High redshift galaxy clusters

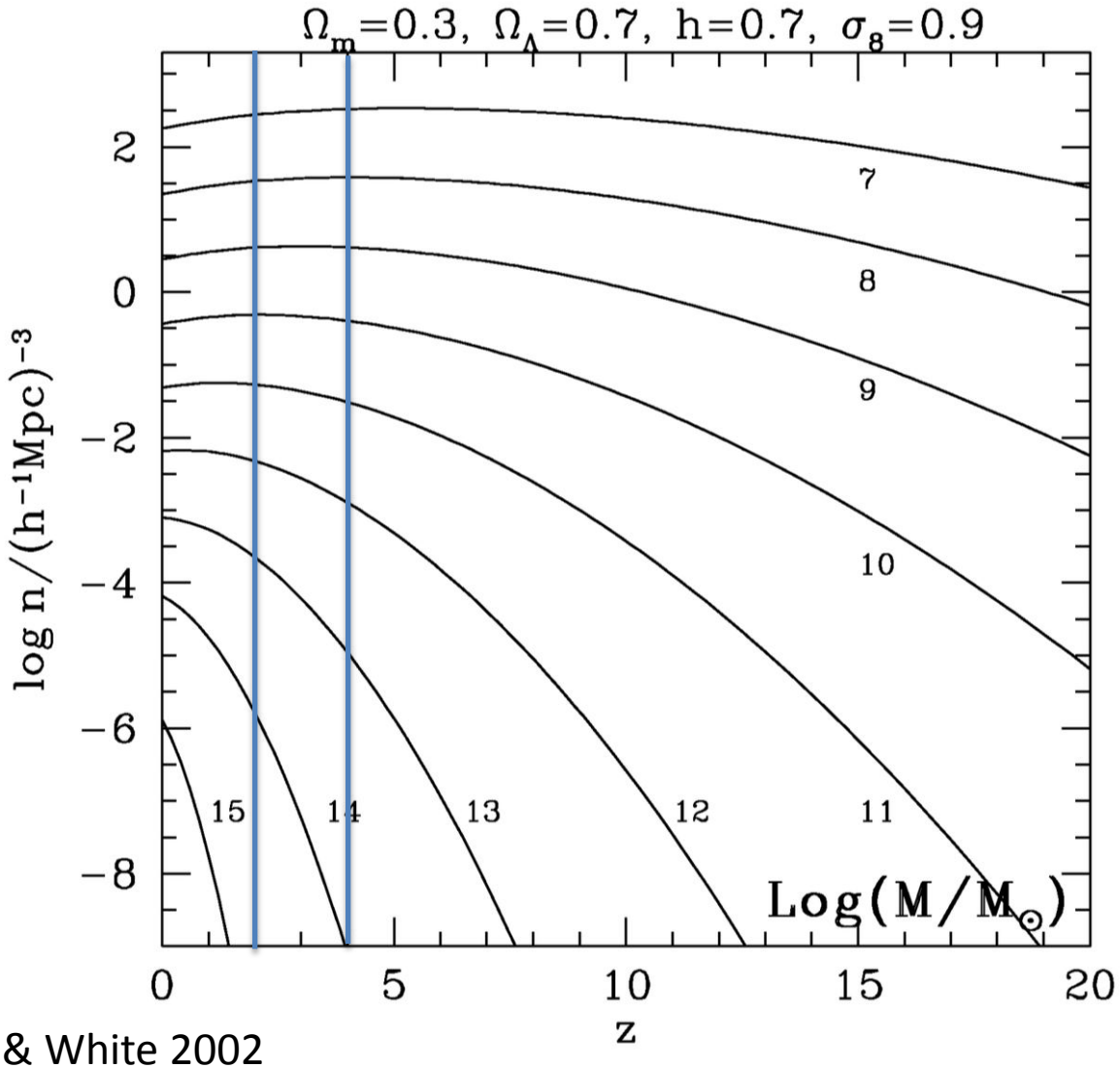
E. Daddi (CEA Saclay)

Outline:

- Why we should care
- Ongoing efforts
- Hot results/open issues
- The future

PNCG 16/11/2017

Redshift evolution of massive dark matter halos → cosmology

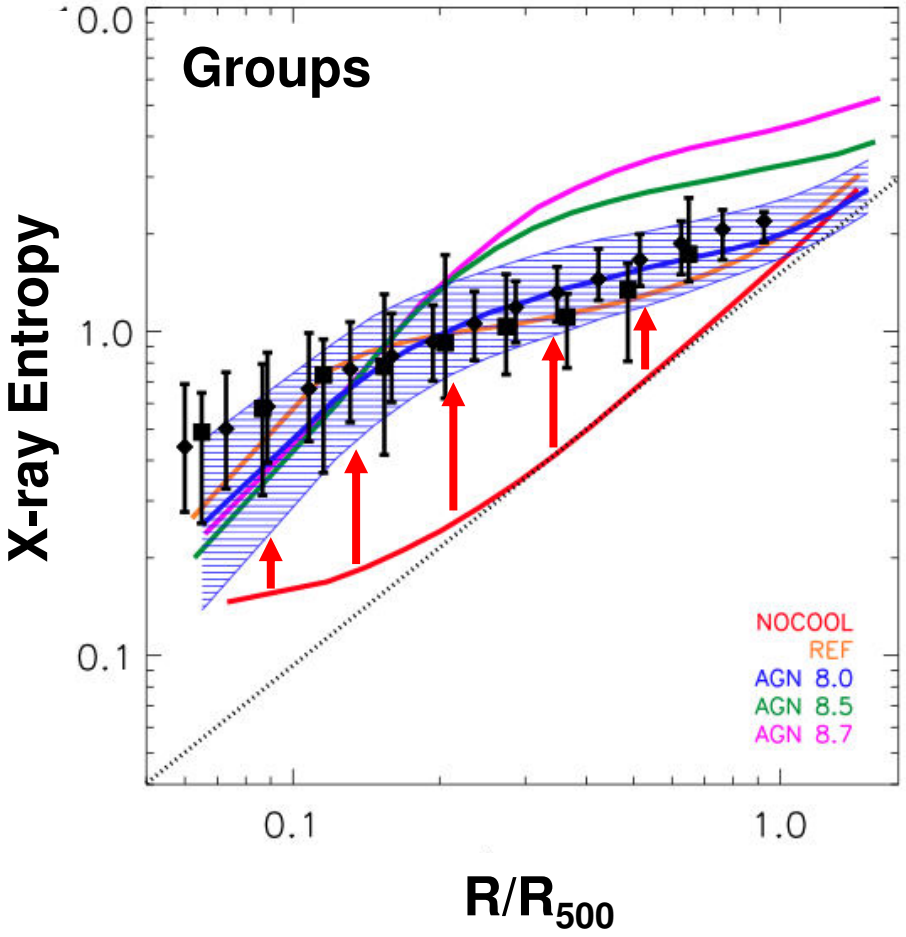


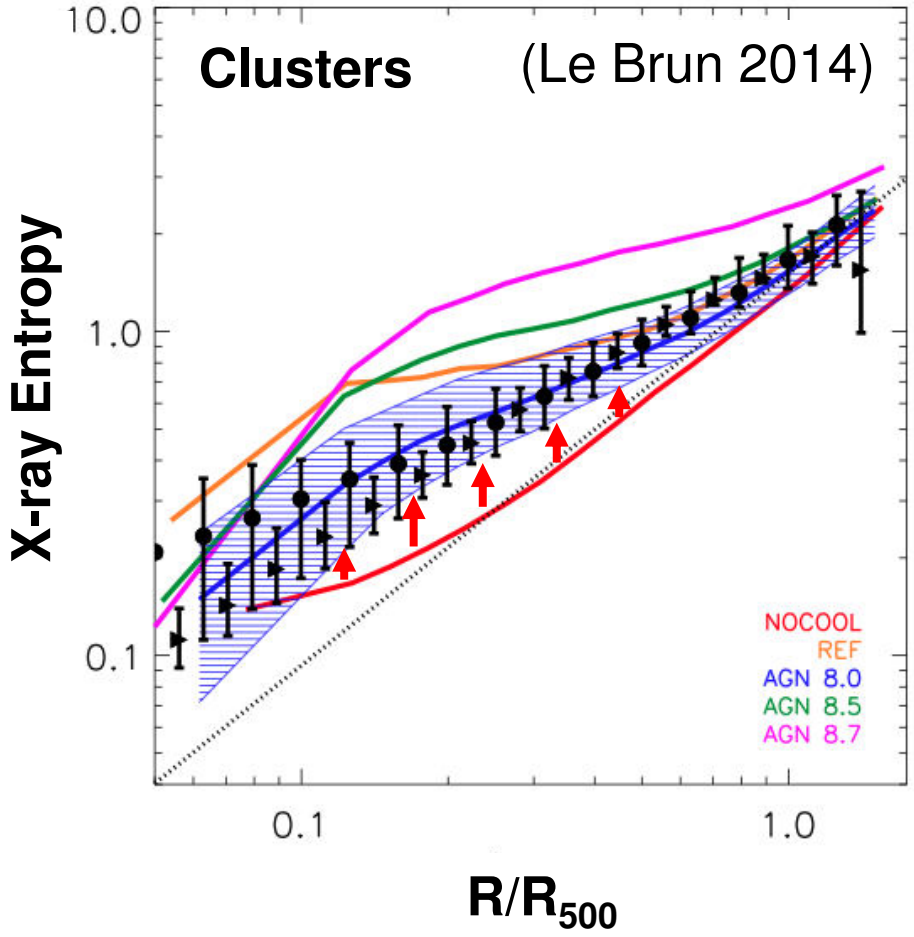
Mo & White 2002

Counts of high-z DM sensitive to sigma_8 and non gaussianities

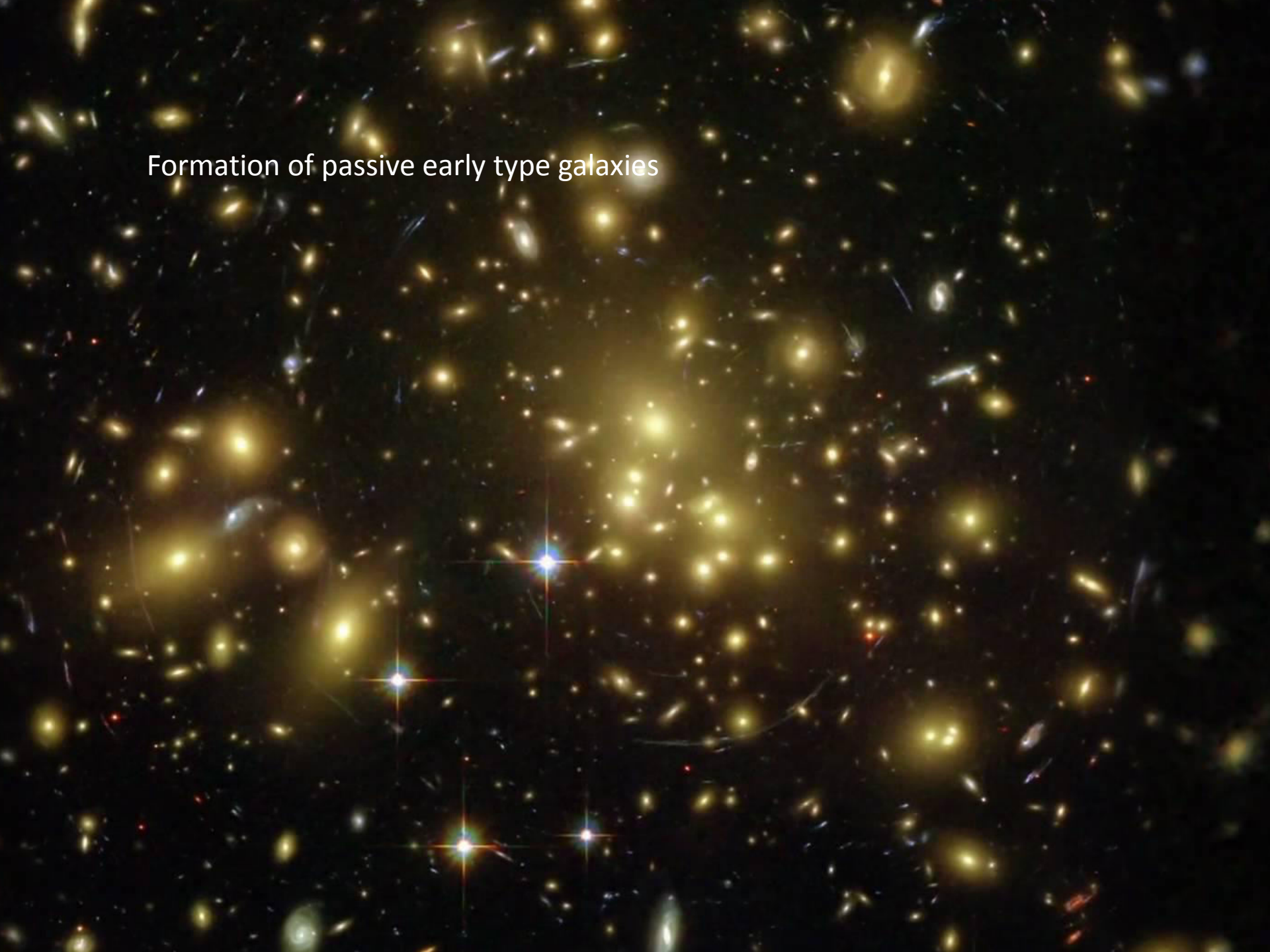
Crucial limitations: numbers and masses for high-z

Hot gas evolution is not trivial!

