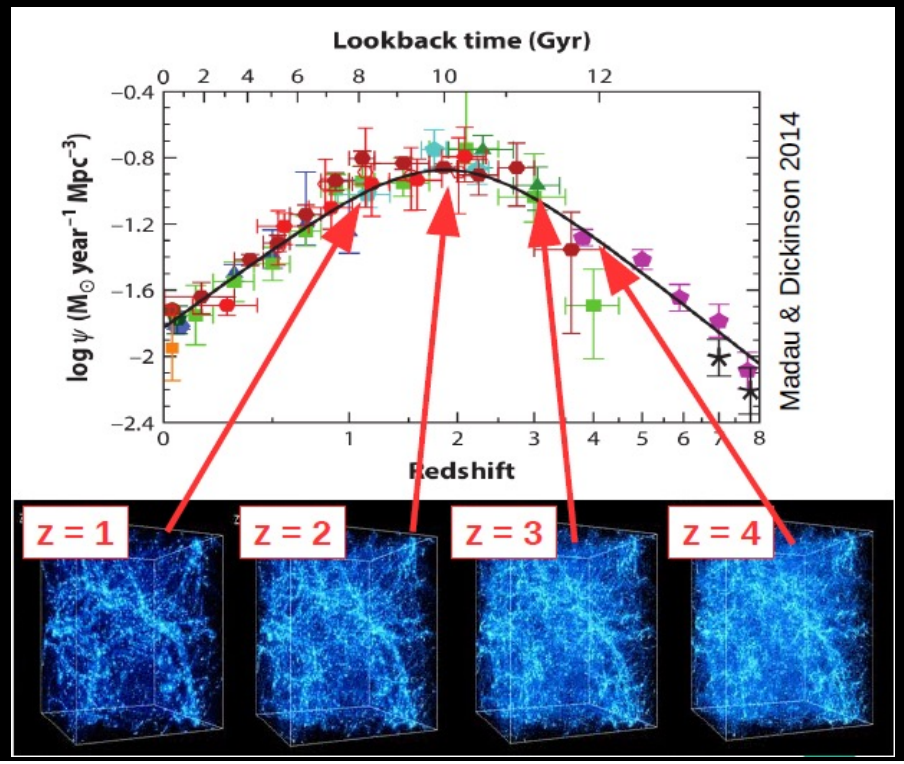
An Optical/NIR Exploration of Forming Cluster Environments at High Redshift with VLT, Keck, and HST

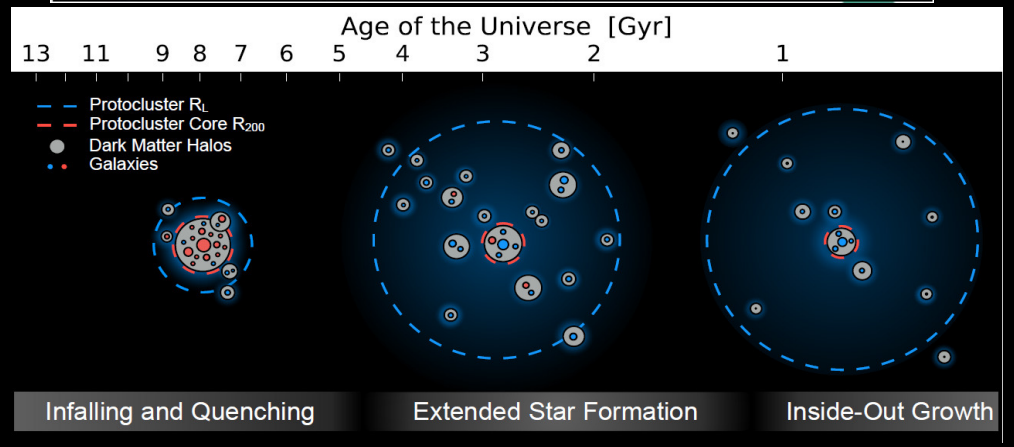
Brian C. Lemaux, Olga Cucciati, Lori Lubin, Roy Gal, Olivier Le Fèvre, Ben Forrest, Ekta Shah, Priti Staab, Denise Hung, Lu Shen and the ORELSE, VUDS, and C3VO Teams

A Journey Through Galactic Environments, Porto Ercole, Italy, 2023 Sept. 25

Some (certainly unneeded) Motivation

So… why study large scale structures at high redshift (z~2-6)?

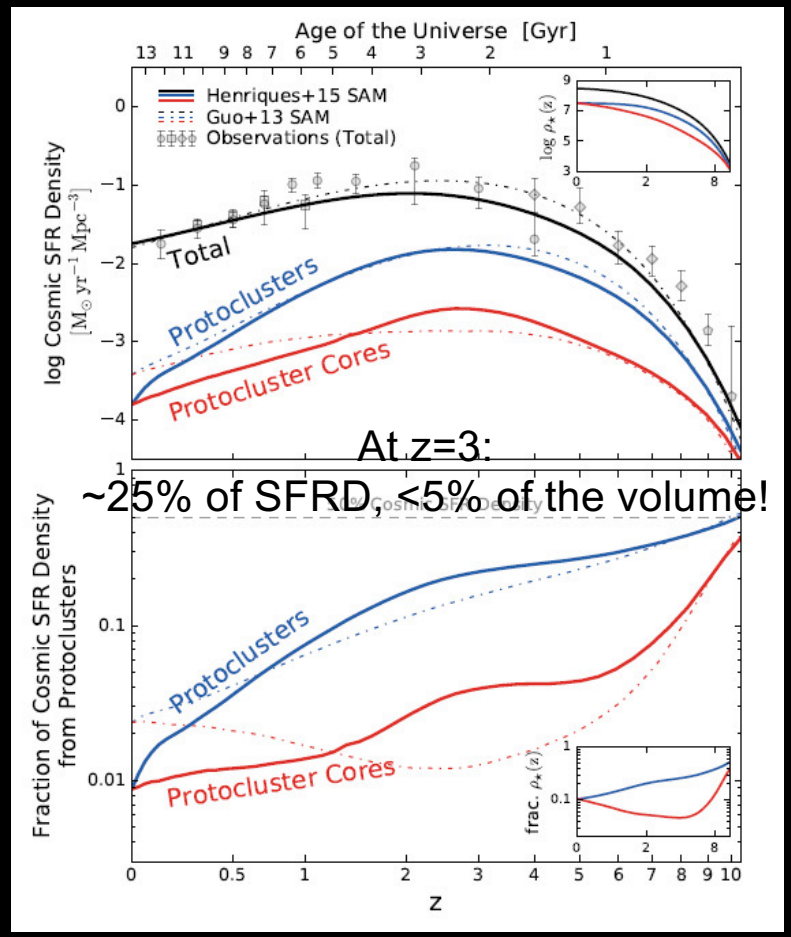




… and not just in the cores (R_{200}), but extended over the entire protocluster!

There's a lot happening everywhere at these redshifts…

… but… maybe especially in forming clusters



Chiang+17 (see also Muldrew+18)

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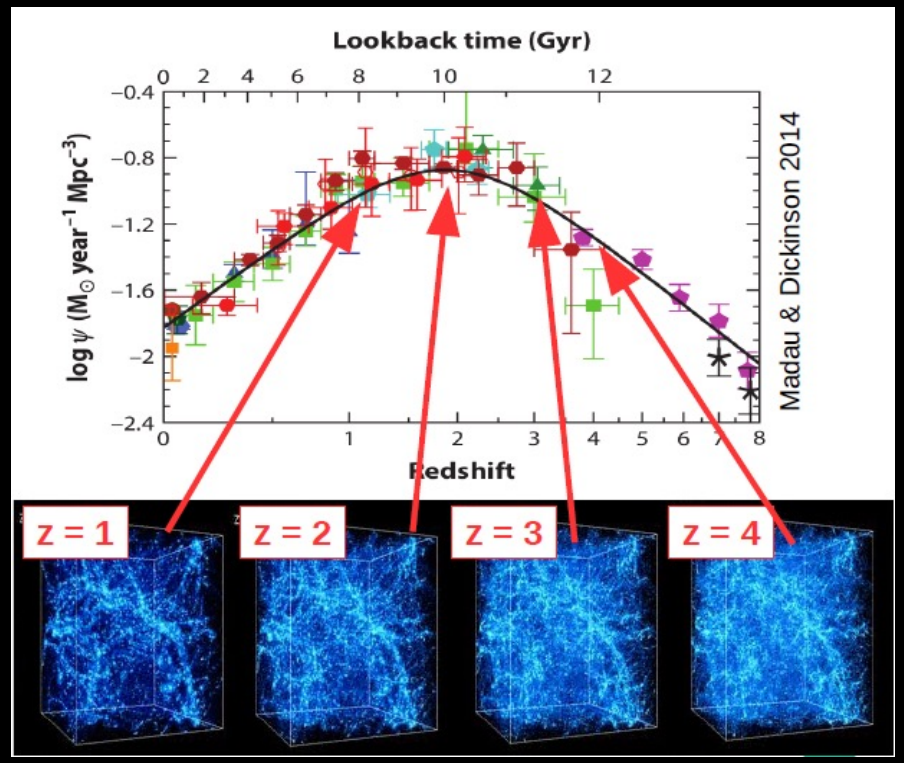
So… then why study large scale structures at high redshift (z~2-6)?



