Study environmental dependence of galaxy properties

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The reasons
Galaxies

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Hubble, 1926
Galaxies

Hubble, 1926

Lilly+, 1995
Red galaxies

Composite spectrum of elliptical galaxy

Blue galaxies

Composite spectrum of Sc/SBc/Scd/SBcd galaxy

Dodonov & Chilingarian 2008
Morphology - density relation

Fig. 9.—Composite projected number density profiles for spiral-rich (a), spiral-poor (b), and cD clusters (c). Spirals are denoted by stars; S0’s, by open circles; and ellipticals, by filled circles.

Dresser, 1980

Fig. 4.—The fraction of E, S0, and S+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.

Oemler, 1974
Morphology - density relation

Fig. 9.—Composite projected number density profiles for spiral-rich (a), spiral-poor (b), and cD clusters (c). Spirals are denoted by stars; S0's, by open circles; and ellipticals, by filled circles.

Oemler, 1974

Dresser, 1980

Kauffmann+, 2004
Feedback

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Fabian +, 2012
How AGNs can acts on physical parameters in galaxy clusters?
The observations
Observations on 1-m Schmidt Telescope

Telescope field of view with 4k x 4k CCD 58 x 58 arcmin, scale 0.868 arcsec/pixel. Observations were in four broad band filters (u, g, r and i SDSS) and in 15 medium band (FWHM=250 Å) filters. Total exposure time in filters were varied from 60 min to 120 min depending from the spectral sensitivity of the CCD.

<table>
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<th>Filter</th>
<th>$\lambda_{cen}$, Å</th>
<th>FWHM (Å)</th>
<th>$m_{lim,5\sigma}$</th>
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Medium band filters set used in observations. CCD spectral response included.
ROSAT survey in the HQS field HS47.5-22

48 overlapping PSPC pointings

574 X-ray sources

K. Molthagen+, 1997
Galaxies sample definition

Galaxies sample is extracted from the full catalog of objects (near 100000 objects) using following criteria:

- Objects brighter than $R_{AB}=23m$;
- Extended index < 0.8;
- Index of contamination ≤ 2.

Into the final sample follow first two criteria we include 39669 objects and after applying third one - we have 36447 objects with clean photometry. Due to the contamination we lose 8.12% of the objects.

We check sample completeness using comparison of galaxies number-counts in g, r and i SDSS filters from our sample with already published data.
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RA = 09h50m00s
DEC = +47d35m00s

Field  2.39 sq. deg.

36447 Galaxies
to R_{AB}=23^{m} with
clean photometry

574 ROSAT Objects
to 3.5*10^{-14} ergs
  cm^{-2}s^{-1}

362 FIRST Objects

293 SDSS QSO
SEDs Analysis

The photometric measurements from filters set provide low resolution spectra for each object which are analyzed by a statistical technique for classification and redshift estimation based on spectral template matching.

For SEDs analysis should be used:
- Stellar spectra library;
- Galaxies spectra library;
- QSO’s spectra library.

Priors for a galaxy with given magnitude having redshift \( Z \).

Star – Galaxy morphology classification index.

As a result we get a probability that object with given SED classified as galaxy or QSO, or Star with known spectral type and redshift.
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Spectral Energy Distribution vs SDSS Spectra

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Comparison between photometric redshifts \(Z_{\text{ph}}\) obtained with ZEBRA in Maximum Likelihood mode with SDSS spectroscopic redshifts \(Z_{\text{sp}}\) along with error distribution \(\Delta Z/(1+Z)\) for all galaxies with known spectroscopic redshifts.

