CLUSTERING ON BL LACS ENVIRONMENTS

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Outline

- Introduction
  - AGNs
  - Blazars
  - Radio galaxies
  - Unification scenario

- Environments
  - FR Is and BL Lacs
  - Clustering methods

- Optical Campaign

Introduction: AGNs

Active Galactic Nuclei: most massive and luminous compact objects in the Universe.

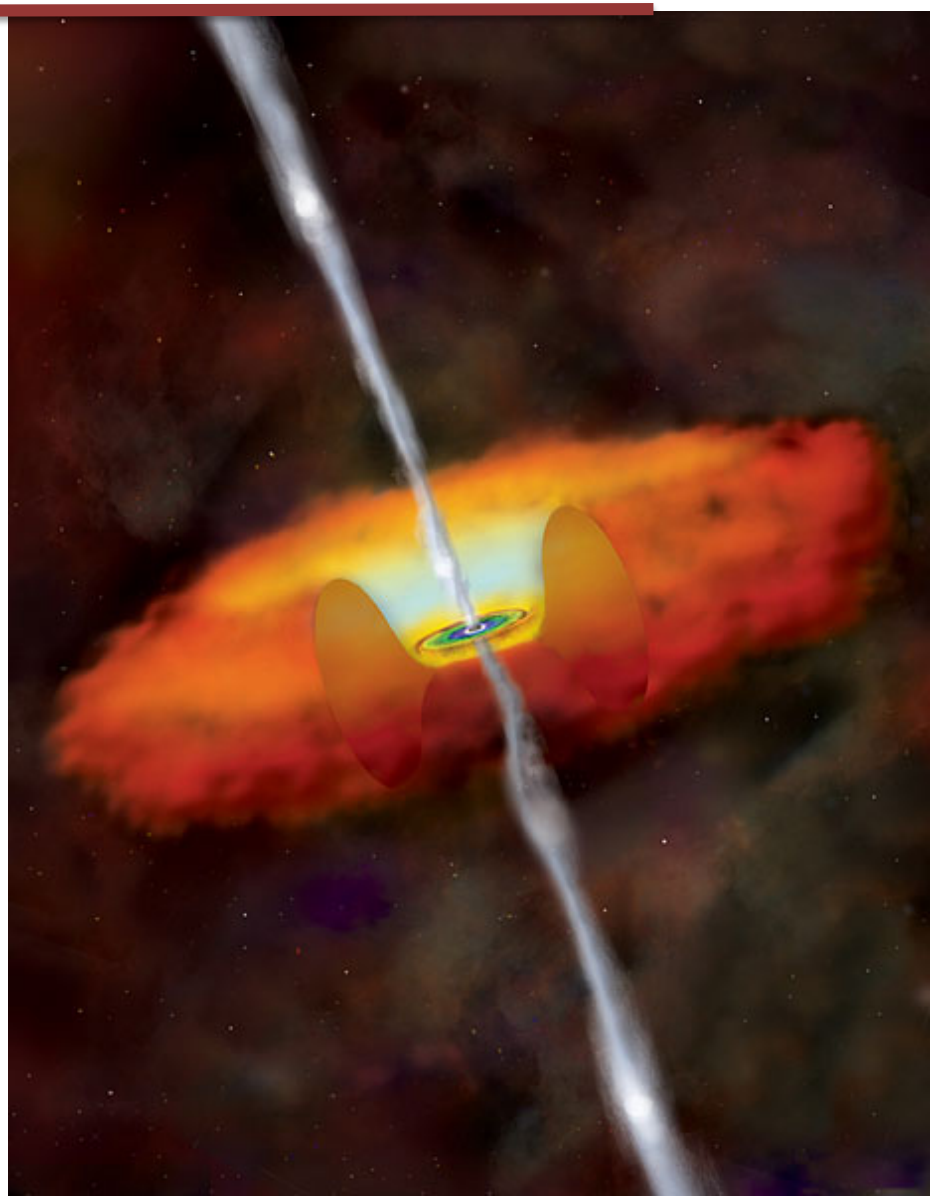
Central engine: accretion onto a supermassive rotating black hole (~ 10^6 M_{sun} up to 10^{10} M_{sun}).

Jets: relativistic outflows.

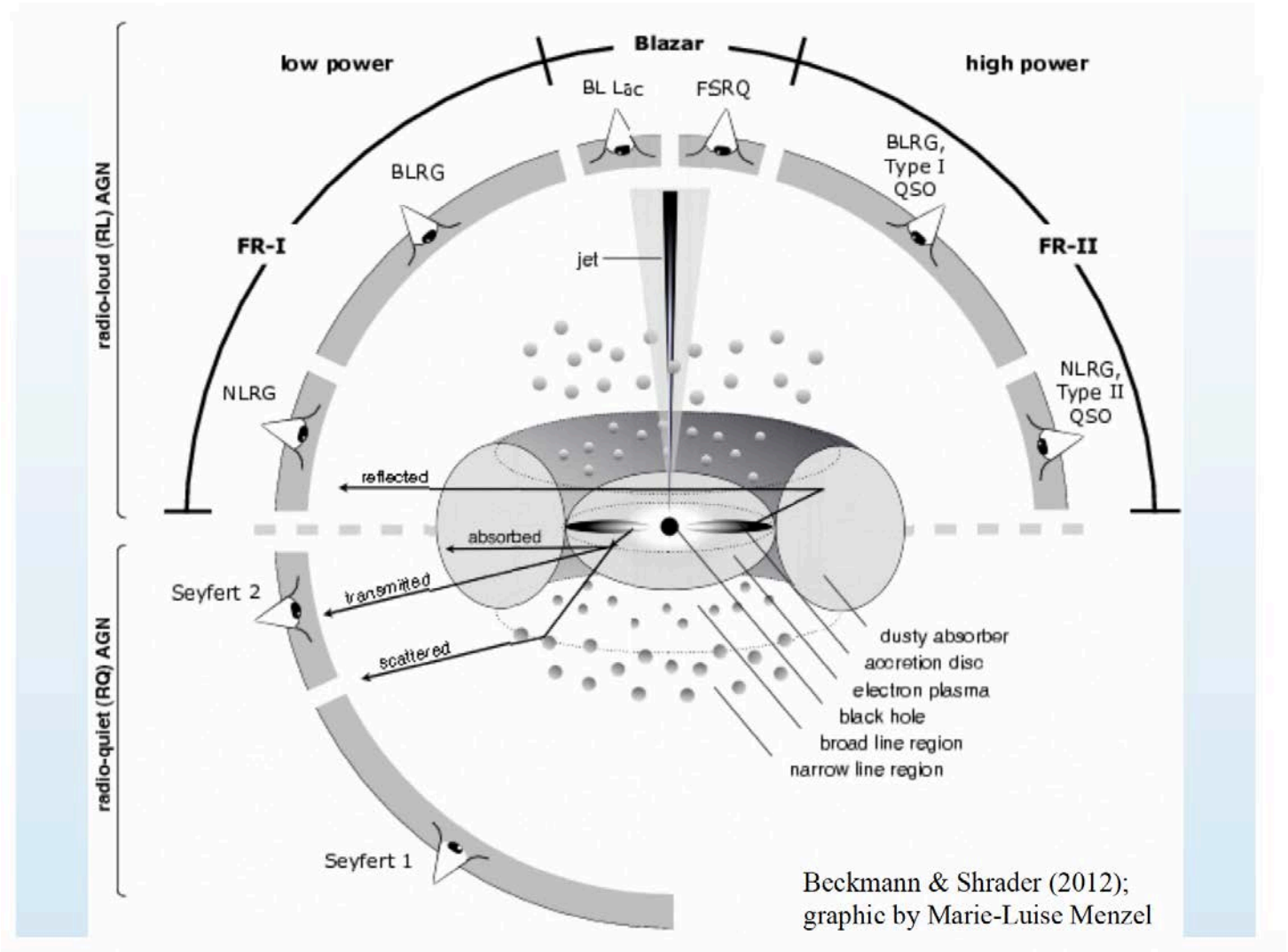
Radiative efficient: most of the energy is radiated away

Bright (10^{41} - 10^{48} erg/sec) and point-like (<<100 pc).

