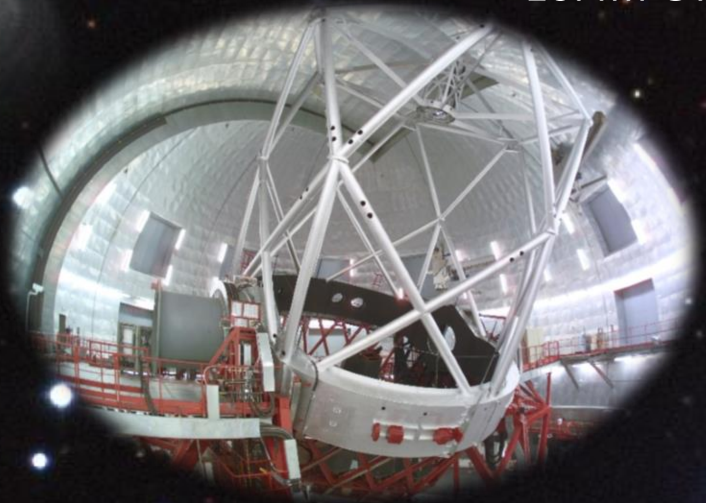
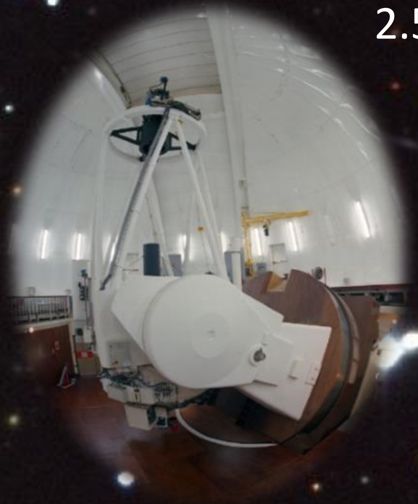
Optical follow-up of galaxy cluster candidates detected by Planck satellite in the PSZ catalogues

Universidad de La Laguna

10.4m GTC



2.5m INT



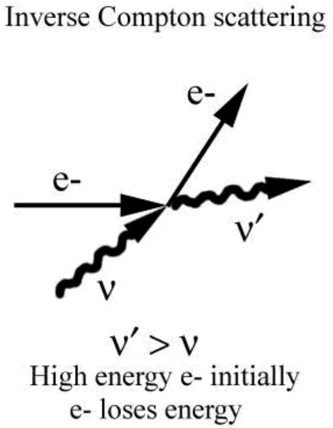
3.5m TNG

Group members:
J.A. Rubiño-Martín
R. Barrena
A. Streblyanska
A. Ferragamo

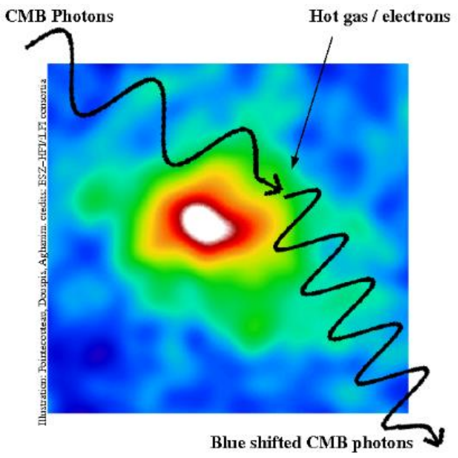
Alejandro Aguado

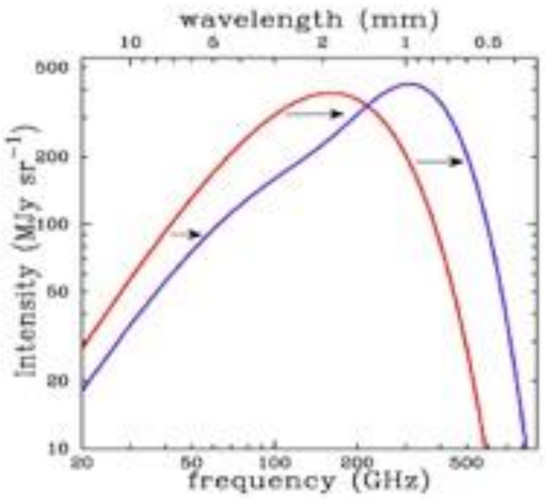
13th July 2017 – Aix en Provence

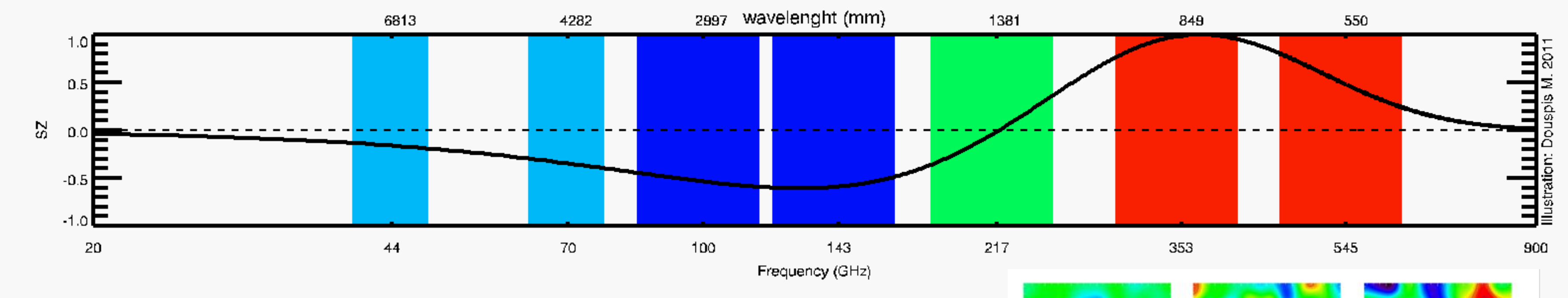
SUNYAEV-ZEL'DOVICH (SZ) EFFECT AND CLUSTER IDENTIFICATION WITH PLANCK



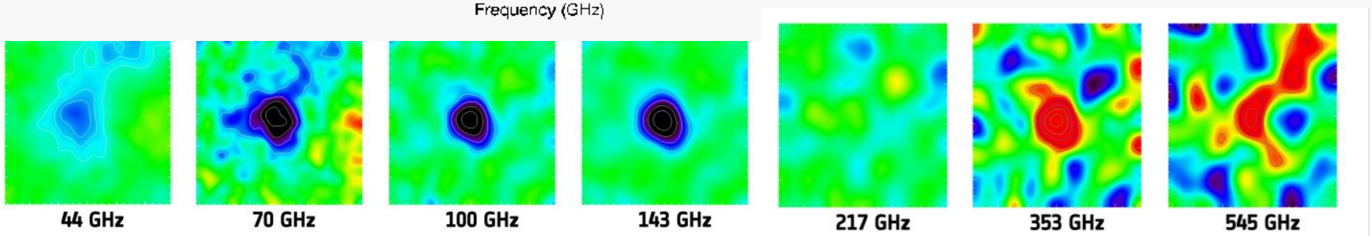
- Distortion of the CMB through inverse Compton scattering by high energy electrons
- Spectrum is shifted
- Drop at low frequencies and increase at higher ones





