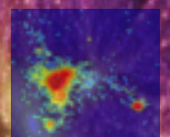
MApping the Most Massive Overdensities Through Hydrogen (MAMMOTH)

Zheng Cai
(Hubble Fellow, UCSC)



Xiaohui Fan (Steward), J. Xavier Prochaska (UCSC), Ann Zabludoff (Steward), Nobunari Kashikawa (NAOJ), Yujin Yang (KASI), Yi-Kuan Chiang (JHU), Sebastien Peirani (IAP), Xian-Zhong Zheng (PMO) + YOU

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z=2-3

Lya forest

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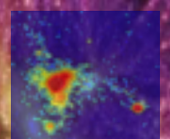

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Different great efforts of tracing high-z matter overdensities:

1 Use biased halos, such as QSOs/sub-mm galaxies/radio galaxies, small duty cycles, maybe highly incomplete

2 Galaxy redshift survey (e.g., Steidel et al. 1998), observationally expensive survey volumes are often limited

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1 Use biased halos, such as QSOs/sub-mm galaxies/radio galaxies, small duty cycles, maybe highly incomplete

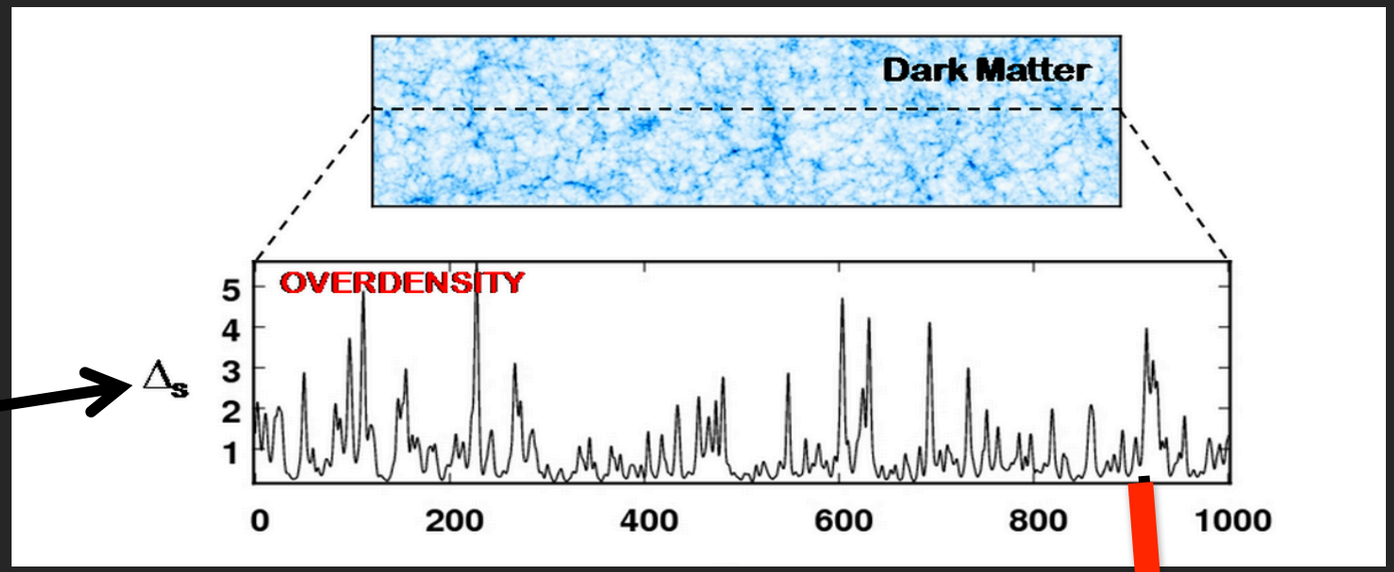
2 Galaxy redshift survey (e.g., Steidel et al. 1998), observationally expensive survey volumes are often limited

A more complete (un-biased) technique to search for galaxy overdensities from a larger volume will be excellent

Lyman alpha absorption tracing underlying matter overdensities

Cai et al. (2016) ApJ, 833, 135

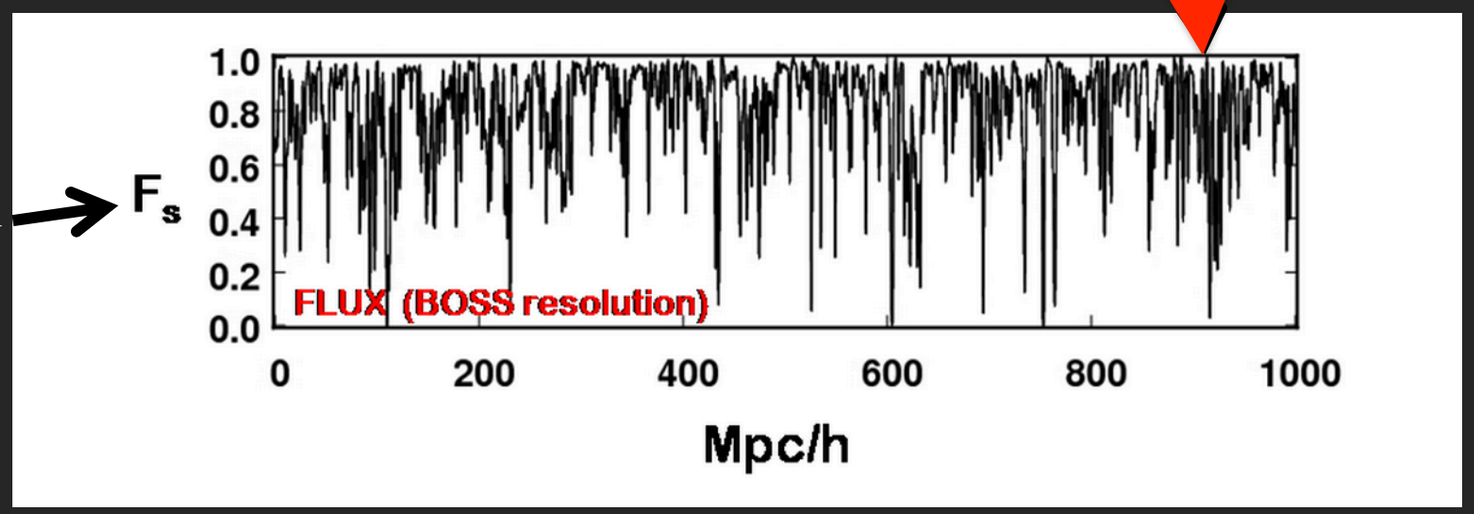
Matter Overdensity



Peirani et al. (2014)

