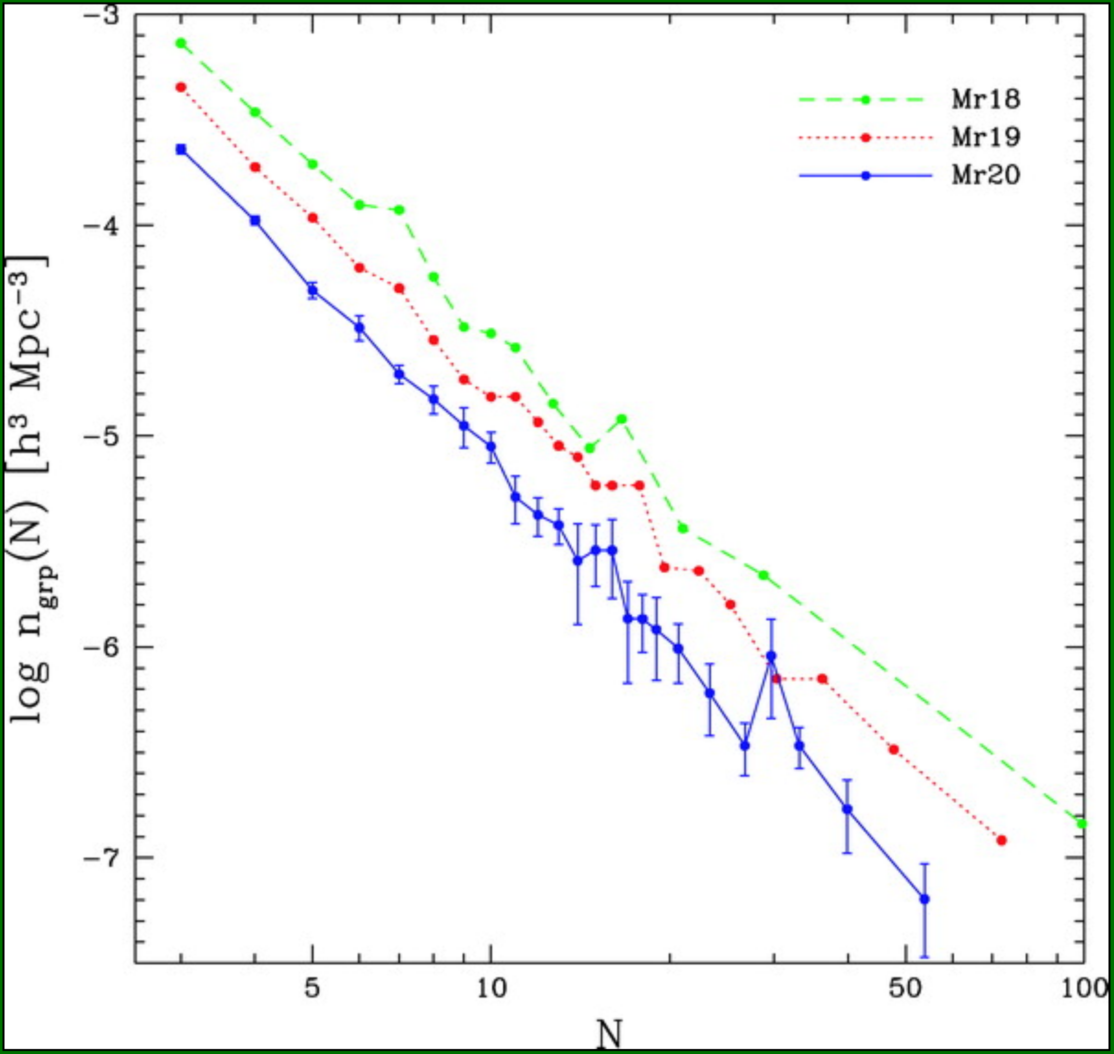
Berlind et al. (2006)

Galaxy groups and clusters



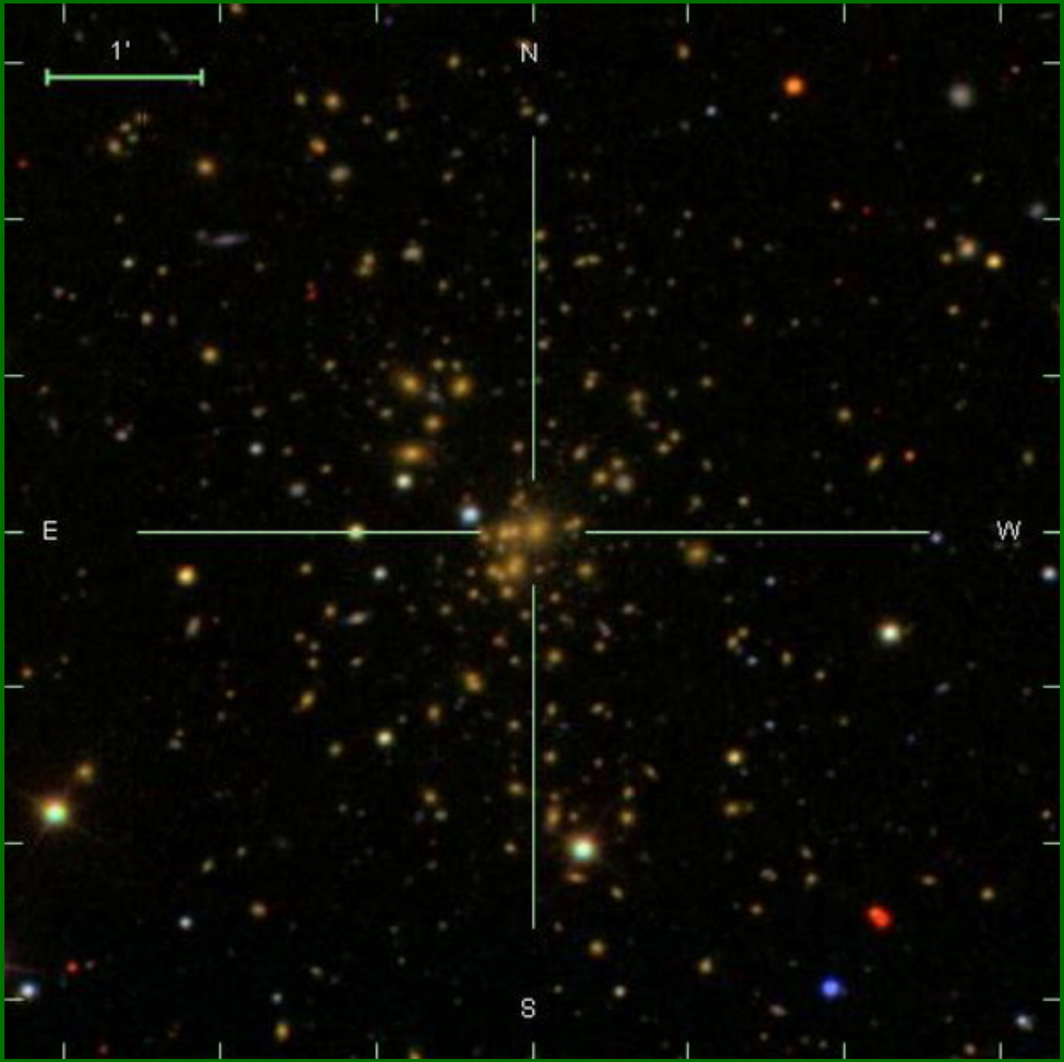
Berlind et al. (2006)

