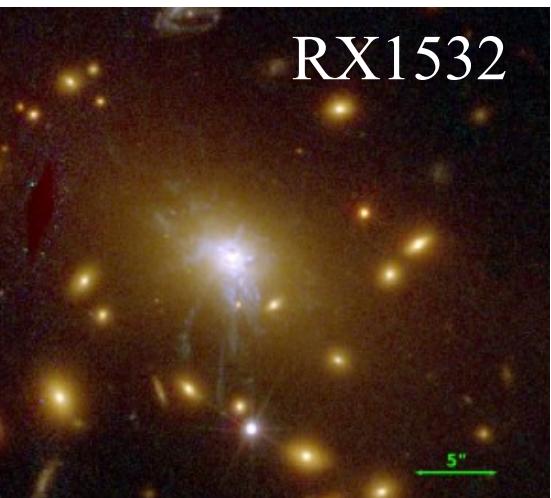
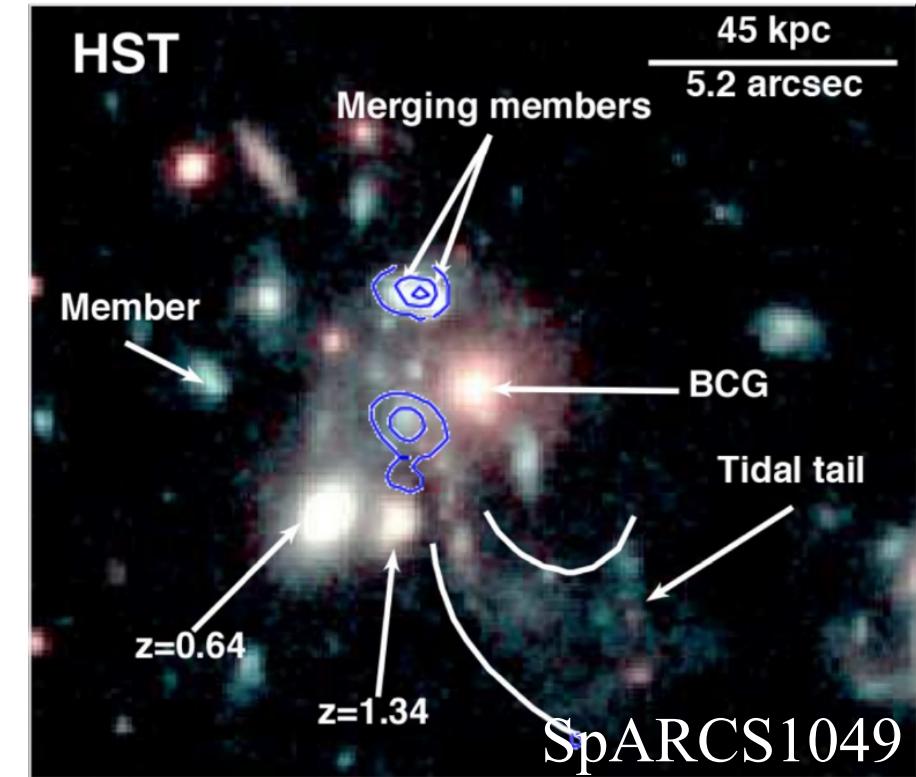


Gas in cluster galaxies at high redshift

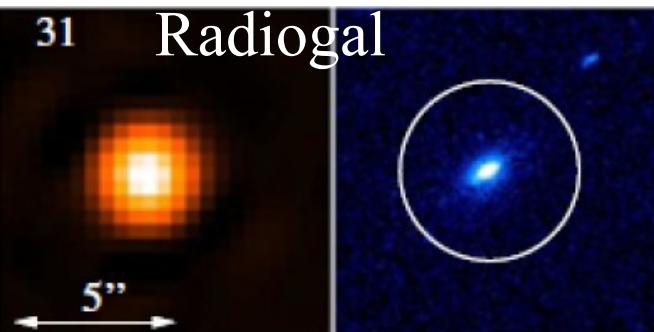
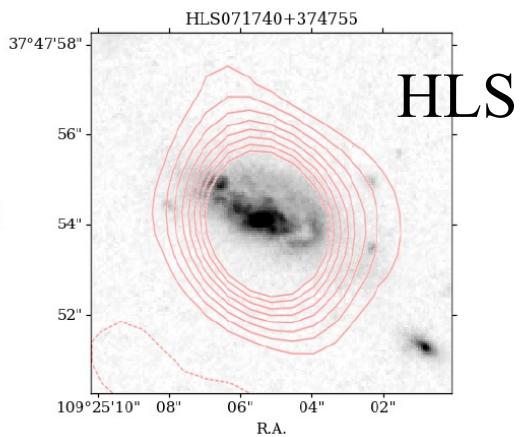
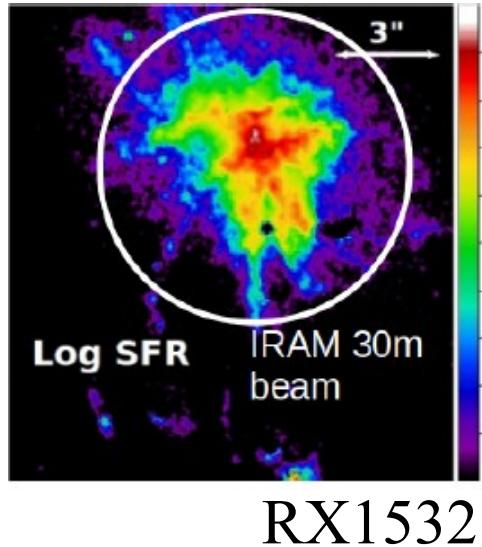


Françoise Combes
Observatoire de Paris

December 2020

Outline

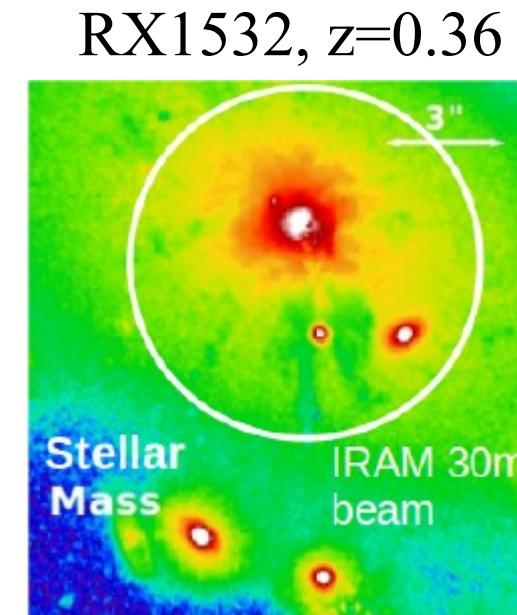
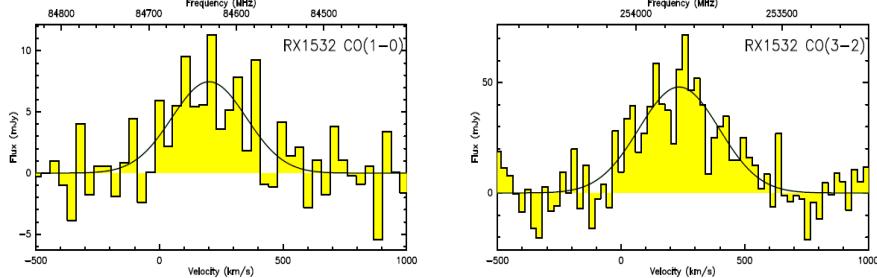
- CLASH cluster galaxies $z=0.2-0.9$
- LOCUSS clusters $z=0.2 - 0.55$
- CL1411.1 $z=0.5$
- BCG at $z=1.7$ SpARCS1049
- Merger at $z=1.2$
- Radio galaxies $z=0.4-2.6$
- SPARCS $z=0.4-3.5$



CLASH Cluster Lensing And Supernova survey with Hubble

18 BCG observed, 1 strong detection, 4 tentative
13 upper limits

RX1532: $\text{SFR} = 100 \text{ M}_\odot/\text{yr}$, $\text{MH}_2 = 8.7 \times 10^{10} \text{ M}_\odot$



$\text{MH}_2/\text{M}_* = 0.4$, RX1532 is rare, star forming and gas rich

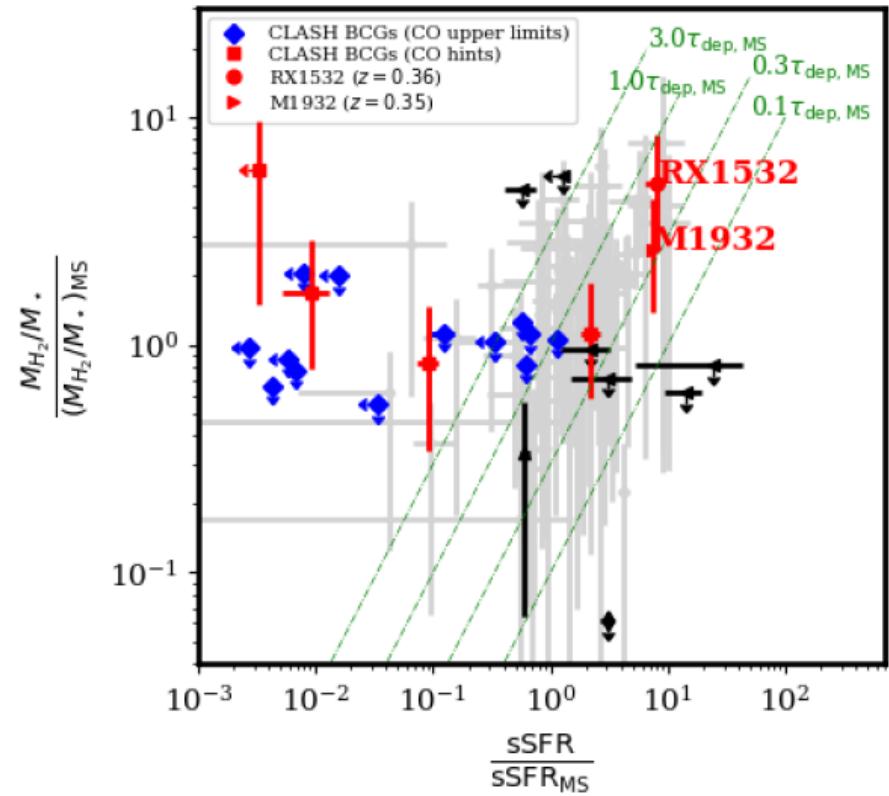
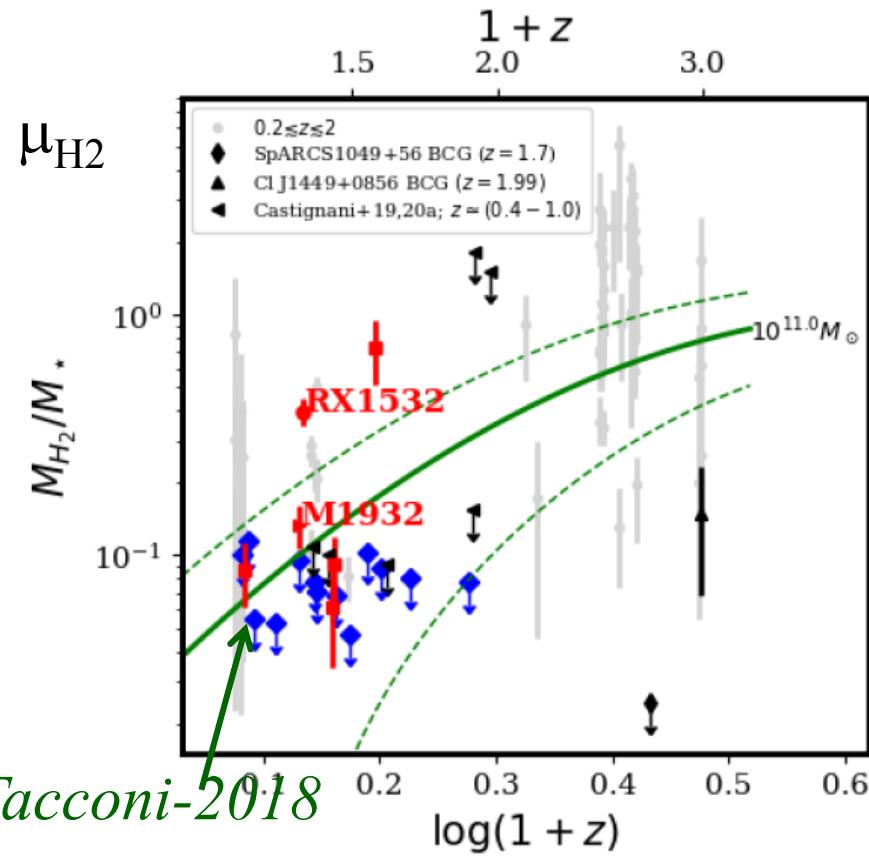
Comparison with X-rays:

Detection when high SFR and low central entropy

Cool core → gas accretion

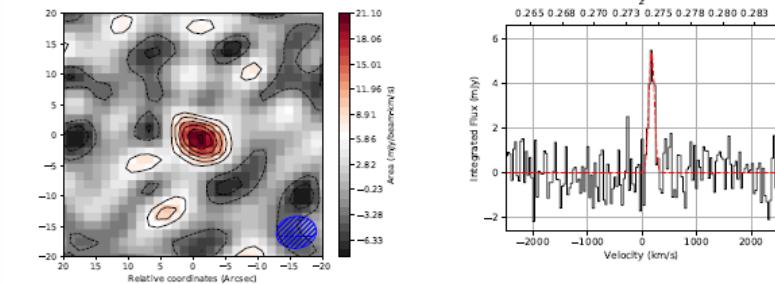
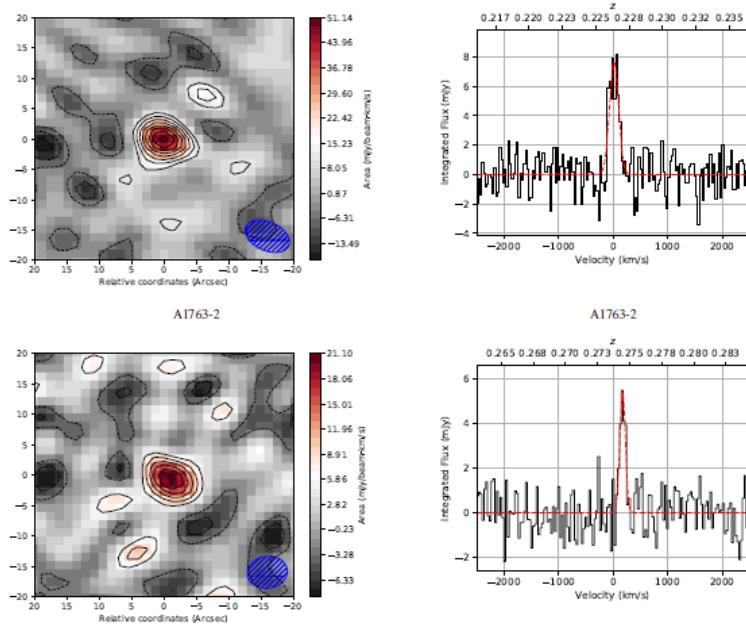
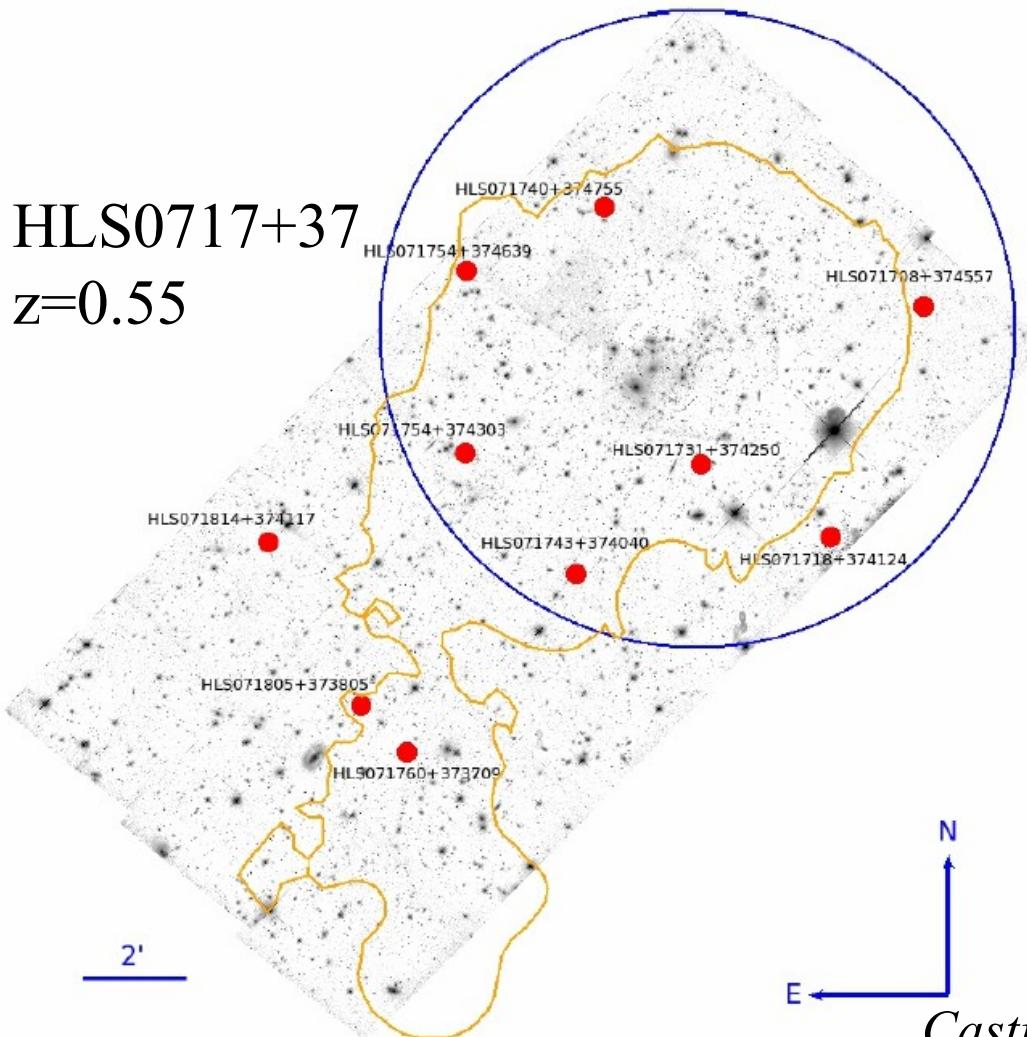
CLASH clusters

