LSST-DESC galaxy clusters at IN2P3

LSST-France, LPC, 4 June 2019

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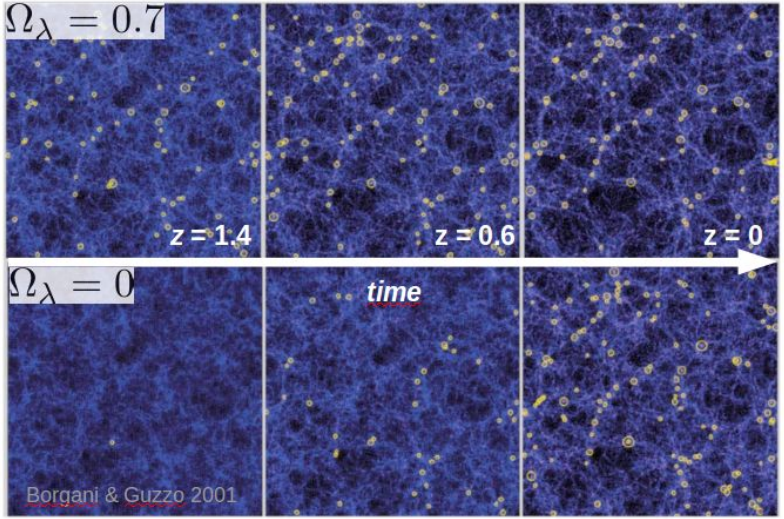
+ M2 students (C. Mibord - LPSC, N. Sanchez - LAPP)

1. Context and overview of ongoing activities (Céline)

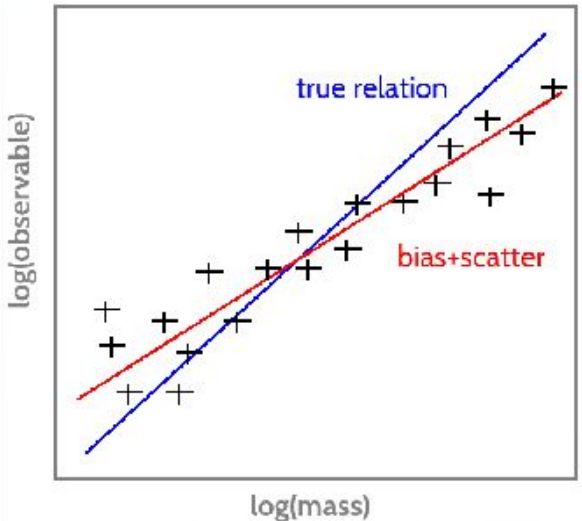
2. Highlight: clusters in DC2 data (Marina)
   a. Evaluation of the representativity of cluster properties in DC2
   b. Test of RedMapper performances and selection function determination

Cluster cosmology : general context



The abundances (and clustering) of galaxy clusters as a function of mass and redshift is a powerful probe of structure growth...

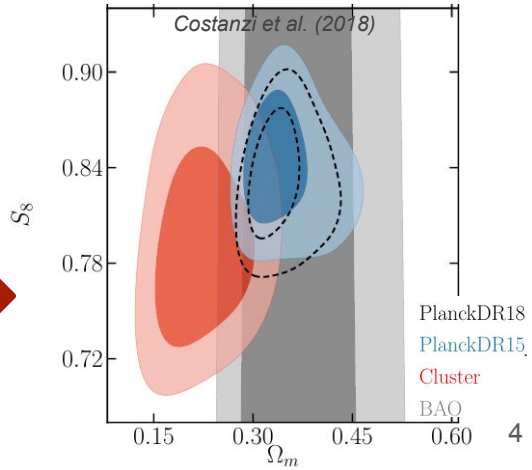
... but the majority of the mass of cluster is not directly observable !



➢ **need to rely on observables** (e.g. richness) **and calibrate mass/observable relations using mass measurements** from e.g. weak lensing

Galaxy cluster cosmology in the optical: basics

1. Galaxy catalog from multi-band photometry
2. Cluster detection from the galaxy catalog
   a. measurement of position, redshift and richness
3. Calibration of the cluster richness
   a. from weak lensing mass measurements
   b. using follow-up observations at other wavelengths
4. Cluster sample characterisation
   a. estimation of the selection function
5. Modelisation of the likelihood and inclusion in the cosmological pipeline



CL@in2p3 at the last meeting...

1. Galaxy catalog from multi-band photometry (DB)
2. Cluster detection from the galaxy catalog
   a. measurement of position, redshift and richness
3. Calibration of the cluster richness
   a. from weak lensing mass measurements (CC, MPL)
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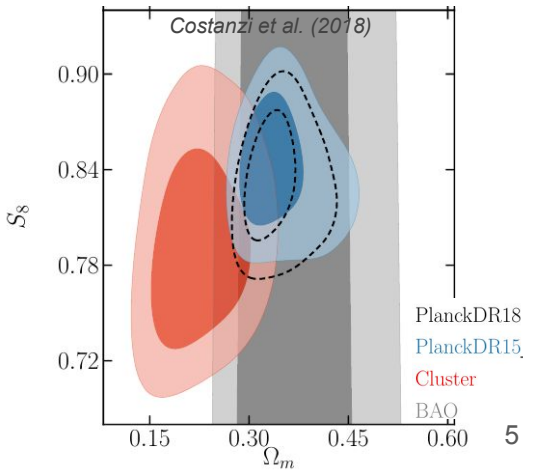
   a. estimation of the selection function
5. Modelisation of the likelihood and inclusion in the cosmological pipeline (MPL)



… and since then (Marina's expertise)

1. Galaxy catalog from multi-band photometry (DB)

2. Cluster detection from the galaxy catalog
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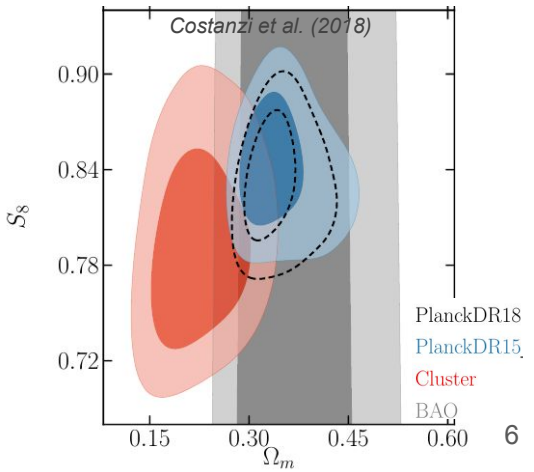

Ongoing work and plans I.