Group/cluster multiplicity/richness function

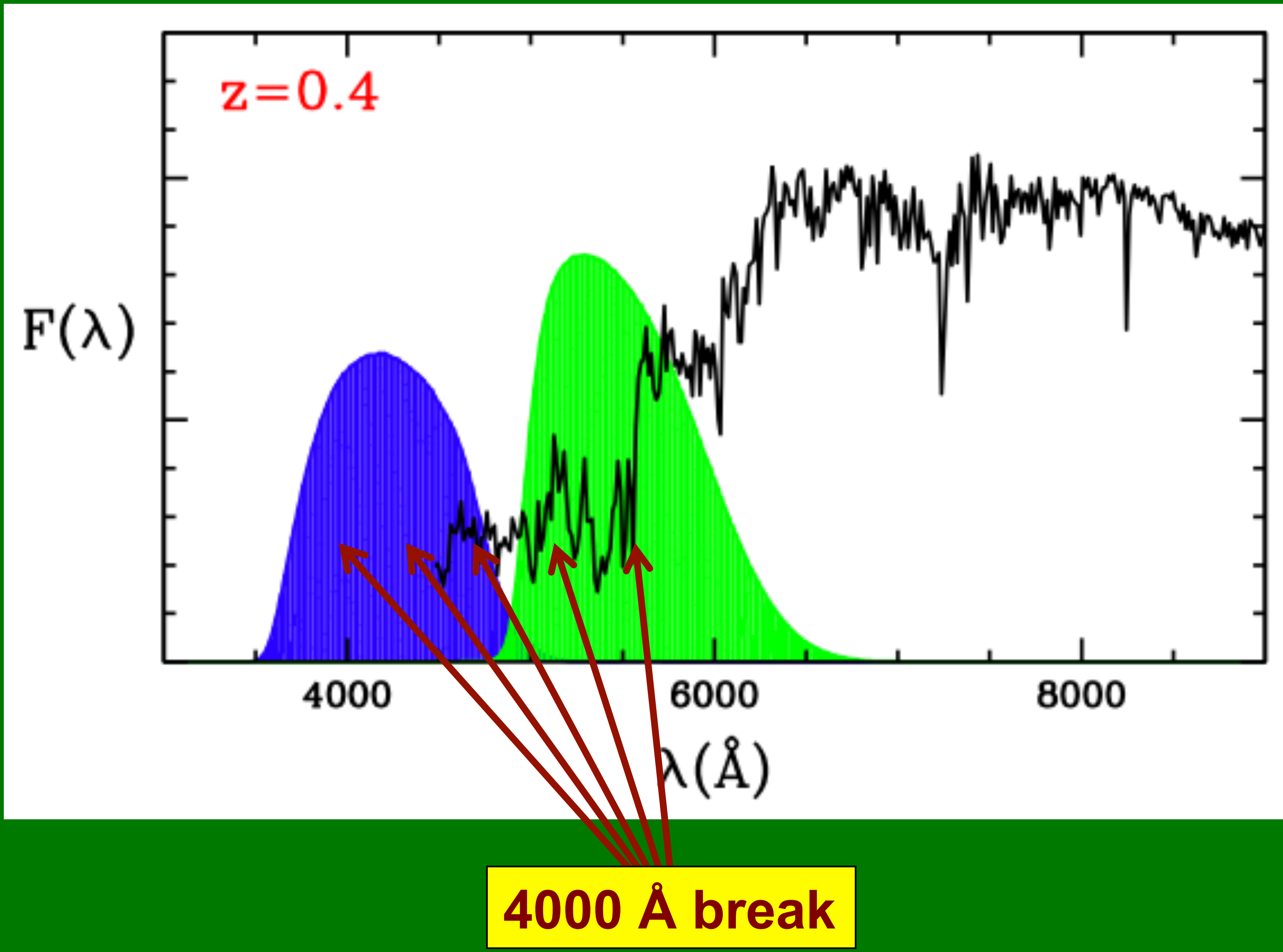


Berlind et al. (2006)

2D Photometric cluster finders



Galaxy groups and clusters



Galaxy groups and clusters

THE ASTROPHYSICAL JOURNAL, 785:104 (33pp), 2014 April 20 doi:10.1088/0004-637X/785/2/104

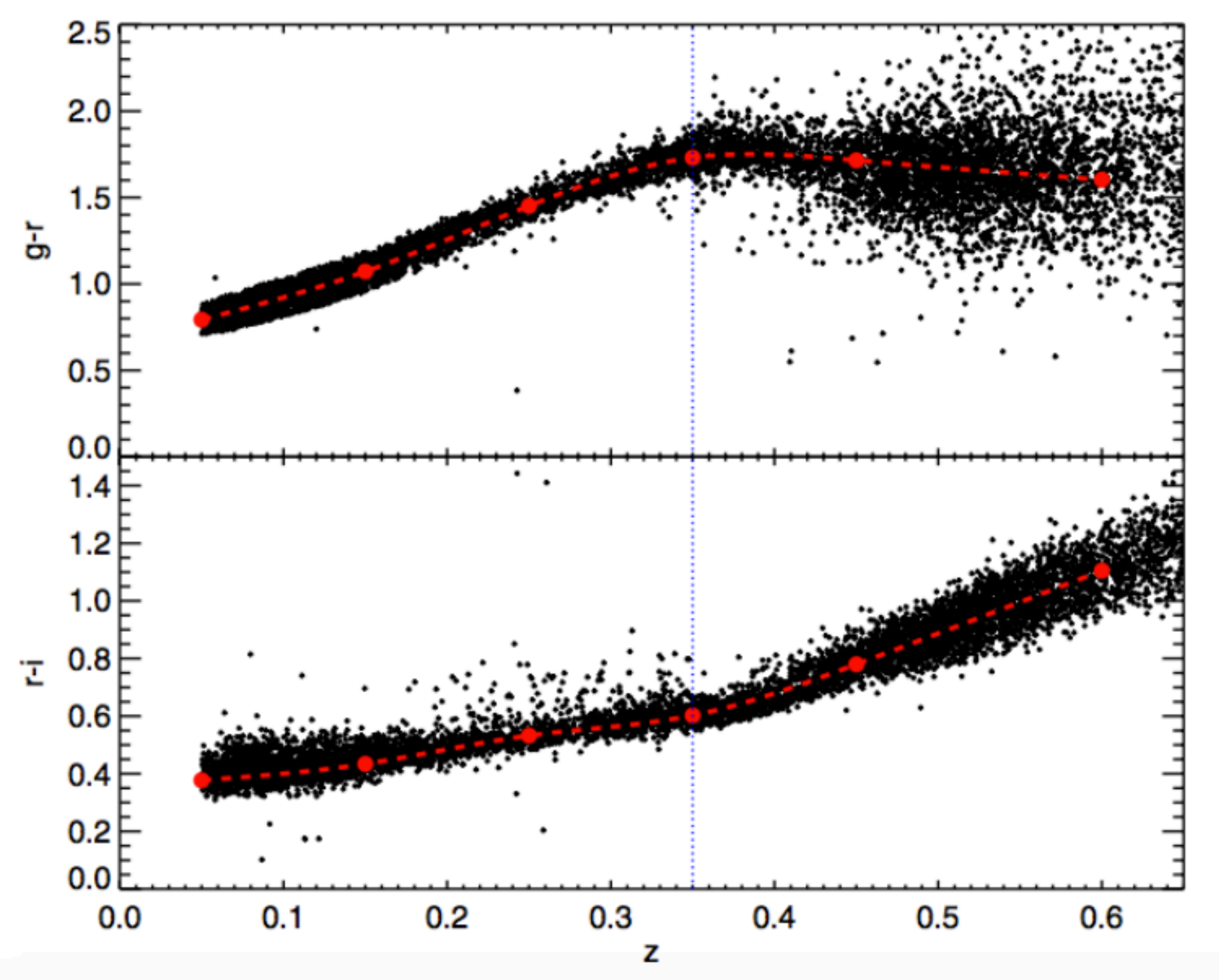
redMaPPer. I. ALGORITHM AND SDSS DR8 CATALOG