Comparison with all cluster galaxies observed in CO

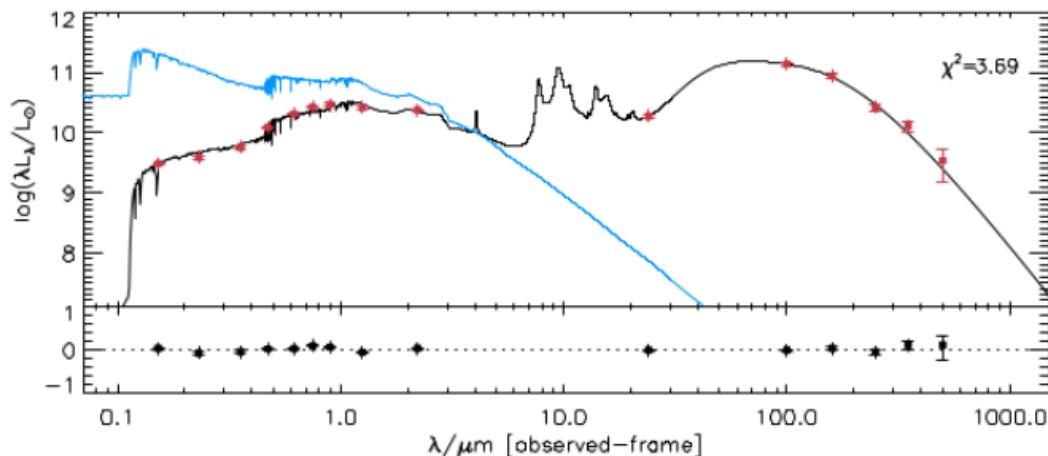


HLS+LOCUSS clusters Local Clusters Substructure Survey

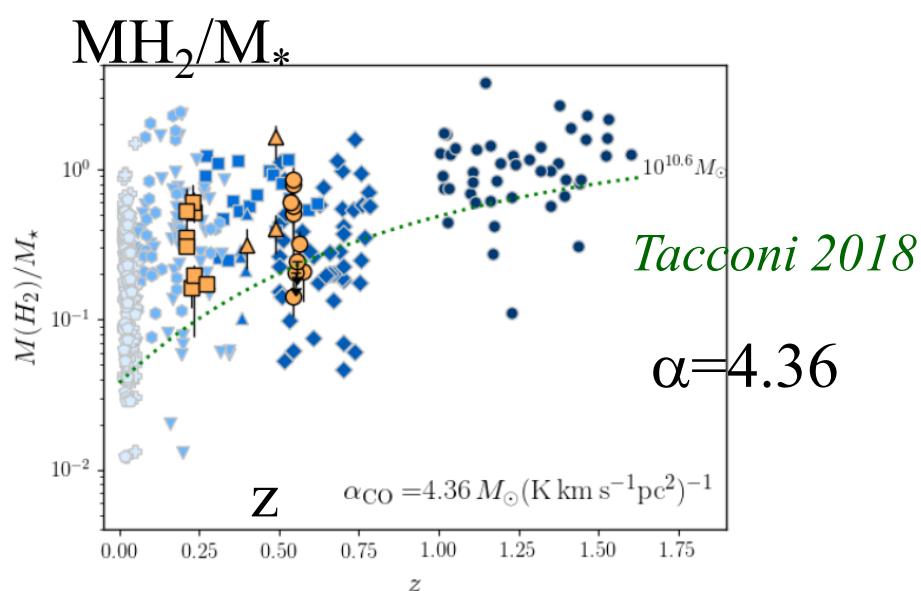
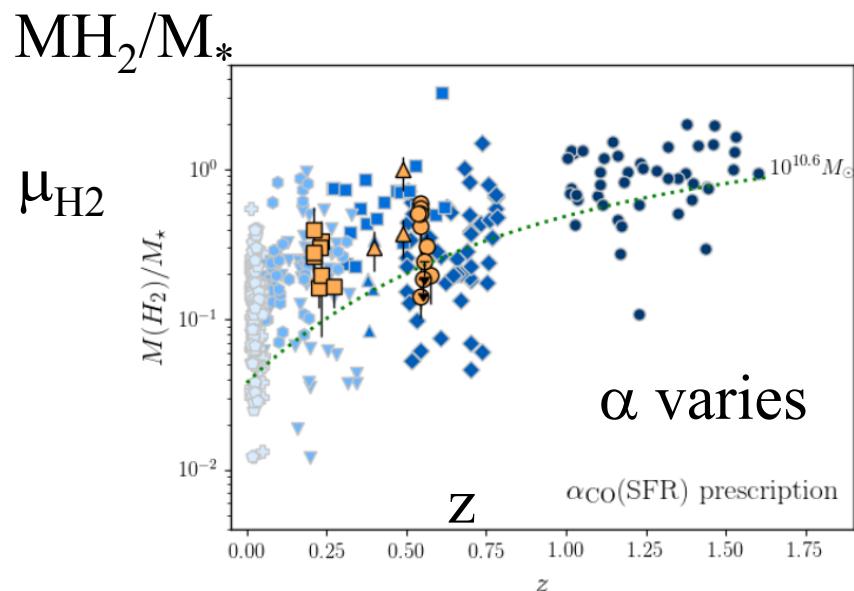
20 LIRGs belonging to 7 clusters at $z=0.2-0.5$, PdB and then NOEMA
18 out of 20 detected, (Abell 697, 963, 1763, and 2219, MACS J0717..)



LOCUSS clusters



A1763-1

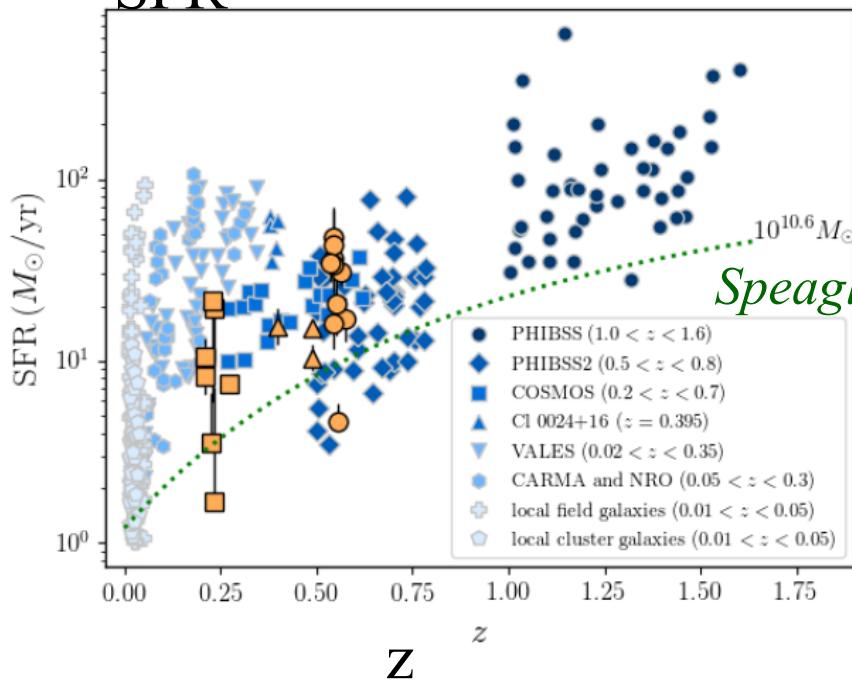


Castignani, Jablonka, Combes et al 2020

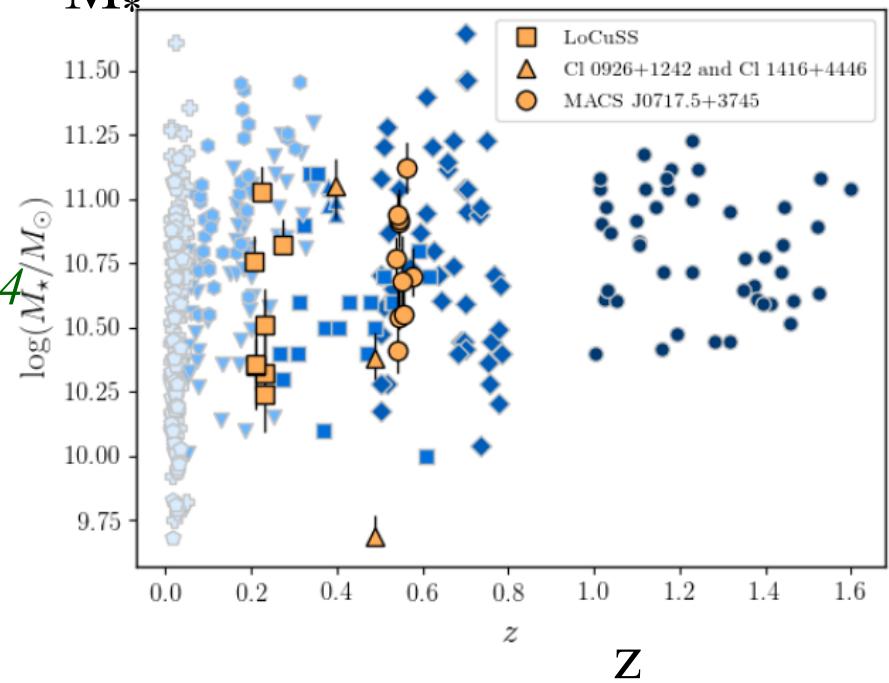
LOCUSS clusters

Comparison sample: PHIBSS, COSMOS, CARMA, etc.
Compared with average mass $\log(M_*) = 10.6$

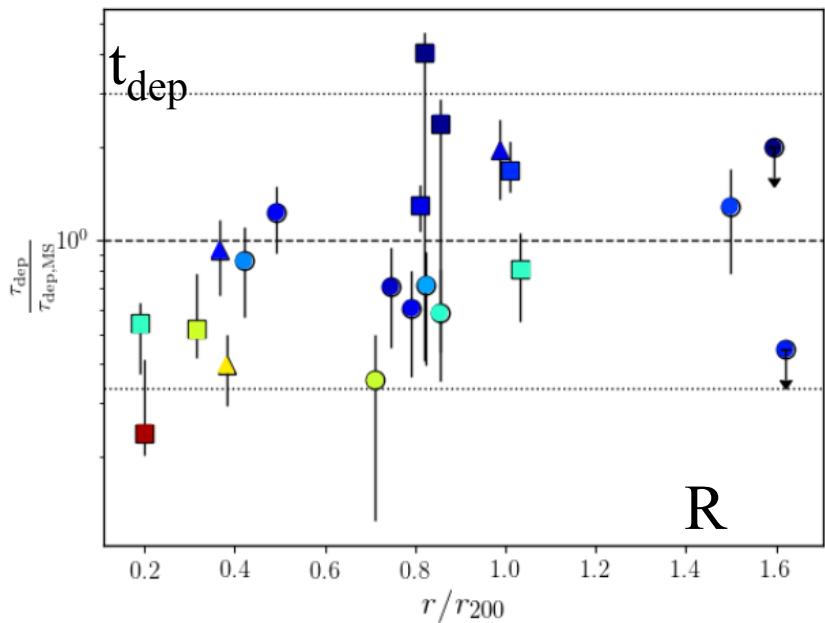
SFR



M_*

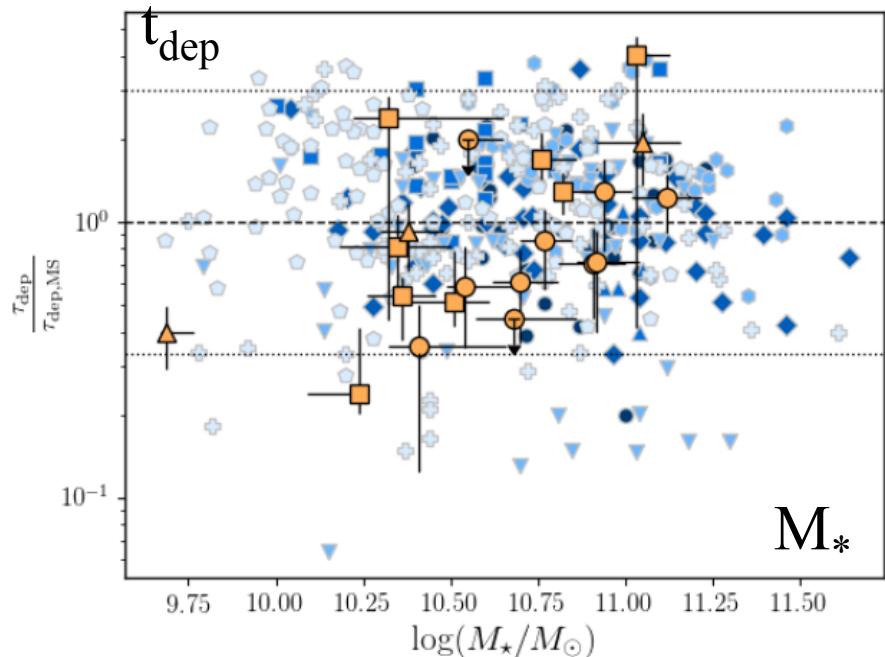
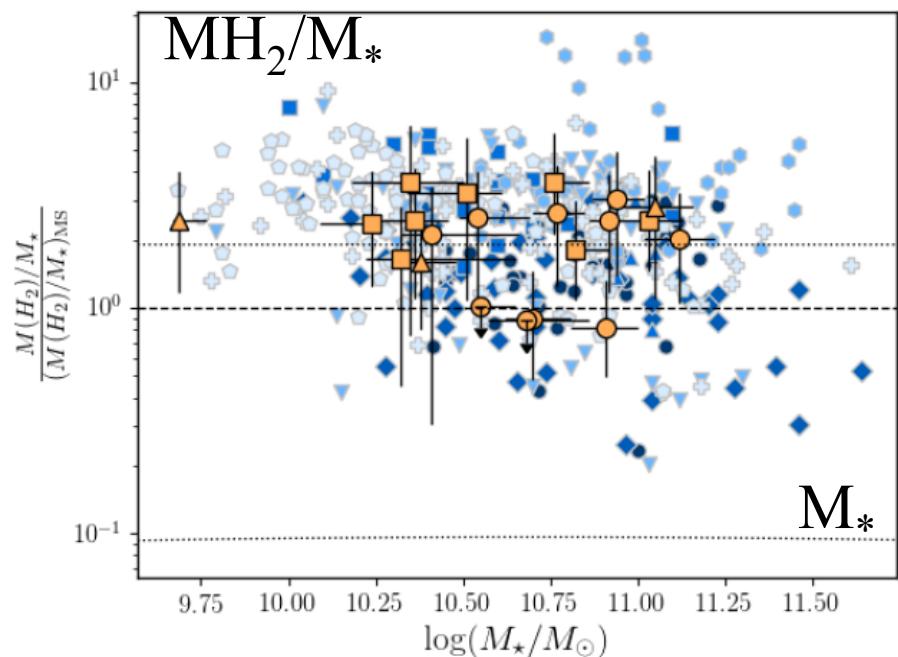


