ATLAS probes of galaxy evolution at the time of clusters formation

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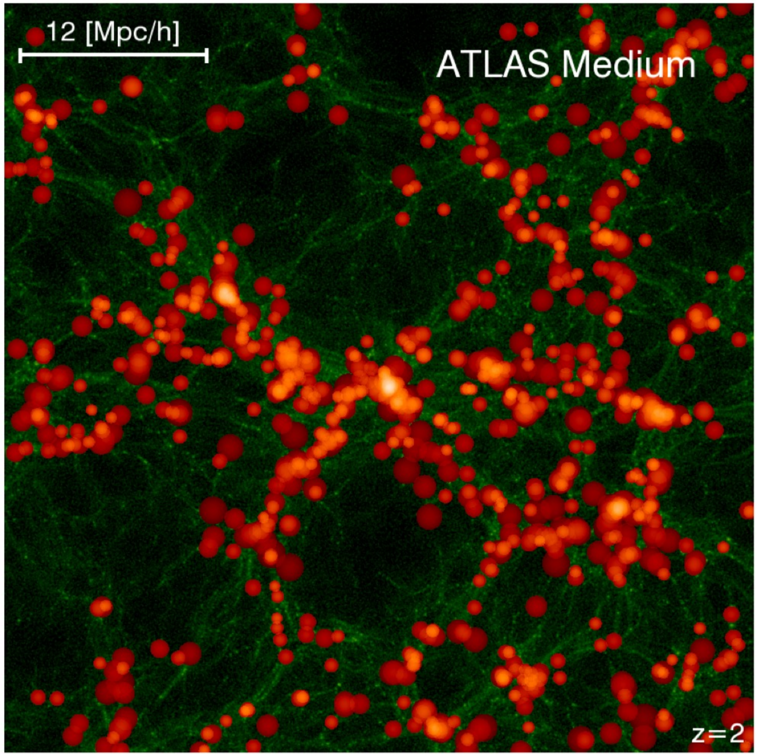
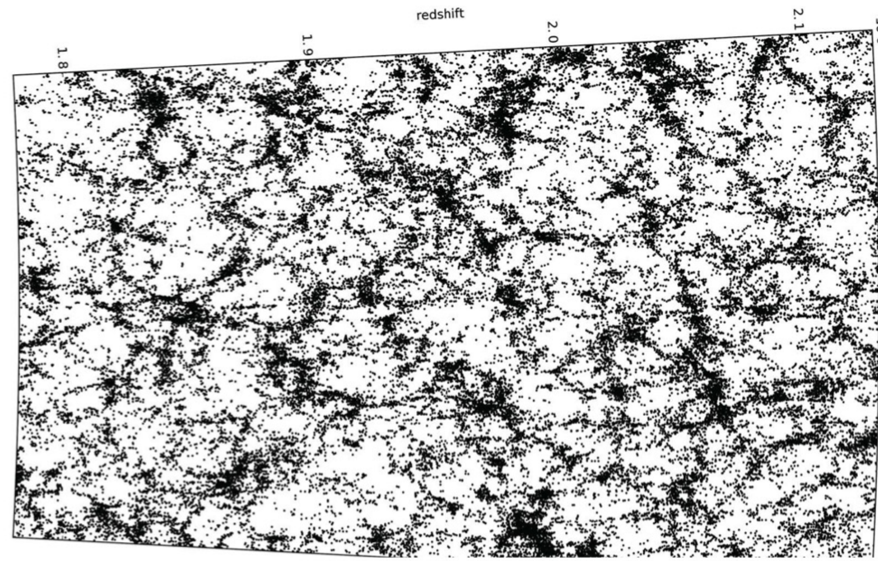
Massively Parallel Large Area Spectroscopy from Space 23/6/2021

Galaxy formation and evolution in the Large Scale Structure: what in practice ?



→ Tailored to individual hosting Dark Matter halos at the peak of the Universe activity (1<z<4)

