LSST-DESC galaxy cluster working group at IN2P3

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LSST DESC Dark Energy Science Collaboration

1) Context of cluster cosmology

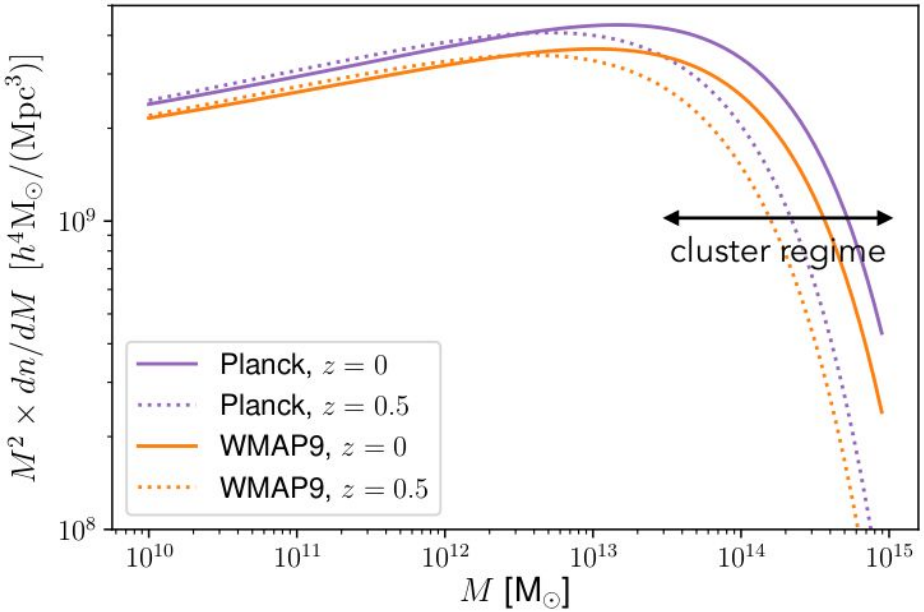
2) Past and current activities in 2019-2020

3) Strategy and roadmap for 2020

Using galaxy clusters as cosmological probes

The abundance of clusters as a function of mass and redshift is a powerful probe of structure growth and may allow to disentangle between cosmological constant or modified gravity for the origin of DE.

Problem : theory **predictions are for dark matter halos** but **we measure galaxy clusters**



Required steps:

1. Build a large and well defined cluster sample.
2. Estimate the mass of the clusters.
3. Build likelihood and compare to theory and simulations of the halo mass function.

Using clusters detected via the LSST

1. Galaxy catalogs from multi-band photometry
   - Color, shape, photo-z [blending, photo-z quality, masks]
2. Cluster detection from the galaxy catalog
   - Measurements of position, redshift and richness
3. Calibration of the cluster richness - mass relation
   - From weak lensing mass measurements
   - Using follow up observations at other wavelengths
4. Cluster sample characterisation
   - Selection function: completeness, purity, biases
5. Modelisation of the likelihood and inclusion in the cluster and joint probes cosmological pipelines
   - Different methodology possible

Using clusters detected via the LSST

1. Galaxy and shape catalogs from multi-band photometry
   a. Color, mask, blending, photo-z quality
2. Cluster detection from the galaxy catalog
   a. Multiband detection, centering, projection effects
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. Selection function: completeness, purity, biases
5. Modelisation of the likelihood and inclusion in the cluster and joint probes cosmological pipelines
   a. Different methodology choices.

All these activities heavily rely on :

- High quality photometry and photo-z
- Simulations
- External multi-wavelengths data sets

(**see Combet et al. for the in3p3 2020 prospectives**)

Using clusters detected via the LSST

1. Galaxy and shape catalogs from multi-band photometry

   DC2 processing and validation

   Reprocessing of existing data

2. Cluster detection from the galaxy catalog and sample characterisation

   Cluster Finder validation

3. Calibration of the cluster richness

   Cluster lensing mass modelling (CLMM)

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Cluster Finder validation

https://github.com/LSSTDESC/CLUSTER_VALIDATION

Goal : *"**Compare the performance of the cluster finder on "truth" and realistic simulated data**, as well as check the mass-richness relation derived directly from halos."* *(SRM tasks "CLFinder DC2 VA")*