LOCUSS clusters

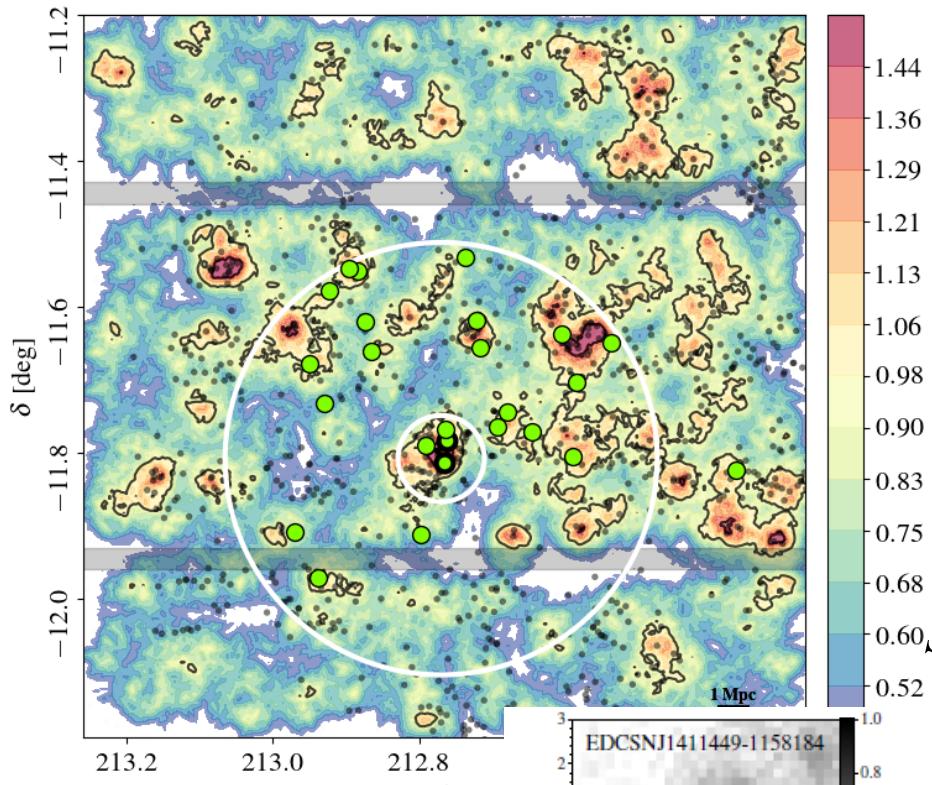


$t_{\text{dep}}/t_{\text{dep,MS}}$
increases with R/R_{200}

Short t_{dep} in the center

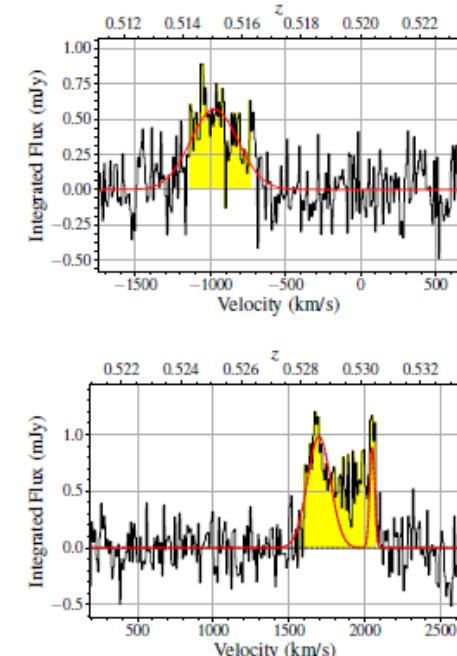
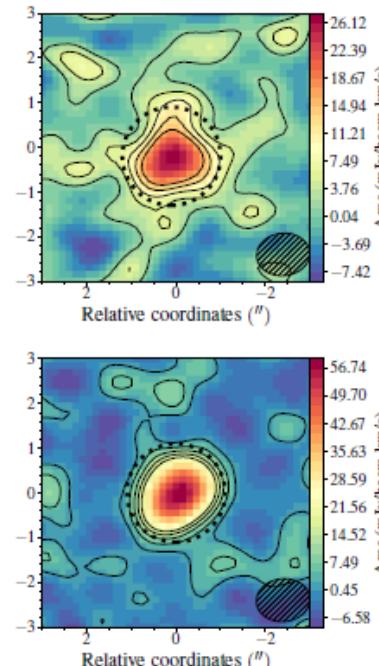
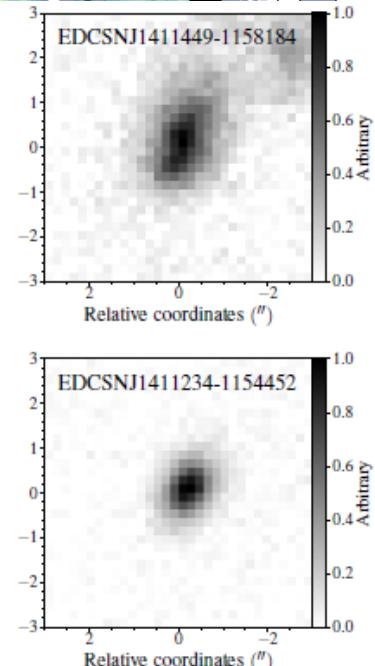


CL1411.1-1148 $z=0.52$



R_{200} and $5 R_{200}$

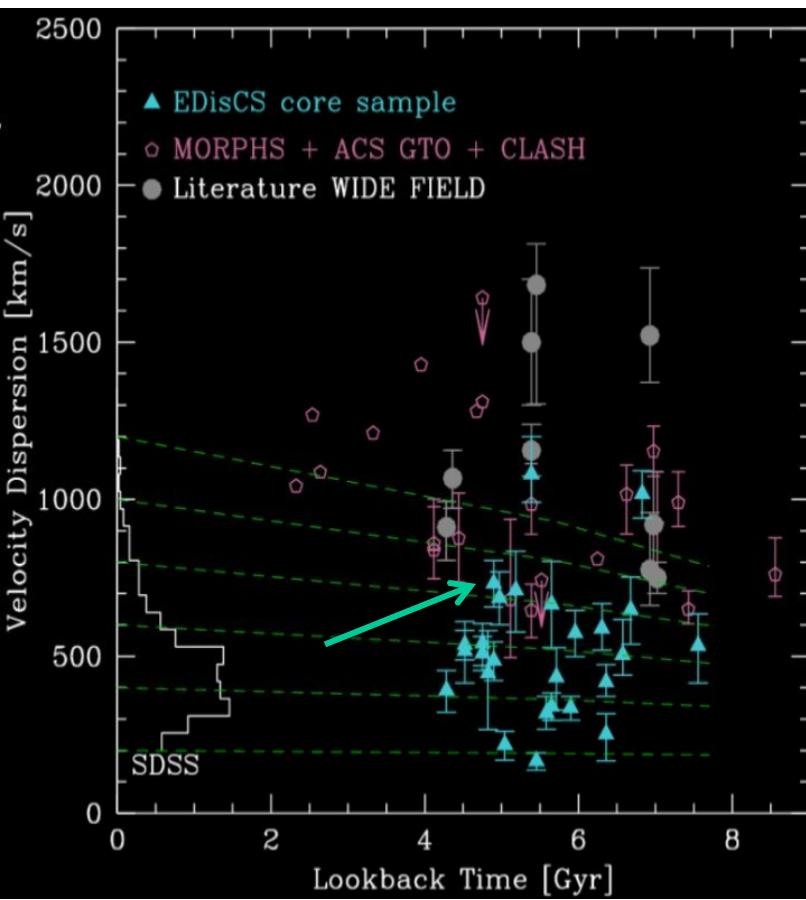
Morphologies
from Megacam
+deconvolution



