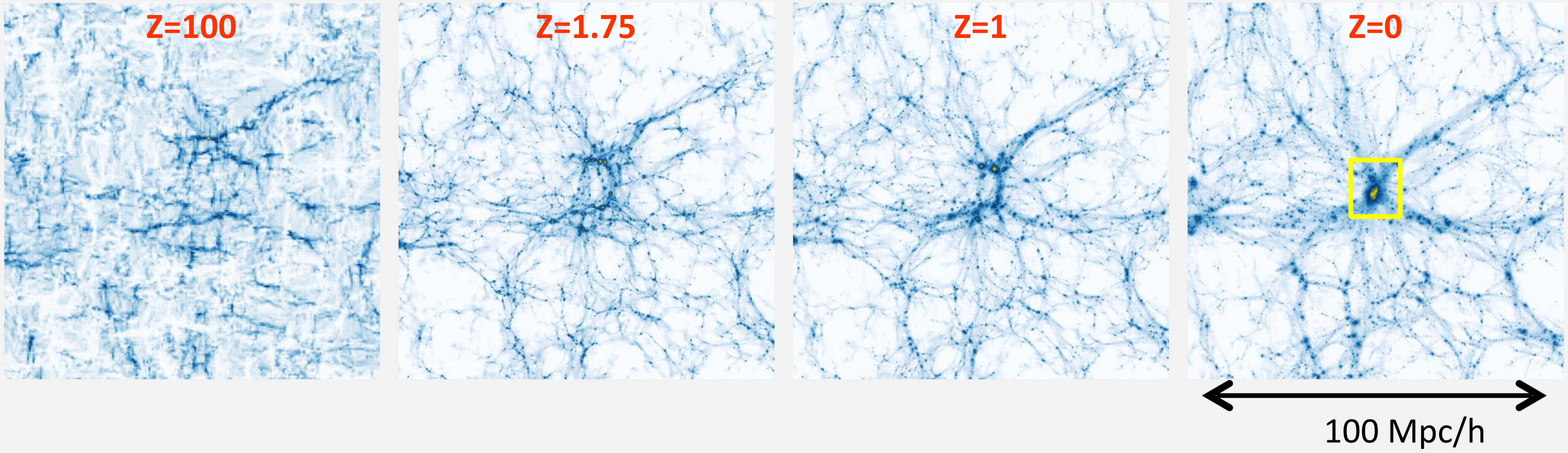
Evolution of Groups and Clusters

M. Arnaud & C. Ferrari

Thanks to E. Daddi, H. Dole, S. Maurogordato for providing slides

Clusters as cosmological probe

RAMSES (Teyssier 2002) simulations run at GENCI (Le Brun et al. in prep.)

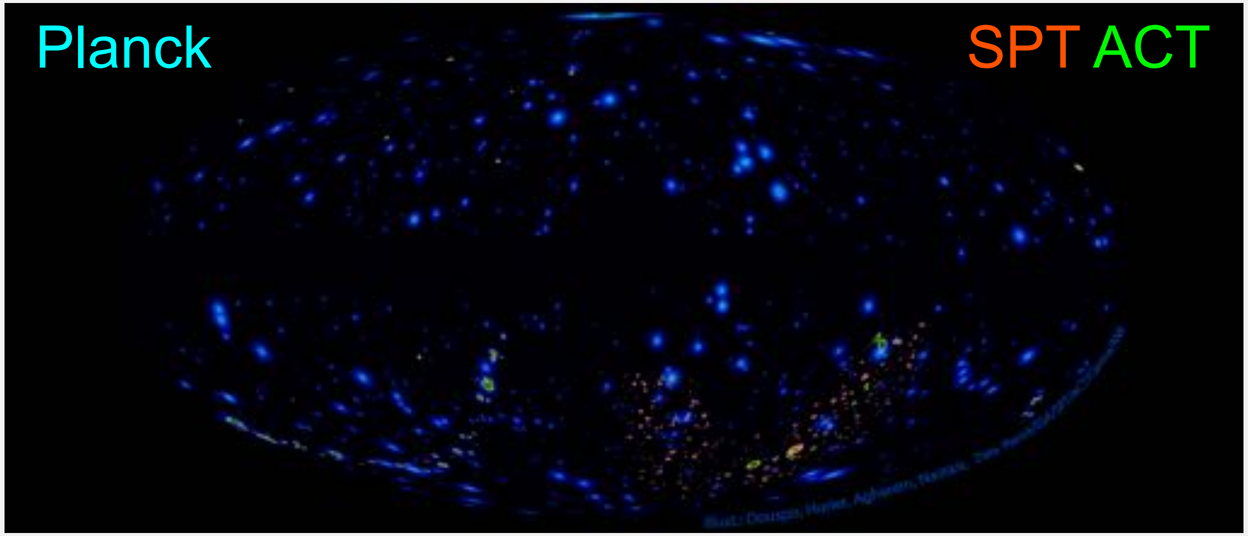


- Nodes of the Cosmic Web; forming and growing since z~2
- Representative pieces of Universe: 90% dark matter; 9% hot gas; 1% galaxies

⇒ Cosmological model from N(z,M), clustering, f_{baryon}

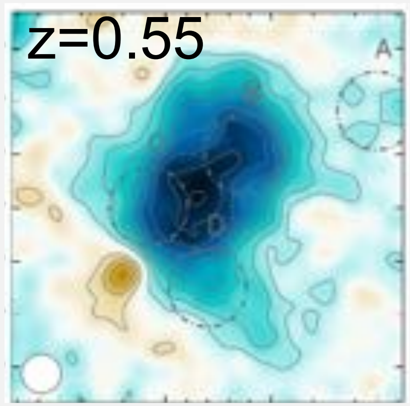
⇒ Structure formation physics (DM & baryons) e.g. from statistical properties

