LBT Observations of the Most Massive Galaxy Protoclusters in the Early Universe

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and collaborators

Questions:

- How to find the most massive large scale structure at high redshift?
- What are the progenitors of the most massive local galaxy cluster ?
- Where are regions representing the most active galaxy assembly ?
- How to find the best sightlines to probe IGM-cGM-galaxy interactions?

-- tracers: early massive galaxy overdensity and proto-clusters

How to find the most massive overdensity and protoclusters at high-redshift?

a. Use biased halos:

Quasars
Sub/mm and Radio galaxies
Lyman alpha blobs
S-Z clusters

they trace collapsed objects, not large scale structure

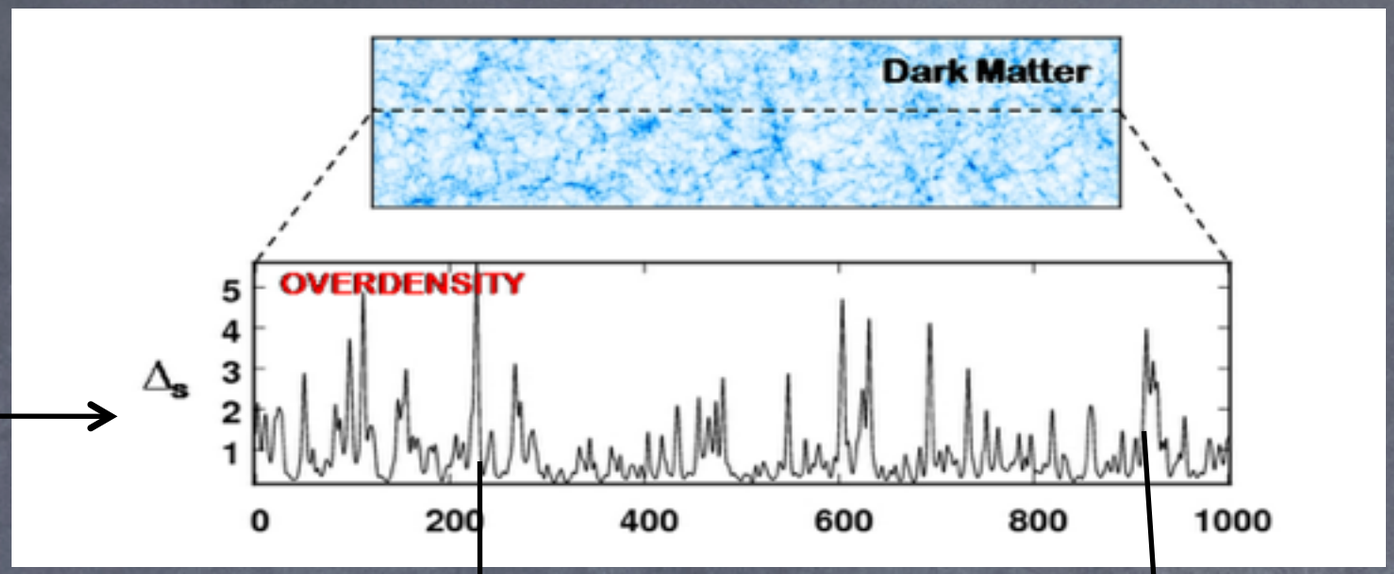
b. galaxy redshift surveys

small FOV for deep field, limited survey volume, incomplete selection because of wavelength coverage and selection technique.

A more complete technique to search galaxy overdensity and protocluster from larger volume will be highly desirable

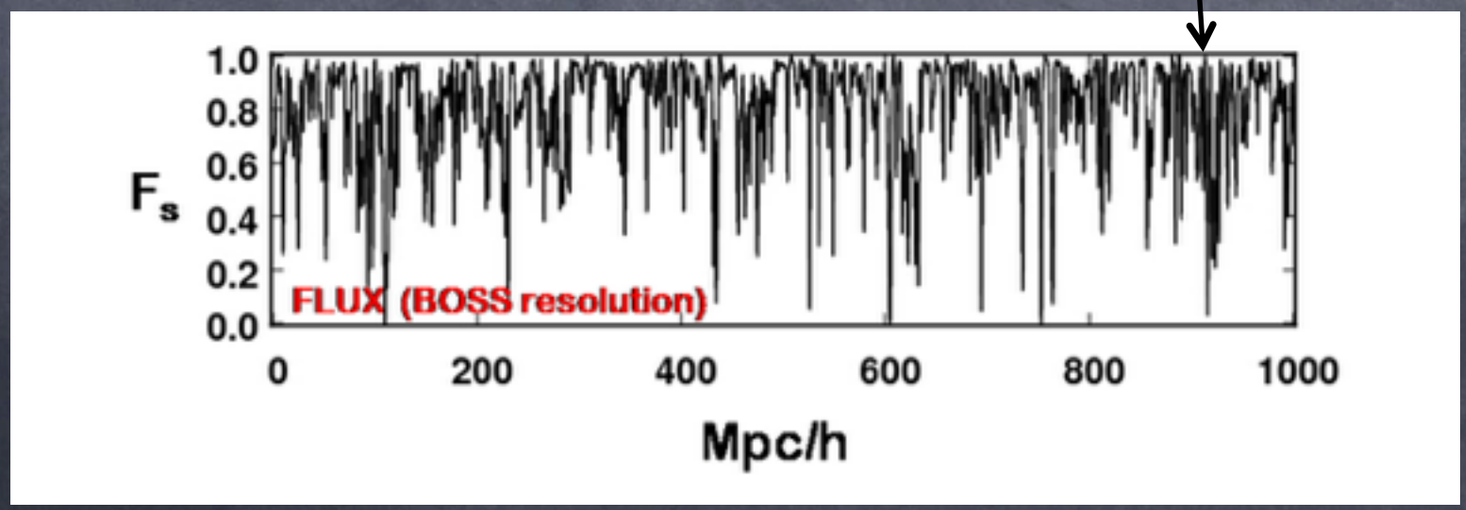
A simple idea: HI absorption traces matter overdensity

