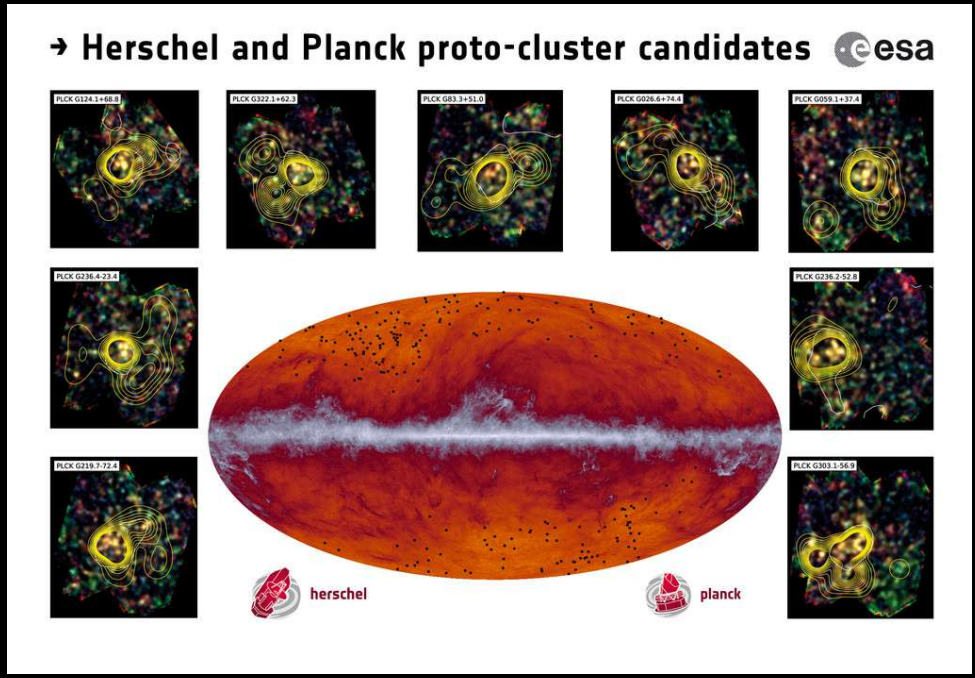
Following-up high *z* clusters in the Planck, Spitzer, JWST & Euclid era

Clément Martinache
Institut d'Astrophysique Spatiale, Univ. Paris-Sud, CNRS, Univ. Paris-Saclay

1 – Importance of z~2 epoch in mass assembly

2 – A unique sample : SPHerIC
(Spitzer Planck Herschel Infrared Clusters)

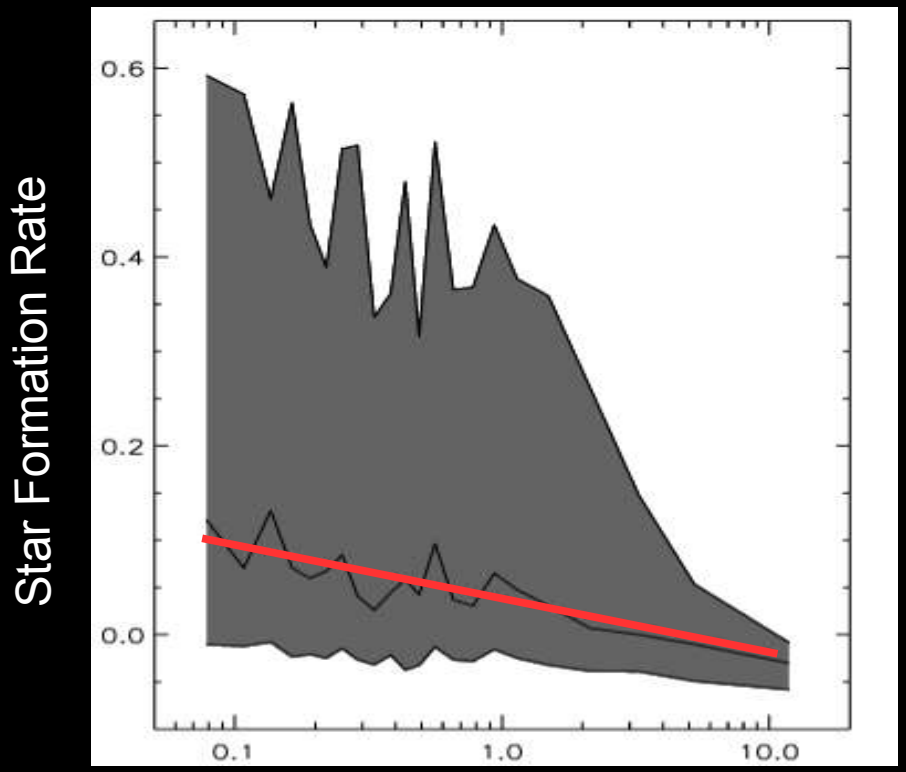
3 – Spectroscopic follow-up with MOONS



Collaborators : Hervé Dole, Alessandro Rettura, Benjamin Clarenc & SPHerIC collaboration.

1)The formation of local cluster galaxies

Local clusters : Dominated by old, massive, passive ellipticals. Essentially no star formation !



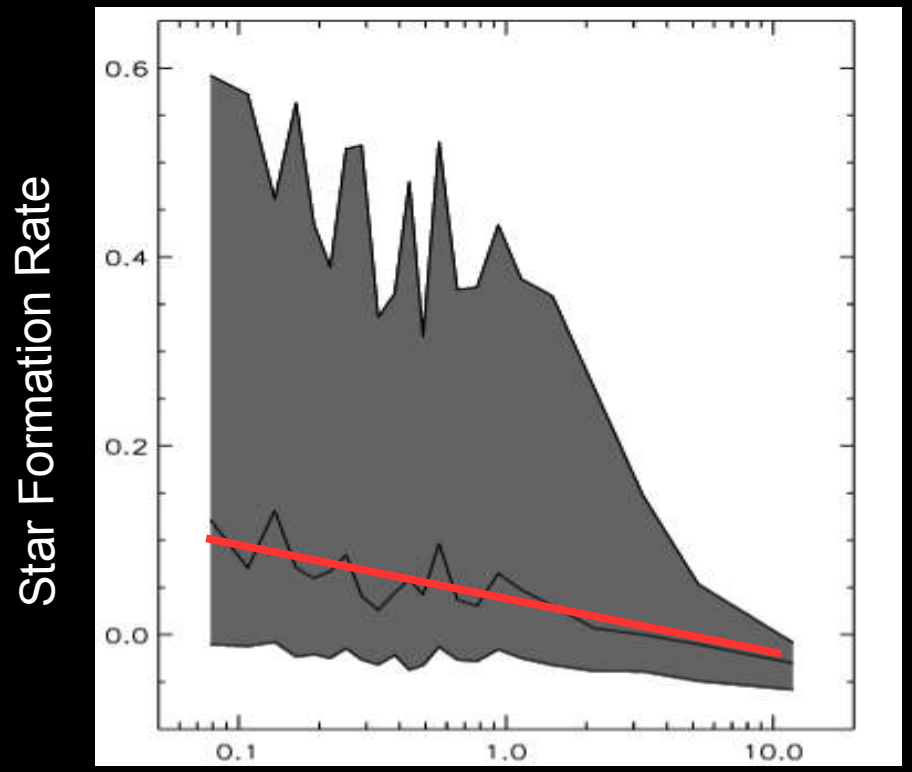
When and how did these galaxies form their stars ?

0.05<z<0.095

Gomez et al., 2003
ApJ 584:210

1)The formation of local cluster galaxies

Local clusters : Dominated by old, massive, passive ellipticals. Essentially no star formation !



When and how did these galaxies form their stars ?