The new window

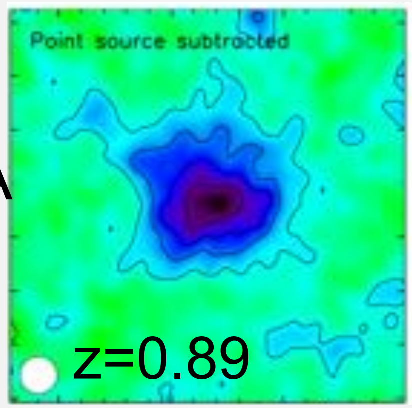


SZDB @IDOC/IAS

From SZ surveys



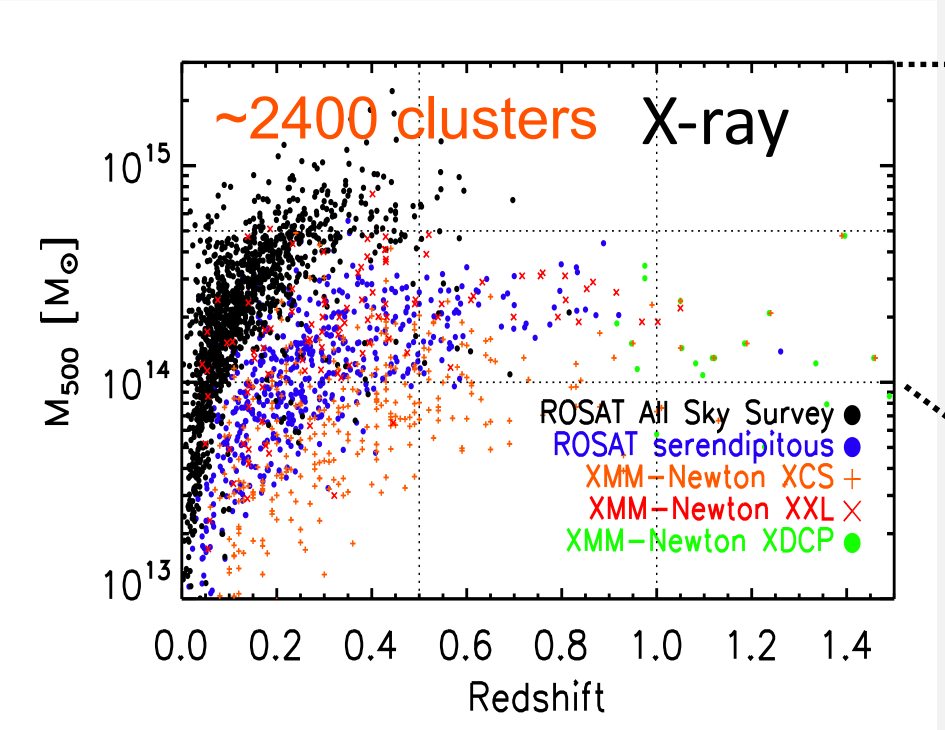
NIKA

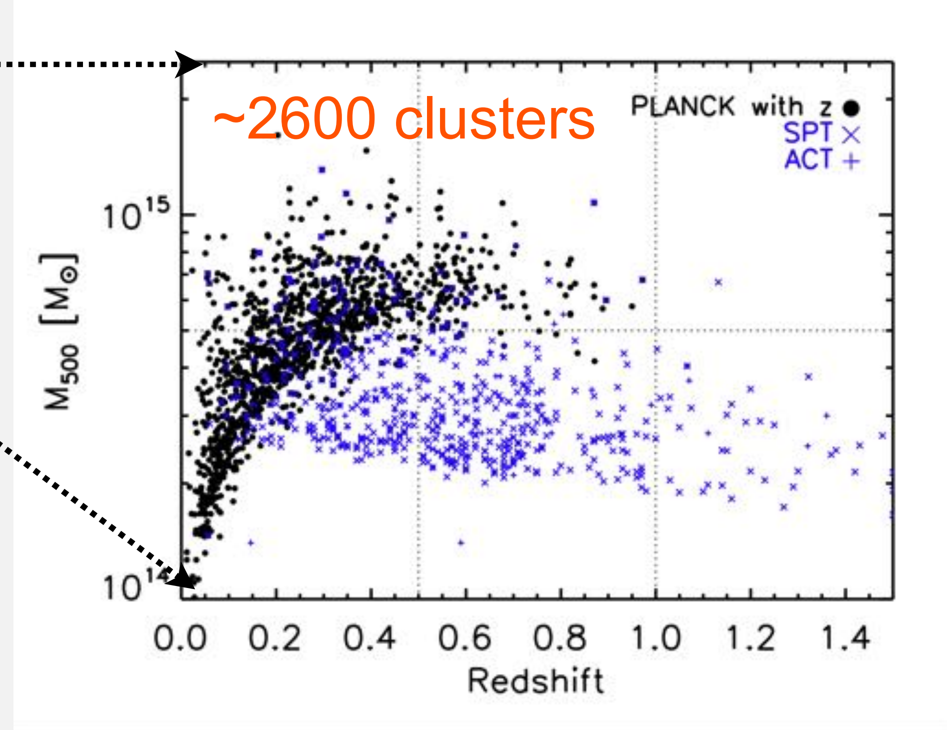


to high resolution SZ imagery

see R. Adam talk

Finding clusters



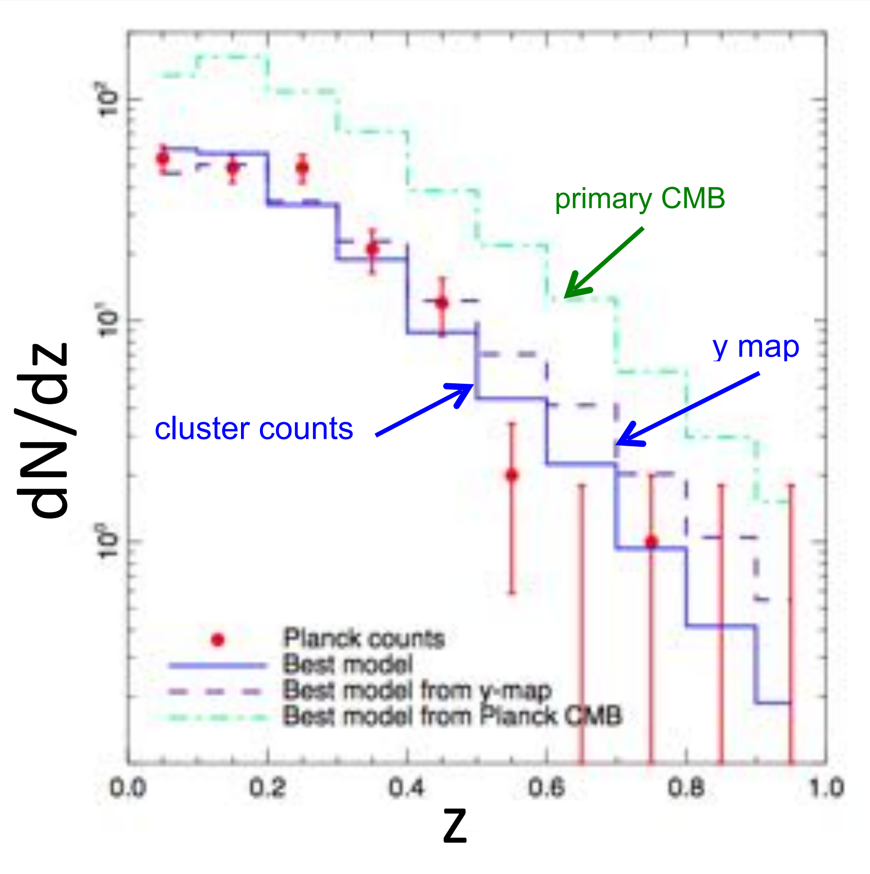


XXL: Pierre+16

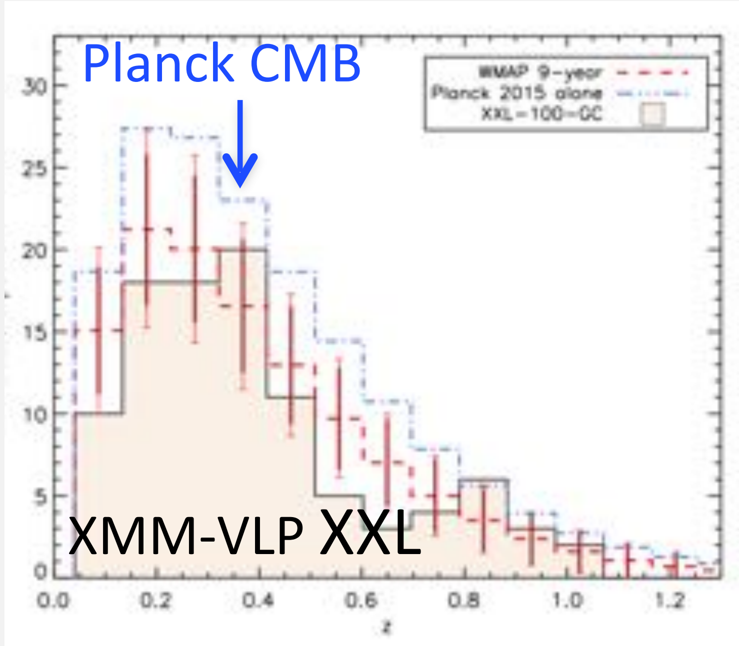
Planck: Early results VIII, 2013 results XXIX-XXXII, 2015 results XXVII
Planck validation &z: ESO-LP on going [Aghanim+]
Megacam [van der Burg, Aussel+, 15]

