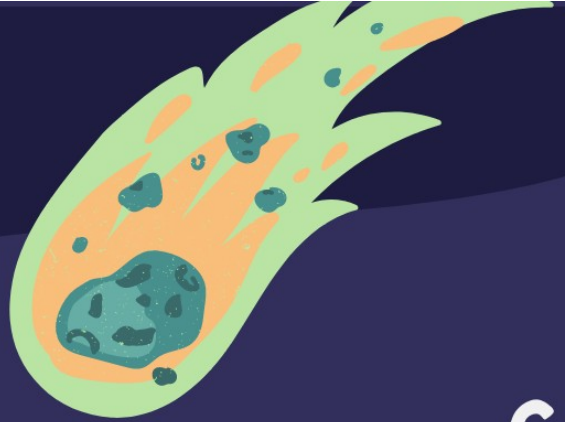


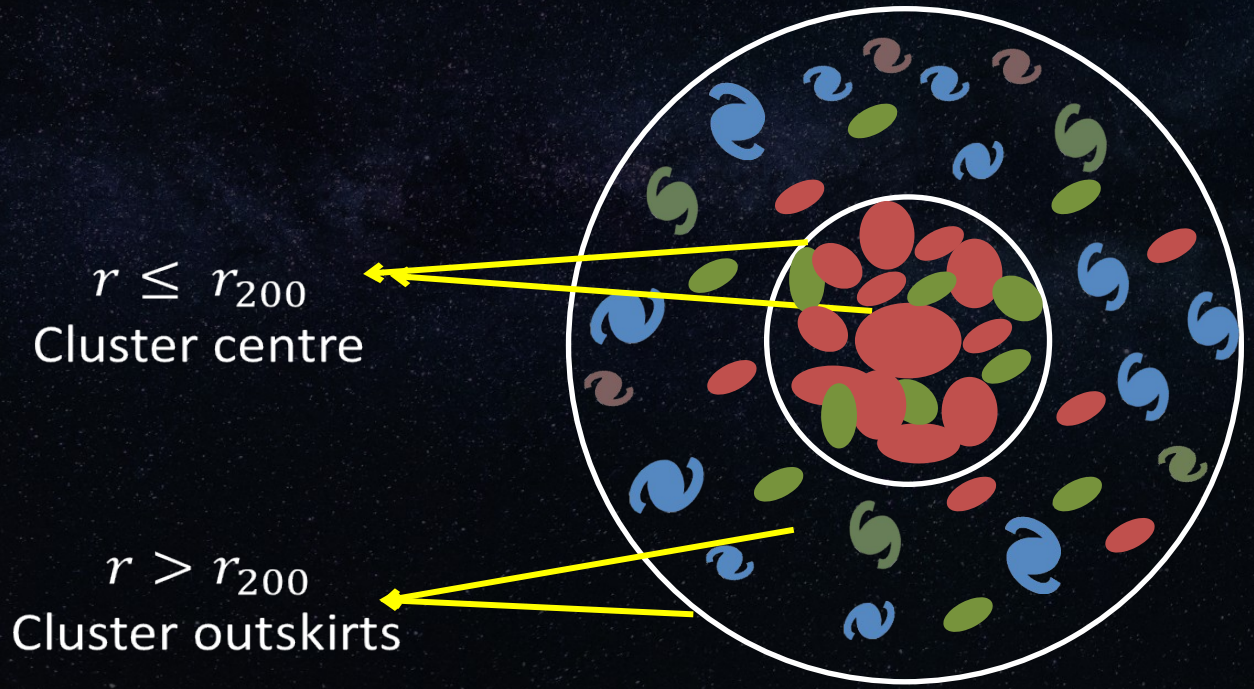
TALCA
UNIVERSIDAD
CHILE

CALSAGOS: CLUSTERING ALGORITHMS APPLIED TO GALAXIES IN OVERDENSE SYSTEMS

Daniela Olave-Rojas

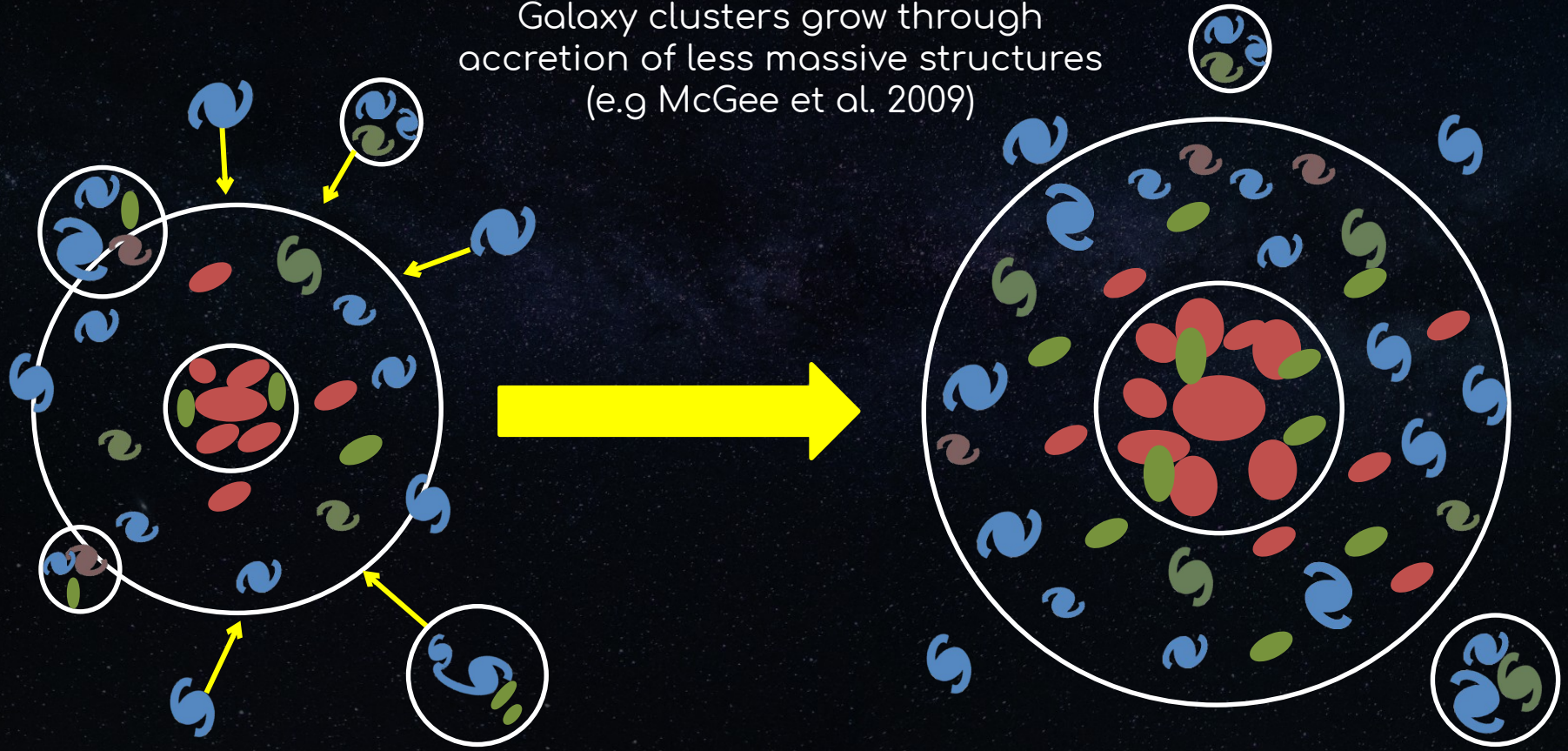
Galaxy Clusters

Cosmic laboratories for the study of the environmental drivers of galaxy evolution (e.g. Dressler 1980, De Lucia et al. 2007, Demarco et al. 2010, Lemaux et al. 2012, Cerulo et al. 2014).



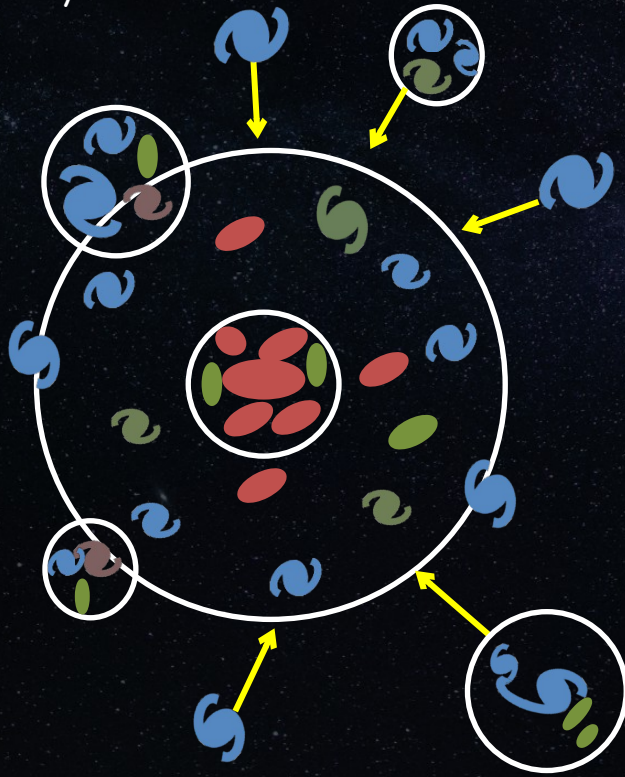
Cluster Mass Assembly in a Hierarchical Universe

Galaxy clusters grow through accretion of less massive structures (e.g McGee et al. 2009)