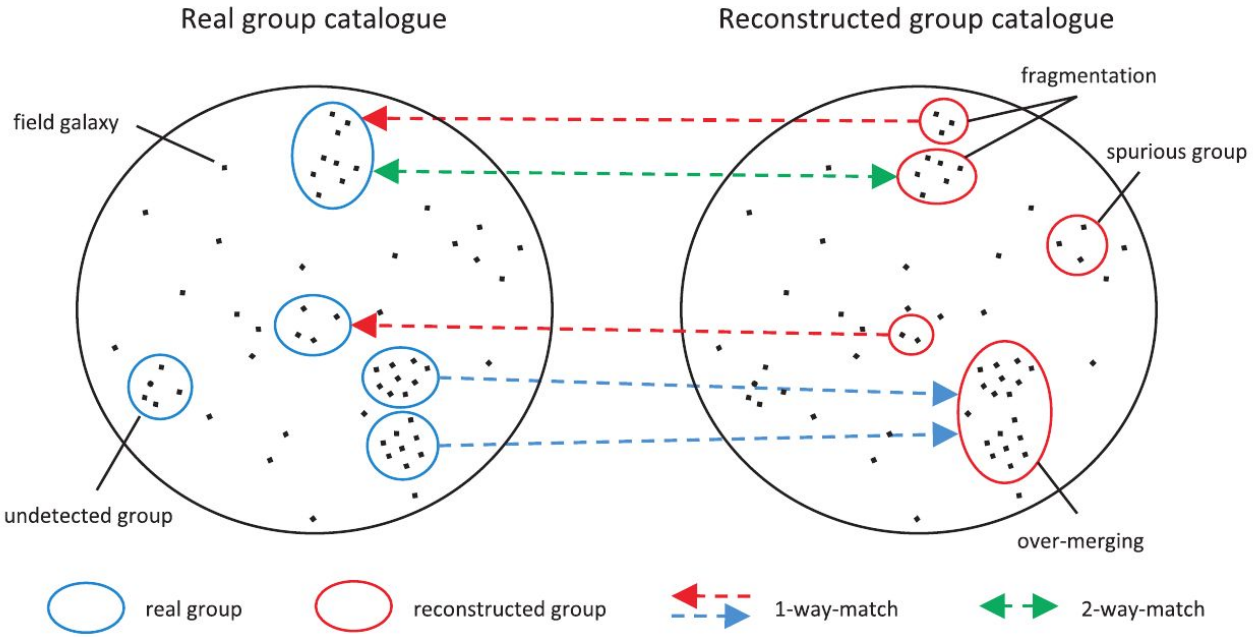
DESC baseline cluster finder : **redMaPPer** *(E. Rykoff et al 2013)*

Work part of **DC2 Project: Running redMaPPer on DC2 Cosmo and Sim Catalogs**

- Code designed to compare cosmoDC2 halo to redMaPPer cosmoDC2 detection catalog *(E. Rykoff)*
- Next : run with redmapper catalog applied on DC2 object catalog *(not yet produced)*
- Presentation at the CL session of the DESC Tucson meeting (RedMaPPer validation framework on DC2)
- Analyses will be included and proposed as a DESC paper

Cluster Finder validation : catalogs association

To measure the CL finder performances on simulation **we first need to match the detected clusters to the mock halos** (see method in e.g. *Euclid collaboration et al 2018*)

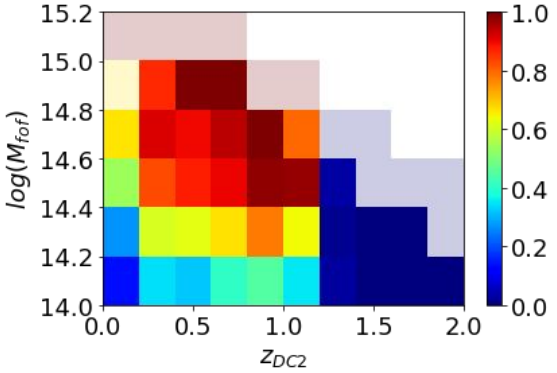


- non-trivial task
- different methods implemented
- impact the results
- global matching statistics as a metric (number of bijective match, fragmentation and overmerging fraction etc…)