Matter Overdensity



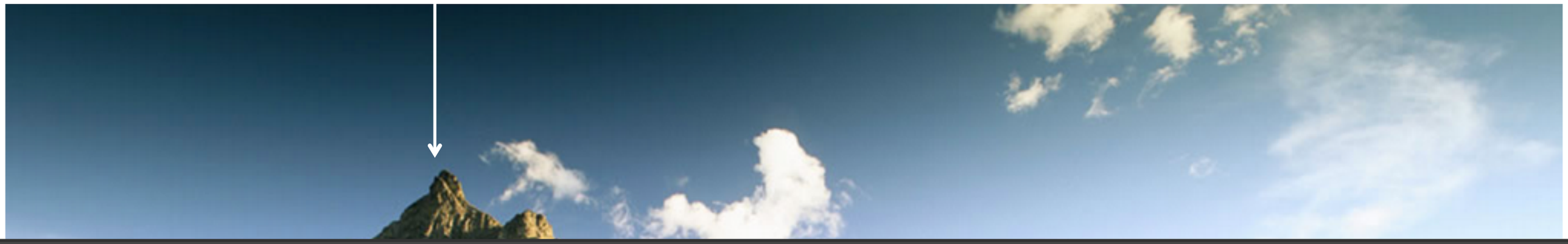
Signature on quasar spectrum

Large scale overdensity
-> large EW of absorption

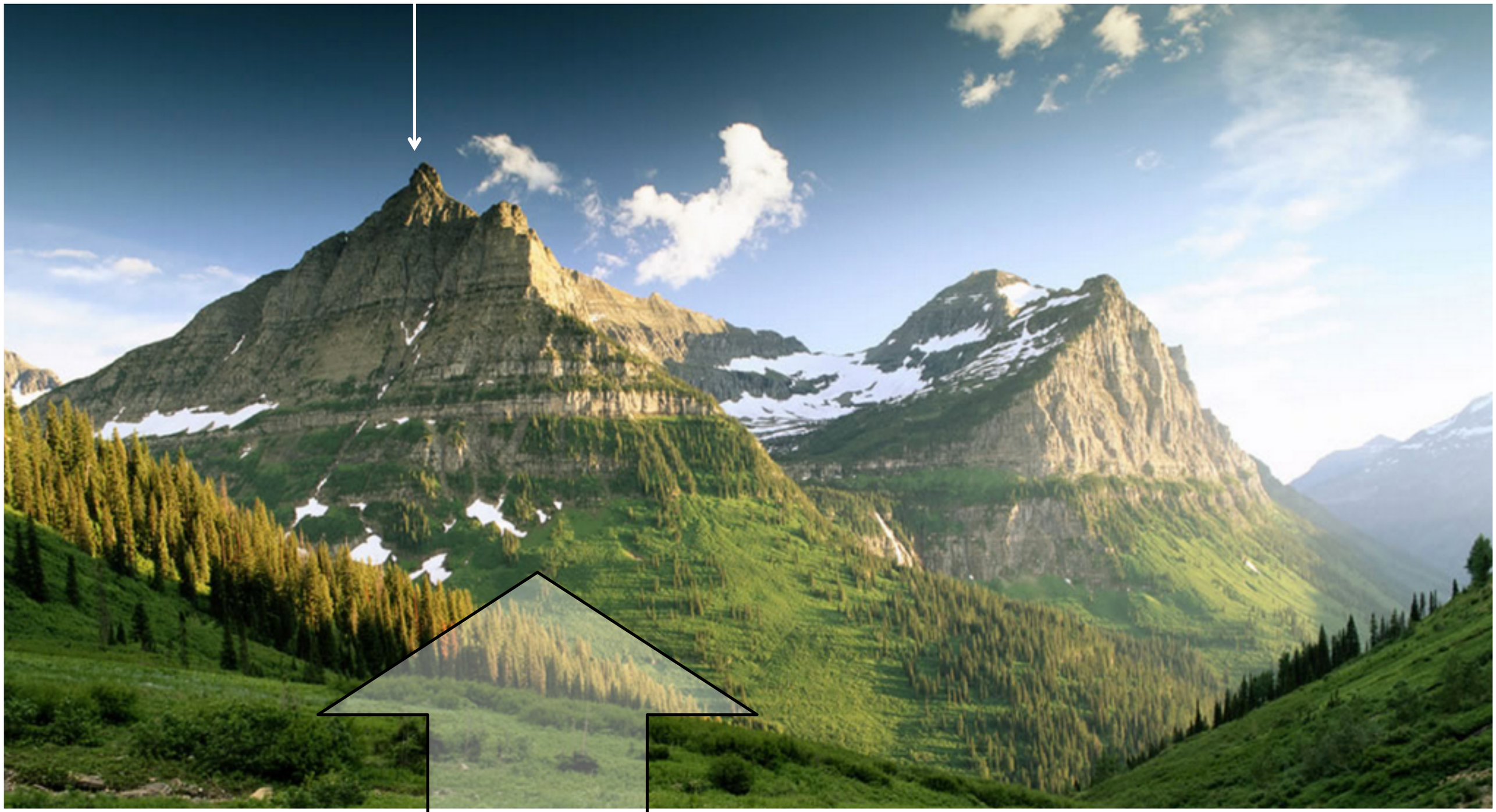


Peirani et al. (2014)

Galaxy



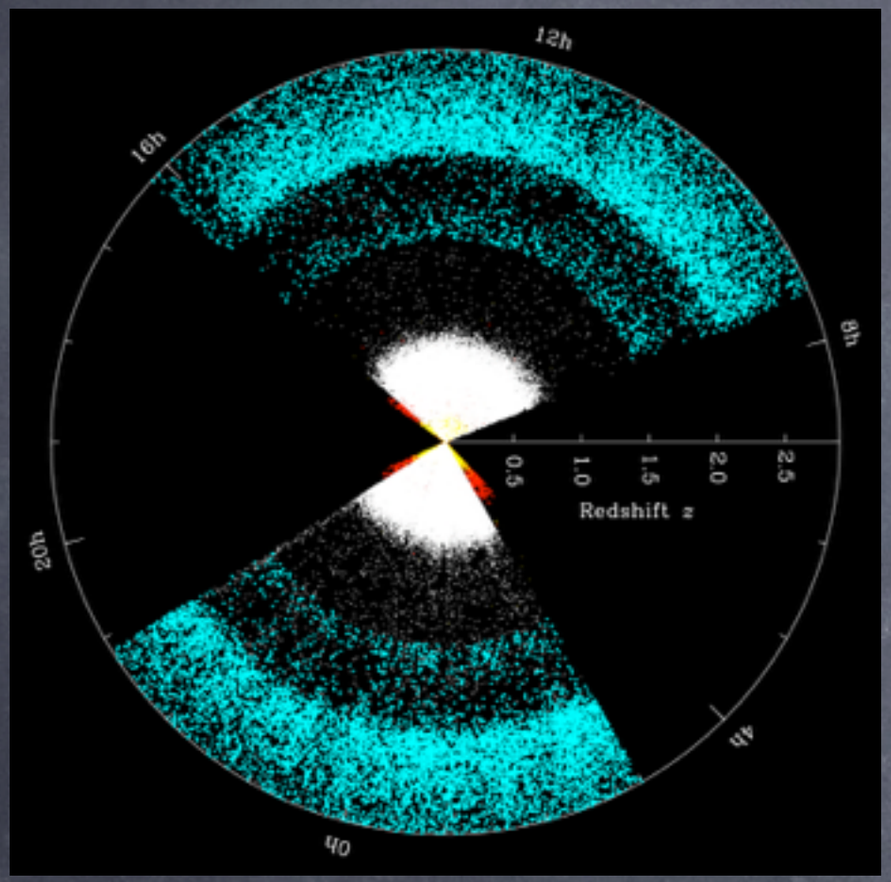
Galaxy

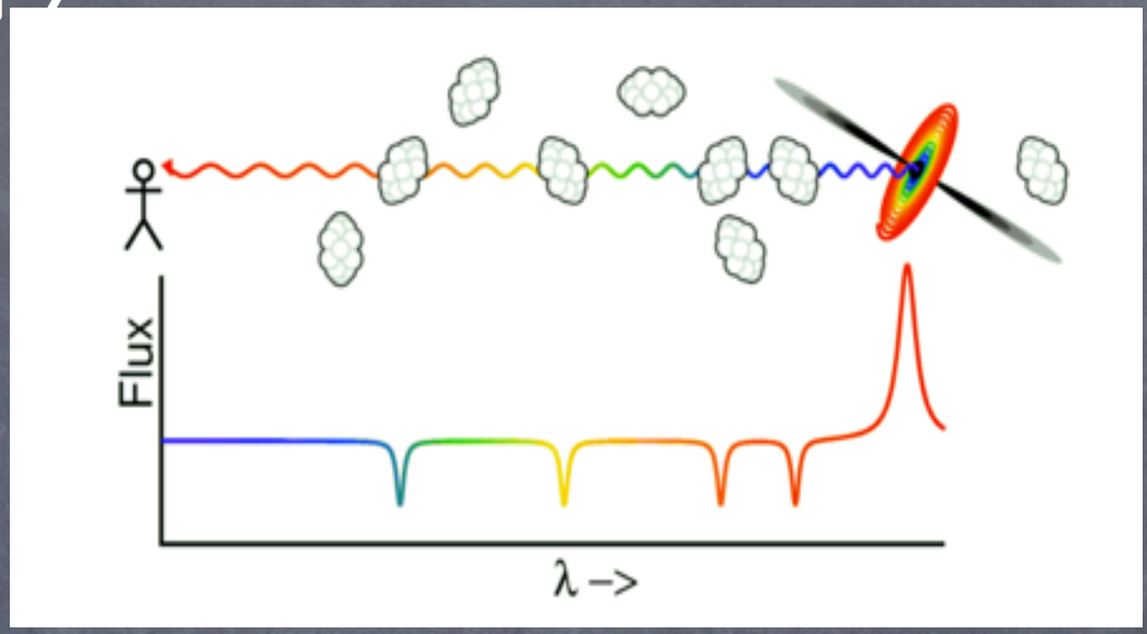


Lyman alpha absorption

The Gold Mine

SDSS-III/IV provides all sky quasar spectroscopy at z=2.5-3.5





-- For each quasar at z=2.5, we could prove z=2.0-2.5, which is about 500Mpc

-- SDSS has >200,000 quasars over > 10,000 deg^2

-- Survey volume of >20 Gpc^3

-- two orders of mag larger than using galaxy redshift survey to search for protoclusters