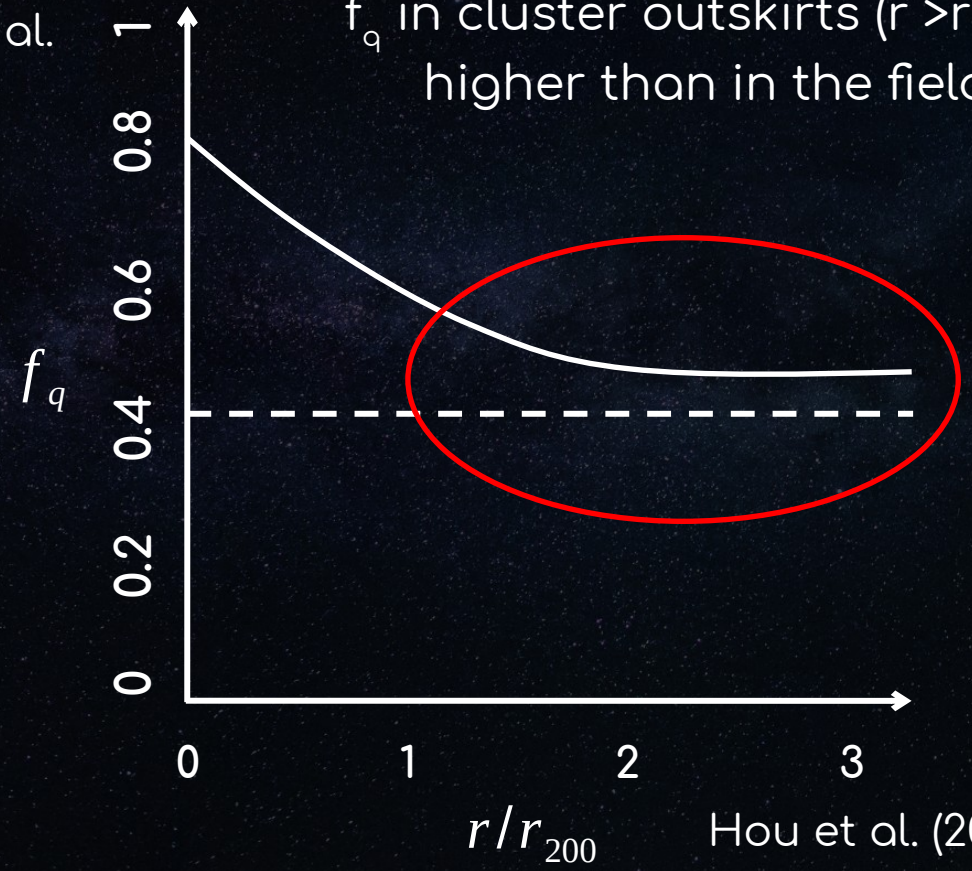


Galaxy Pre-Processing

Pre-processing (e.g Zabludoff & Mulchaey 1998, Fujita 2004, Haines et al. 2015)



f_q in cluster outskirts ($r > r_{200}$) is higher than in the field



Hou et al. (2014)

The project

Title: Understanding the effect of the environment on the evolution of galaxies

Goal: Understand the link between the evolution of galaxies and the formation of their hosting structures

Data: Photometric data from the Southern Photometric Local Universe Survey (S- PLUS; Mendes de Oliveira et al. 2019) + spectroscopic data from archive

The project

The use of the S-PLUS data allows us to:

i. identify groups and substructures in and around galaxy clusters, reaching the outermost regions of clusters (up to ~5r 200),

ii. determine the fraction of passive and star forming galaxies in each environment,

iii. determine the environmental quenching efficiency in substructures and clusters

CALSAGOS

CALSAGOS Clustering ALgorithmS Applied to Galaxies in Overdense Systems

CALSAGOS is a python package develop to select cluster members and to identify substructures in and around galaxy cluster

Olave-Rojas et al. in prep.

CALSAGOS

CALSAGOS uses some pre-existing python modules as:

1. numpy
2. astropy
3. matplotlib
4. sys
5. math
6. sklearn
7. scipy
8. kneebow

CALSAGOS has the following modules:

1. utils
2. redshift_boundaries
3. cluster_kinematics
4. ds_test
5. isomer
6. clumberi
7. lagasu

Olave-Rojas et al. in prep.

CALSAGOS

utils: functions to estimate errors, convert quantities and estimate distances

redshift_boundaries: functions developed to establish the limits in the redshift distribution

cluster_kinematics: functions developed to estimate the kinematic properties of the cluster (velocity dispersion, escape velocity, peculiar velocity)

ds_test: functions developed to implement the Dressler-Shectman Test (DS-Test, Dressler & Shectman, 1988) in a cluster of galaxies

Olave-Rojas et al. in prep.

CALSAGOS

ISOMER: Identifier of SpectrOscopic MembERs allows to identify the spectroscopic cluster members

$$v = c\frac{z - z_{cl}}{1 + z_{cl}}$$

(Harrison 1974)

$$v_{esc} \simeq 927 \left(\frac{M_{200}}{10^{14} h^{-1} M_{\odot}}\right)^{1/2} \left(\frac{r_{200}}{h^{-1} Mpc}\right)^{-1/2} kms^{-1}$$

(Diaferio 1999)

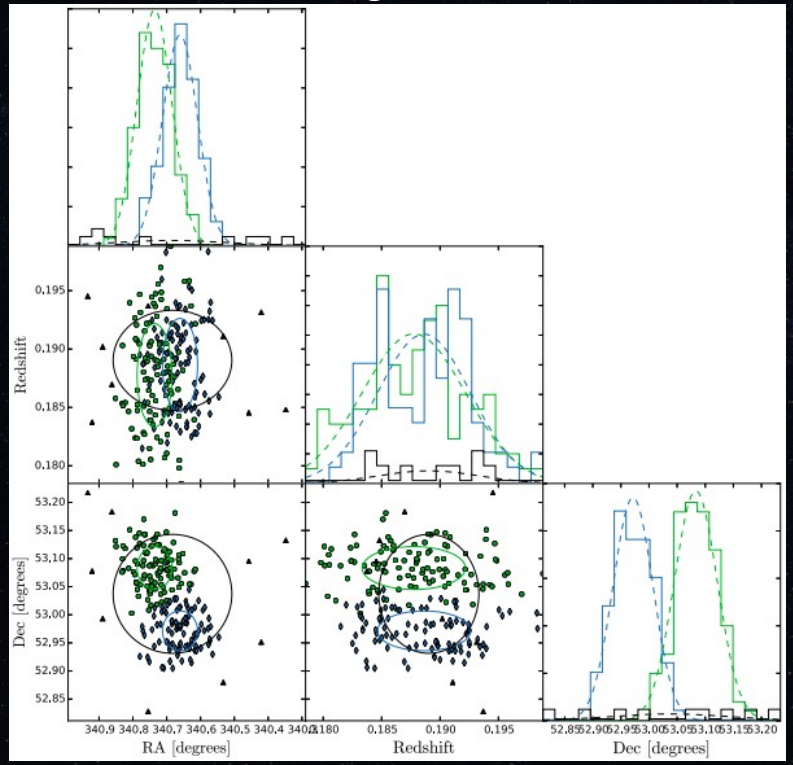
r_{200} is estimated by using equation (7) presented by Finn et al. (2005)

Field interlopers are removed through a 3σ clipping algorithm (see Yahil & Vidal 1977).

Olave-Rojas et al. in prep.

CALSAGOS

CLUMBERI: CLUster MemBER Identifier allows to identify cluster members using a 3D-Gaussian Mixture Modules (GMM)



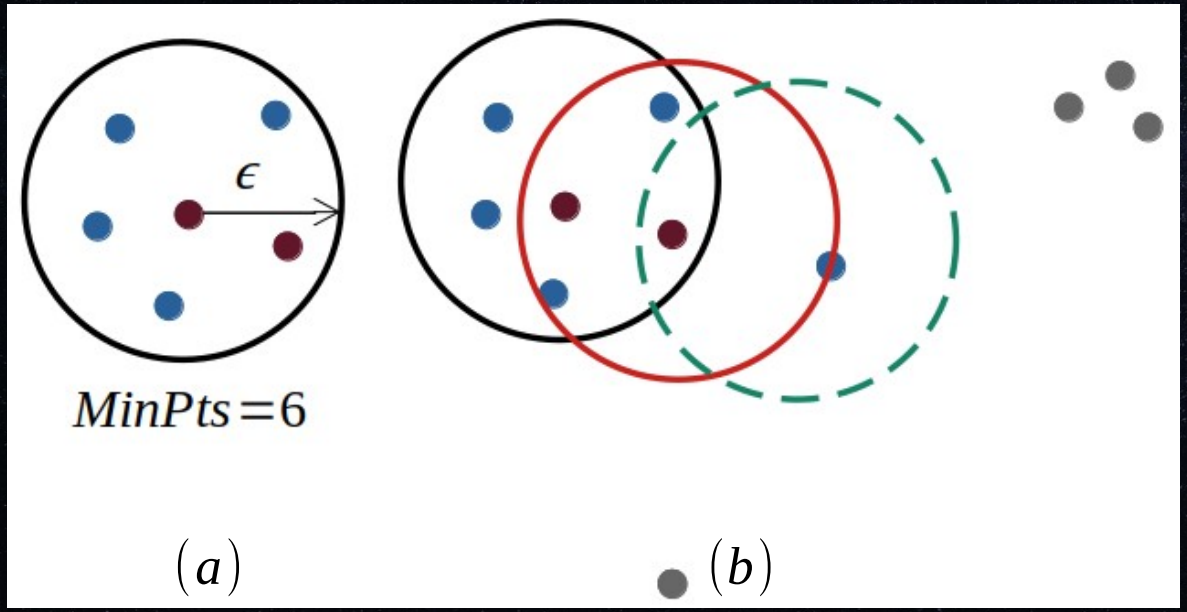
Dawson et al. (2015)

Bayesian Information Criterion (BIC)

Olave-Rojas et al. in prep.

CALSAGOS

LAGASU: LAbeller of GAlaxies within SUbstructures assigns galaxies to different substructures in and around a galaxy cluster



Density-based spatial clustering of applications with noise (DBSCAN, Ester 1996)

GMM ✚ DBSCAN

DBSCAN

Olave-Rojas et al. in prep.