E. S. RYKOFF[1], E. ROZO[1], M. T. BUSHA[2,3], C. E. CUNHA[3], A. FINOGUENOV[4], A. EVRARD[5,6,7], J. HAO[8], B. P. KOESTER[5], A. LEAUTHAUD[9], B. NORD[8], M. PIERRE[10], R. REDDICK[1,3], T. SADIBEKOVA[10], E. S. SHELDON[11], AND R. H. WECHSLER[1,3]

ABSTRACT

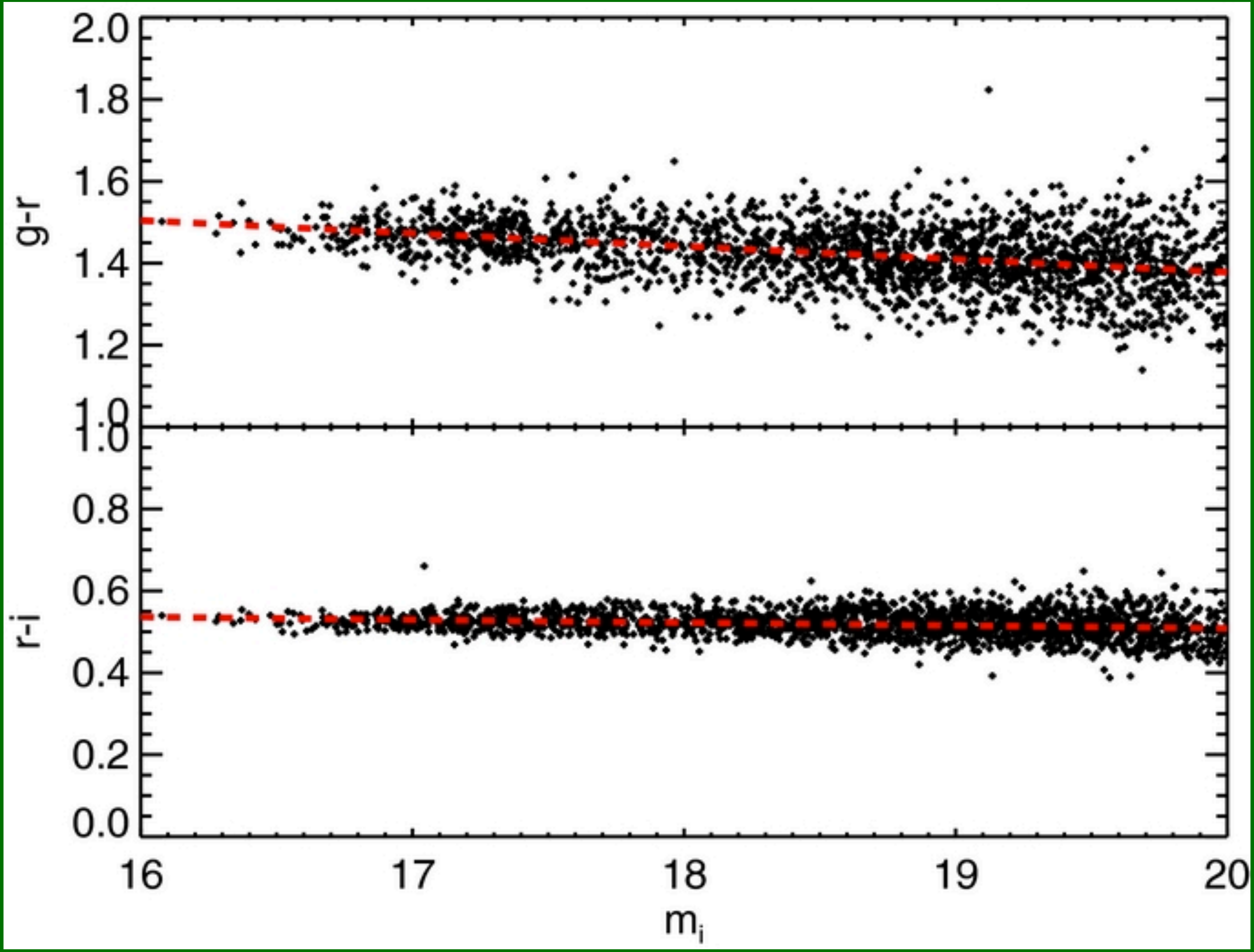
We describe redMaPPer, a new red sequence cluster finder specifically designed to make optimal use of ongoing and near-future large photometric surveys. The algorithm has multiple attractive features: (1) it can iteratively self-train the red sequence model based on a minimal spectroscopic training sample, an important feature for high-redshift surveys. (2) It can handle complex masks with varying depth. (3) It produces cluster-appropriate random points to enable large-scale structure studies. (4) All clusters are assigned a full redshift probability distribution $P(z)$. (5) Similarly, clusters can have multiple candidate central galaxies, each with corresponding centering probabilities. (6) The algorithm is parallel and numerically efficient: it can run a Dark Energy Survey-like catalog in ~500 CPU hours. (7) The algorithm exhibits excellent photometric redshift performance, the richness estimates are tightly correlated with external mass proxies, and the completeness and purity of the corresponding catalogs are superb. We apply the redMaPPer algorithm to ~10,000 deg^2 of SDSS DR8 data and present the resulting catalog of ~25,000 clusters over the redshift range $z \in [0.08, 0.55]$. The redMaPPer photometric redshifts are nearly Gaussian, with a scatter $\sigma_z \approx 0.006$ at $z \approx 0.1$, increasing to $\sigma_z \approx 0.02$ at $z \approx 0.5$ due to increased photometric noise near the survey limit. The median value for $|\Delta z|/(1+z)$ for the full sample is 0.006. The incidence of projection effects is low ($\lesssim$5%). Detailed performance comparisons of the redMaPPer DR8 cluster catalog to X-ray and Sunyaev–Zel'dovich catalogs are presented in a companion paper.

Galaxy groups and clusters



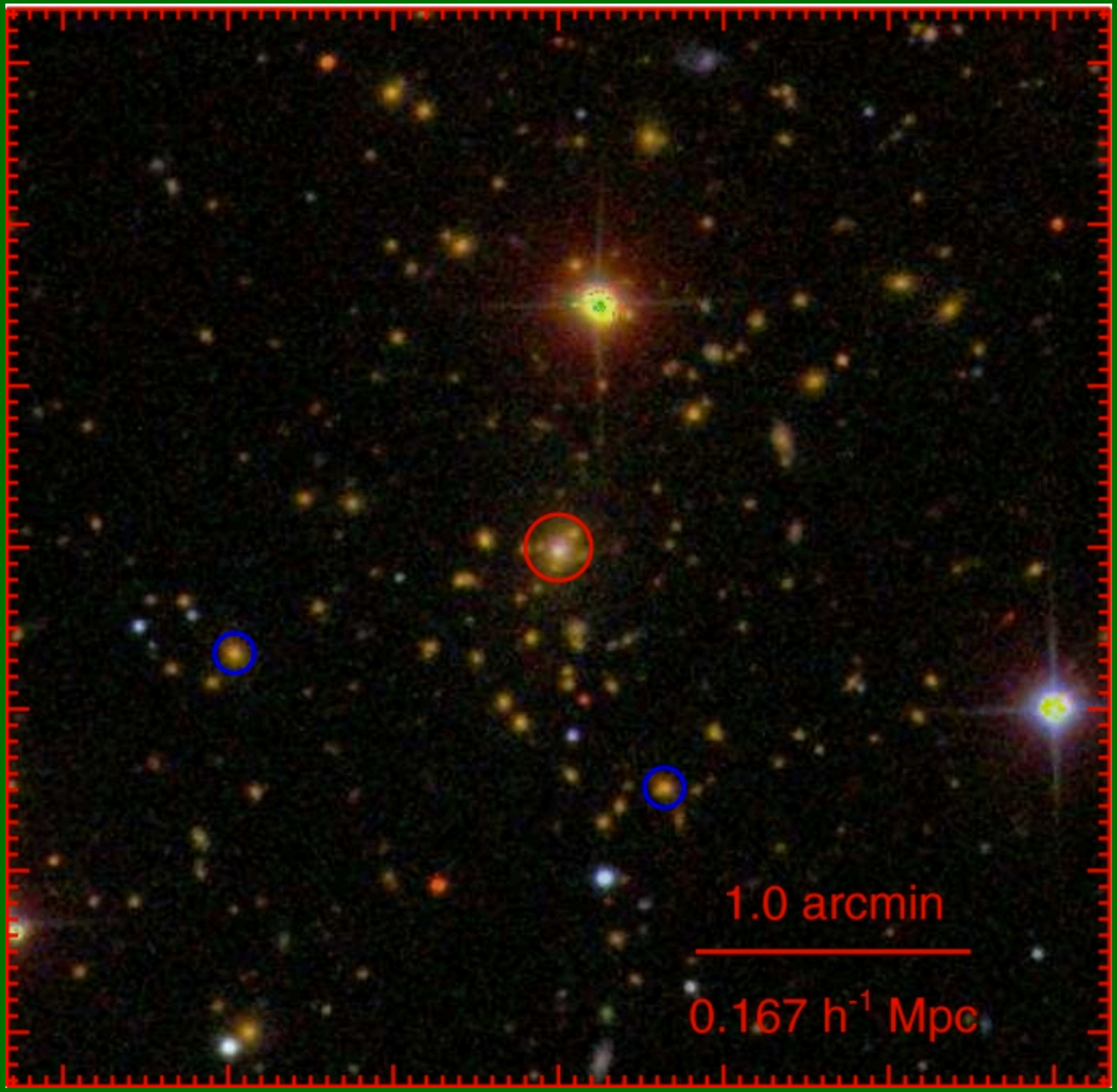
Rykoff et al. (2014)