-- rarest, most massive protoclusters

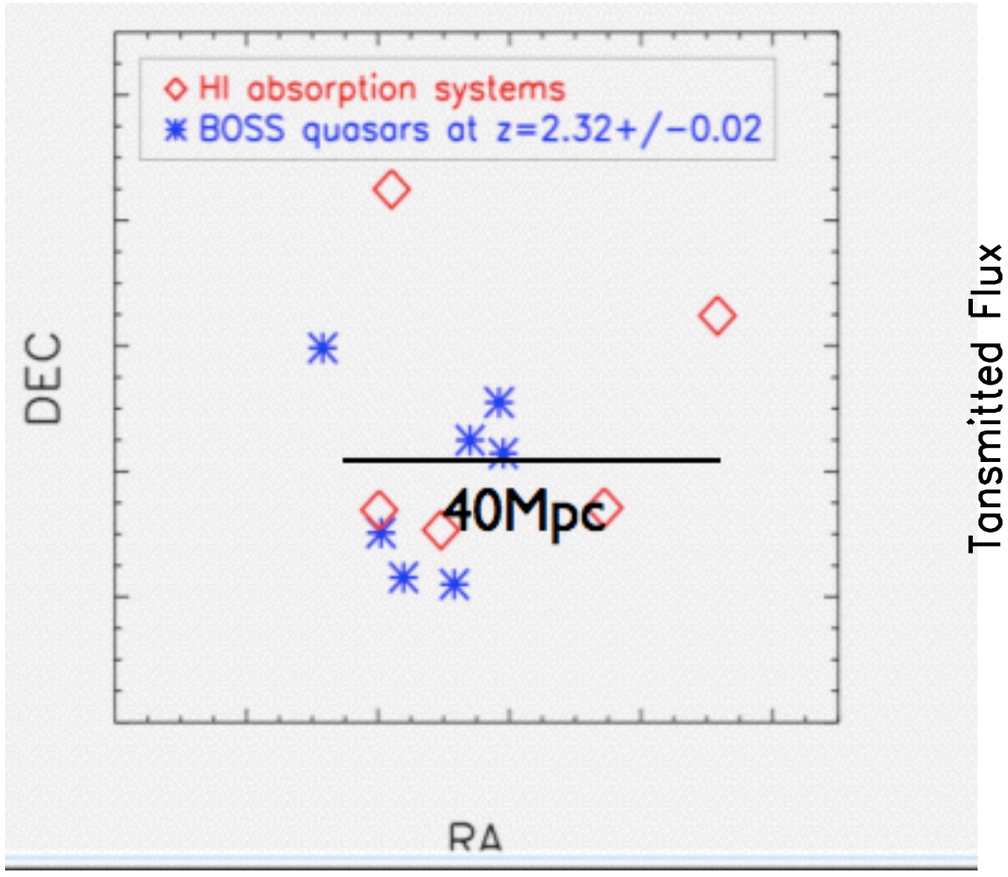
MApping the Most Massive Overdensity Through Hydrogen

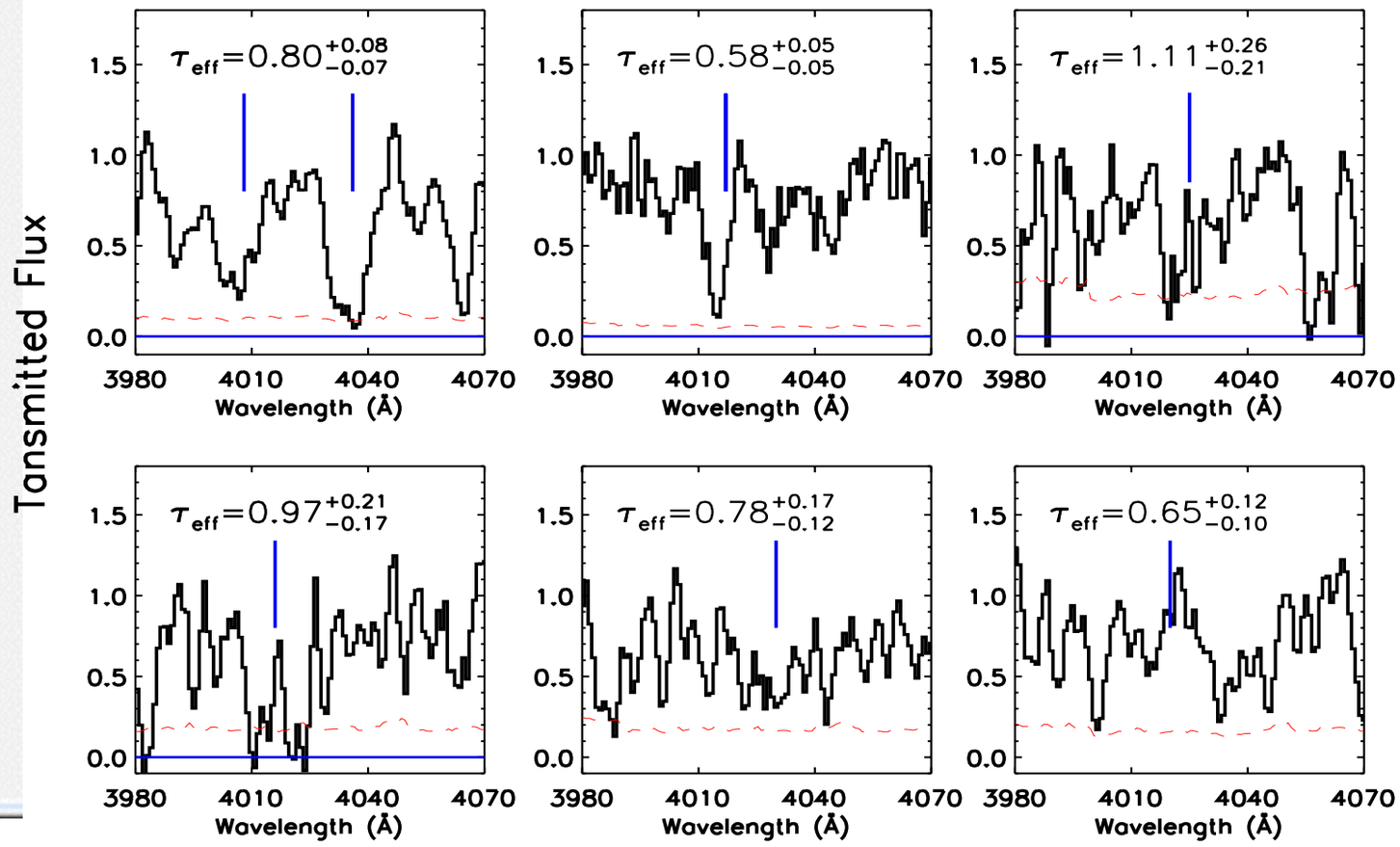
MAMMOTH

Advantages:

- Very large volume probed
- Un-biased tracing: dark matter overdensity-> Hydrogen overdensity, and no duty cycle issue
- Clean physics (UV background uniform at large-scale) HI-> Hydrogen
- Simulation shows that MAMMOTH-selected systems are likely the most extreme galaxy protoclusters (~15Mpc scale), representing the 0.5% most massive structures at z~2

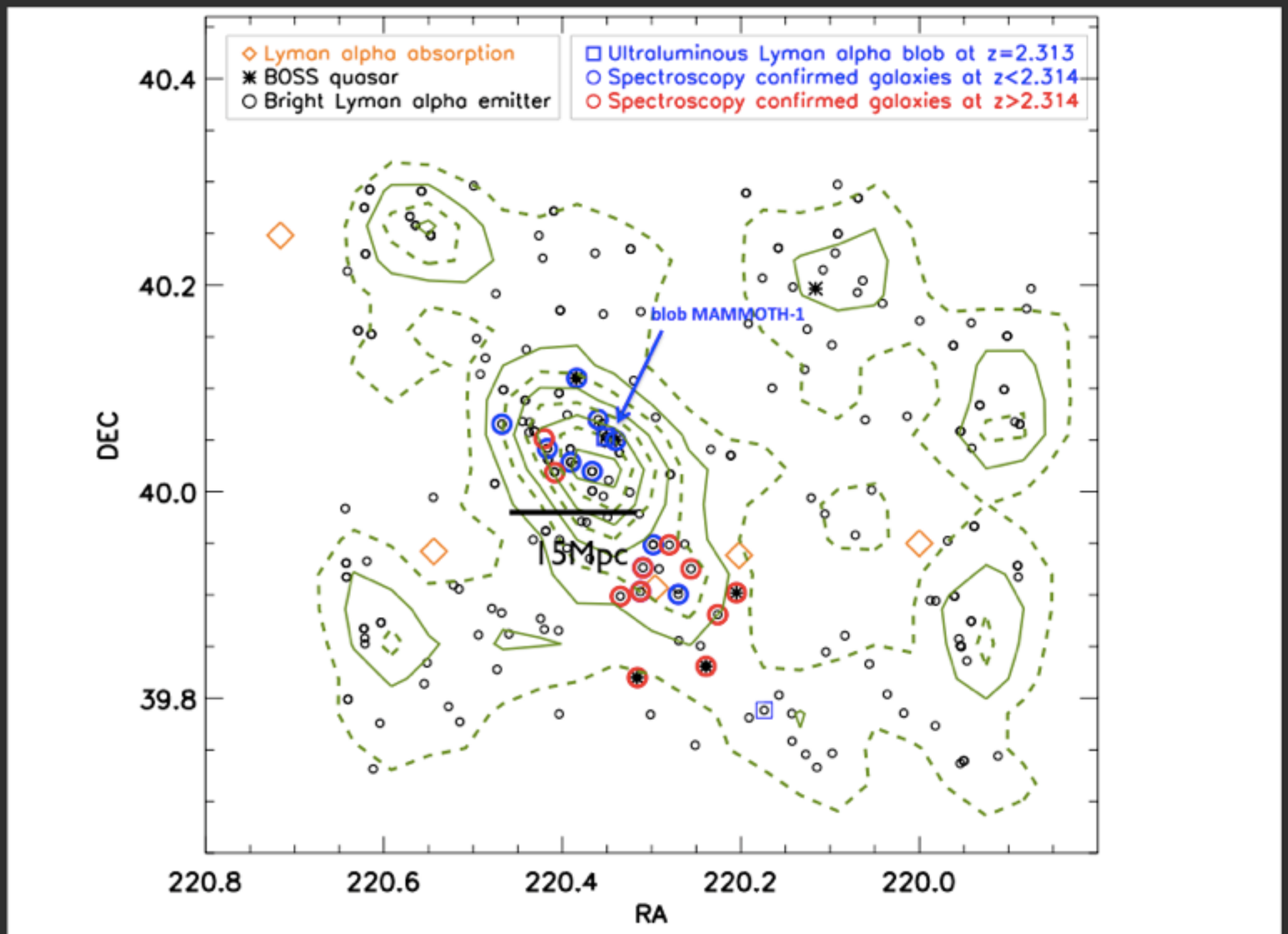
BOSS1441: the first MAMMOTH-selected candidate galaxy protocluster (z=2.32)