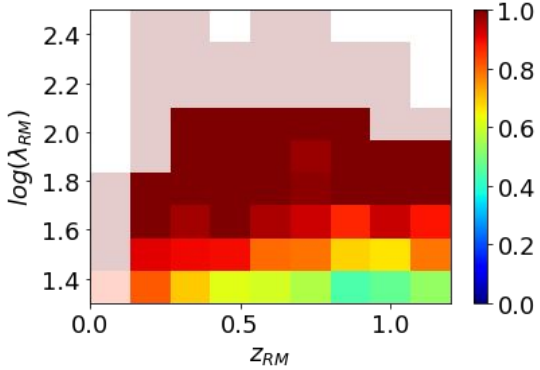
figure from Knobel et al 2009

Cluster Finder validation: automated validation analyses

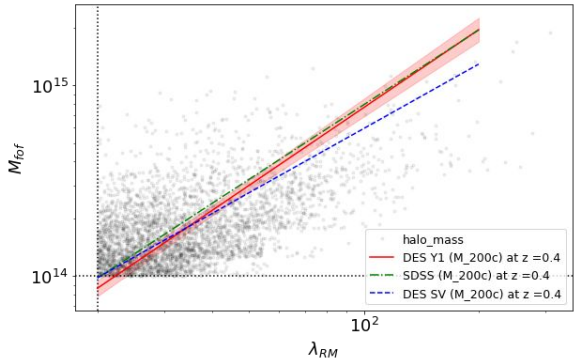
Sample completeness



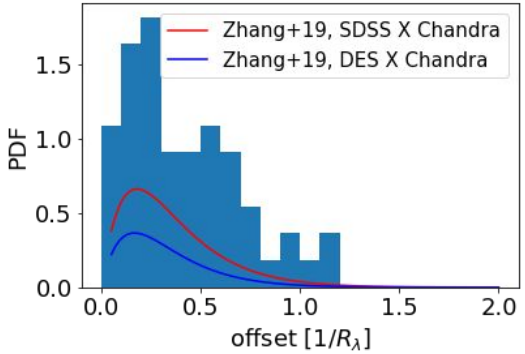
Sample purity



Mass-richness relations

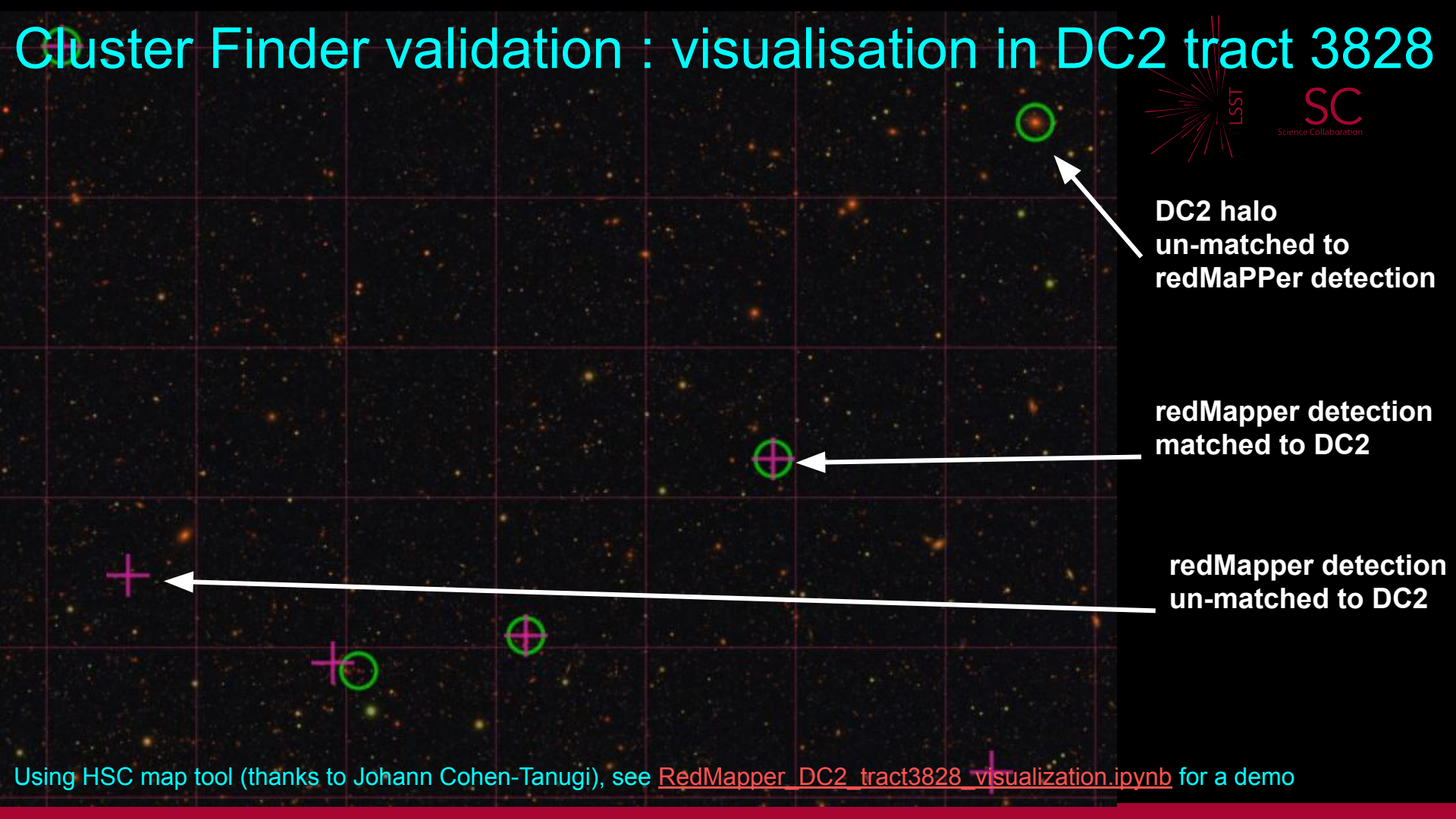


Miscentering

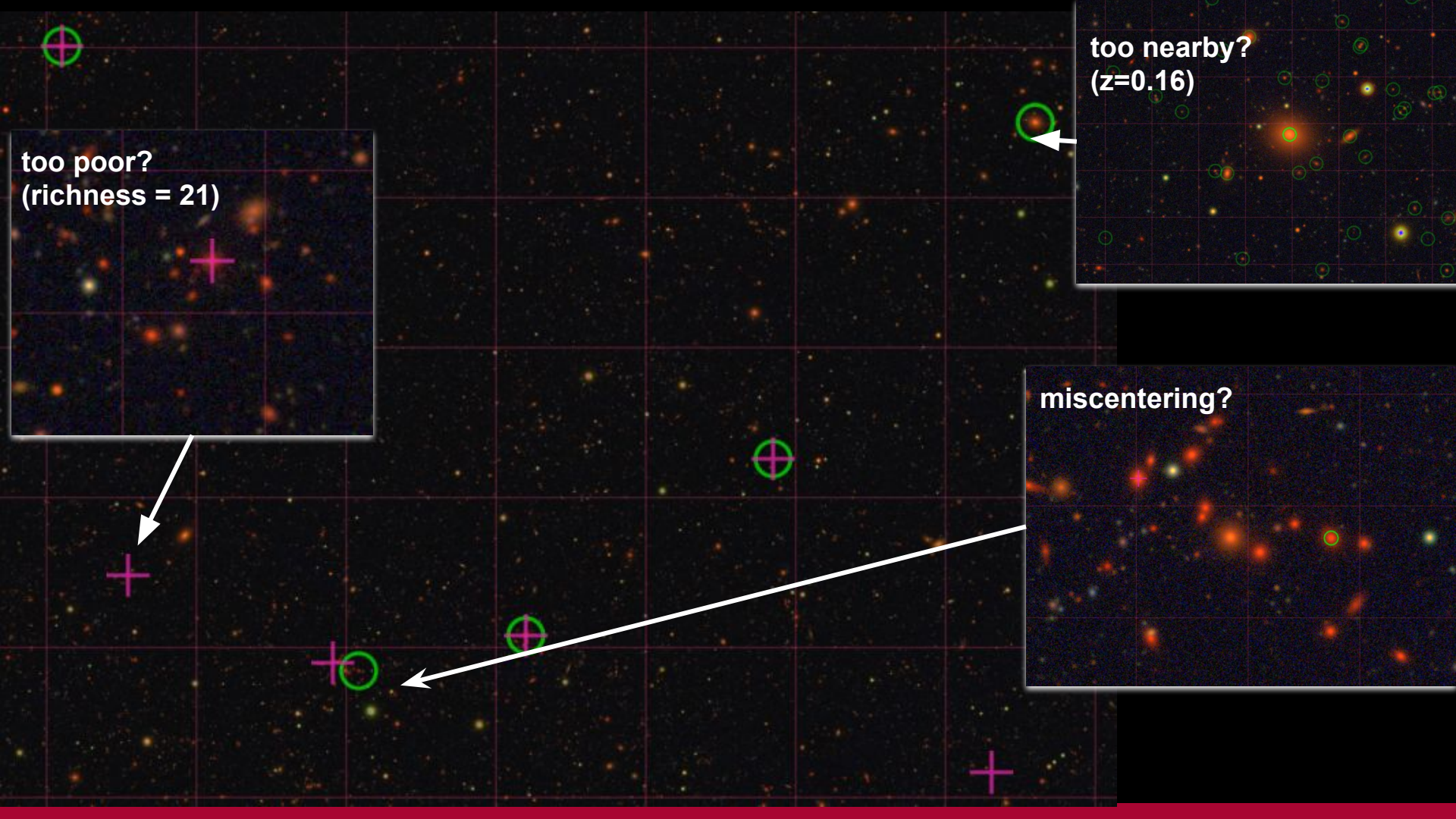