1. Galaxy catalog from multi-band photometry (DB)
   - Using latest version of DM stack (jointcal, NGMIX)
   - Need to update color terms of the `obs_cfht` package
   - Reprocessing of clusters common to DES (dell'Antonio et al.) and CFHT (us)
3. Calibration of the cluster richness
   a. from weak lensing mass measurements (CC, MPL)

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3. Calibration of the cluster richness
   a. from weak lensing mass measurements (CC, MPL)

   - CLMM - DESC galaxy cluster weak-lensing mass modeling tool
   - See slides from last meeting
   - 5-day retreat in Bochum after July DESC meeting (CC, MR, MPL?)

NumCosmo work:
. Diemer-Krastov profile
. Cross-checks against existing softwares (e..g, cluster-toolkit)

5. Modelisation of the likelihood and inclusion in the cosmological pipeline (MPL)

Ongoing work and plans II. → Marina's presentation

2. Cluster detection from the galaxy catalog

4. Cluster sample characterisation

➔ Preliminary tests using the DC2 simulations

- I) Characterisation of cluster properties in DC2 link
- II) Characterisation of the RedMapper DC2 catalog link

I) Characterisation of cluster properties in DC2:

link : contributed notebook as part of the HackUrDC2 Challenge

If used for pipeline developpement, simulations have to be representative of future observed data.

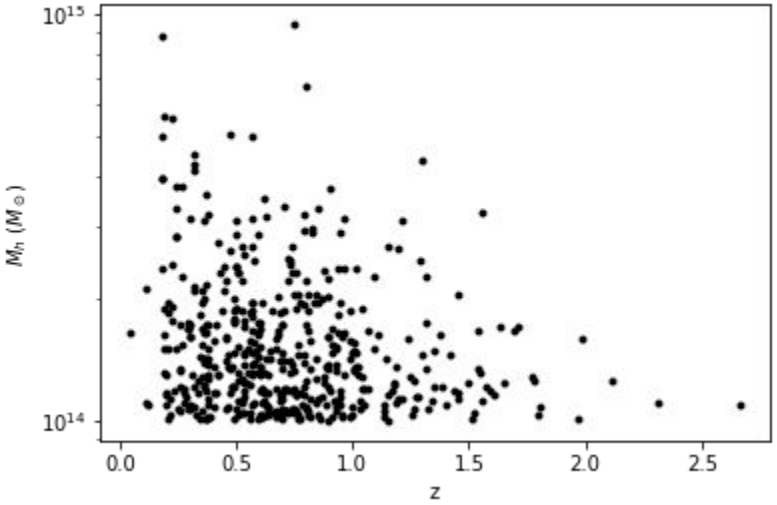
➔ test the modelling of cluster properties in the DC2 extragalactic catalog

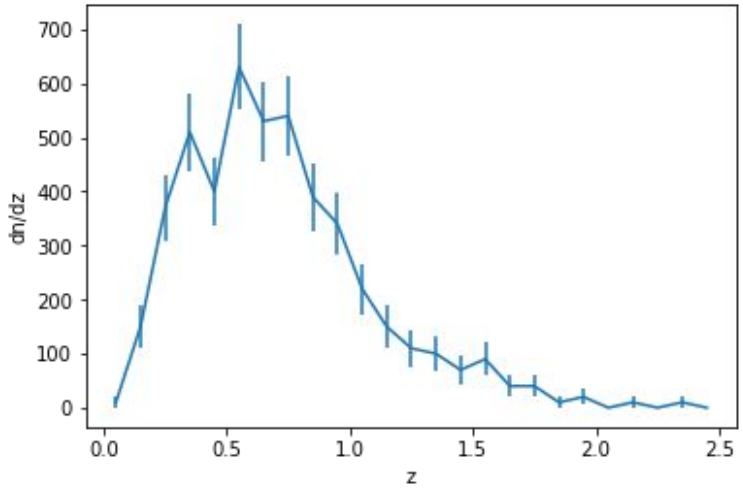
- mass/redshift distribution
- galaxy density profiles
- luminosity function of cluster galaxies
- color magnitude relation for cluster galaxies.

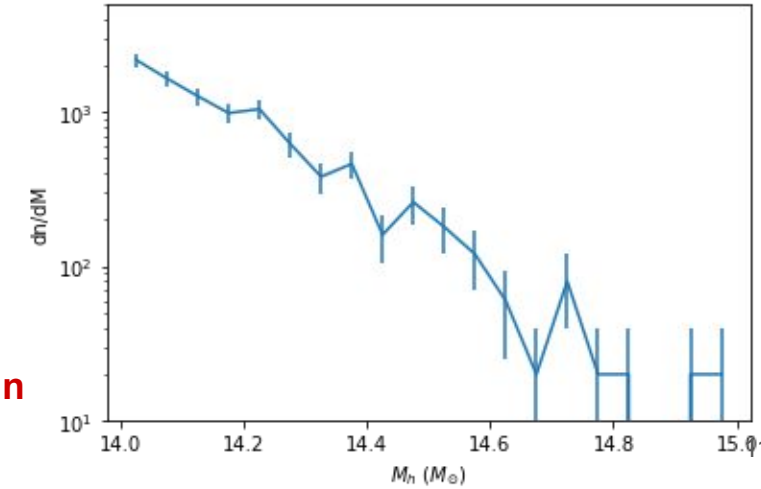
These are the main intrinsic properties that drive cluster detection in the optical.