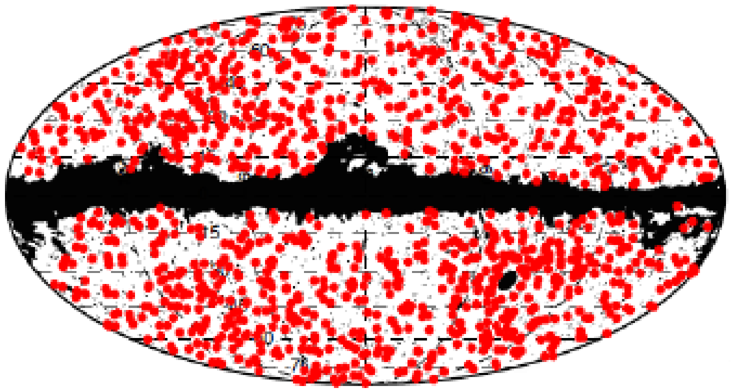


A2319 seen by PLANCK



PLANCK SZ CLUSTER CATALOGUES

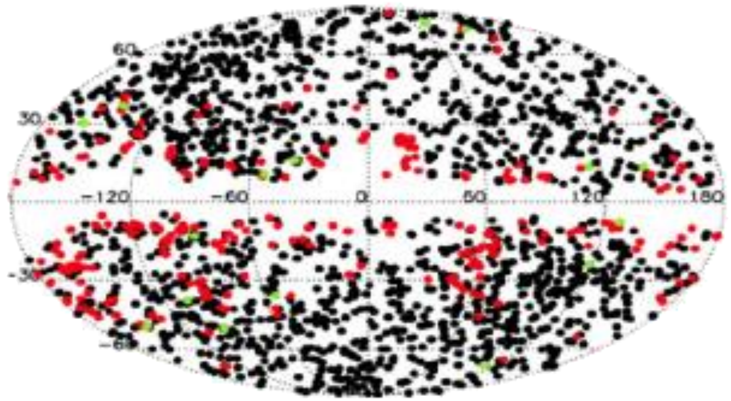
PSZ1



Planck 2013 results. XXVIII

Planck 2013 results. XXXII

PSZ2



Planck 2015 results. XXVII

Sample	PSZ1 2013	PSZ1 2015	PSZ2	Common	New PSZ2
Union	1227	1227	1653	937	716
Intersection	546	546	827	502	325
Confirmed	861	947	1203	820	383
Candidates	366	292	546	99	447
Low reliability	142	131	143	39	104
Total X-ray	501	501	603	477	126
MCXC	455	455	551	427	124
SZ clusters	82	82	110	79	31

Total = 1943
Confirmed = 1330
Unknown = 748

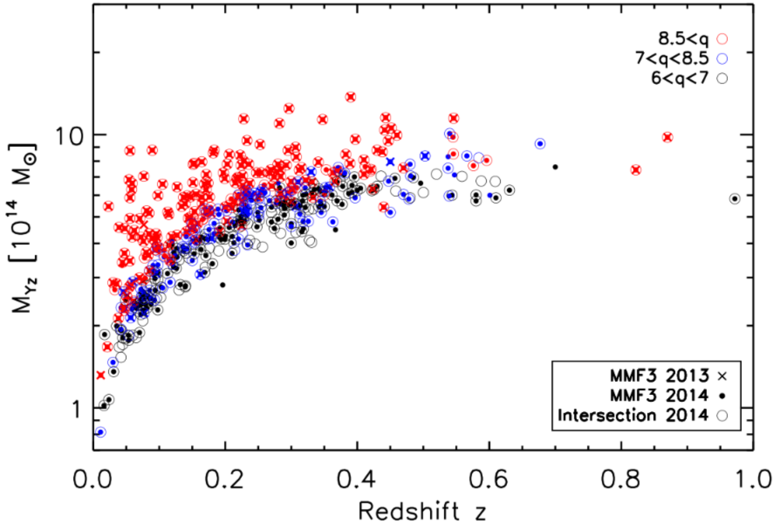
Approximately 450 accesible from the La Palma Observatory with $\delta \succ -20^{o}$

WHY AN OPTICAL FOLLOW-UP?

- Cluster counts are very usefull to constraint cosmological parameters (Ω_m , σ_8 , …)

$$\frac{dN}{dzdq} = \int d\Omega_{\rm mask} \int dM_{500} \frac{dN}{dzdM_{500}d\Omega} P[q|\bar{q}_{\rm m}(M_{500}, z, l, b)]$$

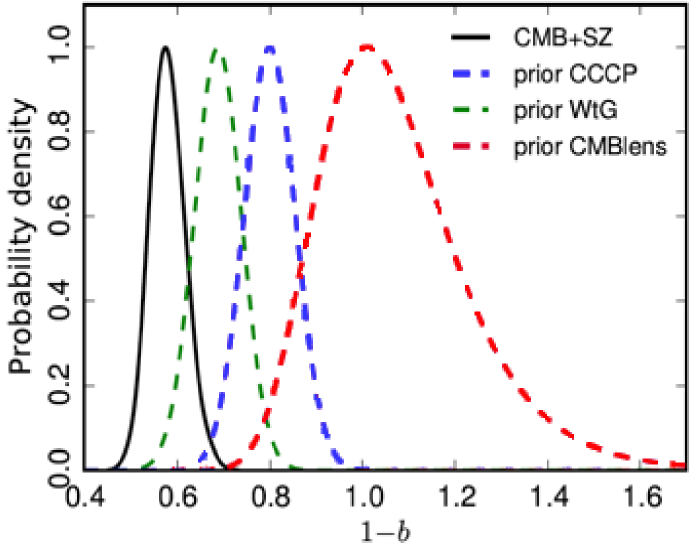
- Cosmology is very sensitive to the survey selection function