- Implemented using GCR catalog
- Run automatically for any catalog version
- Comparison to literature
- Example notebook for each test

Cluster Finder validation : visualisation in DC2 tract 3828



Using HSC map tool (thanks to Johann Cohen-Tanugi), see RedMapper_DC2_tract3828_visualization.ipynb for a demo


too nearby?
(z=0.16)
too poor?
(richness = 21)
miscentering?

Cluster Mass Modeling

https://github.com/LSSTDESC/CLMM

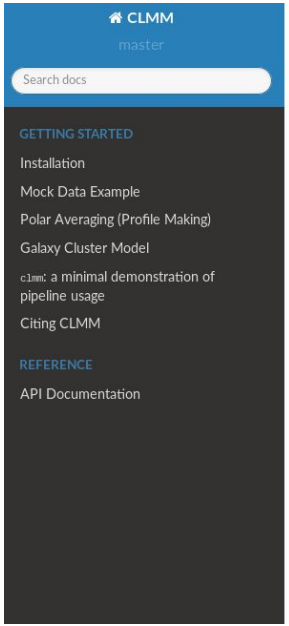
- Python library for performing galaxy cluster weak lensing analyses
- Used by several DESC projects and for different key tasks listed in the SRM
- Public code that follows DESC coding guidelines (automated tests, documentation etc…)

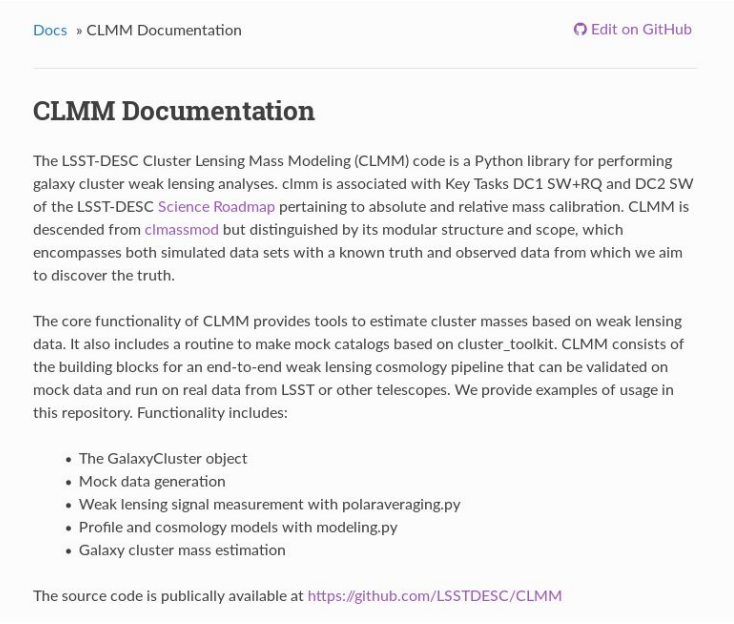
Progress :