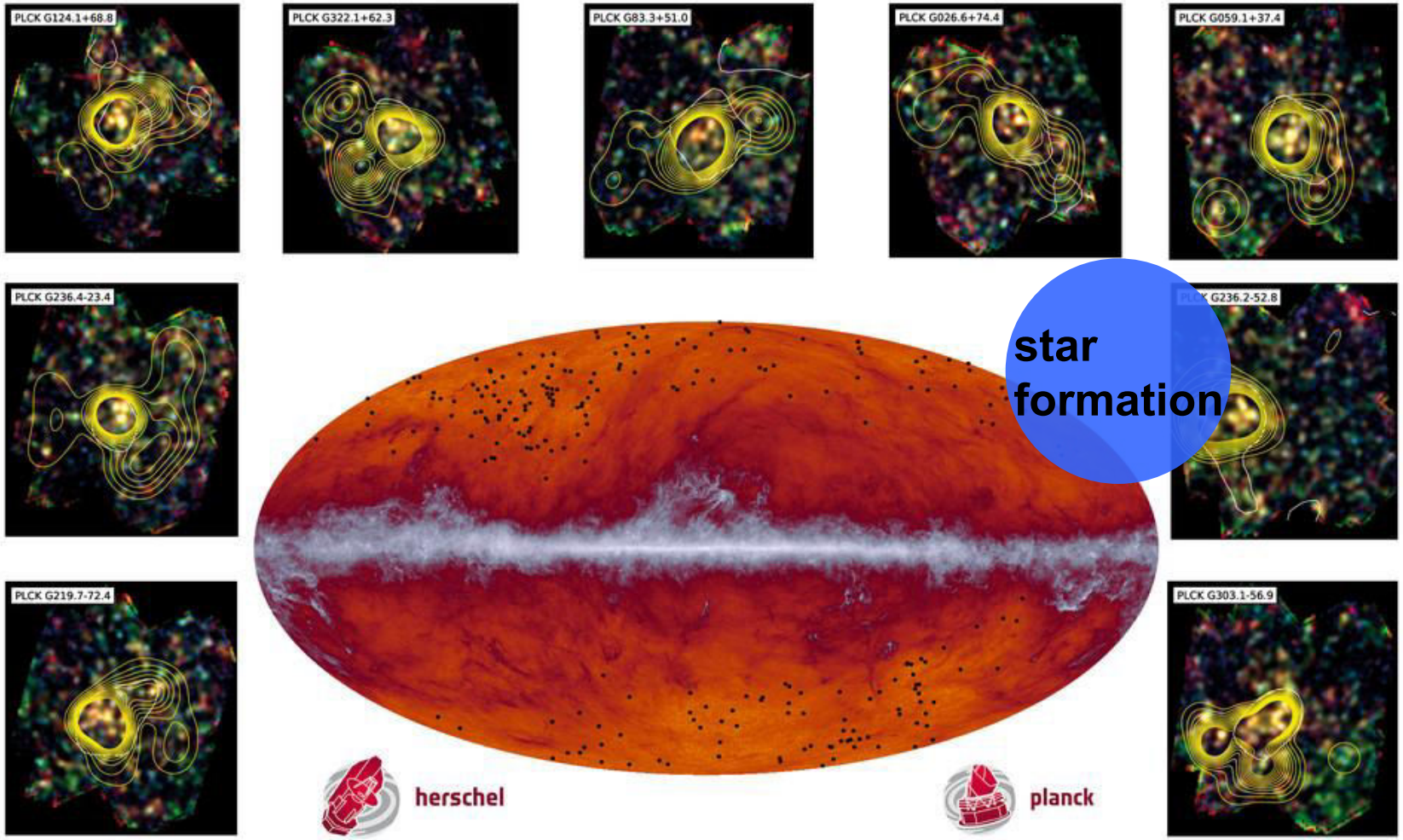




Galaxies/AGNs are thought to **inject this energy** at early times
(i.e., Kaiser 1991, Ponman+1991, Valageas & Silk 1999, Tozzi & Norman 2001)


Formation of passive early type galaxies

→ Herschel and Planck proto-cluster candidates



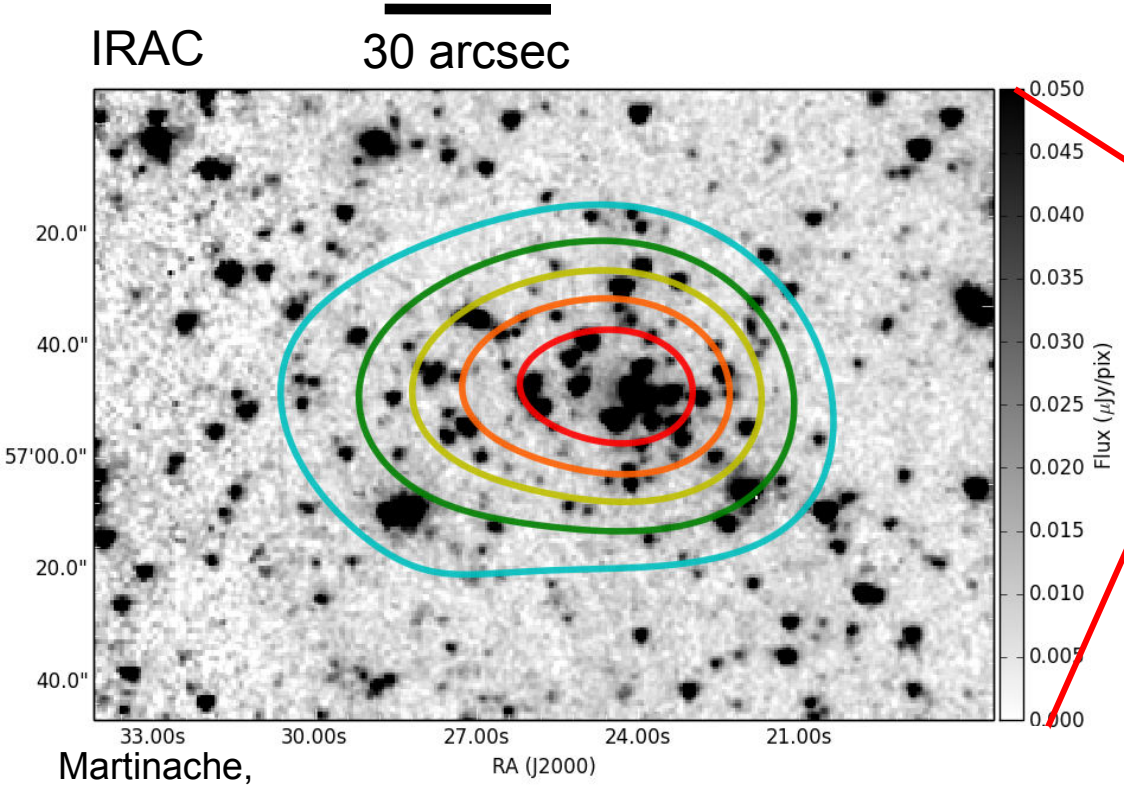
Herve Dole leading at IAS Orsay

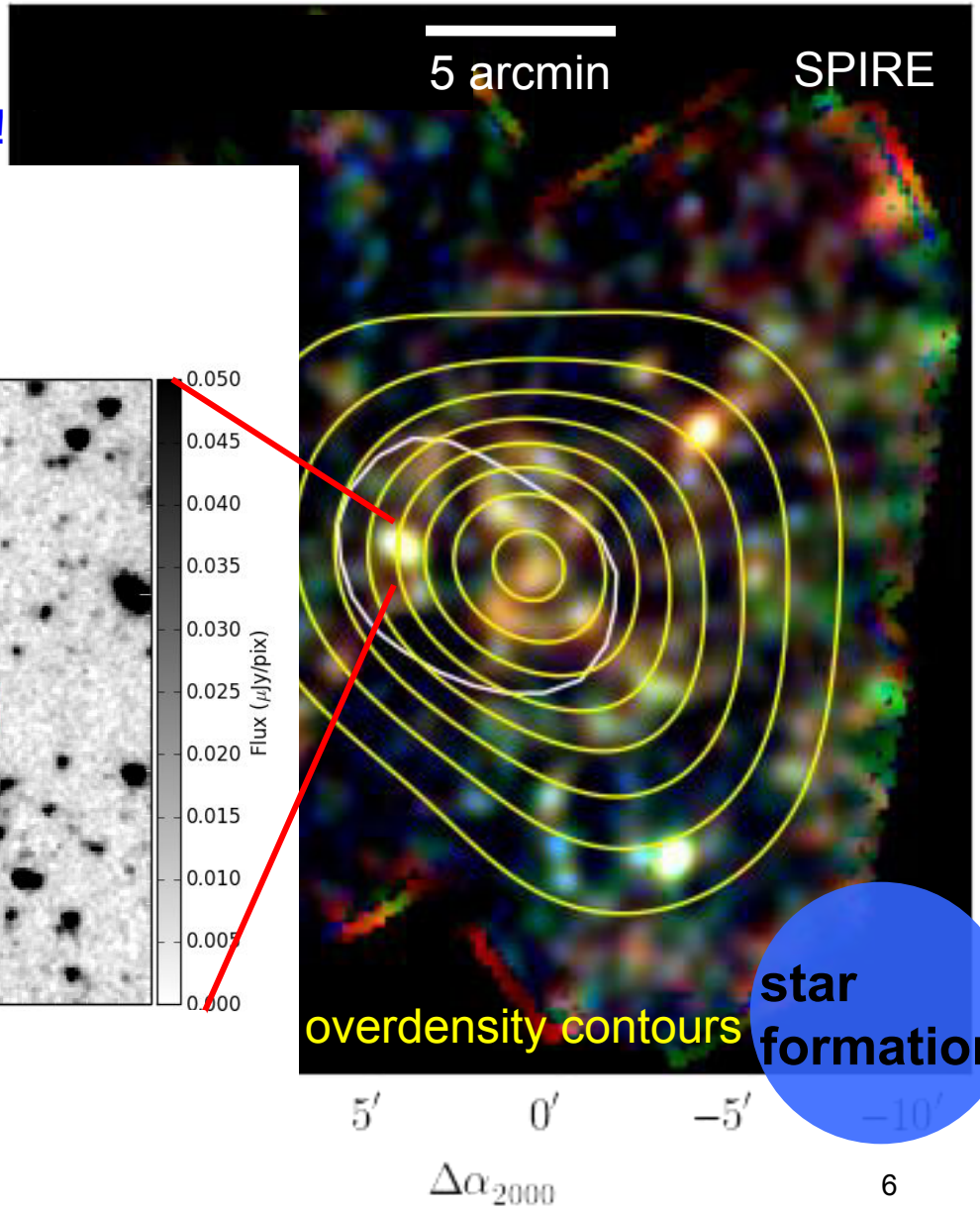
IAS – IRAP
CEA/SAp/AIM – LUTh
LAM – IPAG – LPSC
Caltech – UofA – ESAC

Planck Collab., 2015, Int XXVII, arXiv:1506.01962
Planck Collab., 2015, Int XXXIX, arXiv:1508.04171
Press Releases: ESA, NASA, INSU, A&A

the case of one field: Herschel & Spitzer

Euclid will provide this kind of sensitivity over the whole sky !
JWST can follow-up exquisitely !