Appearance depends on orientation: **Unification model**



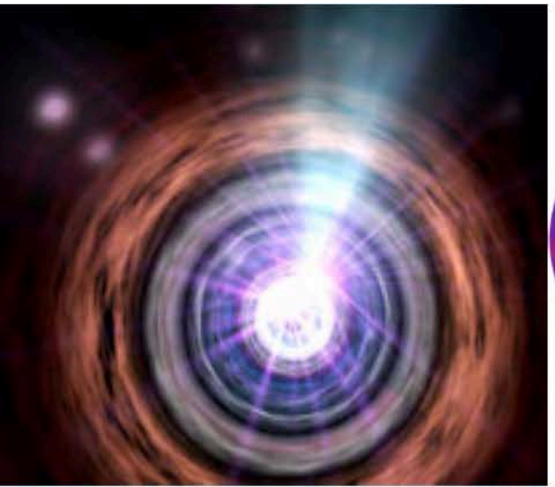
Introduction: Unification model

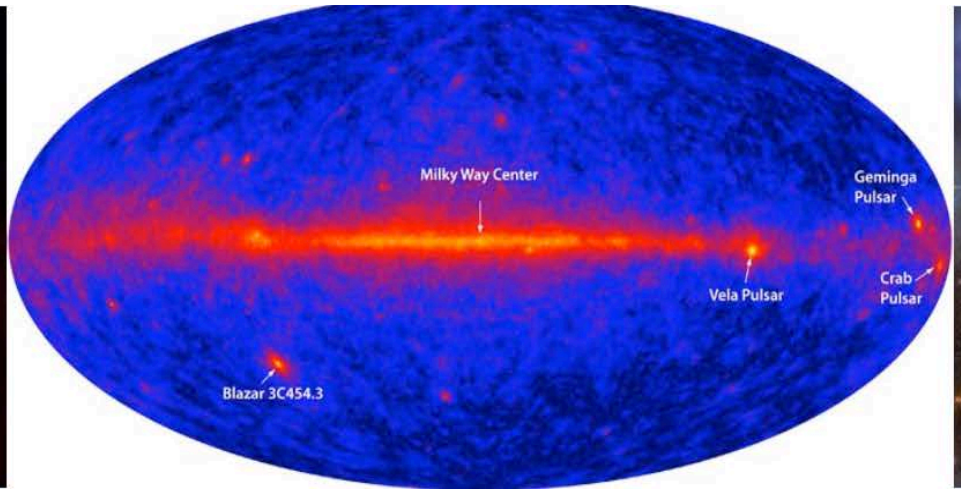


Beckmann & Shrader (2012); graphic by Marie-Luise Menzel

Introduction: blazars

- Rarest class of AGNs.
- Jet pointing towards the observers line of sight.
- Radio loud. Compact.
- Relativistic beaming.
- High and variable polarization.
- Strong non-thermal emission over the entire electromagnetic spectrum.
- High luminosities.





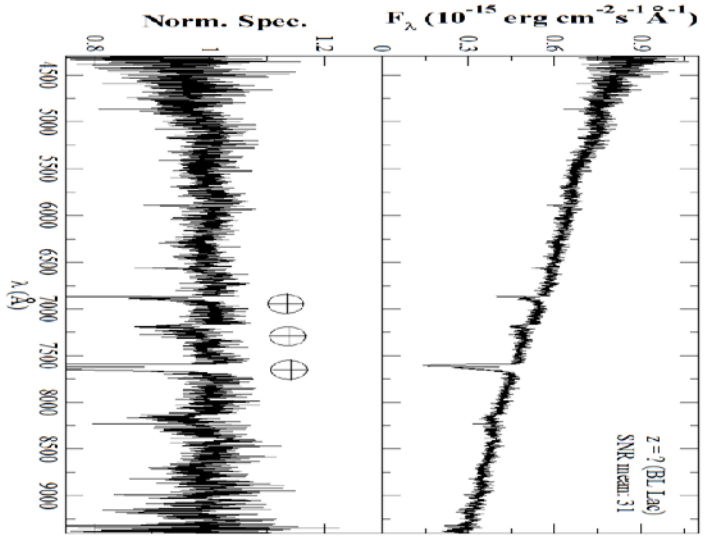
Introduction: blazar classification

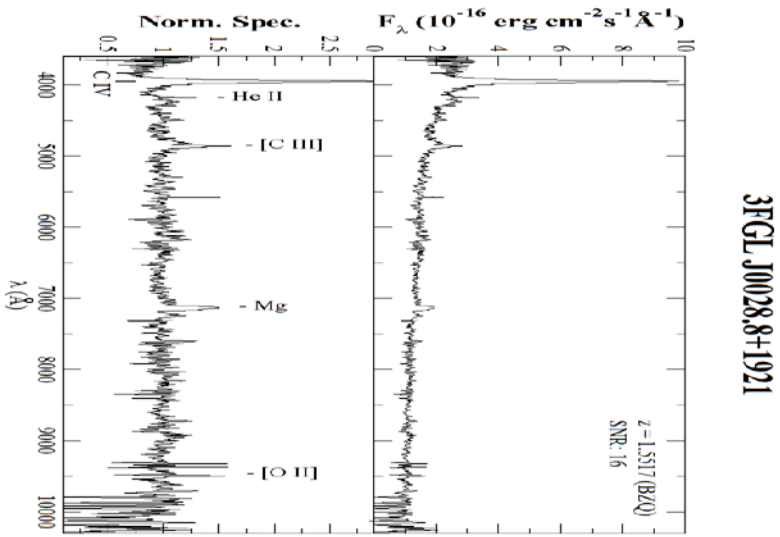
BL Lacertae Objects (BL Lac):

- $L \leq 10^{46}$ erg/s
- Continuum non-thermal radiation
- Spectral features EW < 5 Å

Flat Spectrum Radio Quasars (FSRQs):

- $L \leq 10^{48}$ erg/s
- Flat radio spectra
- Broad emission lines (EW > 5 Å)
- More distant.





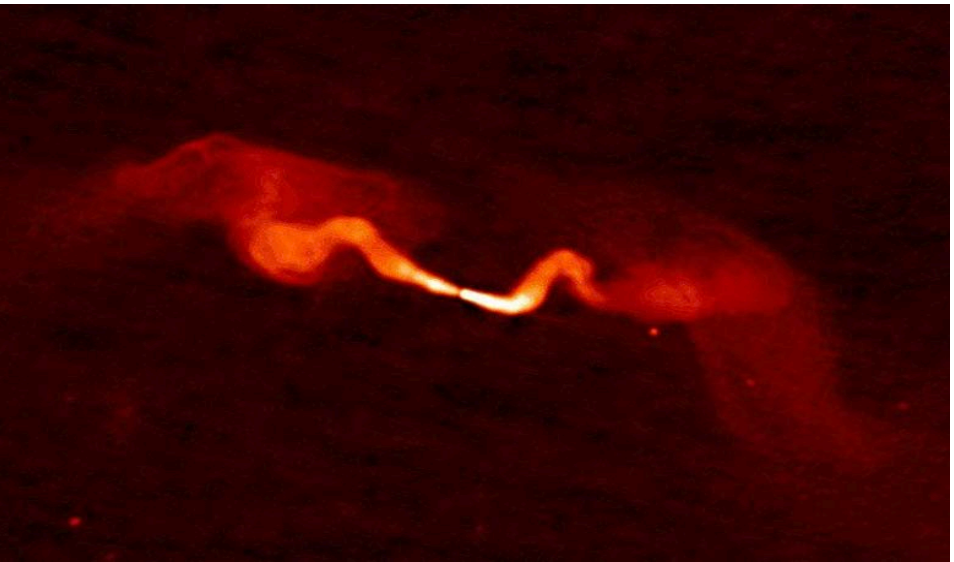
Introduction: radio galaxies. Fanaro-Riley morphological types