CALSAGOS ON S-PLUS MOCKS

Developed by Pablo Araya-Araya as part of S-PLUS collaboration (for details see Araya-Araya et al. 2021)

52987 halos with $13.0 \leq \log(m_{200}/m_{sun}) \leq 15.0$
at $0.006 \leq z \leq 0.6$

$H = 67.3$ [km s^{-1} Mpc^{-1}]

$\Omega_{\Lambda} = 0.685$

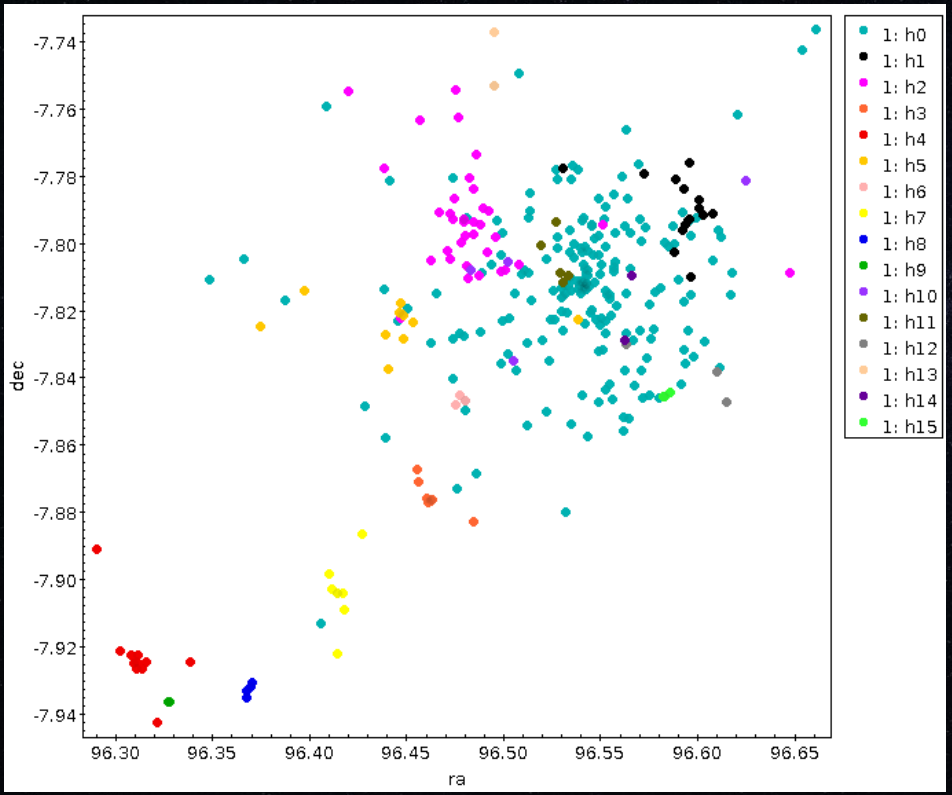
$\Omega_{m} = 0.315$

2524 halos with $\log(m_{200}/m_{sun}) \geq 14.0$
at $0.007 \leq z \leq 0.6$

419904 galaxies

CALSAGOS ON S-PLUS MOCKS

Original halo + subhalos



We remove subhalos with 2 or less members

319 members + 16 subhalos

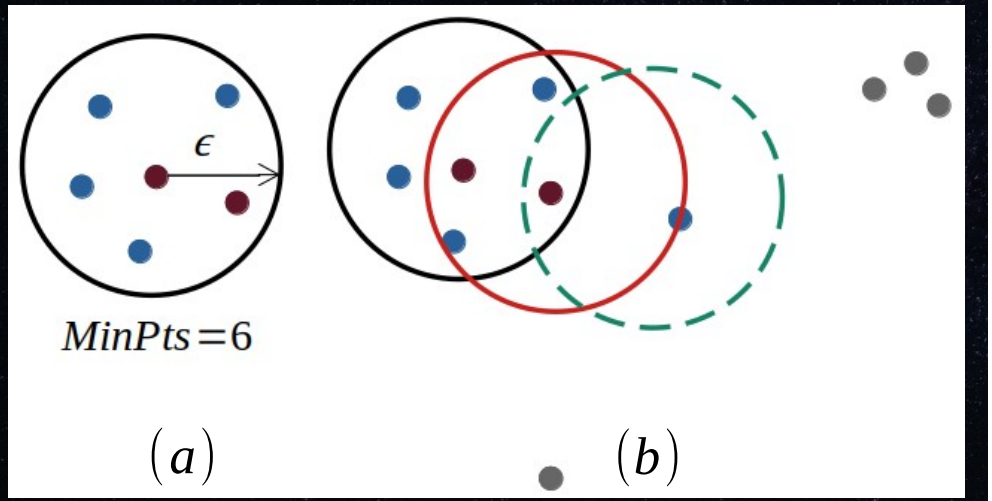
$z \approx 0.34$

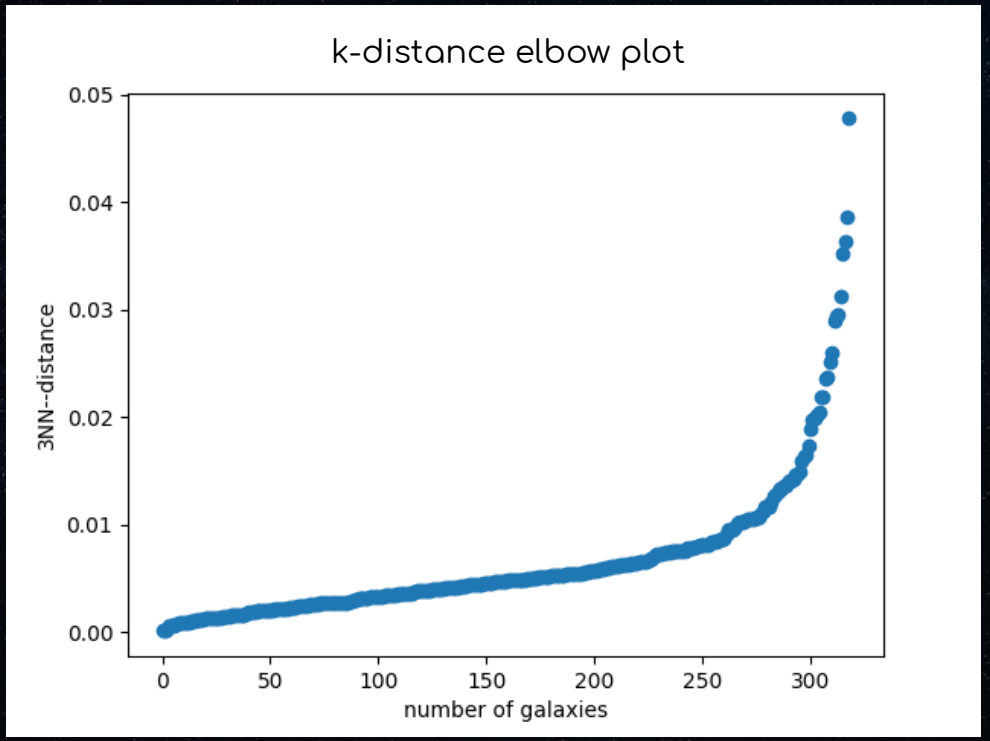
$\log(m_{200}/m_{sun}) \approx 14.89$

Olave-Rojas et al. in prep.

CALSAGOS ON S-PLUS MOCKS

DBSCAN

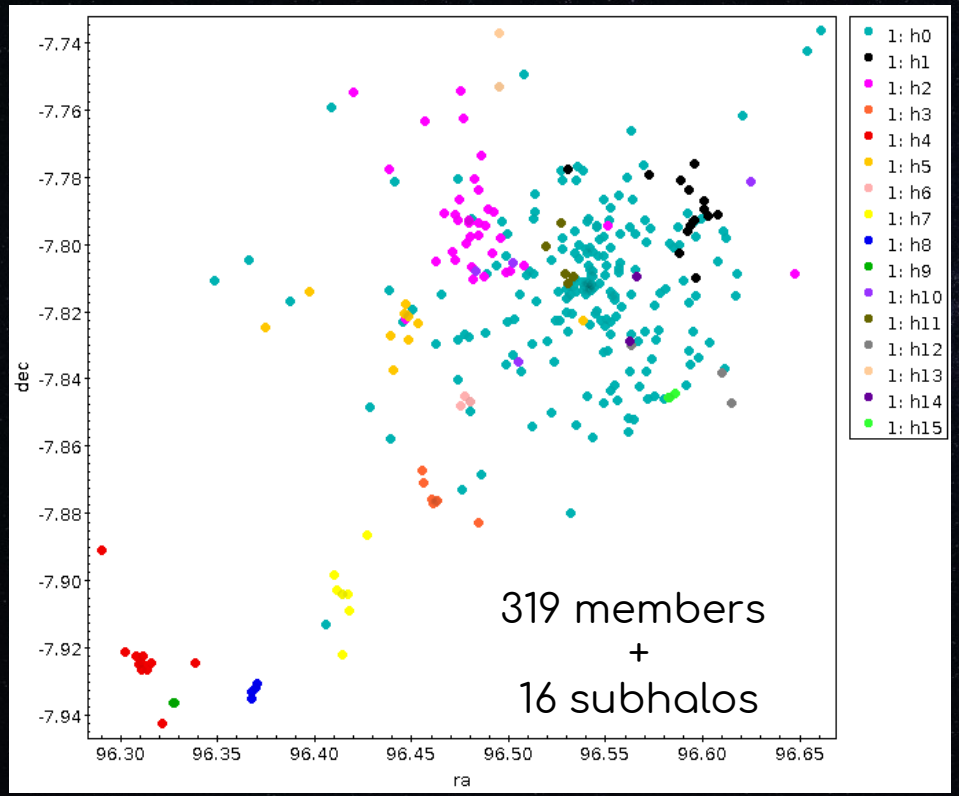




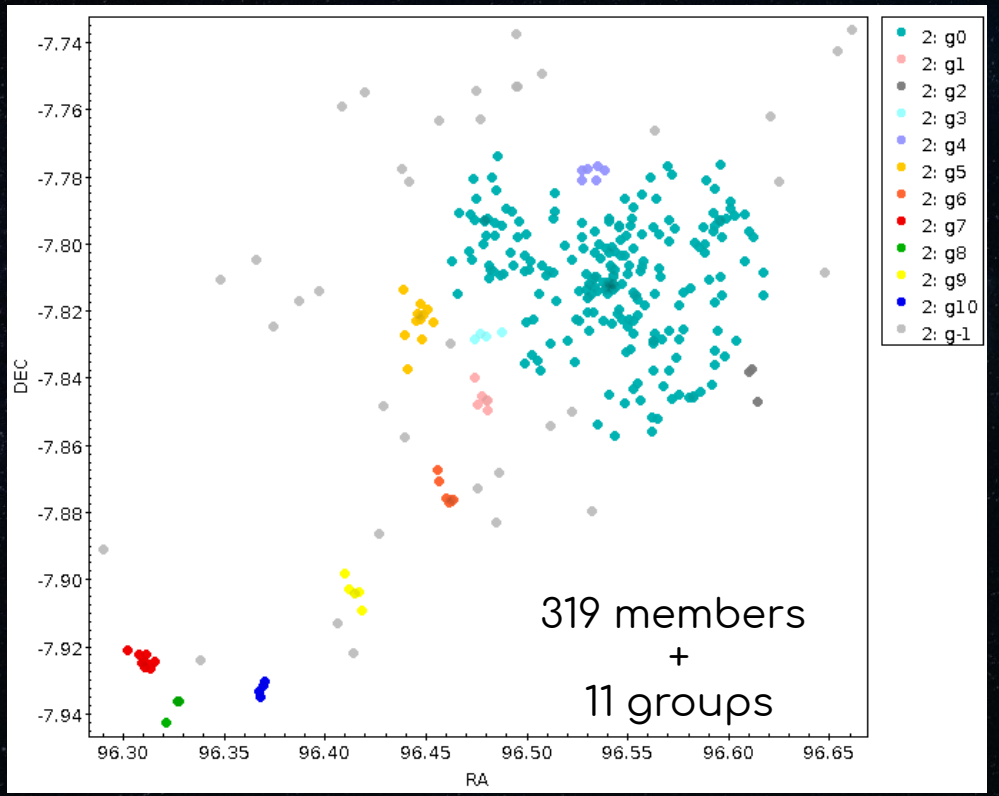
Olave-Rojas et al. in prep.