Martinache, Rettura, Dole, et al., in prep

IRAM 30m CO redshift confirmation

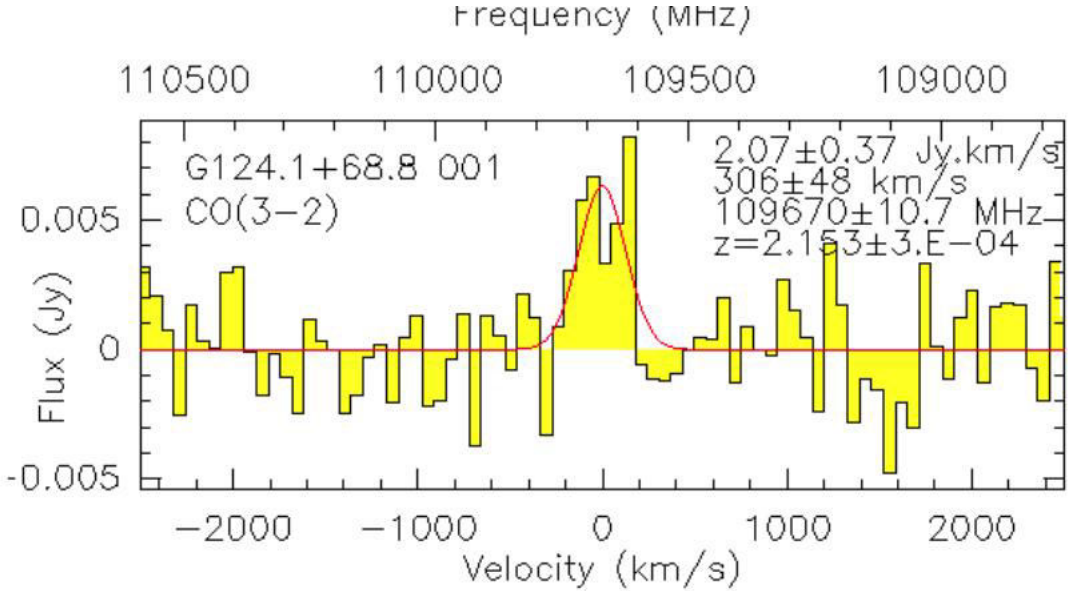
Granada, Spain:

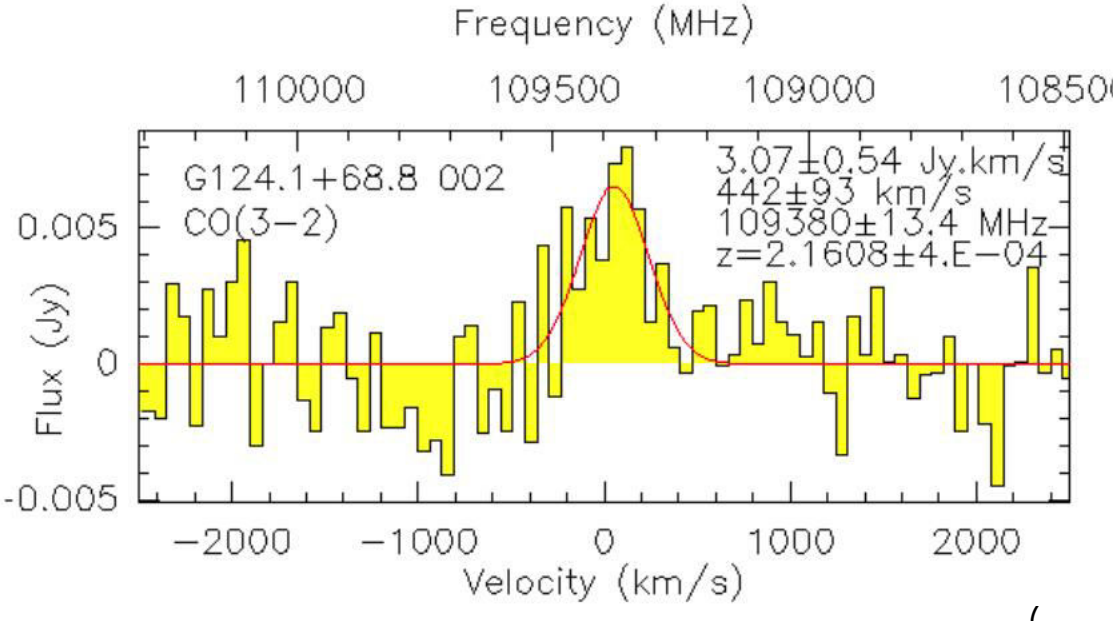
IRAM/30m/EMIR

detect CO lines

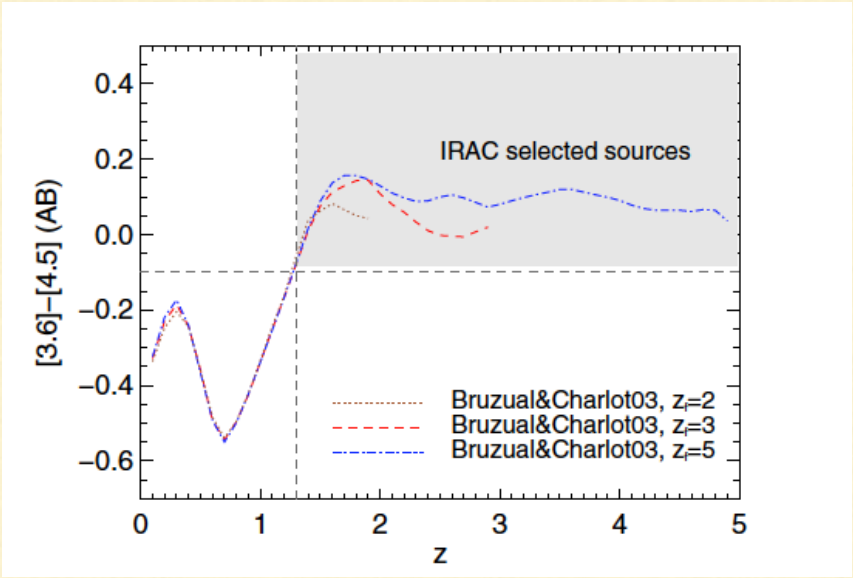
z=2.15

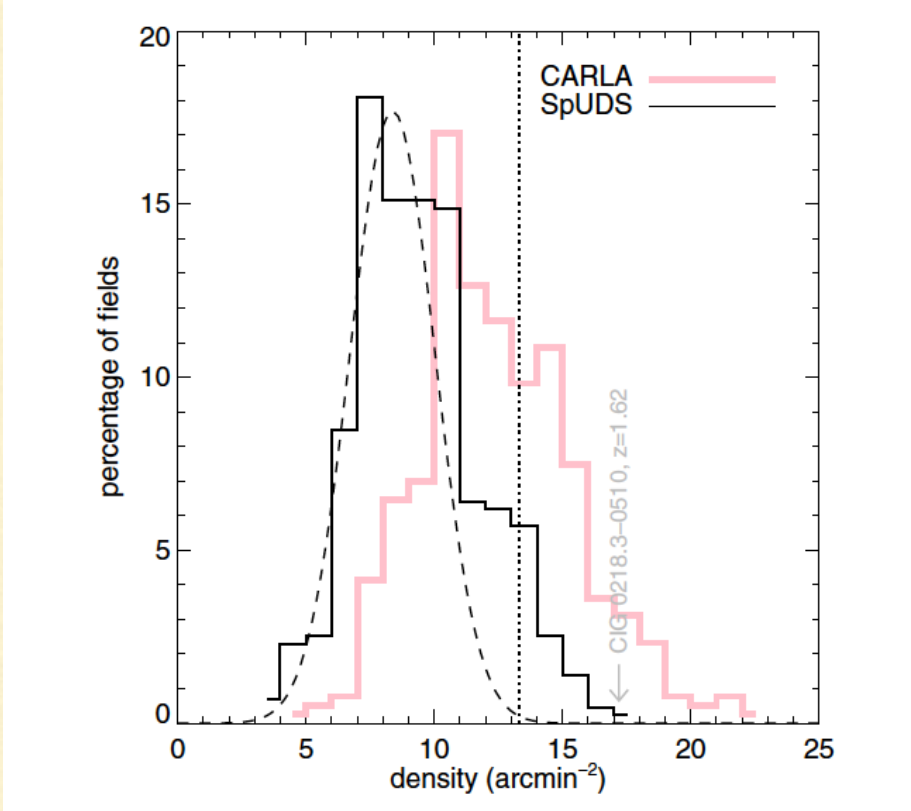
Work by
Clément Martinache,
Benjamin Clarenc,
Matt Lehnert et al.





CLUSTERS AROUND RADIO-LOUD AGNS THE CARLA SURVEY





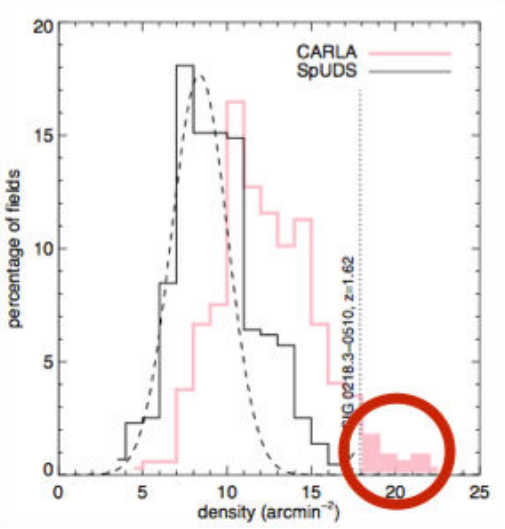
Simona Mei leading French team from Obs Paris

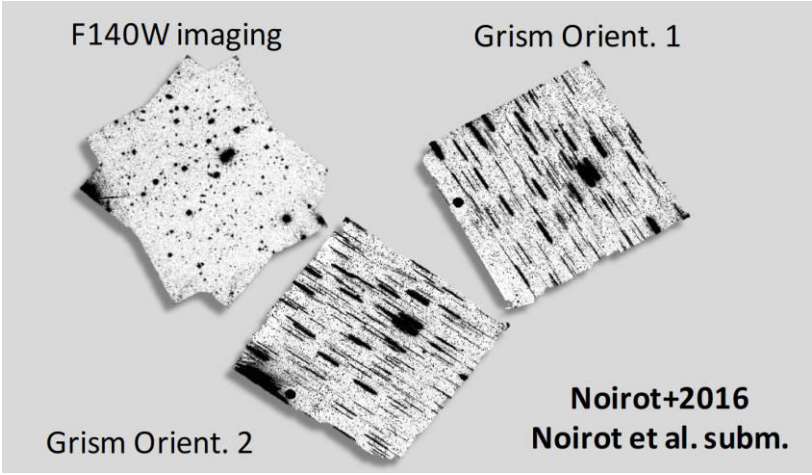
Wylezalek et al. 2013

HST follow-up of the 20 densest candidates

Noirot et al. 2016, 2017

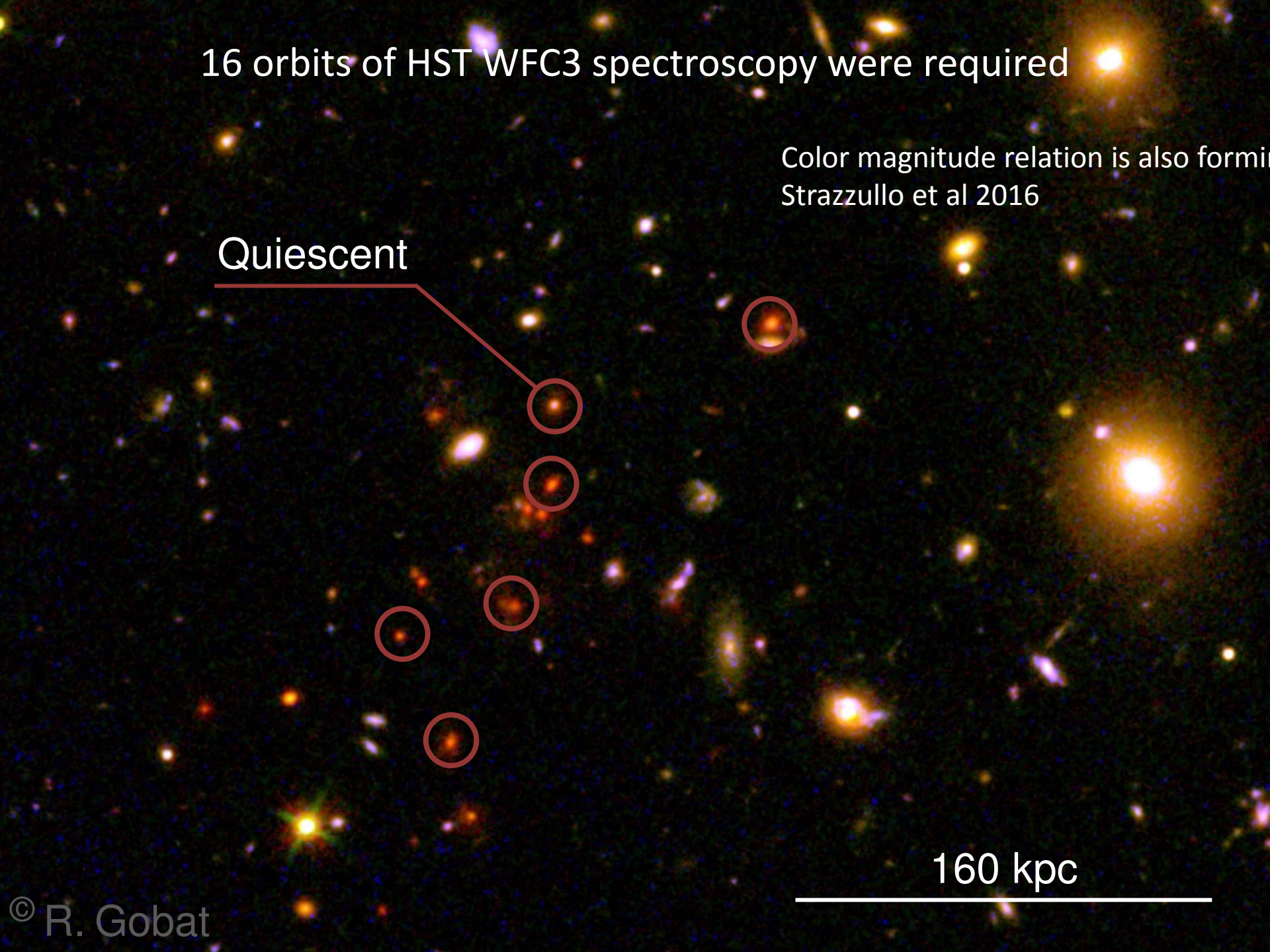
- WFC3/F141W imaging + G141 spectroscopy - 2 orbits with different orientations (P.I. Stern)
- 16/20 have at least 5 galaxies in the WFC3 fov at the same redshift as the RLA
- 3 confirmed clusters/proto-clusters at z~2, and the highest confirmed overdensity is at z=2.8