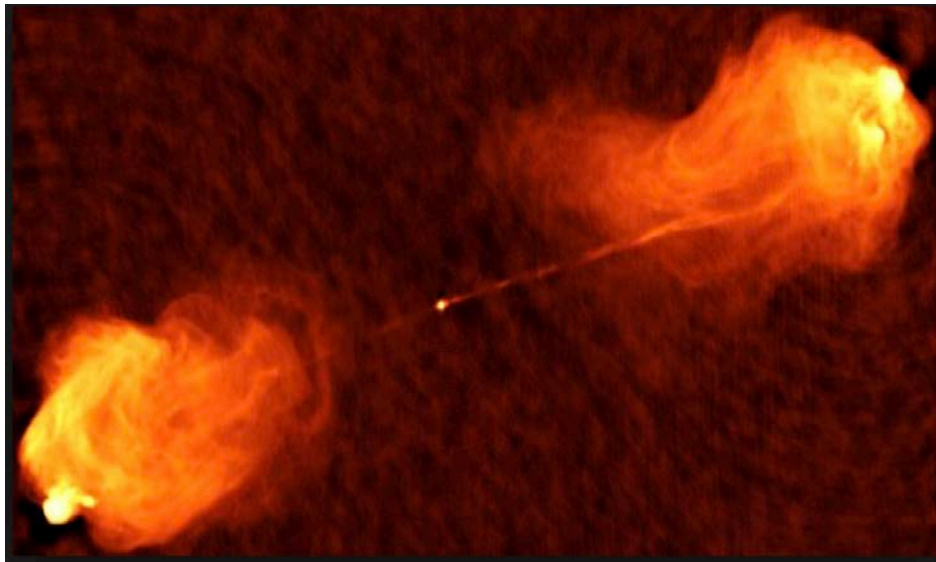
FR I:

- Low power
- Intensity radio jets falls away from the nucleus
- Launched relativistically but decelerate interaction with the environment

FR II:

- High power
- Radio lobes with prominent hot spots and bright outer edges.
- Optical emission lines one order stronger than FR Is.





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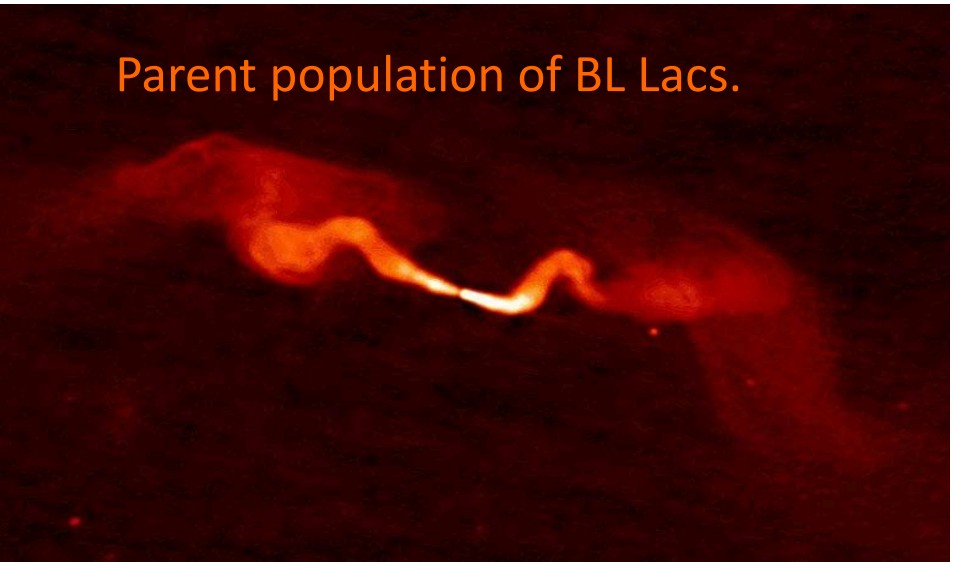
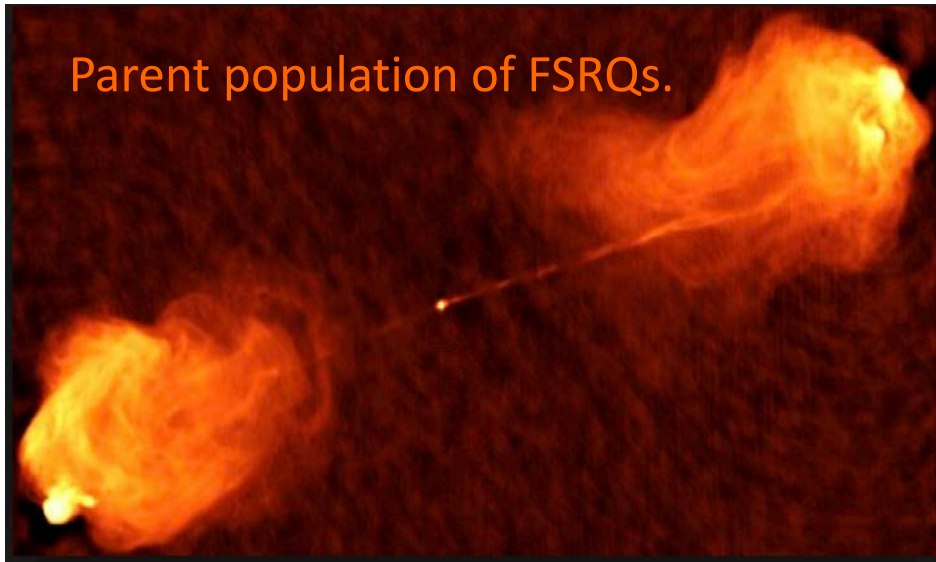