- This is the epoch of formation for modern massive ellipticals, the first seeds of these nascent galaxy clusters

- Observe the reversal of the SFR-density/color-density relationships as gas-rich galaxies coalesce in the protocluster environment

- Search for signs of environmental quenching at these redshifts. What would be causing it?

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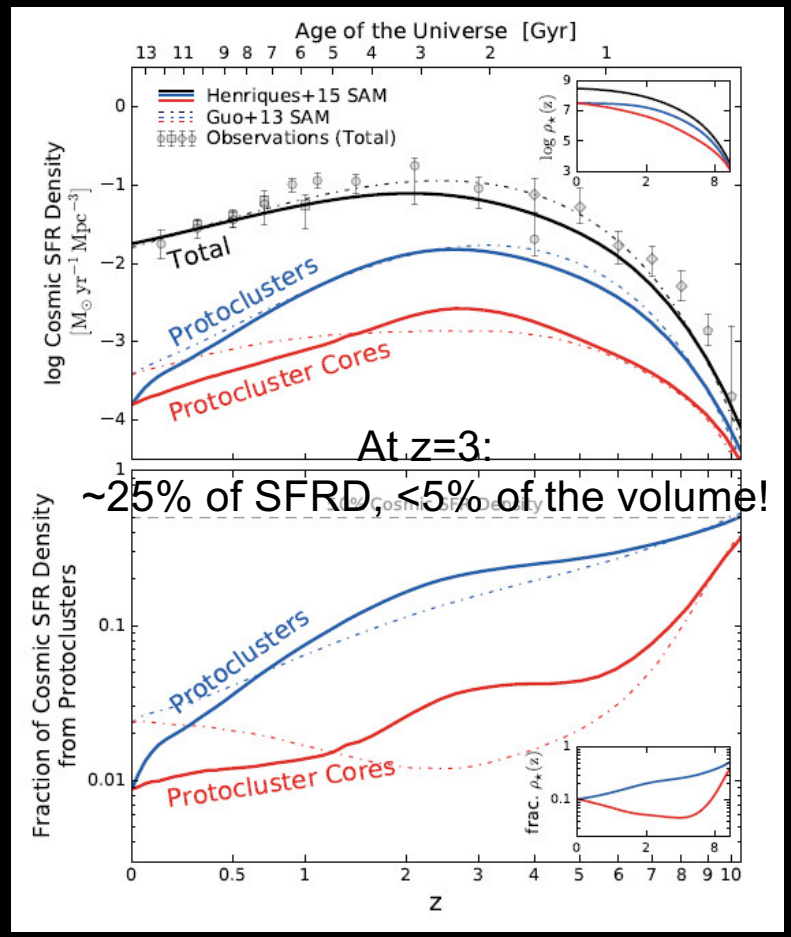

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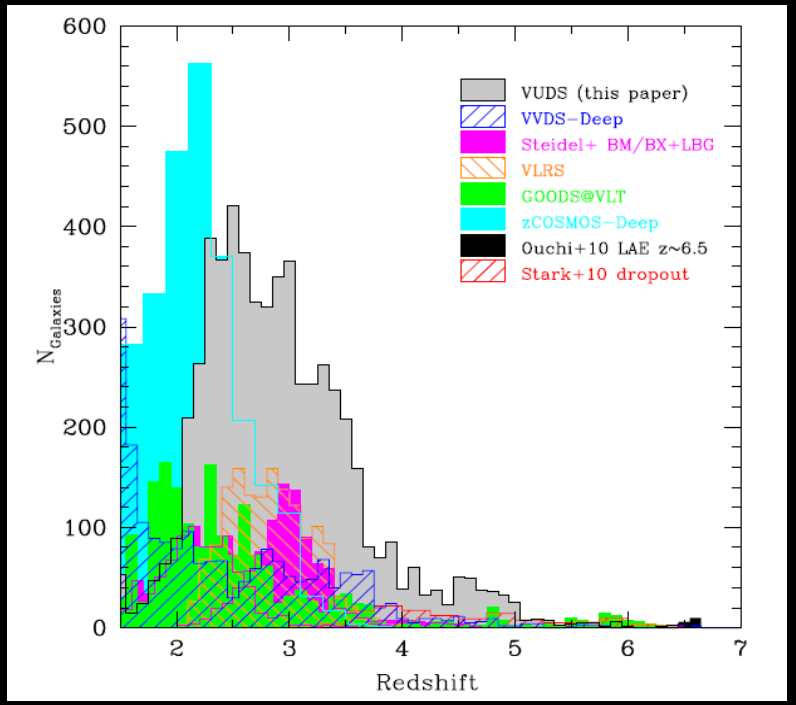
VUDS | VIMOS Ultra Deep Survey

Le Fèvre+15

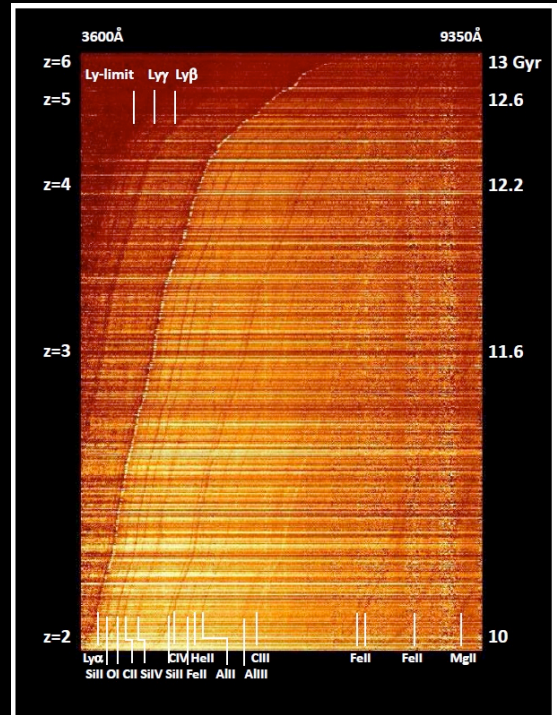


Targeted ~10000 objects in 1 deg^2 over three fields (CFHTLS-D1, ECDFS, COSMOS), all with >= 10-band imaging

Mostly photo-z+magnitude with some color and narrowband cuts

Peak of the magnitude distribution at $i' = 25$ ($\sim 0.3L^*_{UV}$ - $3L^*_{UV}$).