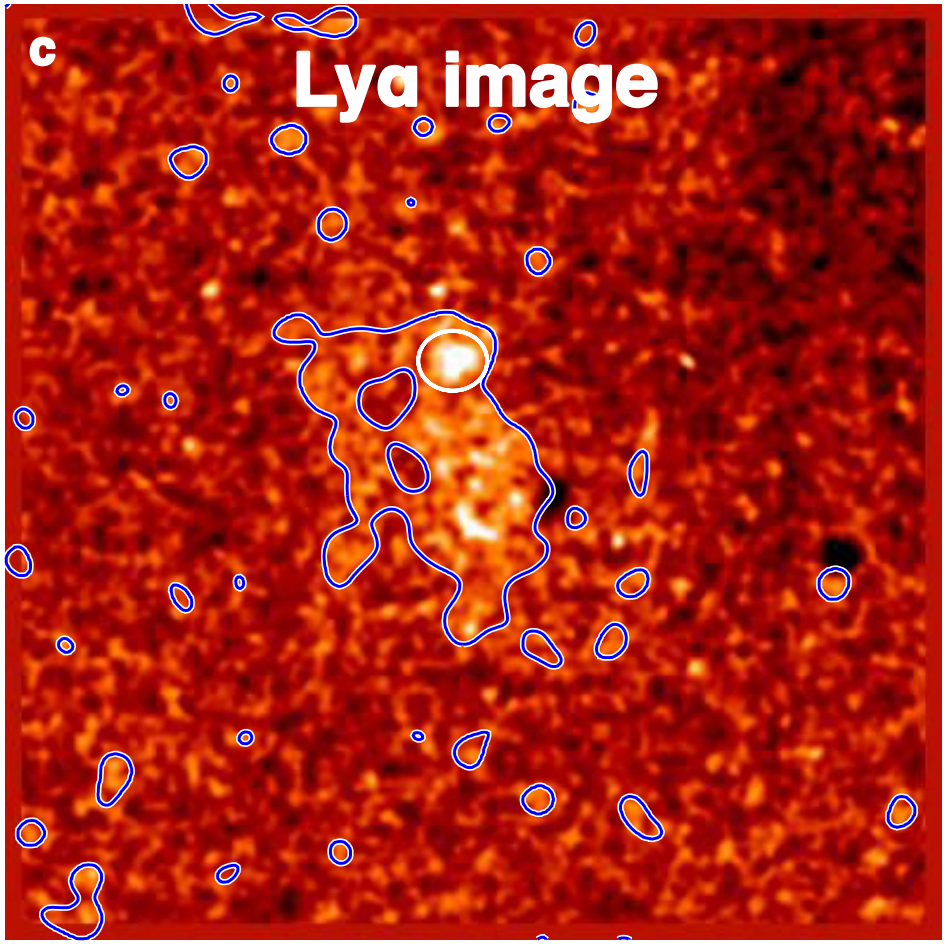
CI1149: 10 years later…

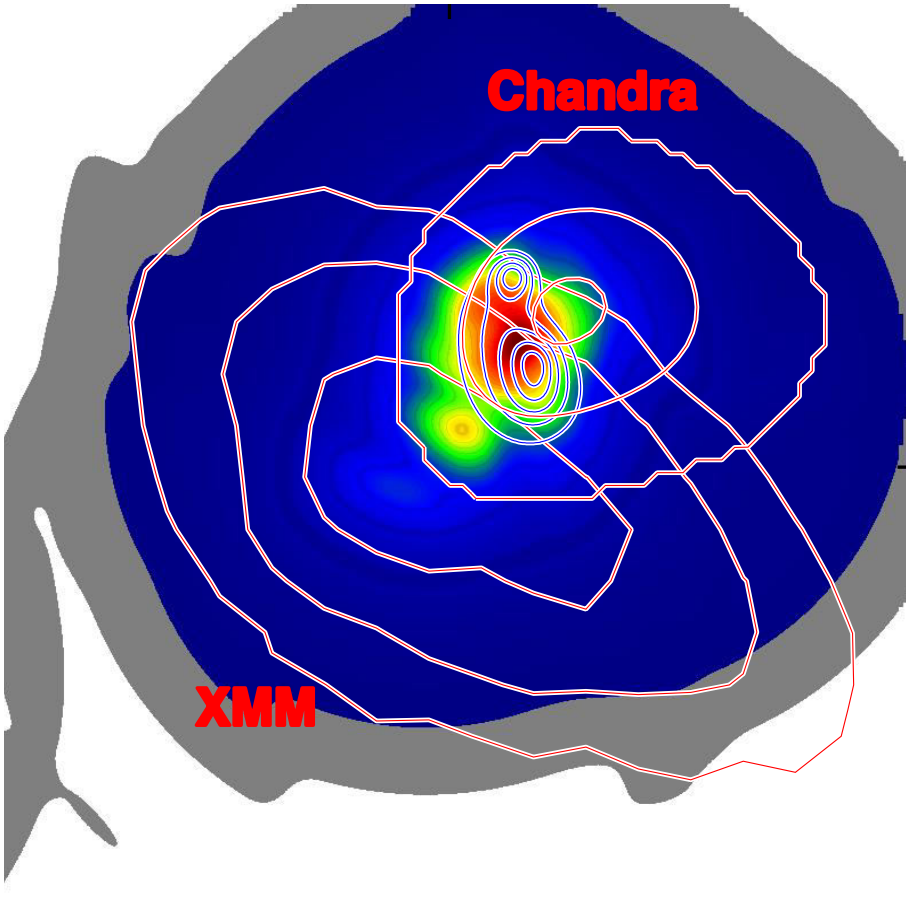
- CL J1149+0856 at ***z* =1.99** is among the most distant clusters known to date, **with X-ray detection** (Gobat+2011)
- ~10^{-15} cgs.
- Massive, red, quiescent members in its core (Strazzullo+2013, Gobat+2013)
- Yet, hosting a significant activity (**two X-ray AGN, several SFGs**, including the proto-BCG, Valentino+2015a)
- Mass ~ 6×10^{13}Msun


16 orbits of HST WFC3 spectroscopy were required
Color magnitude relation is also formi
Strazzullo et al 2016
Quiescent
160 kpc
© R. Gobat

Cold gas co-existing with hot gas

Valentino et al 2016

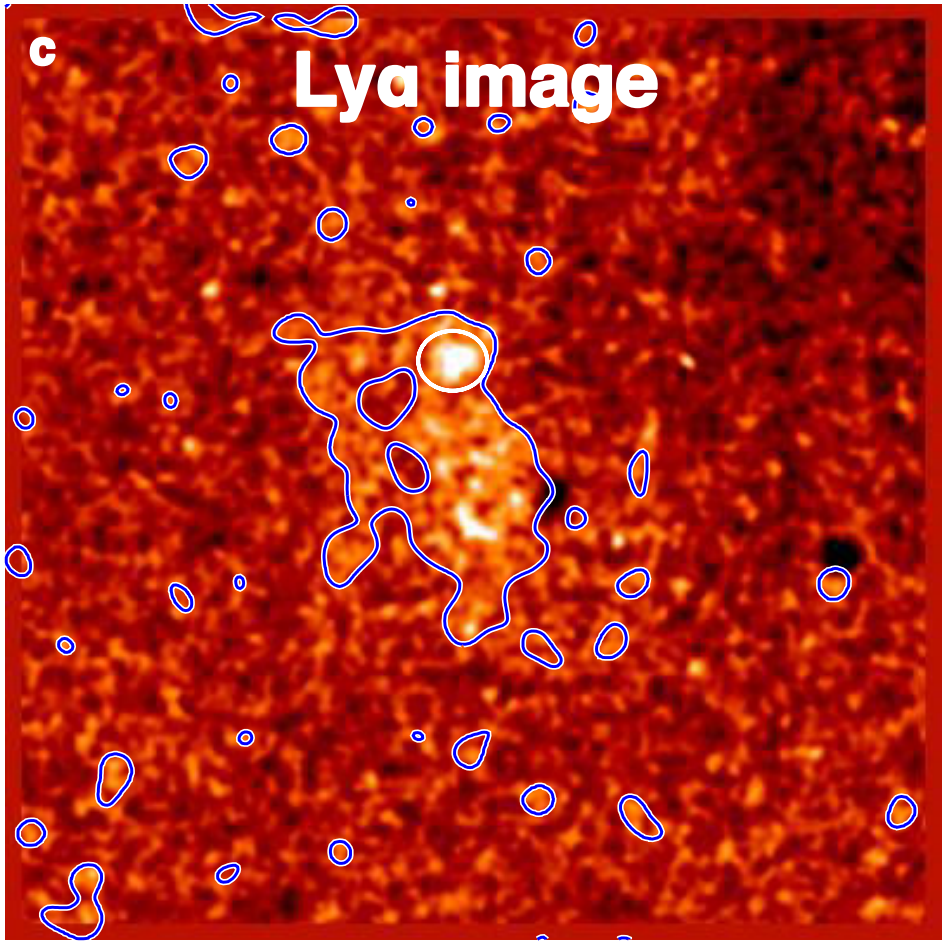




Cold 10^4 K plasma

Hot 10^7 K plasma

Chronicles of a discovery



Time evolution:
Cooling time < 1 Myr
Free-fall time ≈ few 10 Myr
Evaporation time ≤ 100 Myr

Requires constant replenishment:
M_{repl} = M(Lyα) / t(evaporation)
≥ 1000 $M_\odot$ yr^{-1}

Can outflows sustain the replenishment?