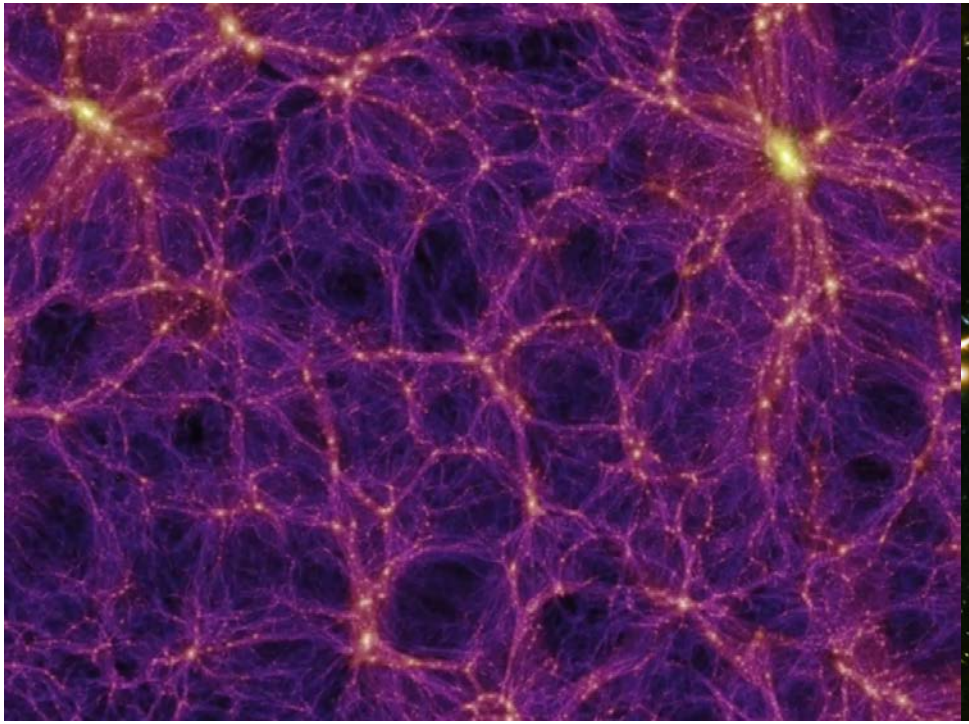
Introduction: Galaxy clusters

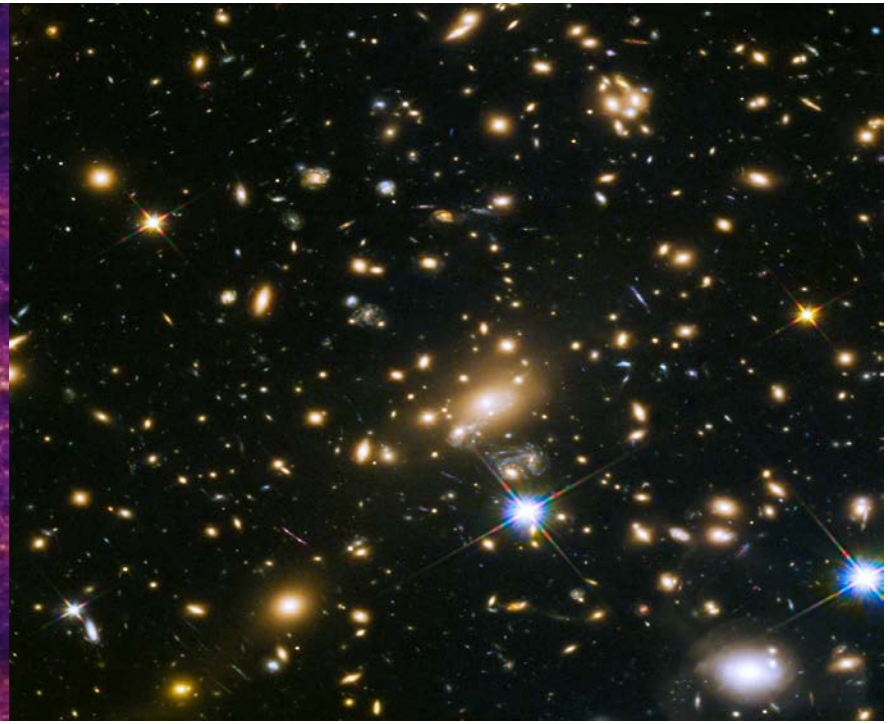
Clusters of galaxies are usually located at the knots of the filamentary structures in the universe.

Largest gravitationally bound objects in the universe.

Typically composed from thirty to thousands of galaxies.

Most of the galaxies are **elliptical**.





Environments: Radio galaxies and blazars

FRIs – BL Lacs both reside in giant elliptical galaxies.

FR Is tend to inhabit moderately rich cluster environments (30 - 80 galaxies) in which they are sometimes the first ranked ellipticals.

Previous studies for BL Lacs are only for a few individual sources and contradictory sometimes. An statistical study has never been performed.

Environments: Goal

If FR Is are the parent population of BL Lacs, they must reside in the same environments→ clusters of Abell richness class 0 (30 – 49 galaxies), 1 (50 – 79 galaxies).

Statistical study of all known BL Lacs (BZCAT): clustering methods.

Redshift unknown: New method to assign redshift to BL Lacs.

Clustering

Cluster analysis divides data into groups (cluster) that are meaningful.

Clustering method: statistical procedure that reorganize a data set into relatively homogeneous groups

Different methods can and do generate different solutions

We use different methods looking for consistence for our results.

A set of data points

A clustering with Two Clusters

A clustering with Four Clusters

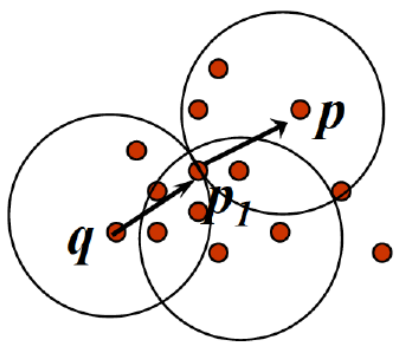
A clustering with Six Clusters

DBSCAN: Density Based Spatial Clustering of Applications with Noises

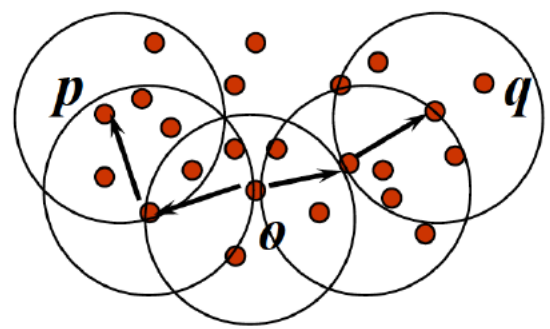
Two points are on the same cluster if they are density reachable and density connected.

Input parameters: Radius “Eps” and MinPts

If a point is not density reachable neither density connected it is noise.



(a) dbscan density reachable



(b) dbscan connected reachable

DBSCAN

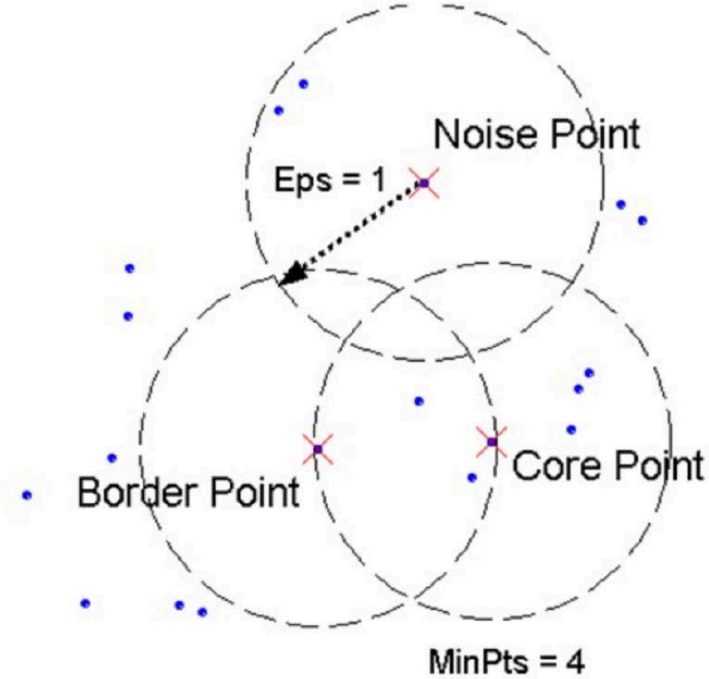
Basic DBSCAN algorithm:
1. Arbitrary select a point p.
2. Retrieve all points density-reachable from p with Eps and MinPts.
3. If p is a core point, a cluster is formed.
4. If p is a border point, no points are density-reachable form p and DBSCAN goes to the next point of the database.
5. Continue the process until all of the points have been processed.

Strengths:

- Resistant to noise.
- Clusters of arbitrary shapes and sizes.

Weaknesses:

- Troubles when the clusters have varying densities.
- Trouble with high dimensional data.
- Strongly initial parameter dependent.



CLIQUE: Clustering with QUEst

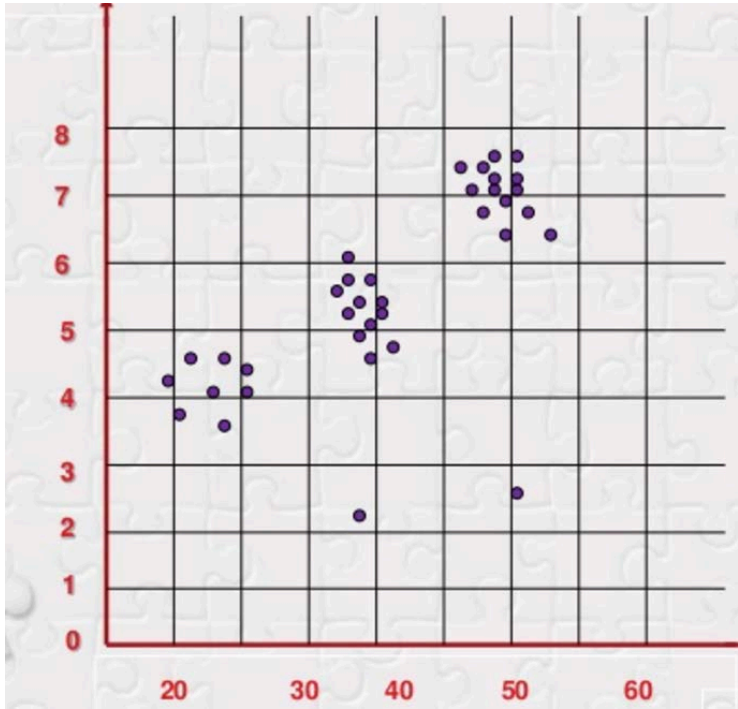
Grid-based clustering. Space into a finite number of cells that form a grid structure on which all the operations for clustering is performed.

Input parameters: Number of cells and MinDensity.