Galaxy groups and clusters



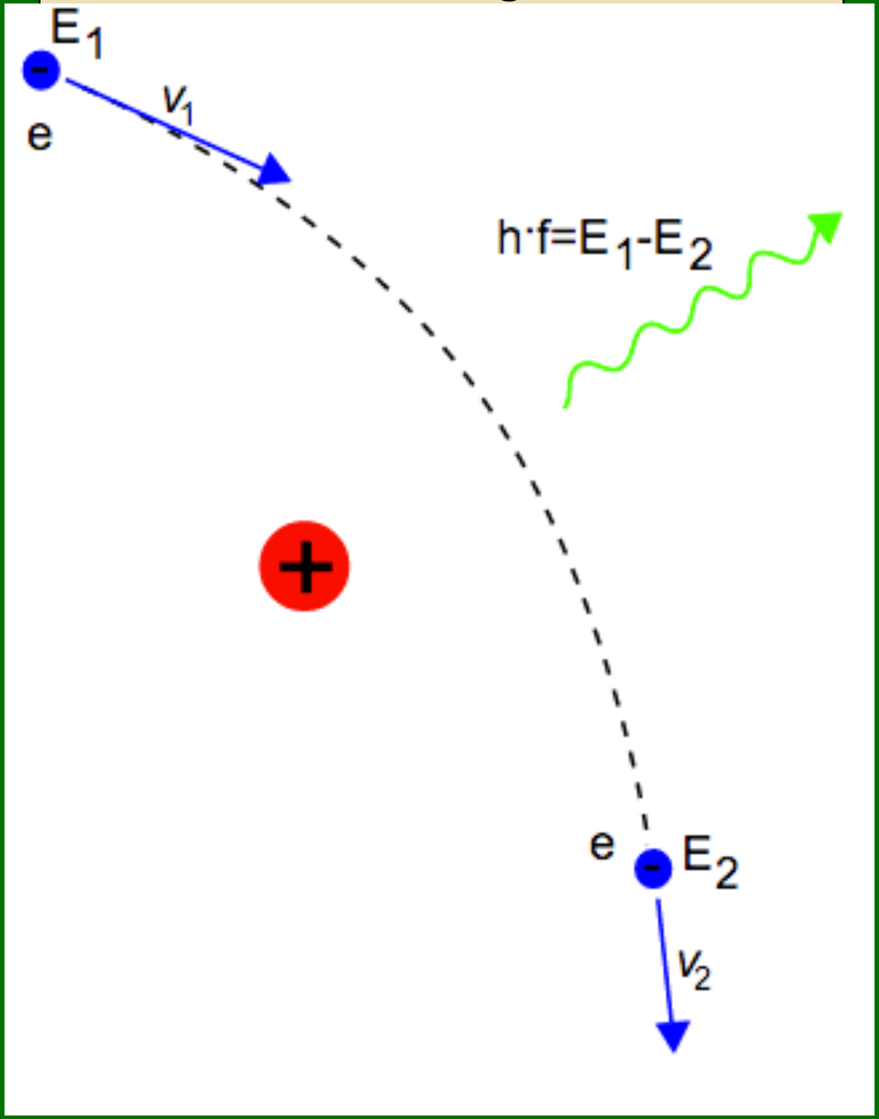
Rykoff et al. (2014)

Galaxy groups and clusters



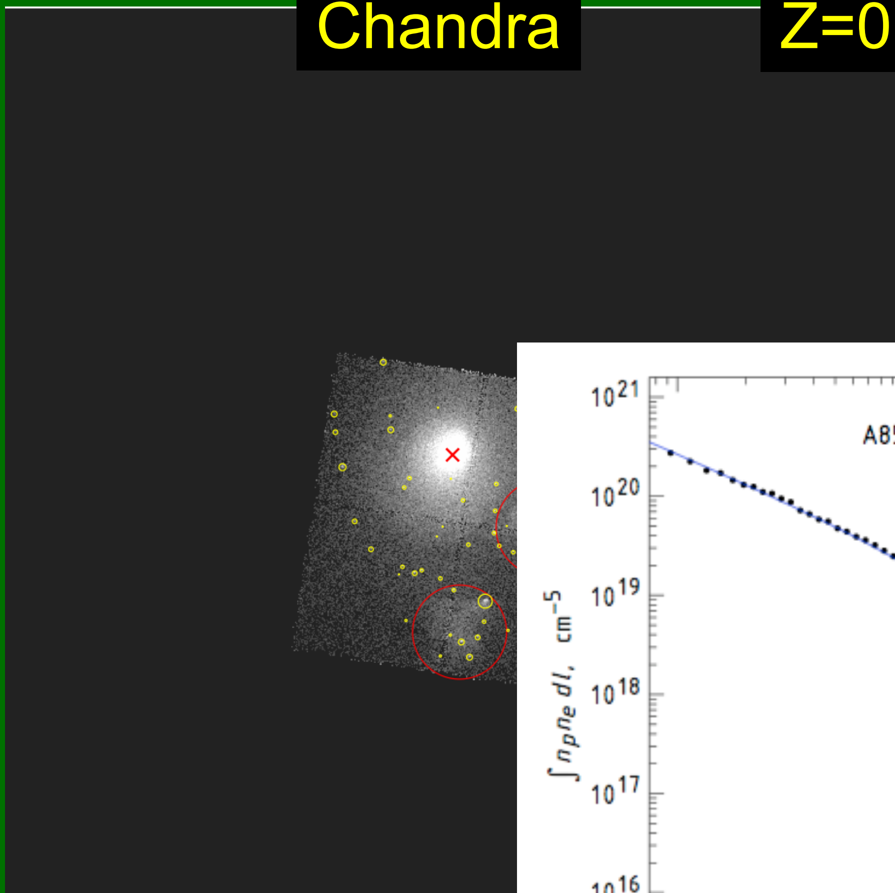
Rykoff et al. (2014)