$\sigma = 710 \text{ km/s}$

27 SFG targetted with ALMA
27 detections

Spérone-Longin, Jablonka, Combes +2020

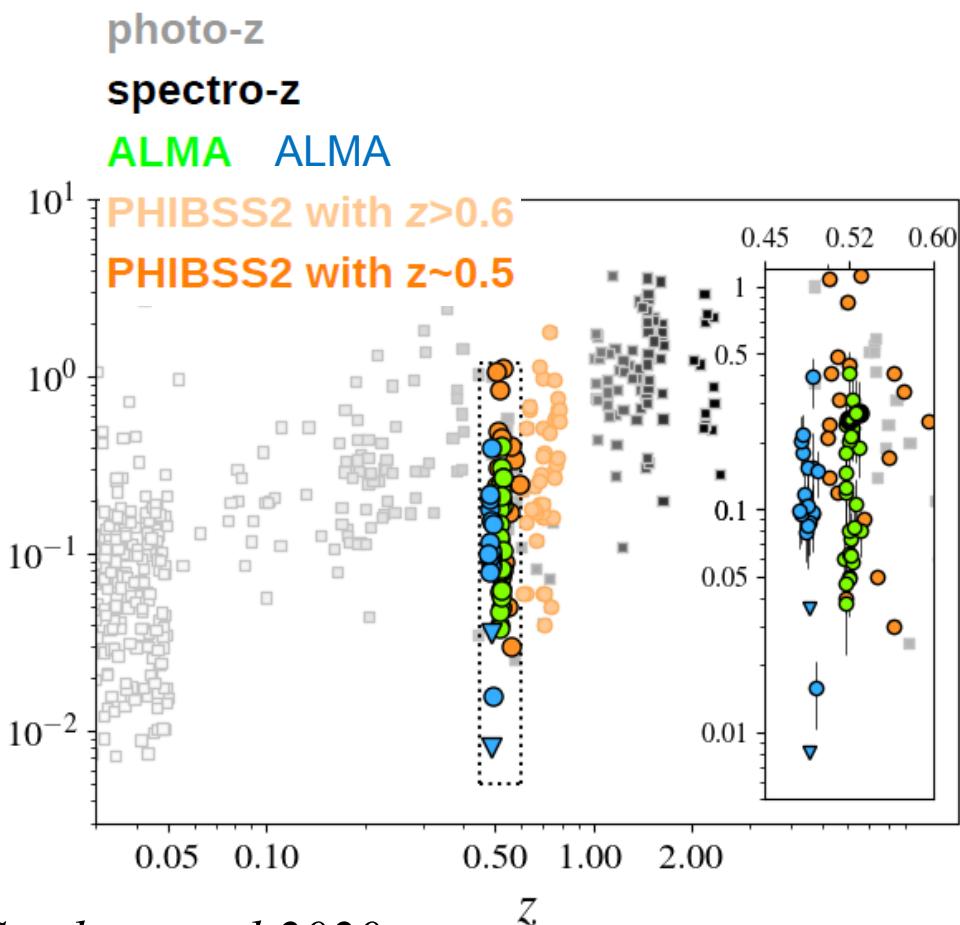


Coverage up to $8 R_{200}$

300 galaxies with z_{spec}

CL1411.1-1148 $z=0.52$
CL1301.7-1137 $z=0.48$

$$\mu_{\text{H}_2} = M_{\text{H}_2}/M_{\text{star}}$$



CL1411.1-1148 $z=0.52$

CL1301.7-1137 $z=0.48$

45% Pink circled: depleted in H₂, at M_*

log(SFR (M_\odot/yr))

-1.0
-0.5
0.0
0.5
1.0
1.5
2.0

photo-z

spectro-z

ALMA

PHIBSS2 with $z>0.6$

PHIBSS2 with $z\sim 0.5$

log(SFR (M_\odot/yr))

-1.0
-0.5
0.0
0.5
1.0
1.5
2.0

log($M_{\text{star}} (M_\odot)$)

log($M_{\text{star}} (M_\odot)$)

μ_{H_2}

10¹
10⁰
10⁻¹
10⁻²

10¹⁰

10¹¹

10¹²

log($M_{\text{star}} (M_\odot)$)

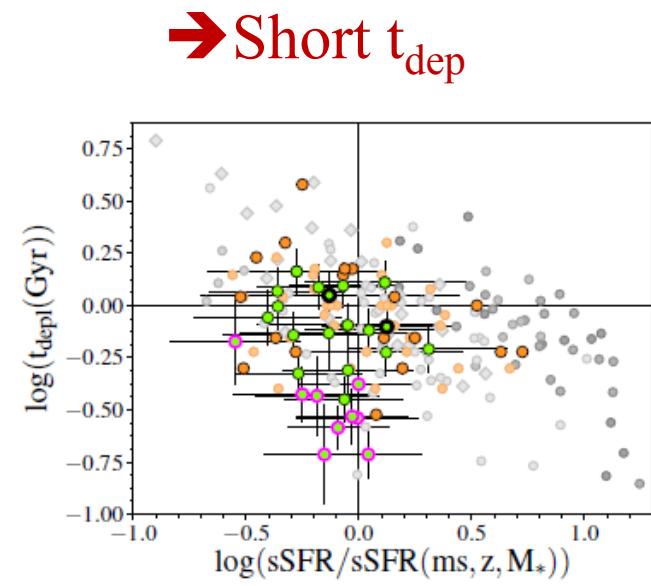
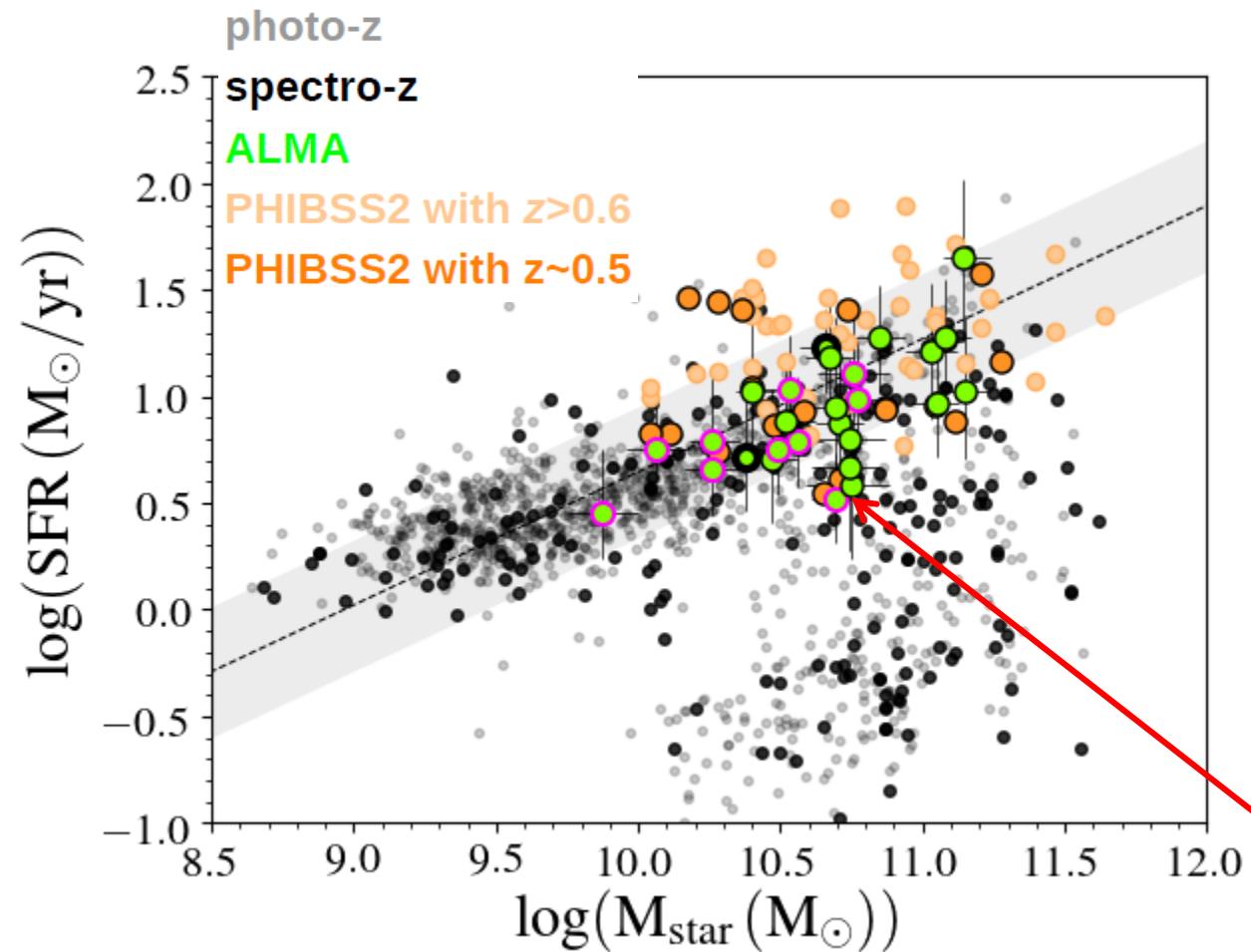
2.00
1.75
1.50
1.25
1.00
0.75
0.50
0.25
0.00

Redshift

PHIBSS2: Freundlich, Combes, Tacconi et al 2019

CL1411.1-1148 z=0.52

However, the pink-circled are within the 0.3des of the MS
→ The H₂ reservoir is depleted, before the SFR is