R~230, 14h integration time per pointing per grism



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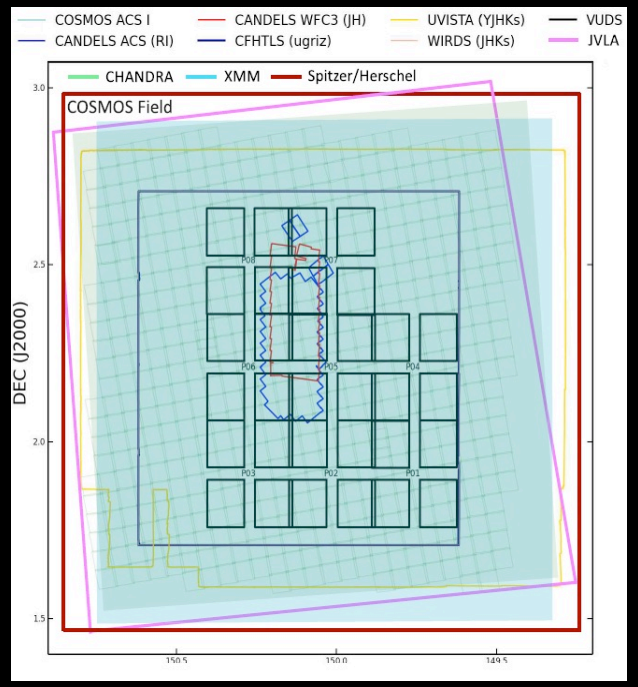
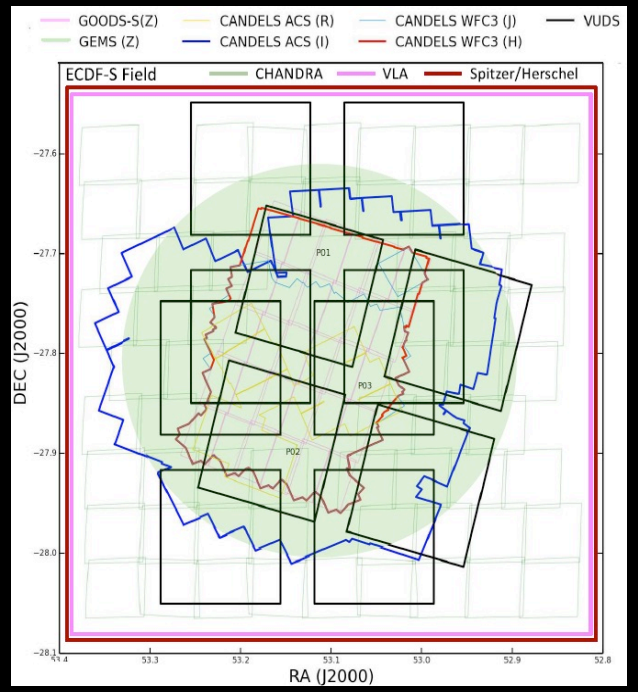
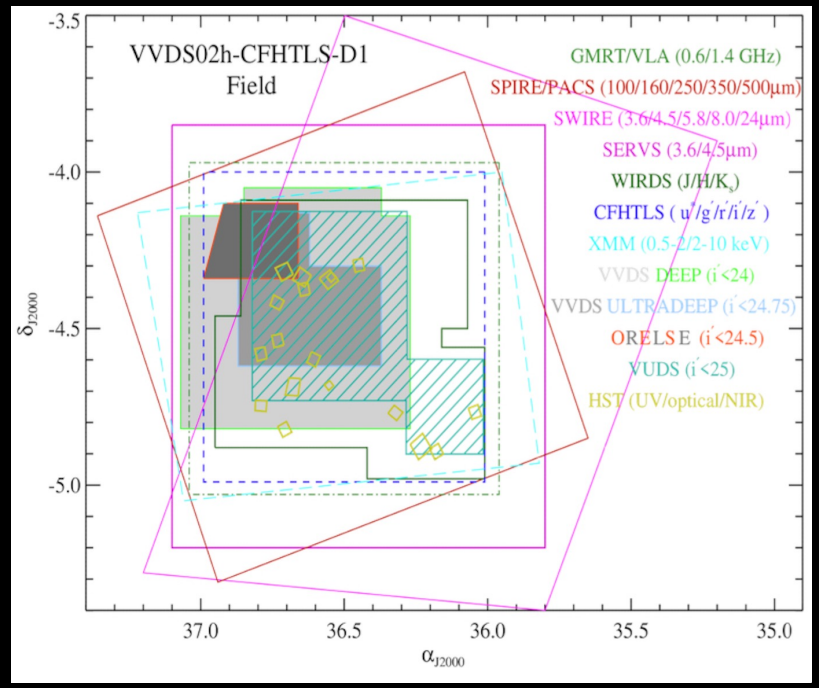
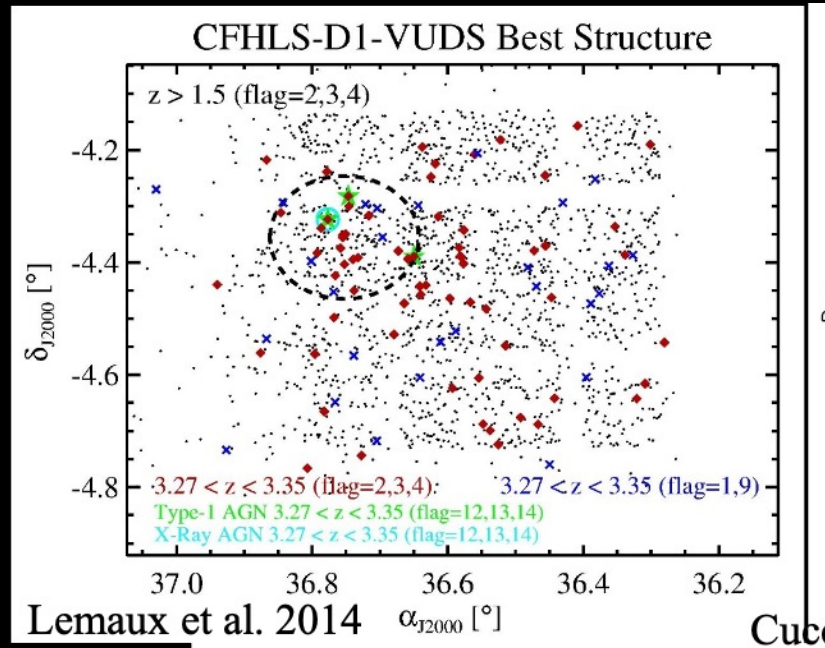