Large z-Mass coverage; Survey complementarity

The discordant Planck cosmology



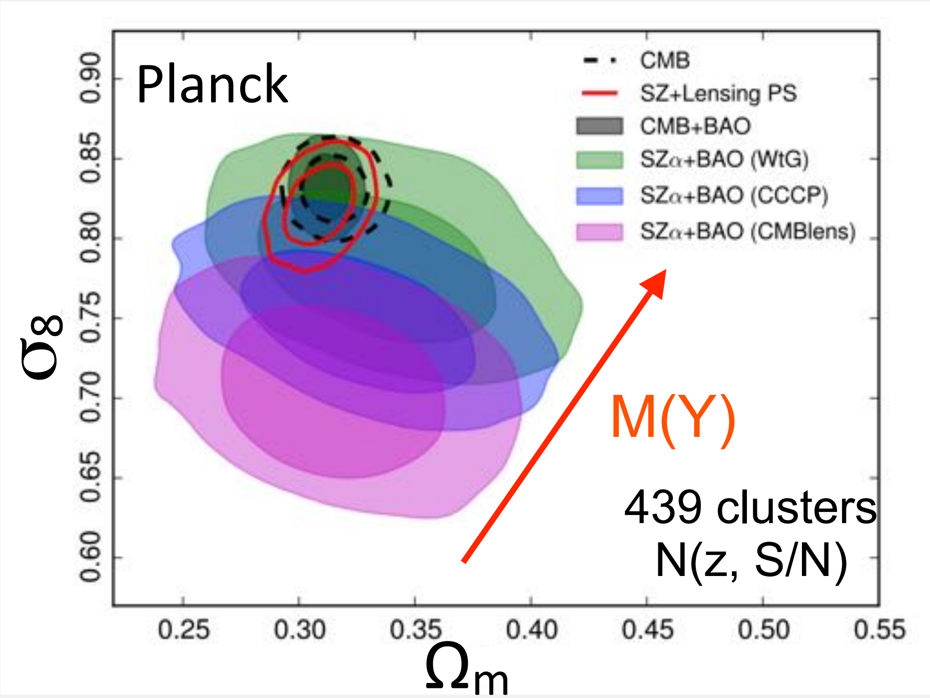
Planck Coll. 2013 results XX



Pacaud et al, 16

Factor of ~2 deficit in number counts vs CMB prediction

The discordant Planck cosmology

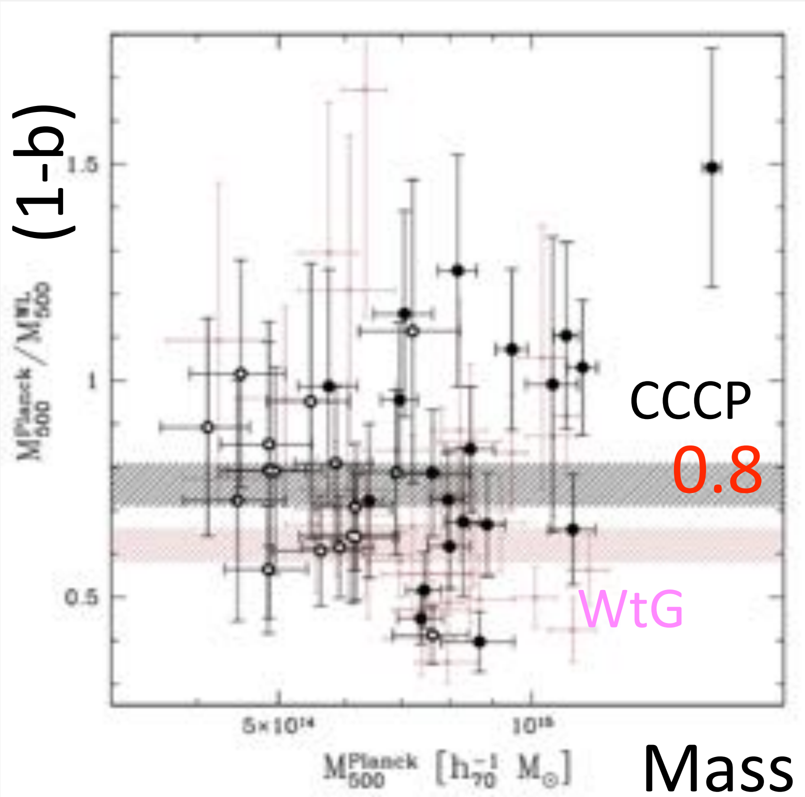


Planck Coll. 2015 results XXIV

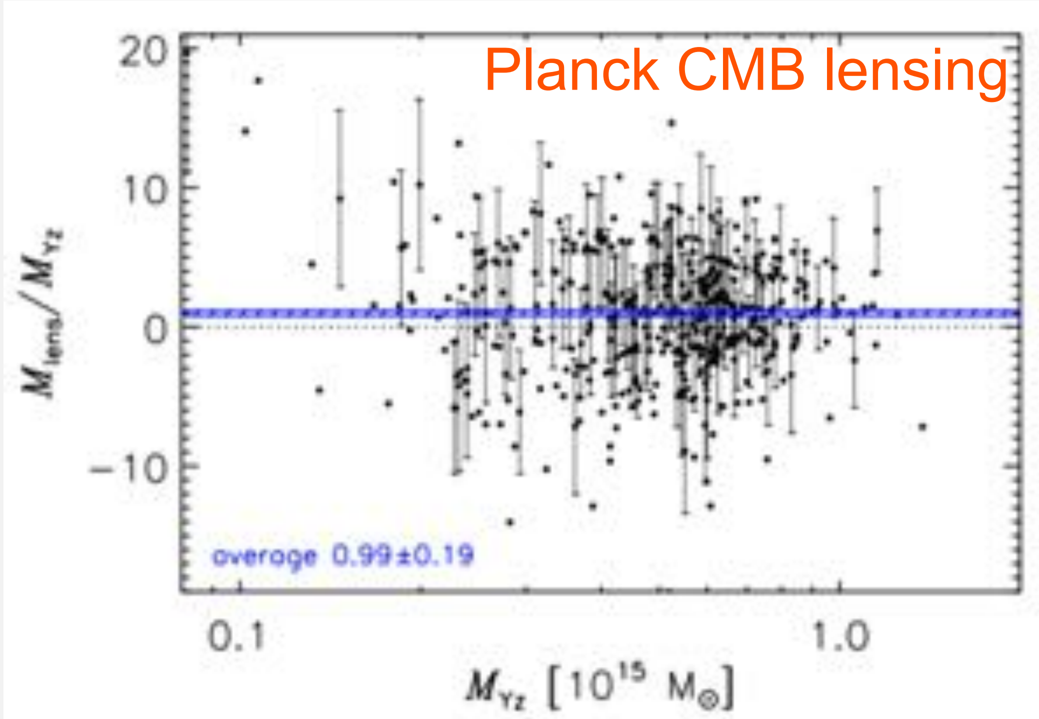
- N(Y) depends on Y-M and N(M)
- New astrophysics (more massive, higher HE bias) and/or Extension of cosmological model (e.g massive neutrinos)?

What is the true mass of clusters?

Lensing mass calibration



Hoekstra+15



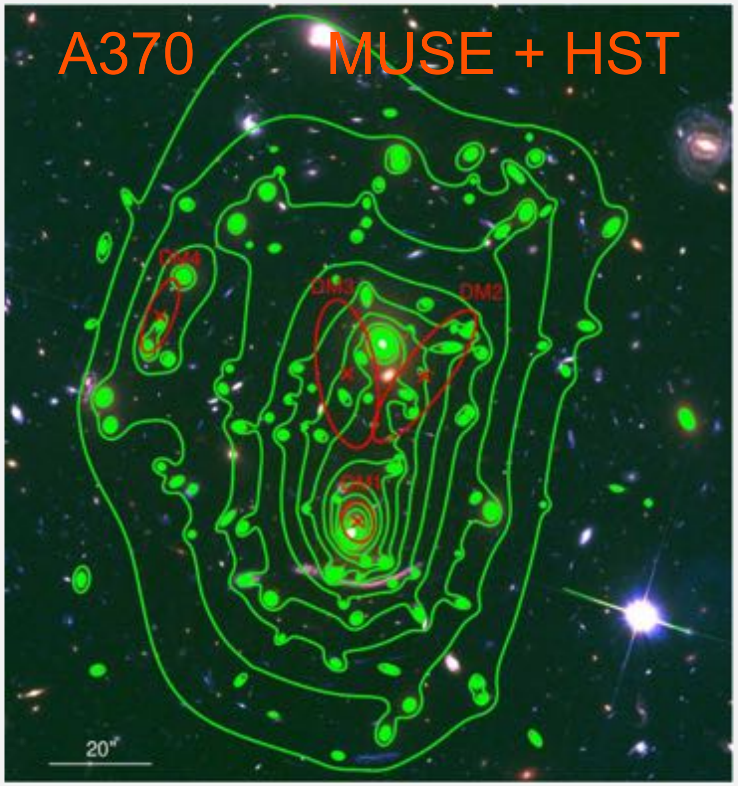
Planck Coll. 2015 results XXIV; Melin & Bartlett, 15

Larger sample
Better control of systematics

New promising technics

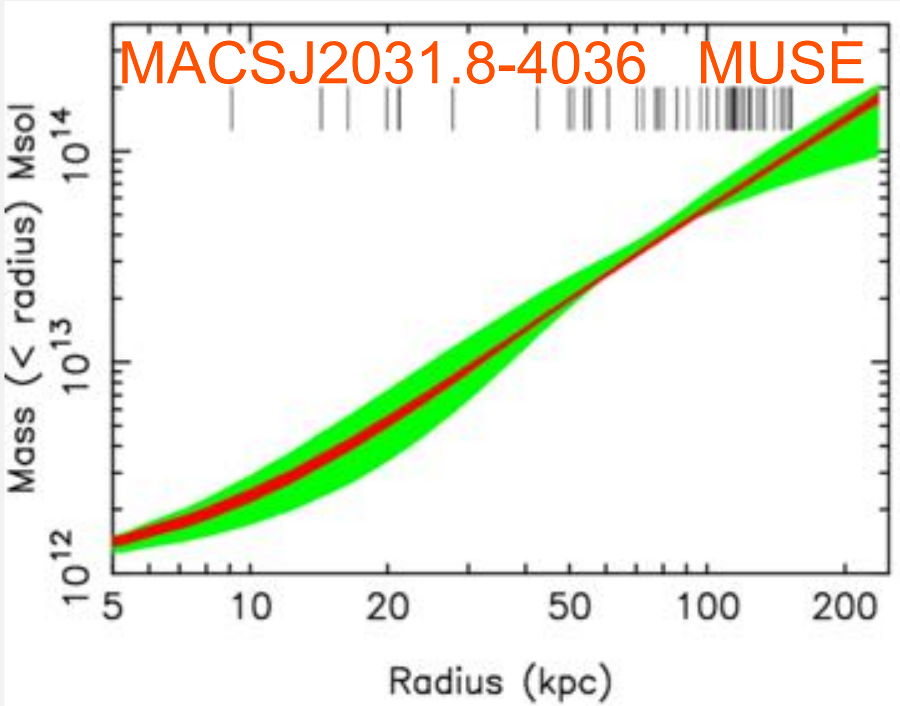
but still M_{WL} systematics; large statistical errors ; no scatter estimate