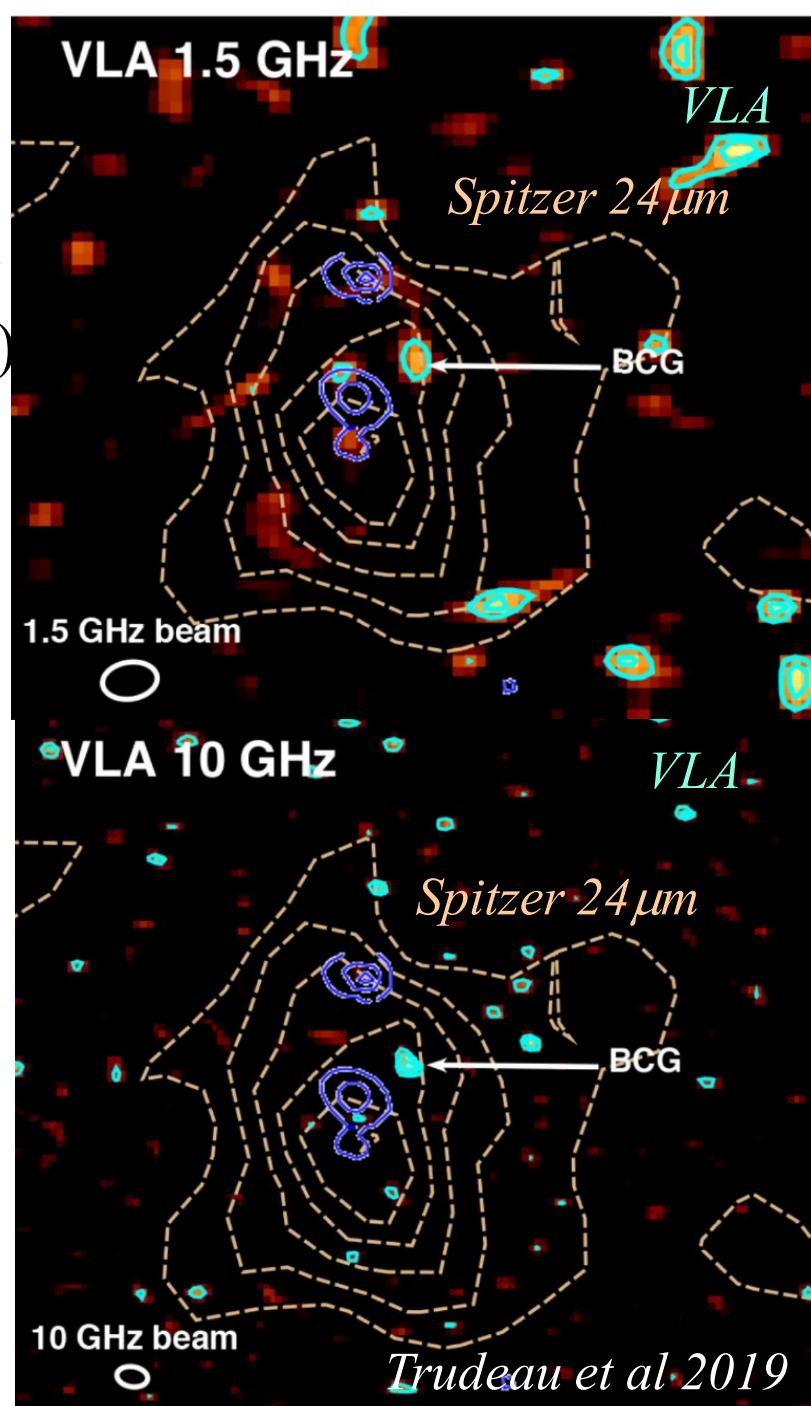
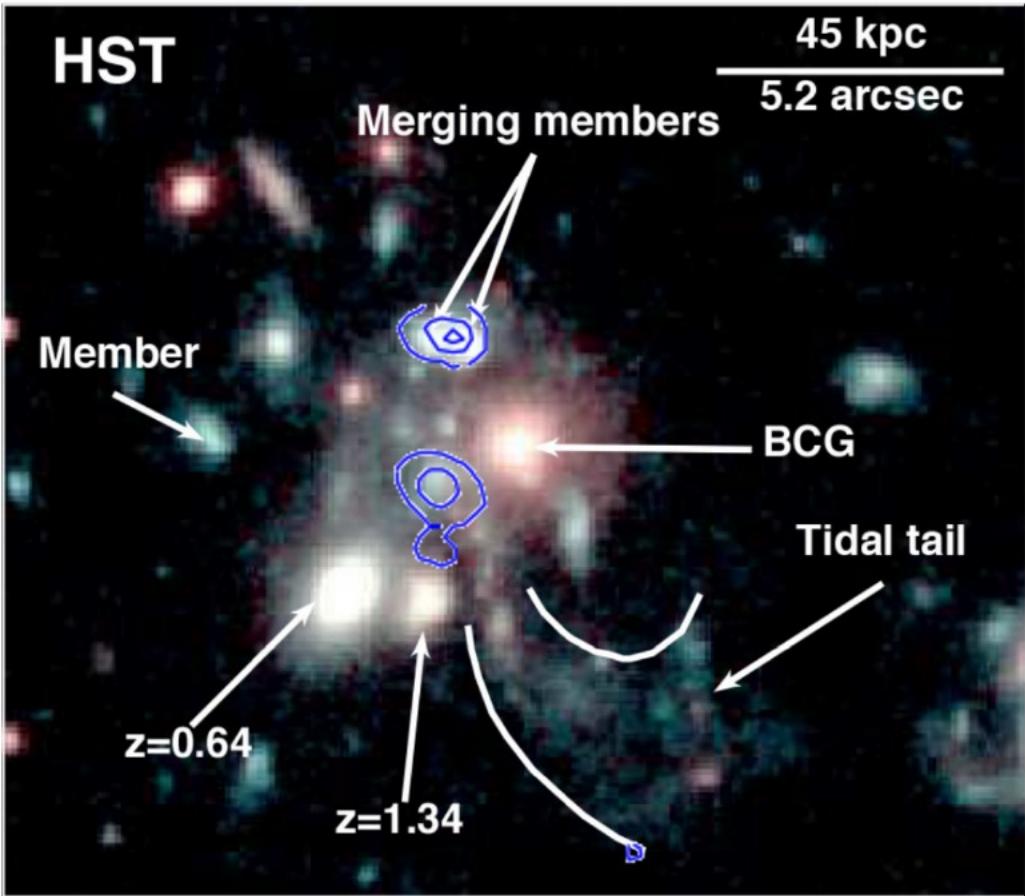


Only 1 galaxy
in the green valley
Towards the
quenched state

BCG in z=1.7 SpARCS1049+56 Cluster

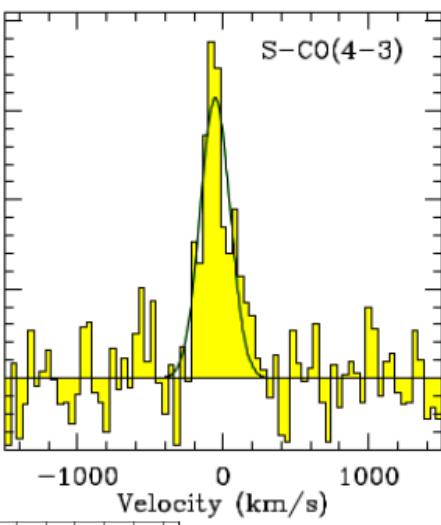
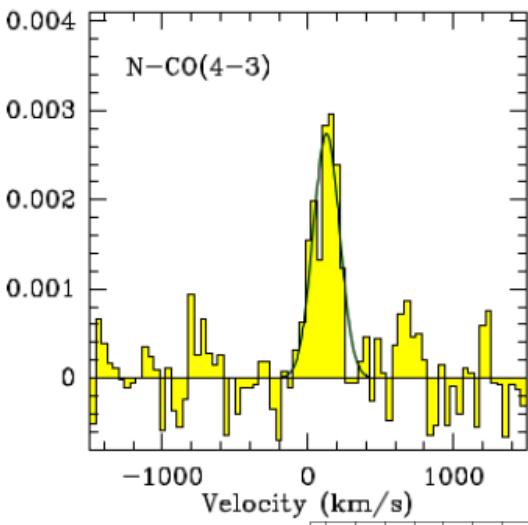
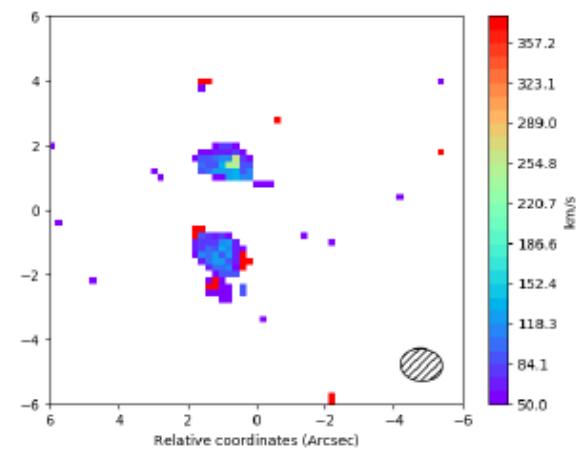
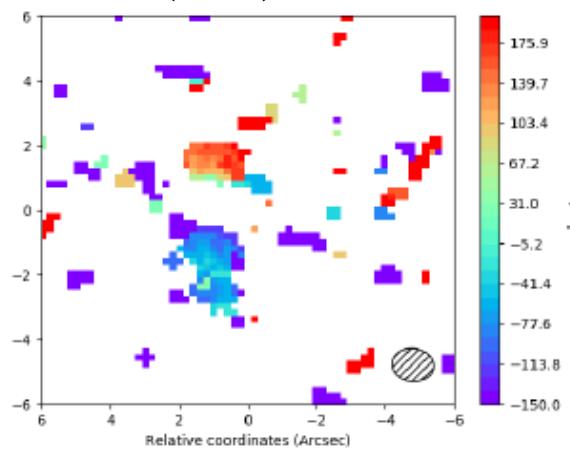
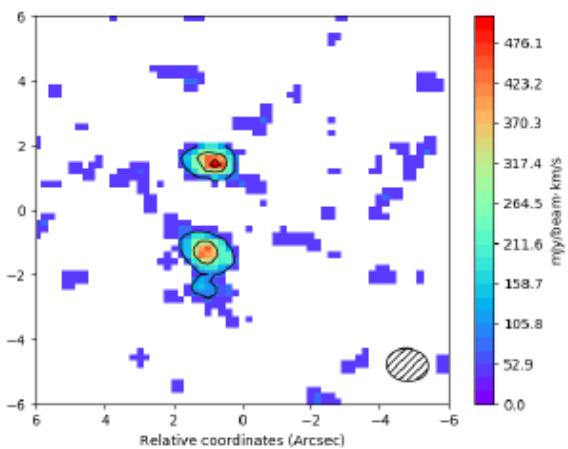
The BCG has no gas! CO(4-3) in a merger
Plus a tidal tail, or jelly-fish (ram-pressure)