0.05<z<0.095

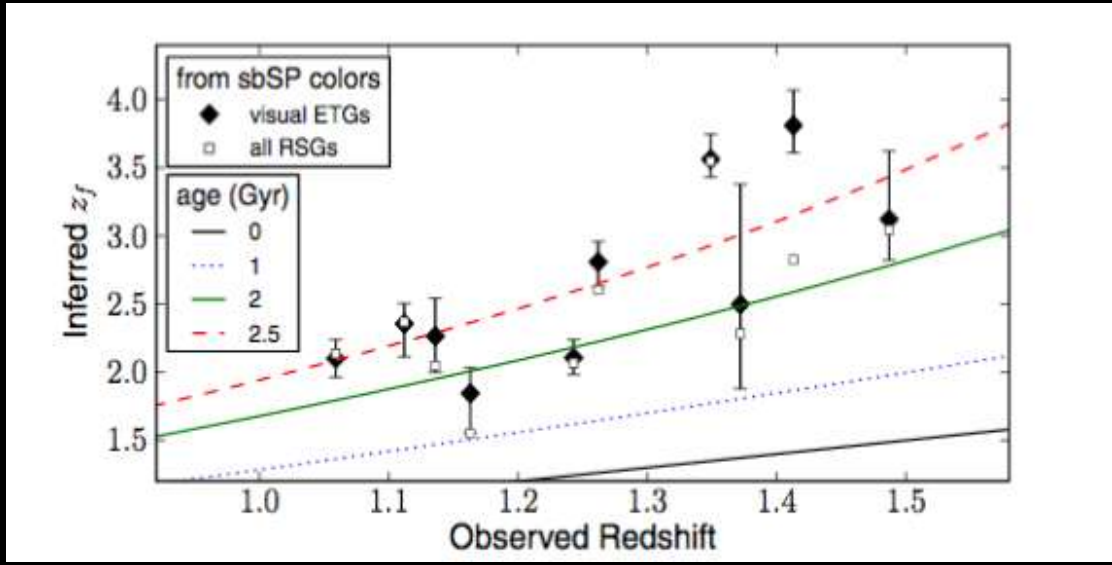
Gomez et al., 2003
ApJ 584:210

1)The formation of local cluster galaxies

→ Intense star formation in cluster galaxies at redshifts > 2-3 then passive evolution

Fossil indication. Need direct observations.

Need sample of structures at z~2.



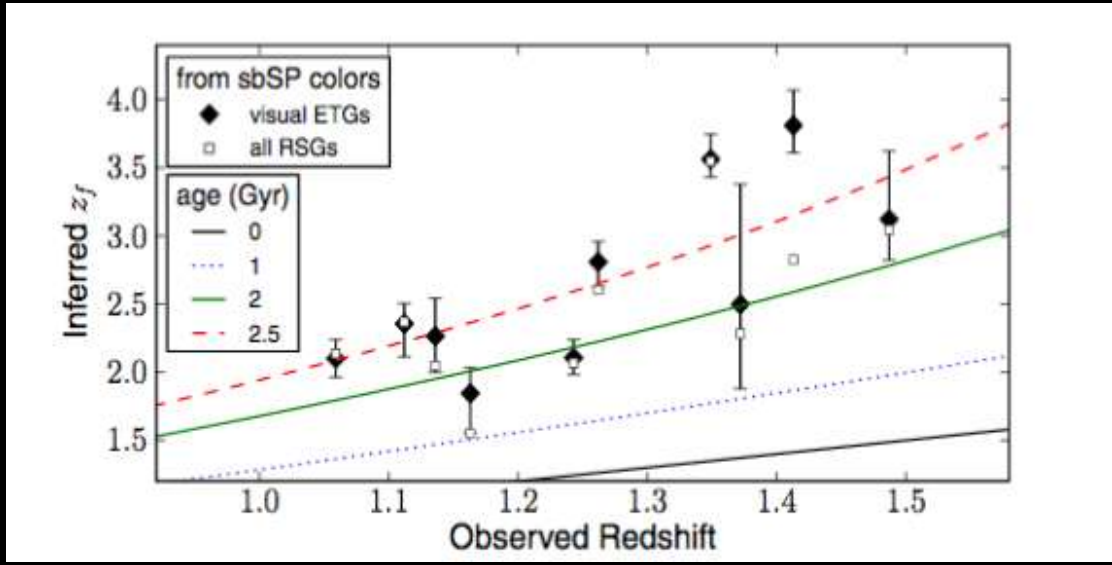
Snyder et al., 2012 – ApJ 756:114

1)The formation of local cluster galaxies

→ Intense star formation in cluster galaxies at redshifts > 2-3 then passive evolution

Fossil indication. Need direct observations.

Need sample of structures at z~2.



Snyder et al., 2012 – ApJ 756:114

1) z=2 : cluster or proto-clusters ?

Chiang et al., 2013
- ApJ 779:127

Cluster :

- $M>10^{14}\ M_{\odot}$
- Virial and hydrostatic equilibirum.
- Dominant dark matter halo

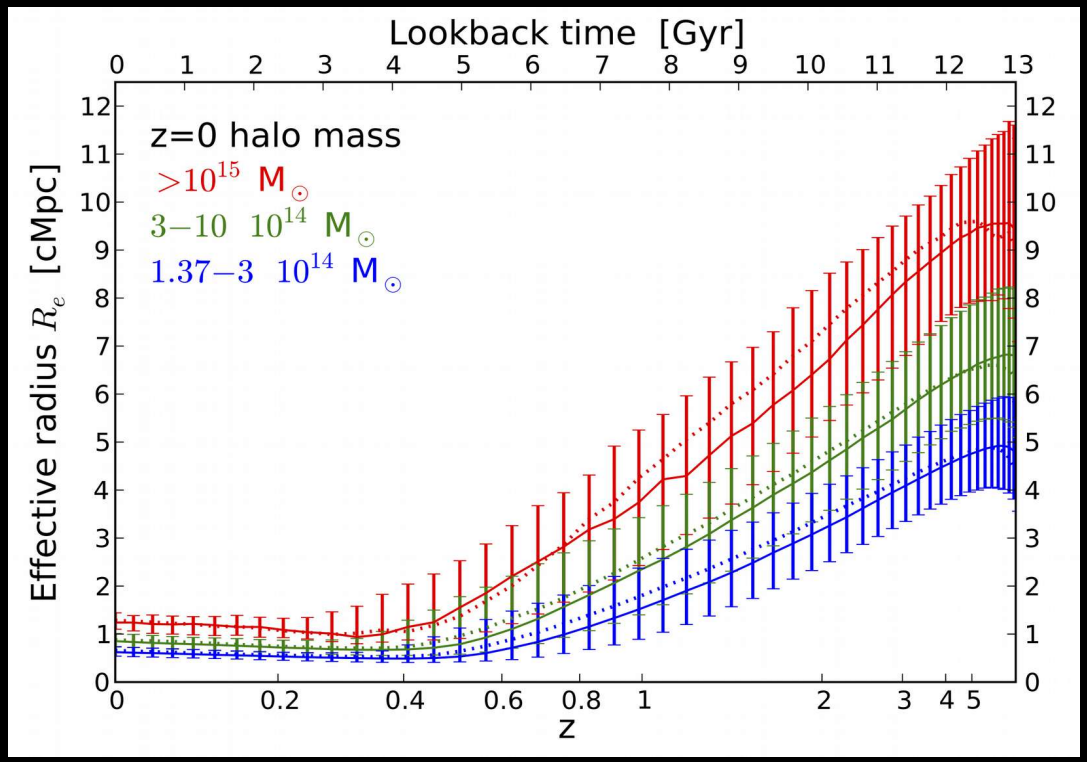
Few clusters at z~2 !

Proto-cluster : (Progenitors of clusters)

- Forming structure

- Not always dominant single DM halo.

- Spatially extended
(up to ~ 10 Mpc = 20') → MOONS !



Given mass at z=0 → different evolutions possible.

High-z clusters/Protoclusters are hard to detect

1) z=2 : cluster or proto-clusters ?