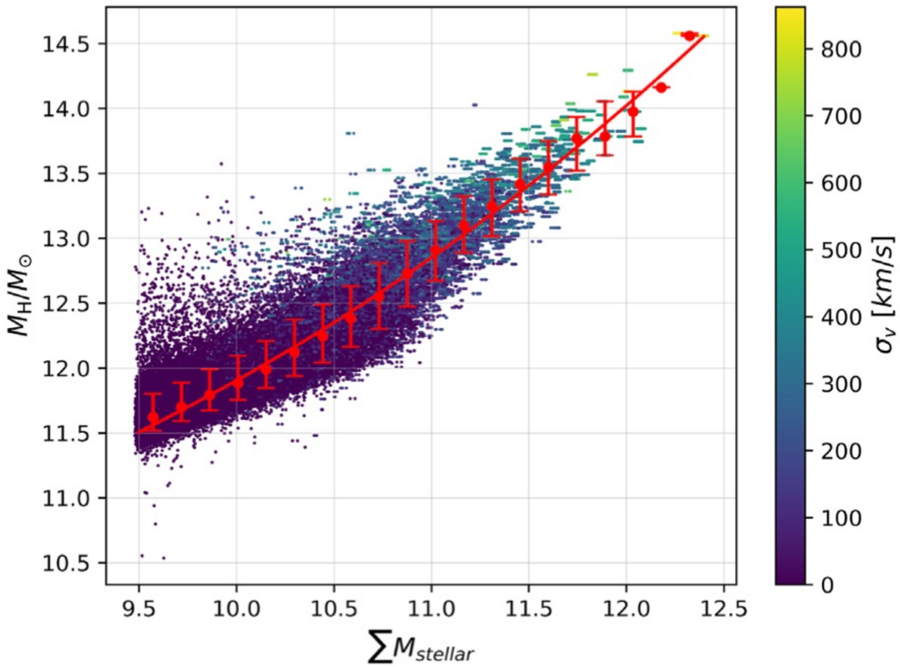


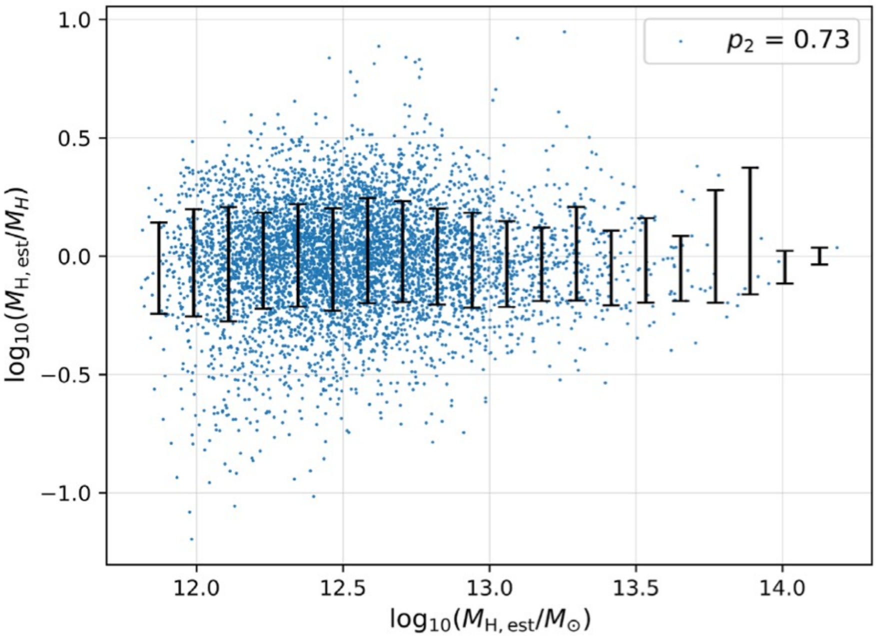
A) How well can we hope to trace DM halos from ATLAS galaxies at z~2-3
   1) method
   2) depth
   3) statistics

A) What open scientific questions we will answer
   1) Gas feeding, star formation, mass growth
   2) Quenching
   3) Morphological transformations

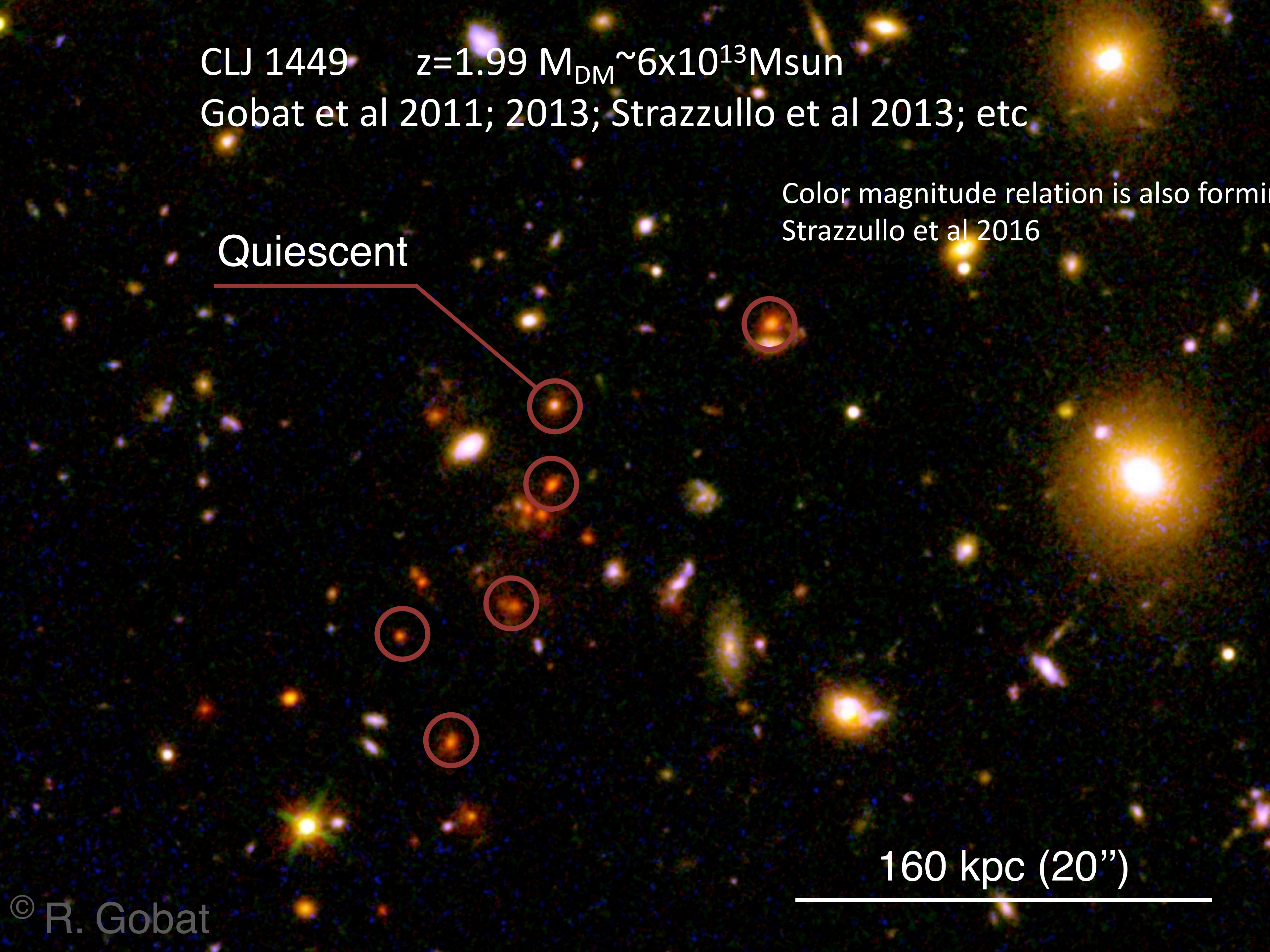
1A) How can we estimate hosting DM halos from a spectroscopic survey ?