- ~12 active people involved (C.C. & M.R)
- 1 week workshop in July
- Hack days and sprint weeks
- Weekly status report meetings

Roadmap :

- V1.0 and associated paper expected for summer 2020
- Application on DC2 data and interfacing with redmapper
- Discussion started for interface with TXPipe and Firecrown (WL and TJP)



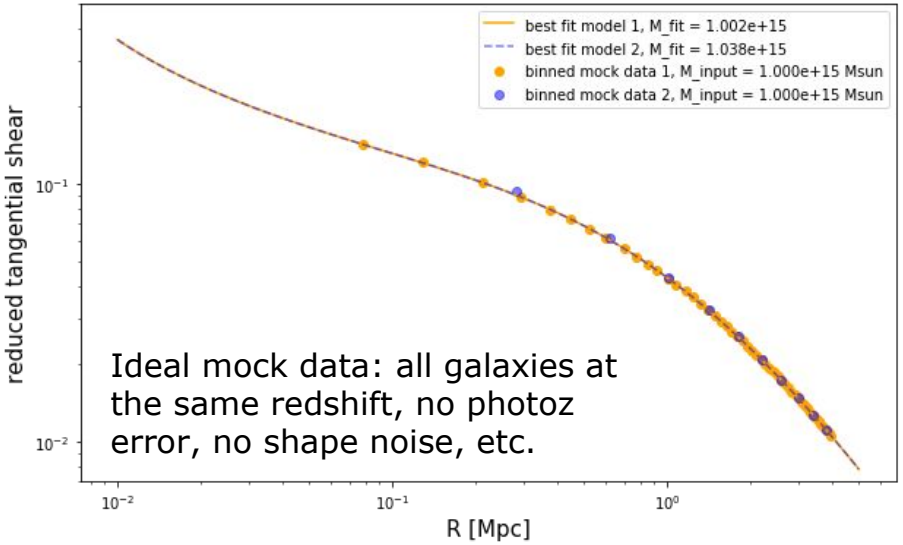


Cluster Mass Modeling

Input : galaxy cluster position and redshift, source galaxy ellipticities (or shear), position and redshift.
- mock data
- DC2 data
- real data

Data processing and data modeling :
- tangential shear profiles
- profile modeling (NFW)
- likelihood maximization