Chiang et al., 2013
- ApJ 779:127

Cluster :

- $M>10^{14}\ M_{\odot}$
- Virial and hydrostatic equilibirum.
- Dominant dark matter halo

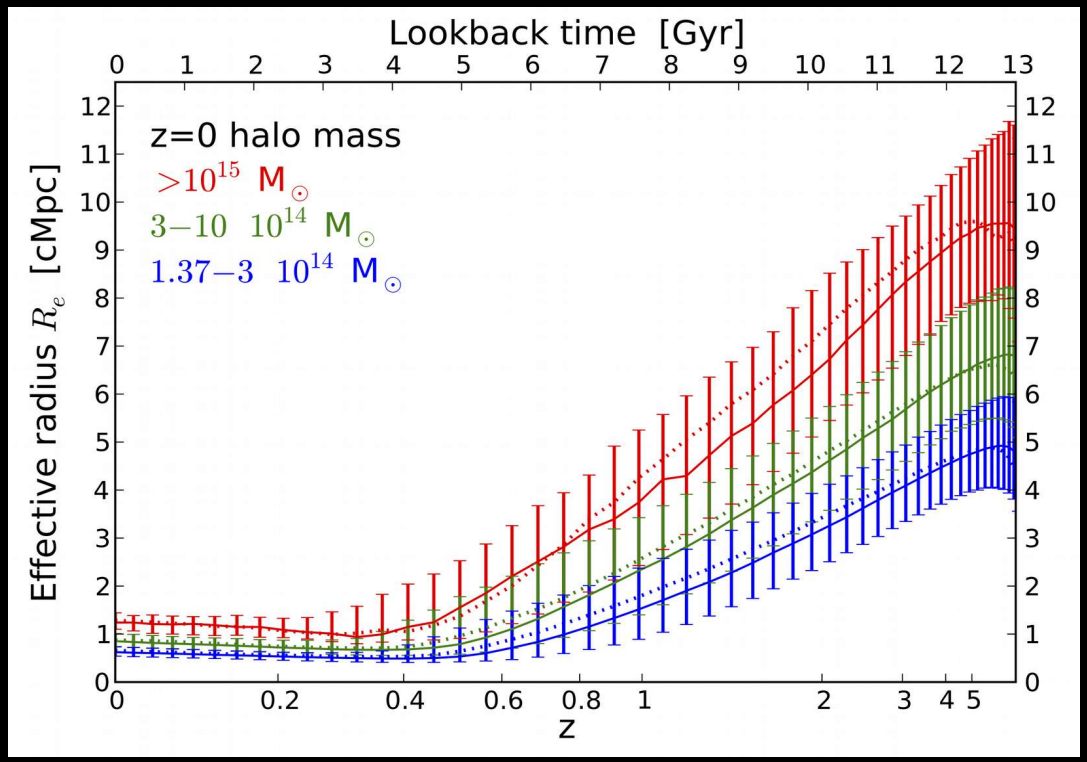
Few clusters at z~2 !

Proto-cluster : (Progenitors of clusters)

- Forming structure

- Not always dominant single DM halo.

- Spatially extended
(up to ~ 10 Mpc = 20') → MOONS !



Given mass at z=0 → different evolutions possible.

High-z clusters/Protoclusters are hard to detect

1) Observed structures z>1.5

- Hundreds of candidates, few confirmed.
- Hundreds of candidates expected with Euclid.

Cluster Name	Redshift z	Discovery Paper	Selection Method
CXO J1415.2+3610	1.52	**Tozzi2013**	X-Ray
XMMU J1007.4+1237	1.555	**Fassbender2011**	X-Ray
XDCP J0044.0-2033	1.58	**Santos2011**	X-Ray
CL J033211.67-274633.8	1.61	**Tanaka2013**	X-Ray
ClG 0218.3-0510	1.62	**Papovich2010**	NIR
SpARCS J022427-032354	1.63	**Muzzin2013**	NIR
SpARCS1049+56	1.70	**Webb2015**	NIR
IDCS J1426.5+3508	1.75	**Stanford2012**	NIR
JKCS041	1.803	**Andreon2014**	NIR
IDCS J1433.2+3306	1.89	**Zeimann2012**	NIR
CL J1449-0856	2.07	**Gobat2011**	NIR
CL J1001+0220	2.506	**Wang2016**	NIR
Cl J0227-042	3.29	**Lemaux2014**	NIR

Extended structures
+
Multiwavelength data needed
=
long follow-up campaigns !

MOONS will be a
major improvement

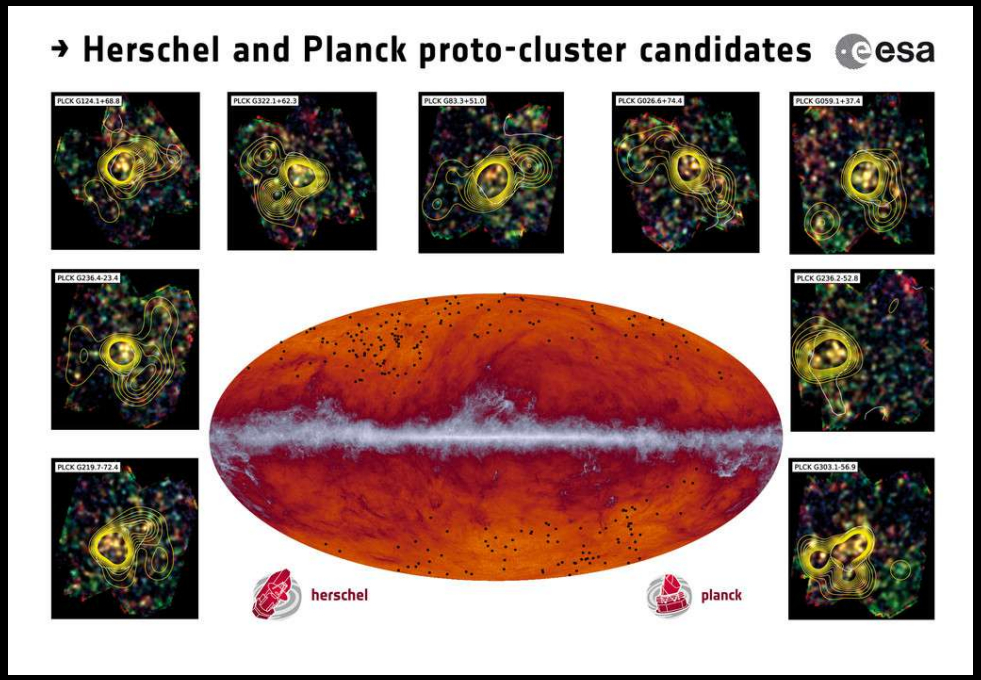
This talk : sample of 84 candidates biased toward intense star-formation

2) Searching for z~2 structures with Planck and Herschel

Planck/HFI assets :

- Probe dusty SF at z~2.
- All sky (26%, Rare objects, 10^{-1} deg^{-2})

→ 2151 candidates
(Planck list of high-z sources)



Planck Intermediate Paper XXXIX

2) Searching for z~2 structures with Planck and Herschel

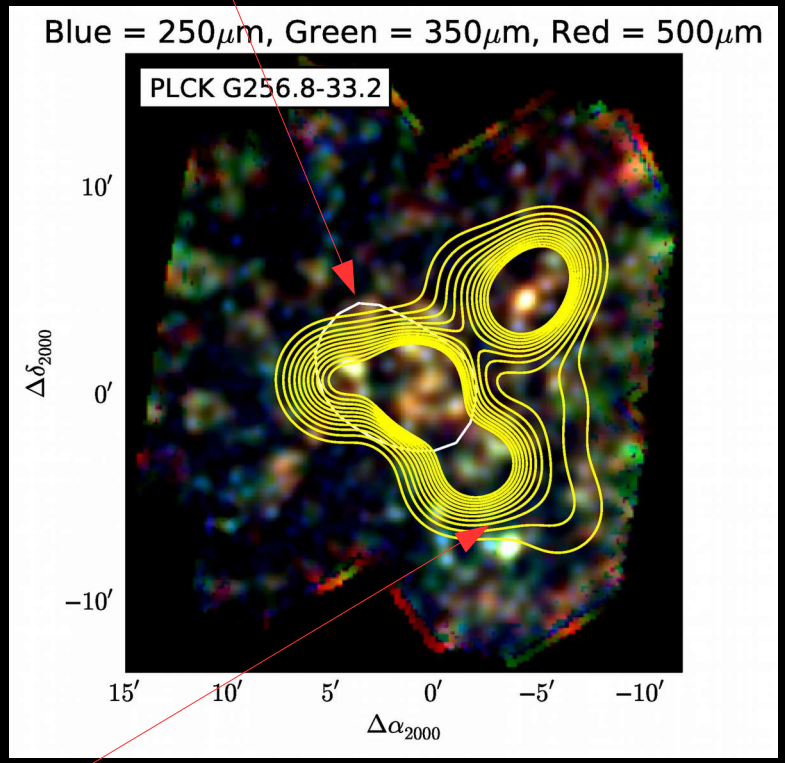
White : Planck source 50% emission contour

232 candidates followed up with Herschel/SPIRE :

1) Only 4 galactic cirrus

2) Overdensities of SPIRE red sources associated with Planck.
→ 50% sample >10σ

3) a) Photo-z ~ 2
b) SFR ~ 700 $M_{\odot} yr^{-1}$ per source.