I) Halo mass/redshift distribution

version : 'cosmoDC2_v1.1.4_small'
475 halos with M > 1e14 Msun/h in 57deg²

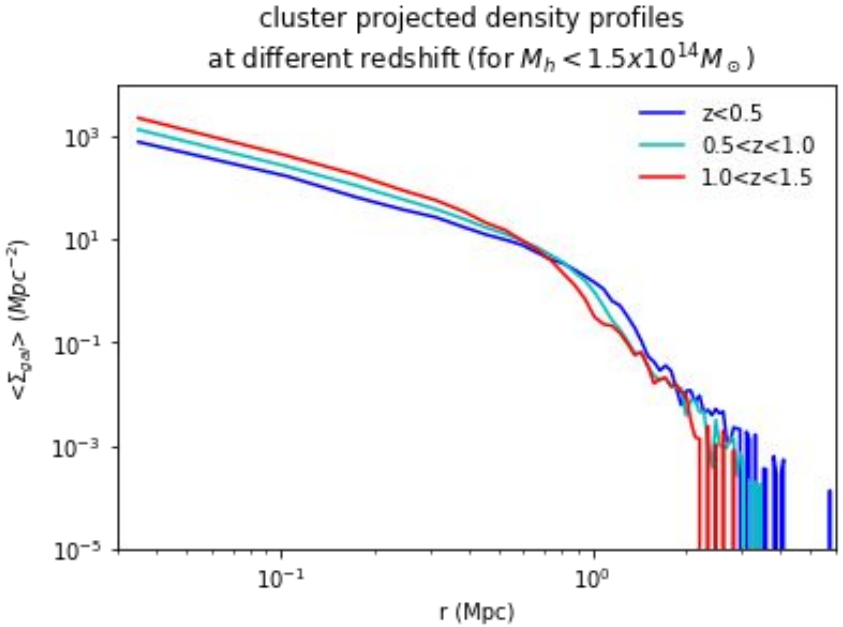


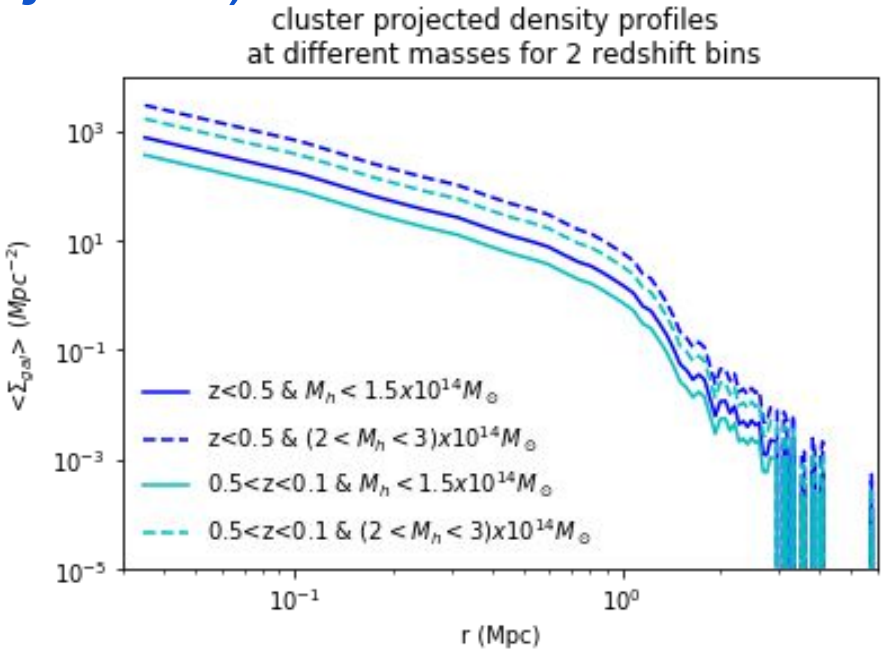




Comparison to theoretical halo mass function difficult because of the halo mass definition in DC2
(FoF masses with b = 0.168) *cf: Nathan Sanchez internship*
Spherical overdensity masses should be given for next run

I) Galaxy density profiles (projected):