Large scale overdensity
→ large EW of absorption

Transmitted Flux in QSO spectra

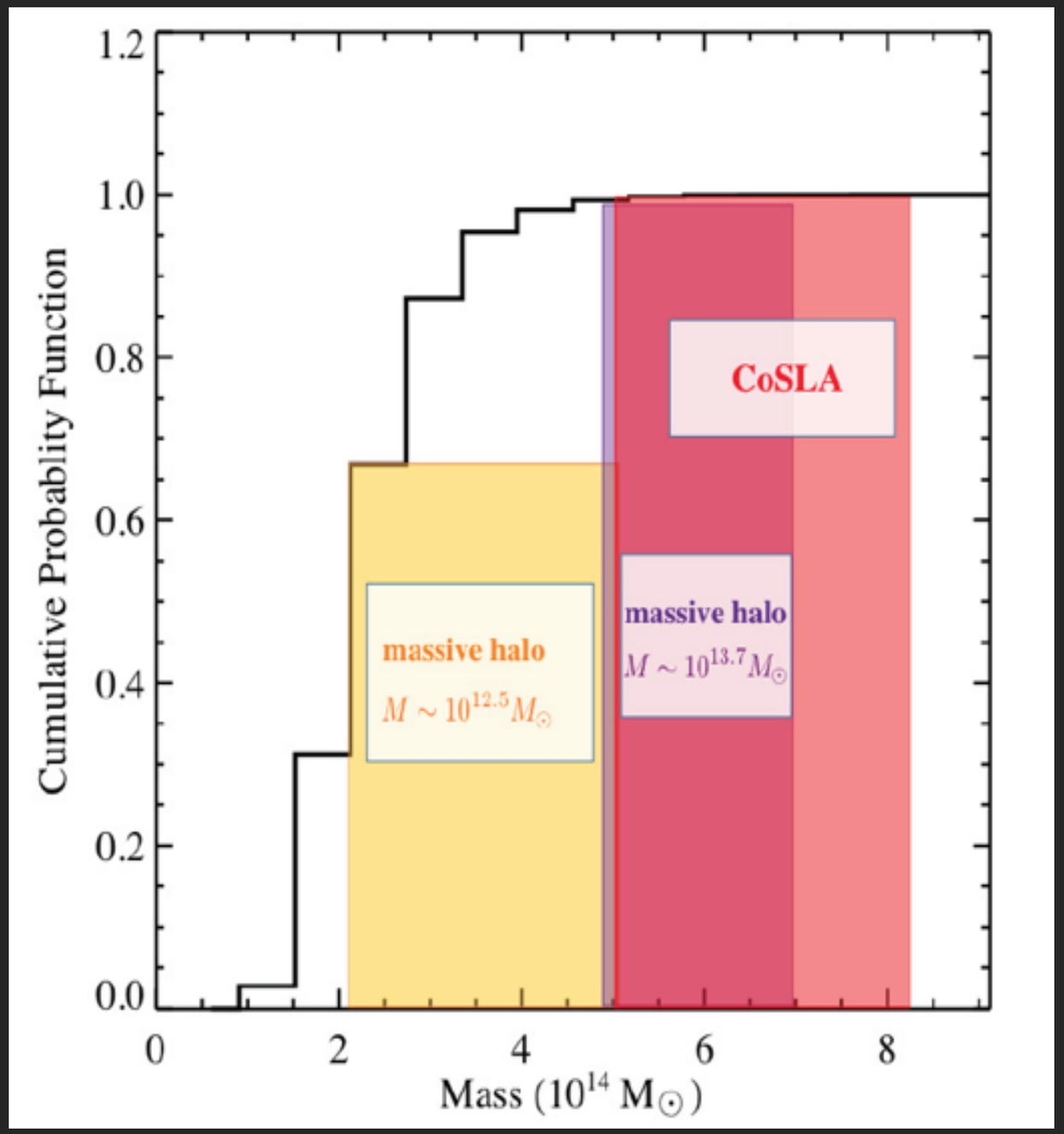


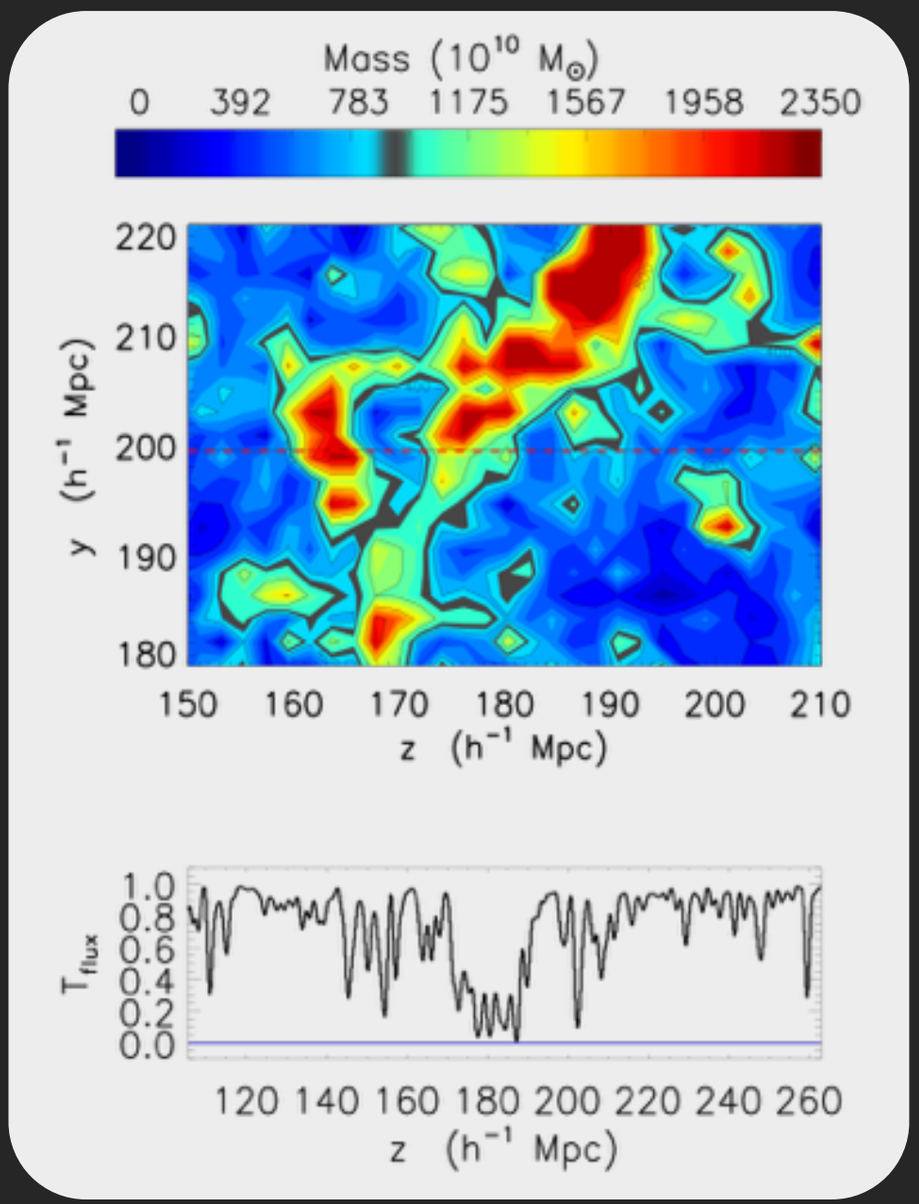
Coherently strong Lya absorption (CoSLAs)

[redacted]

Coherently strong Lya absorption (CoSLAs) trace most massive overdensities.