Yellow : Red sources overdensity contours (>2 σ)

Planck Intermediate Paper XXVII

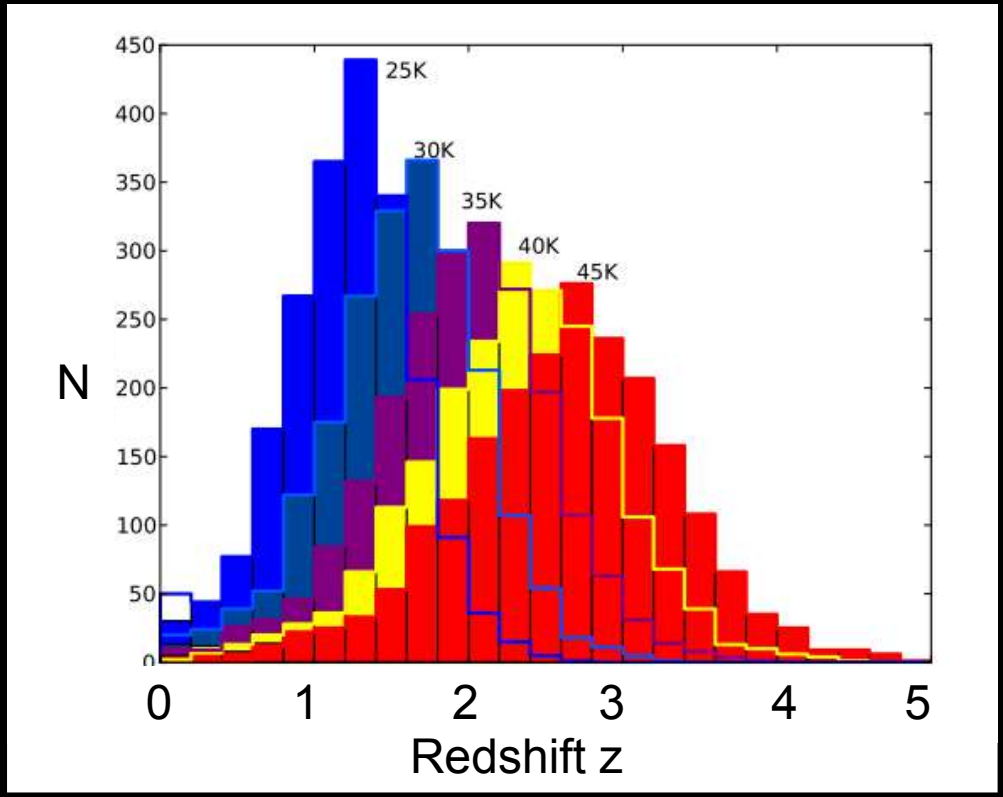
2) Searching for z~2 structures with Planck and Herschel

232 candidates followed up with Herschel/SPIRE :

1) Only 4 galactic cirrus

2) Overdensities of SPIRE red sources associated with Planck.
→ 50% sample >10σ

3) a) Photo-z ~ 2
b) SFR ~ 700 $M_{\odot} yr^{-1}$ per source.



Planck Intermediate Paper XXVII

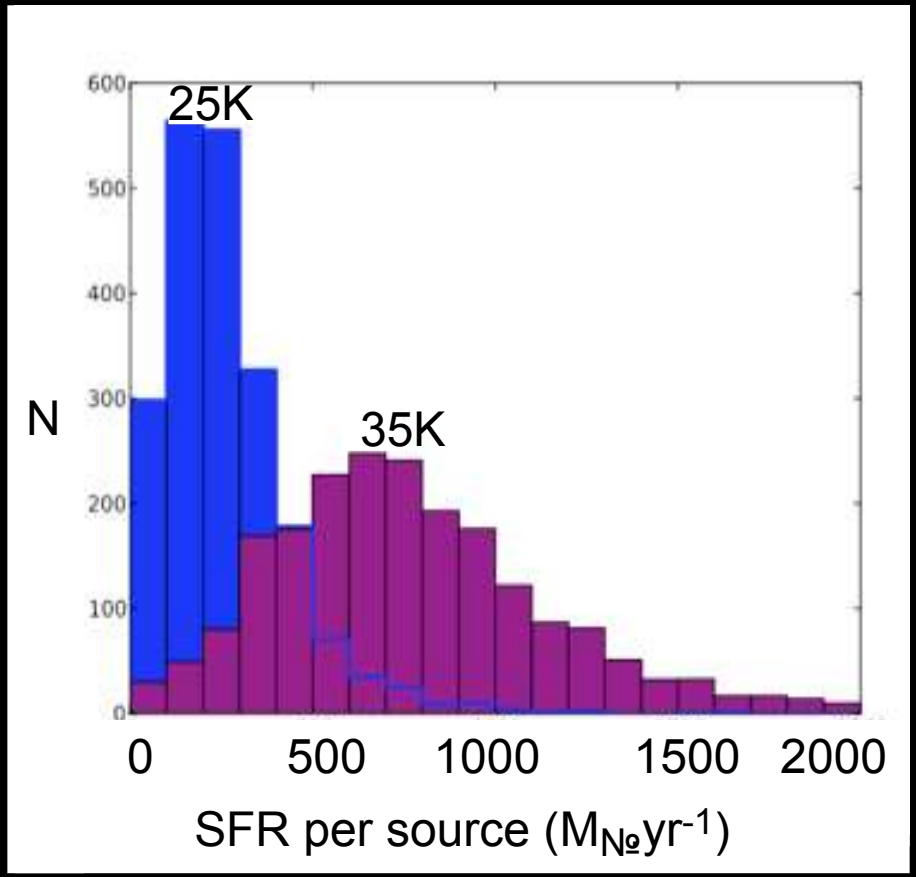
2) Searching for z~2 structures with Planck and Herschel

232 candidates followed up with Herschel/SPIRE :

1) Only 4 galactic cirrus

2) Overdensities of SPIRE red sources associated with Planck.
→ 50% sample >10σ

3) a) Photo-z ~ 2
b) SFR ~ 700 $M_{\odot}yr^{-1}$ per source.