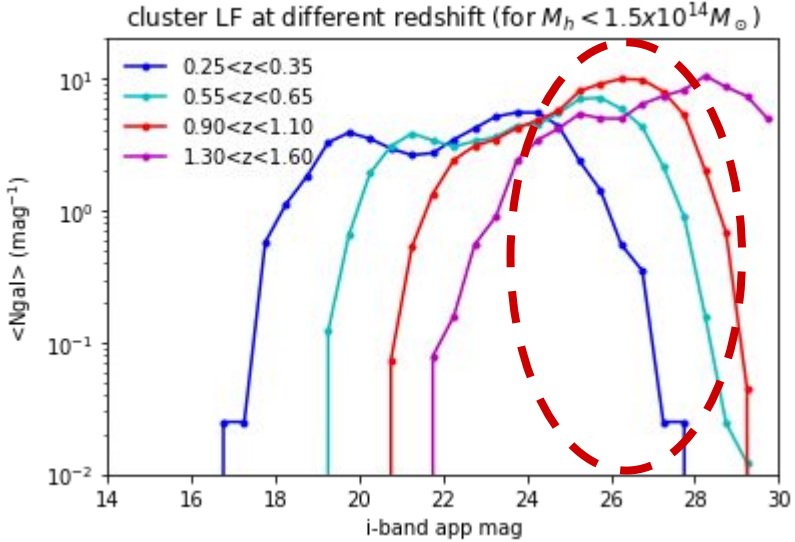


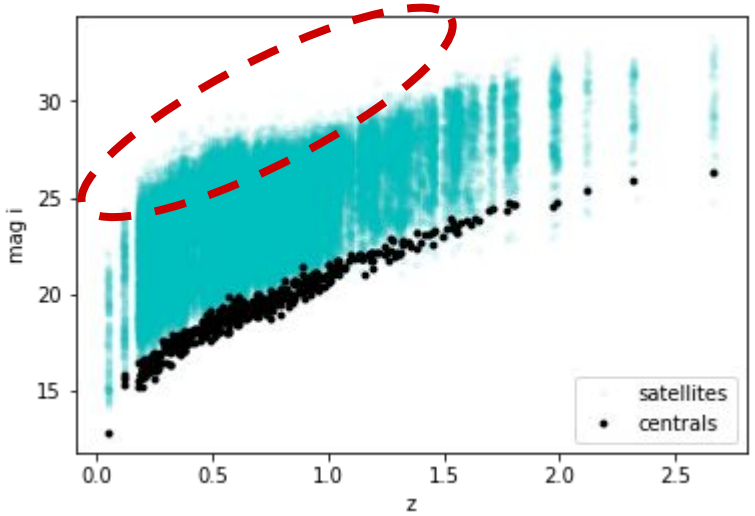


As expected, concentration increases with redshift at fixed mass and amplitude increases with mass at fixed redshift.

Profiles are truncated NFW instead of NFW : this feature revealed a “bug” in the way galaxies are attributed to halos. Cluster galaxy distribution in DC2 do not follow the shape of the dark matter halo (see e.g. Github issue #85

I) Cluster galaxy luminosity distribution



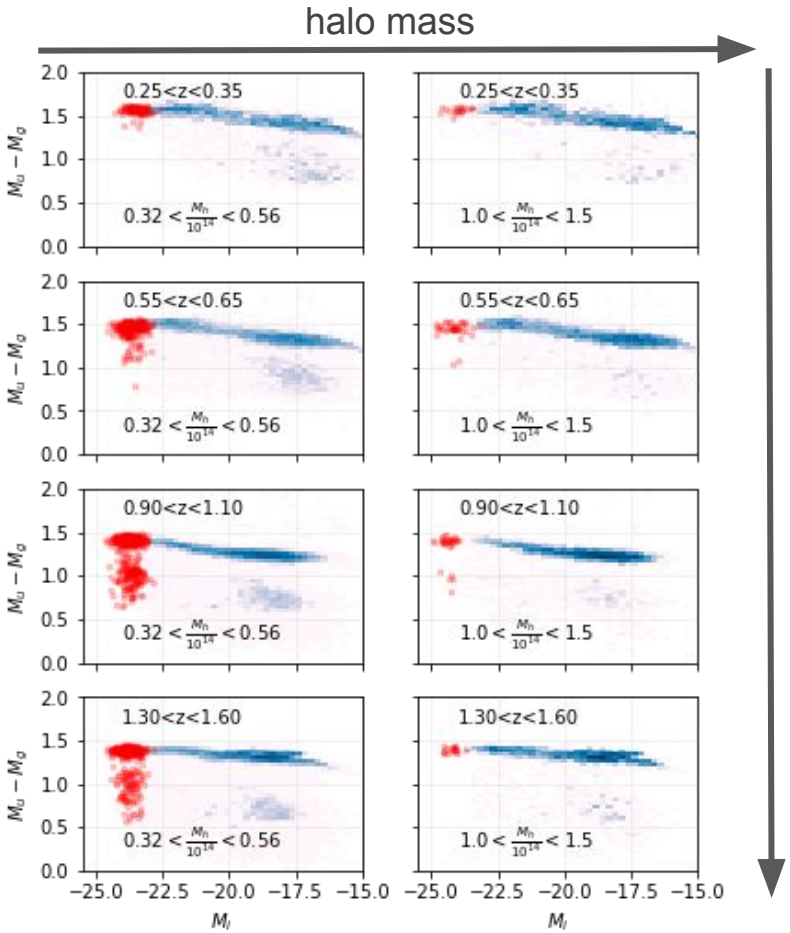


LF seem OK for galaxies brighter than i ~ 24, but **sharp unphysical decline at fainter magnitudes :**

there is a lack of faint clusters galaxies at low redshift.

See ***Github issue #48***

I) Color-magnitude relation for cluster galaxies



Rest frame color magnitude diagrams of cluster galaxies in different mass/redshift bins.

blue: normed density of satellites galaxies

red: central galaxies

Presence of a red sequence and a blue cloud : **expected.**

To much red galaxies, especially at high redshift : **not expected.** (see Github issue # 62).

Presence of blue centrals, might causes detection centring issues **(expected).**

I) Cluster properties in DC2 : conclusions

- overall properties are ok but **need refinement** of :
  - **halo mass definition**
  - **cluster galaxy color model**

- to keep in mind :
  - **galaxies do not follow the shape of the dark matter halo**
  - **the number counts of faint galaxies as a function of redshift is not respected**

These findings were reported and we can hope for improvement for the next run.

II) Characterisation of the RedMapper DC2 catalog

(adapted from presentation at GC SWG telecon)

Reminder: *RedMapper (Rykoff et al +15)* is a cluster finder algorithm that relies on concentration of red galaxies as galaxy cluster tracers. It is the main algorithm used for DES and likely for LSST.