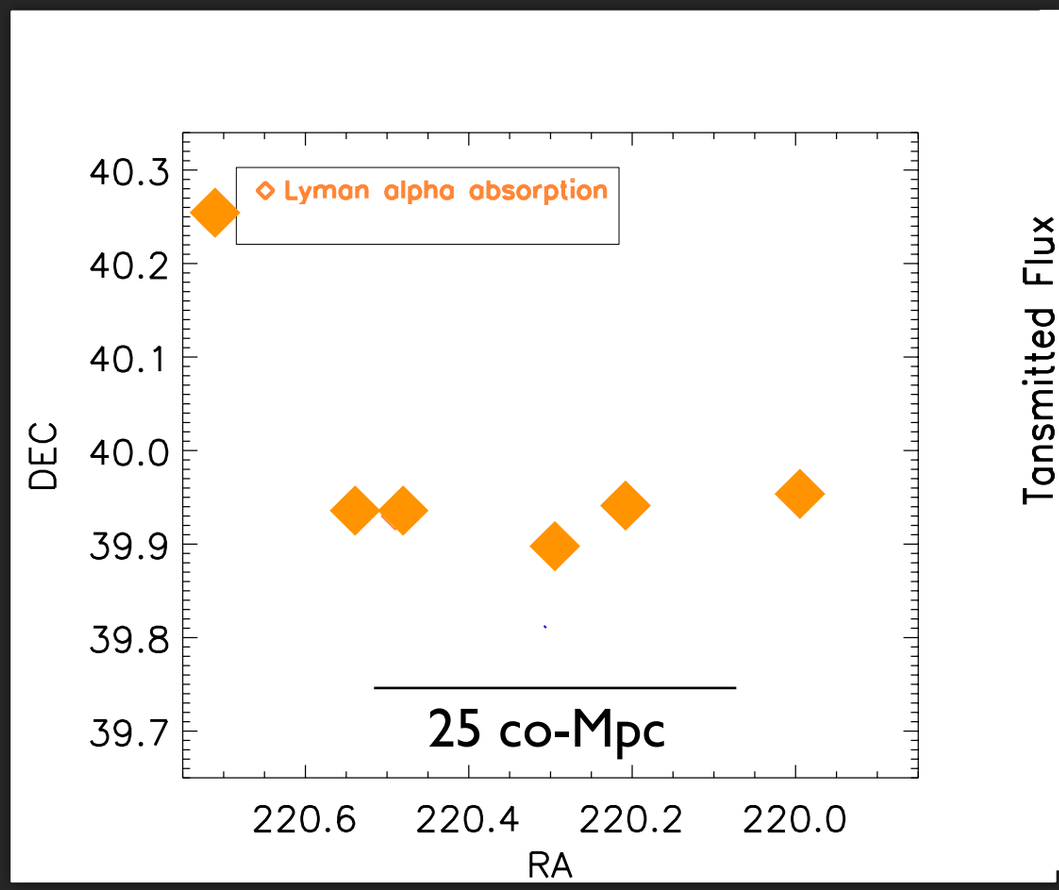
Cai et al. (2016) ApJ, 833, 135

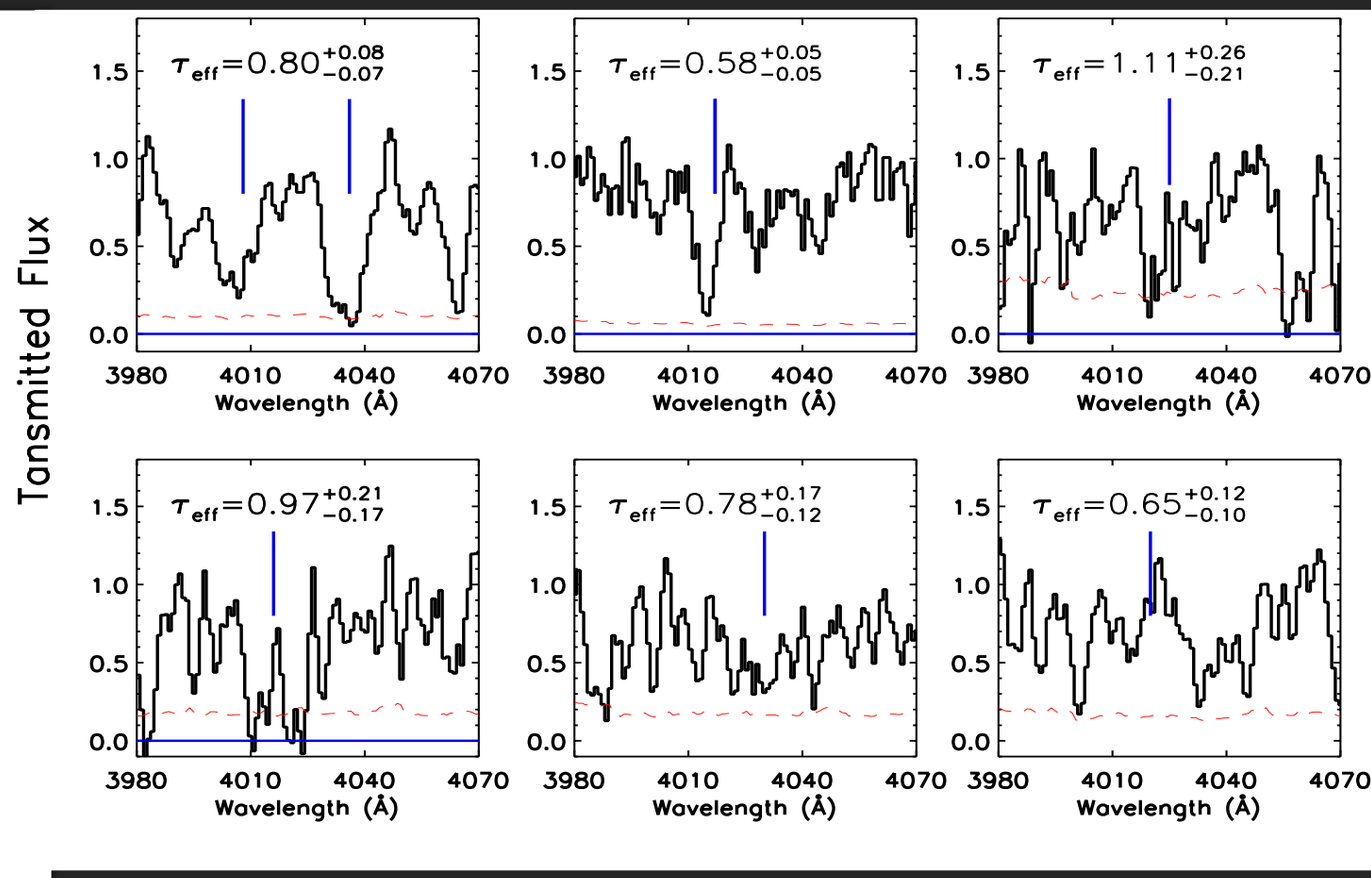




Zheng Cai, UCSC, Aug 5

MAMMOTH protocluster one: BOSS1441 Overdensity at z=2.32+/-0.04 selected from SDSS/BOSS Lya survey (Gpc^3 volume)



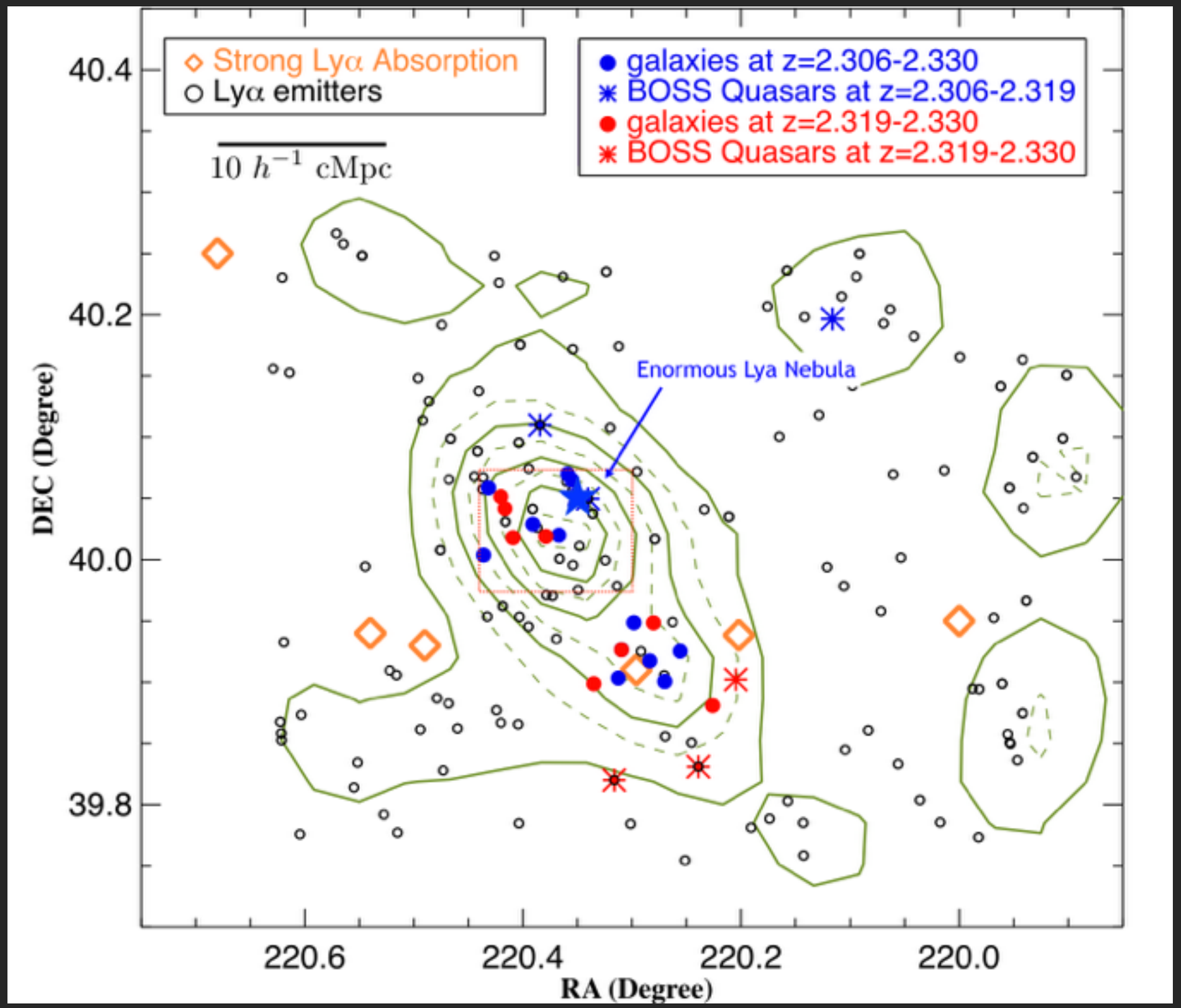


IGM absorption + Multi-quasar within 40Mpc at z=2.32+/-0.02

rare HI absorption group tracing an overdensity at massive end

MAPPING THE MOST MASSIVE OVERDENSITIES (MAMMOTH) II – DISCOVERY OF AN EXTREMELY MASSIVE OVERDENSITY BOSS1441 AT $Z = 2.32$.