Unit: each cell of the grid.

Dense: a unit is dense if the fraction of total data points in a unit exceeds the input model parameter.

Cluster: maximal set of connected dense units.



CLIQUE

Strengths

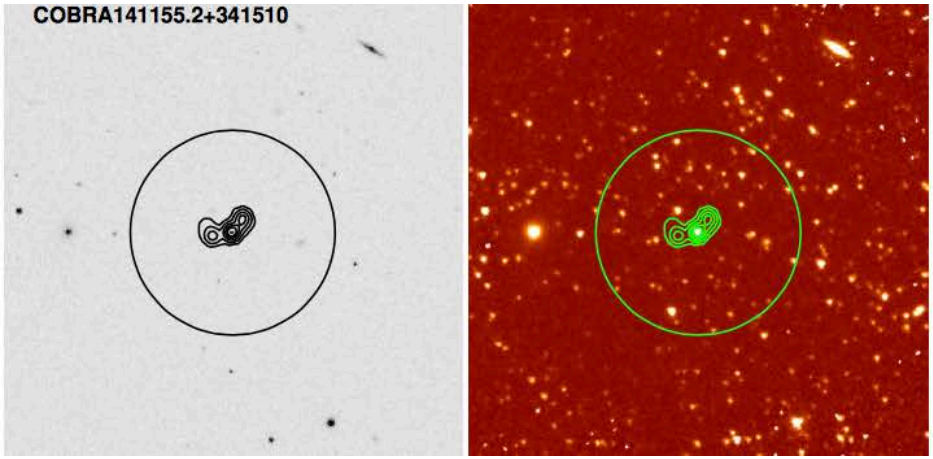
- Fast.
- Efficient.

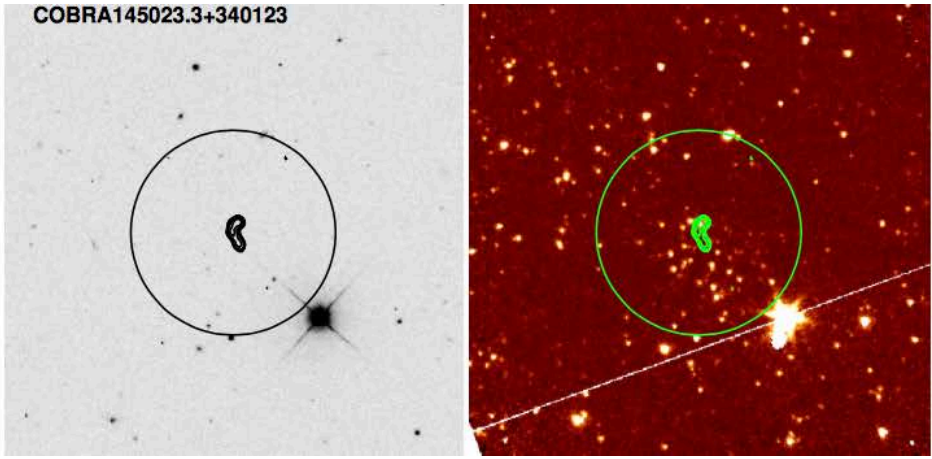
Weaknesses

- Shapes are limited to union of grid cells.
- Accuracy of the cluster may be degraded at the expense of the simplicity of this method.

Efficiency tests

- We try our methods on a catalog of clusters associated with bent-double radio sources COBRA.

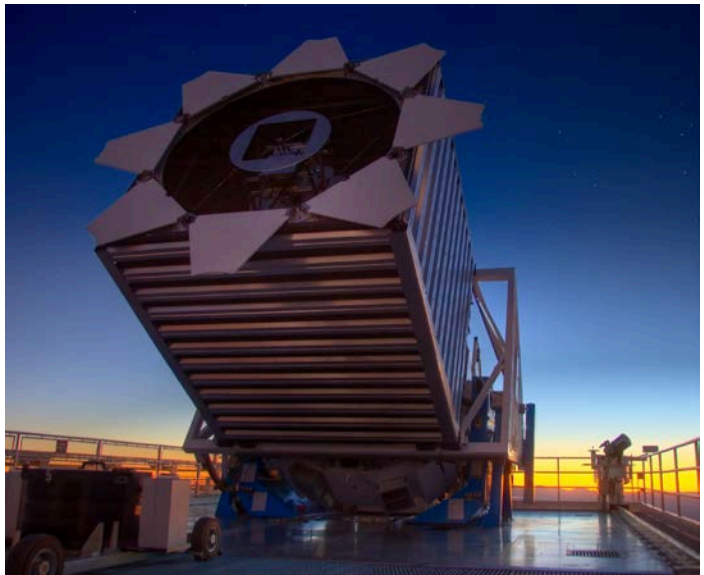


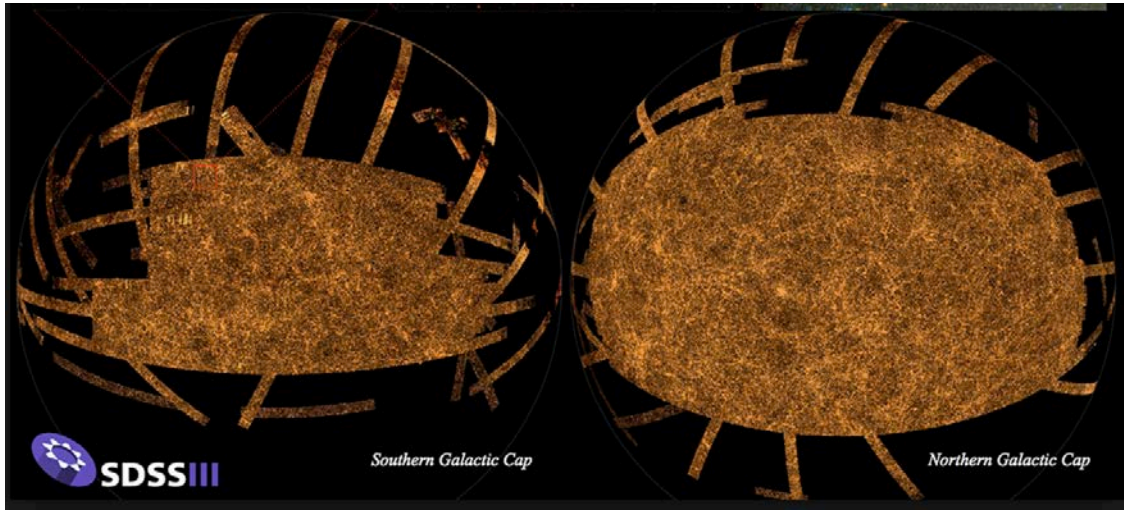


oan Digital Sky Survey

SDSS is a major multi-filter imaging and spectroscopic redshift survey using a dedicated 2.5-m wide-angle optical telescope at Apache Point Observatory in New Mexico, United States.

We use SDSS to look for all the sources in a radius of 2 Mpc around each BL Lac.



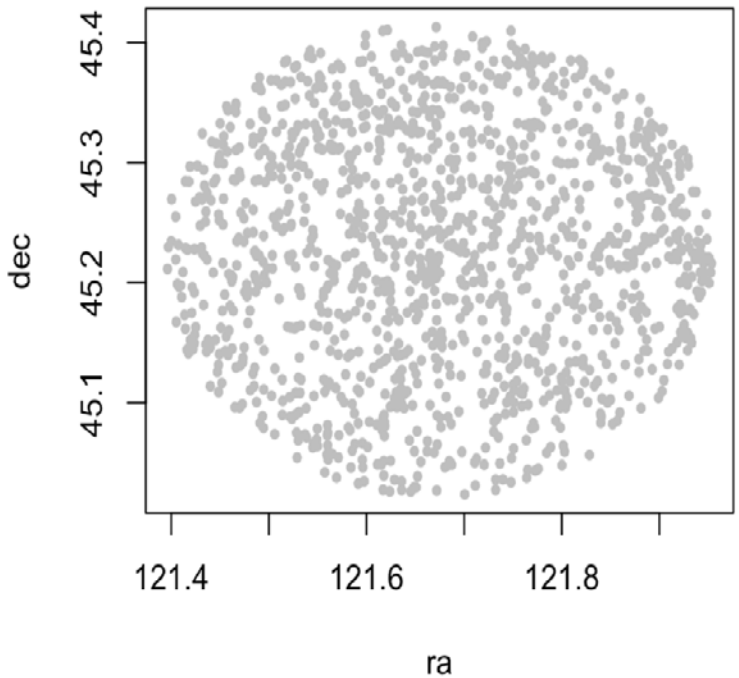


All sources in 2 Mpc radius

Problem: too many sources. It is not possible to apply clustering methods.