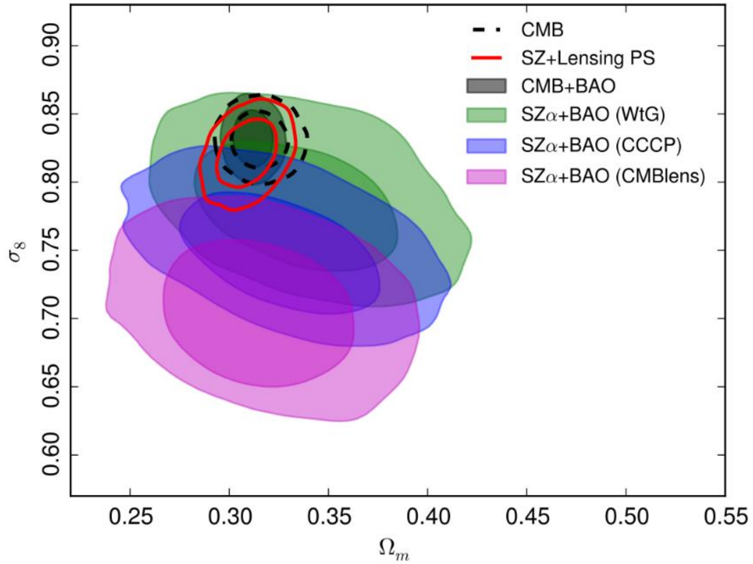


- Need for mass scaling law ($M_{500} - M_{SZ}$) , understanding possible biases

$$M_{500}^{HE} = (1-b)M_{500}^{true}$$

$$(1-b) = 0.8$$





MOTIVATION FOR OUR OPTICAL FOLLOW-UP

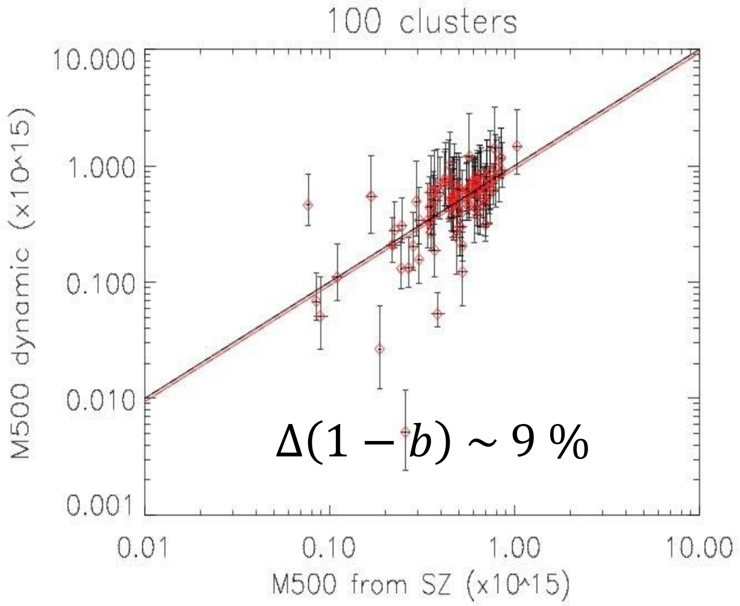
- The SZ-observable (Y) does not depend on redshift
- Does the mass bias depend on z and/or mass?
- Systematic aproach to obtain a complete selection function
- Understand the tension in cosmological parameters derived from the CMB and cluster counts, mostly in σ_8

MOTIVATION FOR OUR OPTICAL FOLLOW-UP

- The SZ-observable (Y) does not depend on redshift
- Does the mass bias depend on z and/or mass?
- Systematic aproach to obtain a complete selection function
- Understand the tension in cosmological parameters derived from the CMB and cluster counts, mostly in σ_8

AIM OF OUR OPTICAL FOLLOW-UP

- Validate unknown candidates
- Obtain dynamical masses
- Use these confirmed candidates to improve uncertainty in mass scaling law.
  $M_{Dyn} = \mathrm{B} \cdot M_{SZ}$
- Do cosmology with the same clusters used for the scaling law



OBSERVATIONAL PROGRAMMES

❑ PSZ1

- ITP (13B-15A)
  - ➢ Imaging
    - ✓ 2.5m INT
    - ✓ 4.2m WHT
  - ➢ Spectroscopy
    - ✓ 3.5m TNG
    - ✓ 4.2m WHT
    - ✓ 10.4m GTC

❑ PSZ2

- LT (15B-17A)
  - ➢ Imaging
    - ✓ 2.5m INT
  - ➢ Spectroscopy
    - ✓ 3.5m TNG
    - ✓ 10.4m GTC

OBSERVATIONAL PROGRAMMES

			TELESCOPE-INSTRUMENT	DIAMETER (m)	FOV	$t_{exp}/band$	LIMITING MAGNITUDES			
							g-band	r-band	i-band	
PSZ1 ITP (13B-15A)	IMAGING		WHT-ACAM	4.2	8’ x 8’	~900 s	24.6	23.7	23.2	
	IMAGING		INT-WFC	2.5	34’ x 34’	~1500 s	24.5	22.7	22.0	**PSZ2** LT (15B-17A)
						t_{exp}	**RESOLUTION**	S/N	**MAGNITUD** r-band	
	SPECTROSCOPY	MOS	TNG-DOLORES	3.5	8’ x 8’	~4000 s	600	~5	~21	
	SPECTROSCOPY	MOS	GTC-OSIRIS	10.4	7.5’ x 3’	~3500 s	300	~5	~23	
	SPECTROSCOPY	LS	WHT-ACAM	4.2	8’ x 8’	~3500 s	450	~5	~20	

OBSERVATIONAL PROGRAMMES

SUMMARY

PSZ1							
Telescope	Mode	Instrument	# Nights	# Clusters			Redshift range
INT	Imaging	WFC	21	86	**204**		-
WHT	Imaging	ACAM	~15	118			-
WHT	LS	ACAM	~9	37	**87**	**187**	$z < 0.3$
GTC	LS	OSIRIS	68 hours	50			$0.1 \leq z \leq 0.85$
GTC	MOS	OSIRIS	37 hours	27	**100**		$0.4 \leq z \leq 0.9$
TNG	MOS	DOLORES	26	73			$0.1 \leq z < 0.4$

PSZ2						
Telescope	Mode	Instrument	# Nights	# Clusters		Redshift range
INT	Imaging	WFC	20 (+2)	174 (+ 14)	**~190**	-
TNG	MOS	DOLORES	7 (+2)	16 (+9)	**~81**	$0.1 \leq z < 0.4$
GTC	MOS	OSIRIS	67 (+2) hours	54 (+2)		$0.4 \leq z \leq 0.9$