➢ estimate performances of RedMapper detection algorithm on DC2

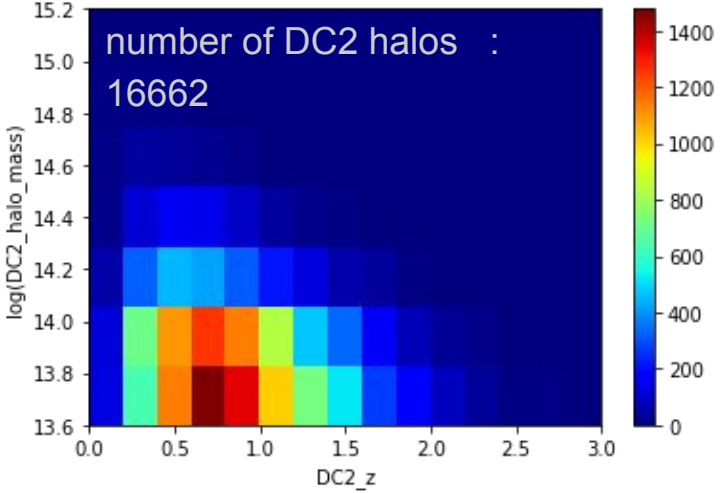
- completeness
- purity
- centering
- richness-mass relation

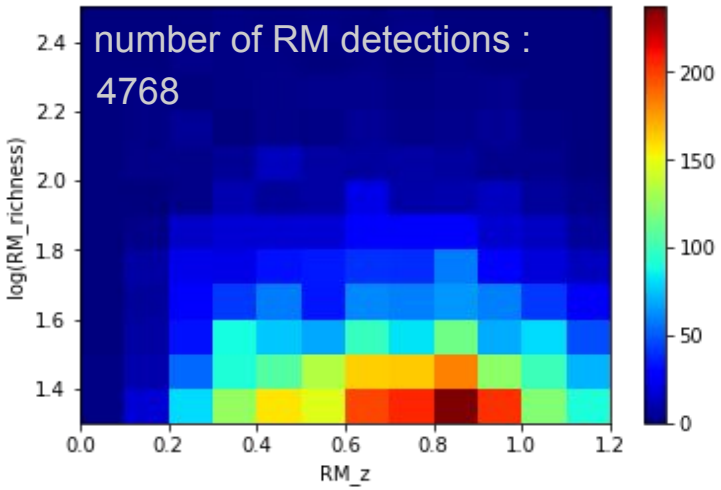
➢ preliminary determination of the RedMapper selection function

II) Application of redMaPPer to DC2

redMaPPer catalog provided by E. Rykoff

- DC2 version used : 'cosmoDC2_v1.1.4' (440 deg²)
- magnitude cut at 'mag_true_z_lsst < 25.5'
- richness cut at lambda > 20
- training on DC2 centrals "*The red-sequence model was trained starting with a sample of ~3000 spectra (true redshift) of halo centrals with halo_mass > 3e13, covering ~30% of the cosmoDC2 footprint. (E. Rykoff)*"
- noise added to magnitudes: "*following the 10 years LSST expectations"(E. Rykoff)*

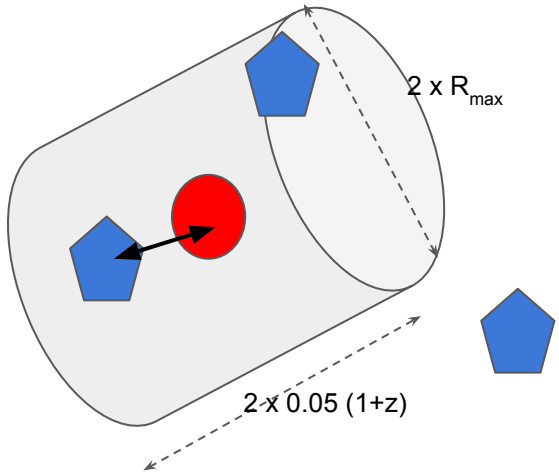




II) Association of RM detections to ‘true’ DC2 halos

warning : Associating detections to ‘true’ halos is a non trivial task and matching criteria are arbitrary.

Here I used “geometrical” methods : objects are associated to the nearest system (in terms of projected distance) within a cylinder defined by a radius R_{max} and a depth : 2 x 0.05 (1+z)



4 definitions of R_{max} tested :

R_{max} = 0.75 Mpc
R_{max} = 0.5 Mpc
R_{max} = R_{fof}
R_{max} = 0.5 R_{fof}

II) redMaPPer performances on DC2: warnings

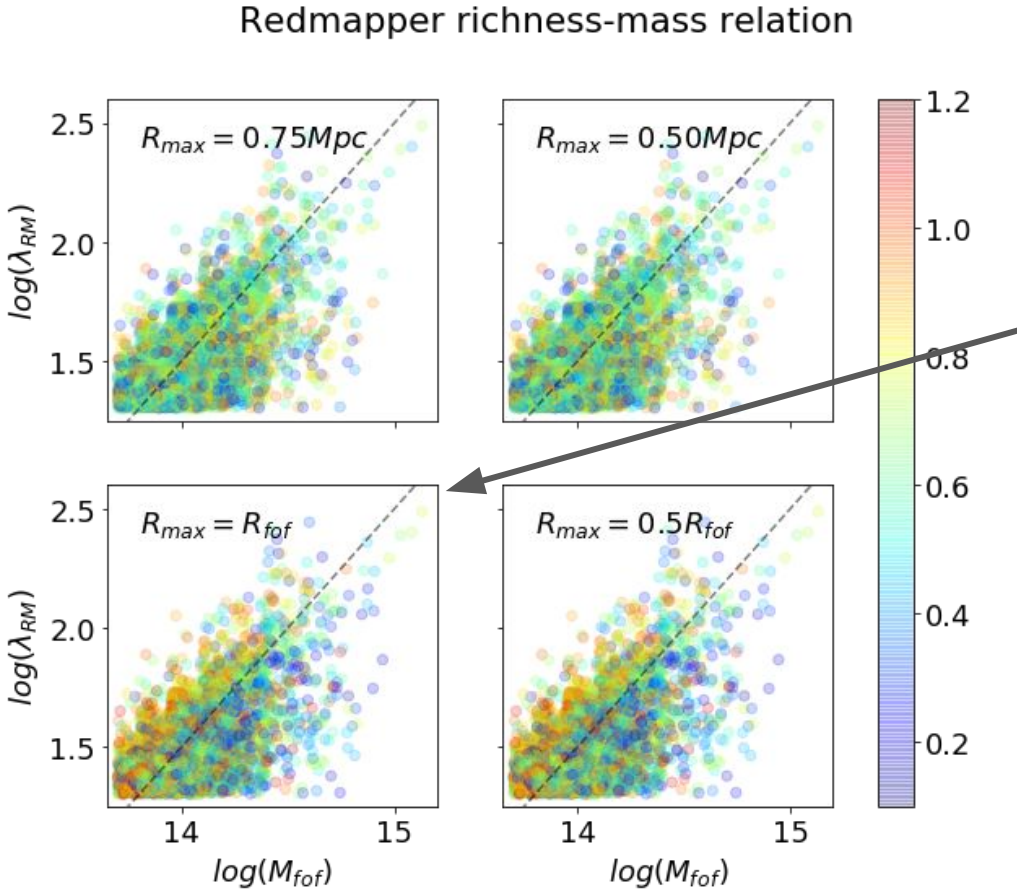
- **DC2 data are ‘perfect’** (e.g. no masks)