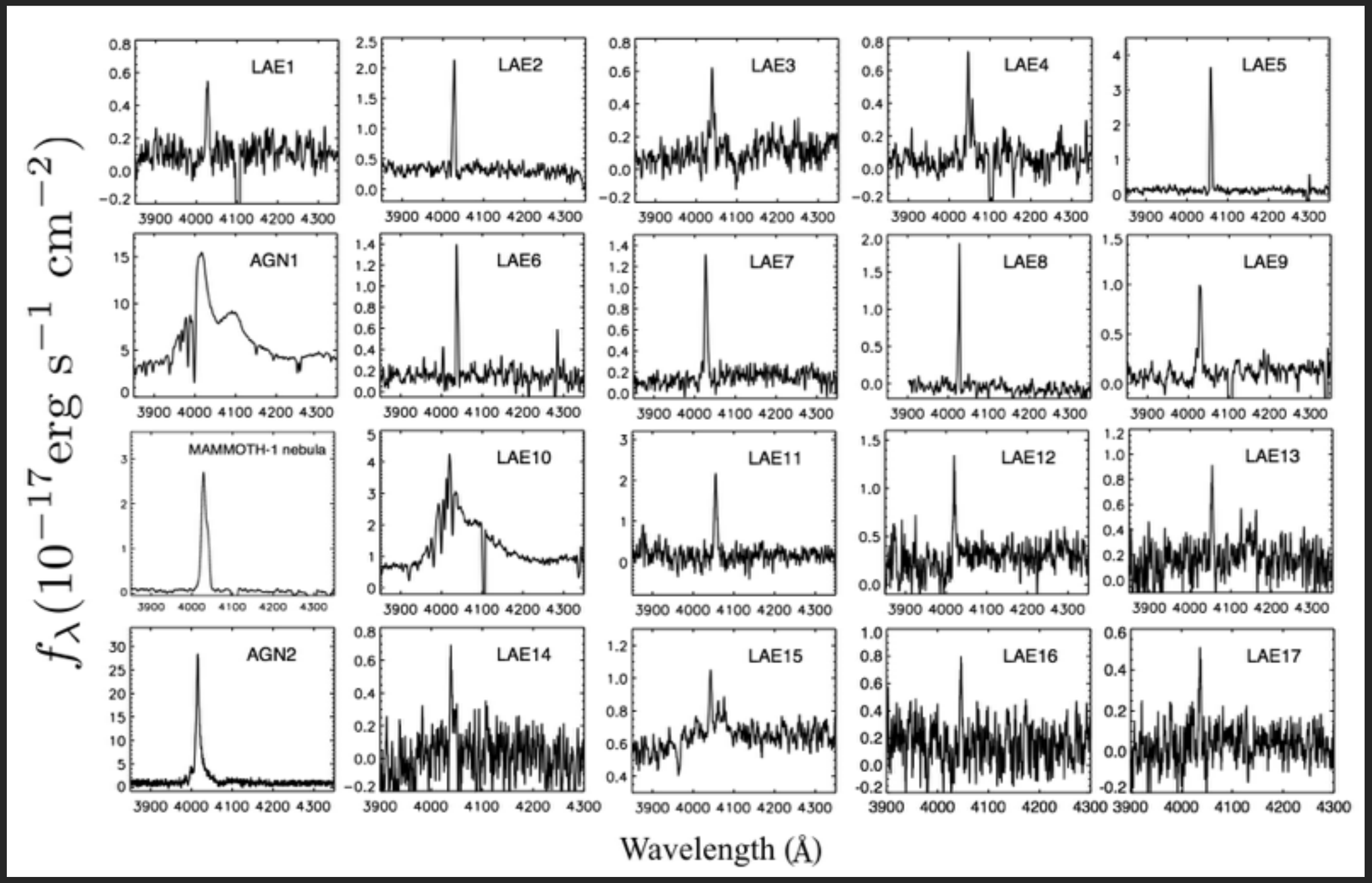
Traced by multiple strong IGM absorptions and multiple quasars within 40 Mpc

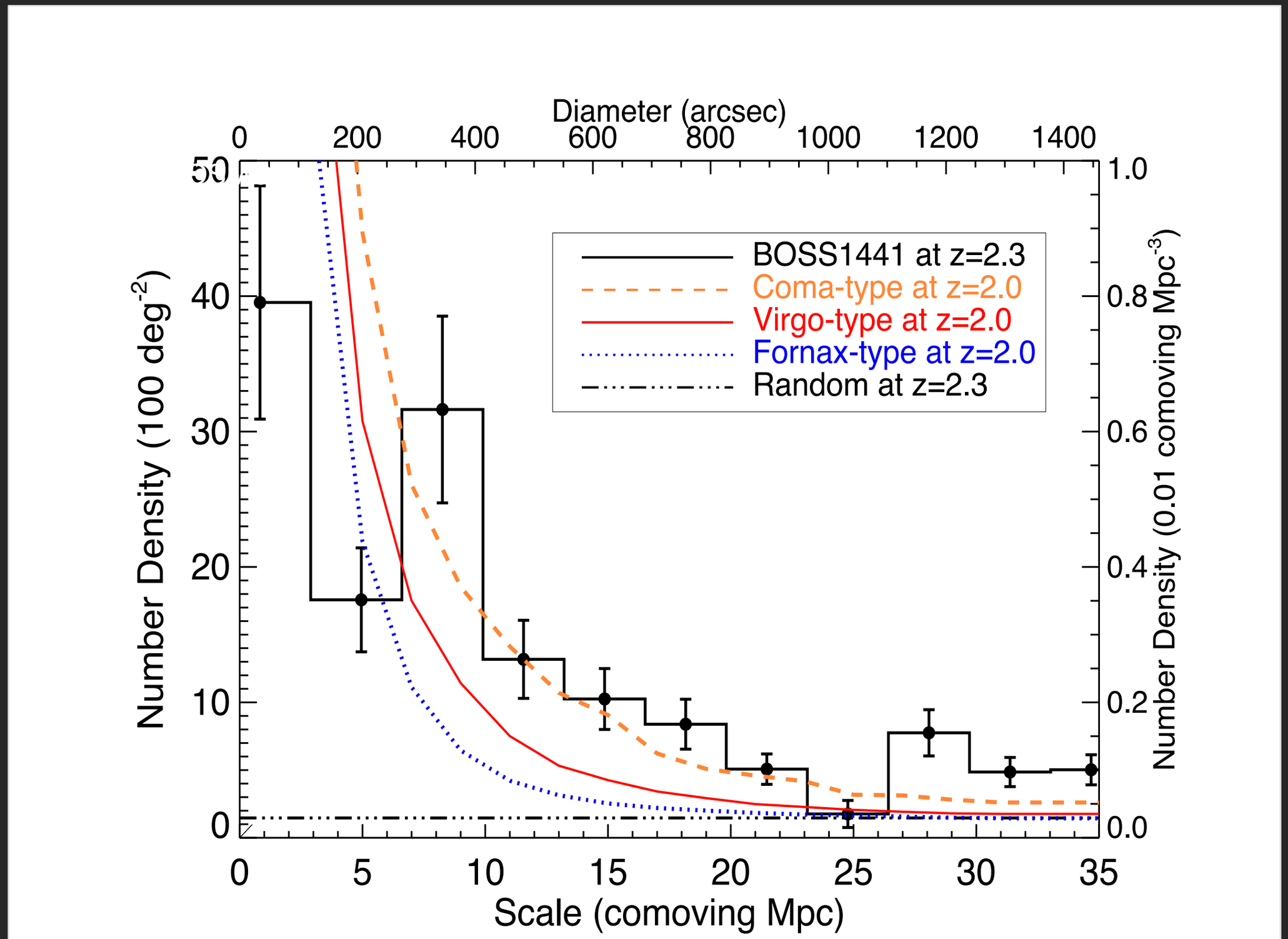
Deep Optical Imaging: KPNO-4m Narrow-band + LBC Broadband