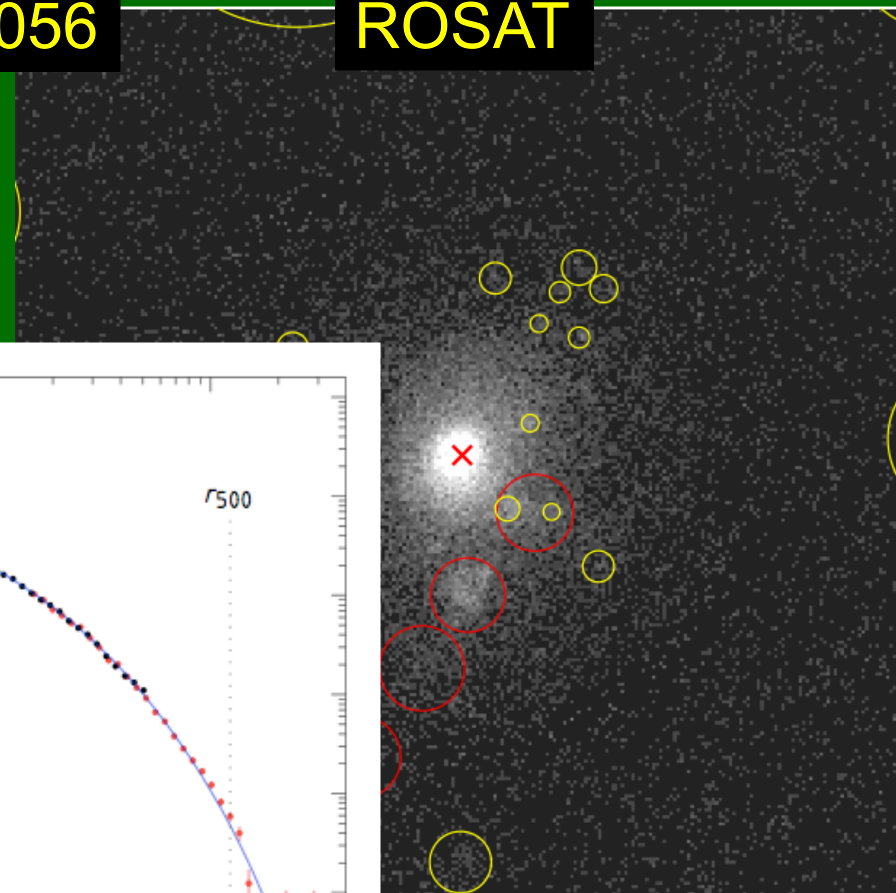
Bremmstrahlung Radiation

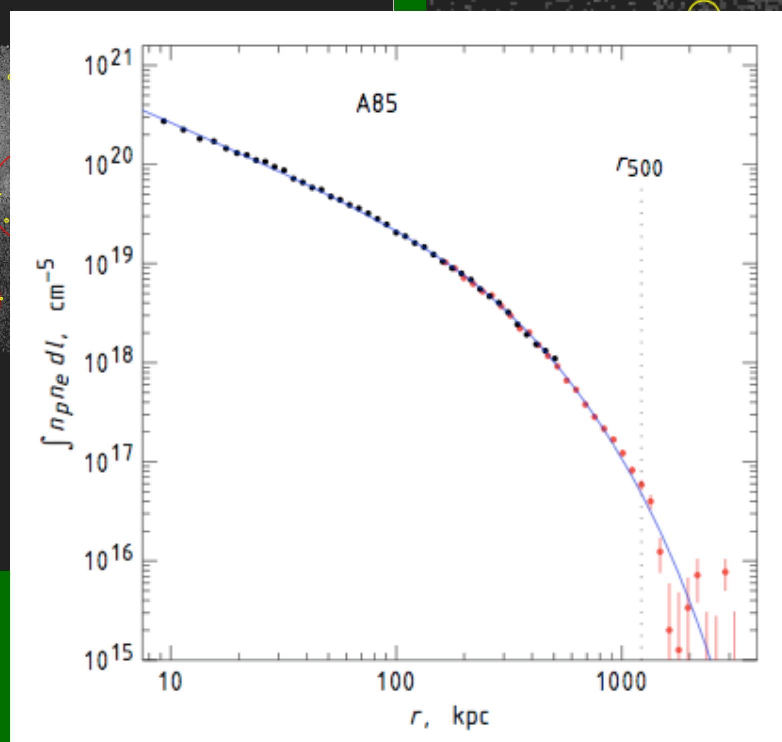


X-ray clusters

Chandra Z=0.056 ROSAT



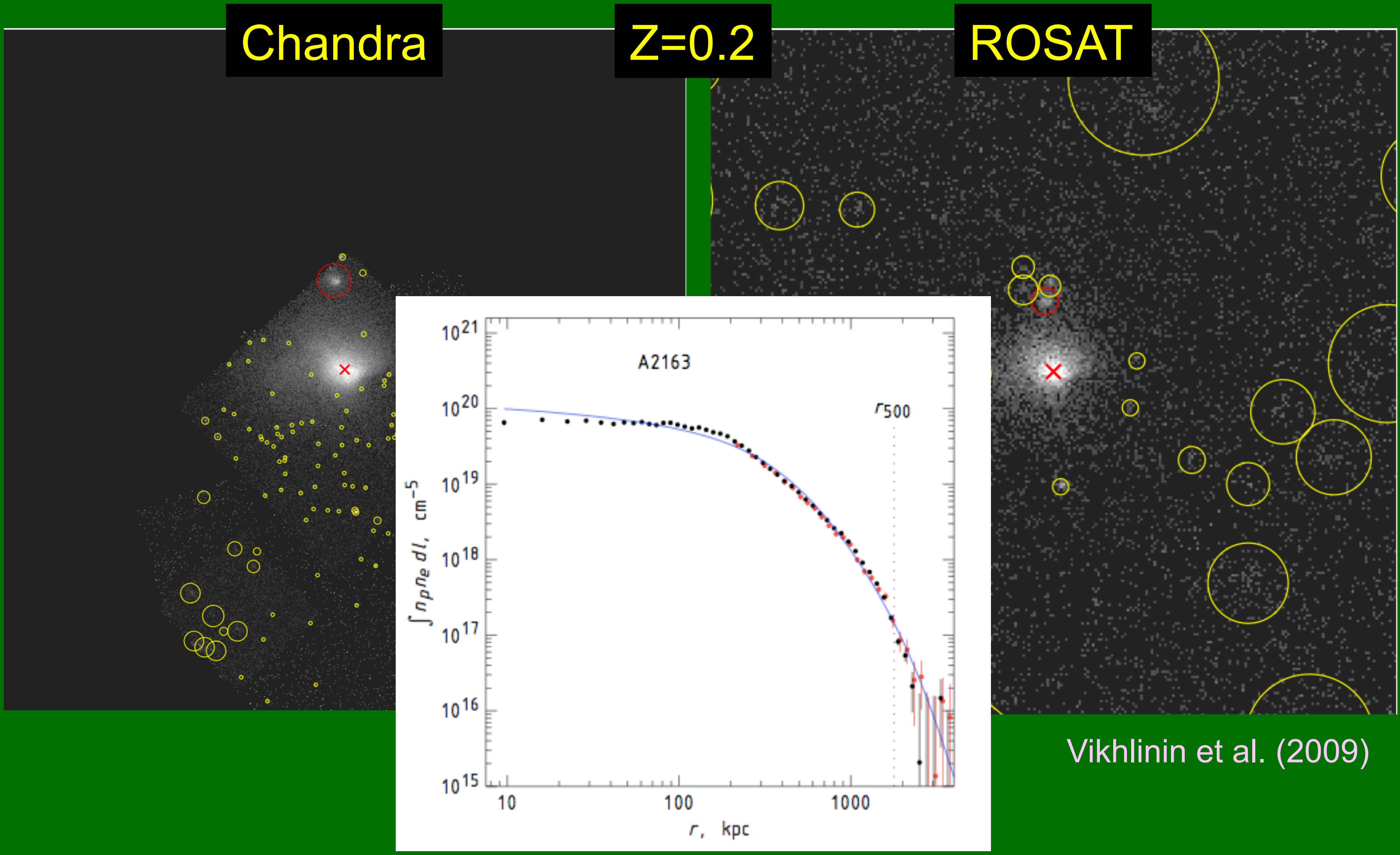




Vikhlinin et al. (2009)