Clean photometry, quality flags and remove stars.

Still not enough.



Galaxy Zoo

Galaxy Zoo is a crowdsourced astronomy project which invites people to assist in the morphological classification of large numbers of galaxies.

Ask volunteers to classify Sloan and Hubble galaxies according to morphology.

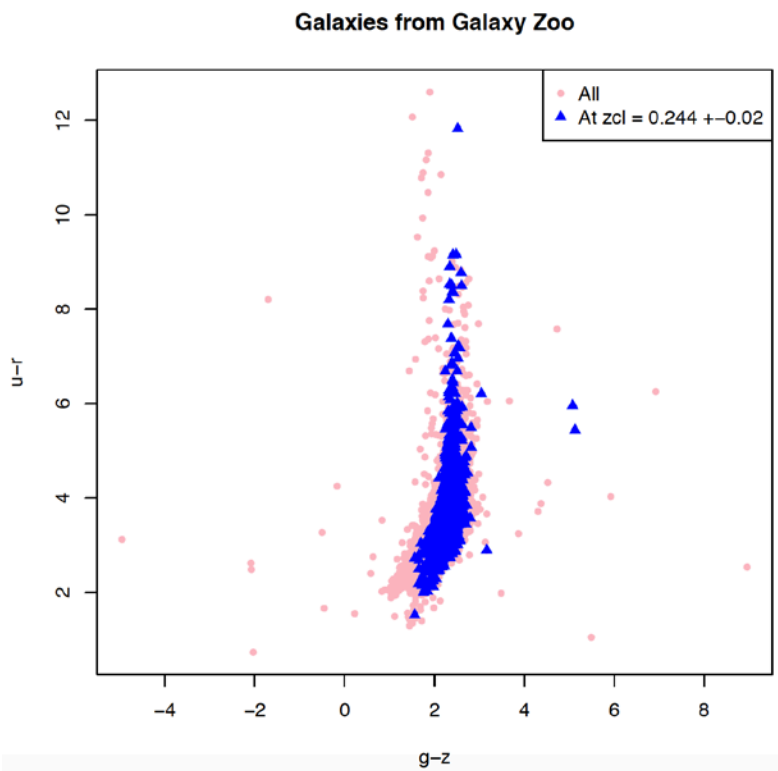
Big statistics: Accurate database. **Reliable**.

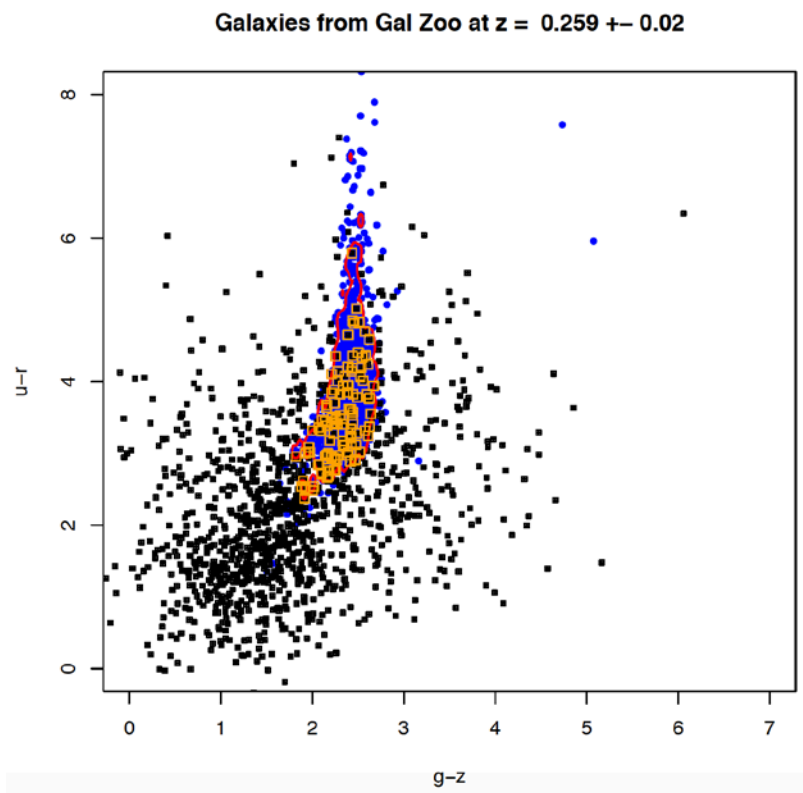
Only elliptical galaxies belong to clusters. We took the **elliptical galaxies** from Galaxy Zoo.

IR colors galaxy zoo

To choose the elliptical galaxies from my sample:

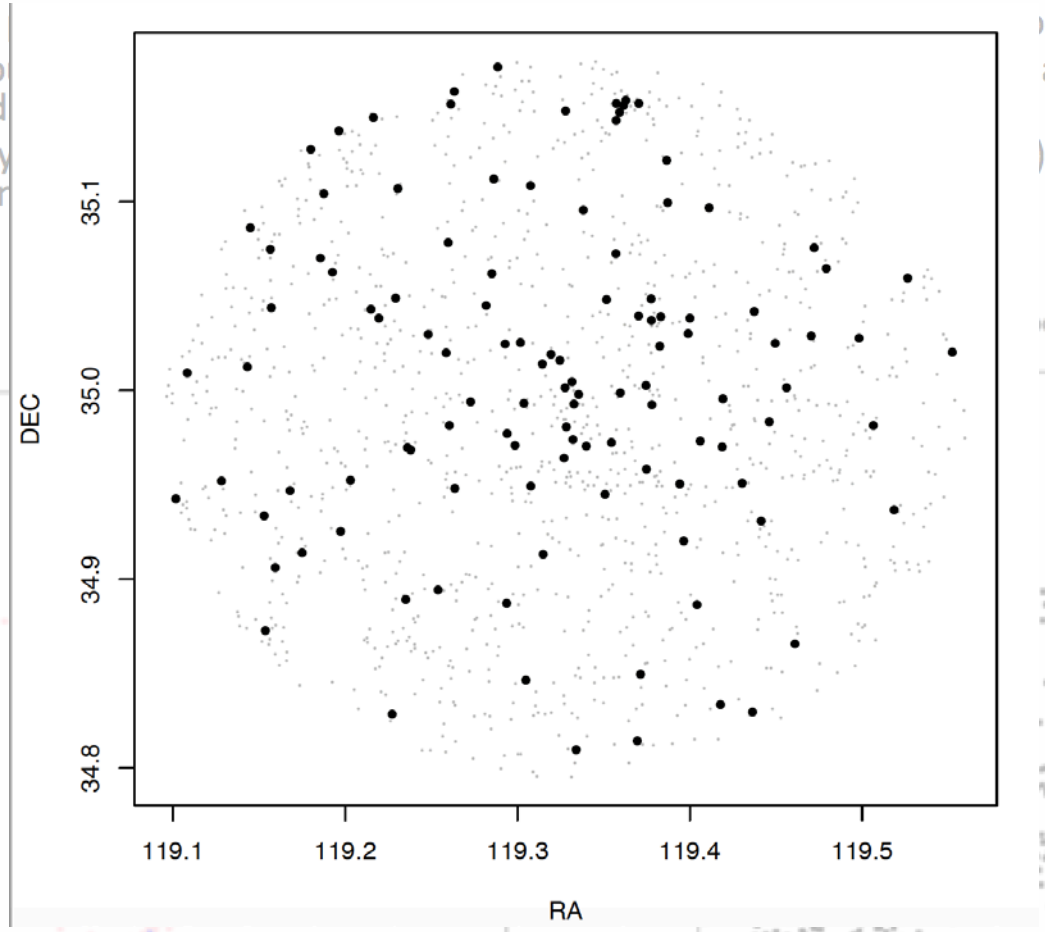
- Color-color plot of the ellipticals from galaxy zoo. Select all the sources from Galaxy Zoo at our redshift +-0.2. Narrow band.
- I plot all my sources (black) with those of galaxy zoo at a determine z (blue) and chose those that fall inside a 95% contour (orange).