CALSAGOS ON S-PLUS MOCKS

Original halo + subhalos



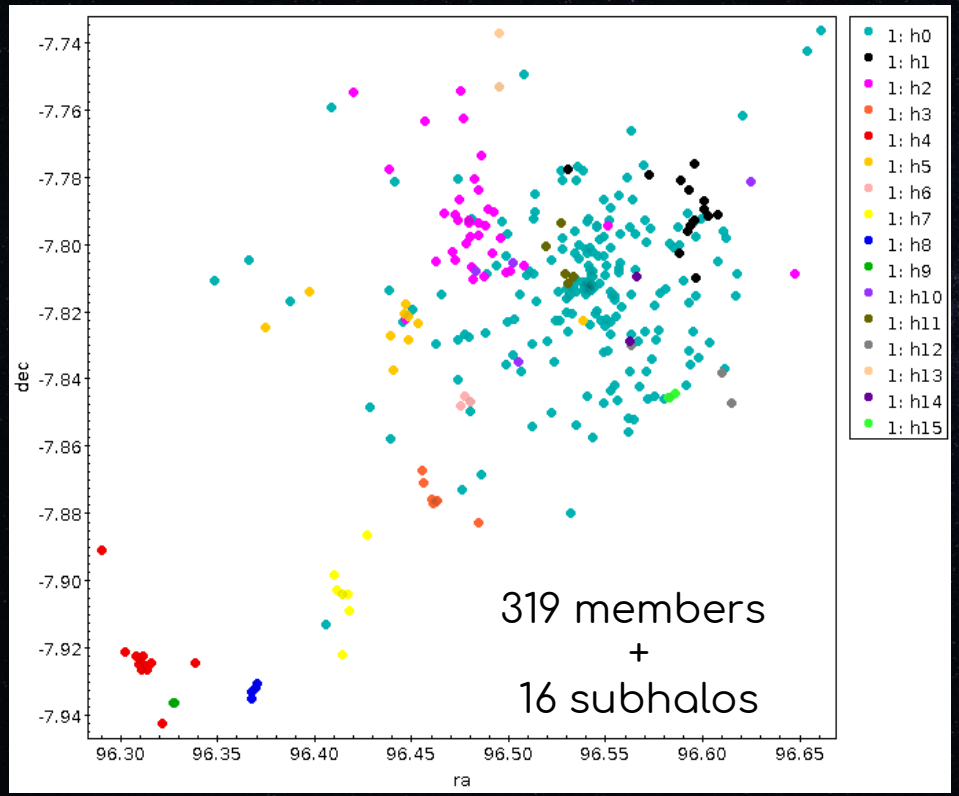
LAGASU application



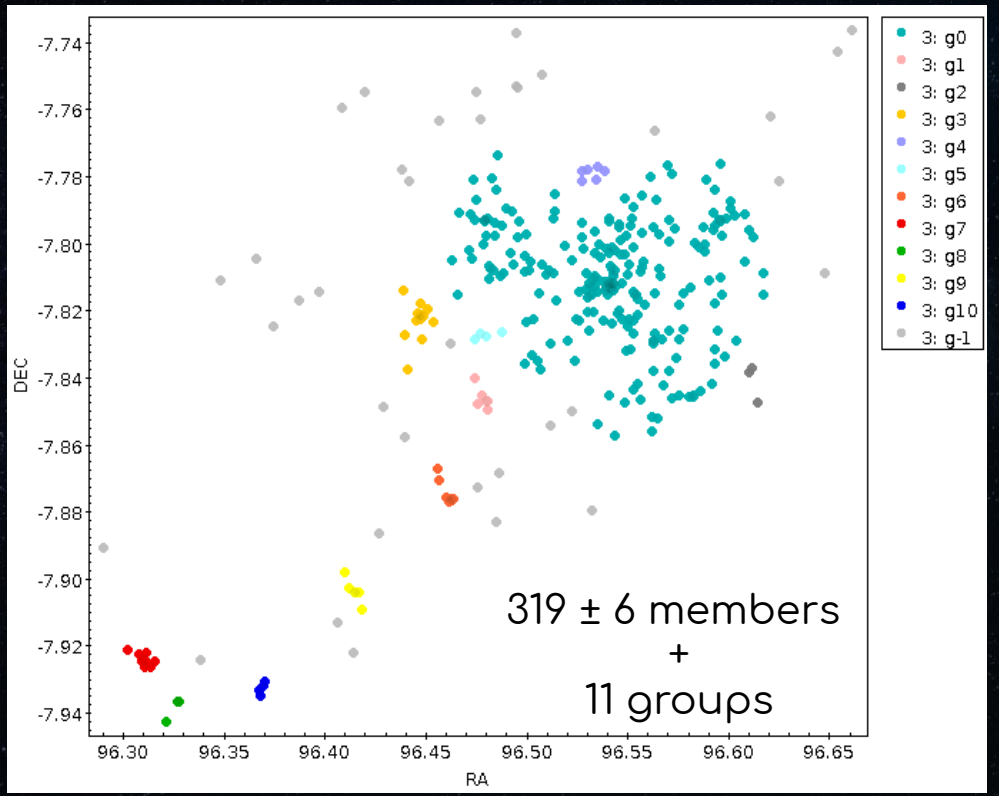
Olave-Rojas et al. in prep.

CALSAGOS ON S-PLUS MOCKS

Original halo + subhalos



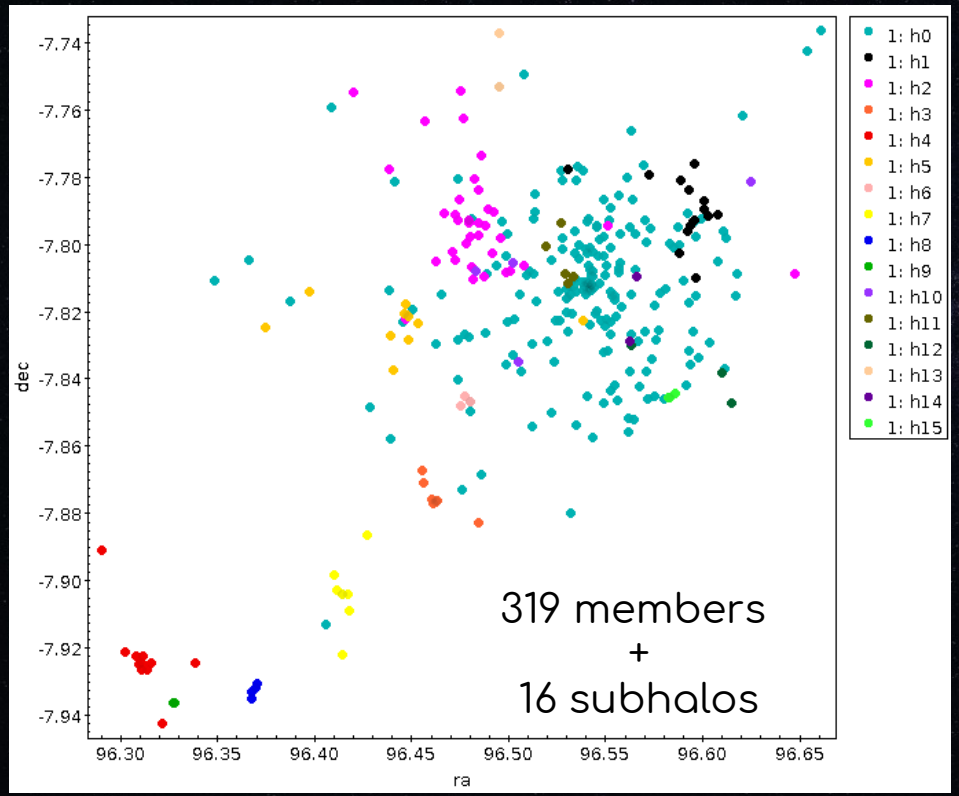
CLUMBERI + LAGASU application



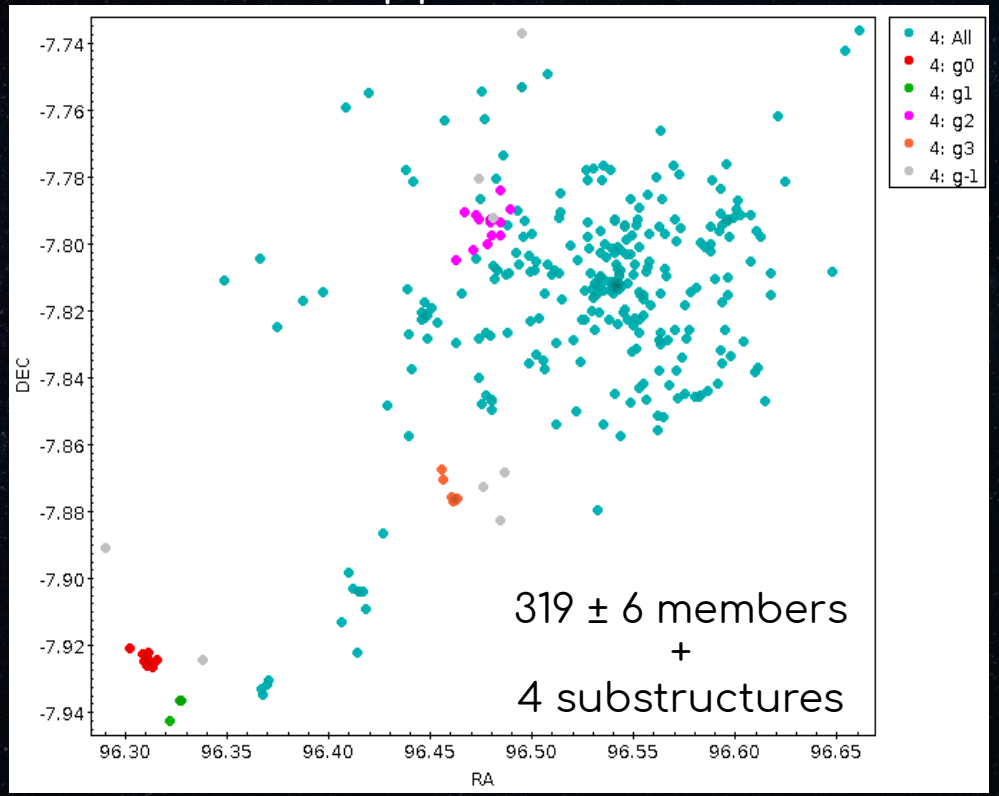
Olave-Rojas et al. in prep.