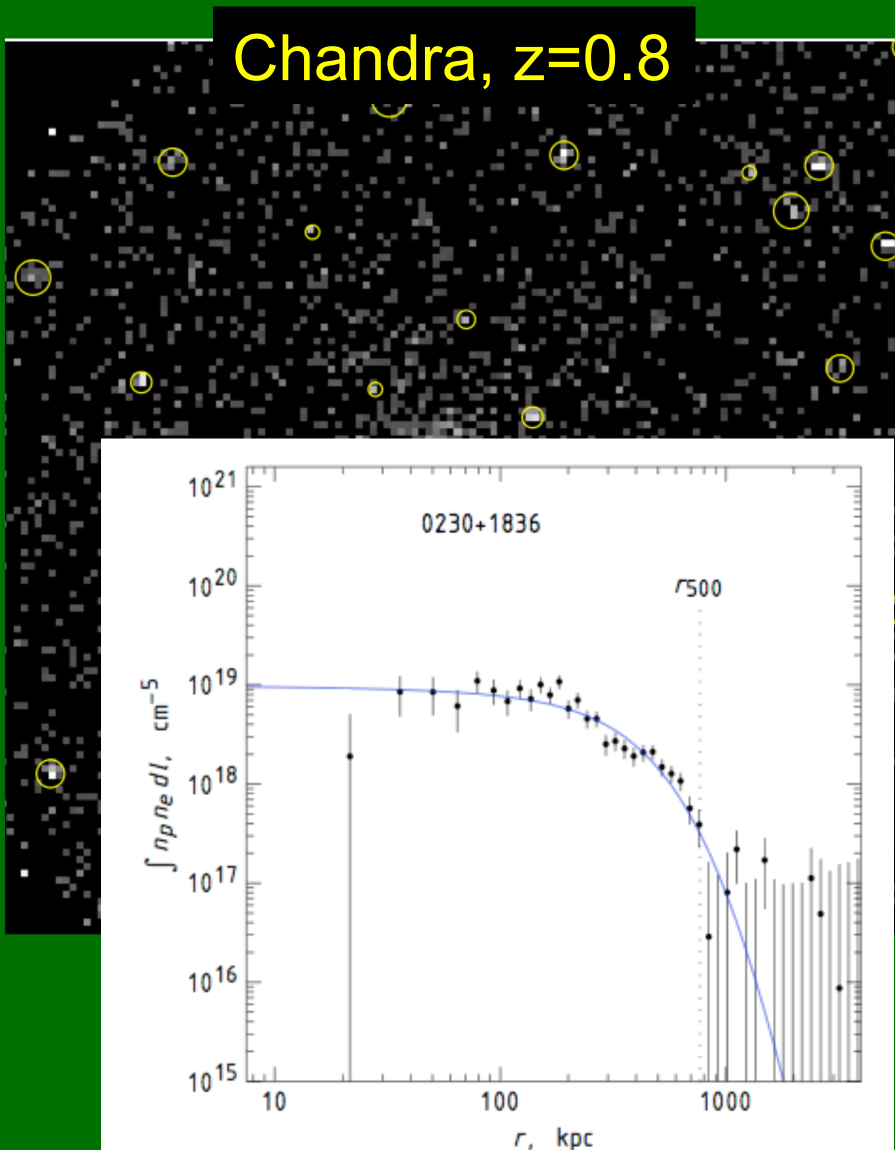
Galaxy groups and clusters

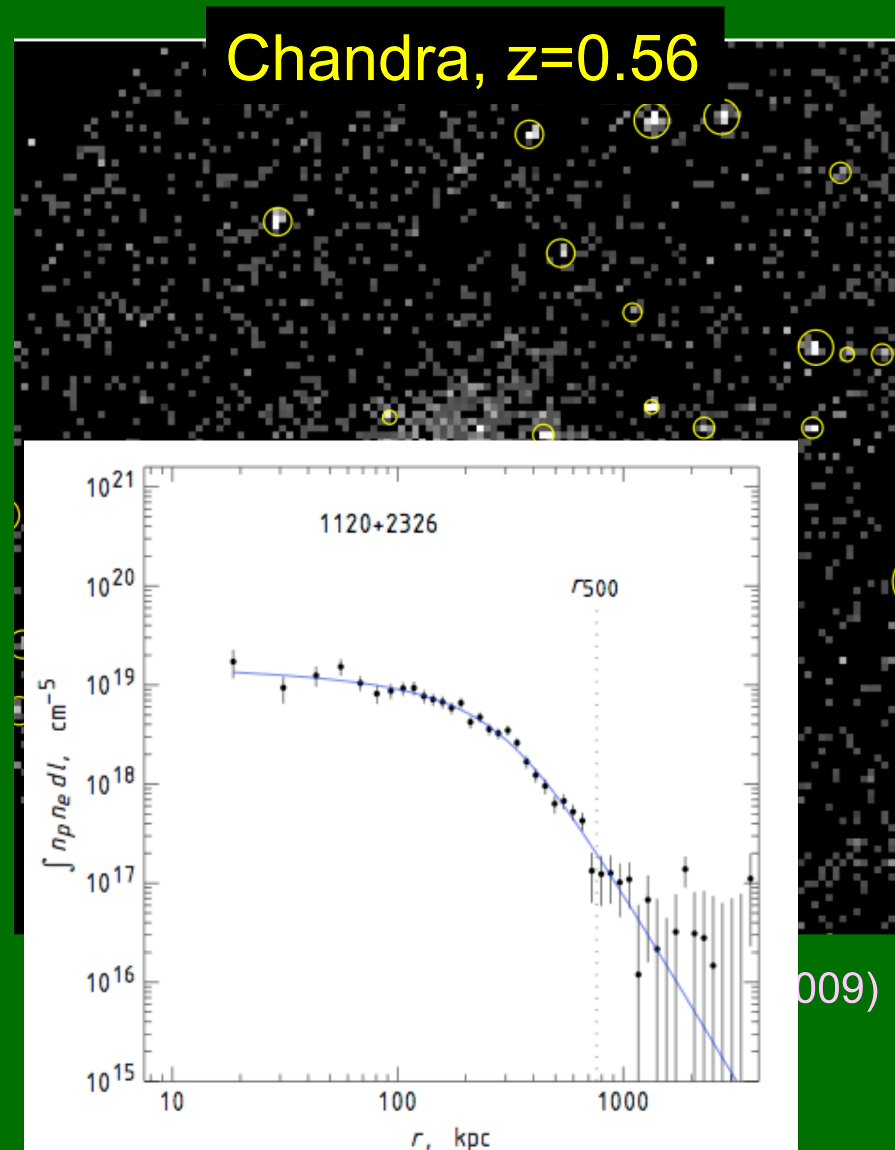
X-ray clusters



Vikhlinin et al. (2009)