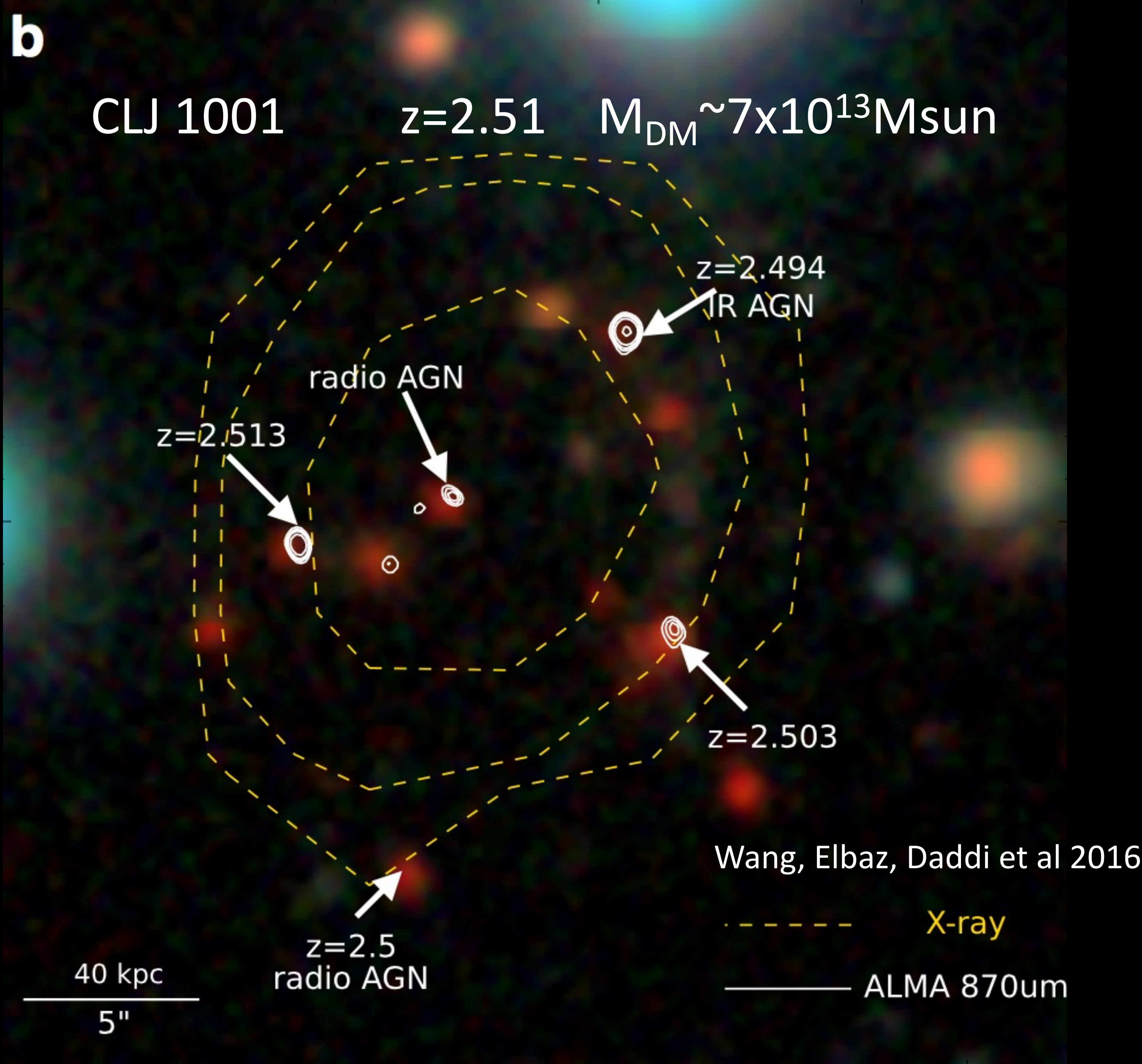
from stellar mass content





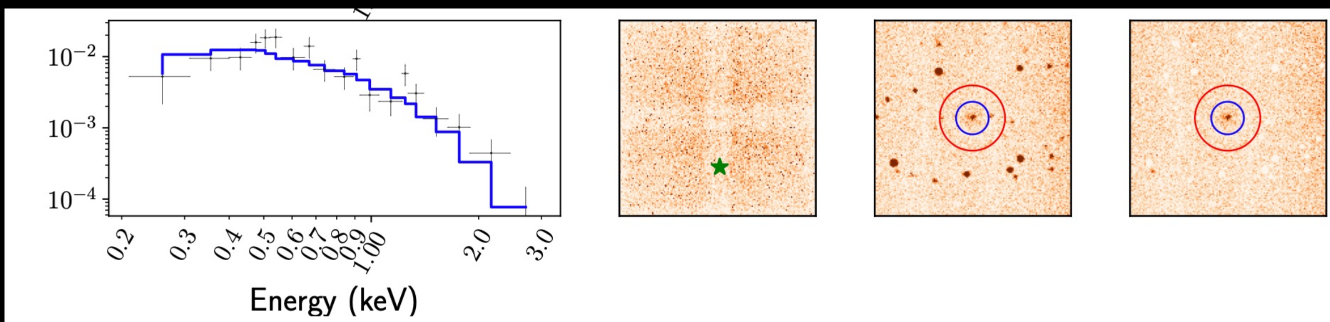
Looser, Lilly et al 2021, using f.o.f. approach
as relevant for example for the MOONRISE survey with MOONS


CLJ 1449 z=1.99 M_{DM}~$6x10^{13}$Msun
Gobat et al 2011; 2013; Strazzullo et al 2013; etc
Color magnitude relation is also formi
Strazzullo et al 2016
Quiescent
160 kpc (20”)
© R. Gobat


b
CLJ 1001
z=2.51
M_{DM}~7x10^{13}Msun
z=2.494
IR AGN
radio AGN
z=2.513
z=2.503
z=2.5
radio AGN
40 kpc
5"
Wang, Elbaz, Daddi et al 2016
X-ray
ALMA 870um