Obtained accuracy \(\sigma_z < 0.028\) and fraction of catastrophic outliers \((\Delta Z/(1+Z) > 0.2) \sim 2.4\%\). Accuracy \(\sigma_z\) changes from 0.011 in magnitude range \(r_{\text{SDSS}} = 16 \text{m} - 20 \text{m}\) till 0.066 in magnitude range \(r_{\text{SDSS}} = 21 \text{m} - 23 \text{m}\).
HS 47.5 + 22 is deep wide homogeneous field (2.386 sq. deg.) with determined x-ray and radio sources in the field. There is only one more the same field (COSMOS field).
The data analysis
Group and clusters of galaxies. First catalogs

THE DISTRIBUTION OF RICH CLUSTERS OF GALAXIES*

GORE O. ABELL†
Mount Wilson and Palomar Observatories
Carnegie Institution of Washington, California Institute of Technology
Received September 30, 1957; revised November 13, 1957

ABSTRACT

A catalogue is prepared of 2712 rich clusters of galaxies found on the National Geographic Society–Palomar Observatory Sky Survey. From the catalogue, 1682 clusters are selected which meet specific criteria for inclusion in a homogeneous statistical sample. An investigation of the sample leads to the following conclusions: (1) the distribution function rapidly as \( n \) decreases; (2) the data allow no significant varies with distance; (3) galactic obscuration of the ori at high northern galactic latitudes around galactic lo random surface distribution of clusters, both when ch distances are considered. An analysis of the distrib second-order clusters, that is, clusters of clusters of gal between the observed distribution and one of comple
Group and clusters of galaxies. First catalogs

Fig. 1. Subset of galaxy counts from COSMOS scans of a photographic plate with the count resolution being 5' × 5'.

Fig. 2. Distribution of galaxies detected down to $B = 21.5$ in field 411 of the ESO/SERC Southern Sky survey. Hatched areas represent areas of the data in which the galaxy numbers are below the overall mean level of 8 (from counts in 5' × 5'). The first isoplethal level is at the mean level, and subsequent isopleths are at intervals of three galaxies per cell thereafter.
Methods

1. X-ray emission from hot gas
Methods

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2. Sunyaev–Zel’dovich effect in the CMB
Methods

1. X-ray emission from hot gas

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3. Cosmic shear due to weak gravitational lensing
Methods

1. X-ray emission from hot gas

2. Sunyaev–Zel’dovich effect in the CMB

3. Cosmic shear due to weak gravitational lensing

4. Galaxy overdensities in optical, near-infrared or mid-IR images
Algorithms (short, incomplete, subjective sample)

1. Counting objects projected onto the field (Shectman +, 1985; Dodd, MacGillivray, 1986)

2. Comparing the distribution functions of objects with Poisson distribution (Limber+, 1953; Neyman & Scott, 1955)

3. Cluster analysis:
   - Minimal spinning tree (Barrow, 1985)
   - Friend-of-friends (More+, 2011)
   - Comparison of correlation functions (Maller+, 2005)

4. Filtering algorithms (Kovac+, 2009)

5. Voronoi diagrams (Ramela+, 2001)
Mock catalogs

**MICECAT v2** galaxy mock:
- ~200 million galaxies
- over 5000 sq. deg
- up to a redshift $z=1.4$

**We use:**
- 10 samples
- 2 sq. deg.
- $R_{ab}=23$ threshold magnitude
- up to a redshift $z=0.8$

Fosalba et al. 2013a,b; Crocce et al. 2013; Castander et al. 2014; Carretero et al. 2014
Basic statistics

Real group catalogue

Reconstructed group catalogue

field galaxy

undetected group

real group

reconstructed group

1-way-match

2-way-match

fragmentation

spurious group

over-merging

Knobel +, 2010
Basic statistics

Completeness:

\[ c_1 = \frac{N_{\text{real}}^{\text{gr}} \rightarrow N_{\text{rec}}^{\text{gr}}}{N_{\text{real}}^{\text{gr}}} \], \quad c_2 = \frac{N_{\text{real}}^{\text{gr}} \leftrightarrow N_{\text{rec}}^{\text{gr}}}{N_{\text{real}}^{\text{gr}}} \]

Purity:

\[ p_1 = \frac{N_{\text{rec}}^{\text{gr}} \rightarrow N_{\text{real}}^{\text{gr}}}{N_{\text{rec}}^{\text{gr}}} \], \quad p_2 = \frac{N_{\text{rec}}^{\text{gr}} \leftrightarrow N_{\text{real}}^{\text{gr}}}{N_{\text{rec}}^{\text{gr}}} \]