Cai et al. (2017b)

LBT/MODS Spectroscopic Follow-ups Observations on BOSS1441



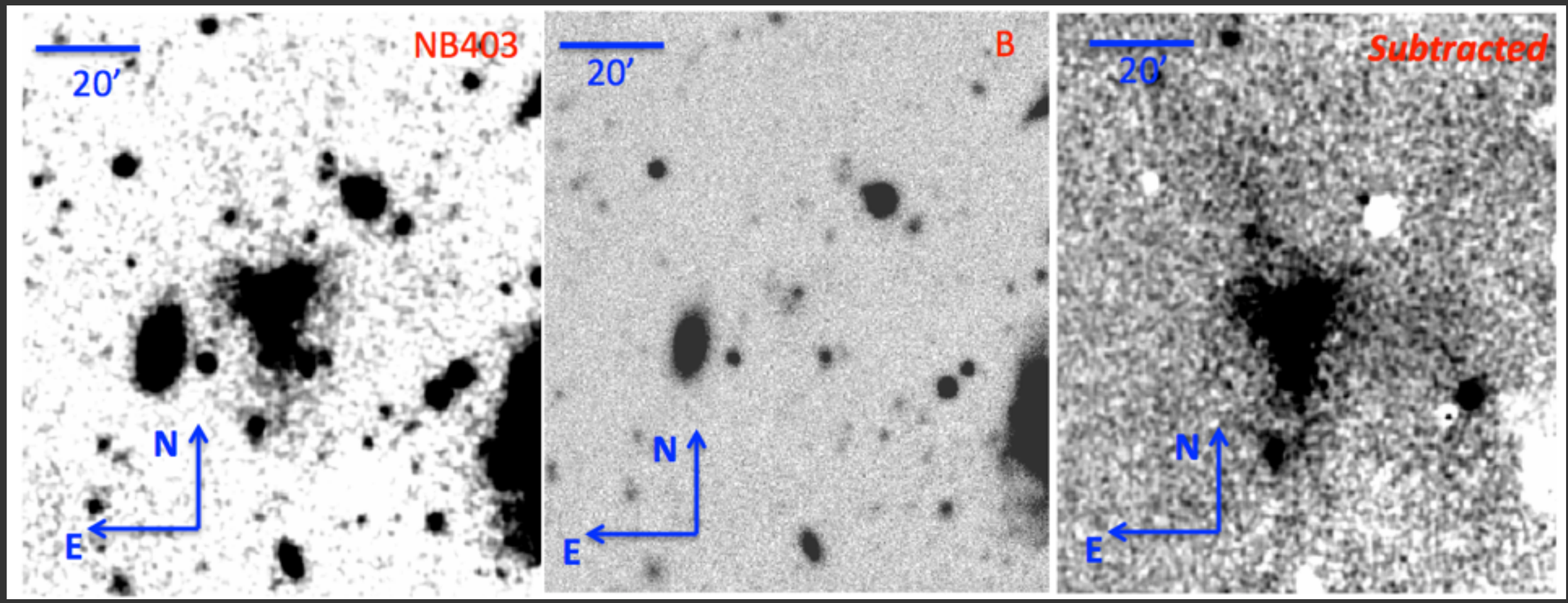

Diameter (arcsec)
0
200
400
600
800
1000
1200
1400
50
40
30
20
10
0
1.0
0.8
0.6
0.4
0.2
0.0
Number Density (100 deg^{-2})
Number Density (0.01 comoving Mpc^{-3})
BOSS1441 at z=2.3
Coma-type at z=2.0
Virgo-type at z=2.0
Fornax-type at z=2.0
Random at z=2.3
0
5
10
15
20
25
30
35
Scale (comoving Mpc)

Physical properties of the overdensity/protocluster (BP14)

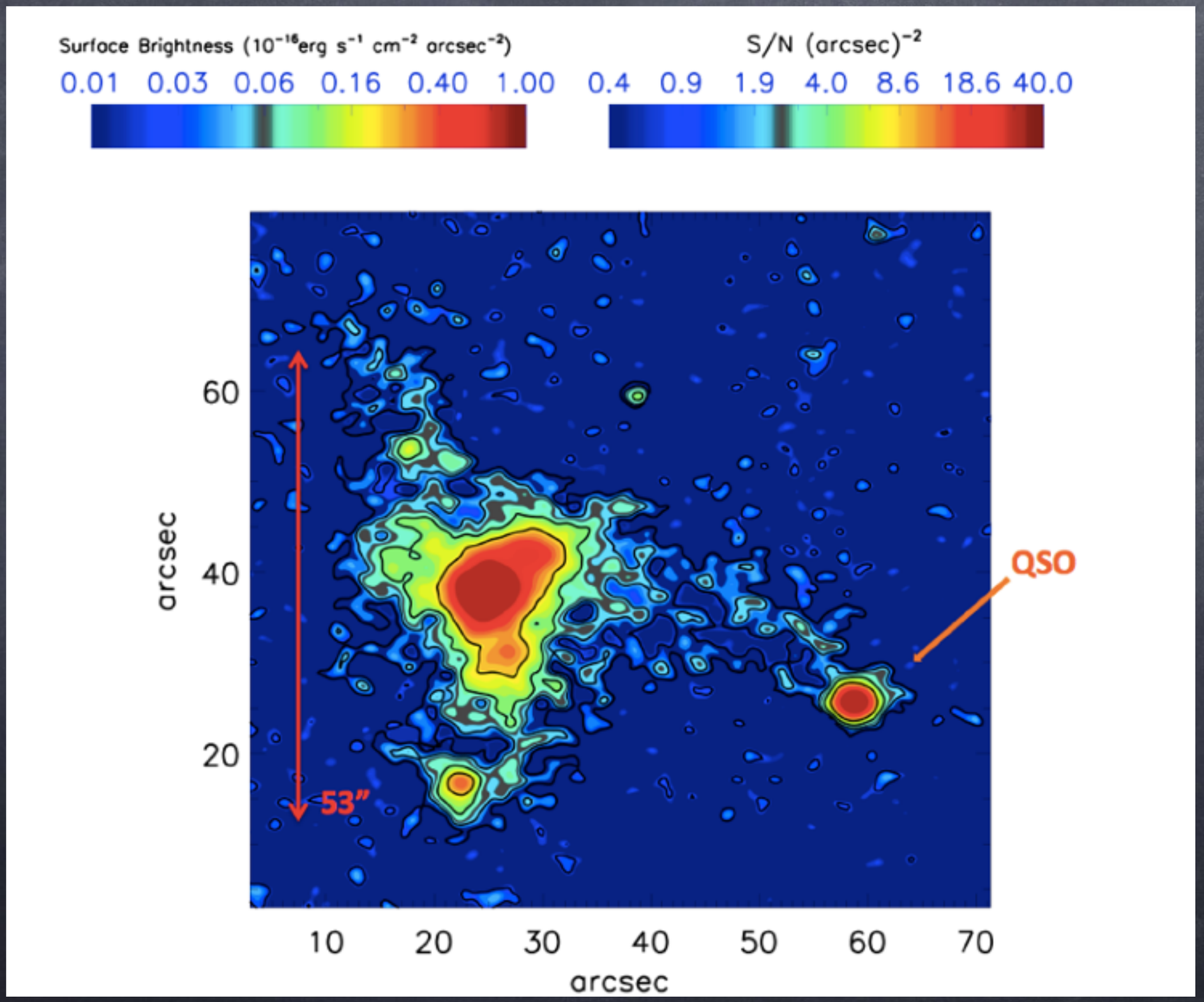
- galaxy overdensity in $30h^{-1}$ Mpc scale
- peak overdensity of LAE: 11 +/-1
- total mass (within 15Mpc): ~$10^{15} M_{sun}$
- progenitor of current day massive cluster
- the most overdensed high-z proto-cluster known

Name	$\langle z \rangle$	Scale	δ_g	mass	Reference
		Mpc		10^{14} $M_\odot$	
MRC0943-242	2.92	20	$2.2^{+0.9}_{-0.7}$	4-5	4,5
COSMOS34 [a]	3.04	15	$2.28^{+1.04}_{-0.79}$	...	8
Slug [b]	2.28	10	modest	...	8
SSA22	3.09	23	$3.6^{+1.4}_{-1.2}$	~ 10	1
TN J1338-1942[c]	4.1	18.	$3.8^{+1.1}_{-0.8}$	7	4,5,6
J1431+3239	3.733	15	4.2 ± 0.9	7	5
HS 1700+643	2.300	19.5	5.7 (6.9 in paper)	12	2,3
This work	2.329 ± 0.013	15	10.6 ± 0.7	10	
This work	2.329 ± 0.013	19.5	8.3 ± 0.7	16	