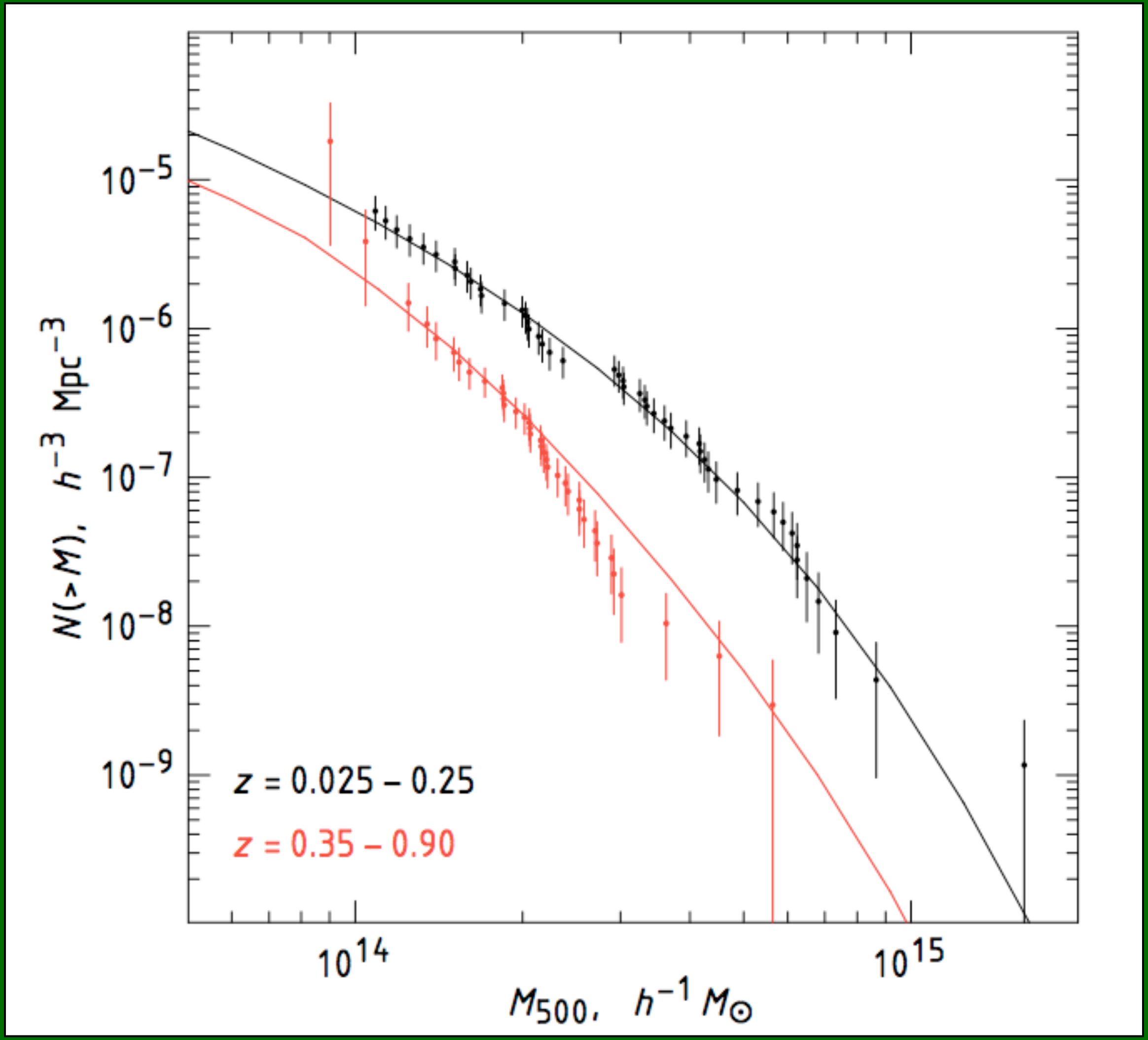
X-ray clusters





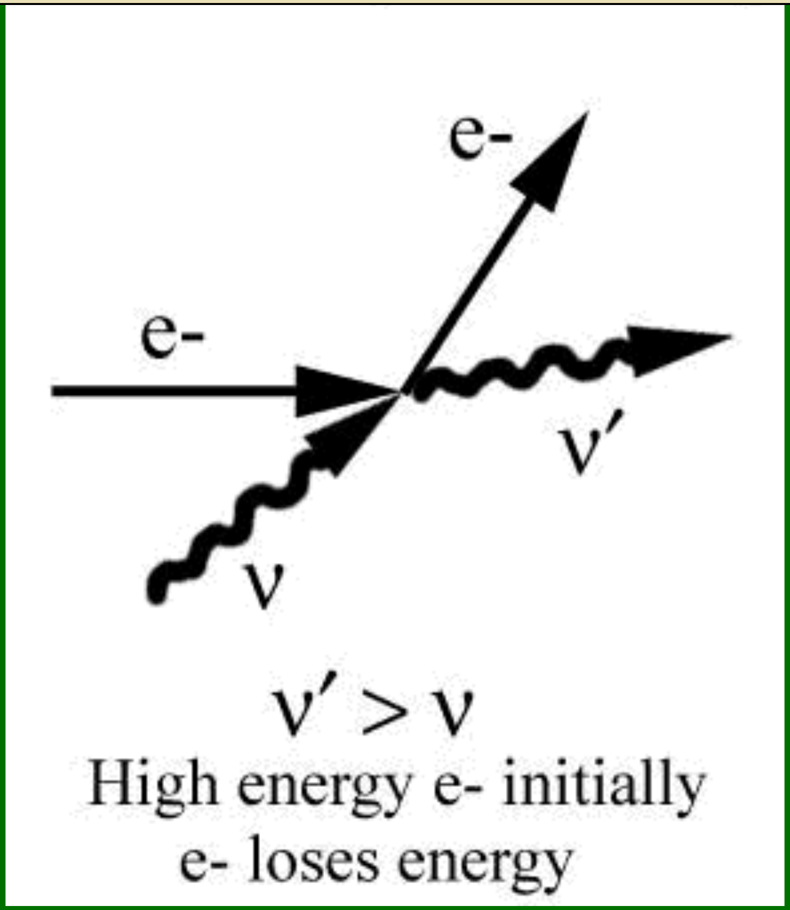
009)