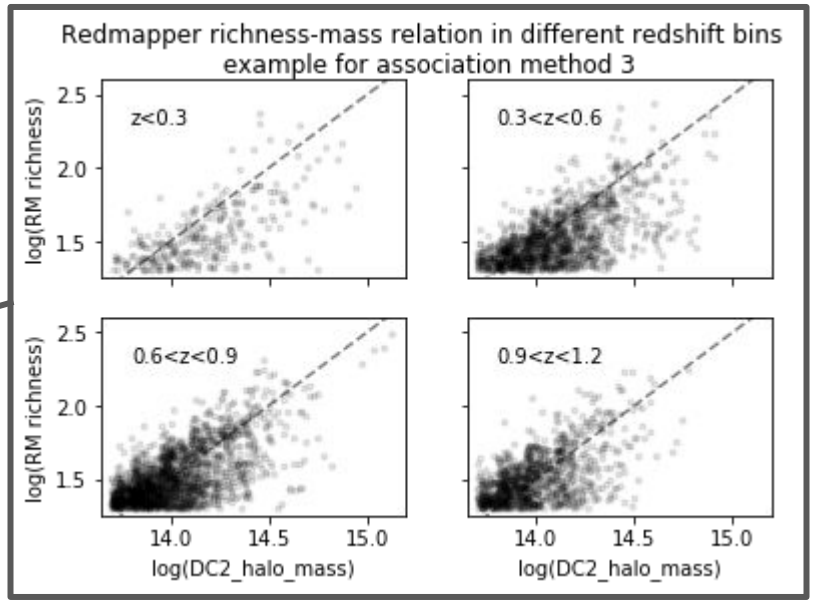
- algorithm **performances depend on the physical model** included in the simulation (e.g. galaxy color)

- **process not conducted blindly** : performances may be overestimated

- matching catalogues is a non trivial task: **estimated performances may depend on association criteria & mass/richness (or SNR) cuts**

II) redMaPPer DC2 richness/mass relation





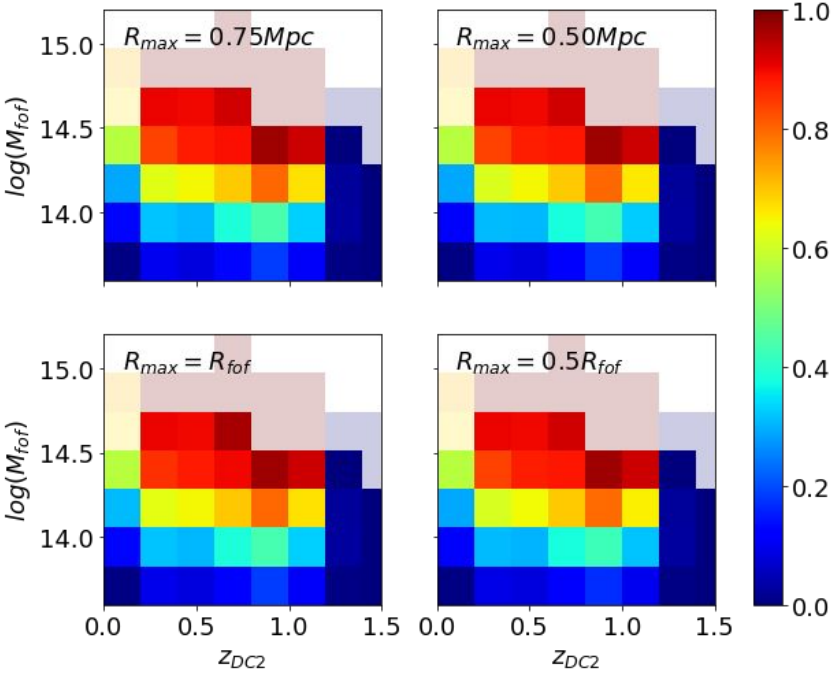
dotted line indicates arbitrary relation with slope = 1

Significant scatter and apparent redshift dependence of the amplitude. **Further work needed to understand why.**