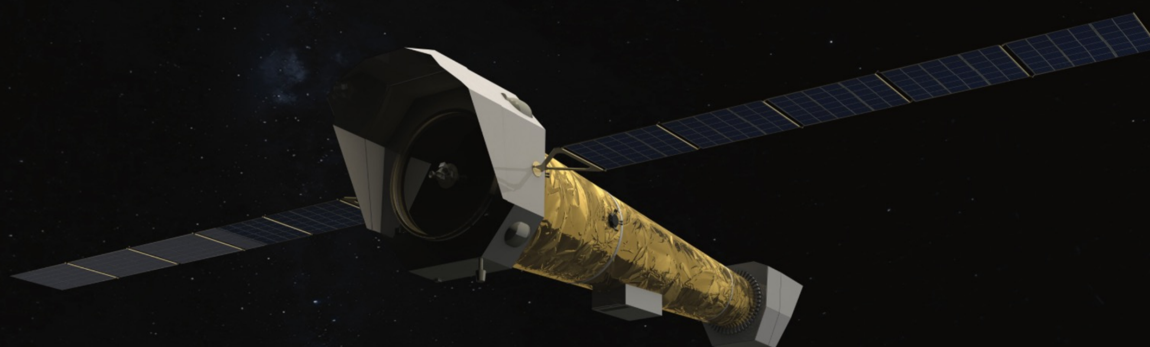
Synergy with the ESA Athena mission (2030+)

Allows us to study crucial baryon phases together:
HOT gas at the time of cluster formation
(*which is when the cold phase is most connected to action*)

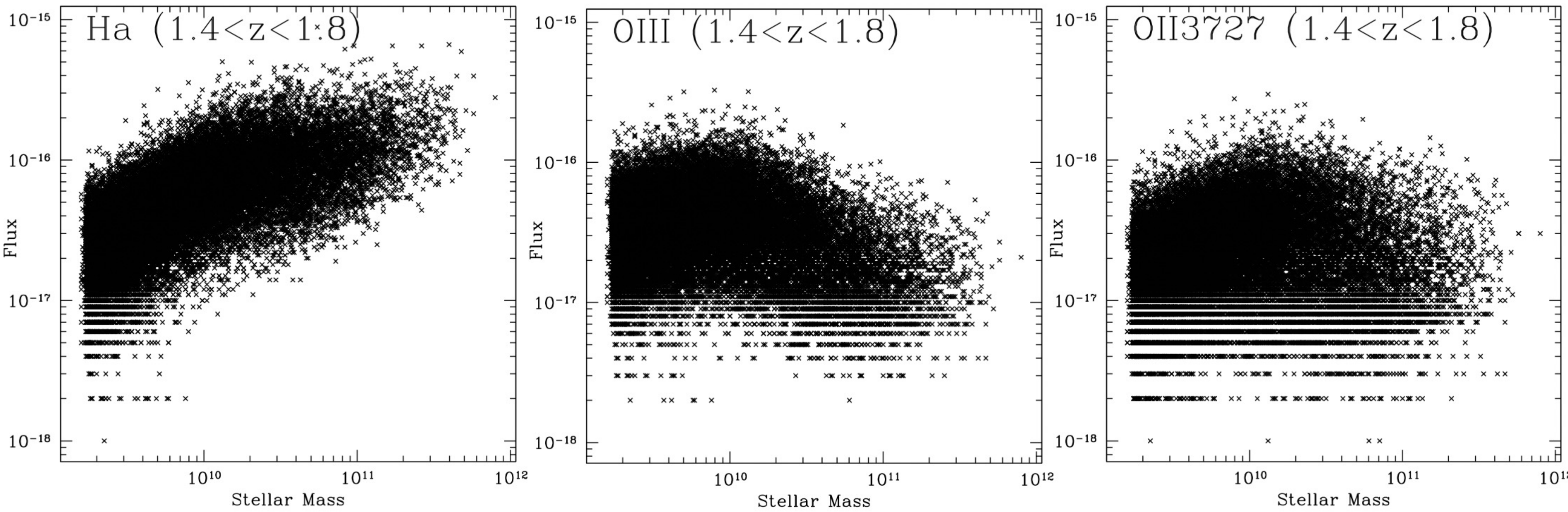


Plus AGN activity

Zhang et al 2020 (80ks spectrum z=2.5 M=5x10^{13}Msun)



2A) Can ATLAS get redshifts z>1.5 structures (and the field…) ?



Valentino et al 2017 predictions calibrated on extensive FMOS spectroscopy (Silverman et al; Kashino et al 2013; 2016) for SF galaxies

<u>Lines at z~2.5(3.5) expected only ~x1.8(x2.5) weaker on average</u>

MOONRISE: 2023+
~10^{-17} limit for lines
Ha to z=1.8, OII, OIII beyond
~10 sq.deg max

ATLAS Survey	Area (deg^2)	Line Flux Depth ($erg/s/cm^2$)	Continuum Depth (AB mag)
Wide	**2000**	**5e-18 (5σ)**	**23 (3σ)**
Medium	**100**	**1.2e-18 (5σ)**	**24.5 (3σ)**
Deep	**1**	**4.6e-19 (5σ)**	**25.5 (3σ)**