Castignani, Combes, Salomé 2020



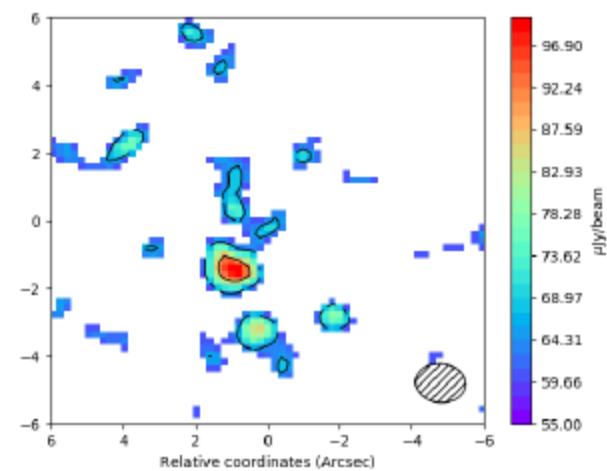
BCG precursor at z=1.7

CO(4-3) moments



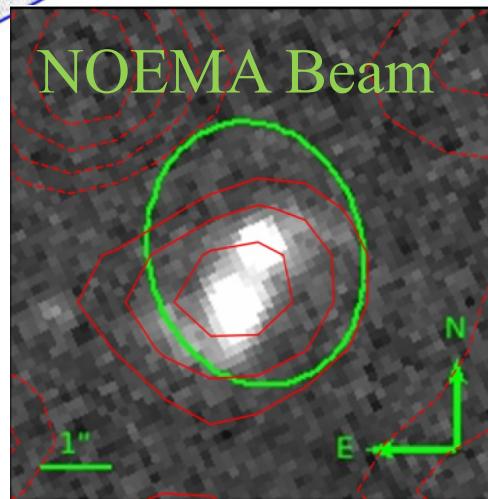
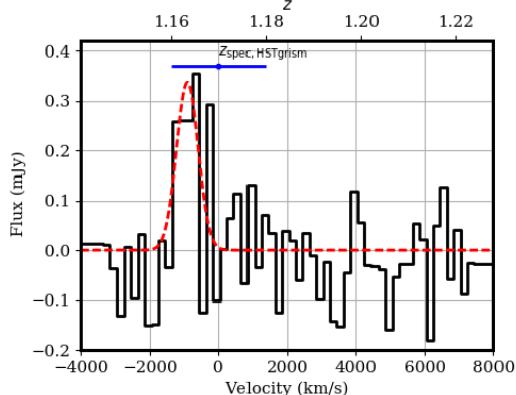
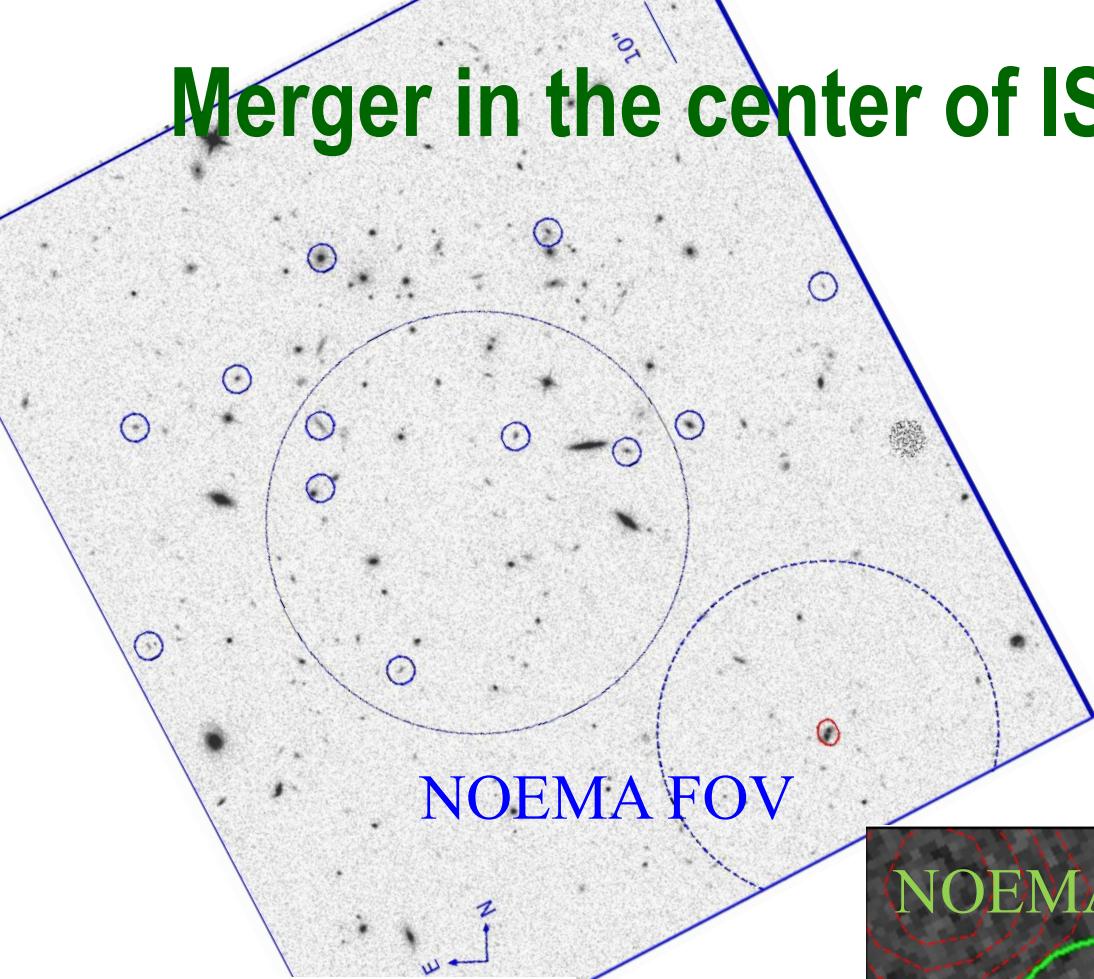
(c)

continuum



(d)

Merger in the center of ICS CS J1426.5+3339



CO(2-1) $z=1.2$

$M(H_2) = 2.2 \cdot 10^{10} M_\odot$

$M_{\text{dust}} < 4.2 \cdot 10^8 M_\odot$

$M_{\text{gas}}/M_* = 0.17$

SFR each $24 M_\odot / \text{yr}$

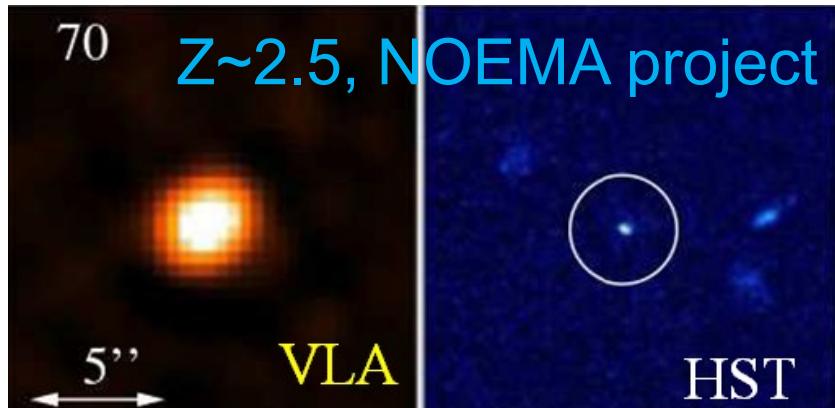
$t_{\text{dep}} = 4 \cdot 10^8 \text{ yr}$

Marginally on the MS

No refueling due
to the cluster ?