Lensing cartography



Lagattuta, Richard,Clément et al, 16

120 new z; 9/15 new multiple images
2 additional mass clumps revealed



Richard et al, 15

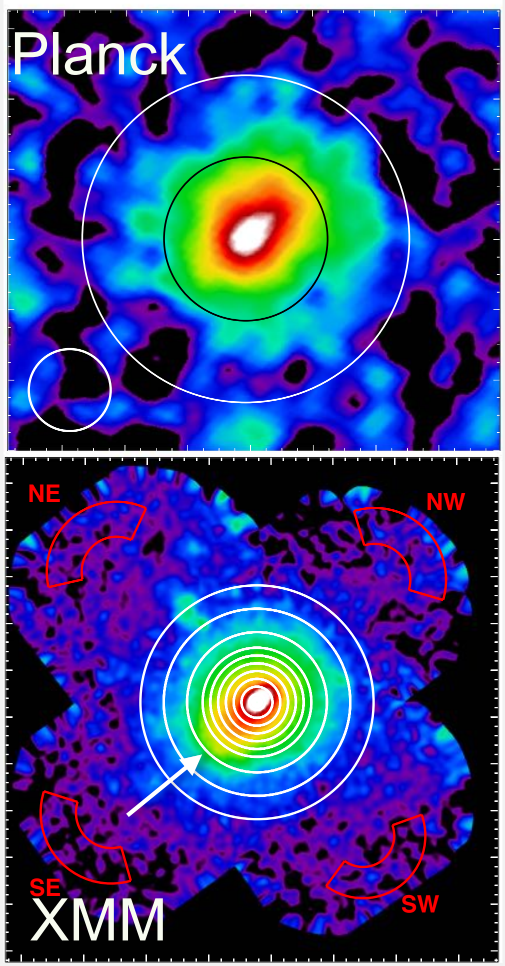
From 1system to 12 systems
5 times better precision on M(r)

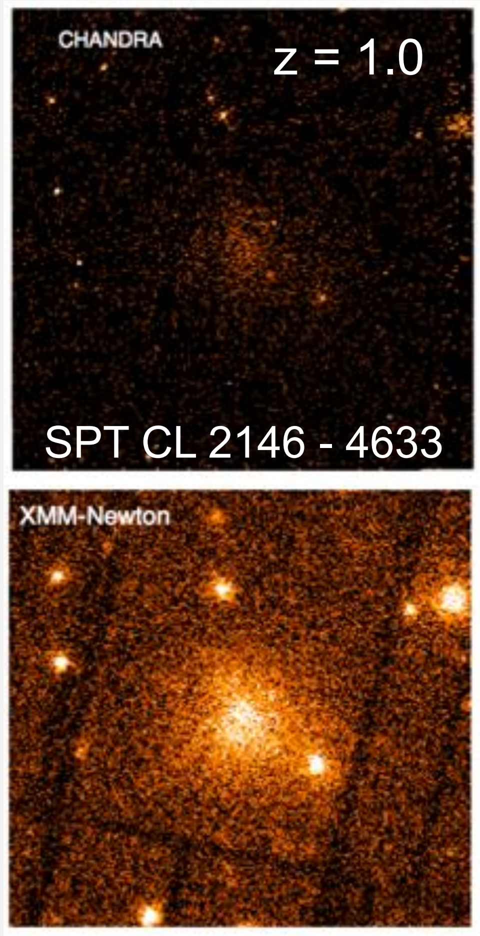
Much better strong lensing constrains in cluster core

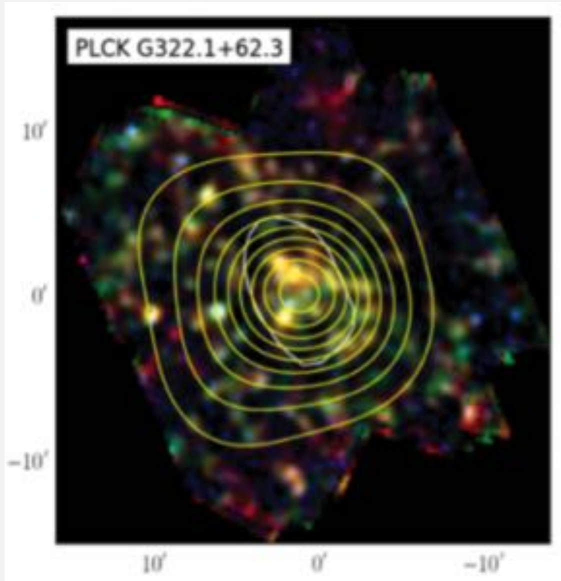
but see Limousin et al, 16

see HFF results (J. Richard talk)

New Frontiers

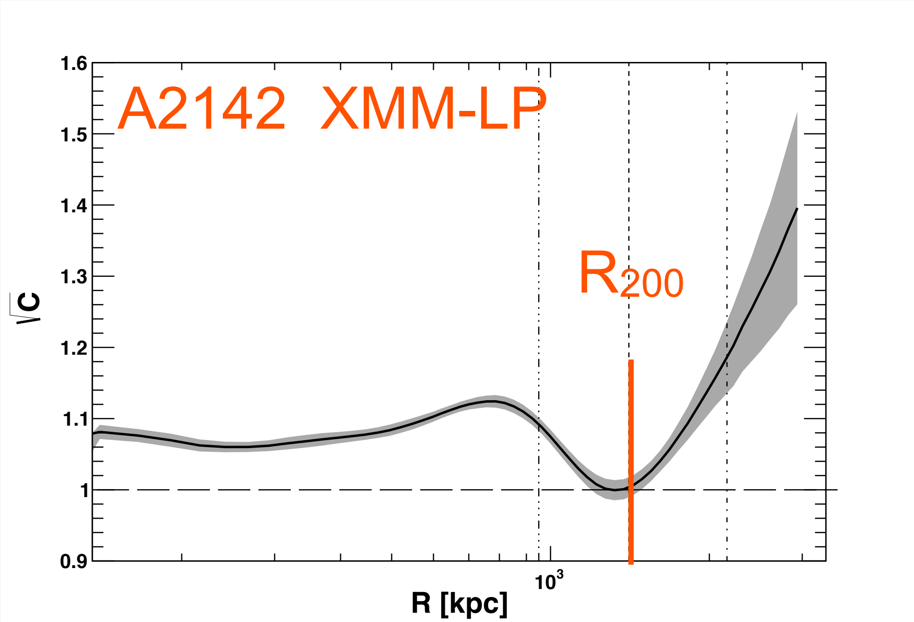




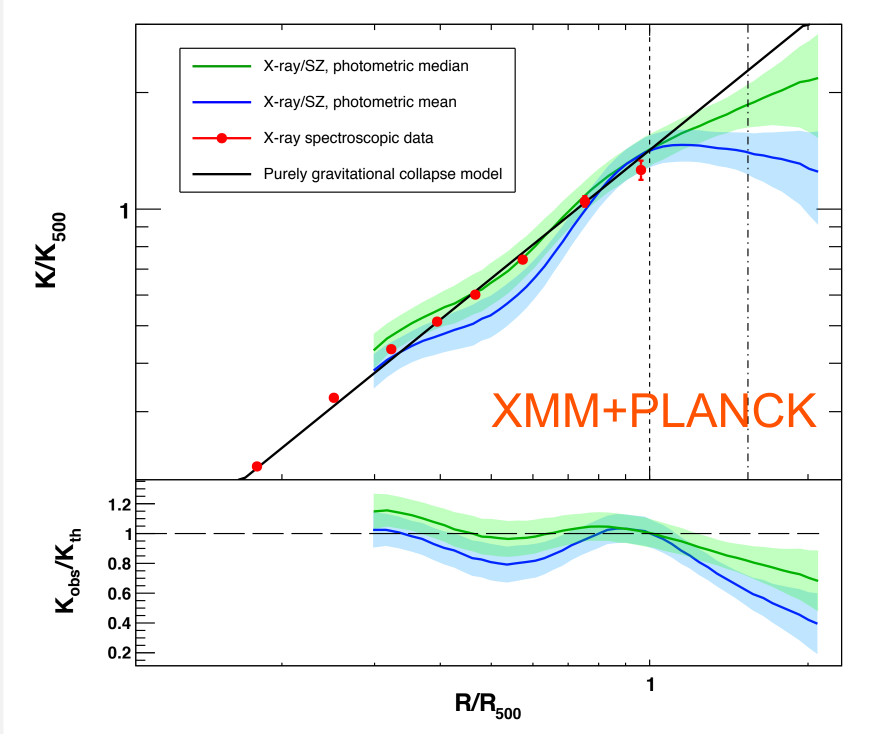


z~0	z~1	z~2
Outskirts	Thermo-dynamical properties evolution (up to z~1)	High z (Proto) clusters