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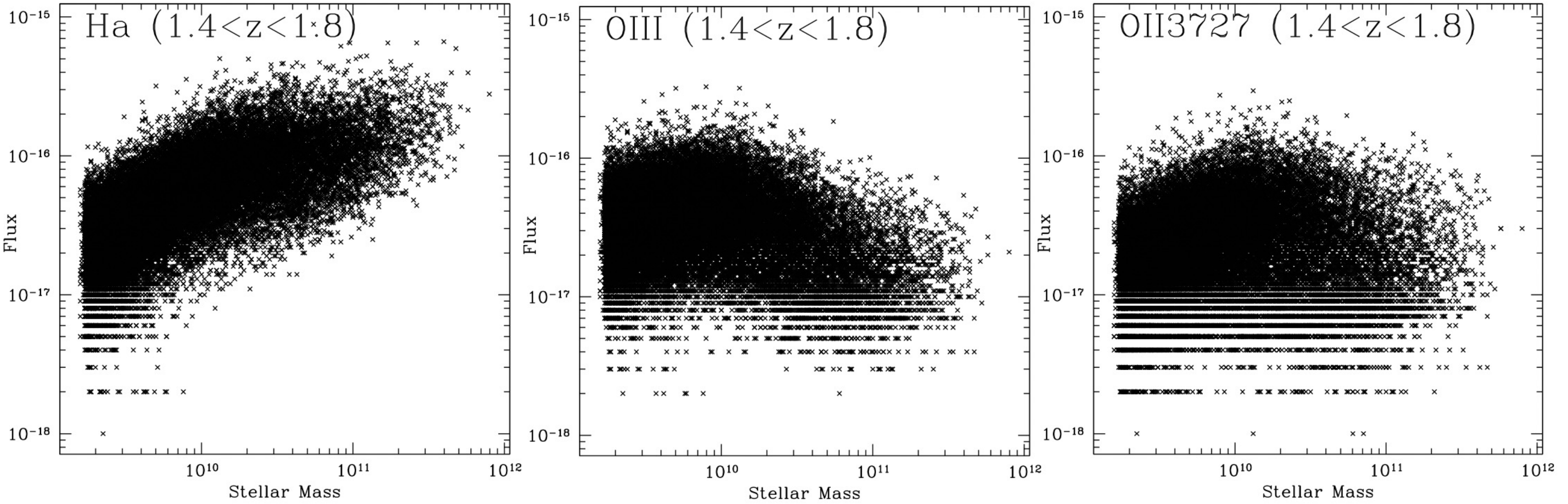

Valentino et al 2017 predictions calibrated on extensive FMOS spectroscopy (Silverman et al; Kashino et al 2013; 2016) for SF galaxies

<Hb> ~ 2x10^{-17} also, fairly const
→ Reliable SFRs from Balmer decr.

Passive: high M* end → redshifts (lack of lines → confirmation)

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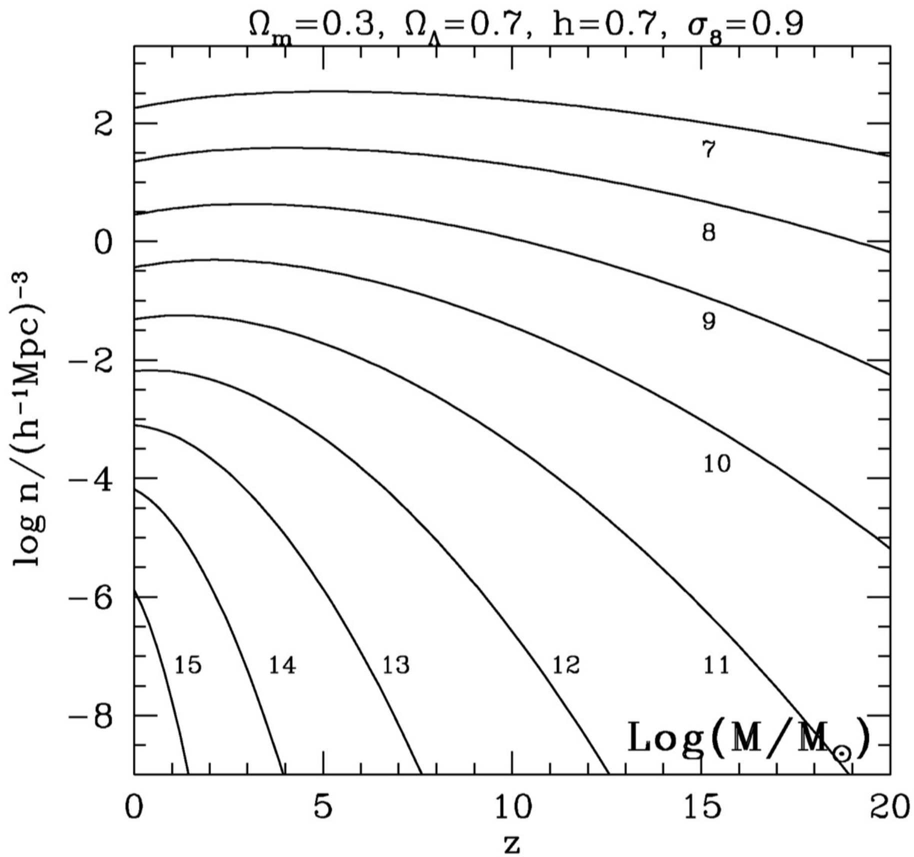
3A) Enough halo statistics from ATLAS ?



Mo & White 2002

Mass dependence:

2<z<3 # halos/deg^2

> 2x10^{13}Msun ~ 300

> 6x10^{13}Msun ~ 1

Redshift dependence:

>4x10^{13} Msun

~40 halos/deg2 at 1.5<z<2

~1 halo/deg2 at 2.5<z<3

The Medium and Wide surveys Absolutely needed to build Statistics on massive halos

