SubFind: searching substructures

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It is well established that the environment play a fundamental role on the galaxy evolution. For this reason galaxy clusters are the ideal laboratory for the study of the environmental drivers of galaxy evolution. Also, according to the hierarchical scenario, galaxy clusters are assembled through the continuous merging of smaller, group-like structures. At $z \sim 0$ a galaxy cluster accreted $\sim$ 40% of their galaxies from infalling groups (McGee et al. 2009). For this reason, the study of the properties of galaxies in the outskirts of galaxy clusers is vital to understand the link between the galaxy evolution and the formation of their hosting structures. However, the first difficulty to overcome in studies of galaxy evolution in clusters is the accurate detection of substructures and infalling groups. For these reason we have develop a python module based on clustering algorithms, which has the ability to search, finds and identify clusters and substructures inside clusters.

What does SubFind do?

SubFind is a python module can be downloaded and installed by anyone. This software can be use only spectroscopic redshift, spectroscopic plus photometric redshift or only photometric information to:

- select the cluster members.
- verifiy whether the cluster contain substructures or not.
- search, find and identify substructures in a galaxy cluster.

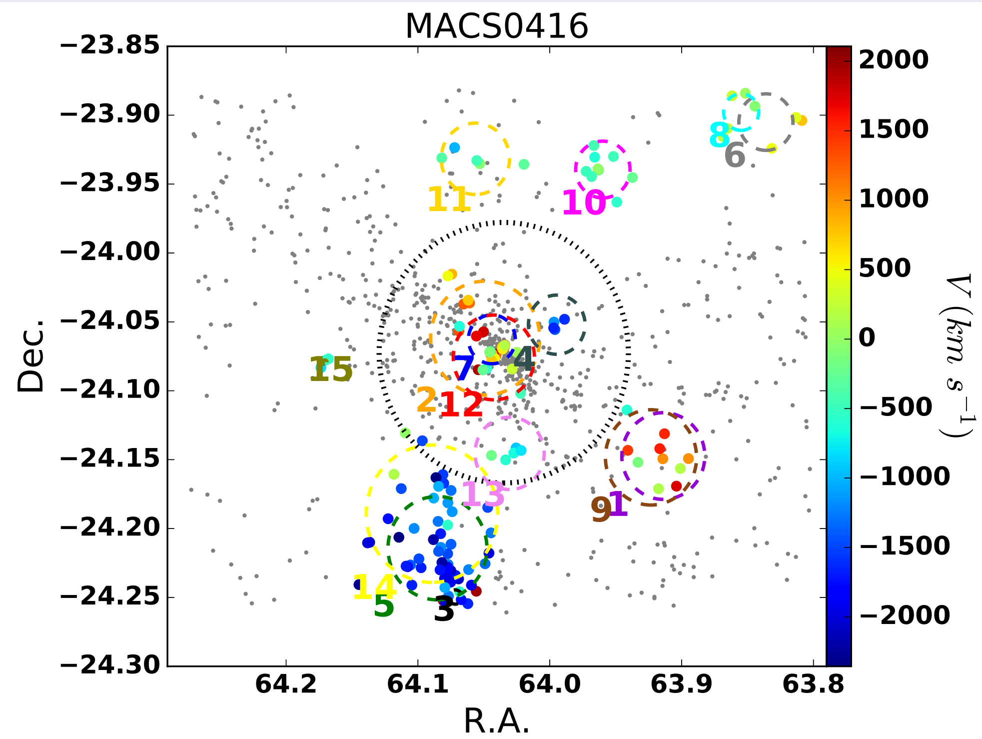

Figure 1: spatial and radial velocity distribution of cluster members for MACS0416. Grey points represent all spectroscopic members. Galaxies inside substructures are plotted with points whose colours indicate the peculiar velocity of the galaxies in the rest frame of the cluster (Olave-Rojas et. al 2018).

How does SubFind work?

- To select spectroscopic members we removed galaxies from the redshift catalogue with a peculiar velocity higher than the v_{esc} of the galaxy cluster, and then we removed the field interlopers through a 3σ clipping algorithm (Yahil Vidal 1977).
- To verify the possibility that a cluster contains substructures we used the Dressler-Shectman Test (Dressler Shectman 1988), which compares the local velocity and velocity dispersion for each galaxy with the cluster global values (Jaff et al. 2013).
- To search, find and identify substructures we separated galaxies ind redshift and we used a cluster algorithm available in python, namely Gaussian Mixture Model (GMM; Muratov Gnedin 2010) and Density-Based Spatial Clustering of Applications with Noise (DBSCAN, Ester et al. 1996).