X-ray clusters

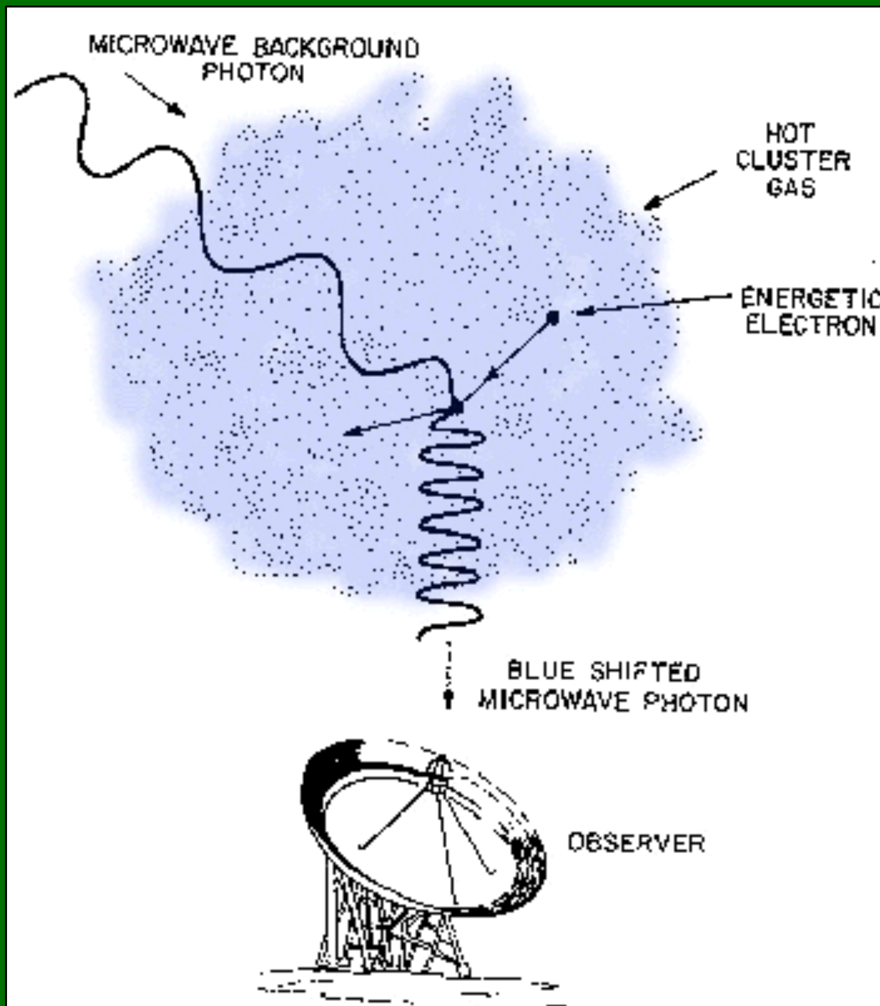


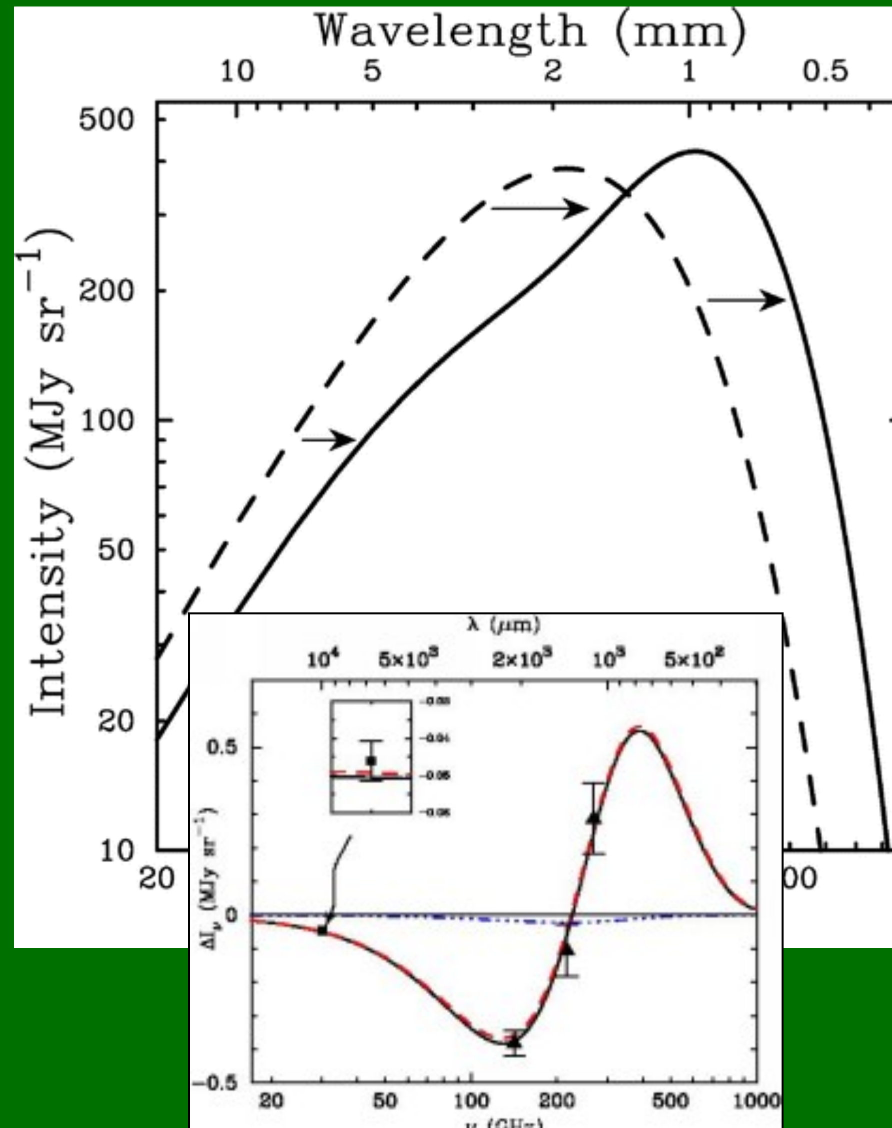
Vikhlinin et al. (2009)

Inverse Compton Scattering



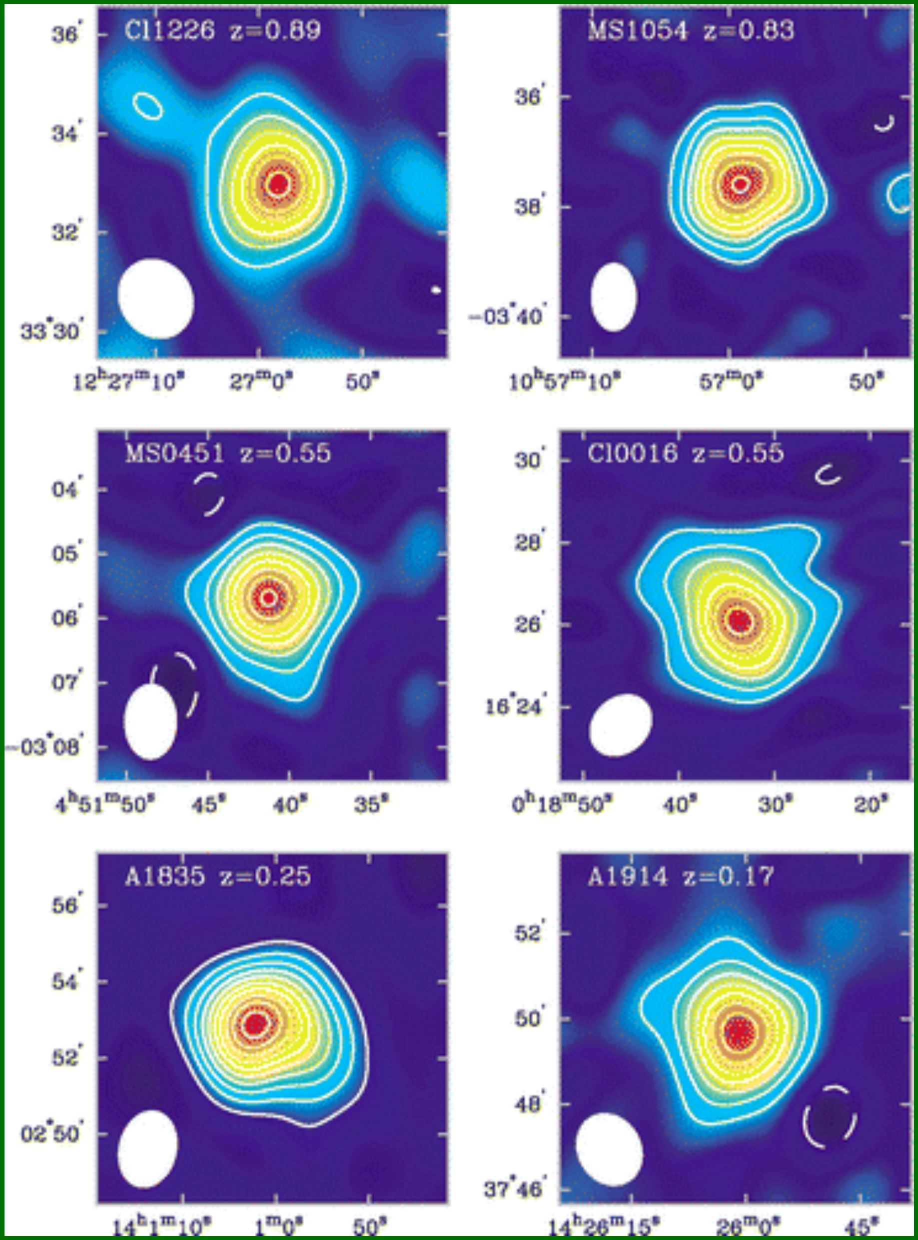
Sunayev-Zel' dovich effect





Carlstrom et al.

Galaxy groups and clusters



SZ clusters

Carlstrom et al.