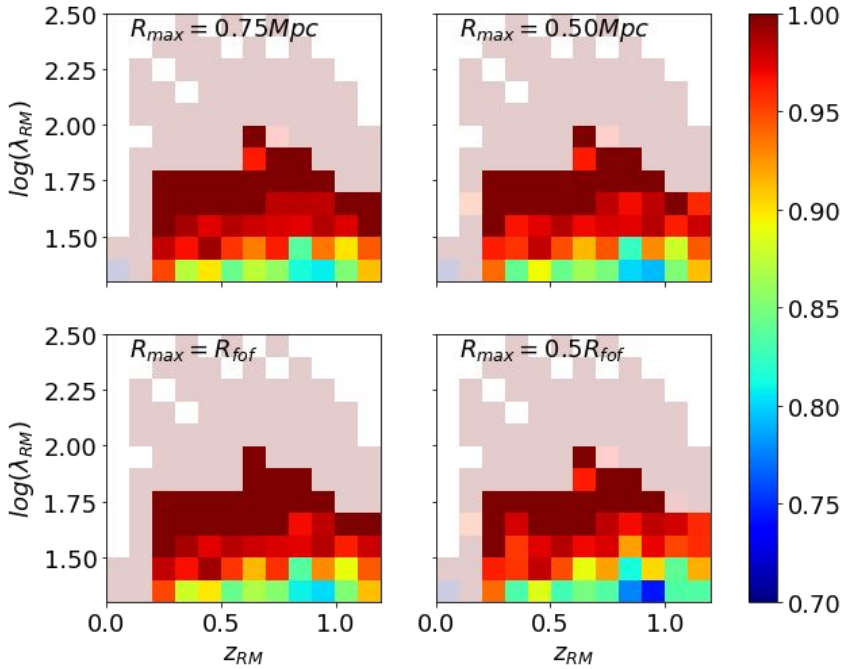
II) redMaPPer DC2 completeness and purity

shadow where #objects <20

$C = \frac{N_{bij}}{N_{DC2}}$ Completeness

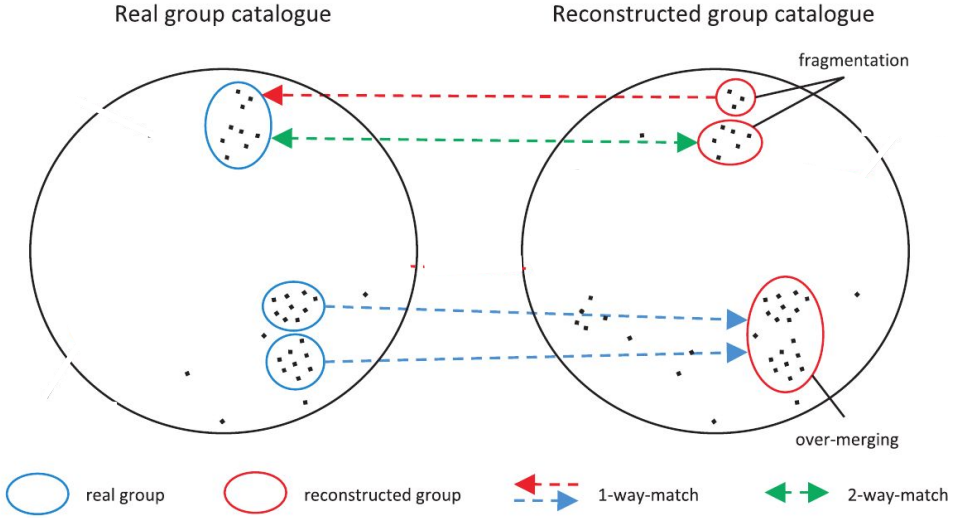


$P = \frac{N_{bij}}{N_{RM}}$ Purity



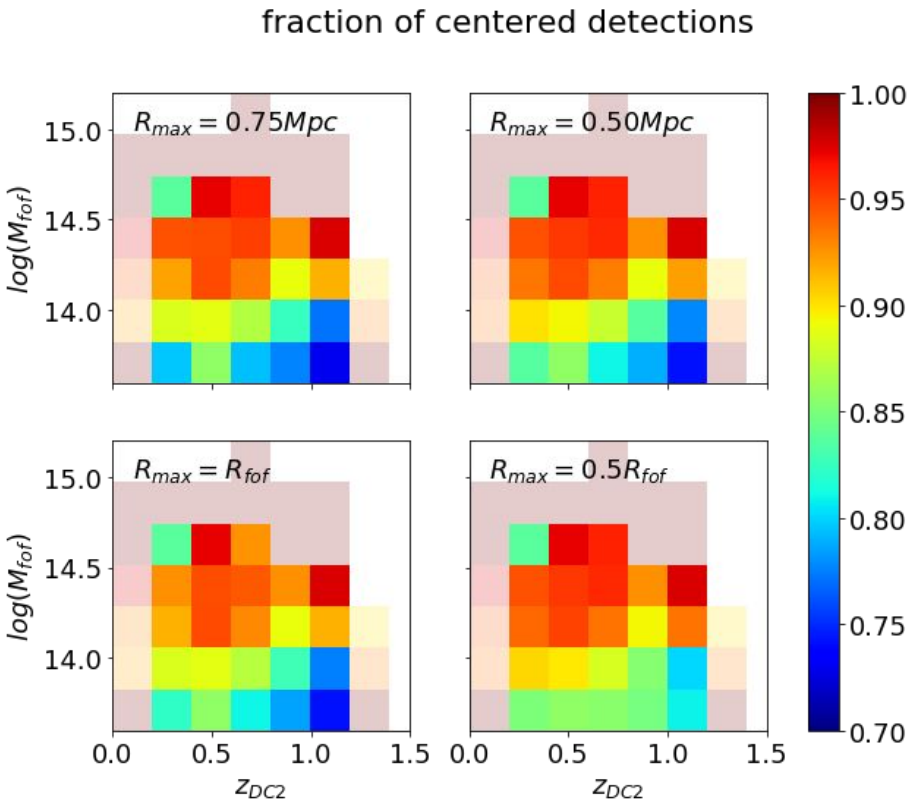
- No detection above z~1.2
- At z<1.2 and log(M)>13.5 overall completeness of ~63% and purity of ~97%.
- Completeness and purity decreases with halo mass (mass-richness scatter + richness & mass cut).
- Almost no differences between the different association criteria.