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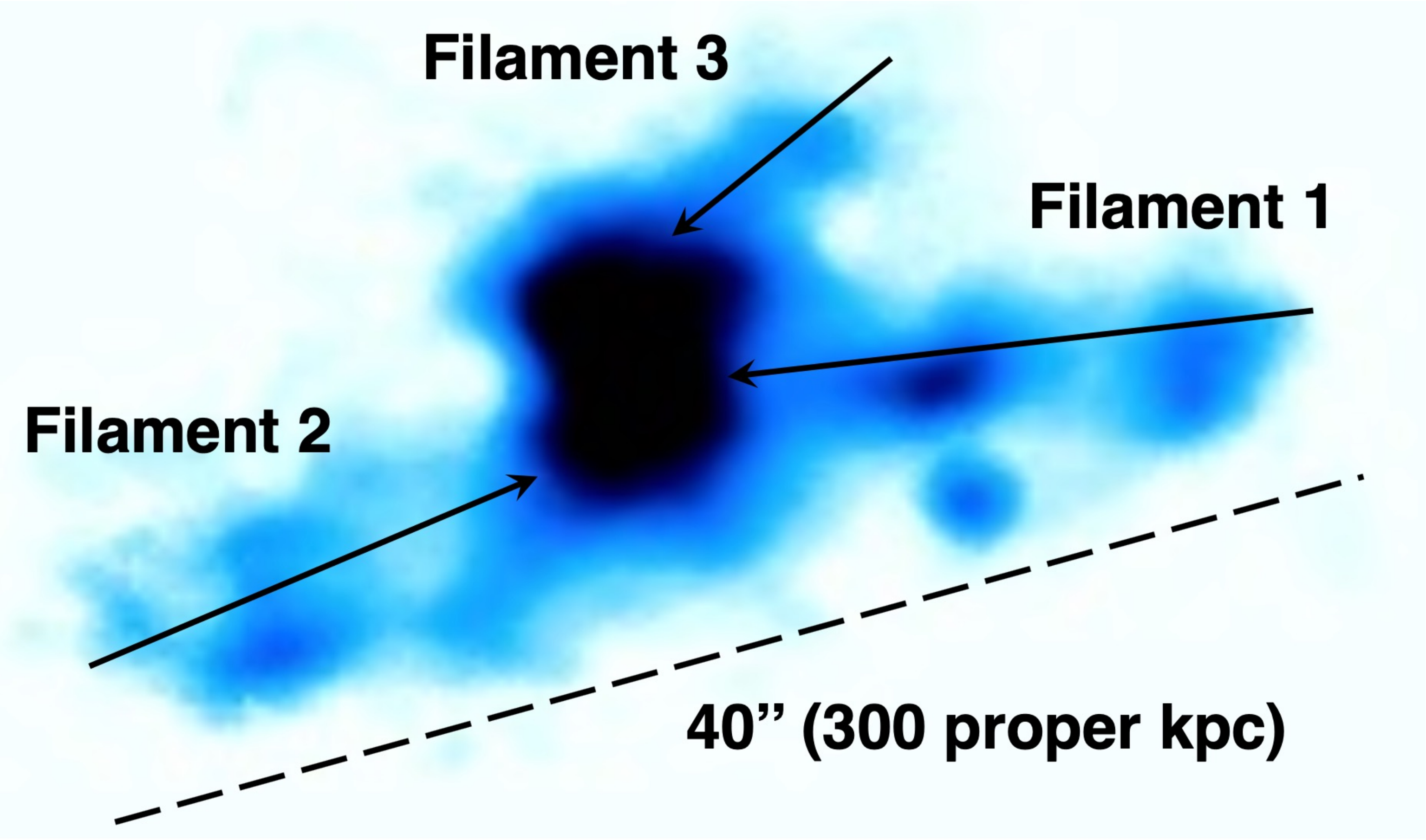
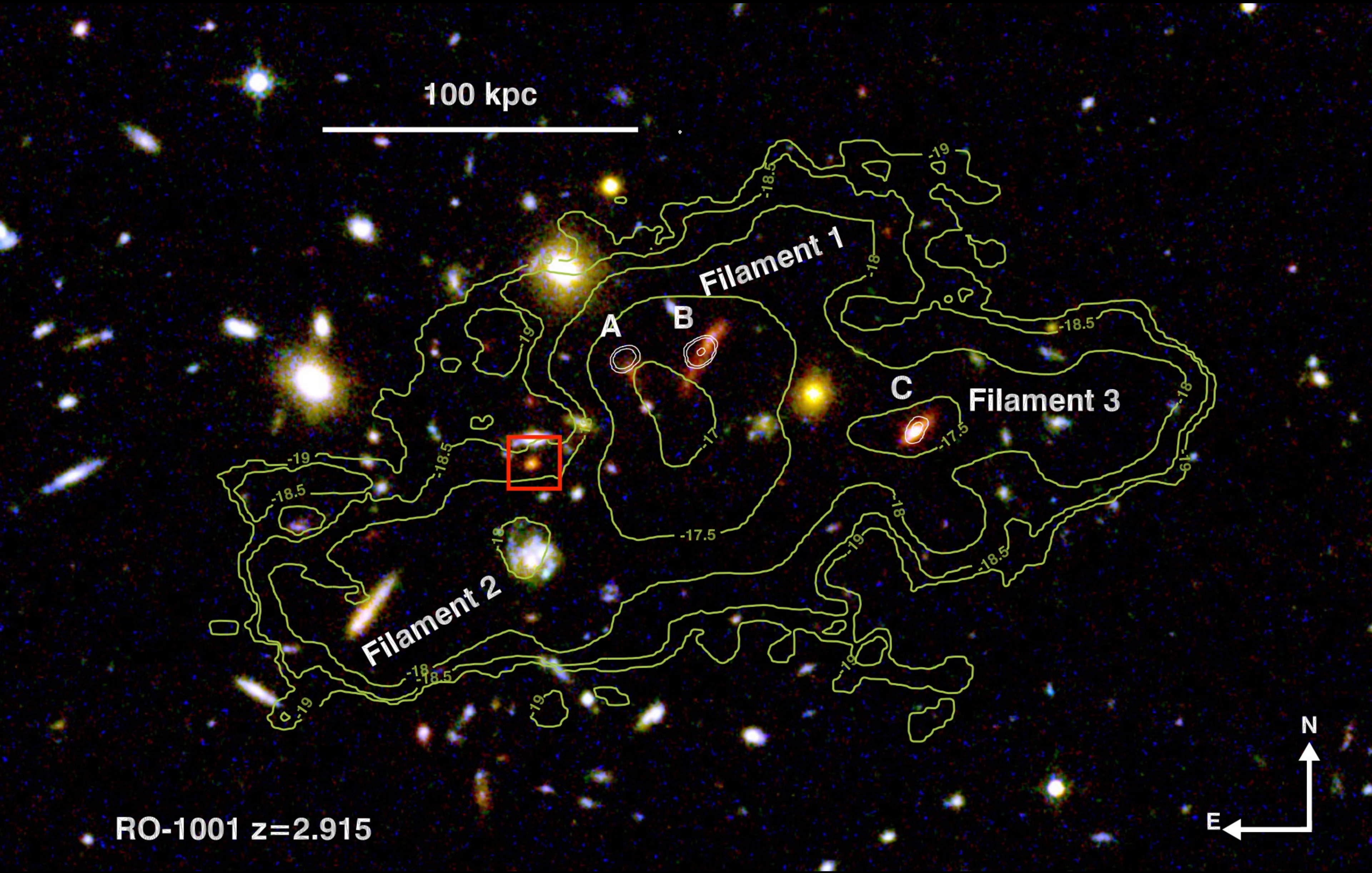
KCWI Lya image of the group RO-1001 @z=2.91