ZHENG CAI[1,2,9], XIAOHUI FAN[2], FUYAN BIAN[3], ANN ZABLUDOFF[2], YUJIN YANG[4], J. XAVIER PROCHASKA[1], IAN MCGREER[2], ZHEN-YA ZHENG[5,6], NOBUNARI KASHIKAWA[7], RAN WANG[8], BRENDA FRYE[2], RICHARD GREEN[2], LINHUA JIANG[8]



Cai et al. (2017b) ApJ 839, 131

BOSS1441 is the first large scale structure with a LAE overdensity of ~11 on (~20 Mpc)^3 volume at z>2.

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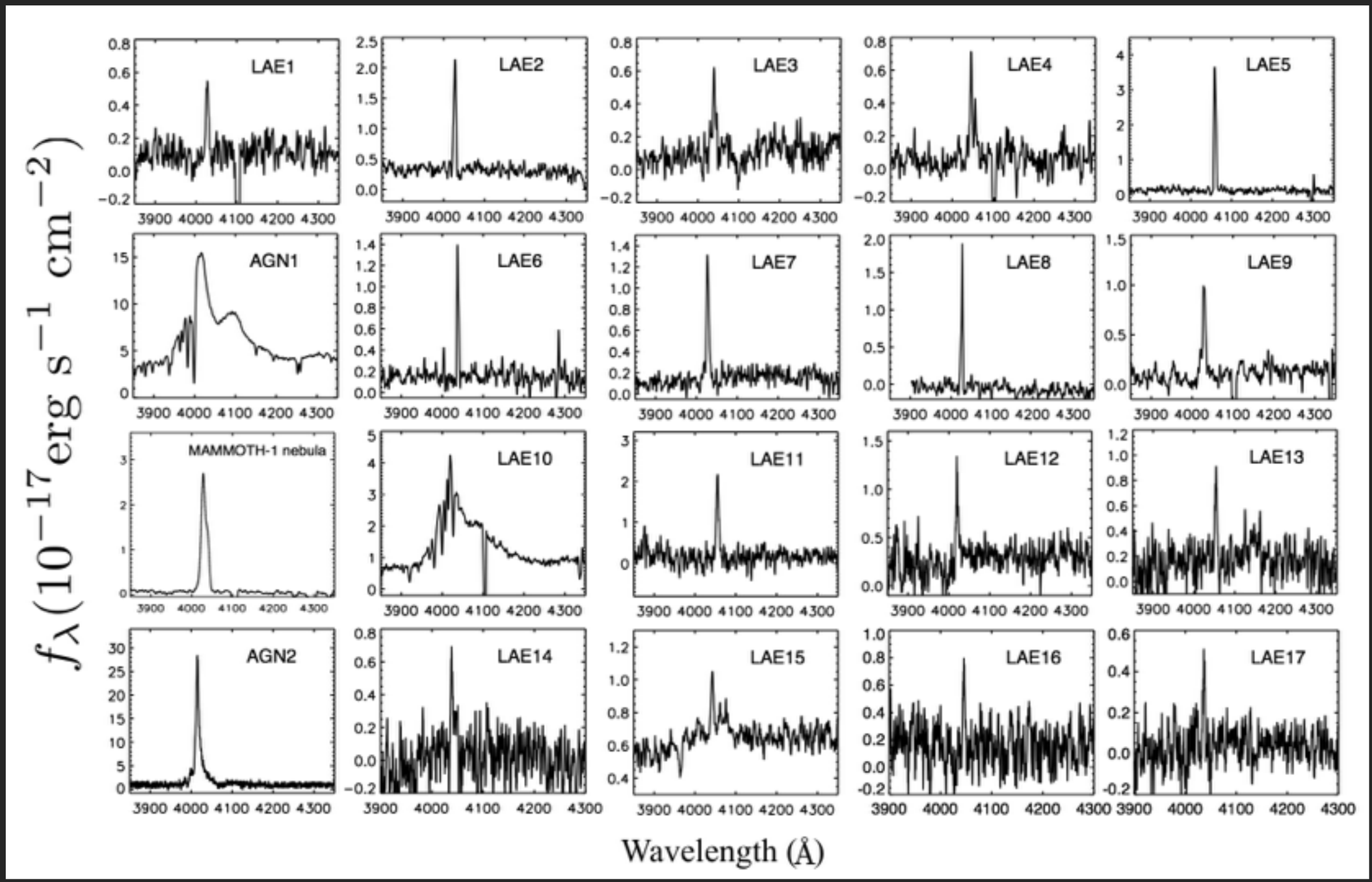
LBT/MODS Spectroscopic Follow-ups Observations on BOSS1441