New Frontiers: outskirts



Tchernin, Eckert, Ettori,Pointecouteau et al, 16

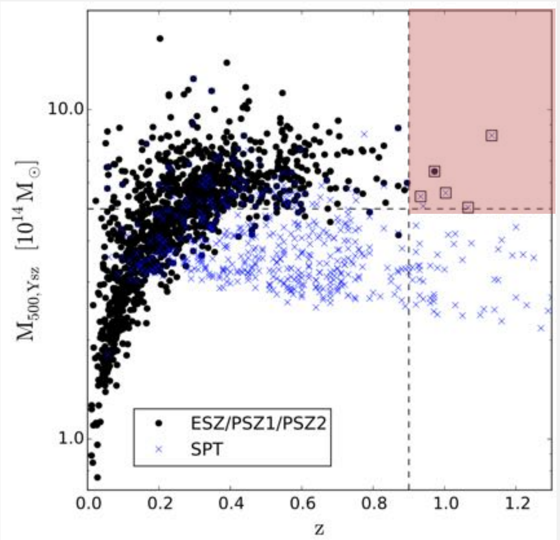


Increase of clumpiness due to asymmetric LSS and cold clumps

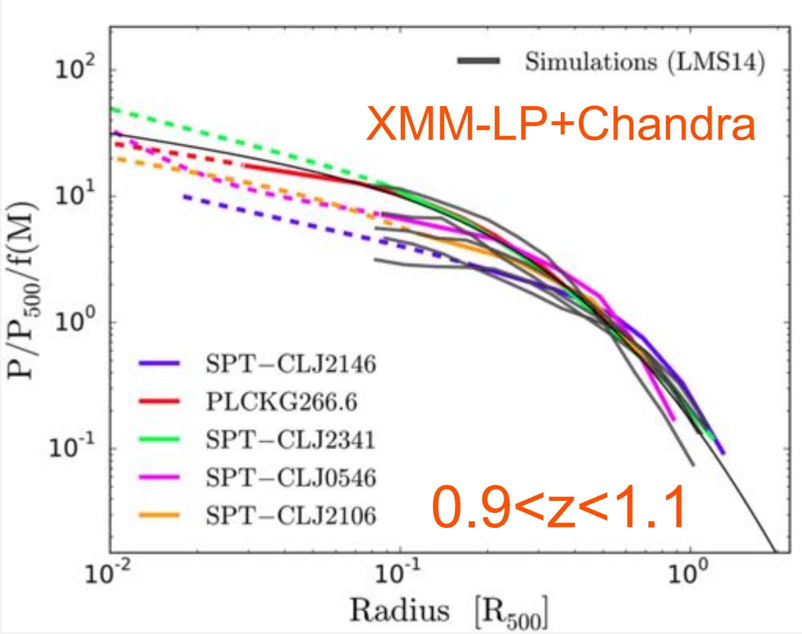
Entropy follows gravitational model

Probe of accretion physics

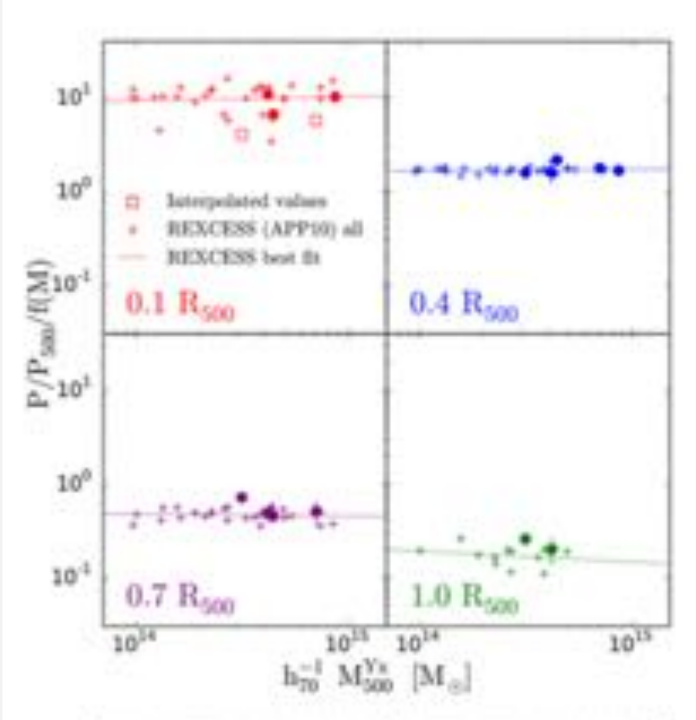
New Frontiers: high z



spat. resolved spectro up to z~1



self-similar evolution in agreement with predictions

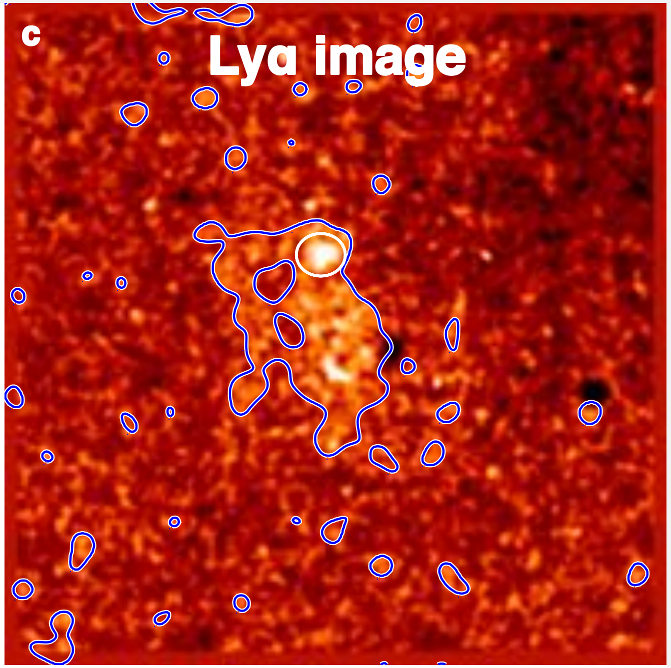


[Bartalucci, Arnaud, Pratt et al 2016]
[Simul: OWLs ,Le Brun+,16]

Test of gravitational physics

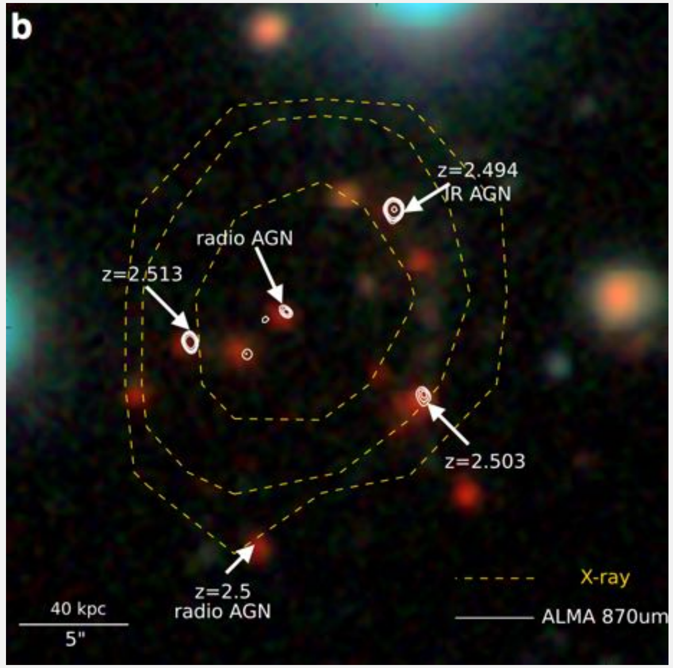
New Frontiers: z>2 clusters

z=1.99
27 spec
members
*(Gobat+11,13
Strazzullo+13)*



(Valentino, Daddi et al 2016).

The first X-ray detected cluster
showing diffuse Lyα emission
First direct clues on the feedback
of galaxy activity on the ICM at z~2

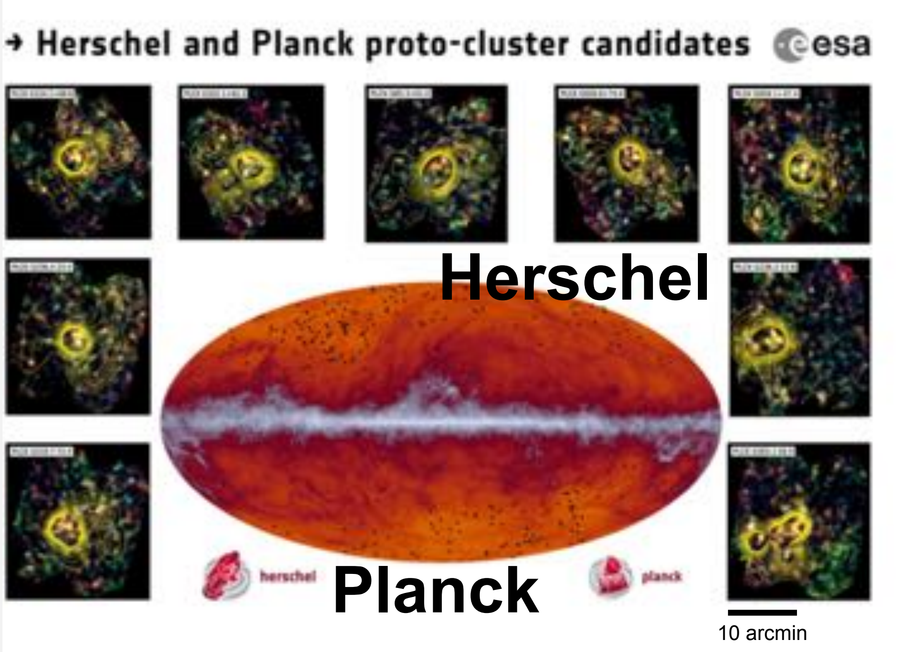


(Wang, Elbaz, Daddi et al 2016)

Most distant X-ray cluster z=2.506
Prodigious SFR ~ 3400M⊙ /yr in the
100kpc core hosting 10^{12}M⊙ of stars
Not expected from models.