Galaxy Success Rate:

\[ S_{\text{gal}} = \frac{S_{\text{real}}^{\text{gal}} \cap S_{\text{rec}}^{\text{gal}}}{S_{\text{real}}^{\text{gal}}} \]

Interloper fraction:

\[ f_I = \frac{S_{\text{rec}}^{\text{gal}} \cap S_{\text{field}}^{\text{gal}}}{S_{\text{rec}}^{\text{gal}}} \]

- \( N_{\text{real}}^{\text{gr}} \) - the number of real groups, \( N_{\text{rec}}^{\text{gr}} \) - the number of reconstructed groups;
- \( N_{\text{real}}^{\text{gr}} \rightarrow N_{\text{rec}}^{\text{gr}} \) - the number of associations of real groups to reconstructed groups;
- \( N_{\text{rec}}^{\text{gr}} \rightarrow N_{\text{real}}^{\text{gr}} \) - the number of associations of reconstructed groups to real groups;
- \( S_{\text{real}}^{\text{gal}} \) - the set of galaxies associated to real groups;
- \( S_{\text{rec}}^{\text{gal}} \) - the set of galaxies associated to reconstructed groups;
- \( S_{\text{field}}^{\text{gal}} \) - the set of real field galaxies.
Filtering algorithm with adaptive kernel

Width of redshift slice:  \( \Delta z = 0.01 \cdot (1 + z) \pm 25\% \)

Density of galaxies distribution:

\[ \delta_i = \frac{s}{4/3 \pi R^3} \]

where \( s \) is the number of the nearest neighbor, \( R \) is the distance for the nearest neighbor.

Mean density in slice:

\[ \overline{\delta} = \frac{1}{n} \sum_{i=1}^{n} \delta_i , \]

where \( n \) is overall number of galaxies in slice.

Density contrast:

\[ \sigma_i + 1 = \frac{(\delta_i - \overline{\delta})}{\overline{\delta}} + 1 \]
Filtering algorithm with adaptive kernel. 2D

\[ N_{\text{neighbor}} = 2 \]

\[ N_{\text{neighbor}} = 5 \]
Filtering algorithm with adaptive kernel. 2D

\[ N_{\text{neighbor}} = 7 \]

\[ N_{\text{neighbor}} = 8 \]
Filtering algorithm with adaptive kernel. 2D

\[ N_{\text{neighbor}} = 10 \]  \hspace{2cm}  \[ N_{\text{neighbor}} = 20 \]
Filtering algorithm with adaptive kernel. 3D

\[ 0.268 < z < 0.287 \]
Filtering algorithm with adaptive kernel. 3D

$0.268 < z < 0.287$
Voronoi diagrams

Density contrast:

\[
\sigma_i = \frac{(\delta_i - \bar{\delta})}{\bar{\delta}}
\]

Mean density in slice:

\[
\bar{\delta} = \frac{1}{n} \sum_{i=1}^{n} \frac{1}{A_i},
\]

where \( A_i \) – is the area of the Voronoi cell around object i and n is the overall number of objects.
Statistics for mock catalogs

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Filtering algorithm with adaptive kernel. 2D. HS 47.5 + 22 field
Filtering algorithm with adaptive kernel. 3D. HS 47.5 + 22 field

Detected cluster MSPM 01061 (Smith +, 2012)

$z_{\text{spec}} = 0.03282$
Conclusion

- We have tested multilateral analysis methods for large-scale distribution of galaxies.
- We explored the photometric properties of the sample of 36447 galaxies at the field HS47.5-22 and obtained spectral types and photometric redshifts for all objects.
- An accuracy of the redshift allows to determine an accessory of a galaxy to a cluster or a group.
- Based on the our photometric data we obtained maps of the contrast of density distribution with adaptive kernel algorithm (2D, 3D) and Voronoi tessellations (2D).

The main goal of our investigation is a study of the connection between star formation rate in galaxies and their position in the large scale distribution.