Planck Intermediate Paper XXVII

2) SPHerIC : Spitzer Planck Herschel Infrared Clusters

Planck : 2151 candidates

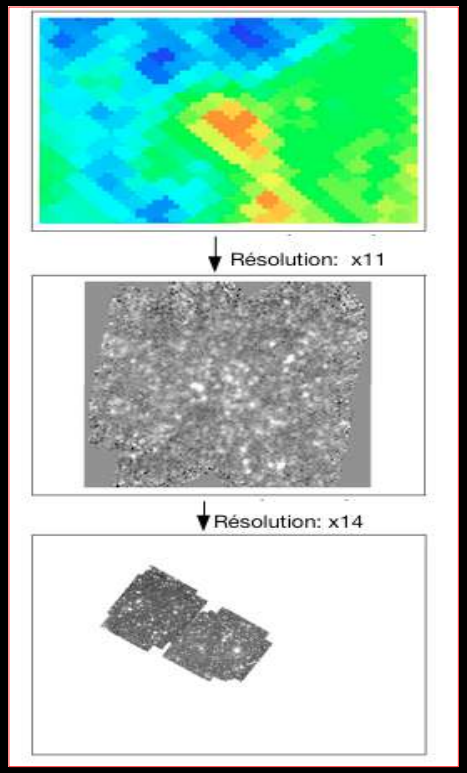
~5' → 353, 545, 857 GHz

Herschel : 228 candidates

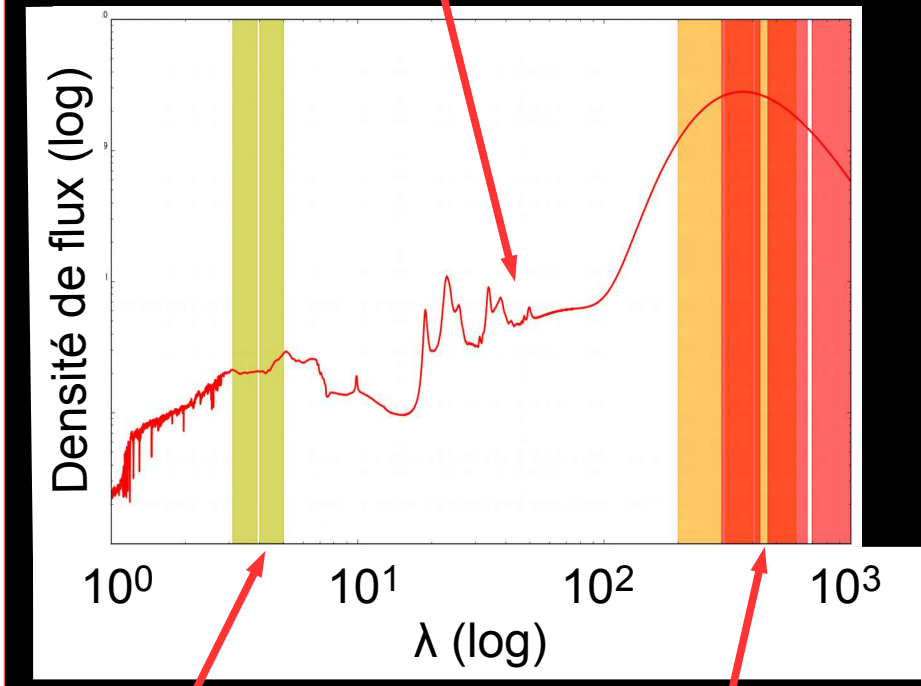
~20" → 250, 350, 500 µm

Spitzer : 84 candidates

~2" 3.6, 4.5 µm



30' x 30'



2 programs (GO9, GO11), 70h of observations, 90 candidates followed-up.

2) SPHerIC

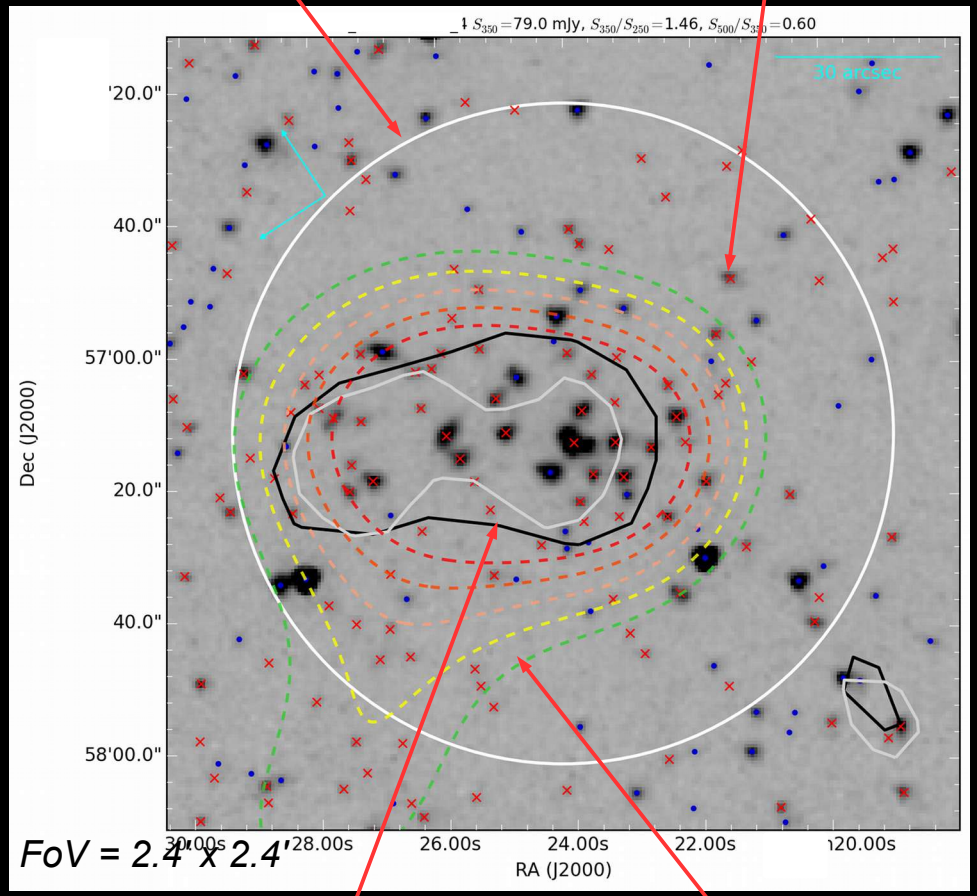
Spitzer : efficient redshift selection with 2 bands only (z>1.3)

Overdensities of high z sources at position of intense star-formation

This candidate :
From SPIRE : z~2, SFR ~ 700 M$_\odot$yr^{-1}
From Spitzer: 26 sources.arcmin^{-2}

White circle:
radius 1', centered on SPIRE emission

Red crosses/Blue dots :
High/low z sources

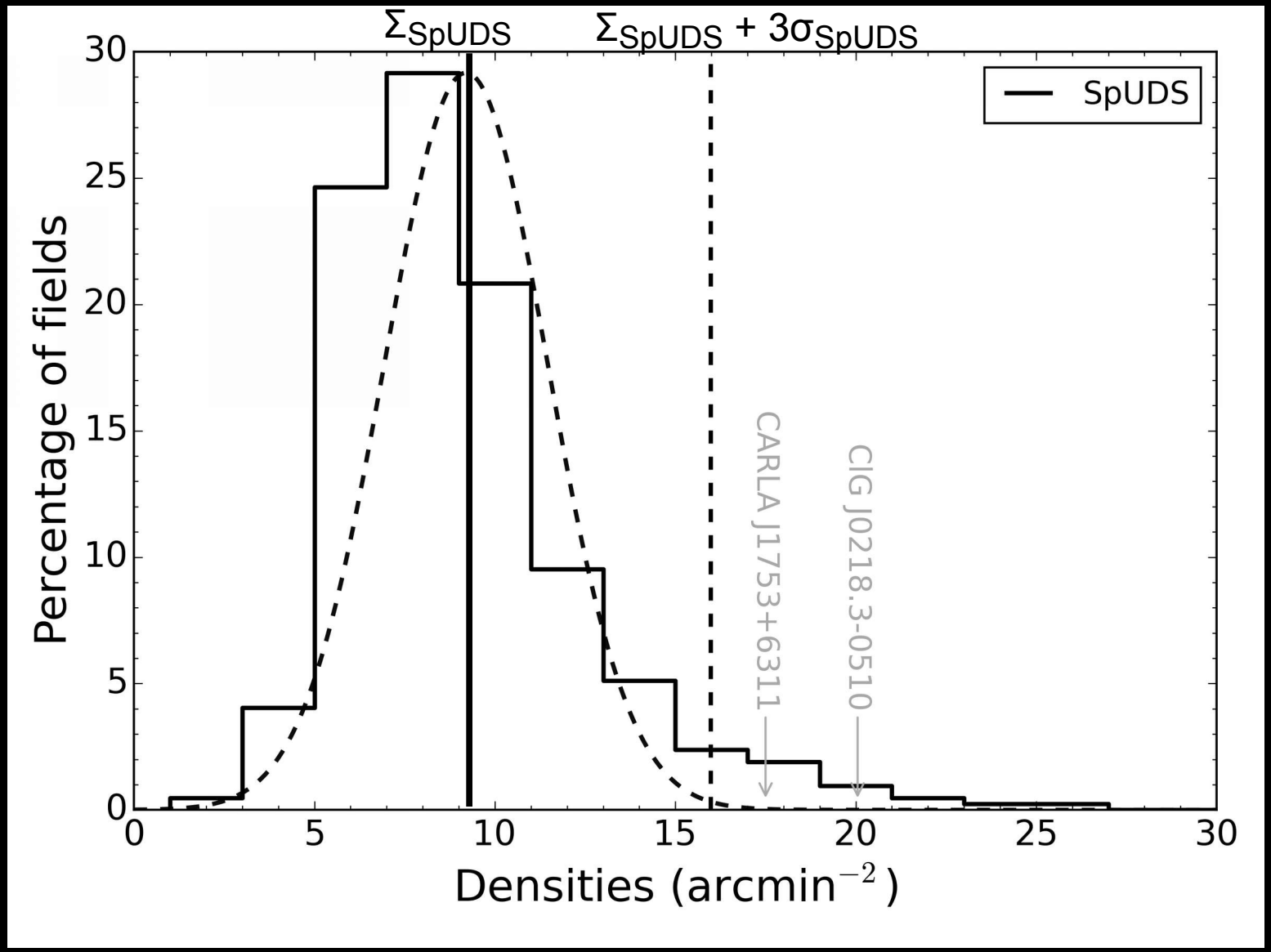


FoV = 2.4' x 2.4'