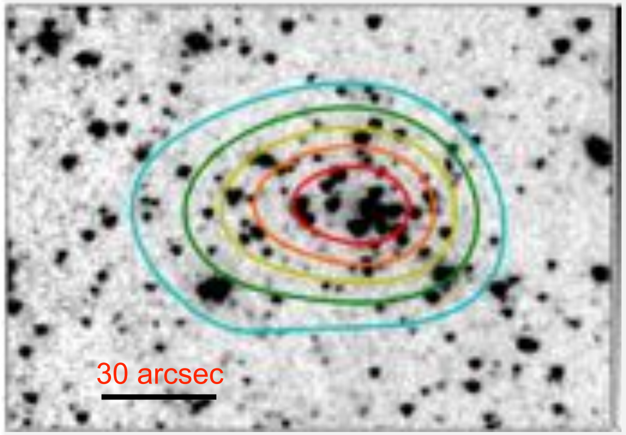
Cold gas and vigorous SF in z>2 clusters

New Frontiers: proto-clusters

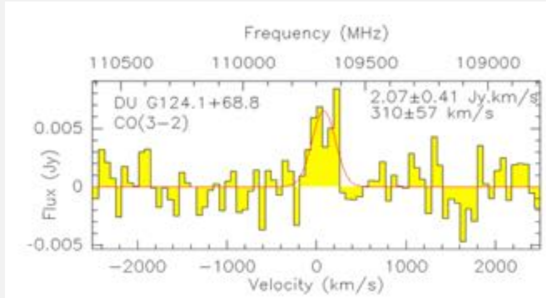


Planck Collab., 2015, XXVII, 2016, XXXIX;
Flores-Cacho et al., 2016; Martinache et al., in prep

Spitzer

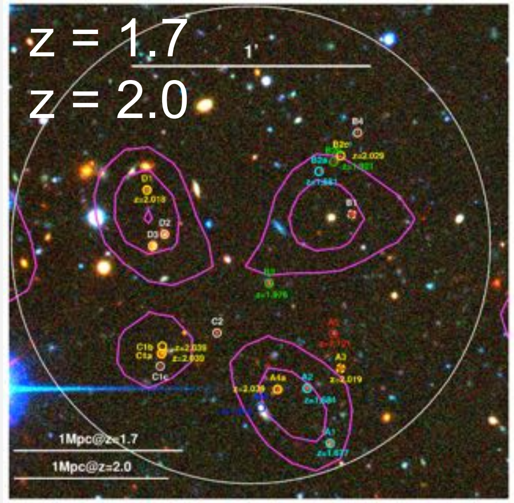


IRAM



few redshifts
z = 2.38
z = 2.15
z = 1.32

CFHT + XShooter

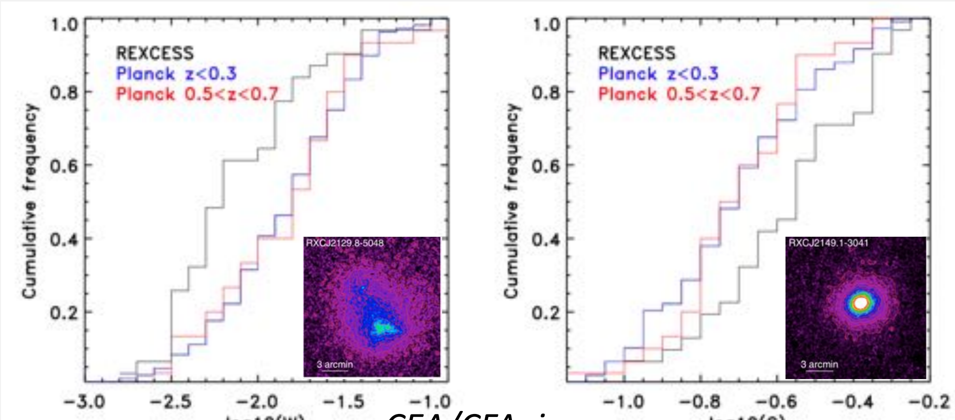


+ Prospects with JWST and Euclid

High-z high-SFR (proto-)clusters

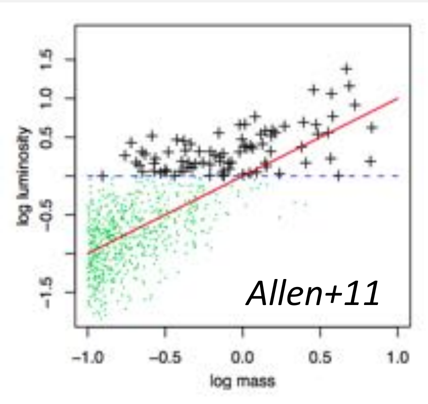
Open Questions & prospectives

Open questions



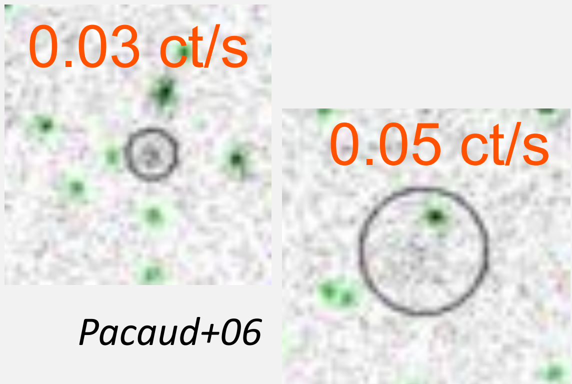
CEA/CFA, in prep.

Dynamical state differs in X-ray & SZ selected sample



Allen+11

Malmquist/Eddington bias



Pacaud+06

Detectability (may) depend on morphology

- Extension of cosmological model and/or revision of cluster physics?
- What is the true mass of clusters ?

But also:

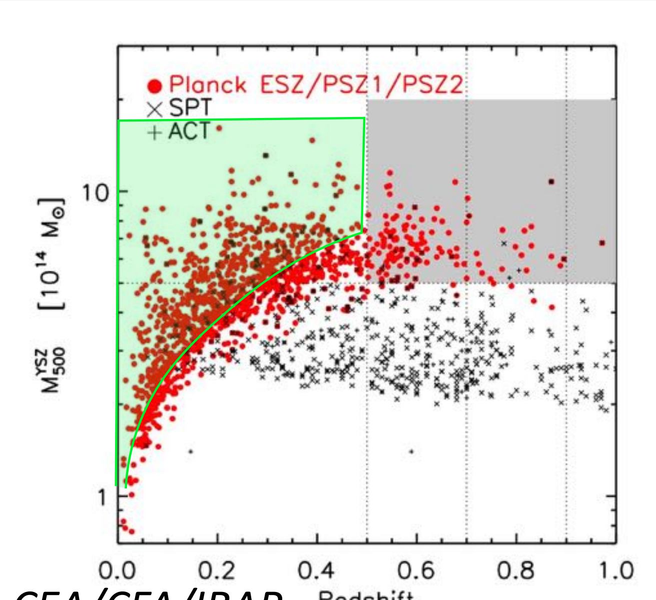
- What is the true underlying cluster population?

and 'old' questions :

- Dark matter collapse
  M(r) *vs z* consistent with LCDM ?
- Baryons physics
  - ⇒ Origin and acceleration of relativistic particles; amount of 'non thermal' energy
  - ⇒ When and how the entropy excess was generated ; Negative versus Positive AGN feedback issue *[Salome+,15,16]*

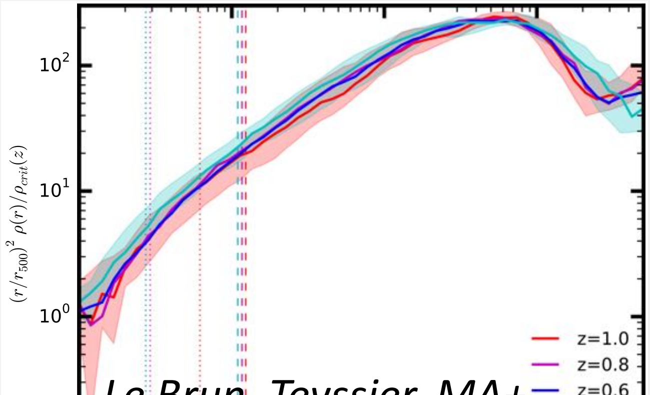
Scatter/morphology (and their evolution) crucial