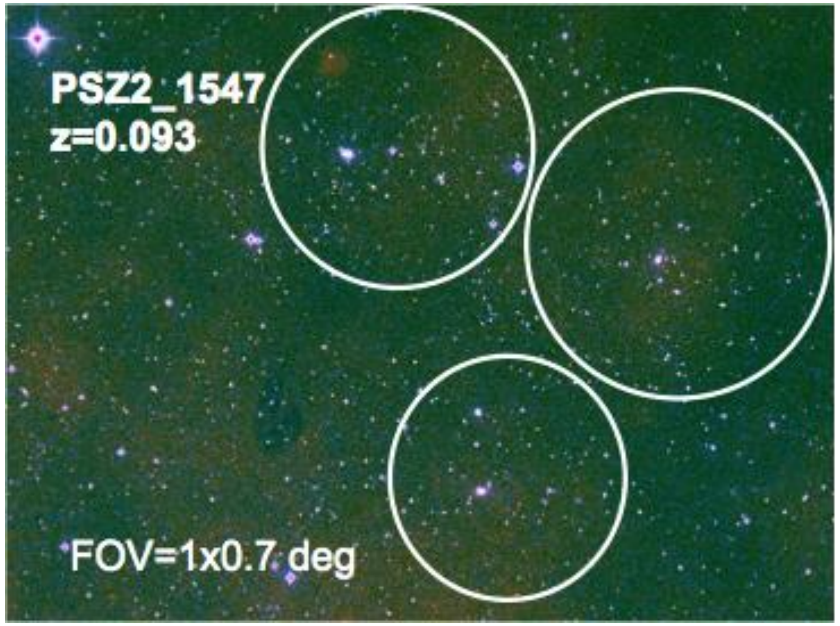
More than
9000
spectra

OBSERVATIONAL STRATEGY

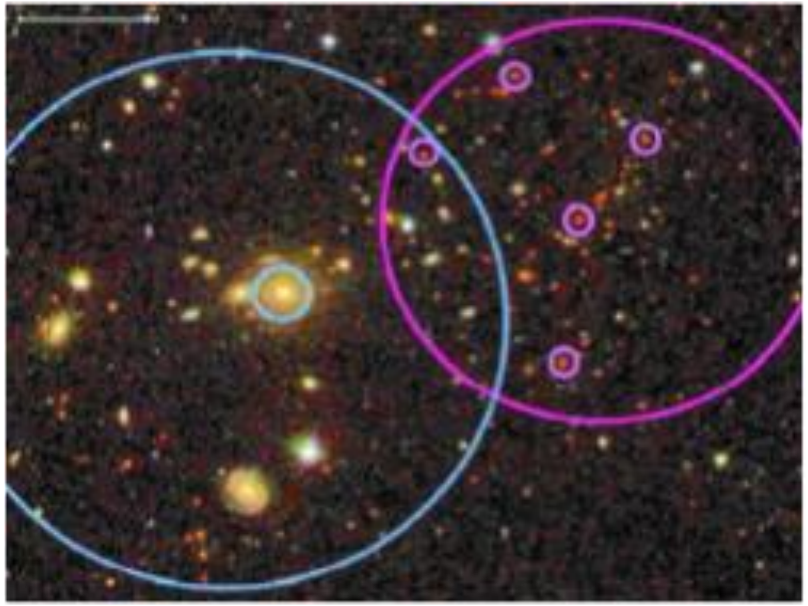
IMAGING

g-, r-, i-band images in order to make RGB images and color-magnitude diagrams

Substructures



Double detections

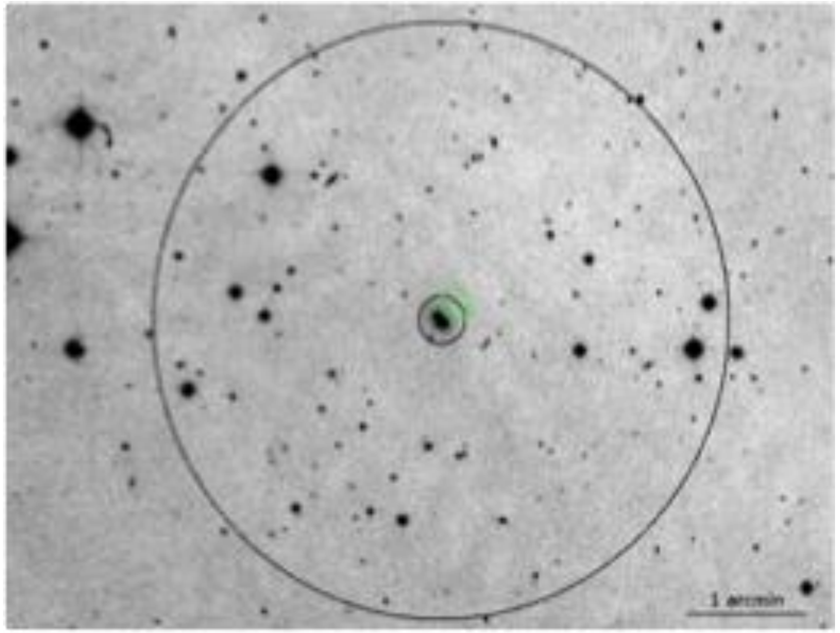


OBSERVATIONAL STRATEGY

IMAGING

g-, r-, i-band images in order to make RGB images and color-magnitude diagrams

Fossil systems



High-z clusters

OBSERVATIONAL STRATEGY

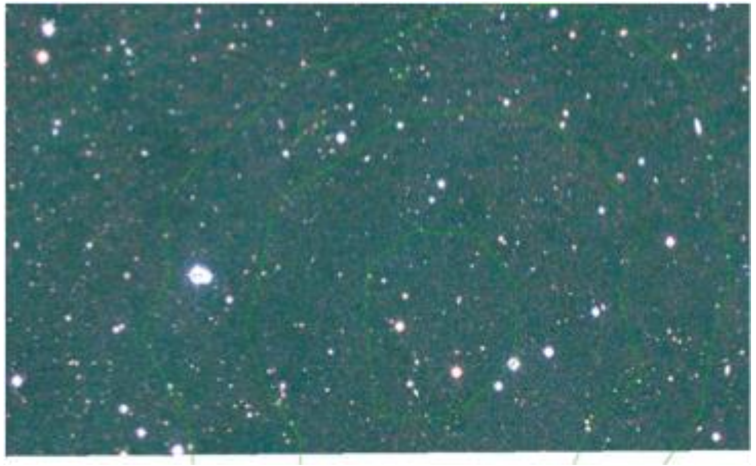
IMAGING

g-, r-, i-band images in order to make RGB images and color-magnitude diagrams

Non-detections

Dust contamination

Misidentifications

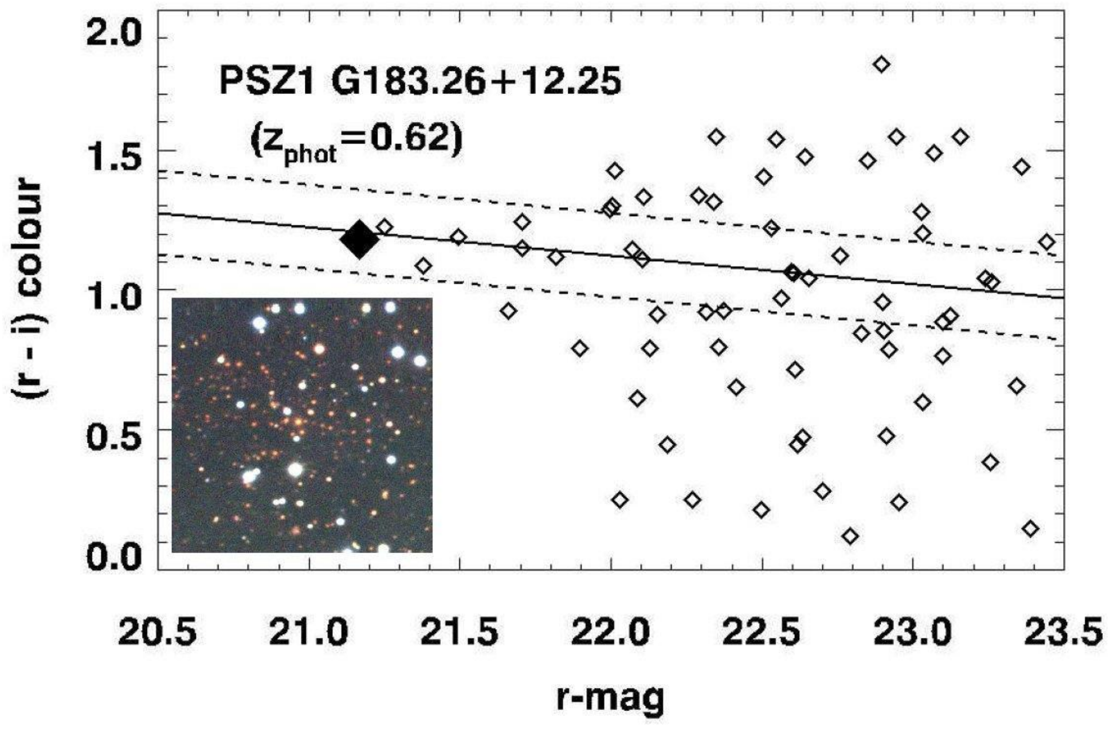


OBSERVATIONAL STRATEGY

IMAGING

g-, r-, i-band images in order to make RGB images and color-magnitude diagrams

Estimation of photo-z from CMDs



$$z_{\rm phot} \approx 0.361(g' - r') - 0.278, \qquad \text{if } (r' - i') \lesssim 0.75$$

$$z_{\rm phot} \approx 0.364(r' - i') + 0.182, \qquad \text{if } (r' - i') \gtrsim 0.75$$