Grey/black line :
SPIRE Emission contour
(3 σ) (250/350 μm)

Dashed colored lines :
Overdensity contours
2.5, 3... 4.5 σ

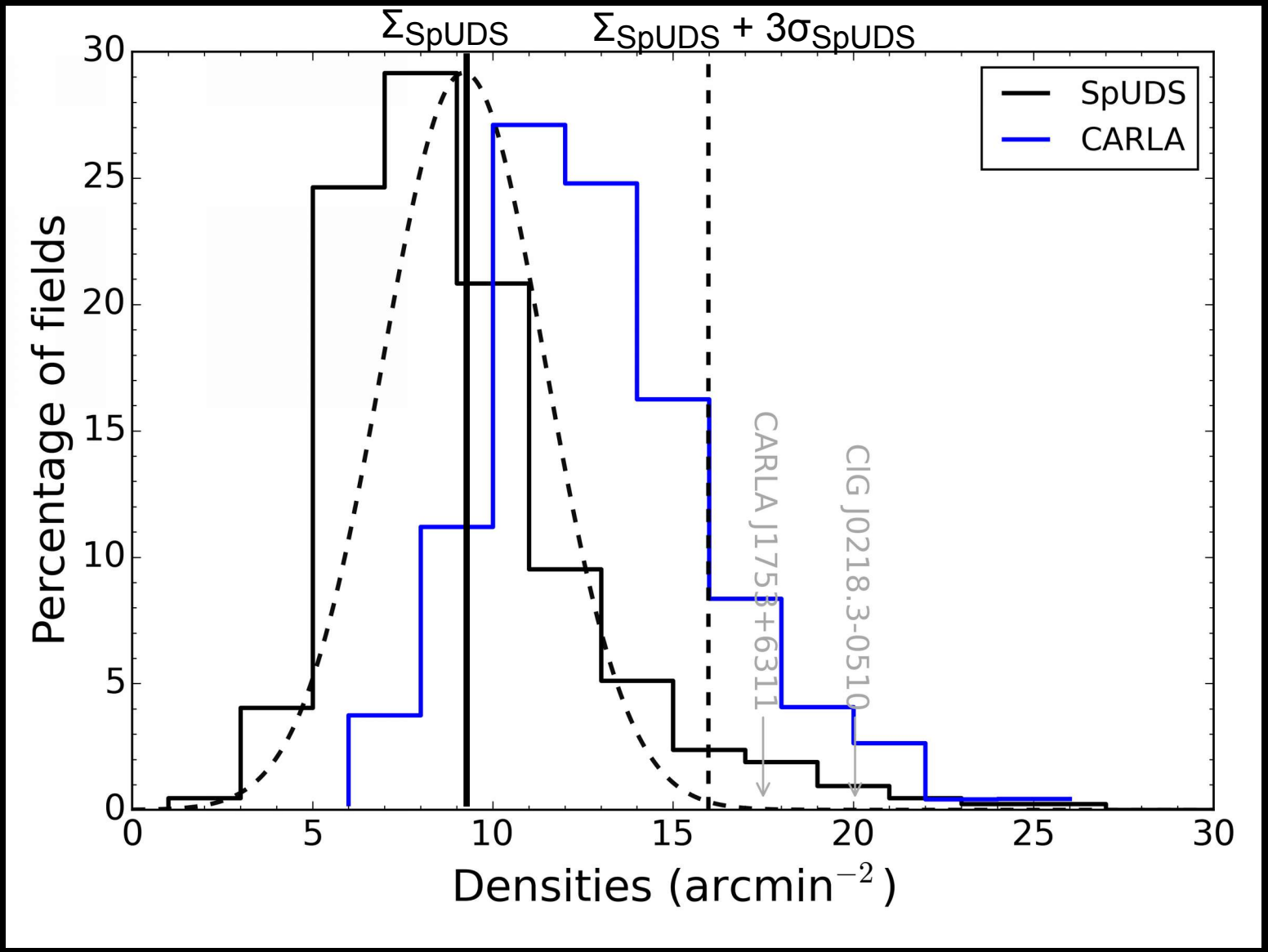
2) SPHerIC : overdensities of high z sources



Random 1' radius circles in SpUDS.

SpUDs :
control field, ~ 1 deg^2

2) SPHerIC : overdensities of high z sources



CARLA : Clusters Around Radio-Loud AGN.

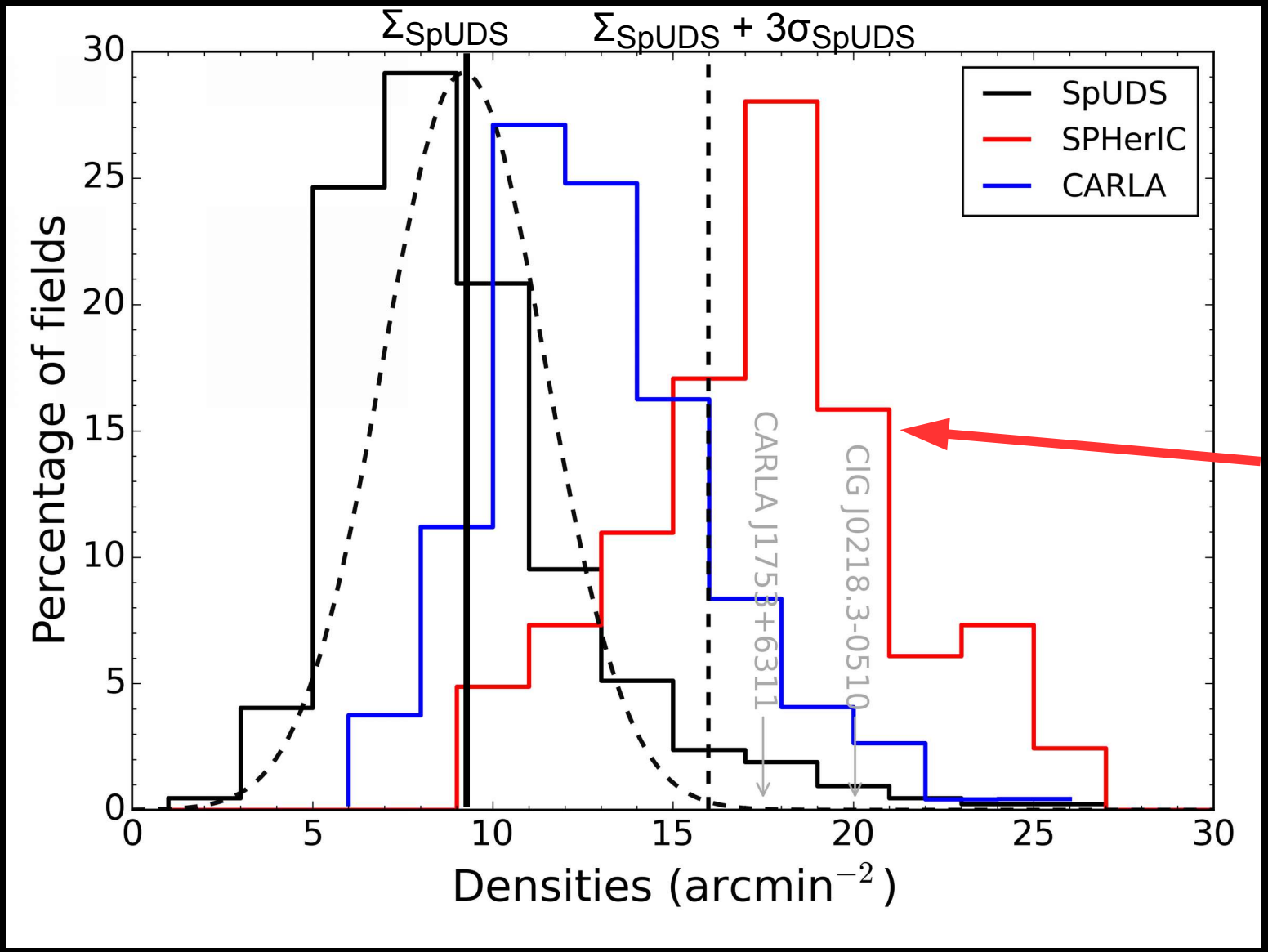
~400 cands

27% are 3σ overdense

Wylezalek, 2013 – ApJ, 769:79.