Finding substructures

The DS-test give us a value (δ_i) that quantifies the galaxy's kinematic deviation with respect to the mean cluster values of velocity and velocity dispersion. A galaxy with a large value of δ_i has a great probability to belong a substructure. However the DS-test does not assign galaxies to a substructure. For this reason we use the GMM and DBSCAN algorithms.

GMM allows to separate galaxies according their redshifts. In this way, we can take into account the projection of the galaxies in the sky. Finally, we use DBSCAN to assign galaxies to a substructure. The substructures are defined as a collection of at least three neighbouring galaxies with a spatial separation of $\sim$ 140 kpc, which is a typical maximum spacing between galaxies within compact groups of galaxies.

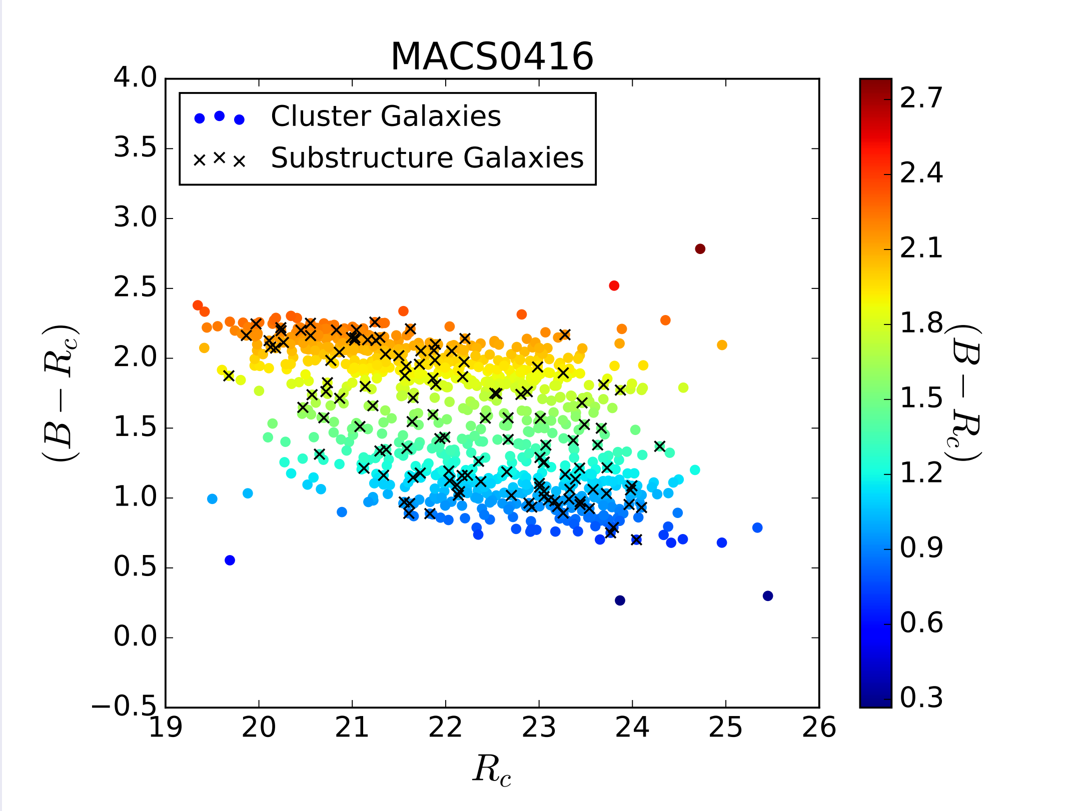

Figure 2: Colour-magnitude diagrams of spectroscopically confirmed cluster members.Cluster member galaxies are plotted with points whose colours indicate the $(B - R_c)$ colour and galaxies in substructures are plotted with black crosses (Olave-Rojas et. al 2018).

Results

In the following, we list our main results:

- We found that the ability to detect substructures depends on the data available regardless of the method used.
- We note that majority of our identified substructures are in the outer ($r > r_{200}$) regions of ours tester cluster.
- We observe and absence of significant differences between the CMDs in cluster and substructures. And we suggest that “SubFind” allows us to assign galaxies to a substructures with an absence of any bias in the kind of galaxies.
- For our tester cluster we recover some substructures identified with other methods (i.e x-ray) and reported in the literature

Summary

- In this poster we have presented a preliminary results using our pyhton module “SubFind”, and we observe that our software has the ability to recover substructures identified with other method in our tester cluster.
- In our tester cluster, we have identified several substructures using a combination of statistical methods (DS-test) and clustering algorithms (DBSCAN). Most of the identified substructures are located in the cluster outskirts ($r \geq r_{200}$), in agreement with literature results.

Future Works

- Test SubFind in other cluster at the same redshift
- Test SubFind in other cluster at different redshift
- Test SubFind in a simulation and cluster with identified substructures to see whereas our software recover or not the substructures in the simulation.

References

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