Planck intermediate results. XXXVI

$$\left\{ \begin{array}{c} z_{phot} < 0.4 \rightarrow DOLORES/TNG \\ z_{phot} > 0.4 \rightarrow OSIRIS/GTC \end{array} \right\}$$

OBSERVATIONAL STRATEGY

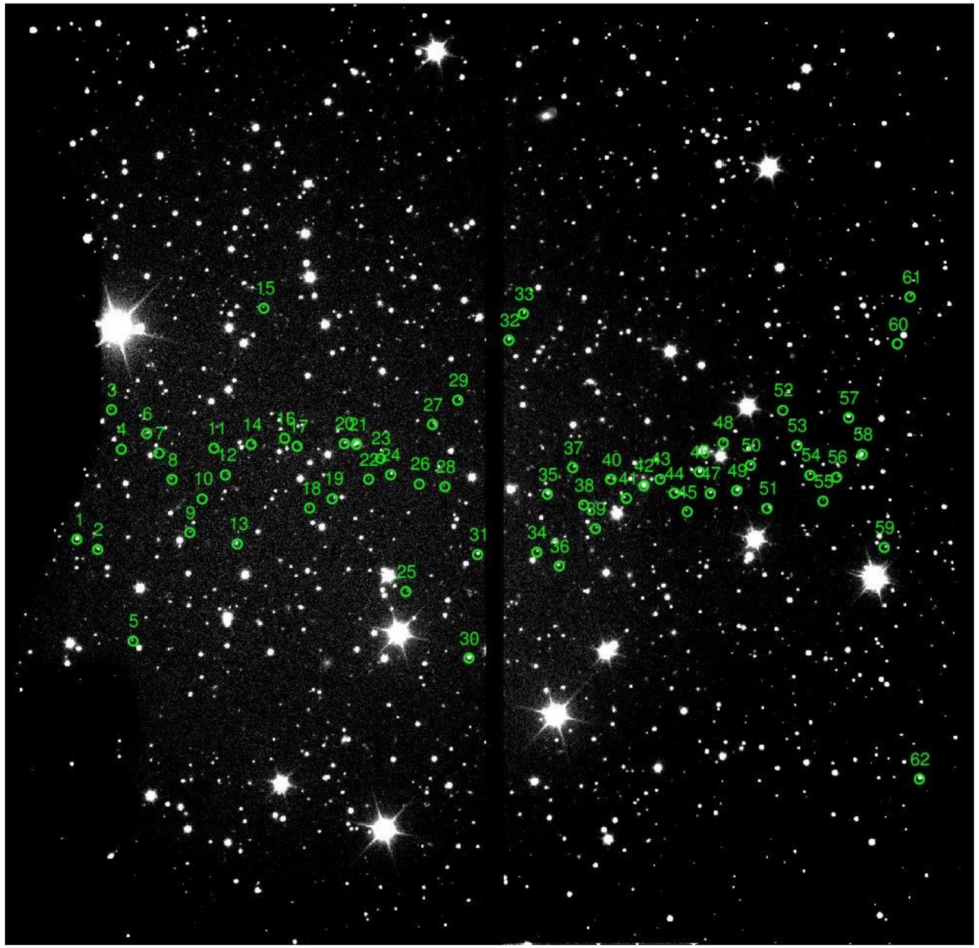
MOS SPECTROSCOPY

- Identification of posible members in the RGB images

OBSERVATIONAL STRATEGY

MOS SPECTROSCOPY

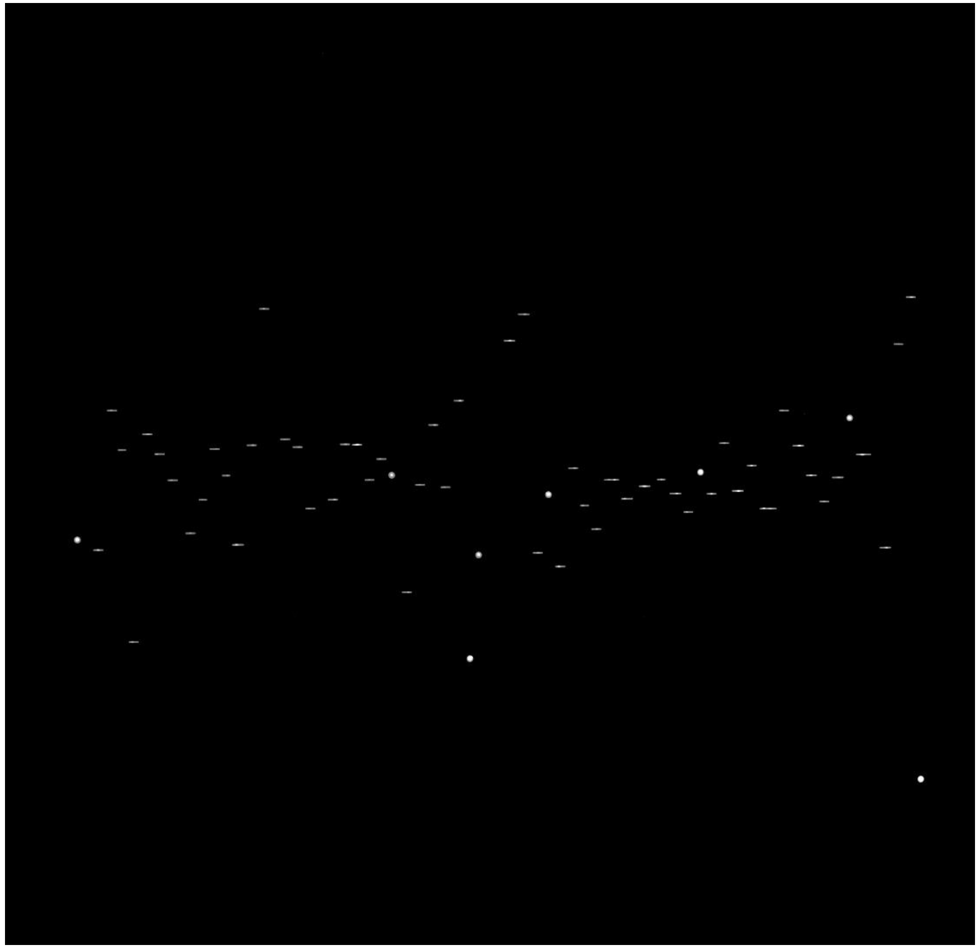
- Identification of posible members in the RGB images
- Ask for preimaging