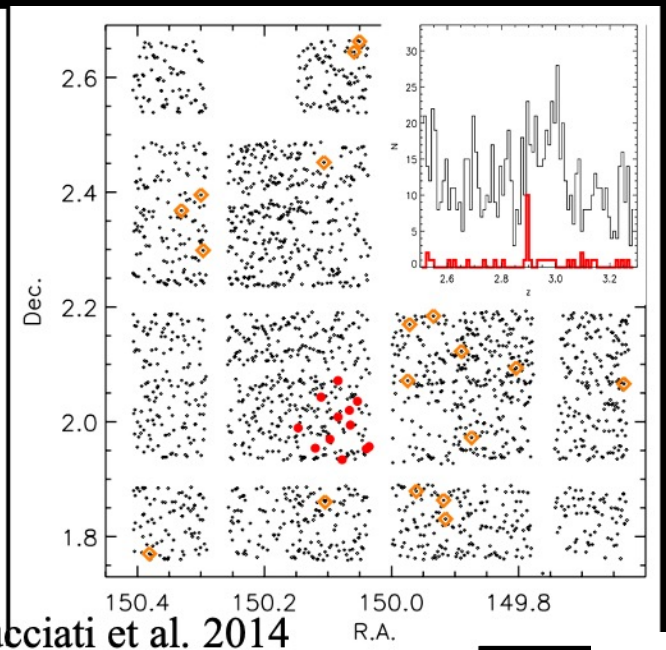




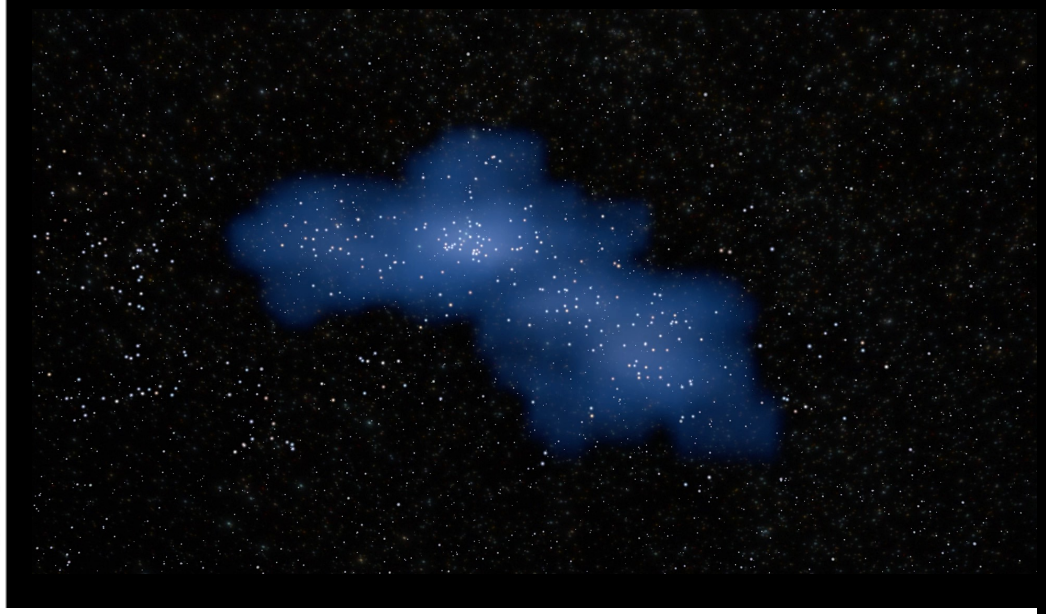
Protostructures in VUDS

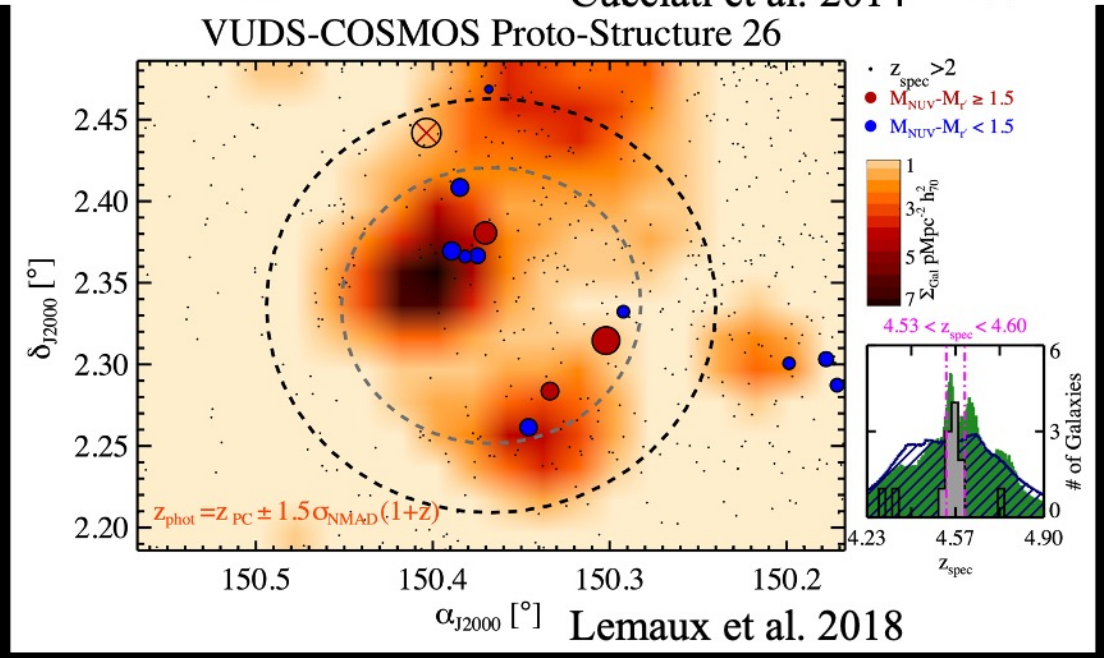


Lemaux et al. 2014



Cucciati et al. 2014





Lemaux et al. 2018

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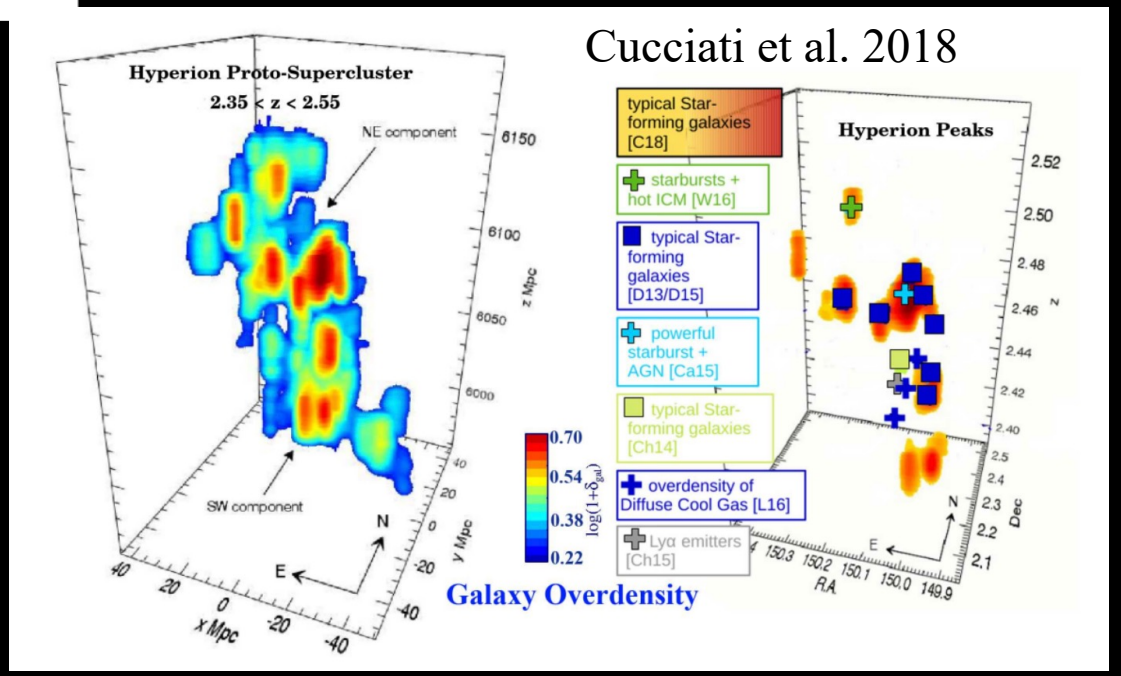
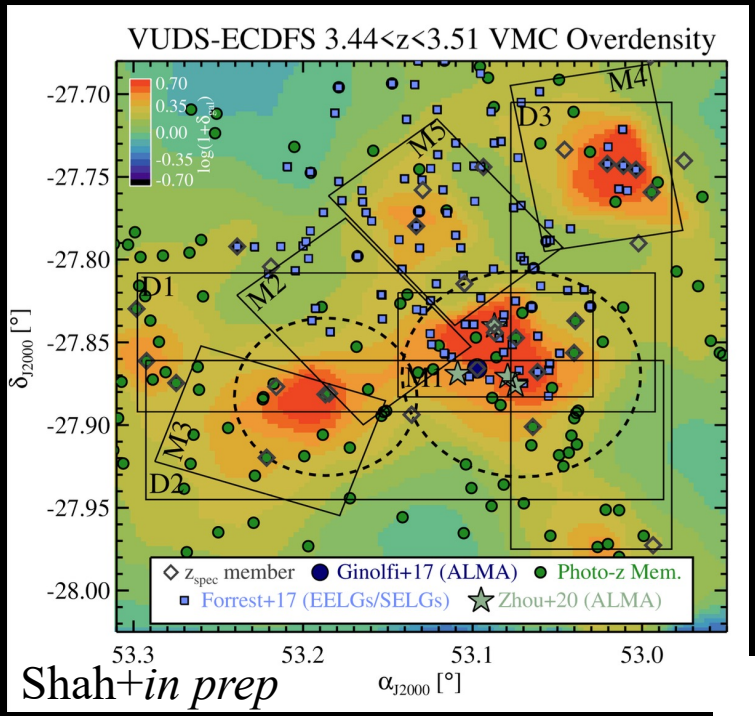


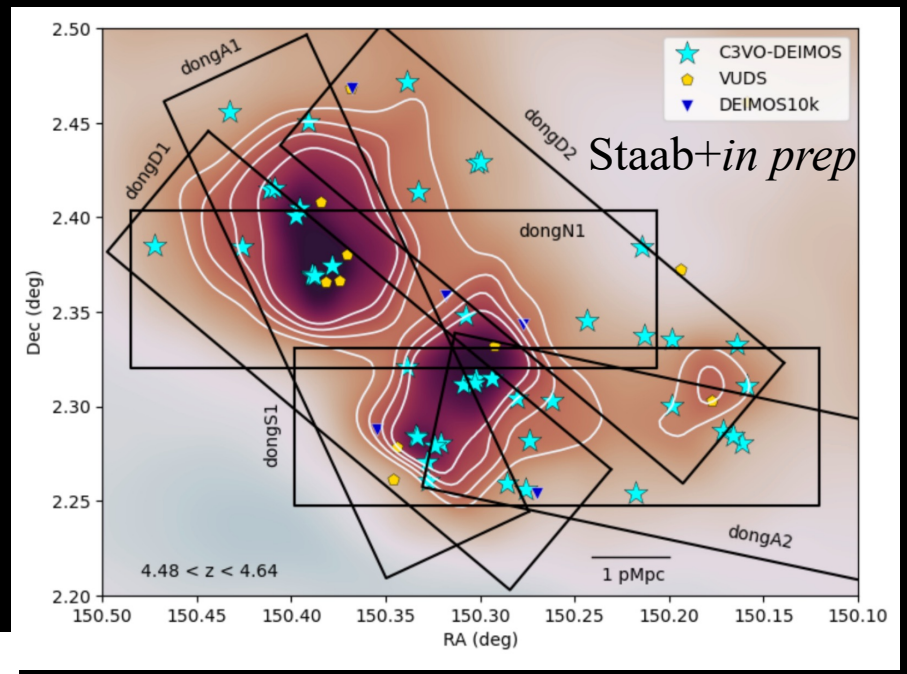
Charting Cluster Construction with VUDS and ORELSE (C3VO)