CALSAGOS ON S-PLUS MOCKS

Original halo + subhalos



CLUMBERI + DS-Test + LAGASU application



Olave-Rojas et al. in prep.

Important Results

- CLUMBERI has an uncertainty around 2% in selecting cluster members and can be used with photometric data
- In general, the substructures find by using DS-Test + LAGASU are real subhalos
- In general, LAGASU finds fewer groups than real subhalos and also finds some “artificial” groups

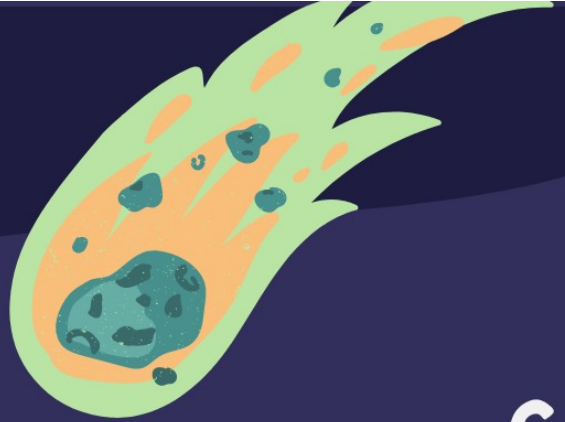
(a)

Future Works

- Quantify the accuracy of CALSAGOS to identify substructures and groups in and around galaxy clusters
- Publish the code
- Applied CALSAGOS to clusters in S-PLUS (pilot project A1644) to study the pre-procesing of galaxies

(a)

daniela.olave@utalca.cl

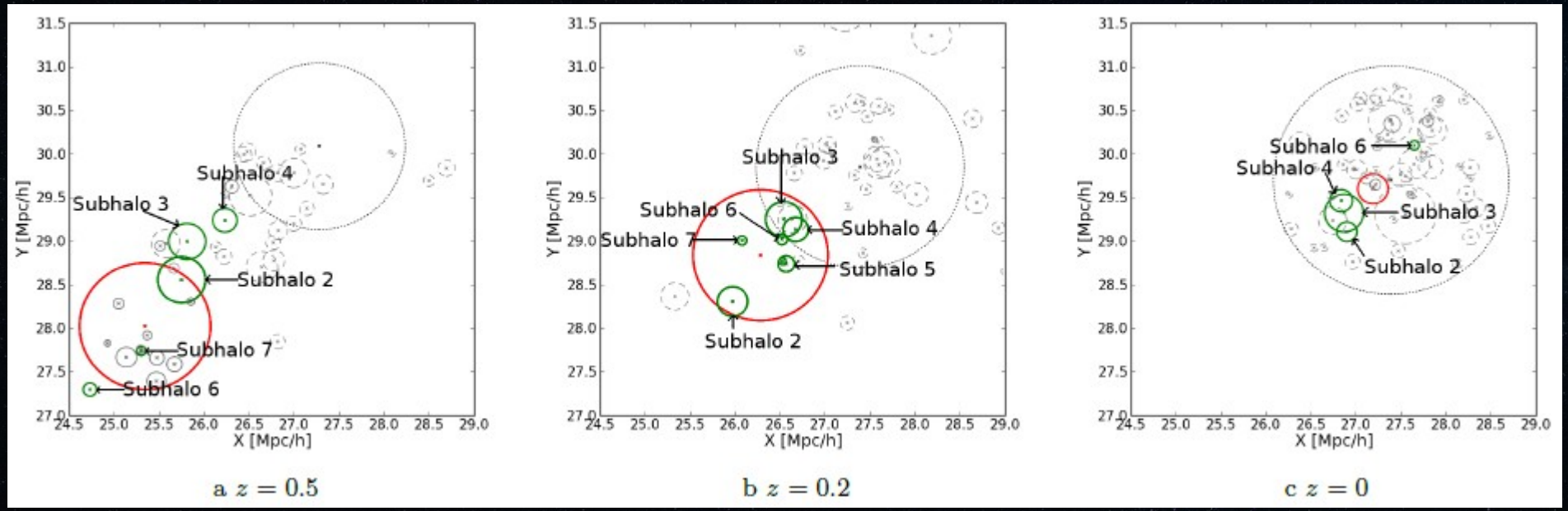


TALCA
UNIVERSIDAD
CHILE

CALSAGOS: CLUSTERING ALGORITHMS APPLIED TO GALAXIES IN OVERDENSE SYSTEMS

Daniela Olave-Rojas

Detection of Substructures



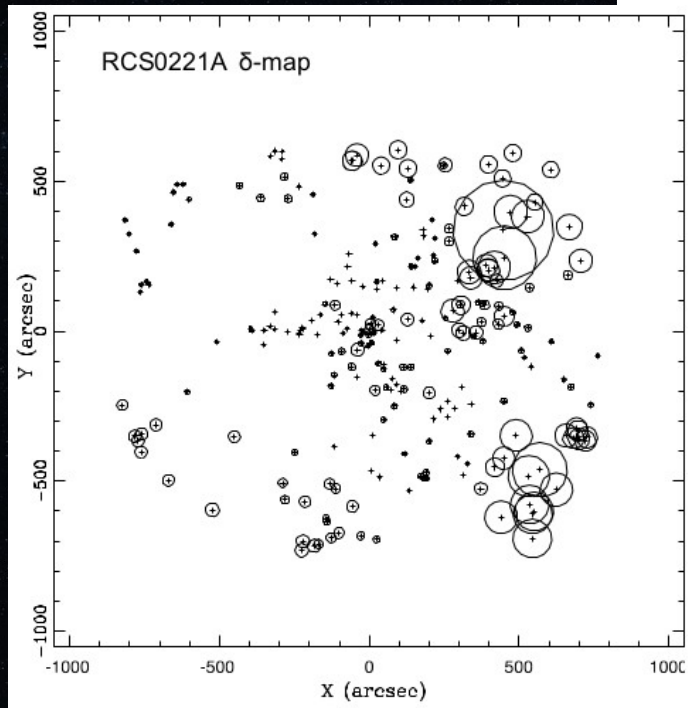
a $z = 0.5$ b $z = 0.2$ c $z = 0$

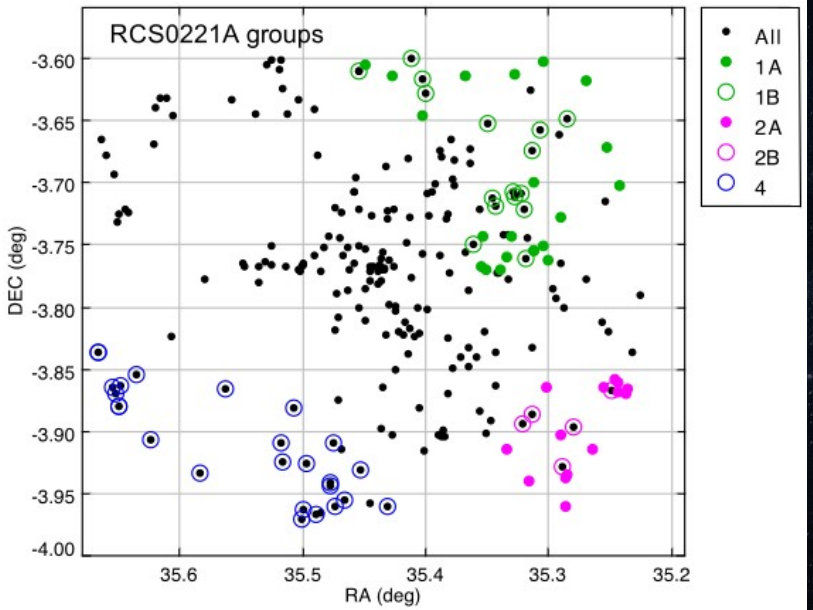
Vijayaraghavan & Ricker (2013)

Detection of Substructures

DS-Test (Dressler & Schectman 1988)

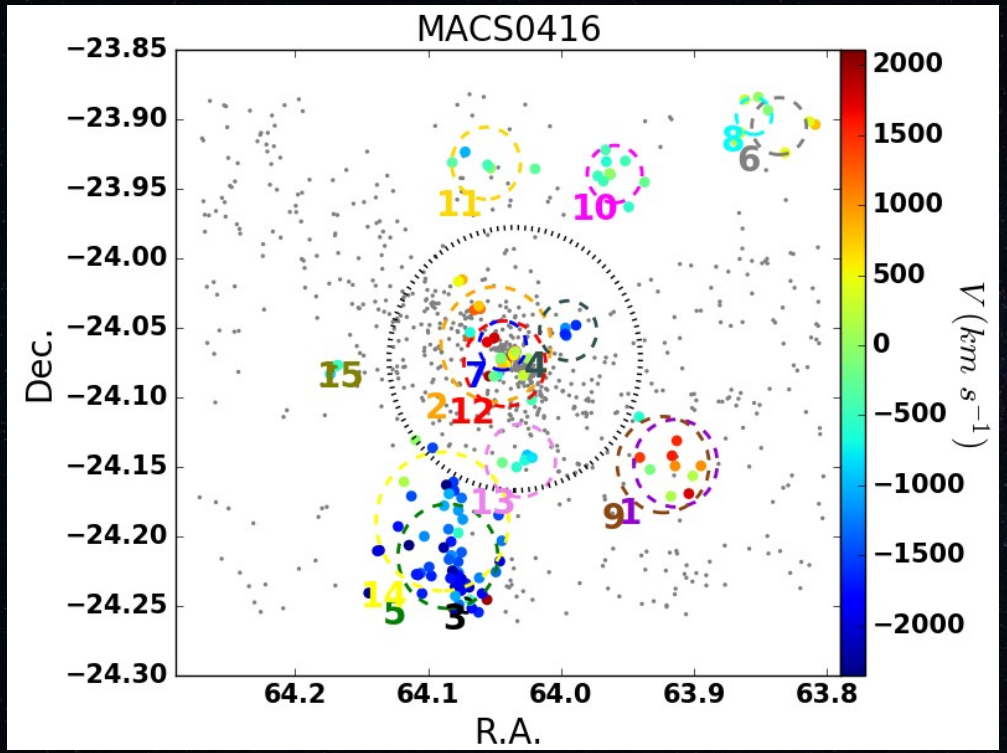
$$\delta_i^2 = \left(\frac{N_{nn}+1}{\sigma_{cl}^2}\right)\left[(\bar{v}_{local}^i - \bar{v}_{cl})^2 + (\sigma_{local}^i - \sigma_{cl})^2\right]$$