Valentino, Daddi, et al 2016

Cold flows required by understanding of SFR evolution

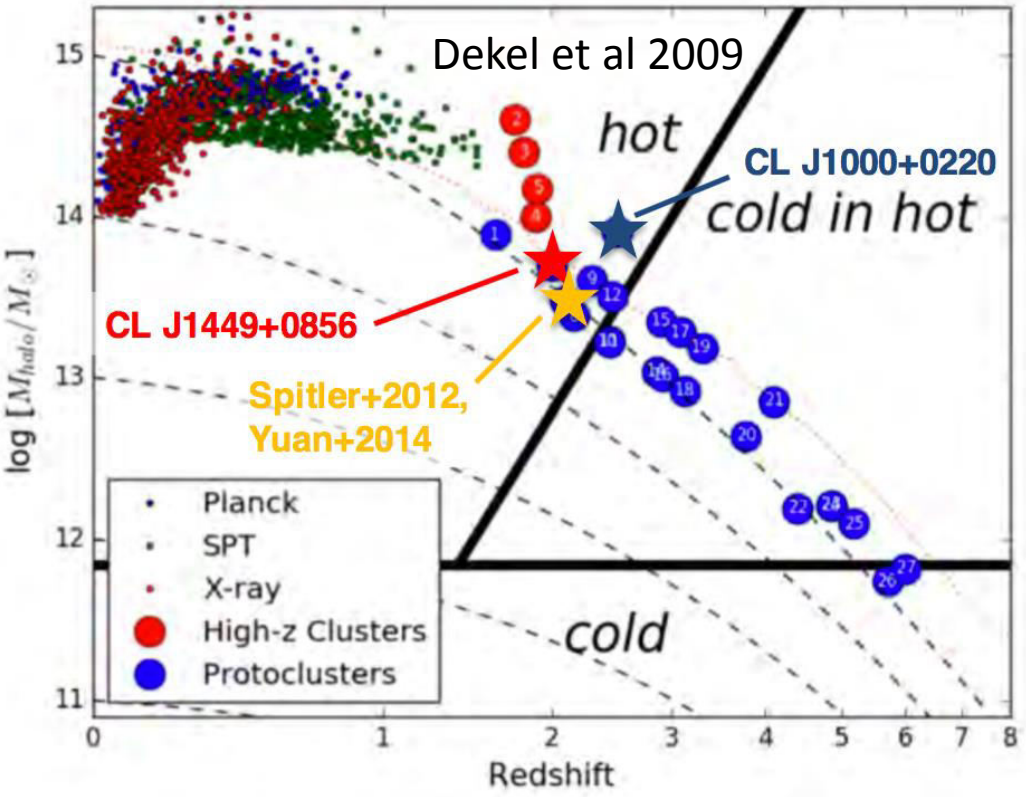
Galaxies have gas consumption times ~0.5-1 Gyr but keep going for x10 longer

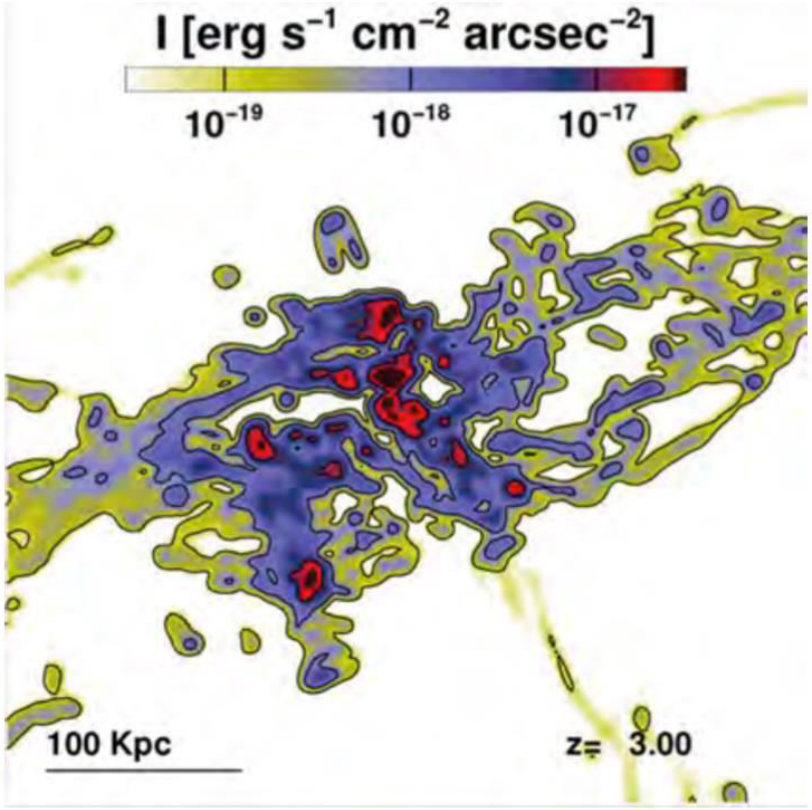
→ Need fueling and replenishment, otherwise cannot work

→ Postulate 'cold flows' accretion to maintain the 'steady state'

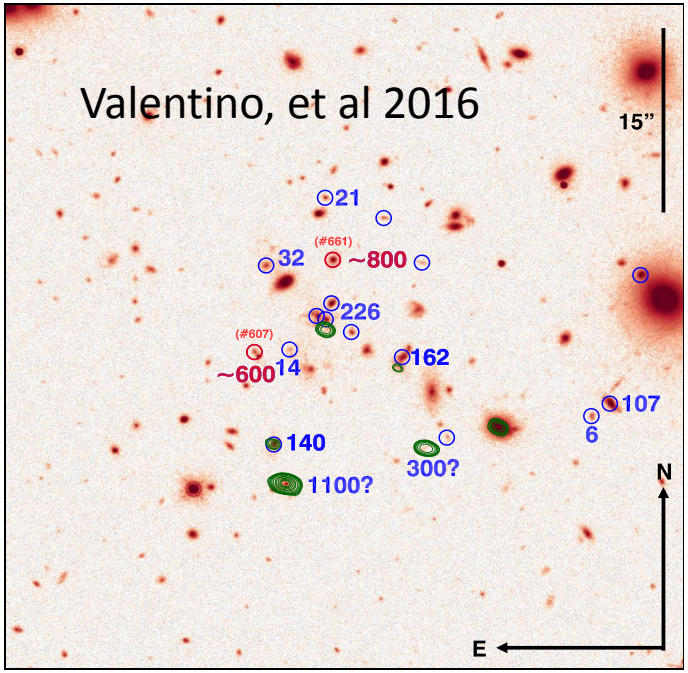
(predicted by theory, never convincingly/definitively observed so far)

Rosdahl & Blaizot 2012





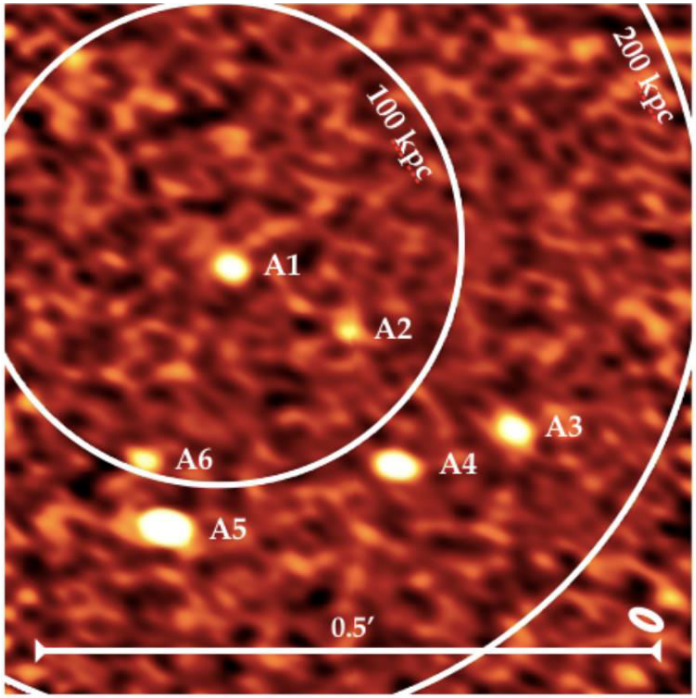
Valentino et al 2015; 2016; Overzier et al 2016

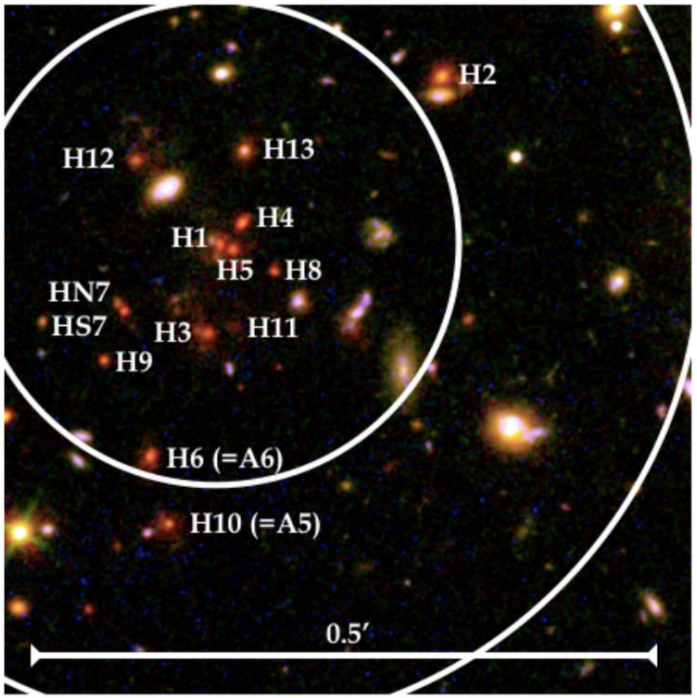


Huge mass outflow rates
(M_{out} ≈ SFR)

From SED modelling, Hα fluxes, and ALMA 870 μm continuum (Strazzullo et al)
SFR ≈ 700 $M_\odot$ yr^{-1}

From SED modelling and X-ray luminosity (Cicone+2014):
AGN ≈ 1400 $M_\odot$ yr^{-1}



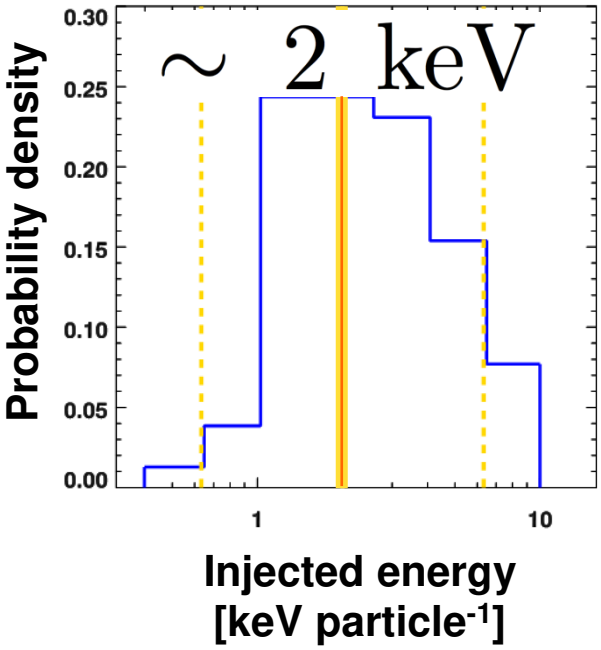


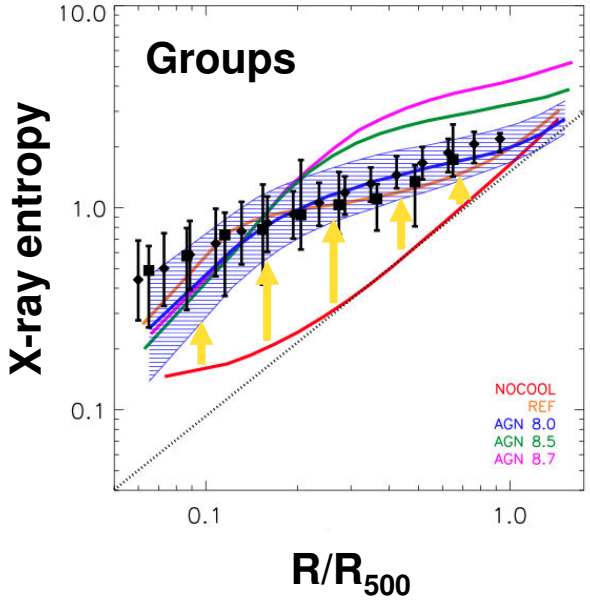
ALMA observations

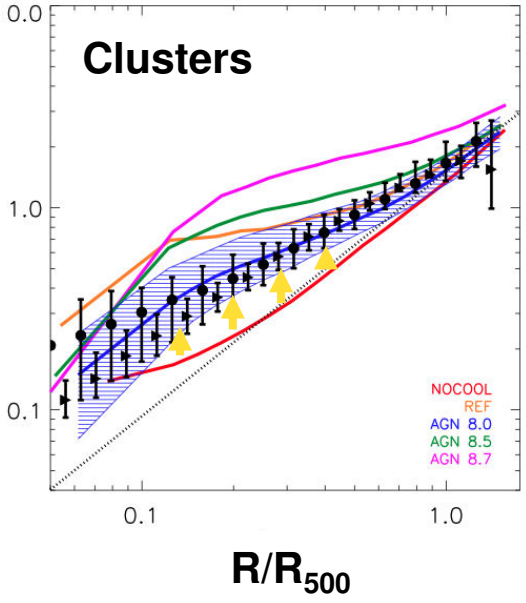
[See Rose Coogan next talk]

Coogan et al 2017
Strazzullo et al 2017
(both submitted)