Returns :
- shear profiles associated with cluster object
- mass estimates

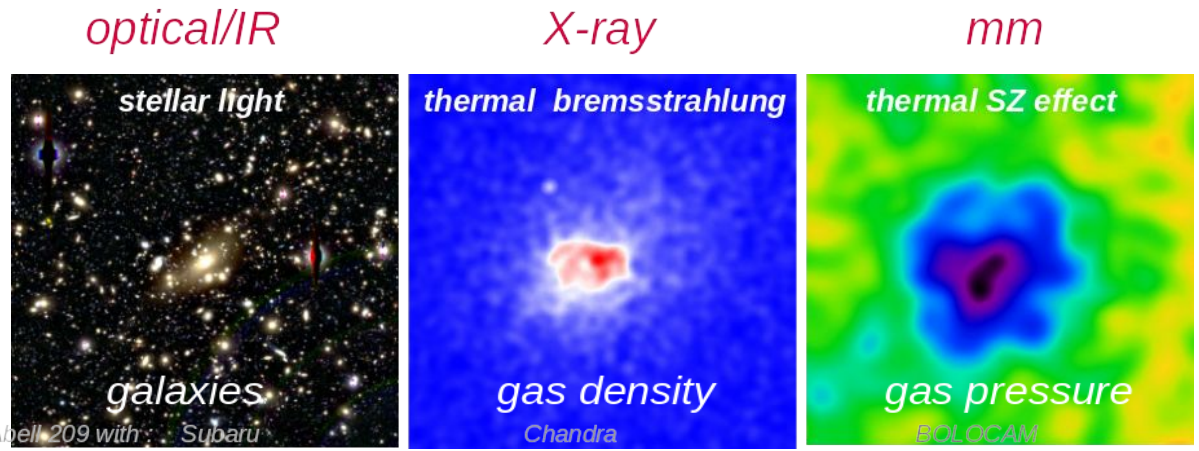


To implement :
- realistic redshift modeling
- projected mass density profiles
- stacking of clusters
- other types of modeling profiles
- baryonic feedback and miscentering

Other relevant activities

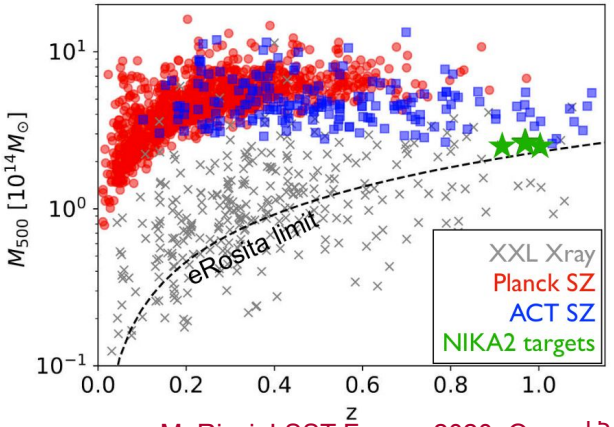
Exploitation of multi-wavelengths synergies

- Document for the in2p3 2020 prospectives (*Combet et al. 2019*)
- Participation to the "baryon-pasting" and "External -synergies" WG



Observational project of clusters in SZ (with NIKA2 @ IRAM-30m)

- Goal : characterize a pilot sample of clusters, typical of future optical/IR, X and mm survey detections, via a multi-wavelengths analysis.
- Ongoing project, first article submitted to A&A, 2 others publications in prep.



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IN2P3 cluster group roadmap for 2020

- **Winter-Spring 2020:**
  - continue effort on CLMM, CL Finder DC2 VA and DC2 VA
  - start new multi-wavelengths analysis of the NIKA2 clusters
  - M2 internship with Céline on CLMM and cosmoDC2 (4 months)

- **Summer 2020 :**
  - M1/L3 internships at LAPP and LPSC
  - CLMM workshop around DESC meeting ?
  - CLMM first release and paper
  - paper on redMaPPer validation

- **Fall 2020 :**
  - end of my contract
  - 2 postdocs in the group for 2 yrs (Labex/LPSC and IN2P3/LAPP)

Strategy and opportunities

- **DESC simulations and CL pipeline :**
  - apply almost end-to-end cluster pipeline on DC2 : from redmapper detections in object catalog to number counts and mass-richness relations

- **Image processing and cluster shear measurements :**
  - Precious experience with the DM stack : re-start reprocessessing activities
  - Clusters are perfect environments to pinpoints systematics
  - Collaboration to be explored with colleagues in Geneva to work on HSC + Megacam data

- **Multi-wavelengths expertise :**
  - Hot topic of the coming years (CL, LSS & WL)
  - Need to build/conserve/confirm french expertise on data & simulations

- **Cosmological statistical analyses :**
  - IEA for collaboration with colleagues in Brazilia

- End of 2020 : need to get ready for commissioning and science verification!

Summary

- We are **highly implicated within DESC and the CL working group**
- We are taking part to **key SRM activities** :
    - DC2 production and validation activities
    - The cluster finder validation
    - The cluster mass modelling pipeline
- As well as in **key discussions and transversal activities :**
    - interface between CL/CS/WL & TJP
    - commissioning planning
    - multi-wavelengths expertise and implication in external data & simulations analyses
- Hopefully we will be able to go even further with the **new members expected.**