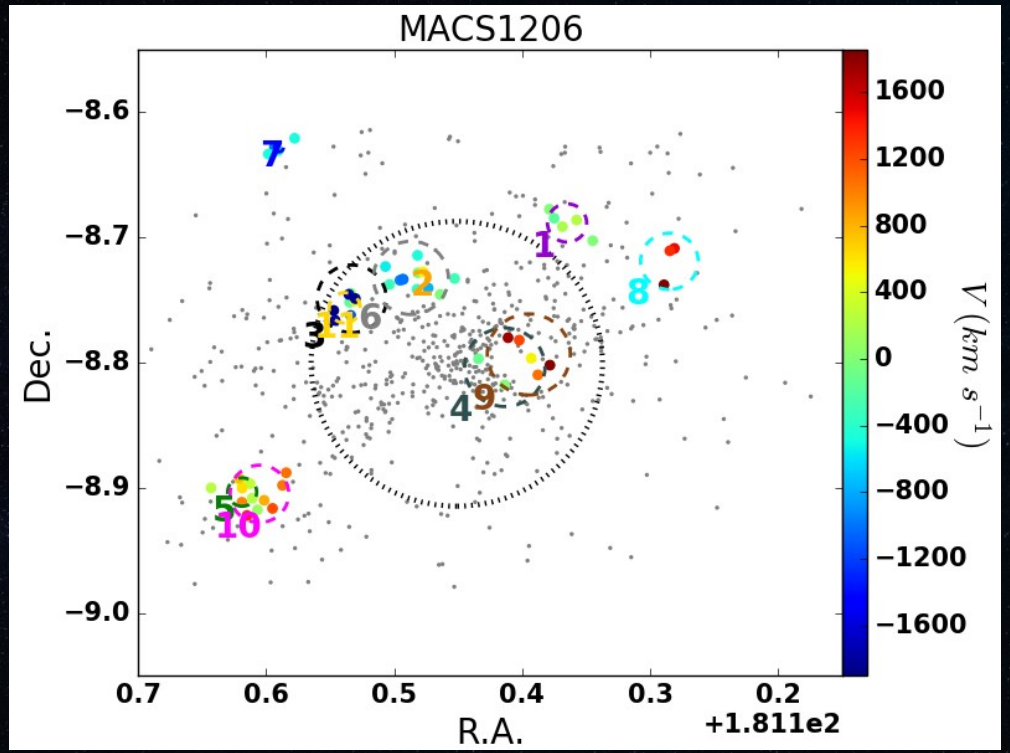




Dressler et al. (2013)

Detection of Substructures



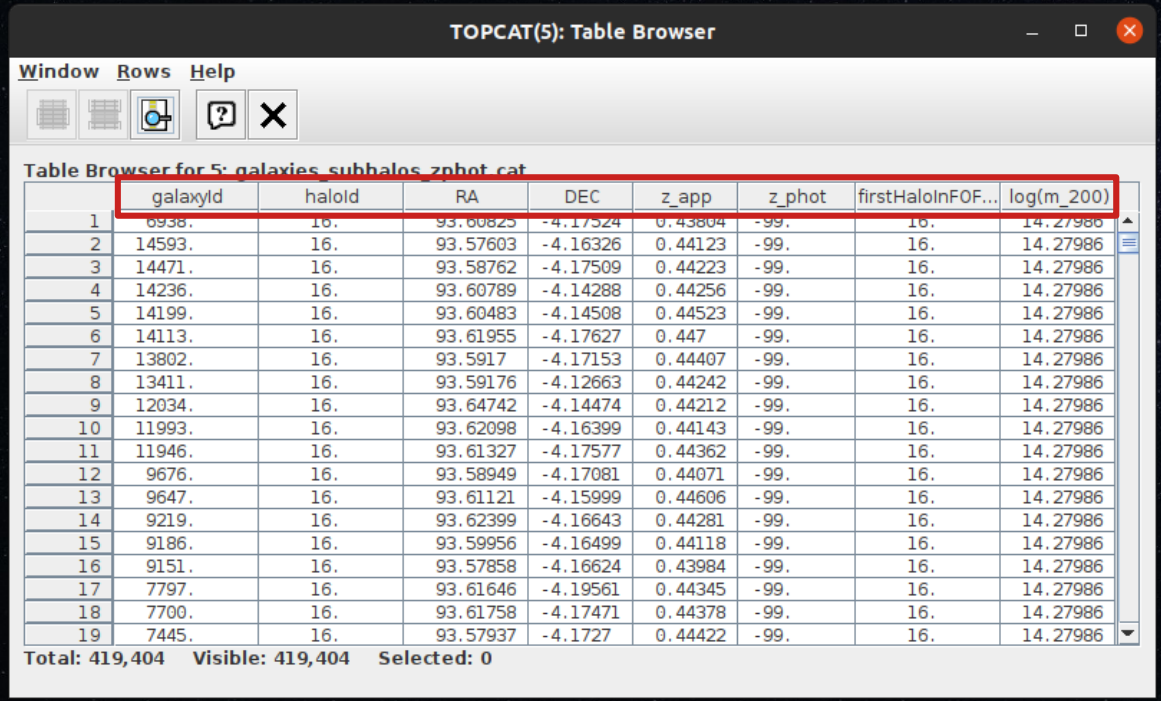


Olave-Rojas et al. (2018)

Dressler-Shectman Test (Dressler & Shectman 1988) ✚ GMM ✚ DBSCAN (Ester et al. 1996)

S-PLUS MOCKS

Developed by Pablo Araya-Araya as part of S-PLUS collaboration (for details see Araya-Araya et al. 2021)



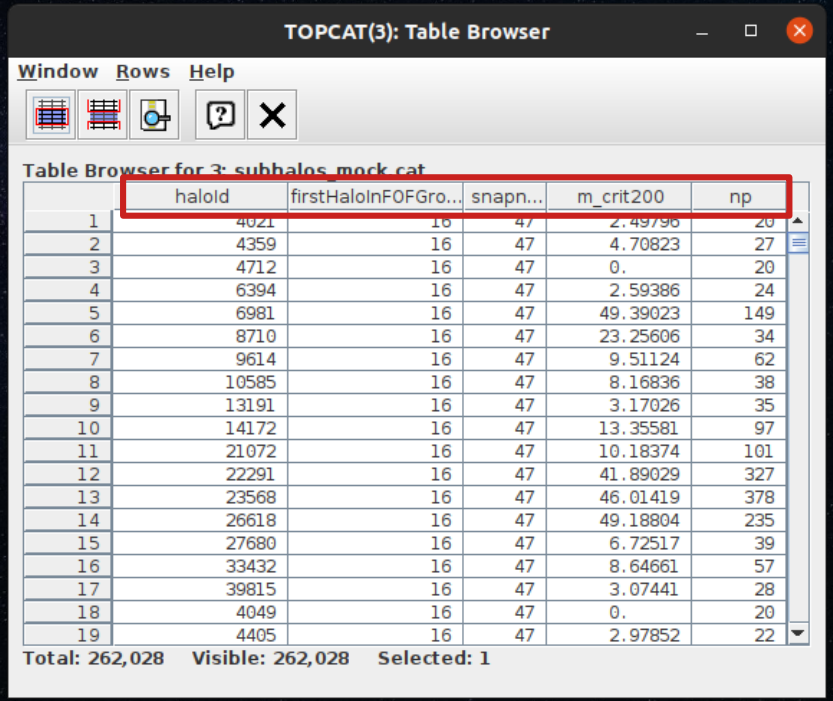
TOPCAT(5): Table Browser

Window Rows Help

Table Browser for 5: galaxies_subhalos_zphot_cat

	galaxyId	haloId	RA	DEC	z_app	z_phot	firstHaloInFOF...	log(m_200)
1	6938.	16.	93.60825	-4.17524	0.43804	-99.	16.	14.27986
2	14593.	16.	93.57603	-4.16326	0.44123	-99.	16.	14.27986
3	14471.	16.	93.58762	-4.17509	0.44223	-99.	16.	14.27986
4	14236.	16.	93.60789	-4.14288	0.44256	-99.	16.	14.27986
5	14199.	16.	93.60483	-4.14508	0.44523	-99.	16.	14.27986
6	14113.	16.	93.61955	-4.17627	0.447	-99.	16.	14.27986
7	13802.	16.	93.5917	-4.17153	0.44407	-99.	16.	14.27986
8	13411.	16.	93.59176	-4.12663	0.44242	-99.	16.	14.27986
9	12034.	16.	93.64742	-4.14474	0.44212	-99.	16.	14.27986
10	11993.	16.	93.62098	-4.16399	0.44143	-99.	16.	14.27986
11	11946.	16.	93.61327	-4.17577	0.44362	-99.	16.	14.27986
12	9676.	16.	93.58949	-4.17081	0.44071	-99.	16.	14.27986
13	9647.	16.	93.61121	-4.15999	0.44606	-99.	16.	14.27986
14	9219.	16.	93.62399	-4.16643	0.44281	-99.	16.	14.27986
15	9186.	16.	93.59956	-4.16499	0.44118	-99.	16.	14.27986
16	9151.	16.	93.57858	-4.16624	0.43984	-99.	16.	14.27986
17	7797.	16.	93.61646	-4.19561	0.44345	-99.	16.	14.27986
18	7700.	16.	93.61758	-4.17471	0.44378	-99.	16.	14.27986
19	7445.	16.	93.57937	-4.1727	0.44422	-99.	16.	14.27986