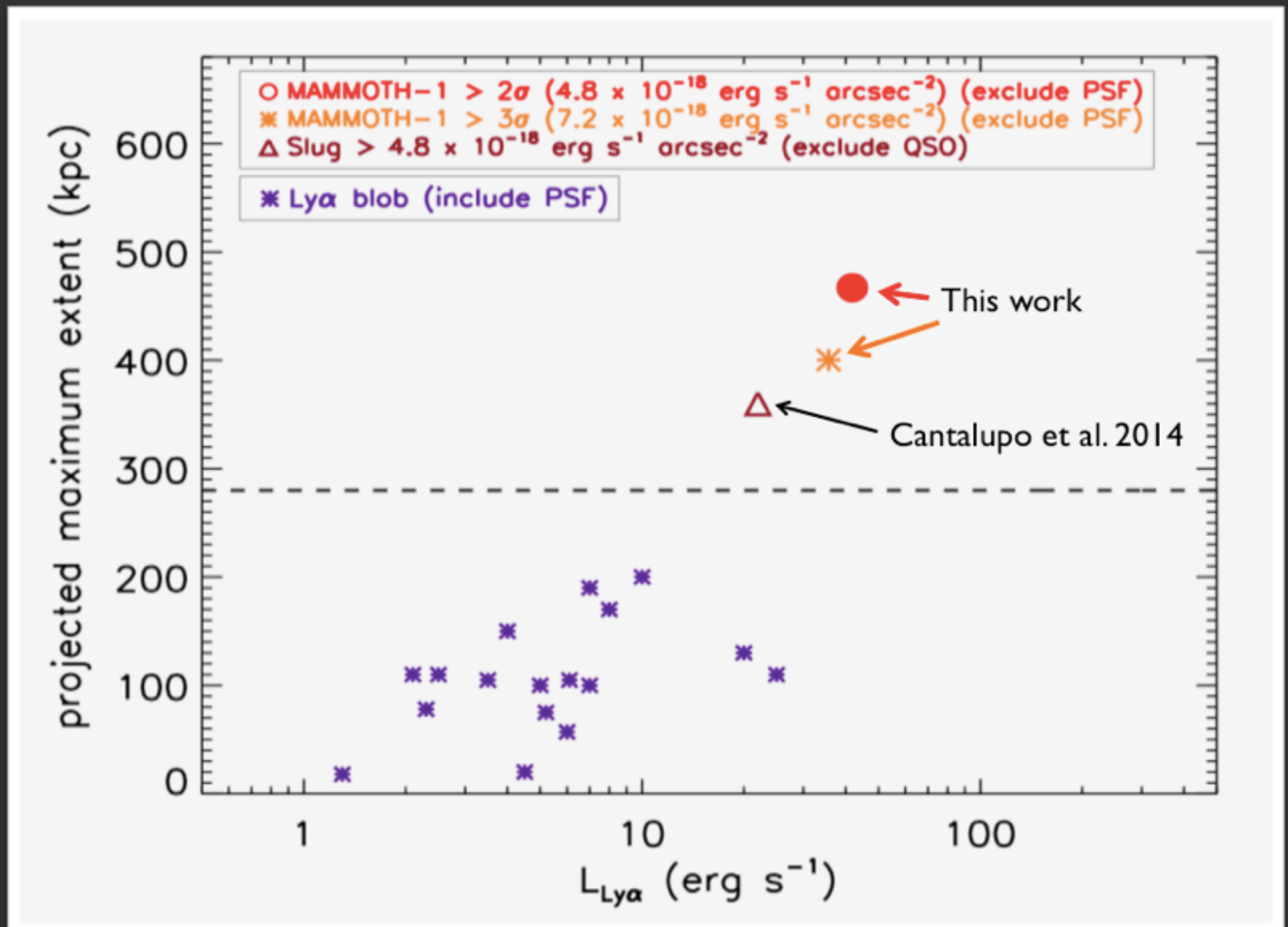
ultraluminous Lyman alpha blob/nebula MAMMOTH-1 at the center of overdensity