A handle on a decade-standing issue



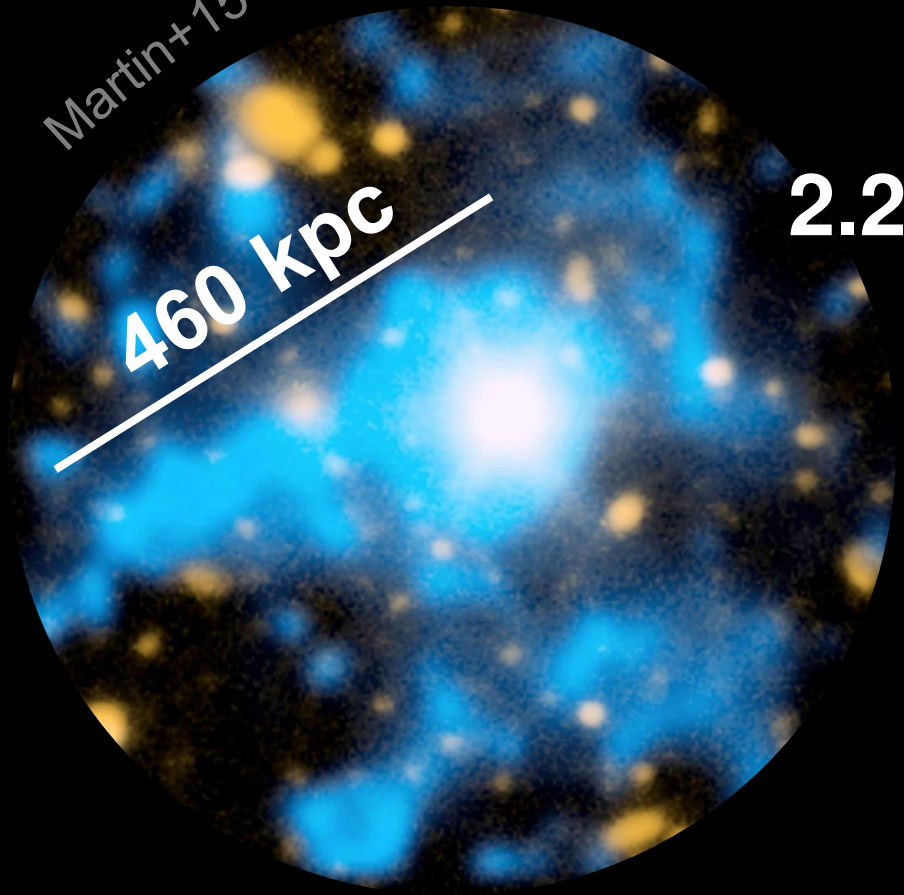




Suite of cosmological simulations **cosmo-OWLS** (Le Brun+2014):

- **NOCOOL model**
- **Fiducial model with AGN feedback**
- **Our observations (adopting a baryon fraction $f_b = 0.15$)**

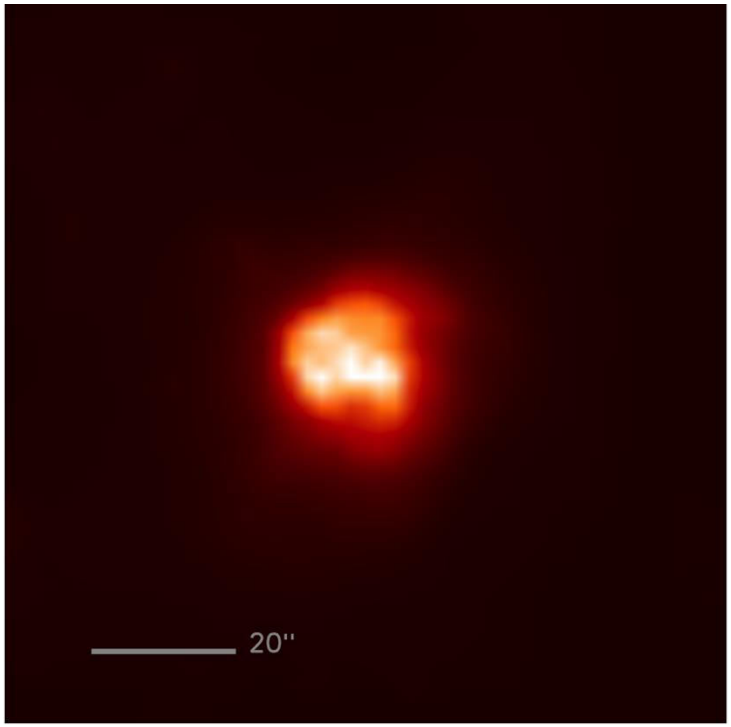
CWI Lya spectroscopy Quasar UM287 at $z = 2.28$

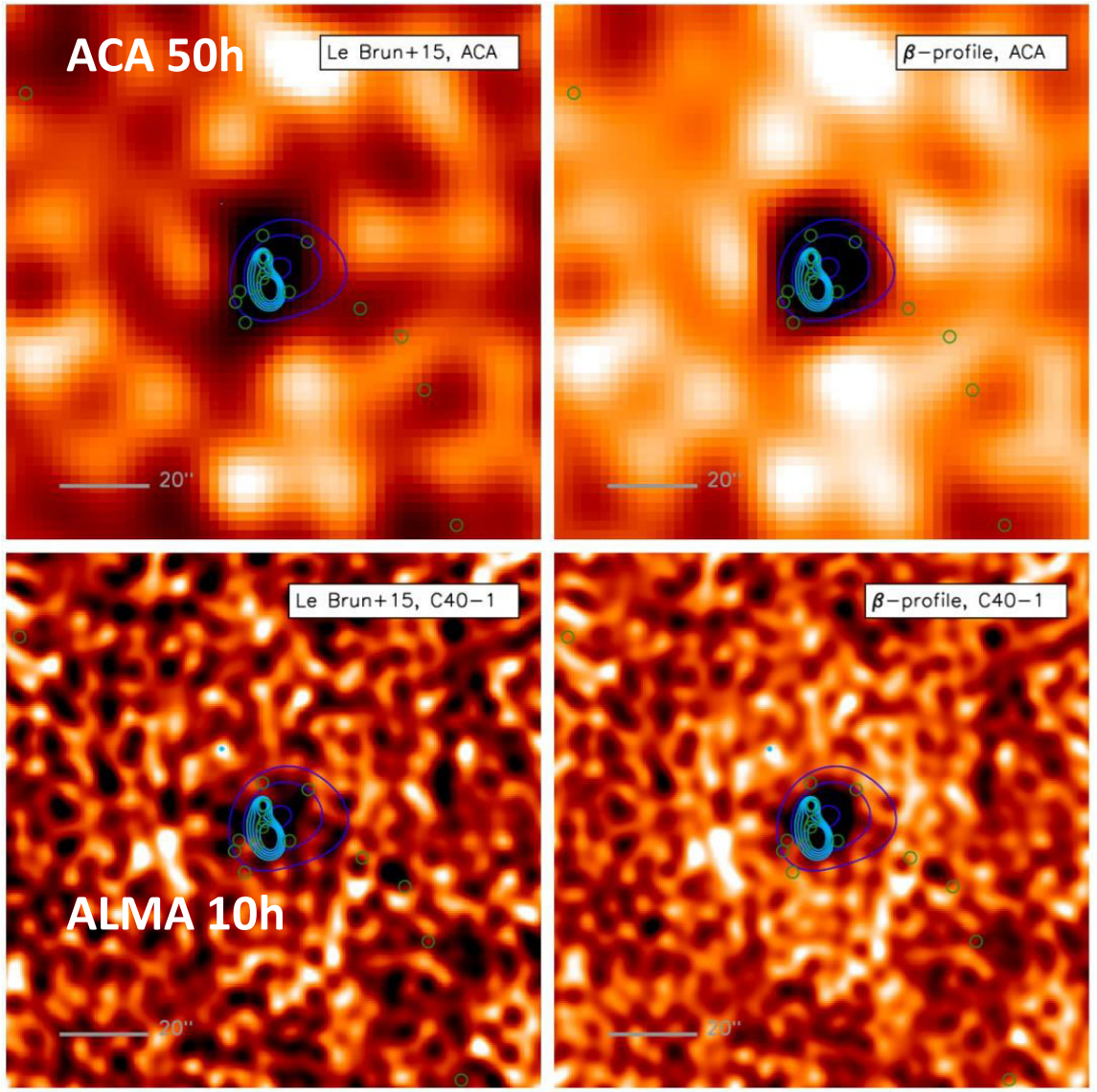


2.2×10^{44} erg s^{-1}

We would need to follow Lya to z~2, but MUSE cannot image cosmic web in Lya at z<3!!
Similar situation for ELTs – no blue coverage (mirrors not optimized for that)
→ But we will be observing Lya in z~2—3 clusters using KCWI at Keck (newly commissioned)

SZ ALMA observations
Cl1149 z=1.99 (sims)