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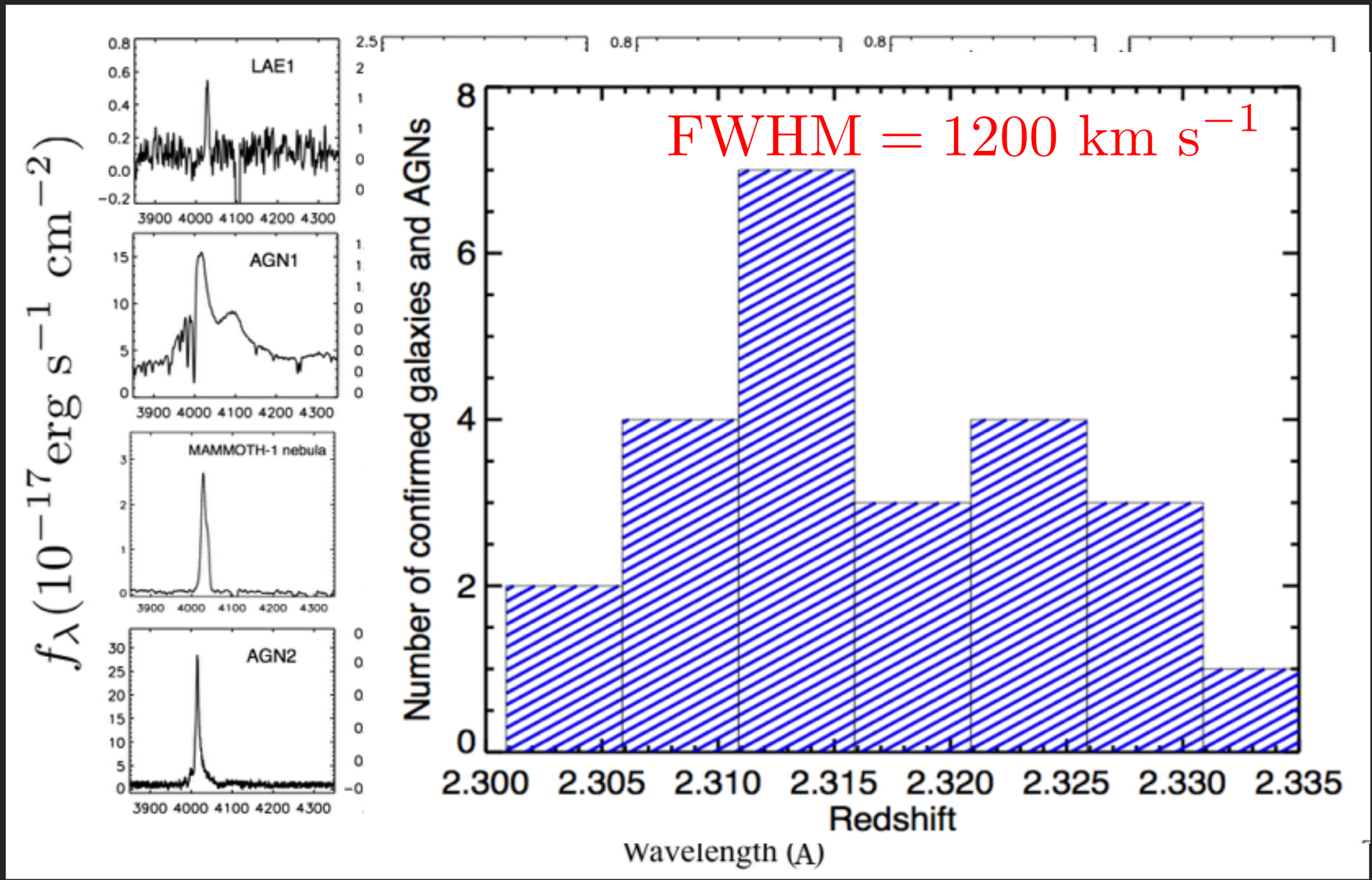
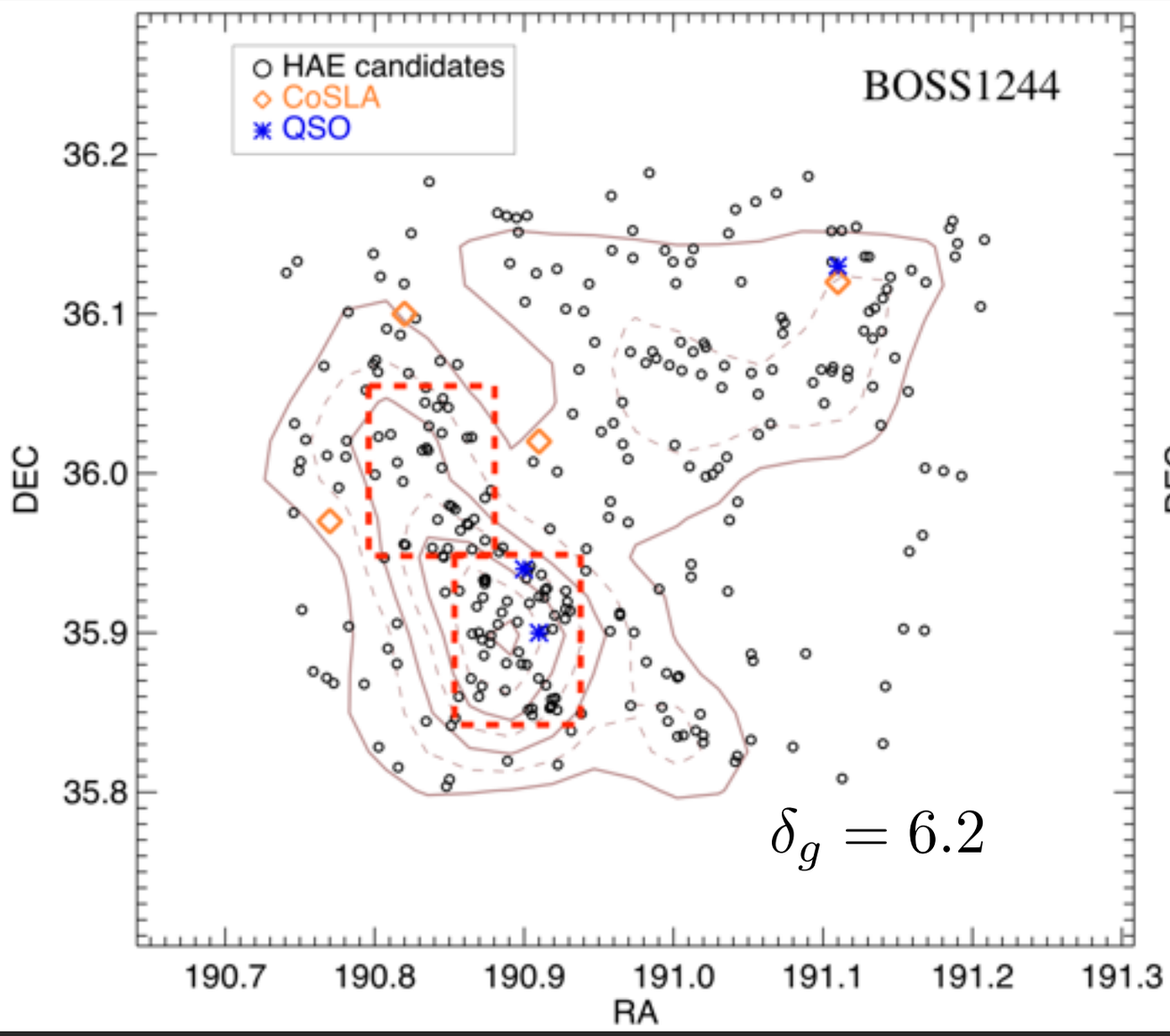
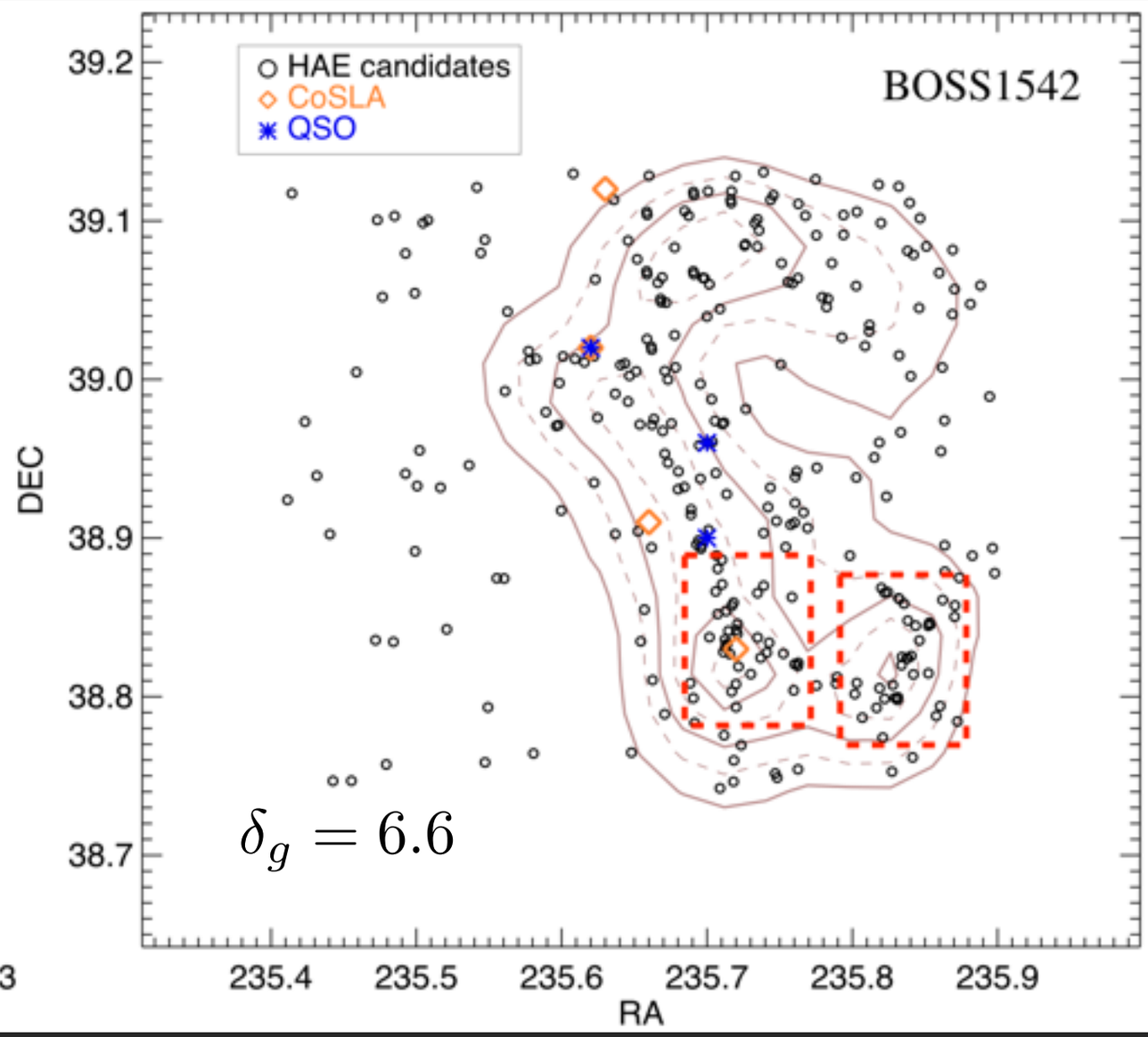