Cluster evolution & physics

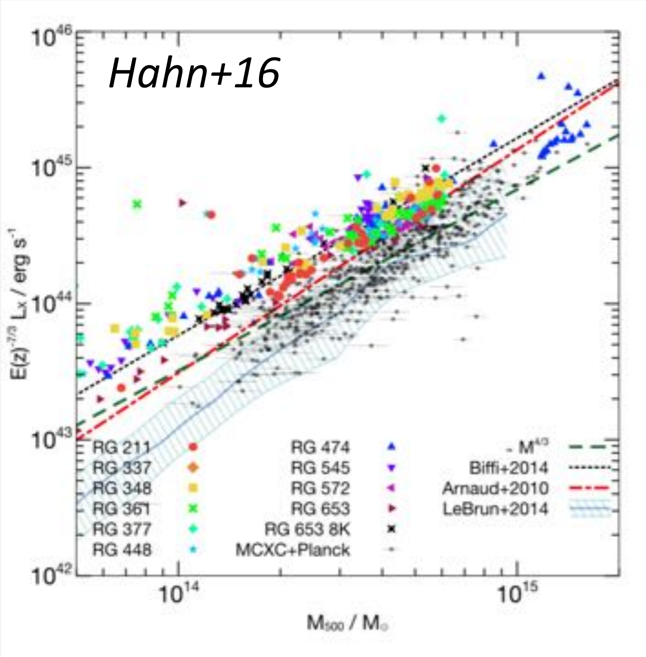


CEA/CFA/IRAP

On going follow-up of large SZ and X-ray samples



Le Brun, Teyssier, MA+

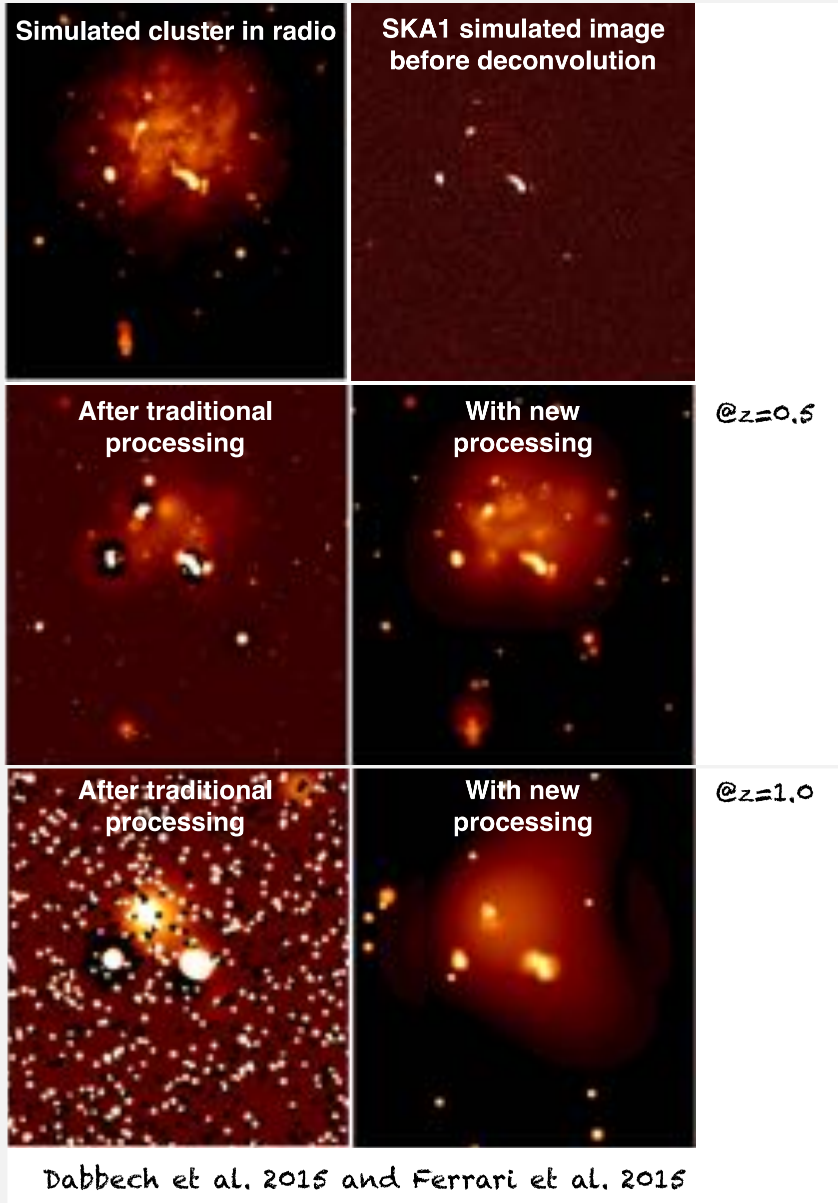


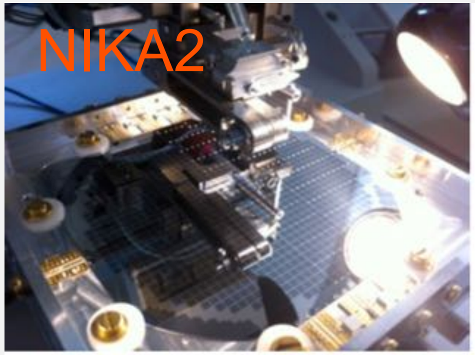
Hahn+16

Numerical simulations essential

- On going Very large DM and adiabatique simulations matching Planck volume and XMM resolution
- SPH: Non grav. physics calibrated at low z (cosmo-OWLS) *Le Brun+14,16*
- AMR (RAMSES)
  - ⇒ New physics:
    - conduction *Dubois+15*
    - RDH *Rosdahl, Blaizot+15*
  - ⇒ Pb with calibration of non gravitational physics *Hahn +15*

The new technics

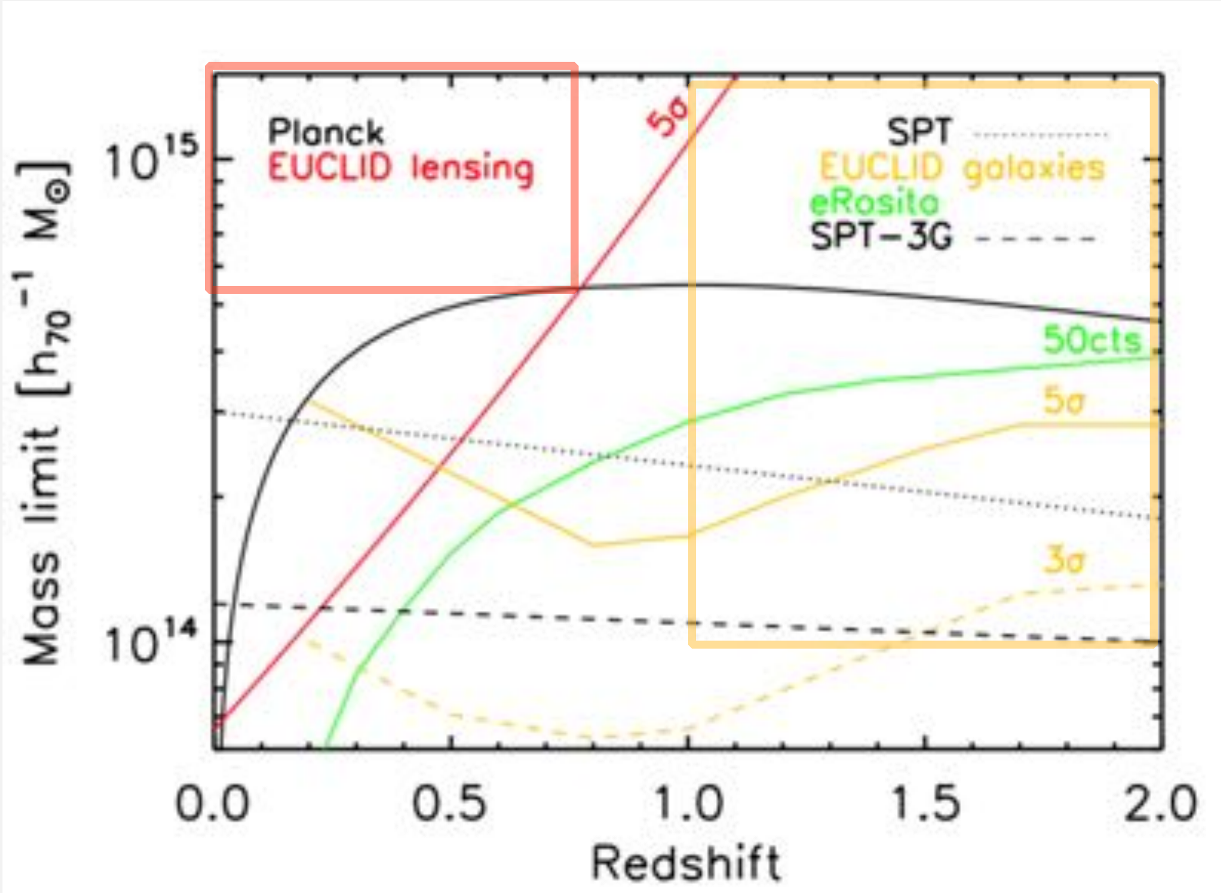




- ICM thermo-dynamical profiles down to low mass & up to high z
  with NIKA2/XMM (see R. Adam talk)

- Non thermal component
  - ⇒ Detection of clusters in radio up to high-z *[Ferrari+15]*
  - ⇒ Magnetic fields
  - ⇒ Thermal vs. Non-Thermal cluster physics
  - ⇒ Evolution of dynamical state

What is the true underlying population?