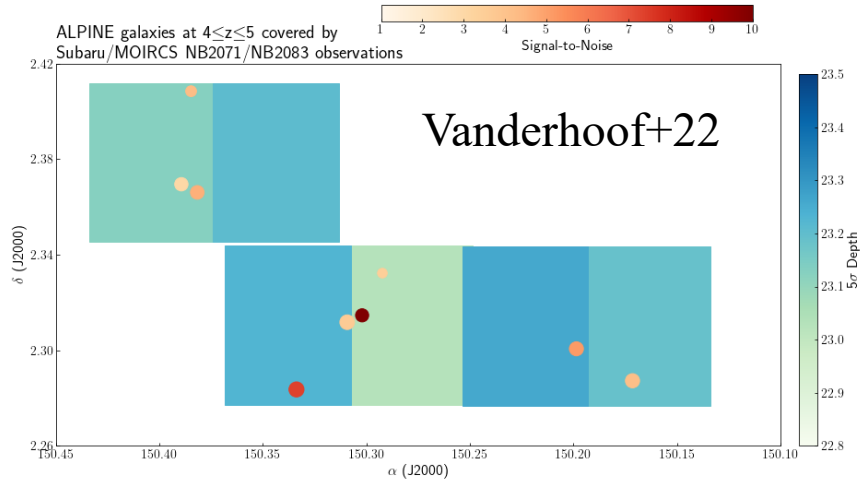


Targeting the six most massive protostructures in VUDS ($2.5 < z < 4.5$)

Observations on LARGE scales (>10 cMpc)

- ~30 nights on Keck DEIMOS/MOSFIRE spectral observations
- ~15 nights on Subaru MOIRCS/SWIMS narrowband observations
- 50 orbit HST program (HST-Hyperion) F160W and G141 grism observations



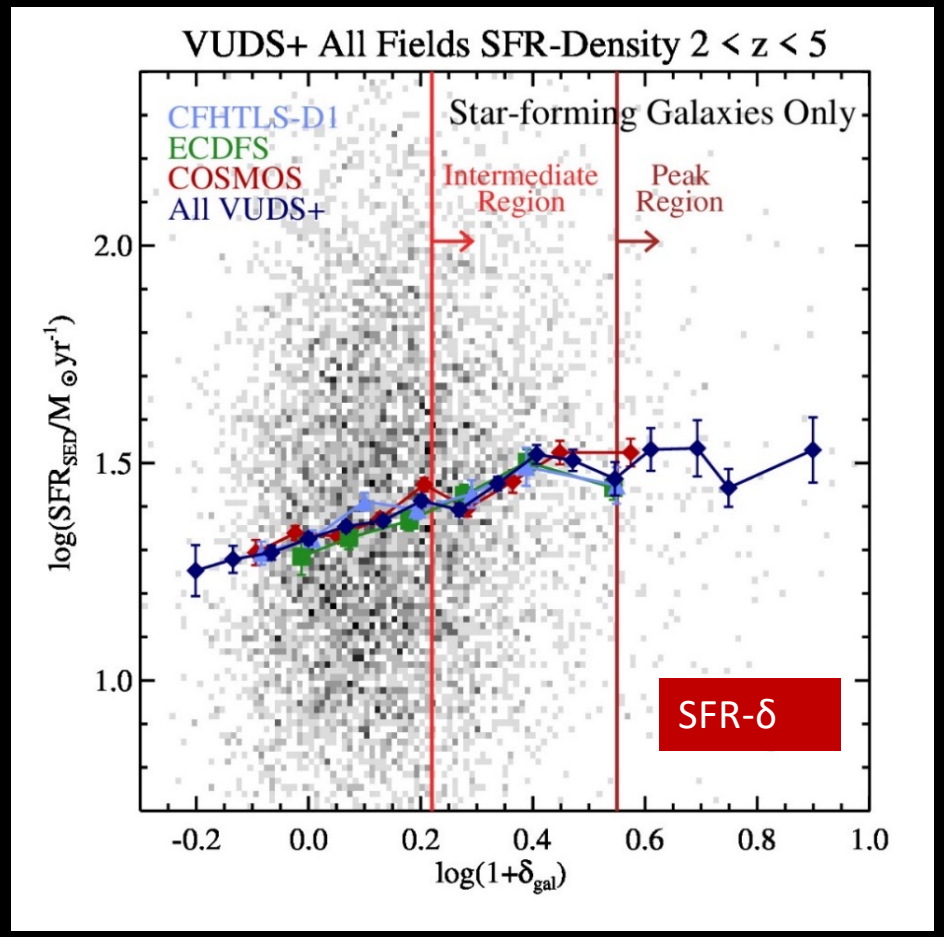


See talks by Ekta Shah, Priti Staab, and Ben Forrest: Case Studies in C3VO

The Reversal of the SFR-Density Relation

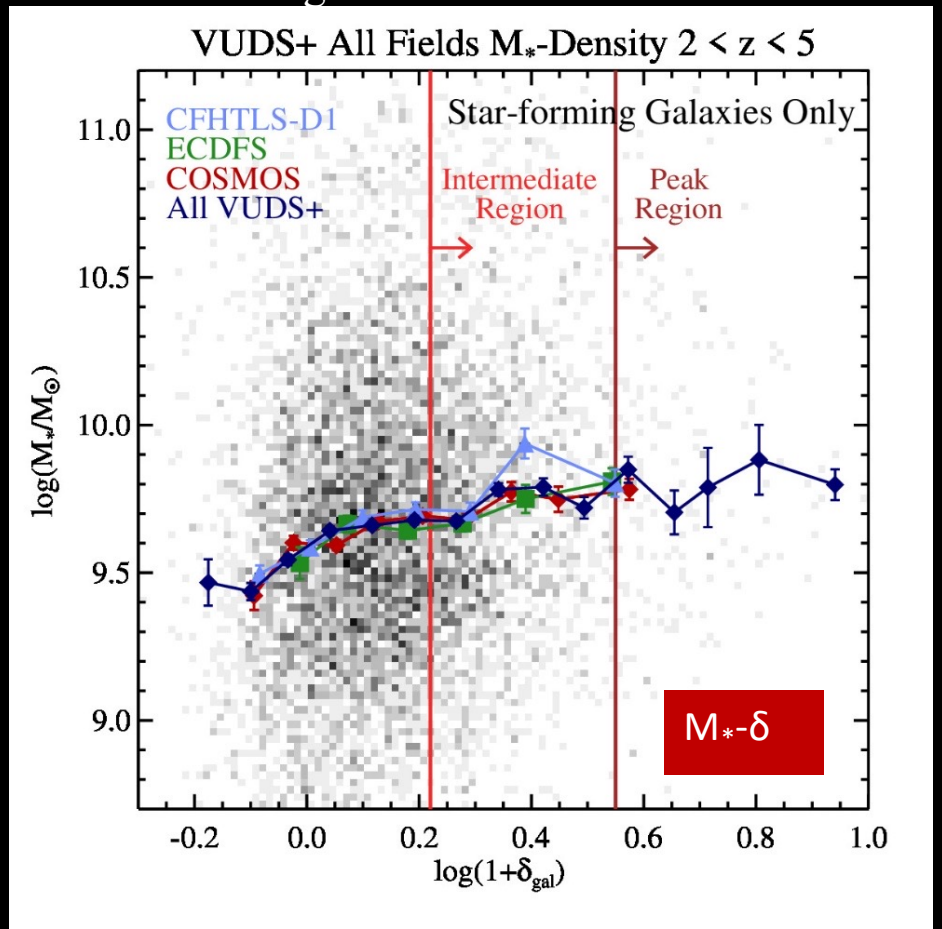
Protostructures in VUDS/C3VO appear to be a wildly heterogeneous population as do the galaxies which reside within them

VUDS+zCOSMOS+VVDS+C3VO DEIMOS+others ($2 < z < 5$): a statistically significant reversal of the SFR-density relation…



Lemaux+22

… but is just a result of the increased number/fraction of massive galaxies in dense environment?