MAMMOTH protoclusters: BOSS1244 and BOSS1542 at z=2.20+/-0.03

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

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

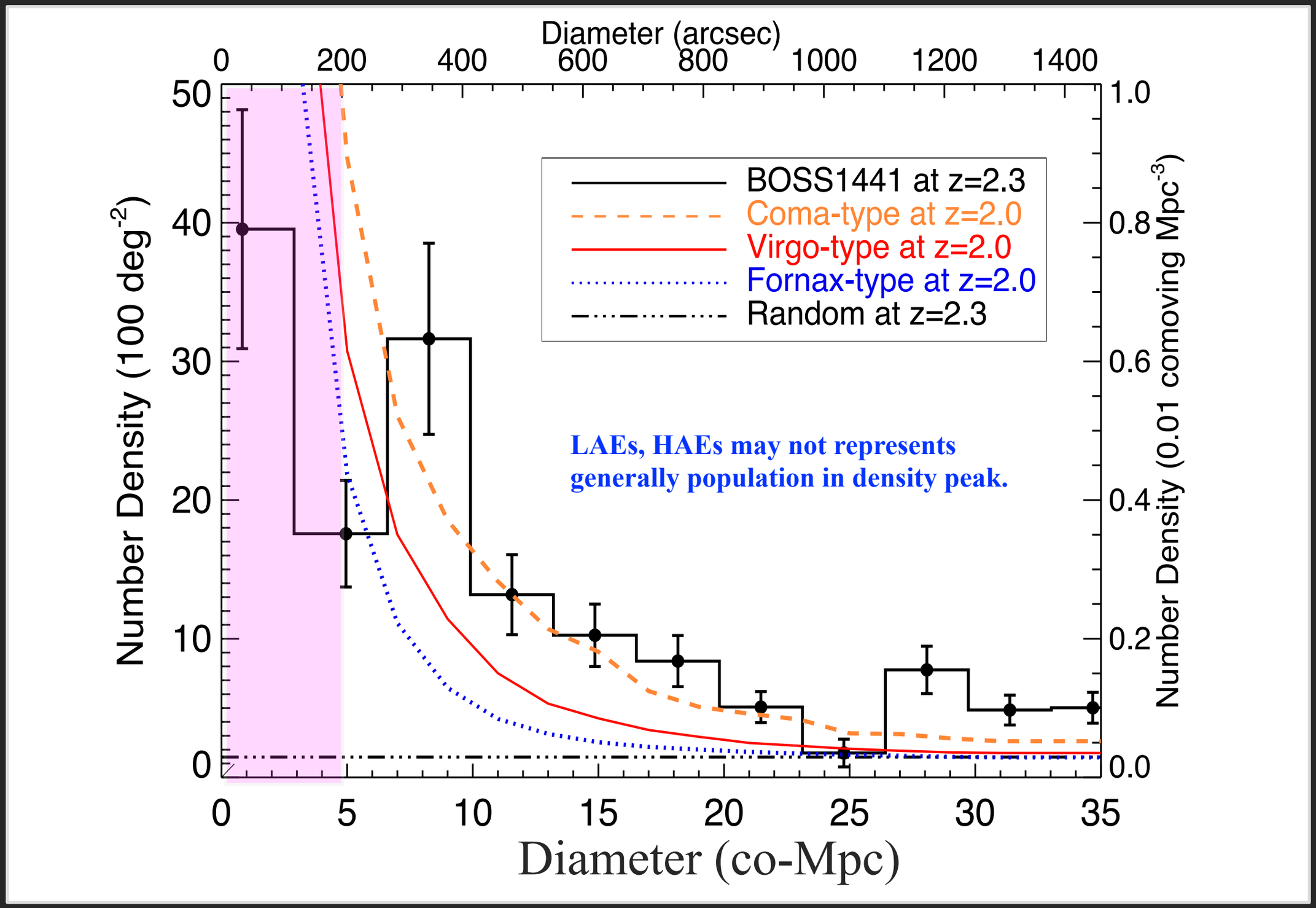




Cai et al. in prep, An et al. in prep.

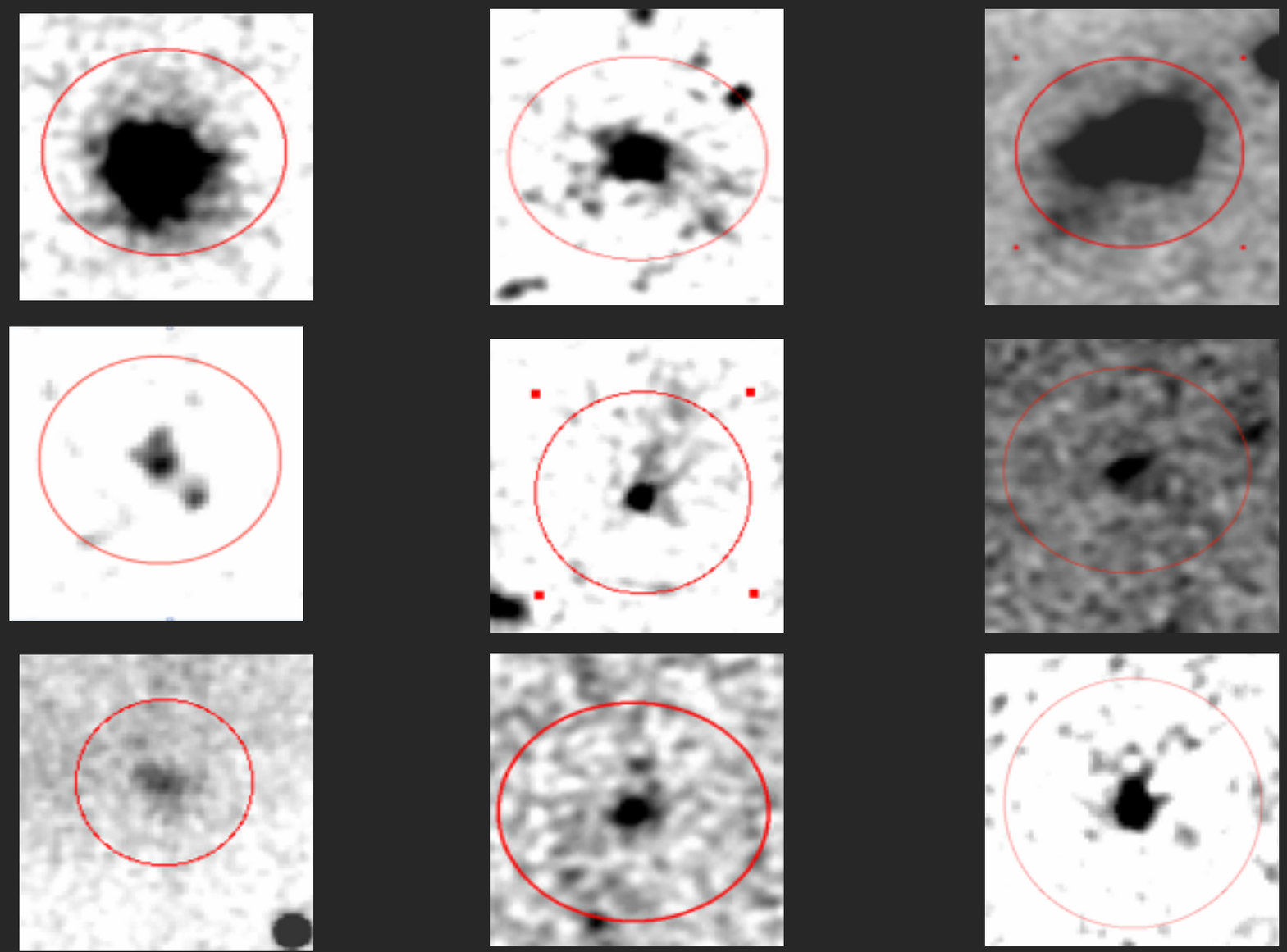
MAMMOTH

HST (cycle 24, 25) observations (25-orbit, PI: Cai) awarded: Deep IR imaging on three MAMMOTH overdensities to study density-morphology relation. (stay tuned)



Is our technique a more effective way of finding Lyman alpha blobs?