Daddi et al 2021; Kalita et al submitted



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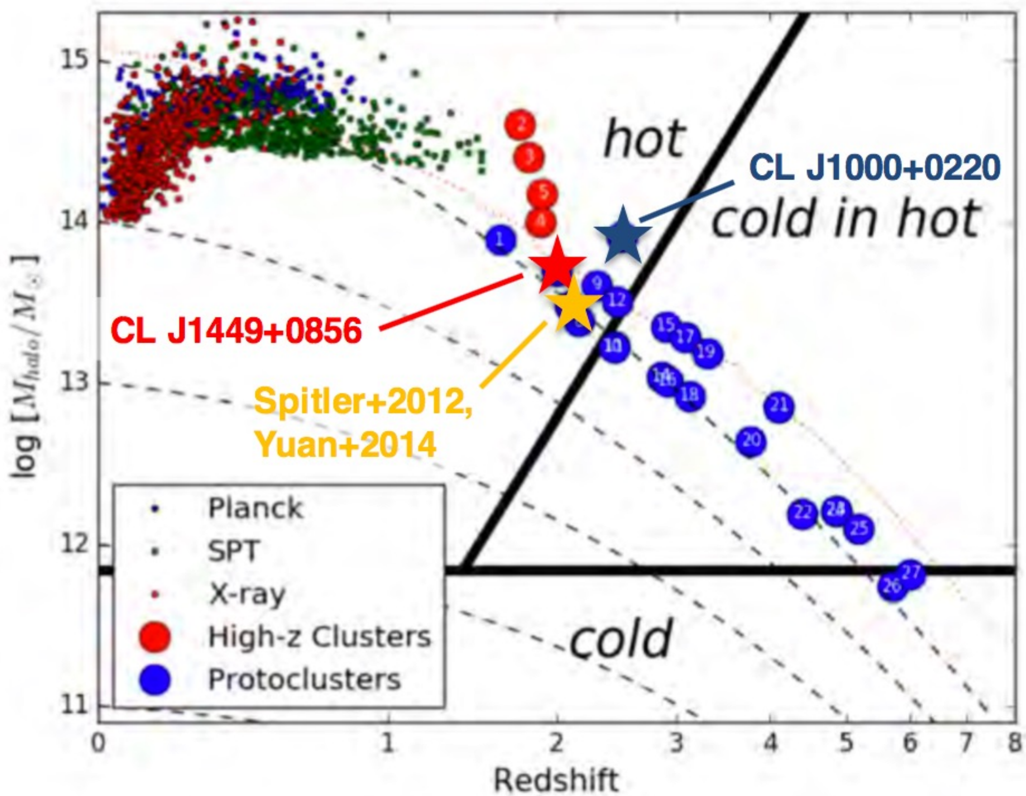
Main science goal: 1) test the gas accretion theory
by measuring distributions of SFR(M_{DM}, z) over M_{DM}~few x10^{13}-10^{14}Msun and 1<z<4



Dekel et al 2009

See implications on SFRs in Behroozi et al 2019

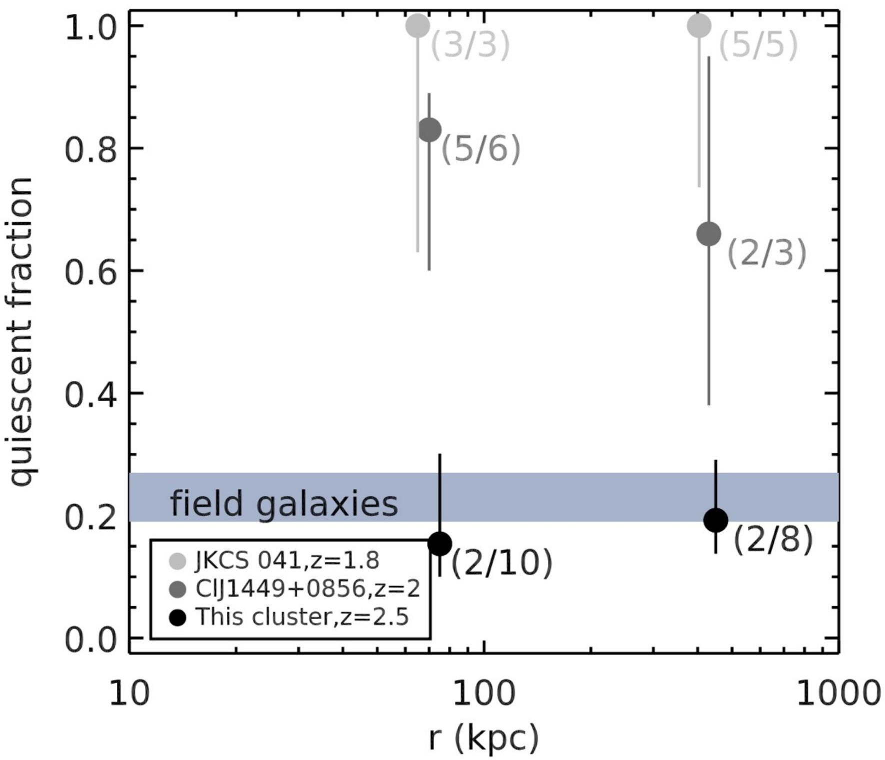
Theory largely untested to date

The main effect (and reason) for this theory is to feed star formation and galaxy growth, so it affects these observables and also quenching through starvation

→ Is there any actual modulation of SFR(M_{DM}, z) due to the cold/hot barreer ?
(hints that DM halo cores pass from being predominantly SF at z>2.5 to SF at z<2)

→ Is there a weak M_{DM} dependence as predicted (mainly redshift driven) ? Or a marked Environmental effect driven by M_{DM} ?