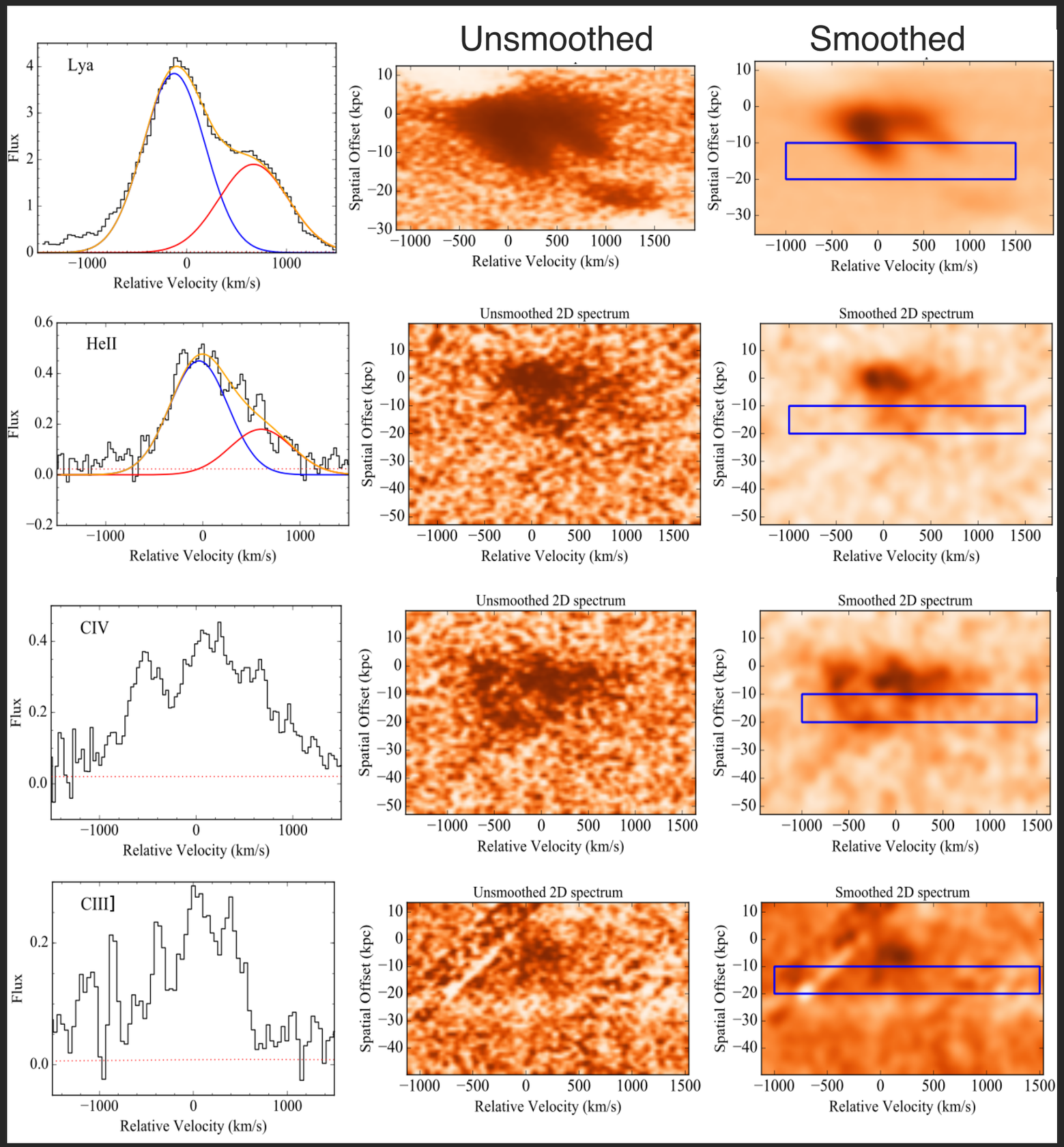
A Ultra-luminous Ly alpha nebula



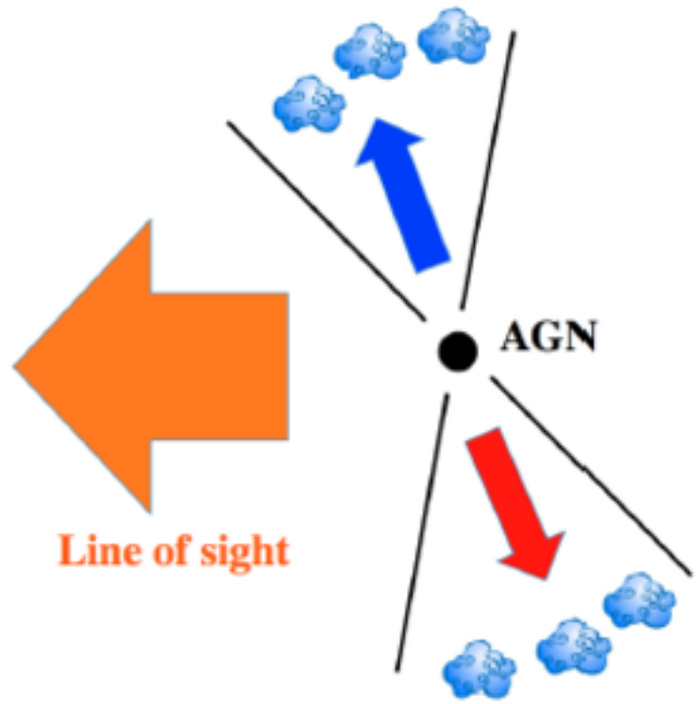
Size - luminosity of various Lya nebula



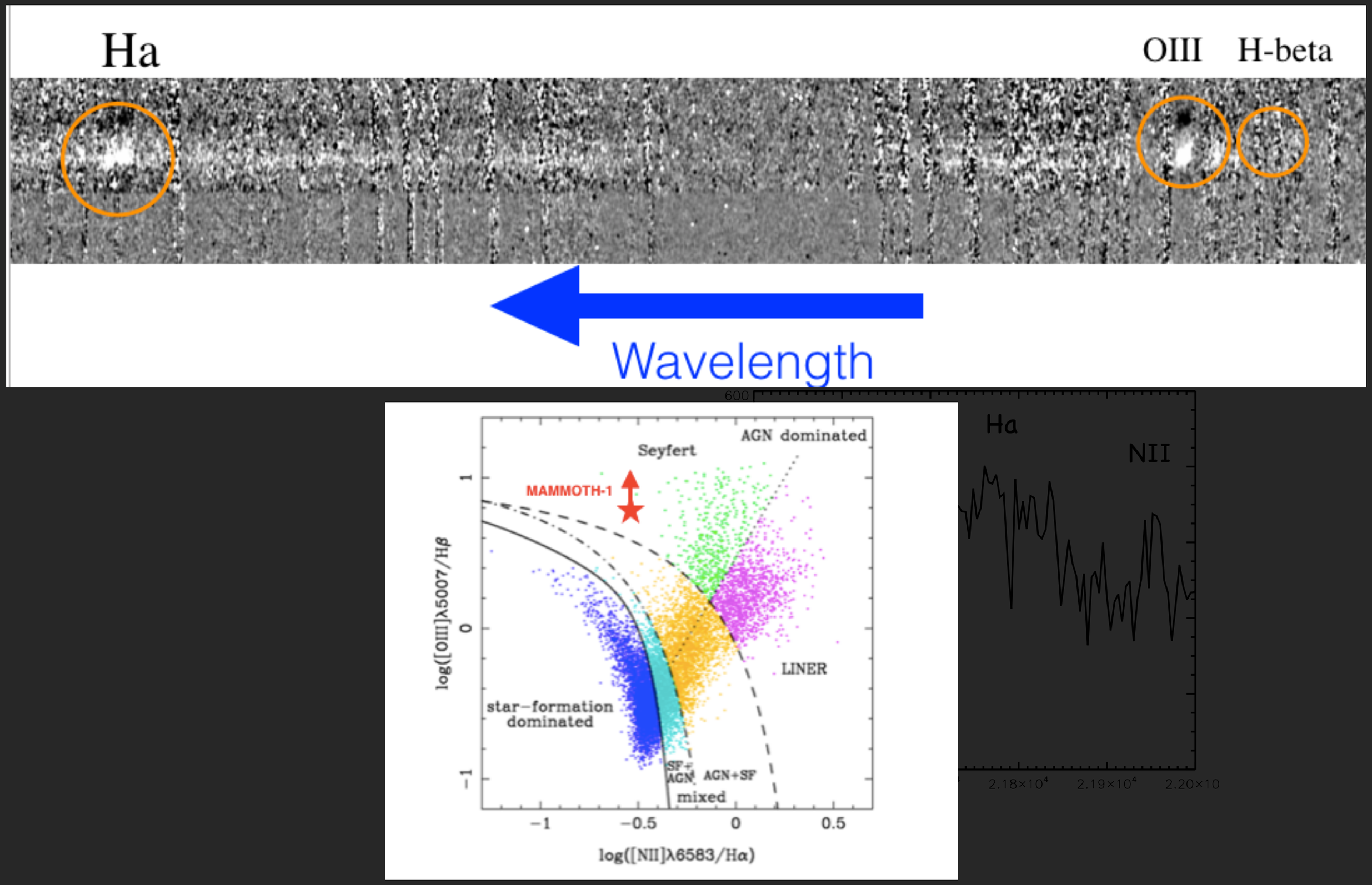
LBT/MODS Observations: large scale kinematics never seen before in other giant nebulae



gas outflow model
(AGN feedback)



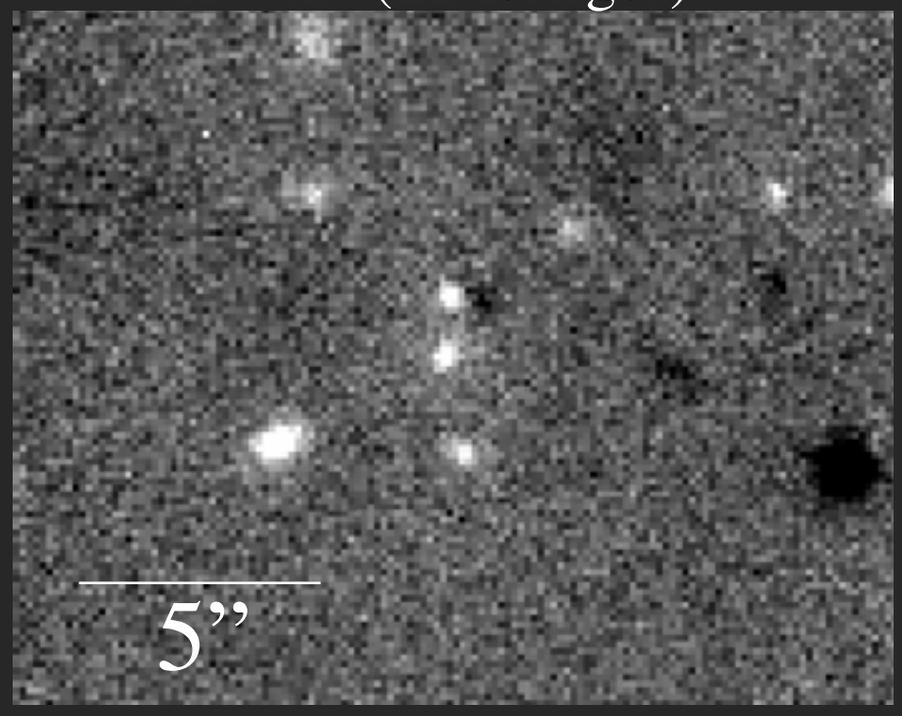
MAMMOTH-1 is powered by a type-II AGN at z=2.3



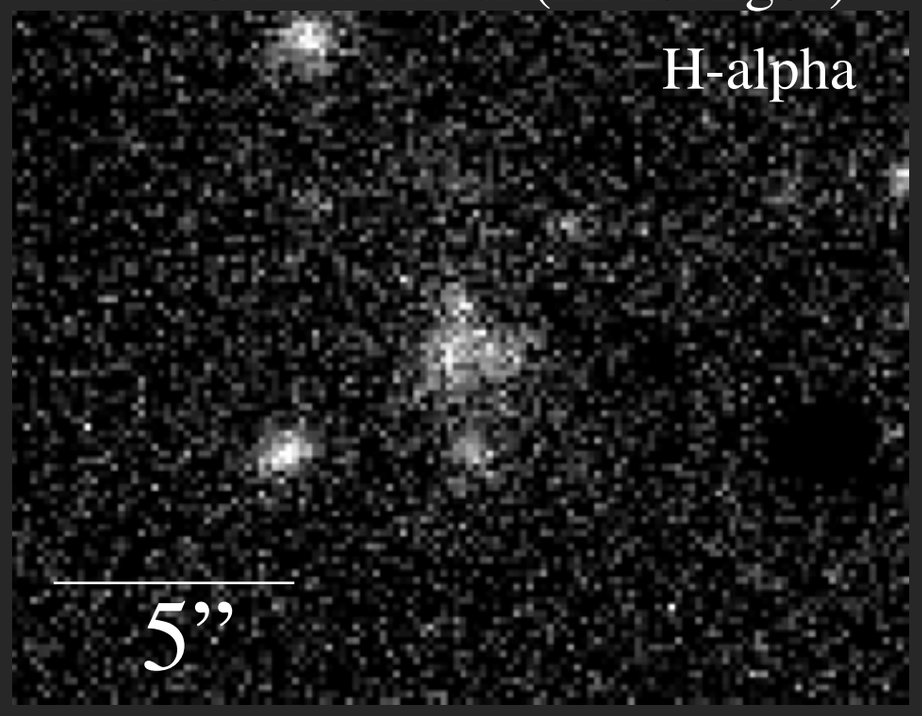
LBT/LUCI Argos commissioning observations