OBSERVATIONAL STRATEGY

MOS SPECTROSCOPY

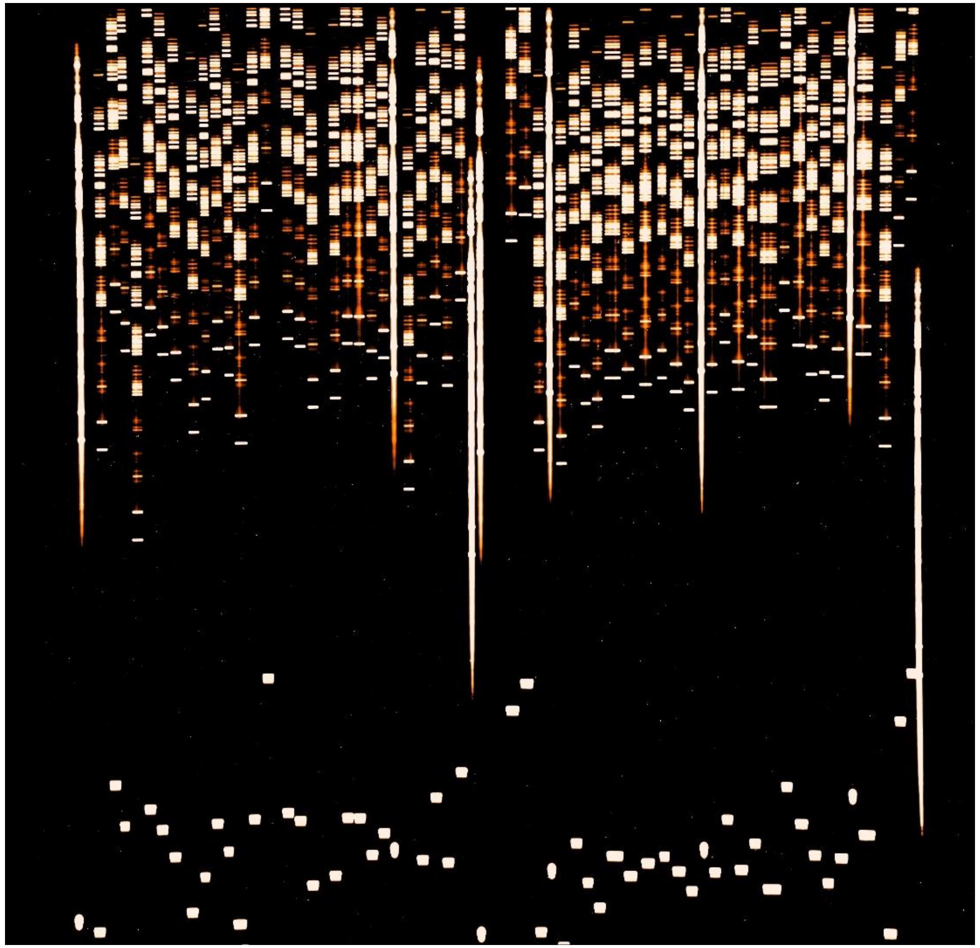
- Identification of posible members in the RGB images
- Ask for preimaging
- Design one mask per cluster based on the preimage, RGBs and CMDs



OBSERVATIONAL STRATEGY

MOS SPECTROSCOPY

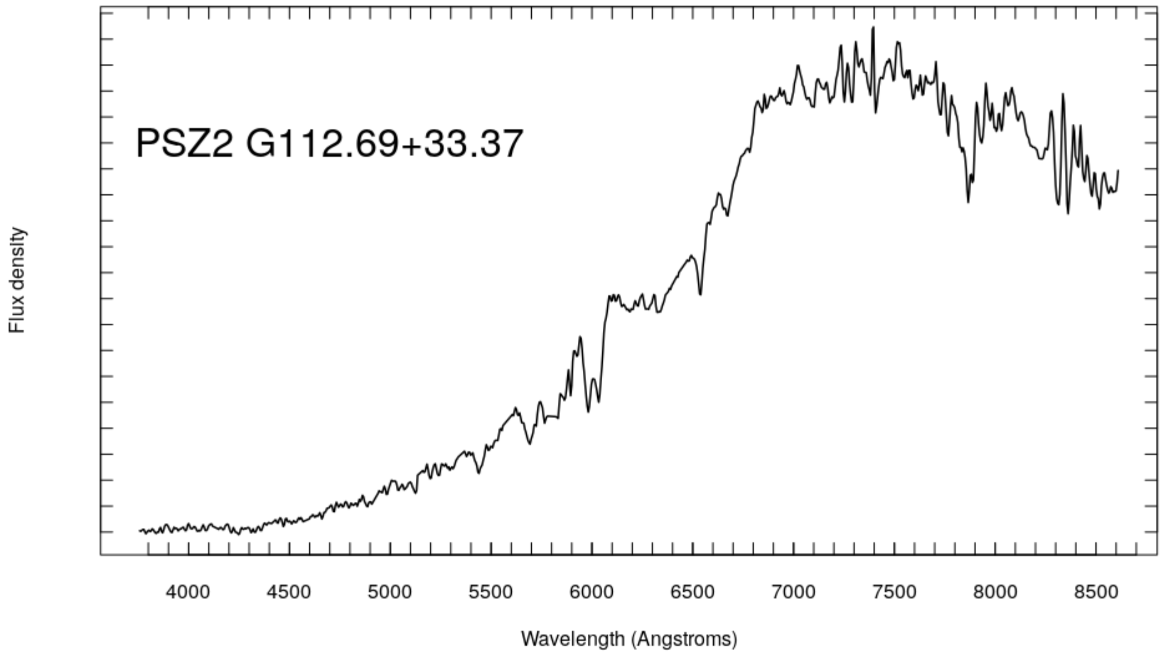
- Identification of posible members in the RGB images
- Ask for preimaging
- Design one mask per cluster based on the preimage, RGBs and CMDs
- Obtain the spectra



OBSERVATIONAL STRATEGY

MOS SPECTROSCOPY

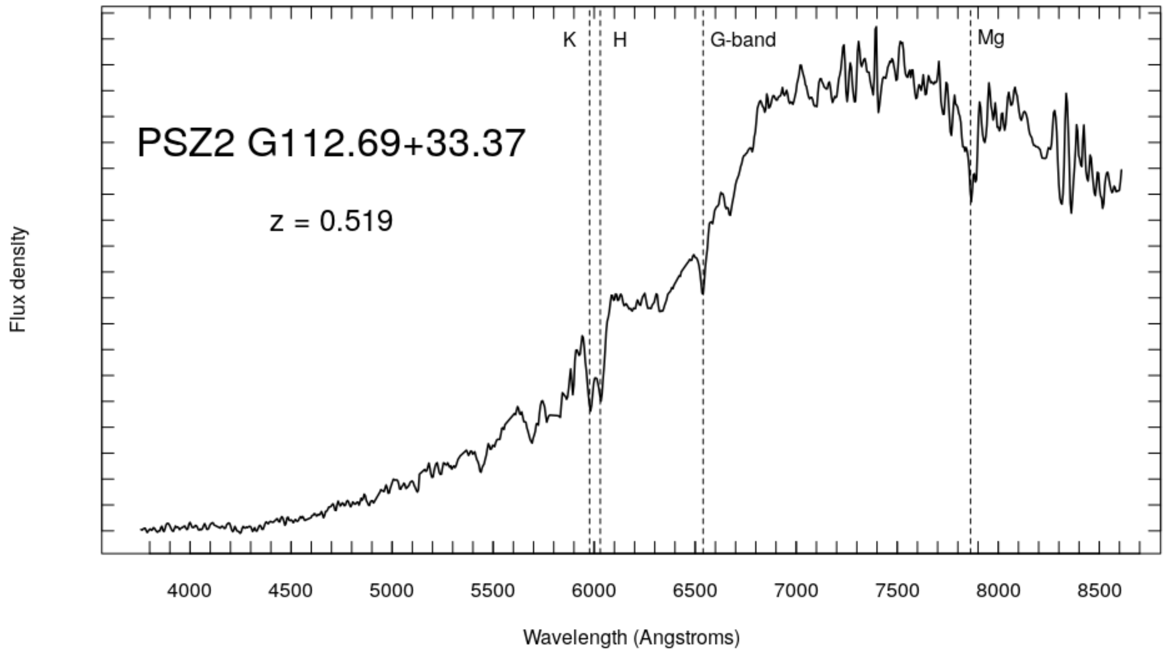
- Identification of posible members in the RGB images
- Ask for preimaging
- Design one mask per cluster based on the preimage, RGBs and CMDs
- Obtain the spectra
- Reduce the spectra