Red circle diameter = 15”



Xu, Cai et al. in prep

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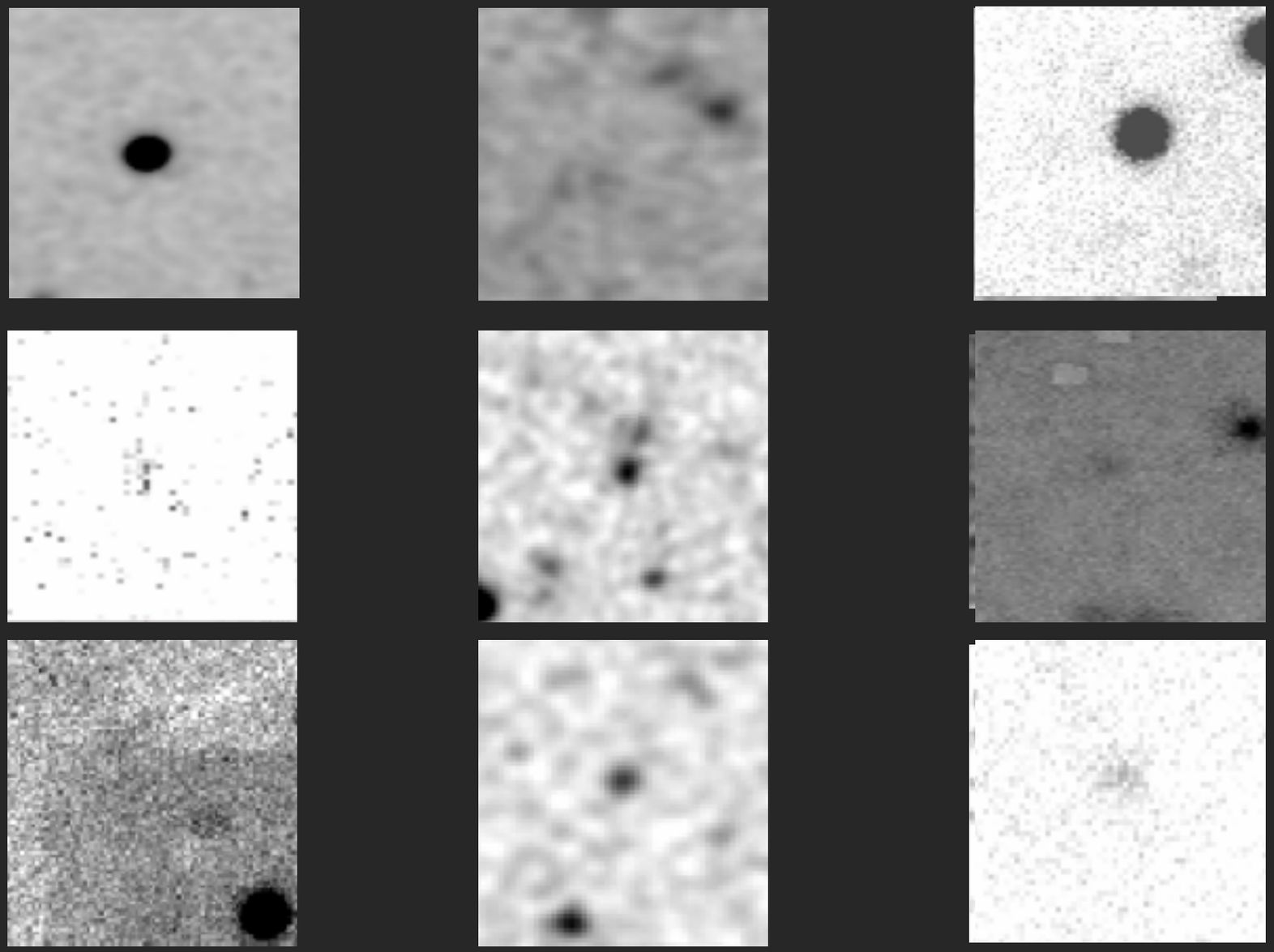


Xu, Cai et al. in prep

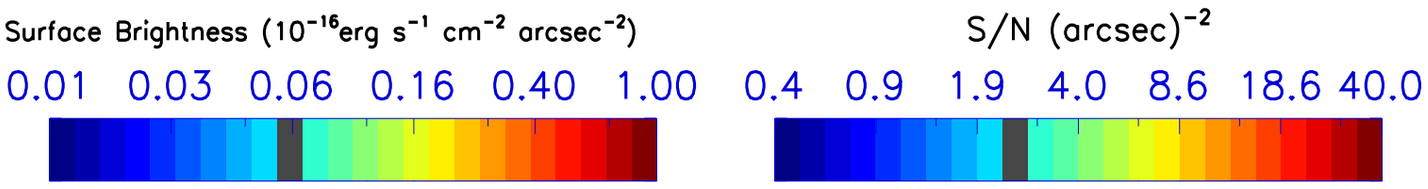
DISCOVERY OF AN ENORMOUS LYα NEBULA IN A MASSIVE GALAXY OVERDENSITY AT $z = 2.3$

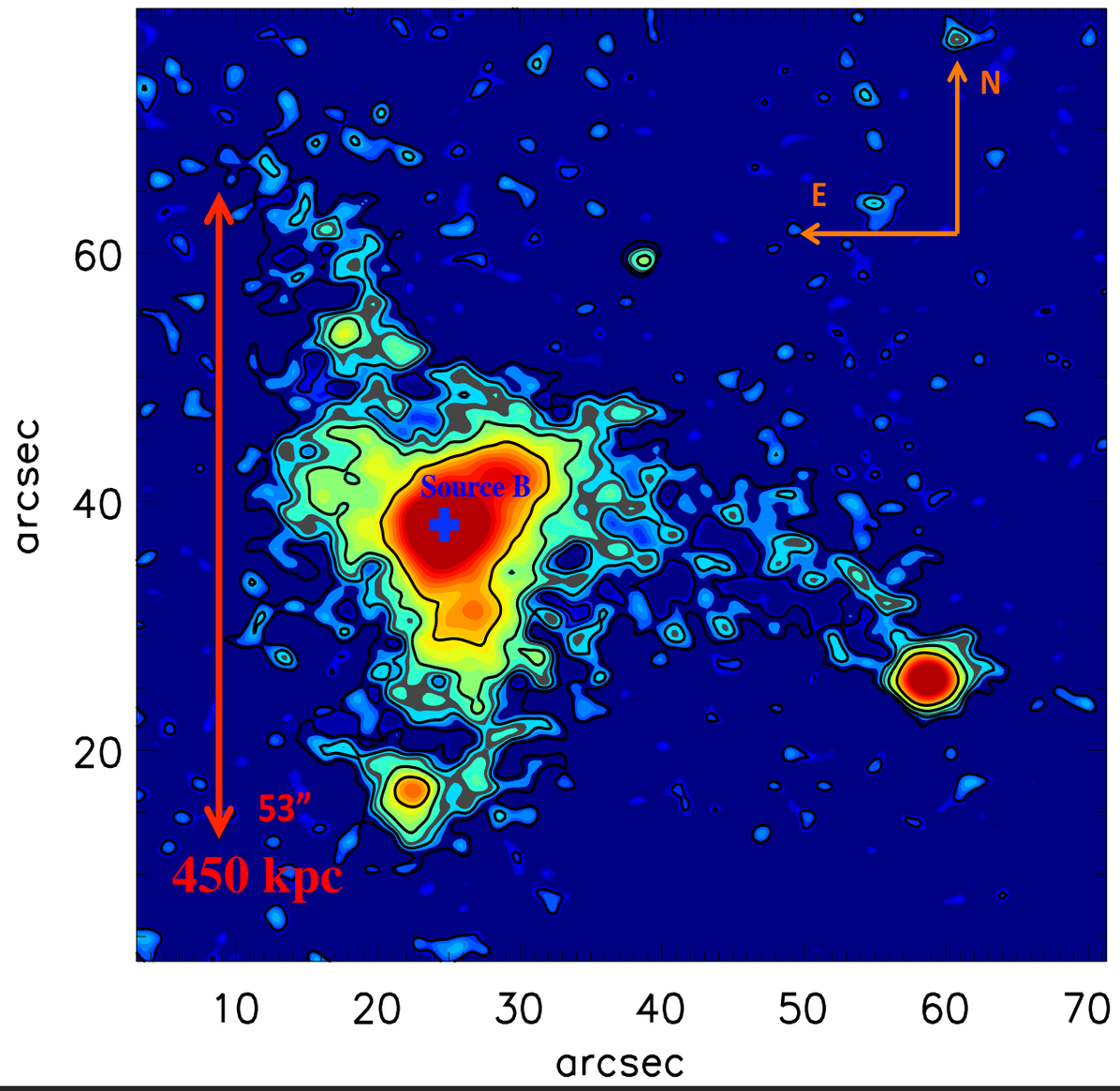
ZHENG CAI[1,2,11], XIAOHUI FAN[2], YUJIN YANG[3], FUYAN BIAN[4], J. XAVIER PROCHASKA[1], ANN ZABLUDOFF[2], IAN MCGREER[2], ZHEN-YA ZHENG[5,6], RICHARD GREEN[2], SEBASTIANO CANTALUPO[7], BRENDA FRYE[2], ERIKA HAMDEN[8], LINHUA JIANG[9], NOBUNARI KASHIKAWA[10], RAN WANG[9]