MAMMOTH-1 field, 4’ FoV FWHM = 0.20”–0.25” in K-band

K-band (LBT/Argos)



Br-Gamma filter (LBT/Argos)

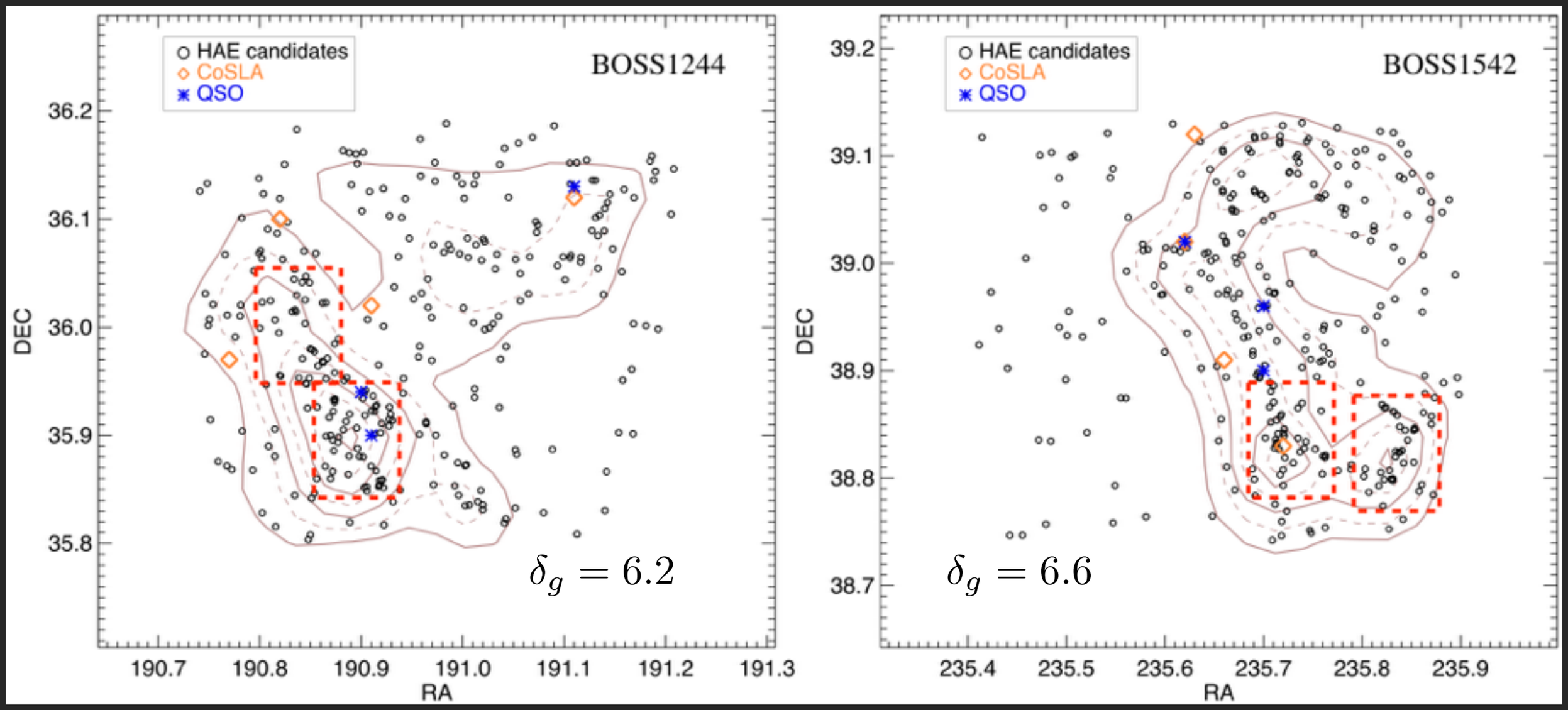


K-band (Subaru, 0.5” seeing)

MAMMOTH protoclusters: BOSS1244 and BOSS1542 at z=2.20+/-0.03

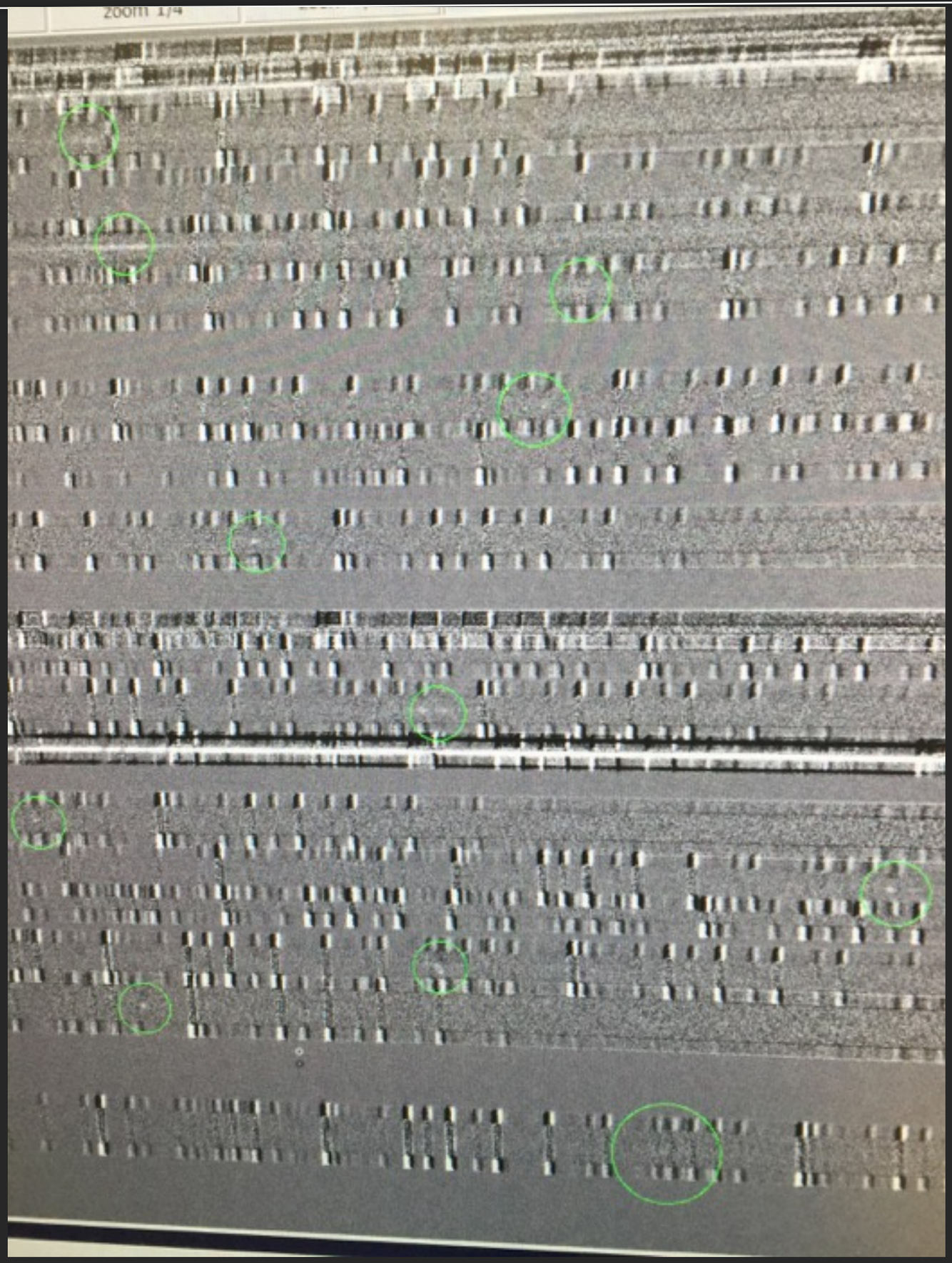
CFHT/WIRcam $H\alpha$ emitters down to L*

Together with BOSS1441, we construct a LSS sample at z > 2



Cai et al. in prep, An et al. in prep.

LBT/LUCI confirmation of HAEs



LUCI I+ II, 2-hours per mask, totally 4 masks. Successful confirmed 70% of HAEs. Detailed analysis to be done.

Summary

- LBT provides a powerful suite of facility instruments for deep extragalactic surveys

- ARGOS will be a game changer in near-IR high-z surveys in the near future