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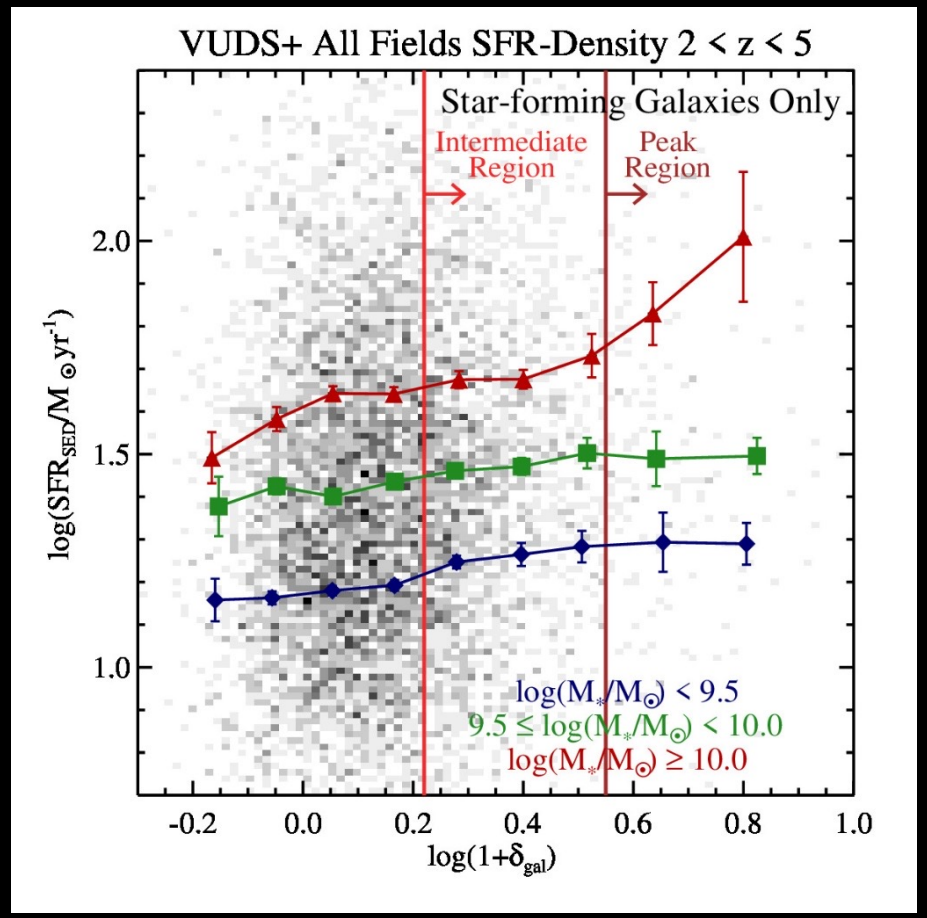

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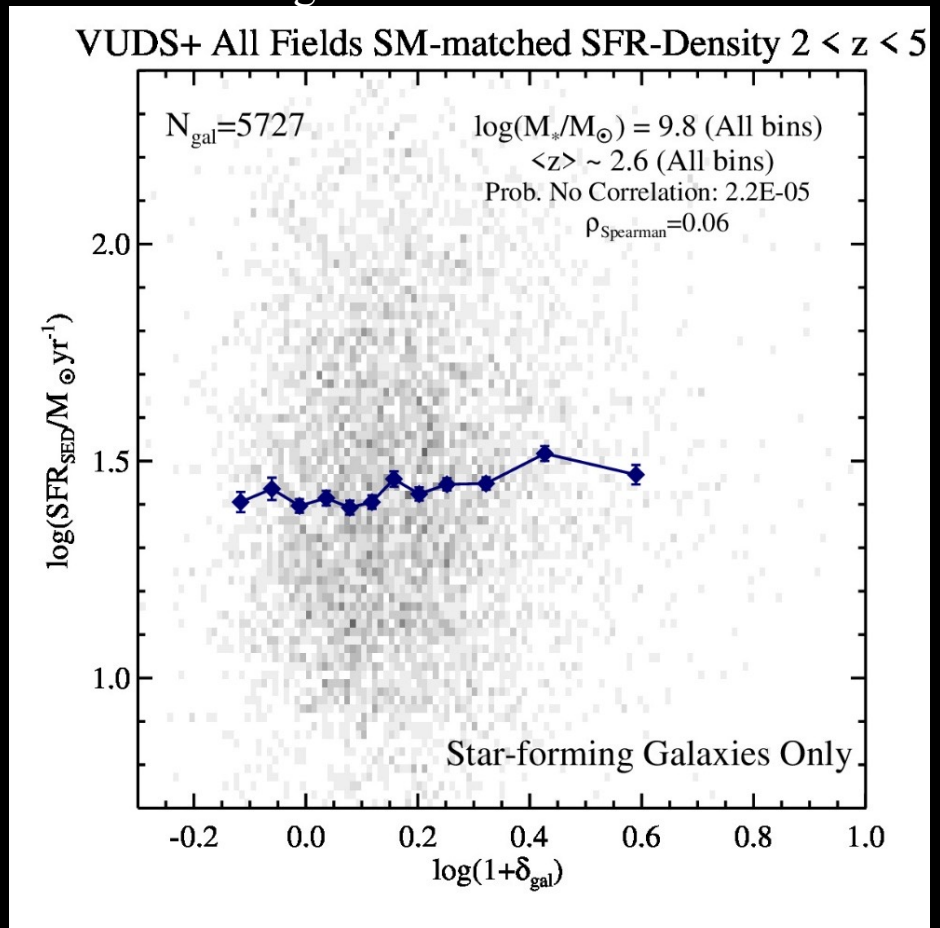
… but is just a result of the increased number/fraction of massive galaxies in dense environment? No!