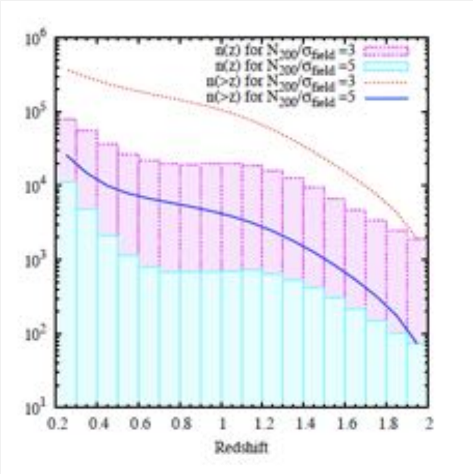


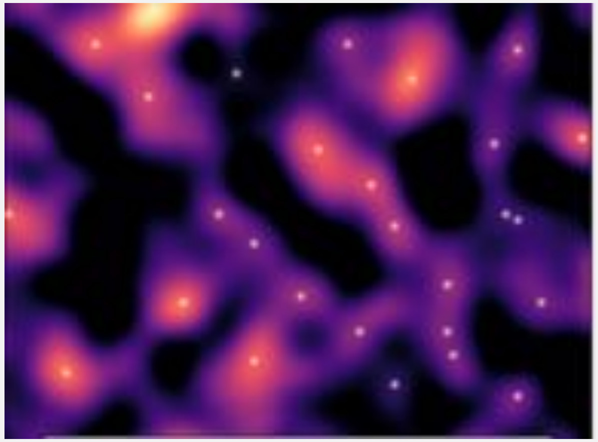
From: Pillepich+12, Sartoris+16, Planck 2015 results XXVII, J Bartlett priv. comm., B.Benson invited talk

Key new prospect

Multiple cluster detection, including via lensing (mass)

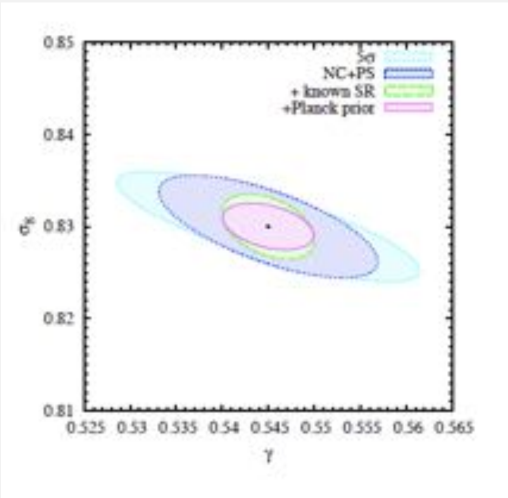
Clusters with EUCLID

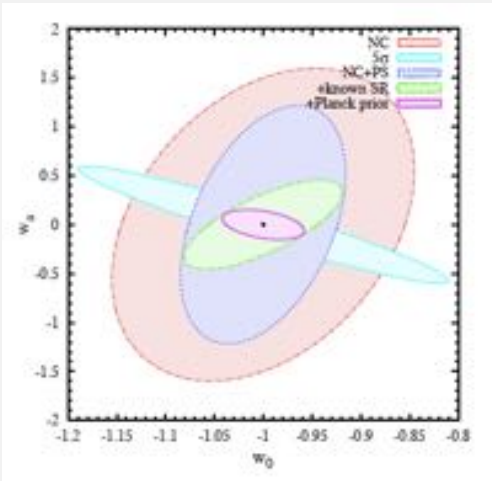




Sartoris + 2016

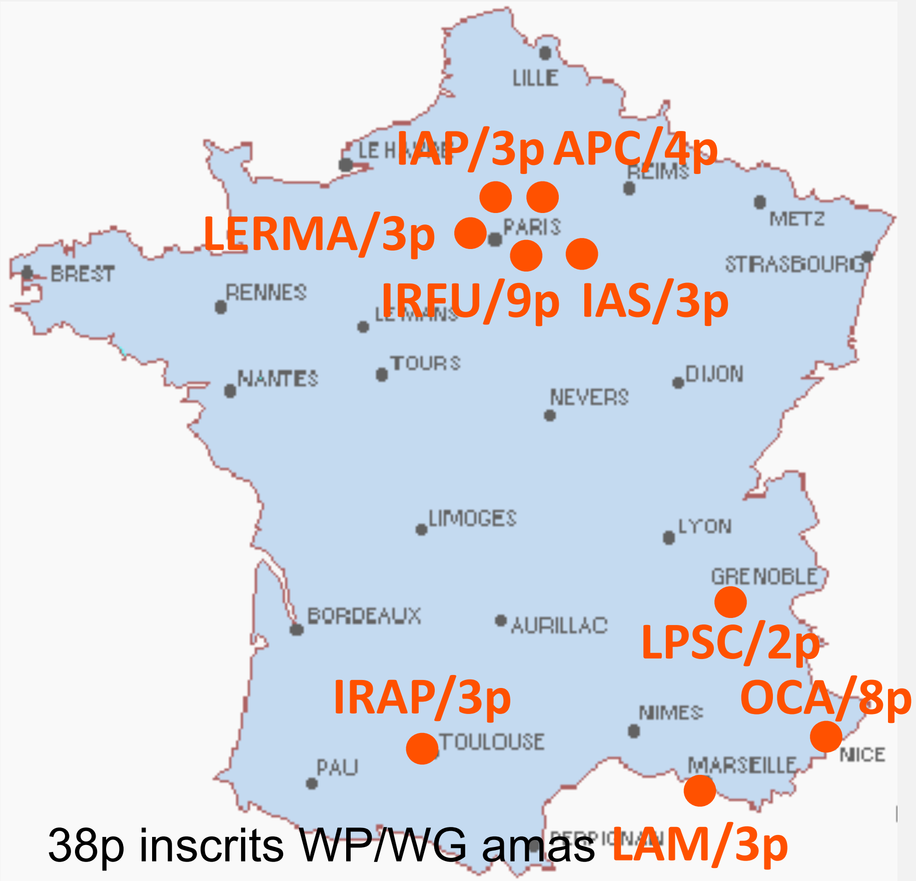
Lin, Kilbinger, Pires, 16





- Euclid Strength
  - ⇒ NIR bands: z[0,2] + 15000 deg2 (Wide)
    4 10^5 amas (S/N >3) with 10^5 @z>1
  - ⇒ Internal calibration of masses and scaling laws from WL and velocity dispersion
- Cosmology (compl. to GC & WL)
  - ⇒ N(z,M) + corrélations + cluster BAOs
  - ⇒ WL peak counts
  - ⇒ DE equation of state
    FoM 400 Δw_0 =0.028 Δw_a= 0.1
    20 % of FoM reached @z=1
  - ⇒ Primordial non gaussianity
  - ⇒ Modified gravity $\Delta\gamma$ = 0.003
  - ⇒ Neutrino mass Δm_ν=0.07 eV
- Astrophysics (Legacy)
  - ⇒ DM halos structures, galaxie orbits
  - ⇒ Baryon evolution: total SFR, colors, morphology
  - ⇒ Protoclusters

EUCLID



- Science Working Group Clusters Deputy lead: APC with coordination WPs:
  - ⇒ Statistics on clusters samples: APC
  - ⇒ Mass-Observable relation: APC & Lagrange
  - ⇒ Astrophysics of galaxy clusters: LERMA
  - ⇒ External data: CEA

- Scientific Ground Segment: OU-LE3 Clusters Workpackage Lead:
  - ⇒ Implementation: Lagrange
  - ⇒ Validation: IRAP

Strong F contribution on clusters

Rôle du PNCG

- Accompagnement projets scientifiques; e.g.
  - ⇒ Exploitation grands télescopes :
    XXL, suivi ESO-LP de Planck; high z Planck-Herschel, VLT/PdB AGN feedback
  - ⇒ Théorie/simulations :
    Tri-axialité, AGN feedback
- Complémentaire ANR (MULTIVERSE..), ERC (M2C, CALENDS..)
  essentiellement missions, niveau ≡ (devrait être) soutien de base…
  overhead non négligeable sur déjà (sur)sélectionné projets
- Activités transverses:
  - ⇒ coordinations activités autour des grands projets (SKA/LOFAR; EUCLID)
  - ⇒ accompagnement émergence Service d'observation : eg MAGYC
- Importance croissante de l'exploitation des archives
  déjà mentionné en 2012; accompagnement ?