OBSERVATIONAL STRATEGY

MOS SPECTROSCOPY

- Identification of posible members in the RGB images
- Ask for preimaging
- Design one mask per cluster based on the preimage, RGBs and CMDs
- Obtain the spectra
- Reduce the spectra
- Adquire radial velocity and therefore the redshift
  - Using cross-correlation (*xcsao* in IRAF) with Kennicutt (1992) templates

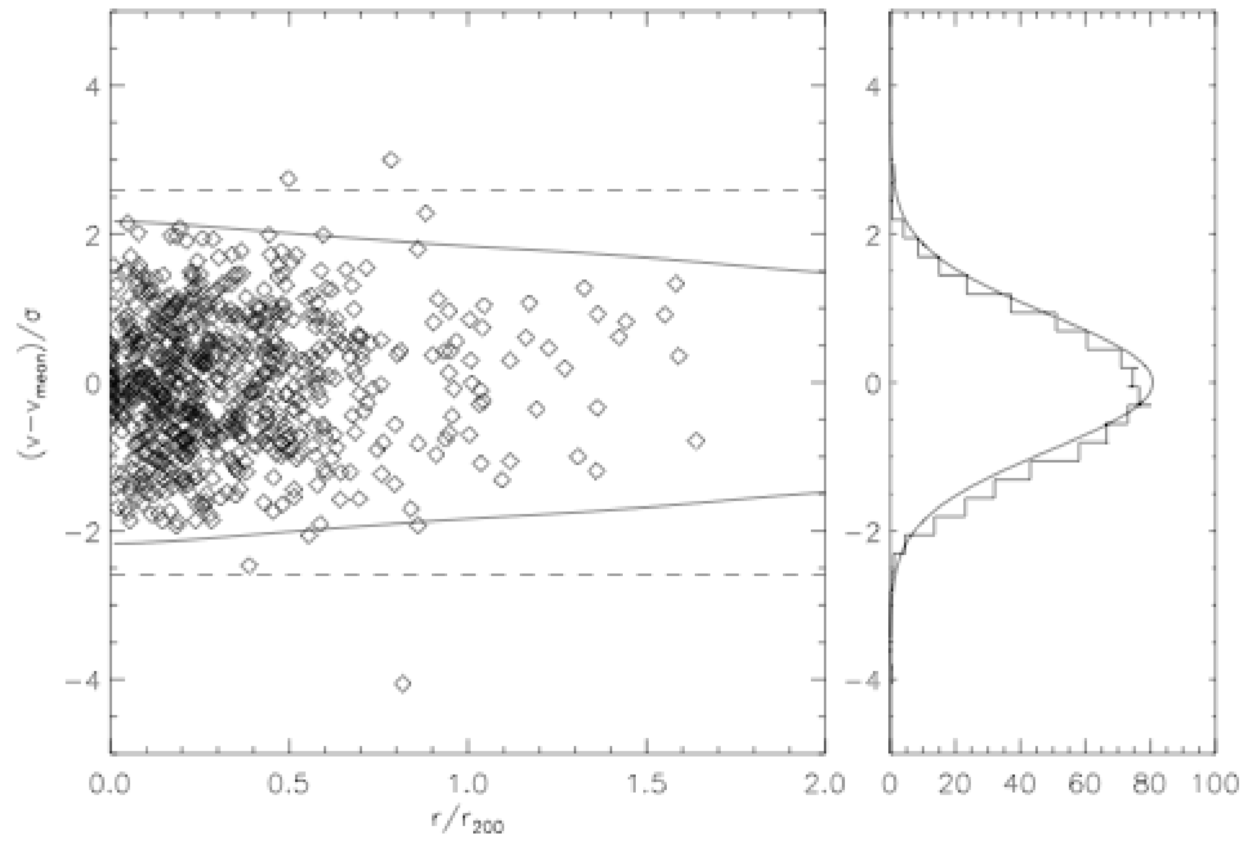


VELOCITY DISPERSION ESTIMATION

MEMBER SELECTION

- Galaxies are selected as members of a cluster if they lay within ± 2500 km/s in rest frame from the mean velocity

- Then we check one by one for special cases such as low mass clusters, substructures, posible interlopers…



VELOCITY DISPERSION ESTIMATION

- We make use of 3 estimators (standard deviation, biweight & gapper) for the calculation of the velocity dispersion
- Currently studying with simulations which one is the most precise and accurate
- We are also implementing various corrections

VELOCITY DISPERSION ESTIMATION

- We make use of 3 estimators (standard deviation, biweight & gapper) for the calculation of the velocity dispersion
- Currently studying with simulations which one is the most precise and accurate
- We are also implementing various corrections

FOR FURTHER DETAILS SEE A.FERRAGAMO’S POSTER

VELOCITY DISPERSION ESTIMATION

- We make use of 3 estimators (standard deviation, biweight & gapper) for the calculation of the velocity dispersion
- Currently studying with simulations which one is the most precise and accurate
- We are also implementing various corrections

FOR FURTHER DETAILS SEE A.FERRAGAMO'S POSTER

DYNAMICAL MASS ESTIMATION

- We use the relation $\sigma_{1D} - M_{200}$ by Munari et al. 2013
  - ❑ Hydrodynamical simulation accounting for AGN feedback & star formation

$$M_{200} = \left[\frac{\sigma_{200}}{A \times h(z)}\right]^{1/\alpha} 10^{15}\mathrm{M}_\odot$$