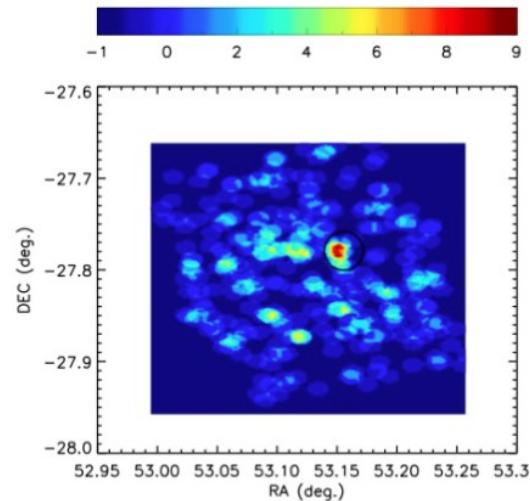
Reversal of SFR-Density relation

Observation of CO in galaxies in clusters and proto-cluster up to $z \sim 2-3$



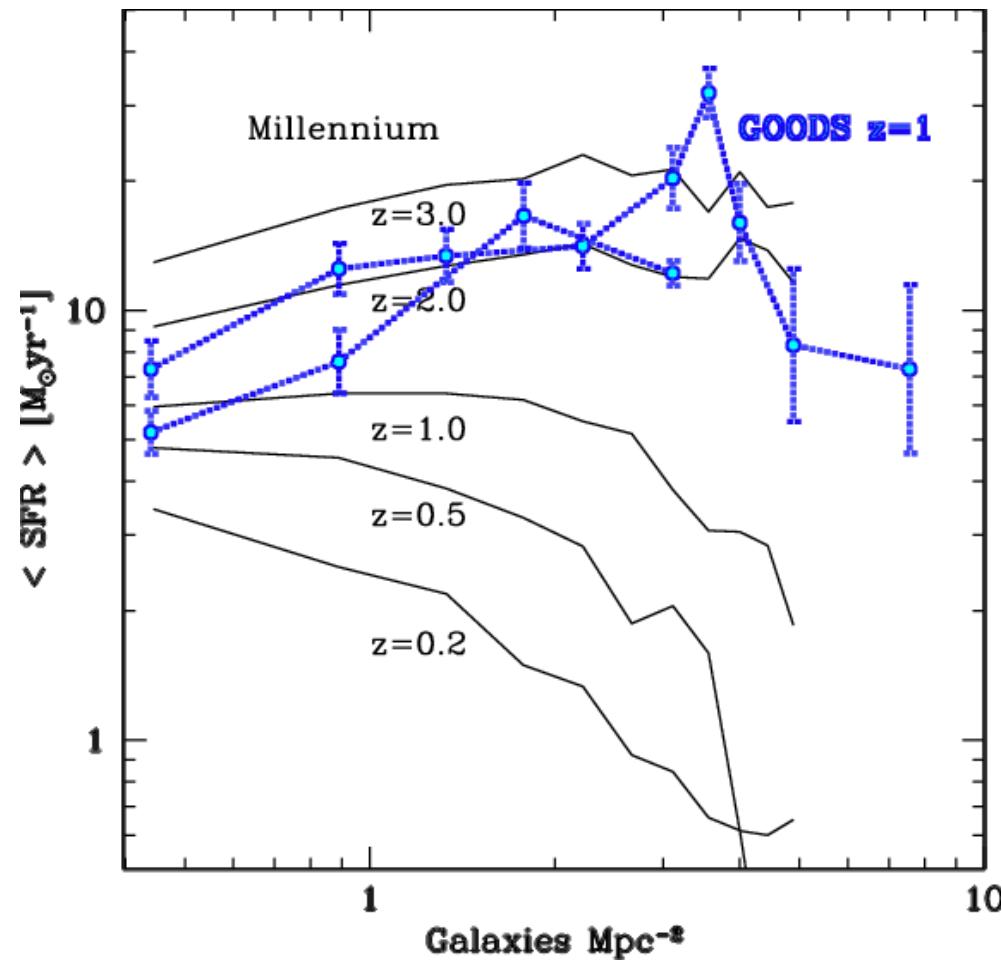
Castignani, Combes, Salome +2019

+ CARLA
NOEMA project



Galametz,
Mei et al 2019

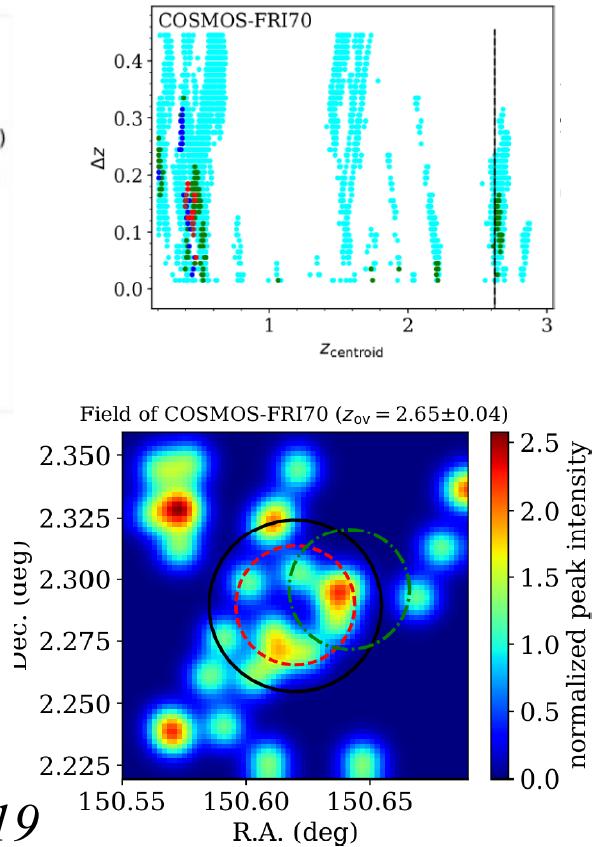
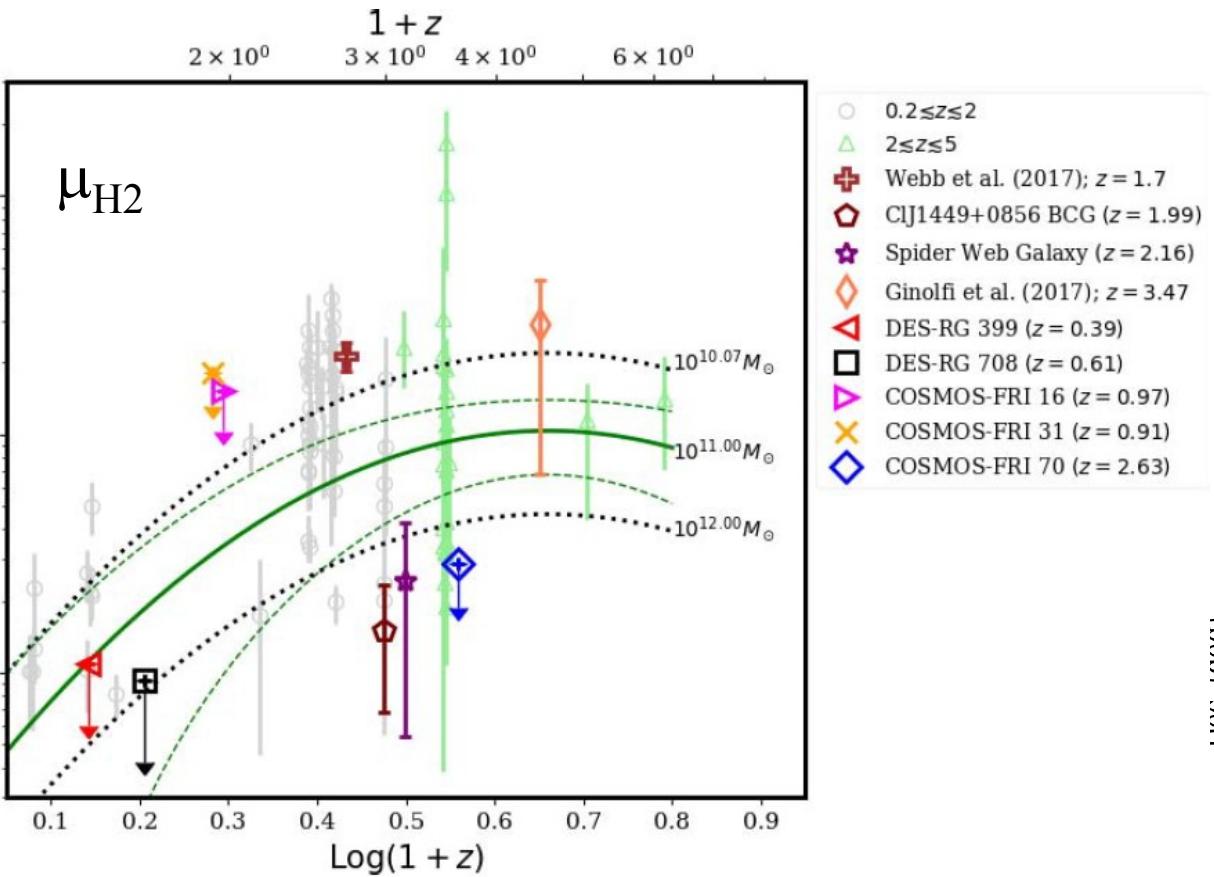
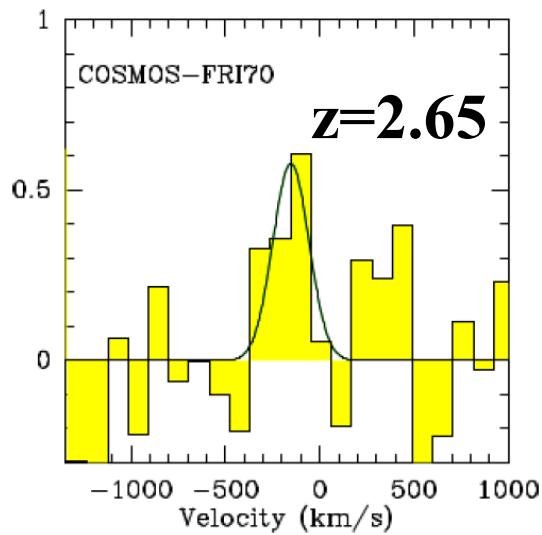
Markov 2020



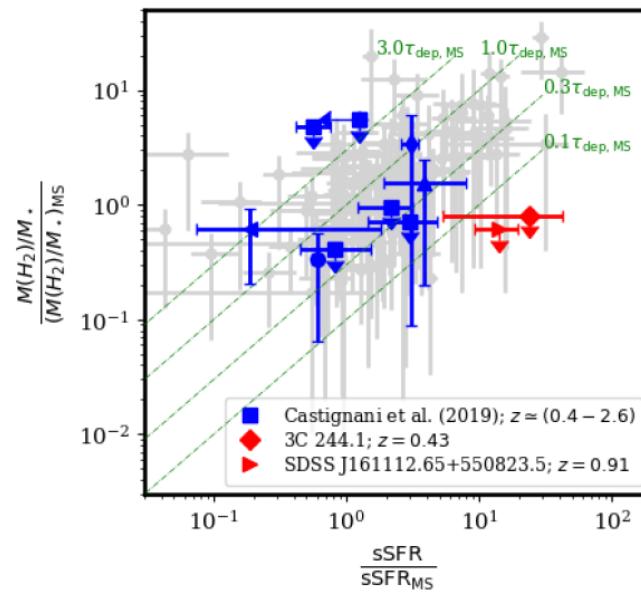
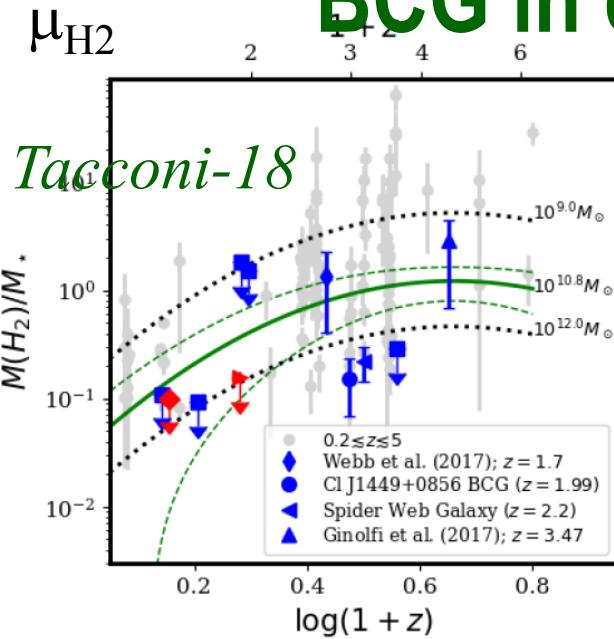
Elbaz et al 2007

Radio galaxies in rich groups

LLRGs (FRI) often BCG-precursors, $10^{14} M_{\odot}$ groups
COSMOS, DES, over-density detected by PPM
Out of 5 sources observed, one detection



BCG in dense clusters z=0.4-3.5

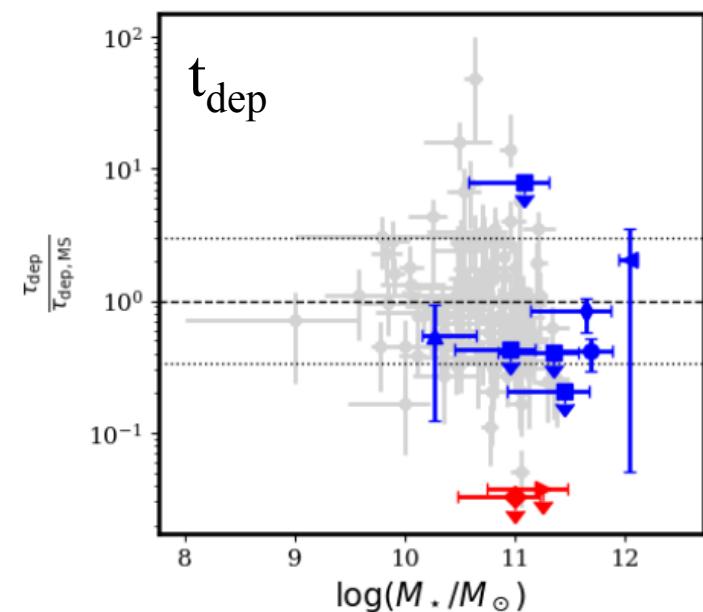
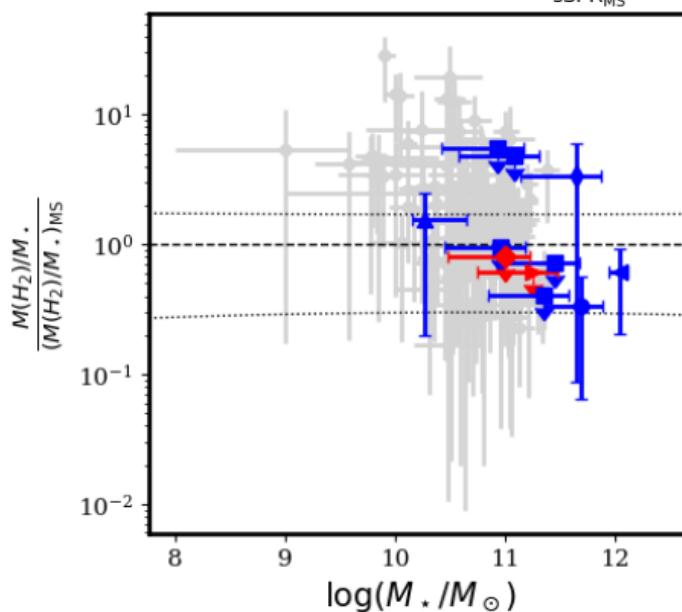


High SFR, but compact
→ Influence of Environment

118 gal in 33 clus

3C244.1 & SDSS16
 $MH_2/M_* < 0.2$
 $t_{dep} < 40$ Myr

Out of 11 BCG,
75% have low
 MH_2/M_*
And low t_{dep}



SUMMARY

→ BCG with SFR and gas: when CC clusters low entropy gas

→ BCG precursors: can be on the MS, but quite short t_{dep}

→ Impact of environment: CL1411 $z=0.5$, 2 steps, SFR still on MS, but H₂ depleted, then SFR quenched

→ t_{dep} increase with distance to cluster
short t_{dep} in the center,
BCG very compact