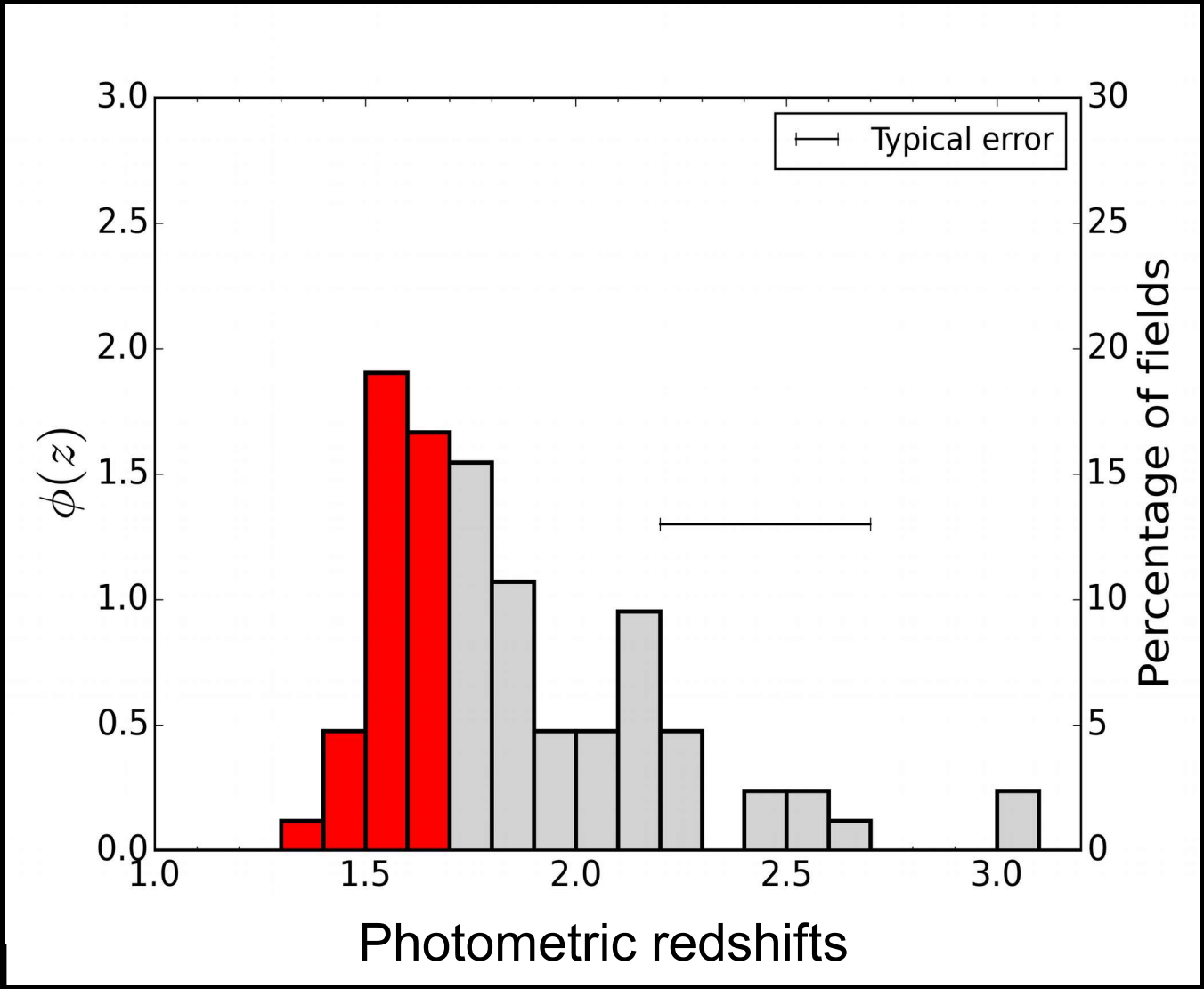
Wylezalek, 2014 – ApJ, 786:717.

2) SPHerIC : overdensities of high z sources



Our sample : 76% are 3σ overdense

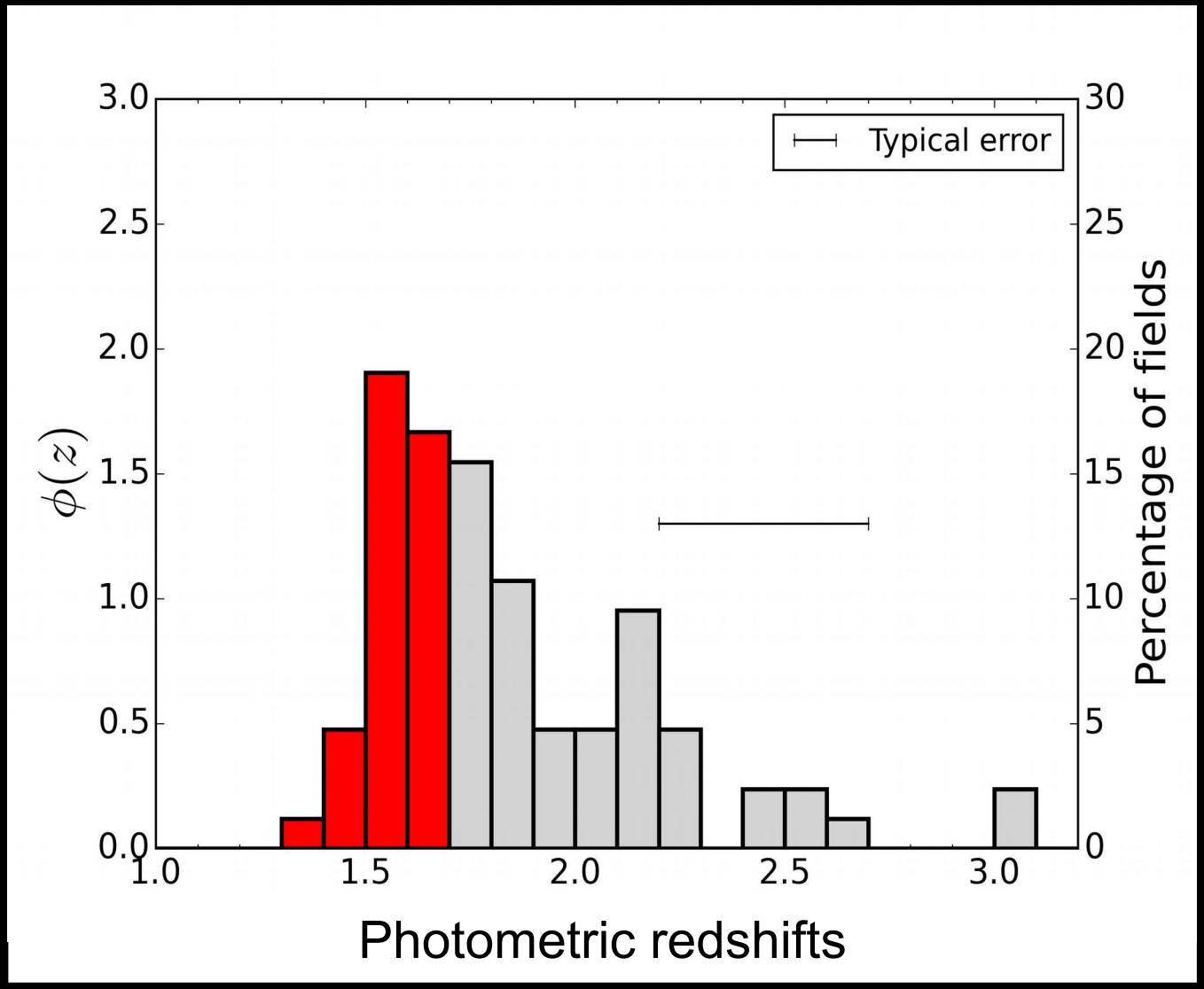
2)SPHerIC : Photometric redshift estimation



Grayed : z>1.7
(plateau [3.6]-[4.5] vs. z)

From median color sources r<1' from SPIRE source, [4.5]<22.