$$A = 1177 \pm 4.2$$
$$\alpha = 0.364 \pm 0.0021$$

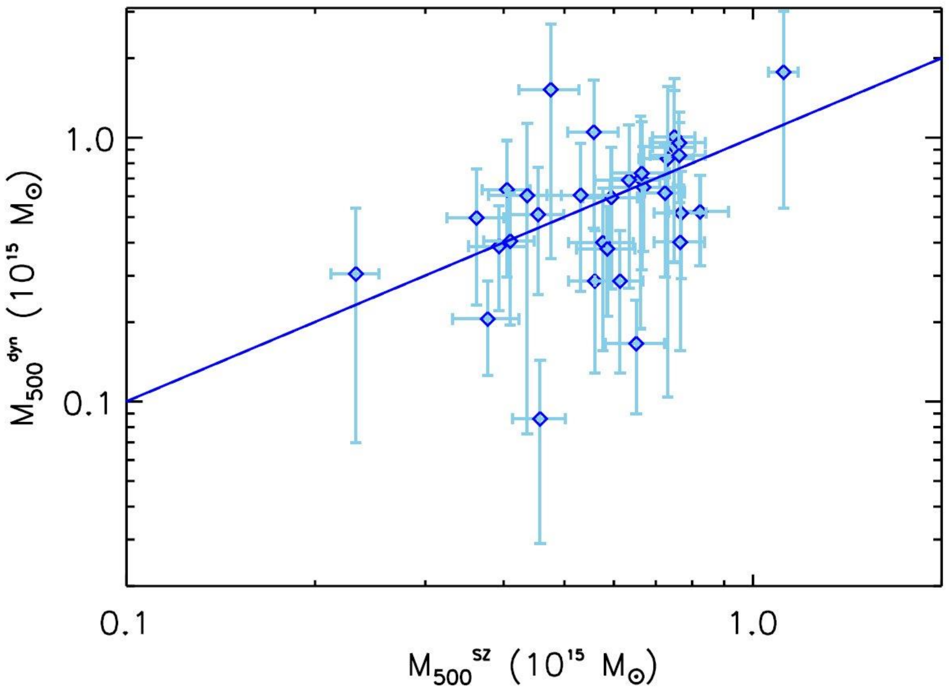
PSZ1 PRELIMINARY RESULTS

- Scaling relation:

$$\left\langle M_{500}^{dyn} \right\rangle = \beta \left\langle M_{500}^{true} \right\rangle$$

$$\left\langle M_{500}^{SZ} \right\rangle = (1 - \mathrm{b}) \left\langle M_{500}^{true} \right\rangle$$

$$\boldsymbol{B} = \frac{\beta}{1 - \mathrm{b}} = \frac{\left\langle M_{500}^{dyn} \right\rangle}{\left\langle M_{500}^{SZ} \right\rangle}$$



Our spectroscopic sample consists of 107 clusters but we only use 35 for this preliminary analysis with the following characteristics:

- More than 8 members
- $\sigma \geq 500\, km/s$
- $SNR \geq 5$ in *Planck* catalogues

$$\mathbf{B = 1.00 \pm 0.15}$$

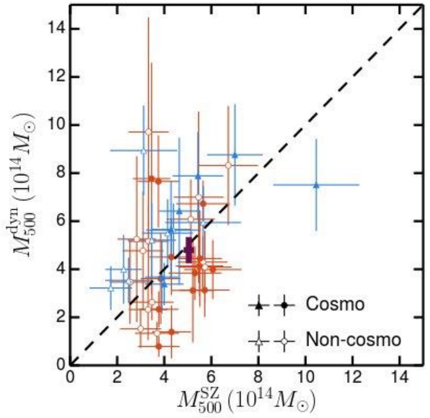
PSZ1 PRELIMINARY RESULTS

- Scaling relation:

$$\langle M_{500}^{dyn} \rangle = \beta \, \langle M_{500}^{true} \rangle$$

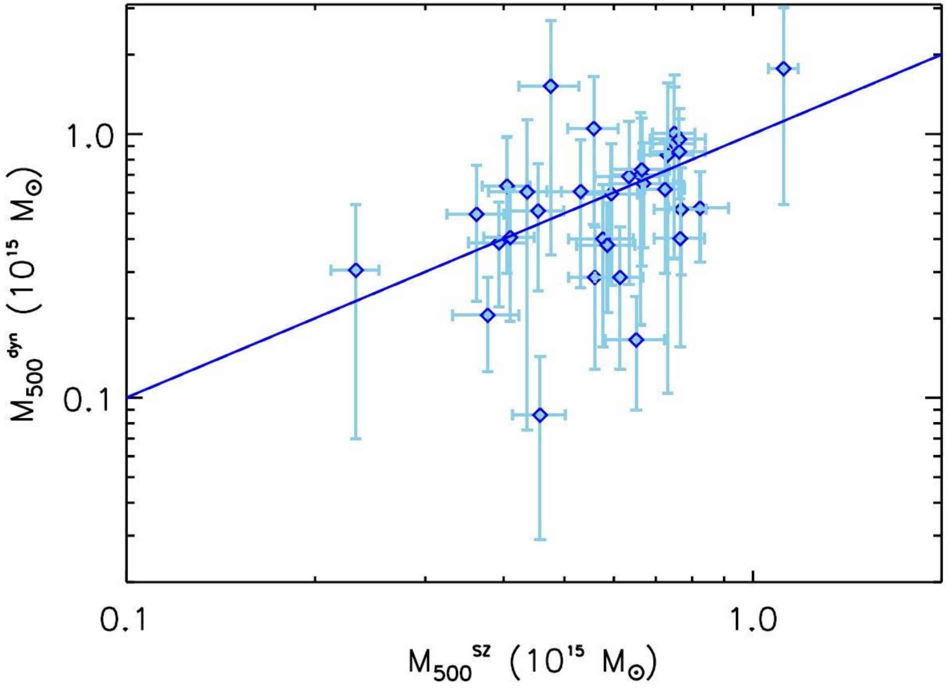
$$\langle M_{500}^{SZ} \rangle = (1 - \mathrm{b}) \, \langle M_{500}^{true} \rangle$$

$$\boldsymbol{B} = \frac{\beta}{1 - \mathrm{b}} = \frac{\langle M_{500}^{dyn} \rangle}{\langle M_{500}^{SZ} \rangle}$$



ACT data (21 clusters)
Sifon et al. (2016)

$$\frac{(1 - b_{\rm SZ})}{\beta_{\rm dyn}} = 1.10 \pm 0.13.$$



Our spectroscopic sample consists of 107 clusters but we only use 35 for this preliminary analysis with the following characteristics:

- More than 8 members
- $\sigma \geq 500\, km/s$
- $SNR \geq 5$ in *Planck* catalogues

$$\mathbf{B = 1.00 \pm 0.15}$$

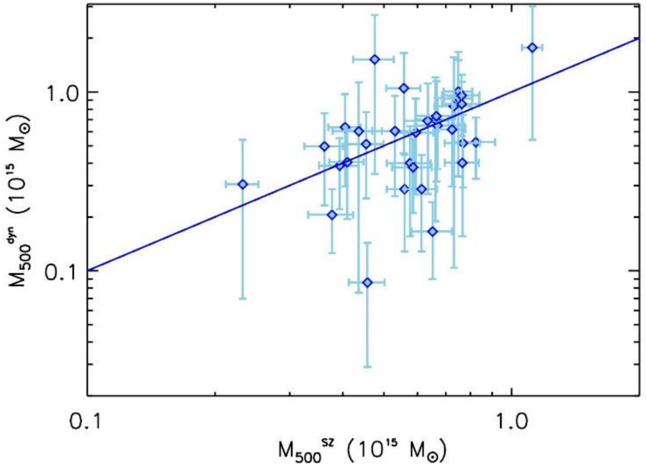
SUMMARY

- We have observed around 400 candidates for both PSZ1 and PSZ2 catalogues
- We have officially confirmed more than 150 new clusters from PSZ1

- PSZ2 catalogue follow-up still ongoing work
  - ➢ The observational programme will be finished by August 2017

- We have performed a preliminary analysis with PSZ1 data obtaining a bias value of:

$$\mathbf{B = 1.00 \pm 0.15}$$



COMING SOON…

- Calculate the B-value and implement the corrections on the velocity dispersion and mass estimations for PSZ2 data
- Estimate Ω_m and σ_8 using this B-value