Total: 419,404 Visible: 419,404 Selected: 0



TOPCAT(3): Table Browser

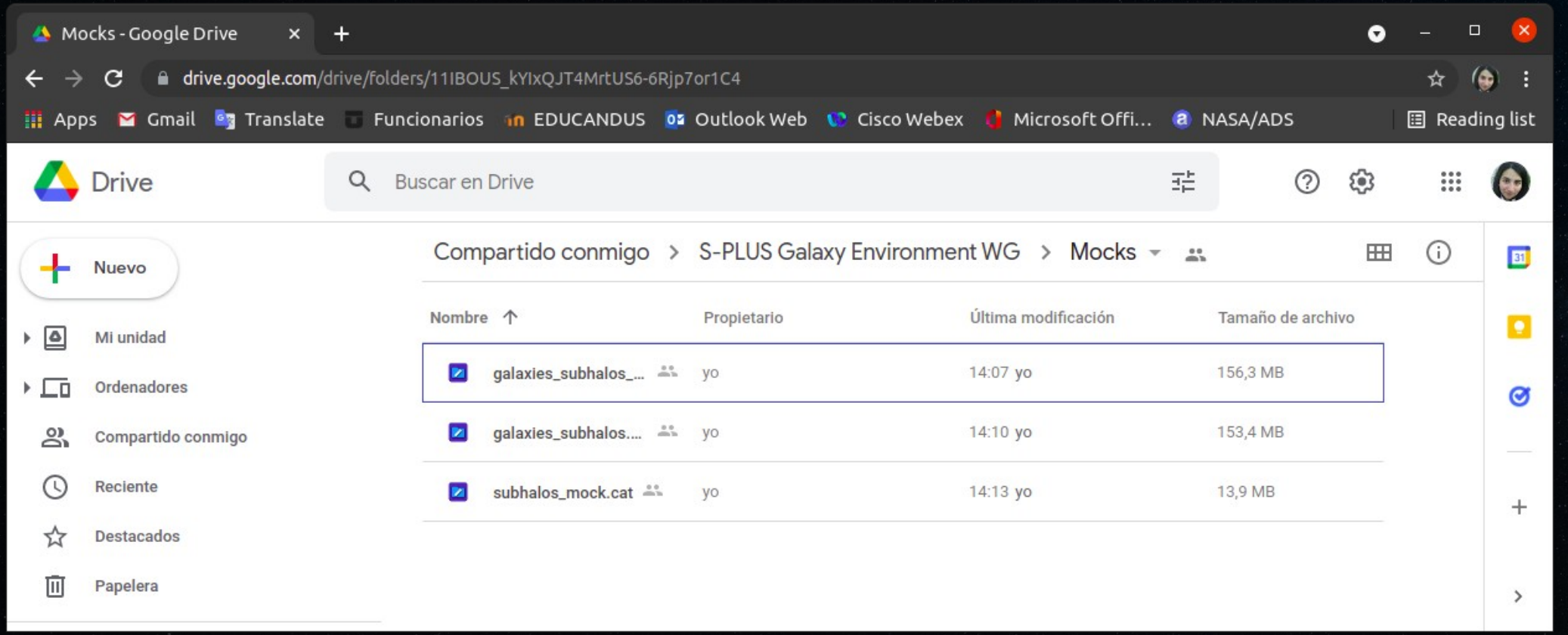
Window Rows Help

Table Browser for 3: subhalos_mock_cat

	haloId	firstHaloInFOFGro...	snapn...	m_crit200	np
1	4021	16	47	2.49796	20
2	4359	16	47	4.70823	27
3	4712	16	47	0.	20
4	6394	16	47	2.59386	24
5	6981	16	47	49.39023	149
6	8710	16	47	23.25606	34
7	9614	16	47	9.51124	62
8	10585	16	47	8.16836	38
9	13191	16	47	3.17026	35
10	14172	16	47	13.35581	97
11	21072	16	47	10.18374	101
12	22291	16	47	41.89029	327
13	23568	16	47	46.01419	378
14	26618	16	47	49.18804	235
15	27680	16	47	6.72517	39
16	33432	16	47	8.64661	57
17	39815	16	47	3.07441	28
18	4049	16	47	0.	20
19	4405	16	47	2.97852	22

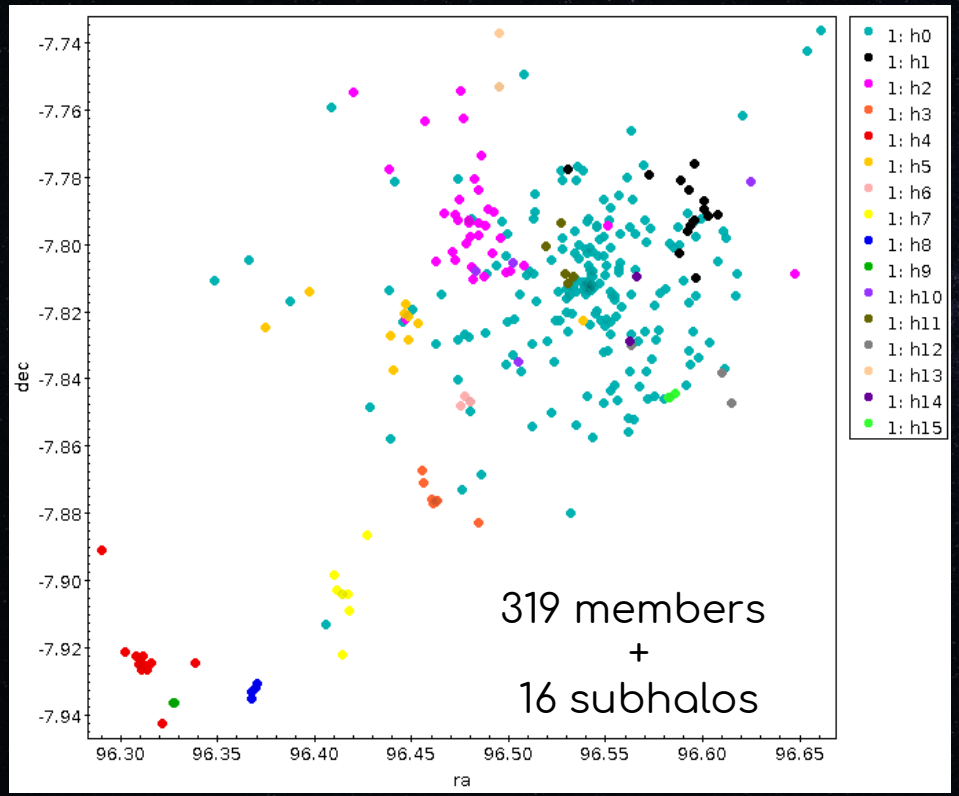
Total: 262,028 Visible: 262,028 Selected: 1

S-PLUS MOCKS

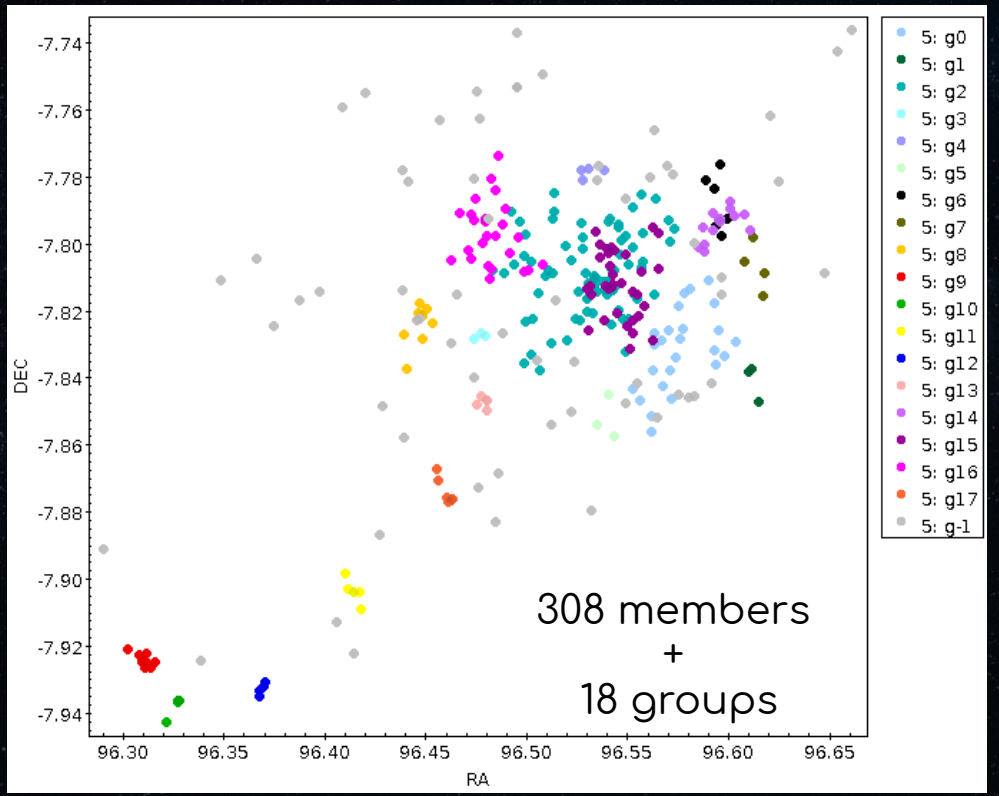

Mocks - Google Drive
drive.google.com/drive/folders/11IBOUS_kYIxQJT4MrtUS6-6Rjp7or1C4
Apps
Gmail
Translate
Funcionarios
EDUCANDUS
Outlook Web
Cisco Webex
Microsoft Offi...
NASA/ADS
Reading list
Drive
Buscar en Drive
Nuevo
Mi unidad
Ordenadores
Compartido conmigo
Reciente
Destacados
Papelera
Compartido conmigo > S-PLUS Galaxy Environment WG > Mocks
Nombre
Propietario
Última modificación
Tamaño de archivo
galaxies_subhalos_... yo 14:07 yo 156,3 MB
galaxies_subhalos.... yo 14:10 yo 153,4 MB
subhalos_mock.cat yo 14:13 yo 13,9 MB