II) redMaPPer DC2 fragmentation and overmerging



association criteria	R_{max} = 0.75 Mpc	R_{max} = 0.5 Mpc	$R_{max} = R_{fof}$	$R_{max} = 0.5 \times R_{fof}$
fragmentation fraction	~0.13%	~0.07%	~ 0.18%	0.00%
over-merging fraction	~4.81%	~2.86%	~4.35%	~4.44%

II) redMaPPer DC2 centring efficiency



~ 92% of RM detections associated to DC2 halos are centered on the DC2 centrals

For low mass & high redshift clusters the fraction decreases (as the fraction of blue centrals in DC2, see slide 14.)

II) Characterisation of the RedMapper DC2 catalog: conclusions

- **preliminary pipeline to investigate cluster finder algorithms performances** vs simulation in place

- preliminary performances of redMaPPer on DC2 :
  - high scatter in richness mass relations?
  - **completeness of ~67% and purity of ~97% at z<1.2,** with catalogs cut at Mfof>5.10^13 Msol and lambda>20
  - **low fragmentation** (<1%) **and over-merging** (few %) fractions
  - **92% of associated detections are well centred**

- need to think about **training samples representative of the LSST spectro** sample and **take into account more systematics** in the simulation and **conduct the detection blindly**

I & II) What's next?

- More precise association method to develop could be used to set the base for a forward model for the abundance+WL signal+clustering (see eg Murata et al. 2017).
- Investigate richness/mass relations in details.
- Measure the WL mass of redmapper detections in DC2 (CLMM project for hack week).
- Richness recovery can be tested by injecting fake cluters in catalogs : could we do the same in the imsim images to measure systematics due to e.g. blending?
- No redMaPPer detection at z>~1.2 . Could we use a complementary algorithm ?

Thank you for your attention.
Any questions?

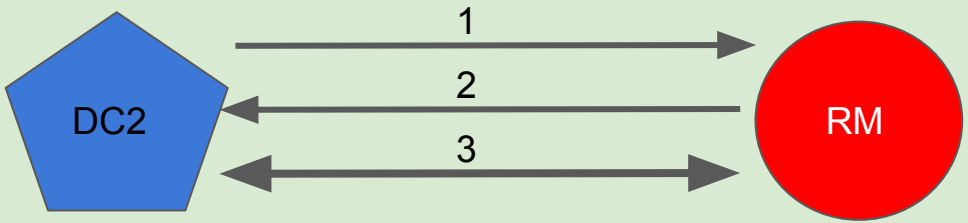
Association of RM detections to ‘true’ DC2 halos

The associations are computed :

1 - going from the DC2 true halos to the RM detections (DC2 => RM, one way)

2 - going from the RM detections to the DC2 true halos (RM => DC2, one way)

3 - as the intersection of (1) and (2) (DC2 <=>RM, bijective associations, two ways)



redMaPPer performances on DC2 : definitions

- Completeness: $C = \frac{N_{bij}}{N_{DC2}}$
- Purity: $P = \frac{N_{bij}}{N_{RM}}$
- Fragmentation fraction : $F_{frag} = \frac{N_{N_{DC2=>RM}>1}}{N_{bij}}$
- Over-merging fraction : $F_{ov.merg.} = \frac{N_{N_{RM=>DC2}>1}}{N_{bij}}$

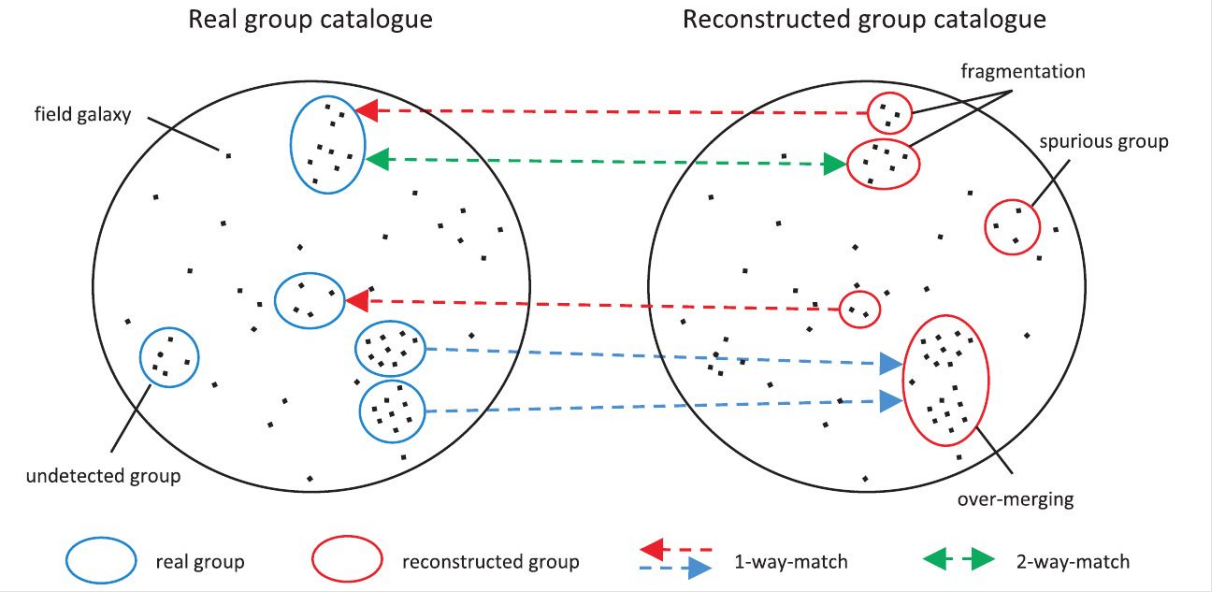


figure from Kobel et al 2009