Additional (important/associated) science drivers:
2) what drives galaxy quenching in forming cluster cores ?



Wang et al 2016

→ Measure quiescent fraction fQ(M_{DM}, z) and its dispersion

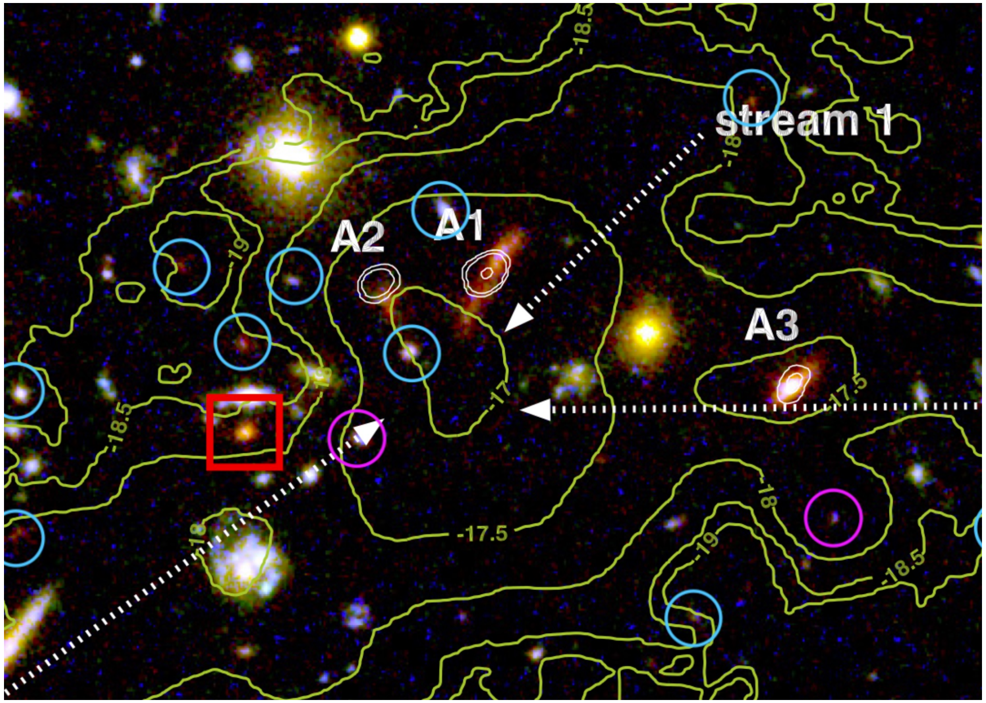
Connected to SFR(M_{DM}, z) but crucially different: how much of galaxy quenching is from starvation ?

→ Measure average ages of passive galaxies t_{50}(M_{DM}, z) and their dispersion

Is there an age-environment relation imprinted at high-z ?

Additional (important/associated) science drivers:

3) what is the relation with morphological transformations ?



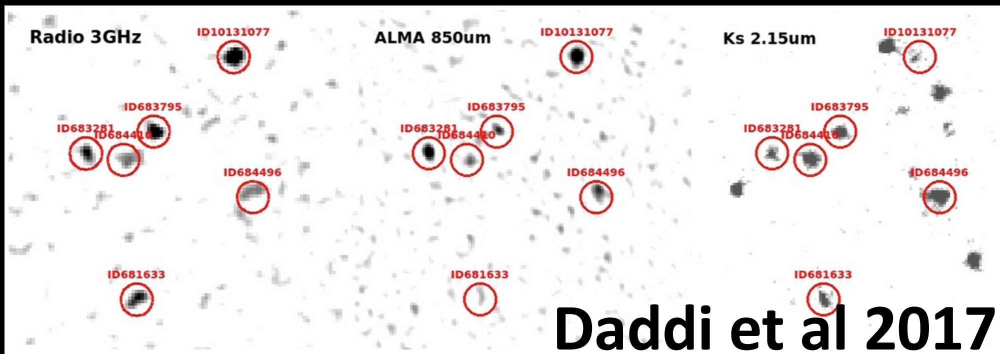
Kalita et al 2021 submitted
Deep HST+ALMA
on z=2.91 RO-1001 group (Daddi et al 2021)

→ Measure morphological fraction $fM(M_{DM}, z)$, where M (Morphology) can be size/compactness, n-sersic, you name it (including mergers)

Connected to quenching but crucially different: e.g., starvation or AGN does not affect morphology, but mergers do

This requires morphologies from Euclid/Roman (and ALMA) plus the ATLAS spetcroscopy (redshift and physical properties)

Synergy with SKA/ngVLA (but also ALMA)



Daddi et al 2017

1) Selection of most active early clusters

2) Provides SFRs,
AGN mechanical feedback

3) Plus HI gas, probing accretion from 21cm line ?

Hugely uncertain,
but would be a major breakthrough

Conclusions:

ATLAS will be a phenomenal machine to quantitatively tailor measurements of Galaxy Formation and Evolution to the underlying hosting DM halos

ATLAS will quantitatively test theories for:

- Gas feeding of galaxies and ensuing star formation regulation (feedback as a result)
- What regulated quenching and role played by environment (DM halo mass)
- Galaxies morphological transformations and role played by environment (DM halo mass)

(this part with the crucial morphological info from Euclid/Roman)