CALSAGOS ON S-PLUS MOCKS

Original halo + subhalos



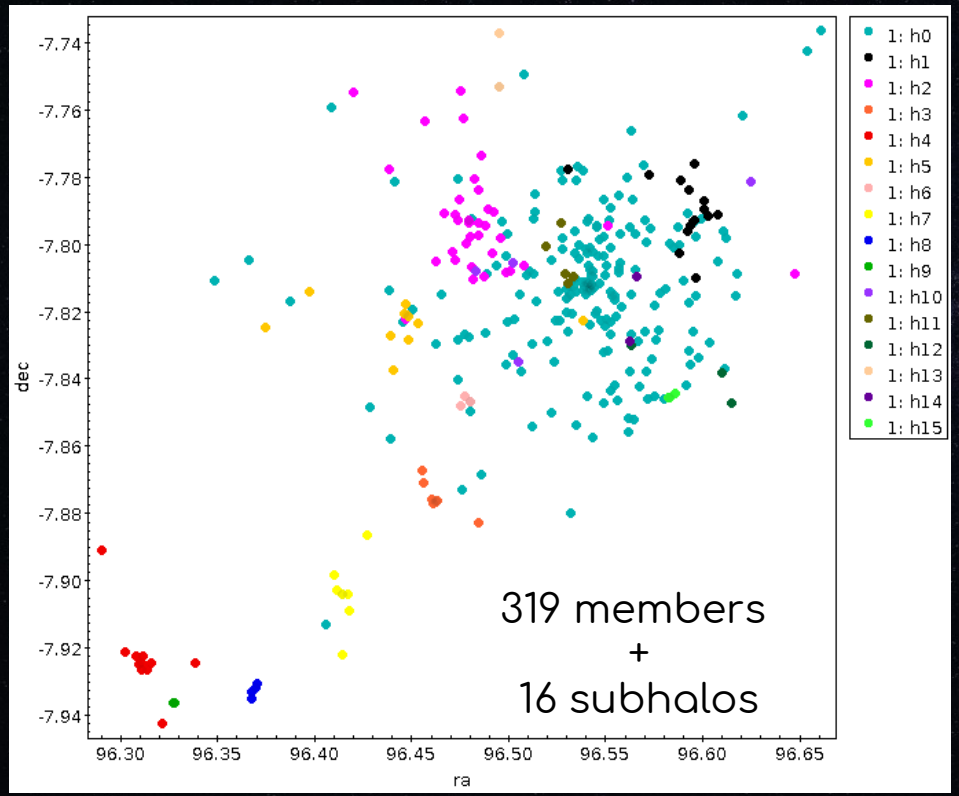
ISOMER + LAGASU application



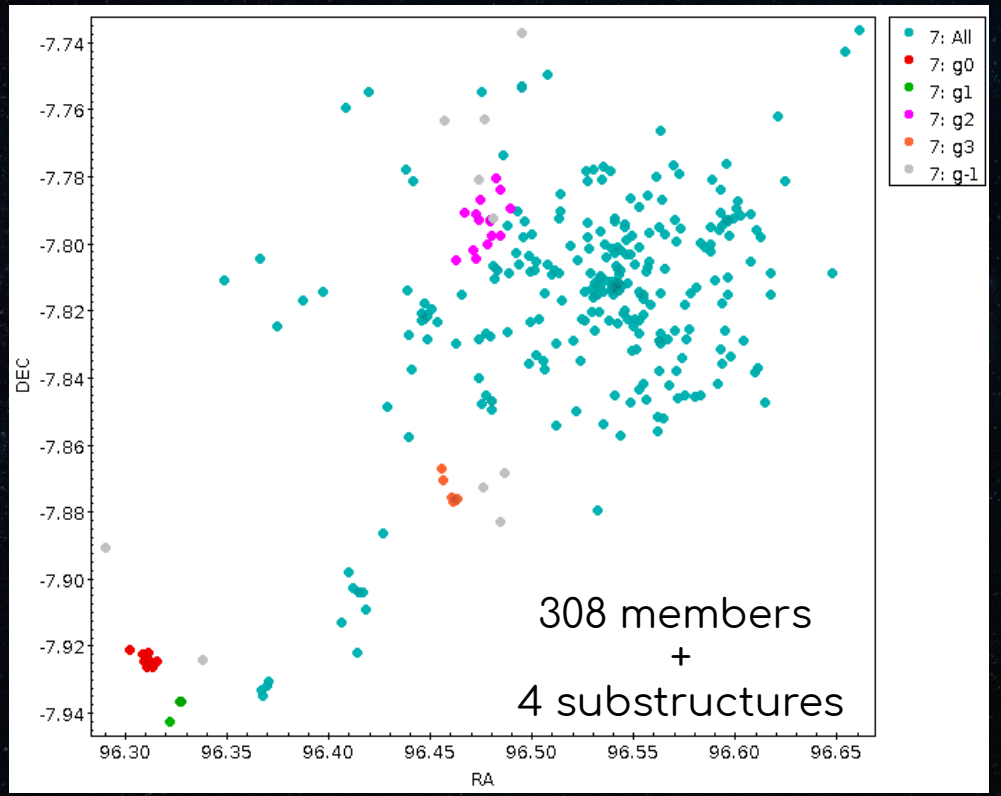
Olave-Rojas et al. in prep.

CALSAGOS ON S-PLUS MOCKS

Original halo + subhalos



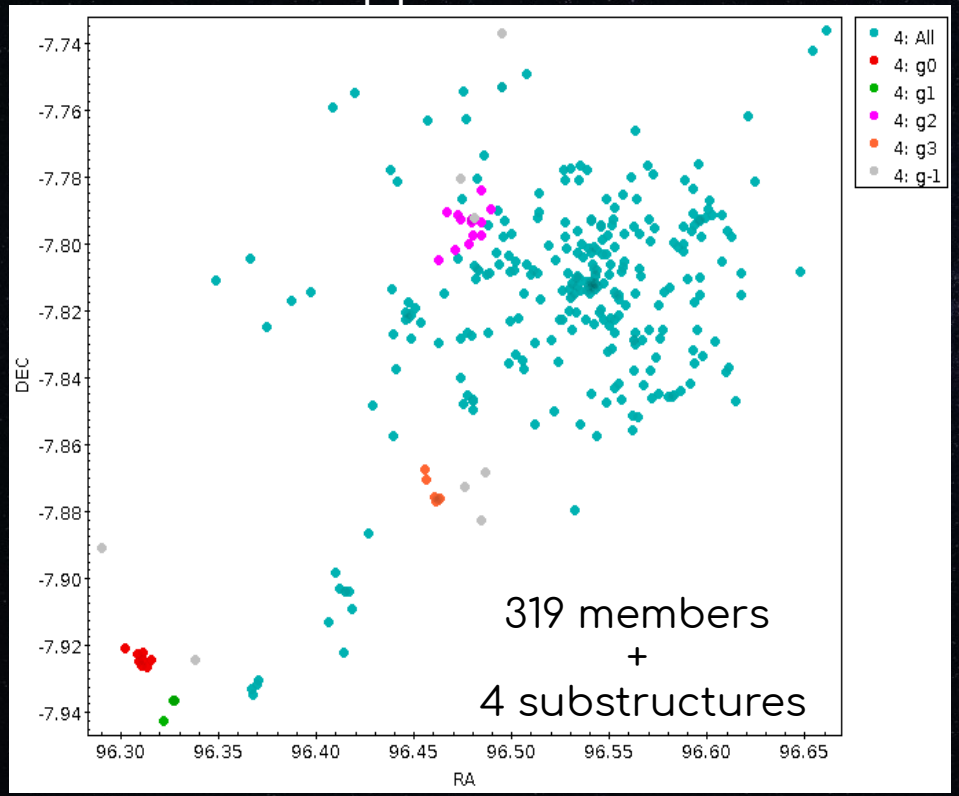
ISOMER + DS-Test + LAGASU application



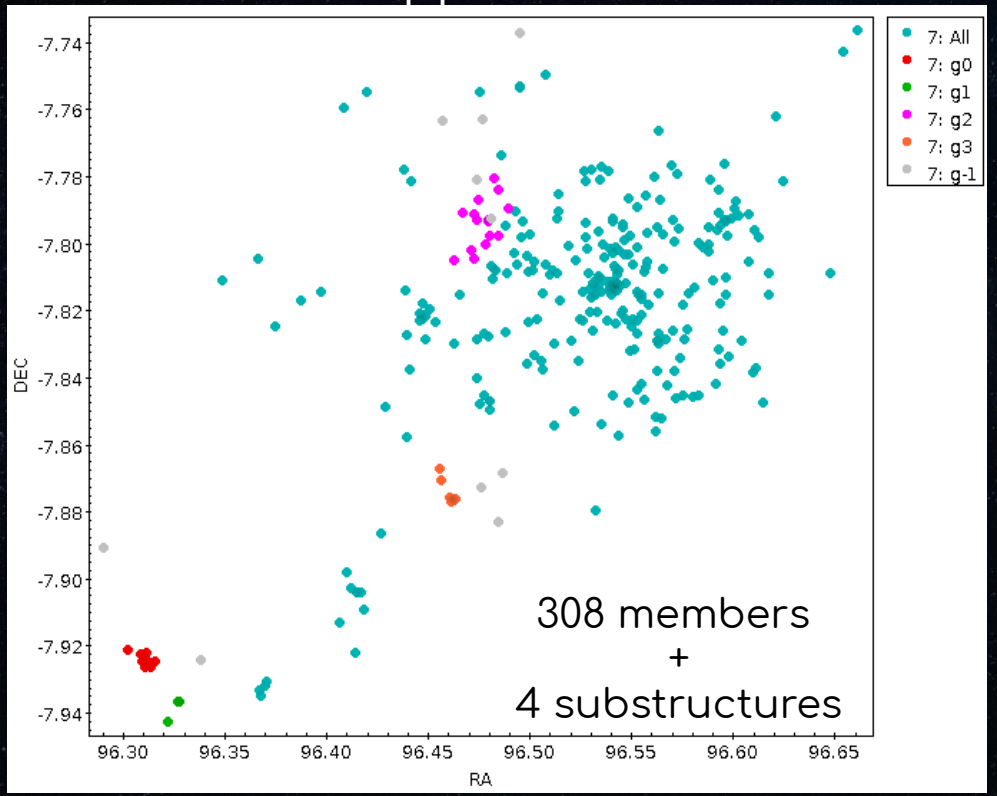
Olave-Rojas et al. in prep.

CALSAGOS ON S-PLUS MOCKS

CLUMBERI + DS-Test + LAGASU application



ISOMER + DS-Test + LAGASU application



Olave-Rojas et al. in prep.