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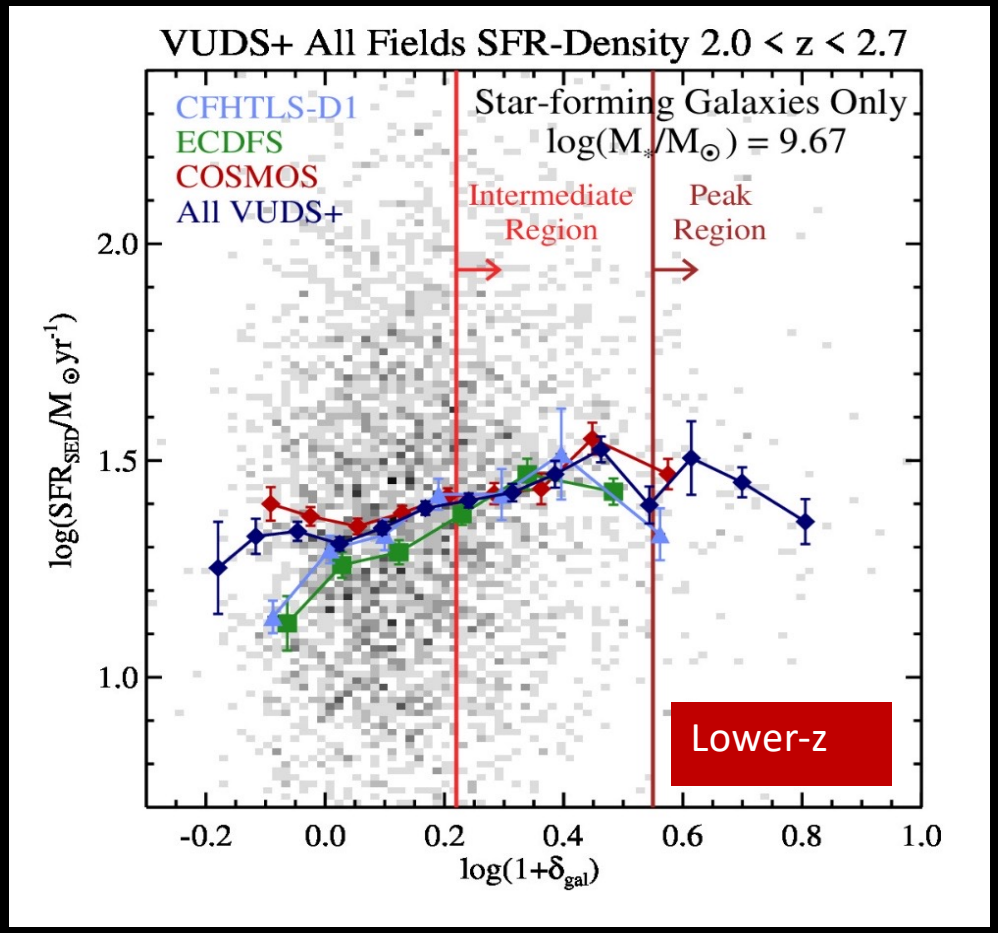
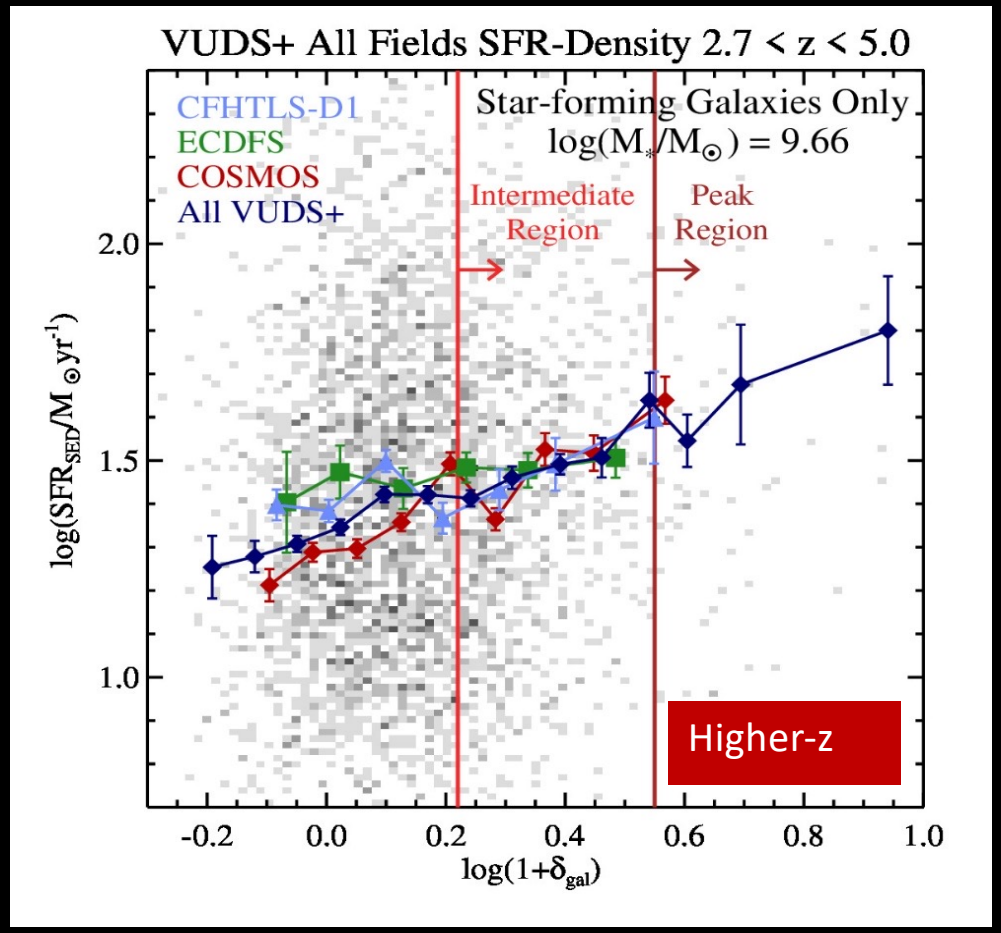
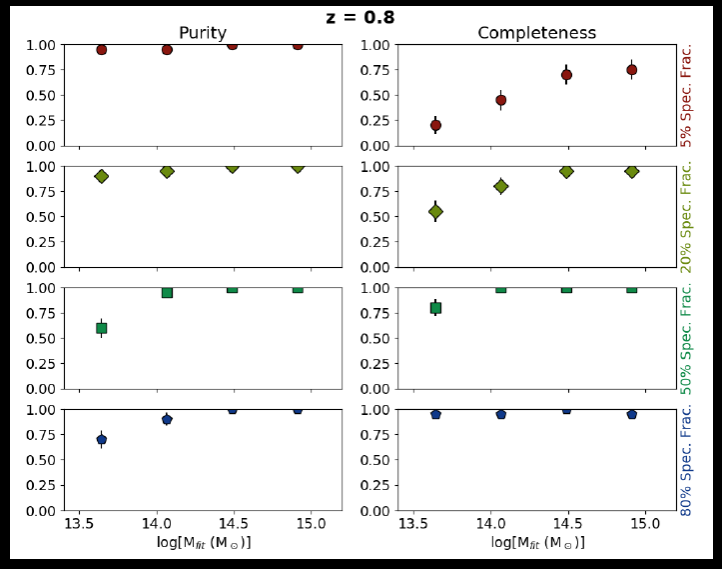
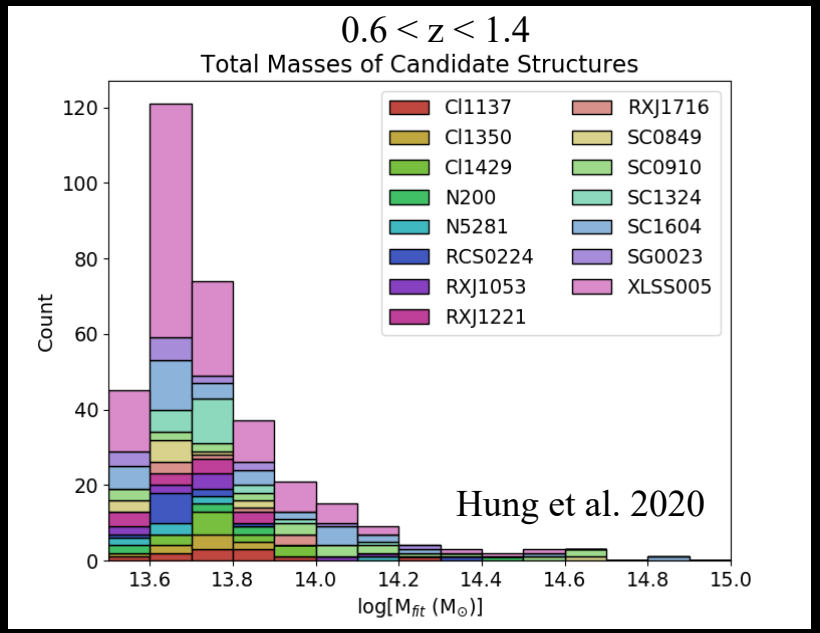