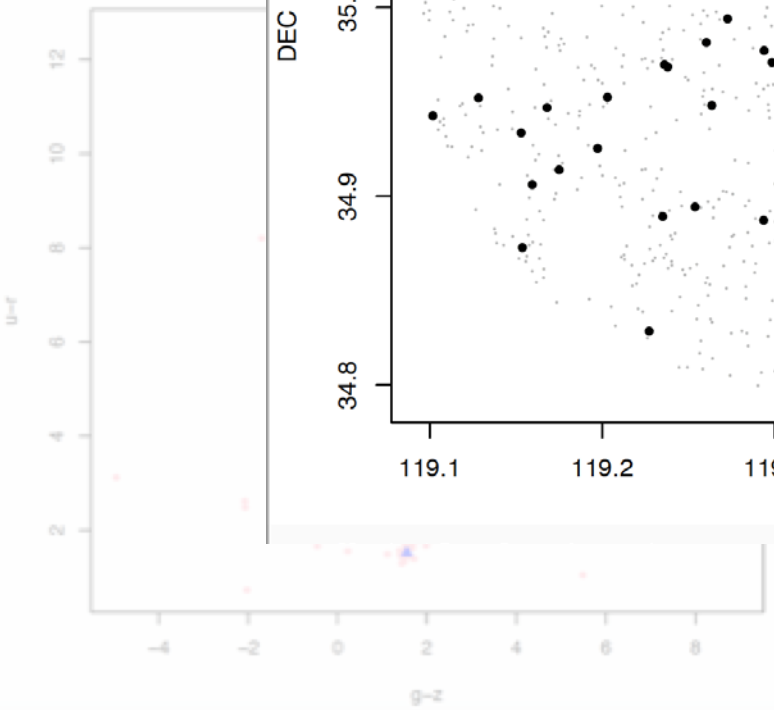


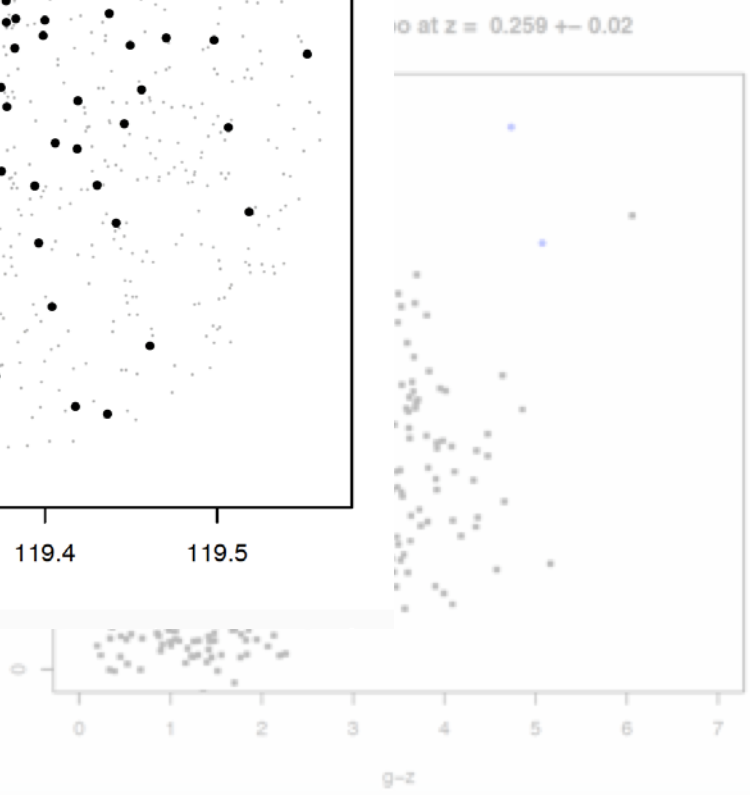


IR colors galaxy zoo

- In a color-color):
- Select all the so a narrow band is at the same red
- I overplot all my) and chose those that fall ir