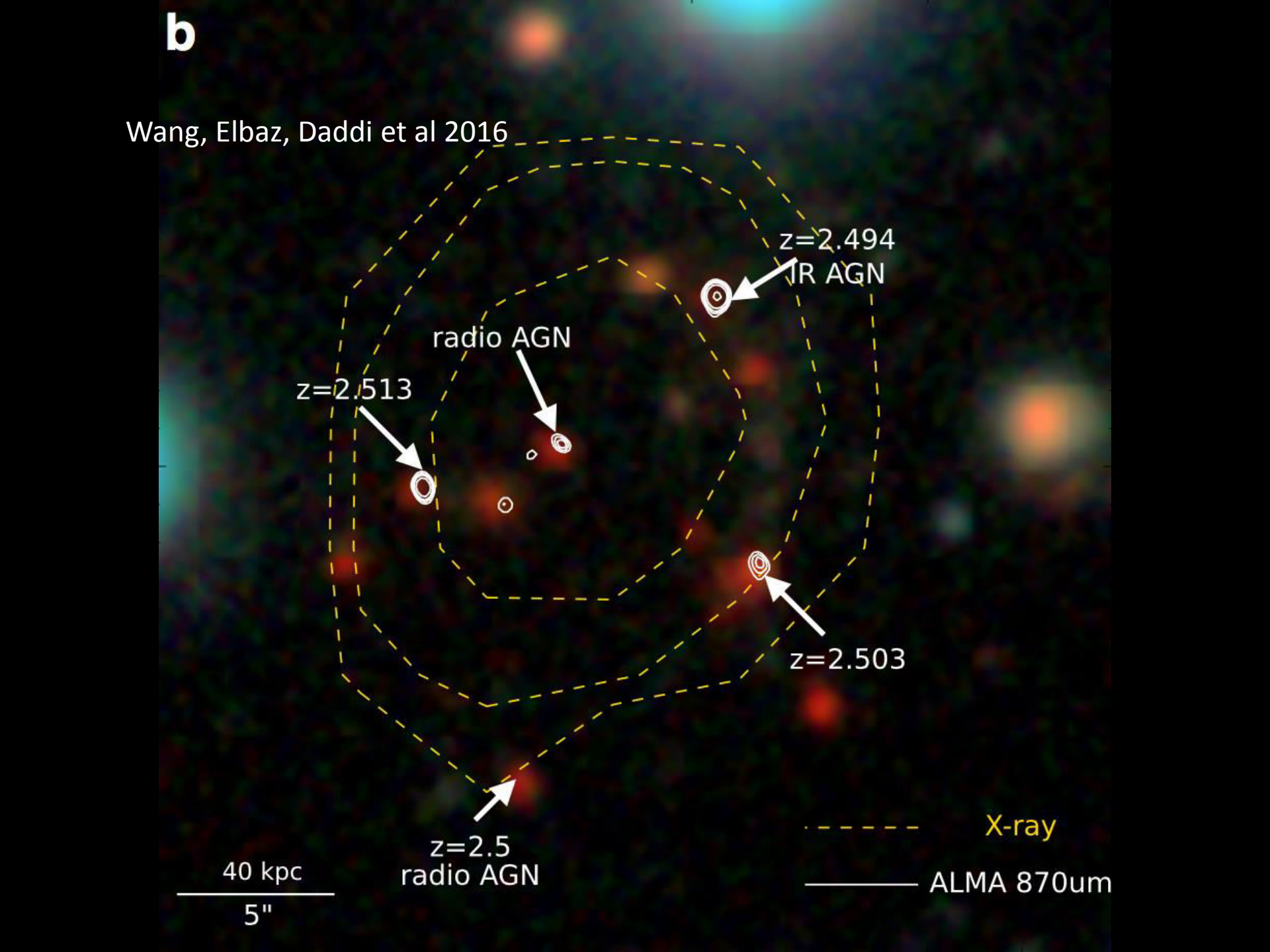




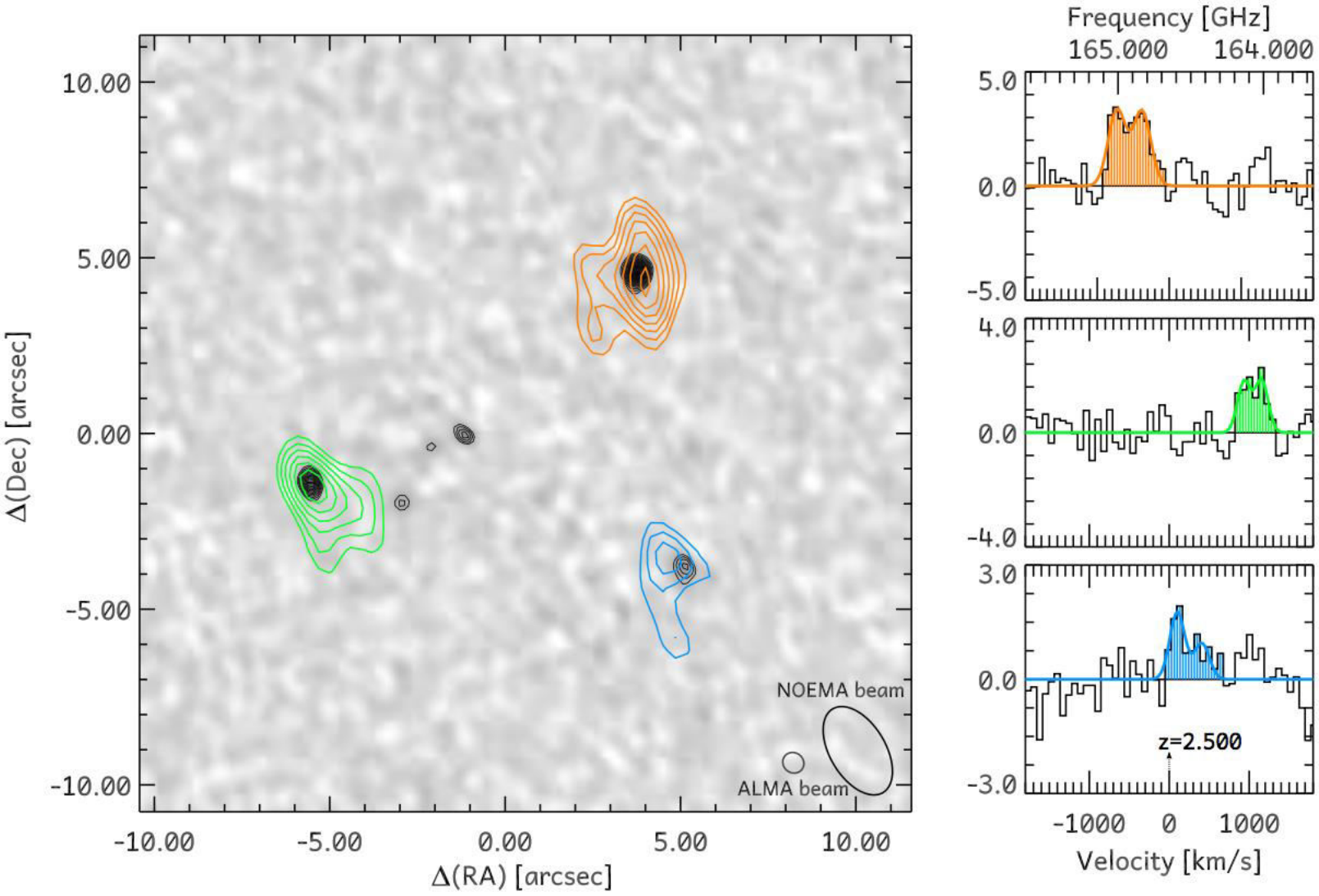
Profile depends on heating history
→ Signal also

Data received, being analysed

ALMA much more powerful for this science once Band1 will be available (30GHz)


b
Wang, Elbaz, Daddi et al 2016
z=2.494
IR AGN
radio AGN
z=2.513
z=2.503
z=2.5
radio AGN
40 kpc
5"
X-ray
ALMA 870um

The core of the cluster (100 kpc diamater) contains 3400 Msun/yr SFR (Herschel, ALMA)
Early spectroscopic confirmation of the cluster obtained with NOEMA/IRAM
(now we have 17 members now, also from KMOS/VLT)

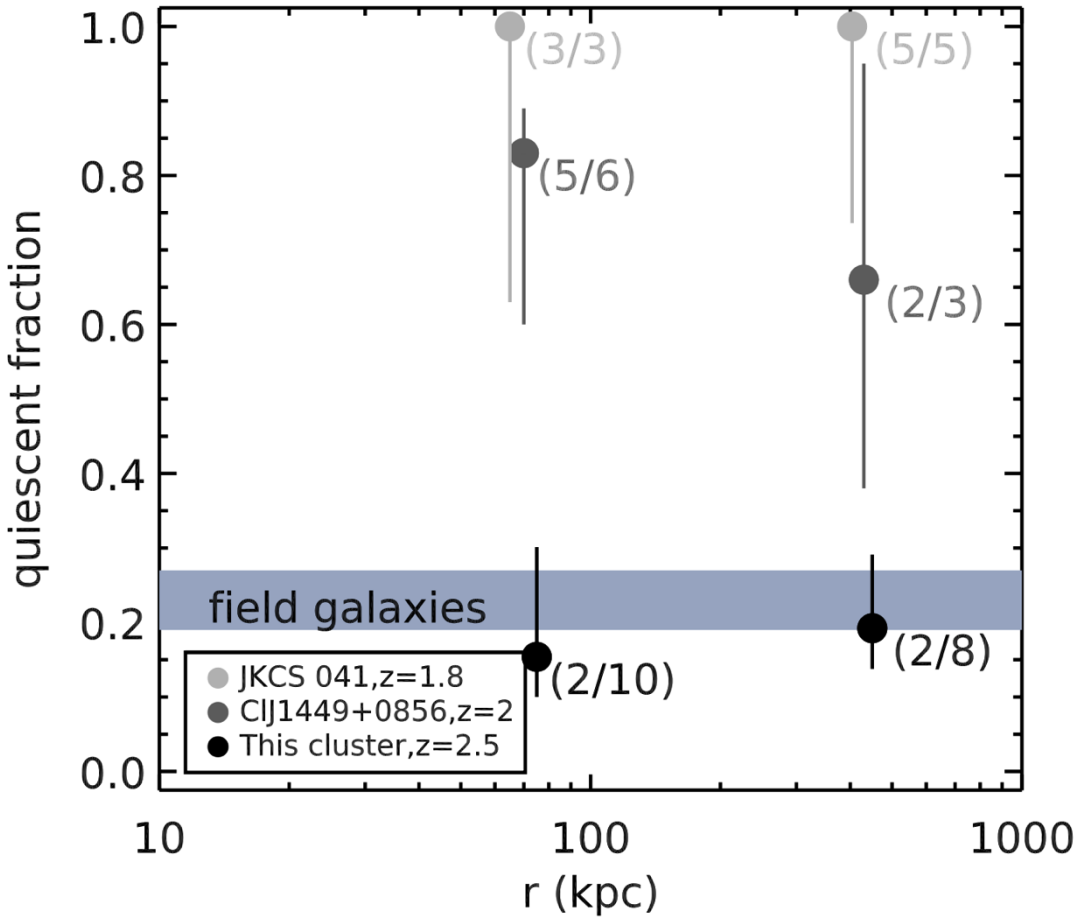


Wang, Elbaz, Daddi et al 2016

Quiescent galaxies missing in the core

Passive ellipticals become such only inside clusters ?

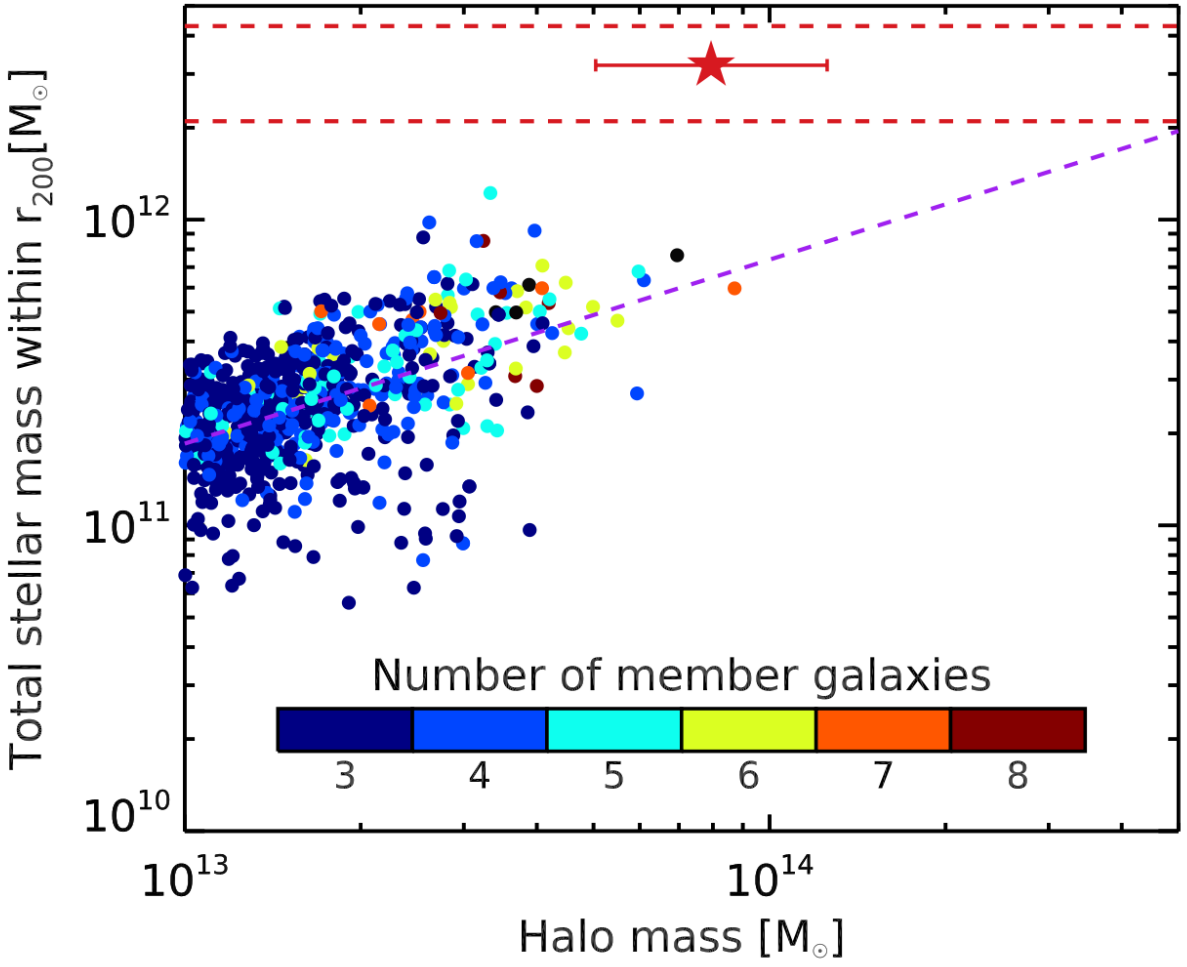
Key to understand the formation of passive ellipticals ?