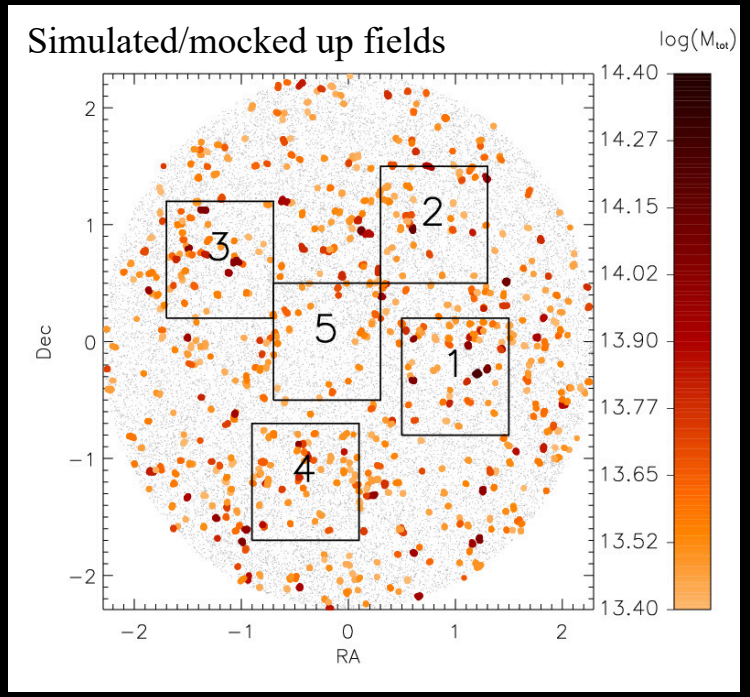


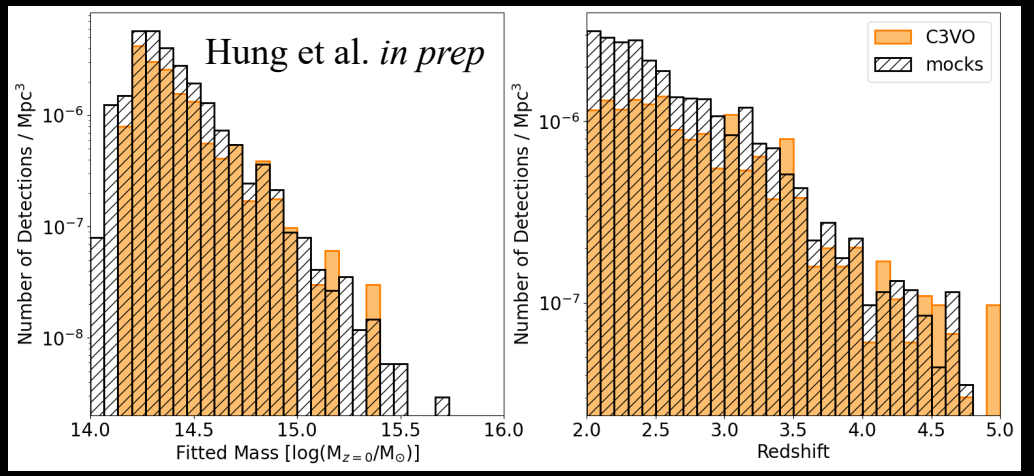
Lemaux+22

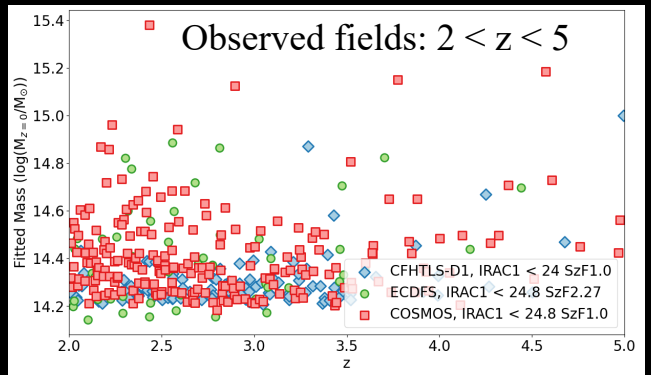
VMC mapping + training on mocked up custom light cone/semi-empirical approaches: ~750 structures in C3VO at 0.6 < z < 5 with measured masses

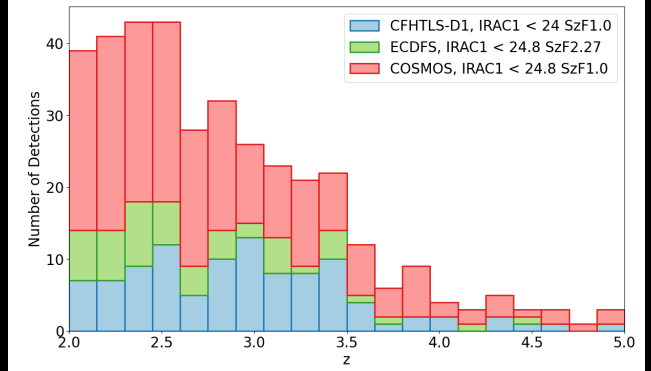


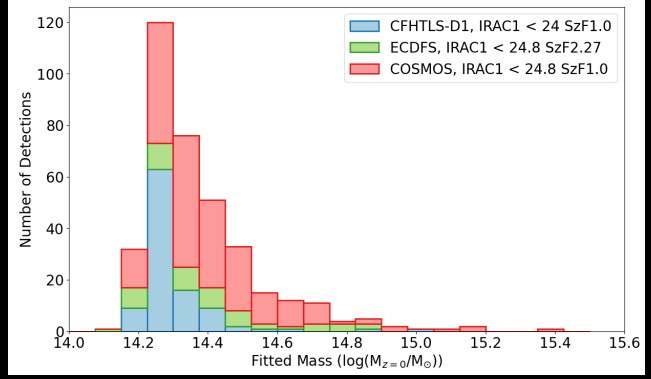












Conclusions

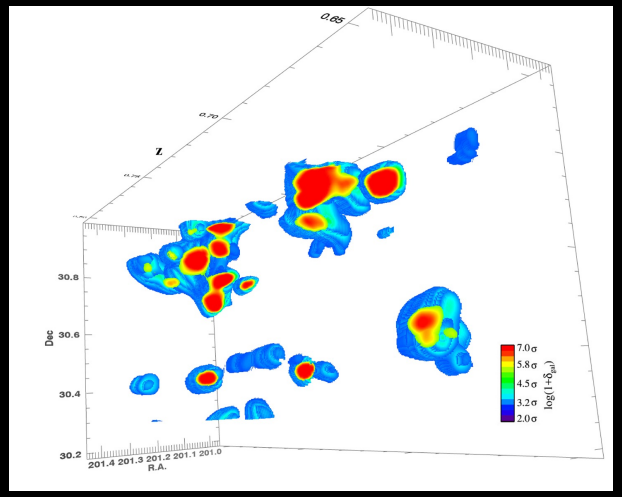
- Optical/NIR observations are powerful to discover and characterize (proto)clusters at z>0.5 *if* care is taken in selection and sampling

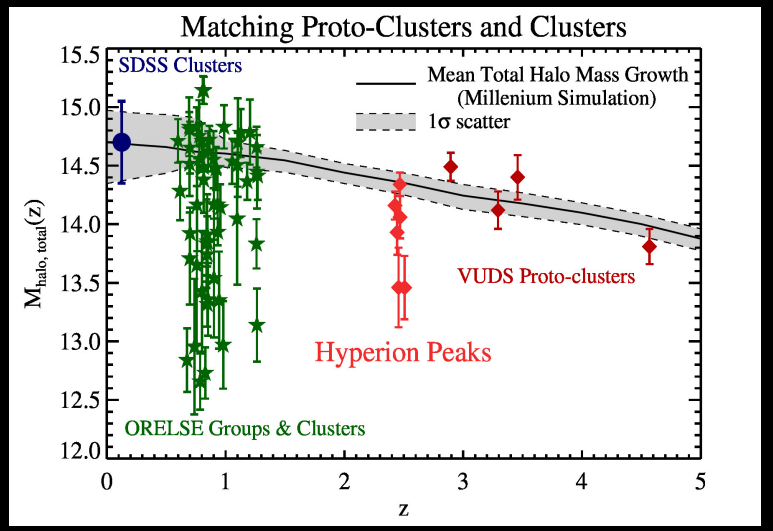
- Many protostructures discovered in the C3VO survey, follow-up is revealing stronger stellar mass segregation in some, stronger star formation segregation in others (see talks by B. Forrest, P. Staab, and E. Shah)

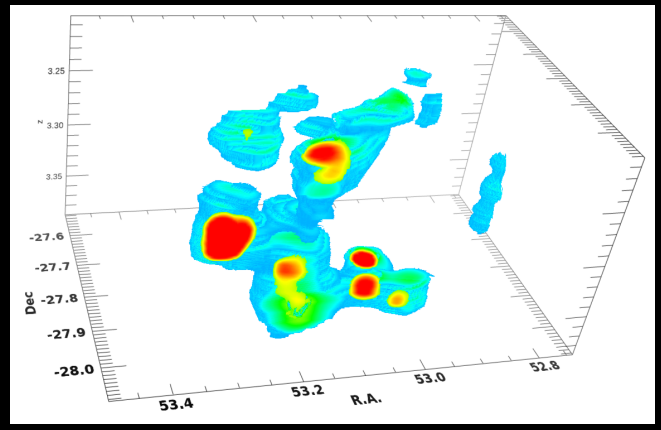
- Evidence for the reversal of the SFR-density relation for SFGs at z>2, however some protoclusters show an excess of redder, older galaxies (both effects can be present!).

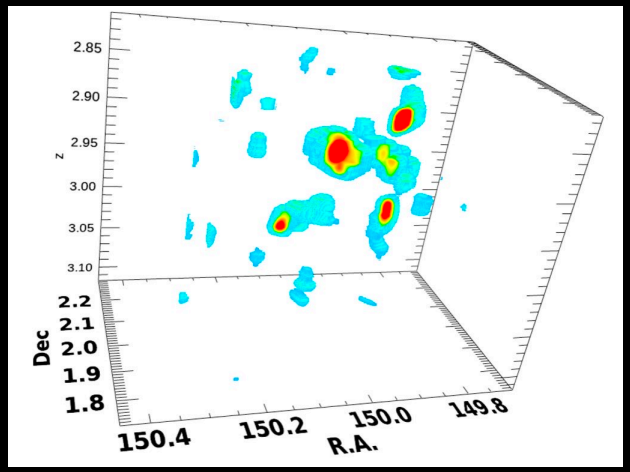
- Approximately 750 groups, clusters, superclusters, and their progenitors discovered C3VO. Much more to come!

- ORELSE final catalogs/data available! (email ORELSE@ucdavis.edu)









Mahalo! Grazie!