2)SPHerIC : Photometric redshift estimation



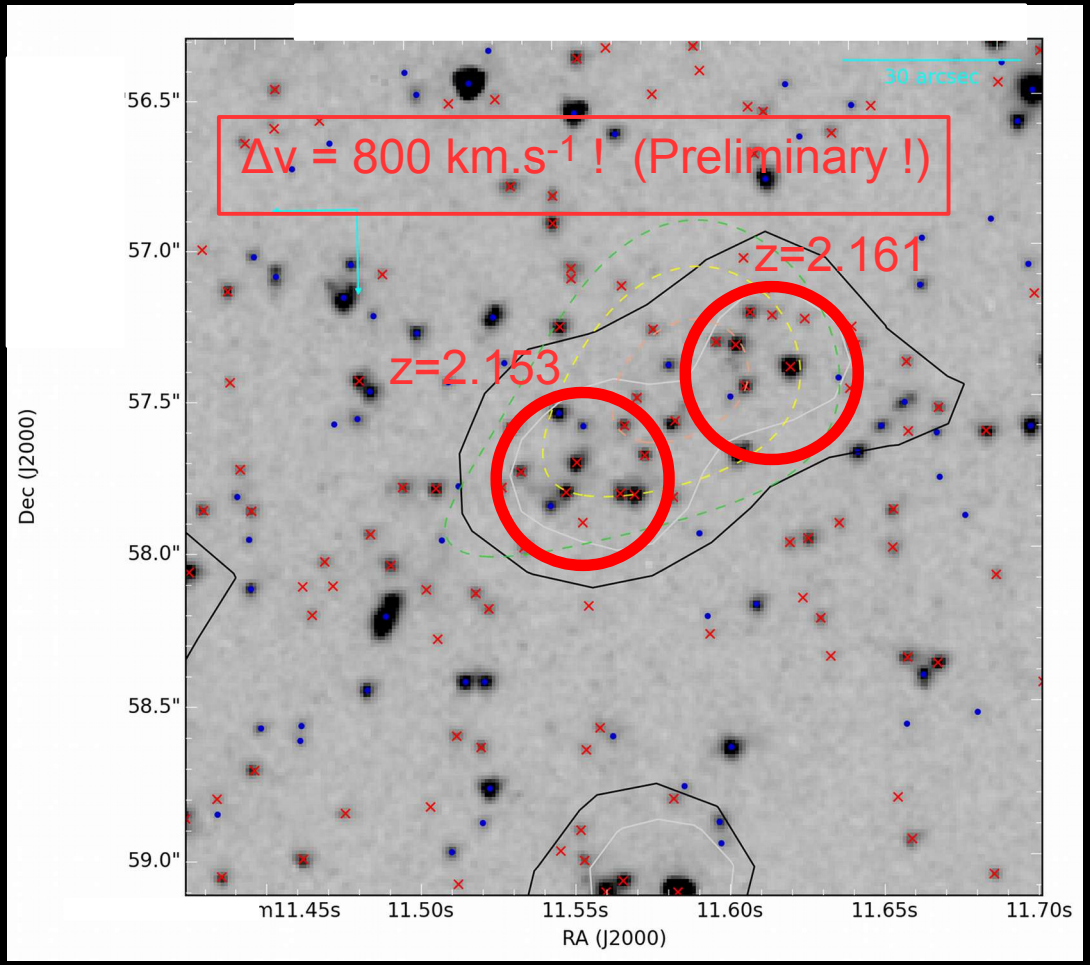
Need Spectroscopic redshifts

First confirmations in the millimeter (30m/EMIR)
Z= 1.32, 2.15, 2.36

Grayed : z>1.7
(plateau [3.6]-[4.5] vs. z)

From median color sources r<1' from SPIRE source, [4.5]<22.

3) Millimeter Follow-up : IRAM 30m/EMIR



4 SPIRE sources in 3 Planck sources confirmed (z=1.32, 2.15, 2.15, 2.36). 1 awaiting confirmation (z=2.55).

NIR spectroscopy →
confirm structure, identify members, number IRAC sources responsible for SPIRE emission ? + SFR, AGN

SFR ~ 1700 $M_\odot yr^{-1}$ (SPIRE)

M_{mol} = 2.6+/-0.5 10^{11} $M_\odot$

$T_{depletion,\ gaz}$ ~ 10^8 years

3) MOONS for protoclusters

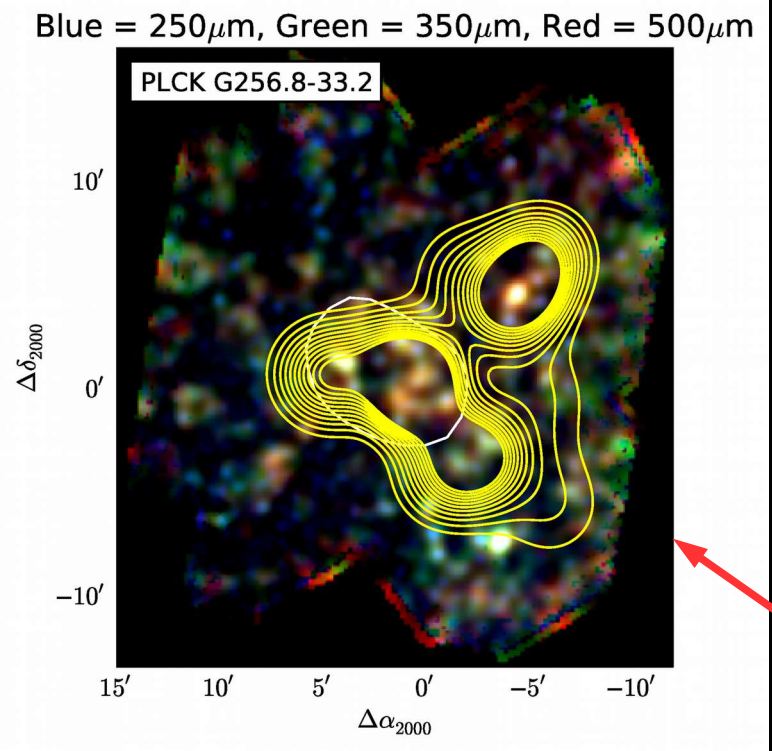
- FoV : 500 arcmin^2 + 1000 Fibers → Possibility of follow-up every galaxy in candidate fields !

- 0.65 – 1.8 μm → Hα z<1.7, CaII z<2.5

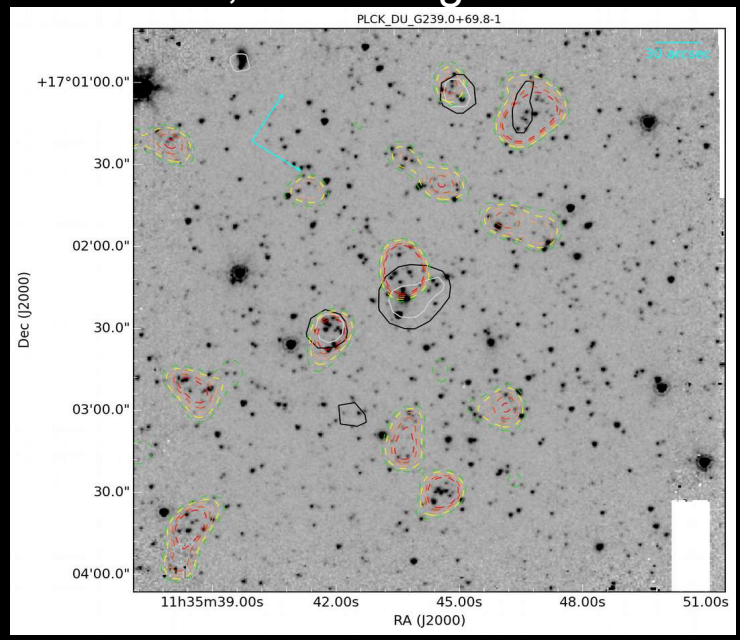
- Sensitivity ?

- **Unique opportunity to unveil progenitors of today's massive clusters in critical phase !**

25' x 25'



~ 5' x 5' ; ~1000 high-z sources



Will need photometric follow-up →
Already underway with CFHT (15 fields)

Conclusions

- SPHerIC :Unique sample biased toward the most intense star forming regions at z~2.
- Spitzer : large overdensities of high-z galaxies.
- First spectroscopic redshifts arriving, but need NIR spectroscopy on large areas !

- MOONS -> unique opportunity to study crucial epoch of cluster formation.