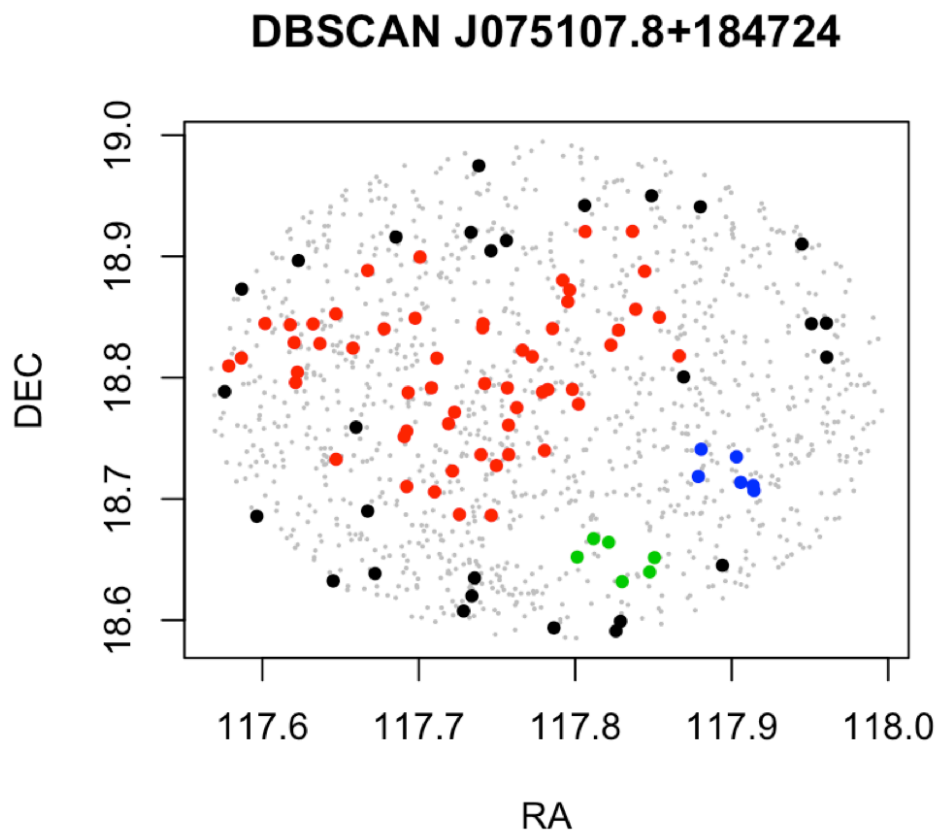






DBSCAN

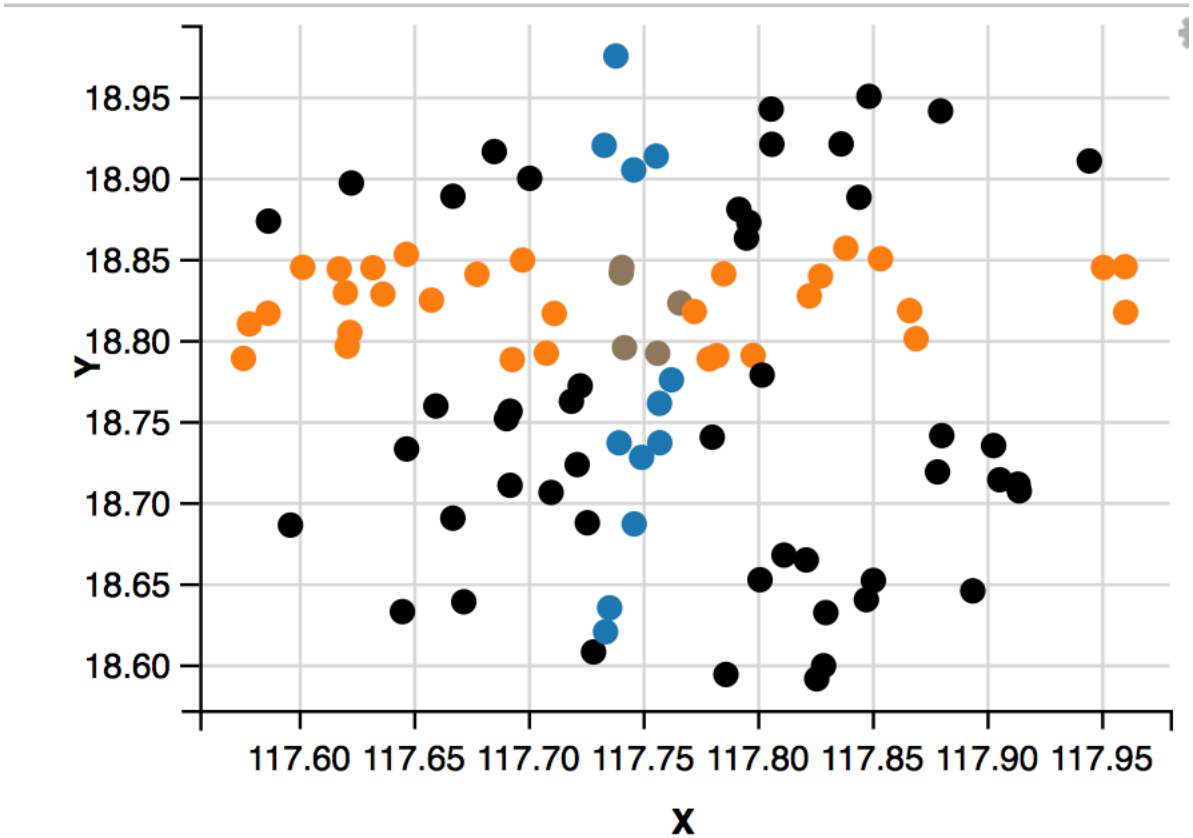
Richness in agreement with COBRA.
Problem: Satellite clusters. Needs implementation.



Richness DBSCAN = 56

CLIQUE

Consistent with DBSCAN.
Problem: Elongated clusters. Needs implementation.



Future work

Implementation of DBSCAN and CLIQUE.

Development of other algorithms such as Minimum Spanning Tree.

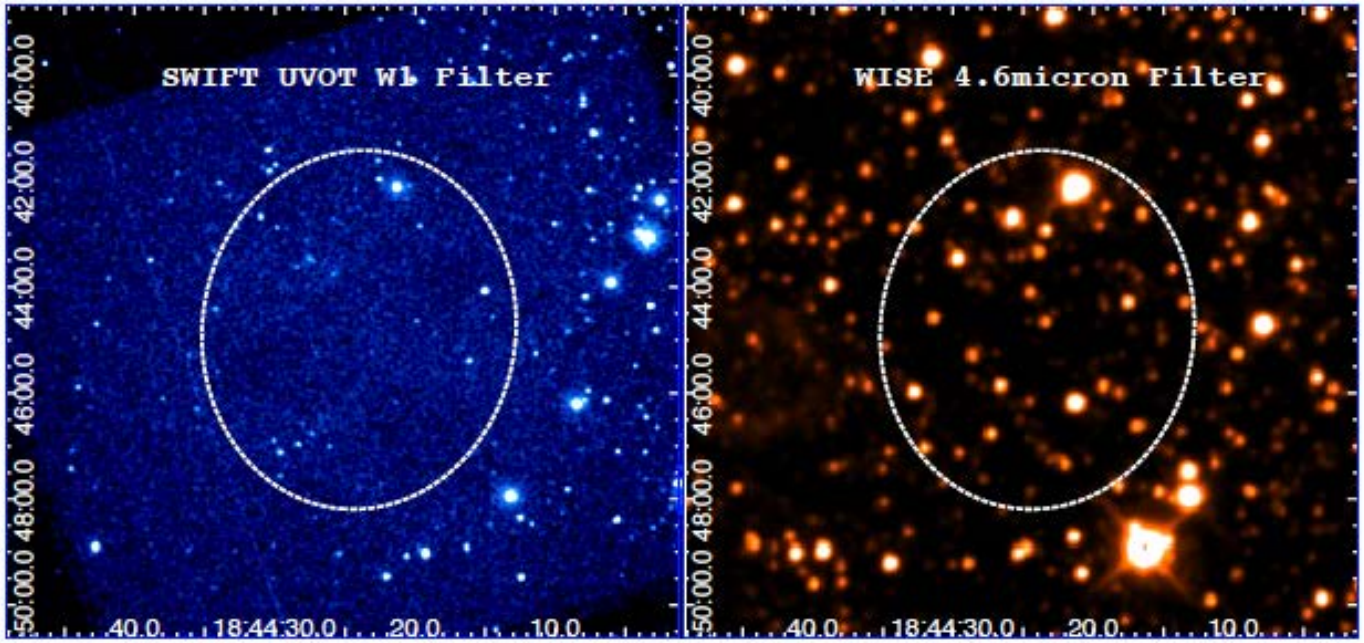
Application of these methods to all the BL Lacs in BZCAT.

Optical campaign: challenges of the gamma-ray source associations

Fermi Gamma-ray Space Telescope: Large positional uncertainties. Large number potential low energy counterparts.

Unidentified/unassociated gamma-ray sources: 43% 1FGL - 31% 2FGL - 33% 3FGL.

A better understanding of the nature of the UGSs is crucial to accurately estimate the blazar contribution to the extragalactic gamma-ray background

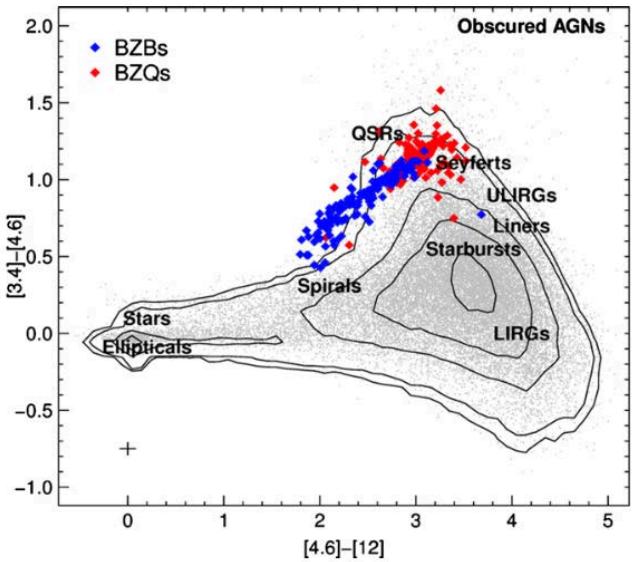


Optical campaign: search for potential counterparts of UGSs

Large Fermi-LAT uncertainty regions (~10') → numerous counterparts, need a method to pinpoint reliable blazar candidates

WISE all-sky survey. In the color-color diagram gamma-ray blazars dominated by non-thermal emission lie in a distant region than other extragalactic sources. **WISE gamma-ray strip**.

Method to recognize gamma-ray blazar candidates lying within UGSs position uncertainty.



Optical campaign: summary

Published papers as First Author:

Optical Spectroscopic Observations of Gamma-ray Blazar Candidates. V. TNG, KPNO, and OAN Observations of Blazar Candidates of Uncertain Type in the Northern Hemisphere

Álvarez Crespo, N., Masetti, N., Landoni, M. e tal. 2016 AJ, 151, 32

Optical Spectroscopic Observations of Gamma-Ray Blazar Candidates. VI. Further Observations from TNG, WHT, OAN, SOAR, and Magellan Telescopes

Álvarez Crespo, N.,Massaro, F., Milisavljevic, D. et al. 2016 AJ, 151, 95

Optical archival spectra of blazar candidates of uncertain type in the 3rd Fermi Large Area Telescope Catalog

Álvarez Crespo, N., Massaro, F., D'Abrusco, R. et al. 2016c ApSS 361, 316

Optical campaign: ongoing

- Data to be published:

  SOAR (Chile): 5 nights (2 on site + 3 remotely)

  KPNO (US): 5 nights

  NOT (Spain): 1 night
- More nights next semester:

  SOAR: 3 nights

  BLANCO (Chile): 2 nights

  KPNO: 2 nights