Wang et al 2016

Millennium simulation (Henriques et al 2015)

Over 75 square degrees of simulation cones (vs 1.5 observed, 50x smaller)
From 0—10 comparable DM halos (following uncertainty on the exact mass of our structure)
But nothing with as much stellar mass concentration (by > x3)



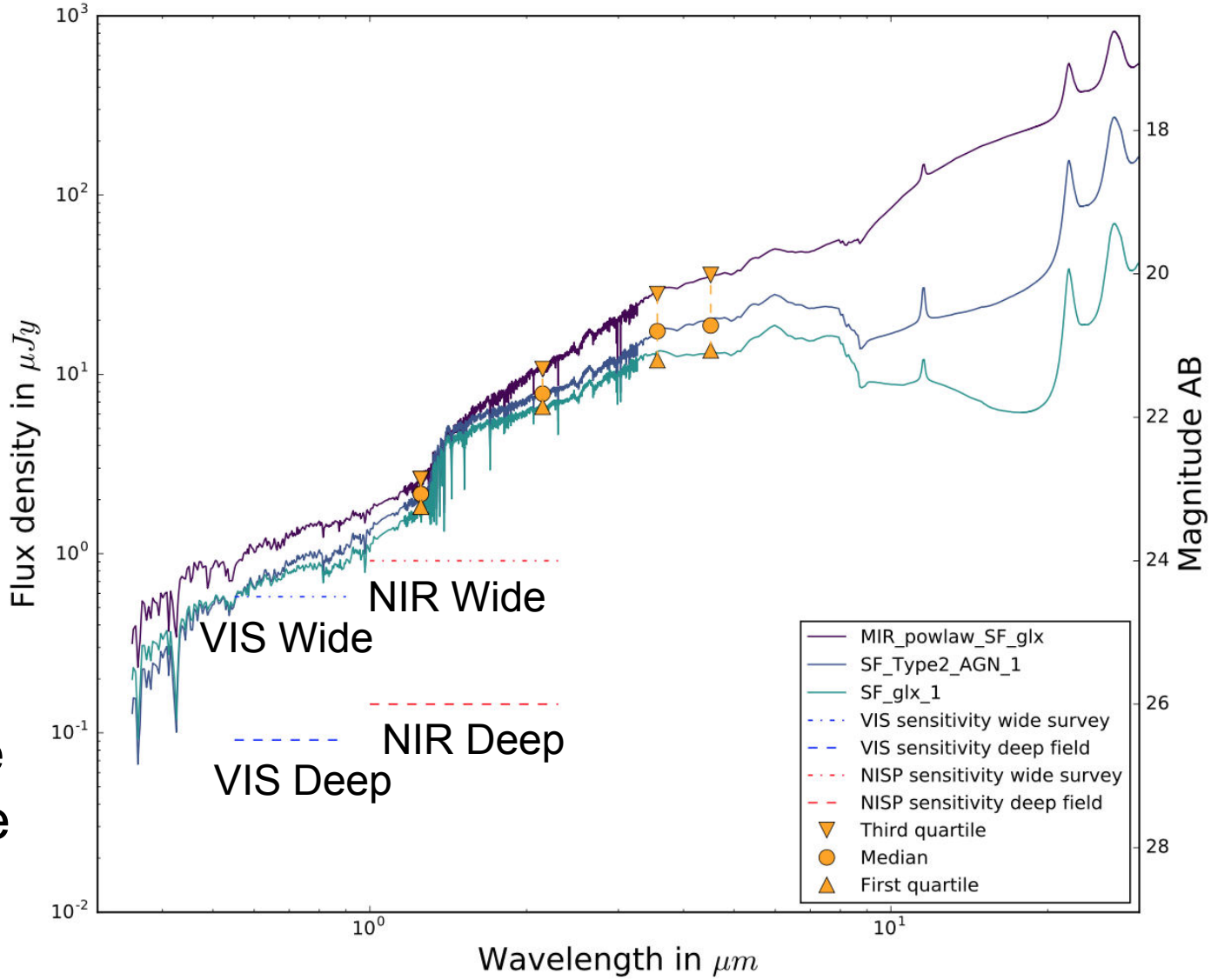
Wang et al 2016

There could be more than forecasted currently?

Possible cosmology sensitive observations

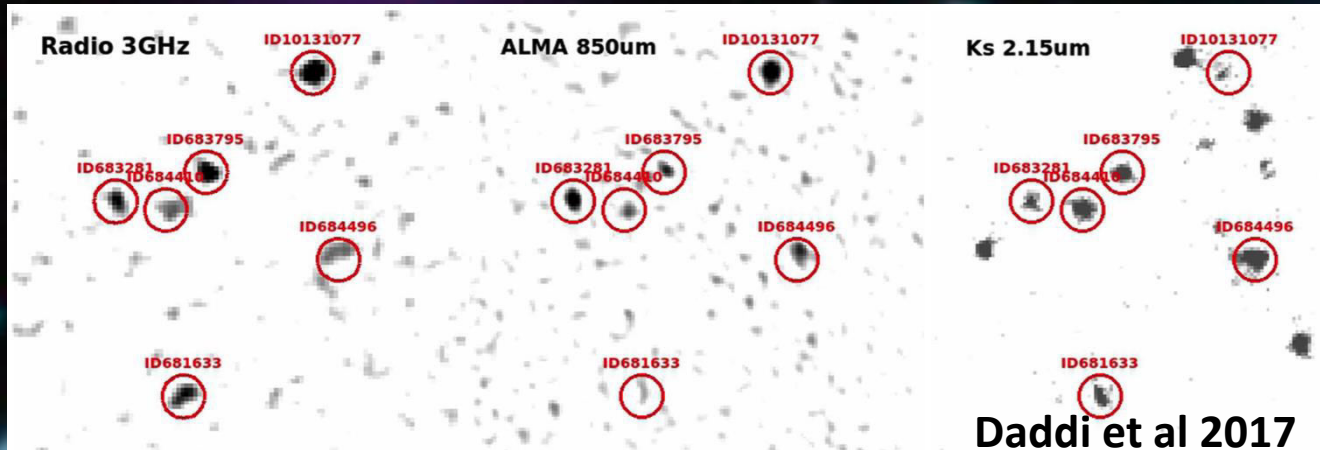
Euclid great potential

Wang+16
z=2.5 cluster



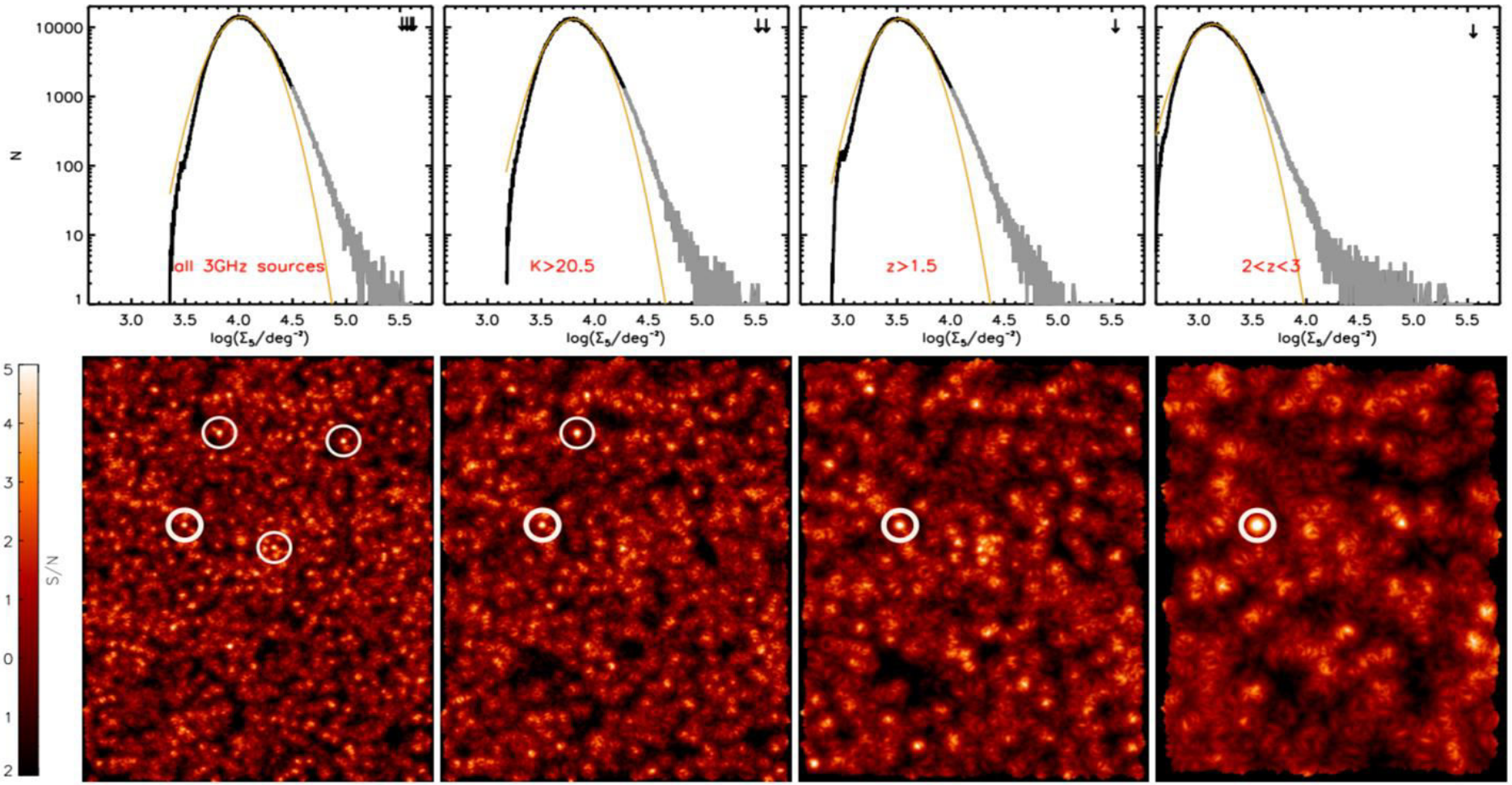
=> Euclid data will be full of those clusters !

Louis Legrand, Clément Martinache, Benjamin Clarenc, T. Etourneau, H. Dole



Daddi et al 2017

Using radio continuum to identify the most distant galaxy clusters (Daddi et al 2017)



SKA1 surveys will return > 100—1000 clusters like Wang et al 2016

Athena 400ks spectrum (from YB):
very accurate T and abundances measures
Notice: redshift measurement! *extremely hard otherwise*

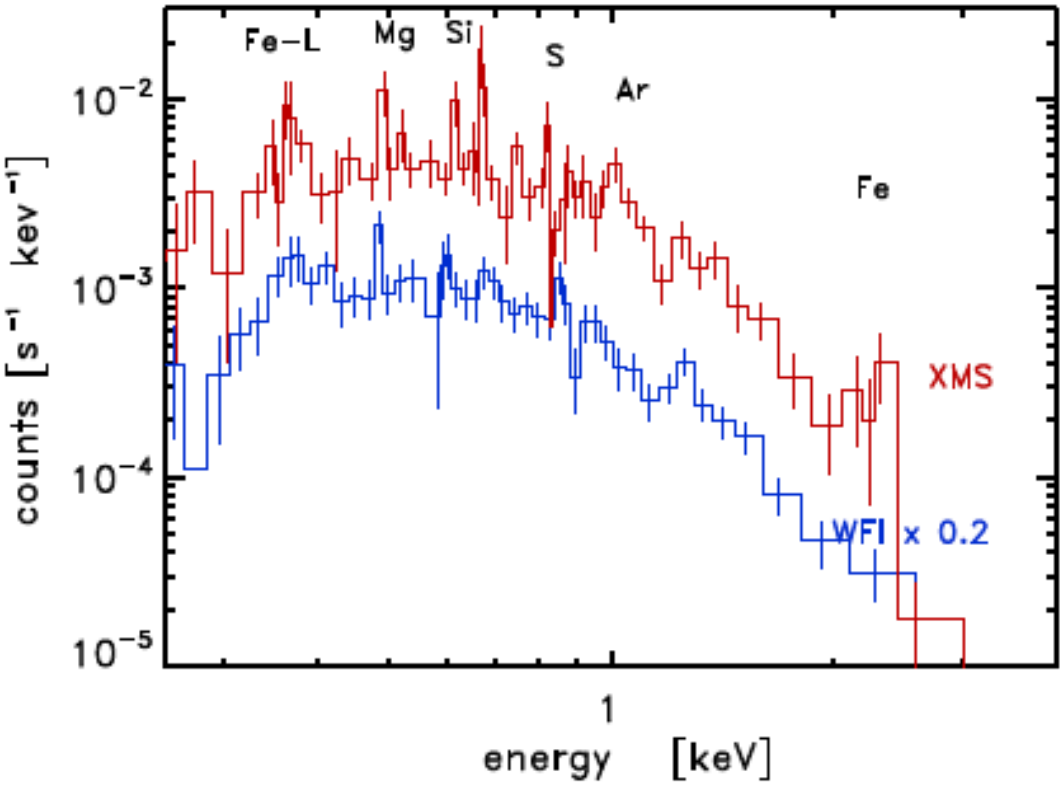


Figure 2.36. *Simulated, background subtracted spectrum of a galaxy group at z=2 with flux (0.5-2 keV) =10^{-15} erg s^{-1} cm^{-2} and temperature =2 keV with a deep exposure of 400 ks with the Athena-XMS and WFI detectors (WFI spectrum is scaled down by a factor of 5 to aid visibility). The temperature and abundances can be measured with good precision ($\Delta T < 0.1$ keV).*

Problem: AGN contamination hard to filter-out with 5-10" resolution
AGN activity becoming much more prominent to higher-z!
(following in parallel the rise of SFR and gas content in the Universe)

Summary

Clusters at z>~2 will become very interesting targets for the next decades to study structure assembly, cosmology, and galaxy formation and evolution.

France teams are at the forefront: Planck, radiogalaxies, ‘template clusters’ (but also protoclusters)

Cool new science:

- Lya nebulas/feedback/cold flows
- ICL origin/mergers/assembly
- Transformation to passive ETGs
- Early DM peaks for cosmology