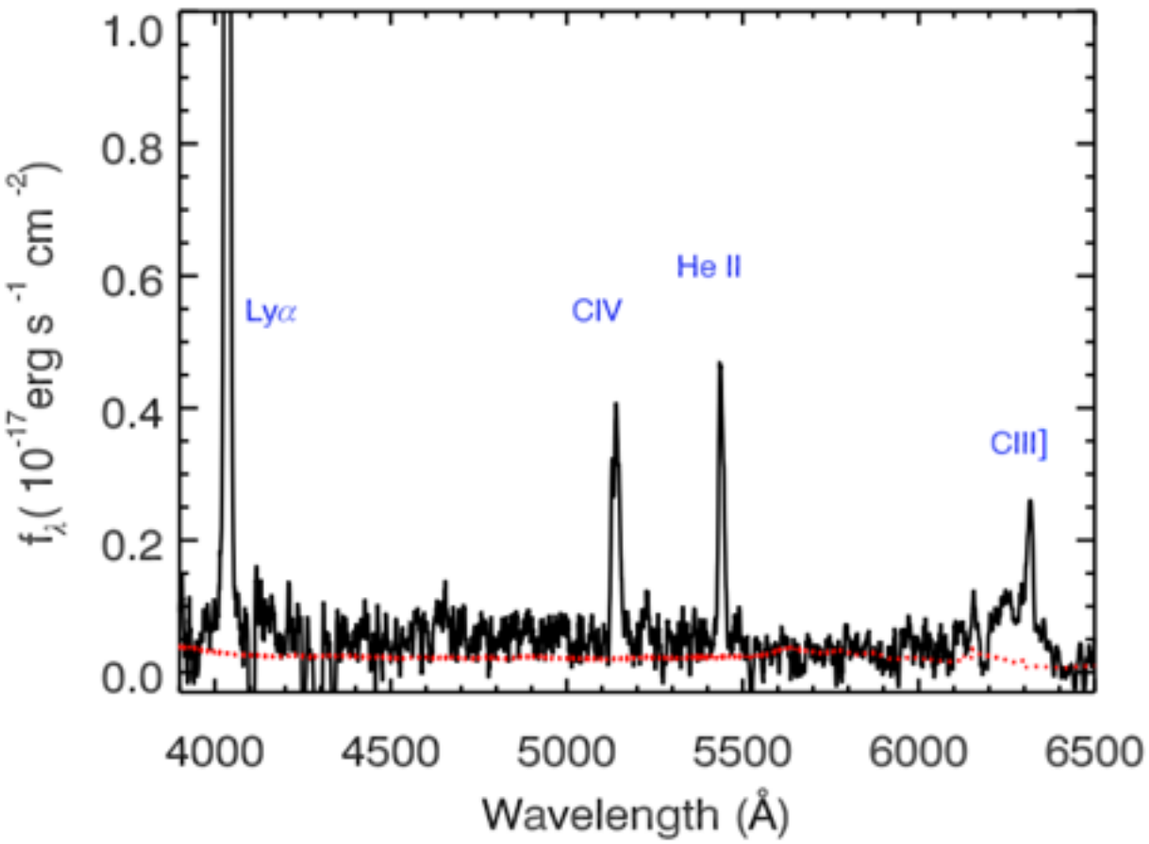
MAMMOTH-1 nebula

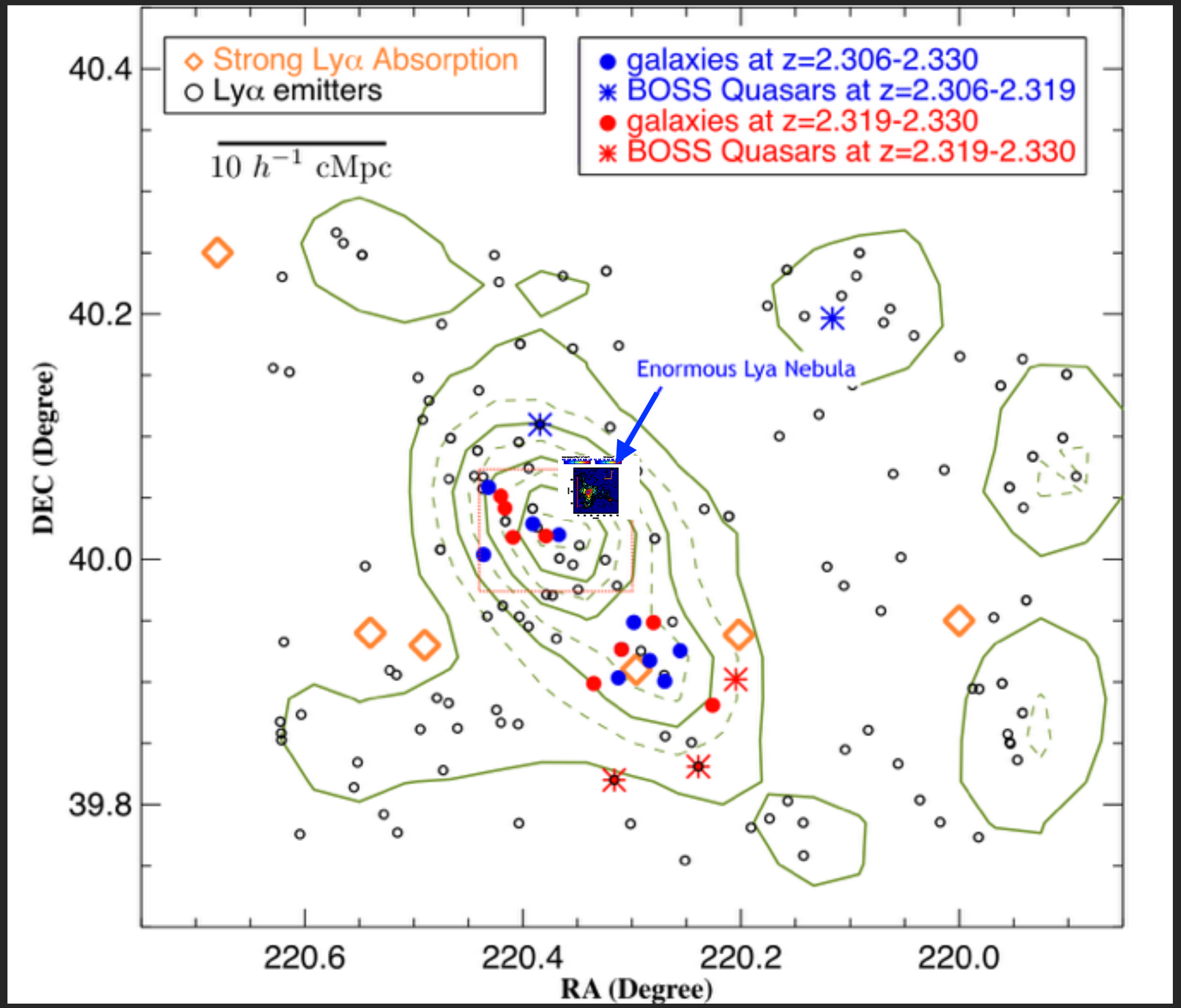
Cai et al. (2017) ApJ, 831, 71

radio quiet source





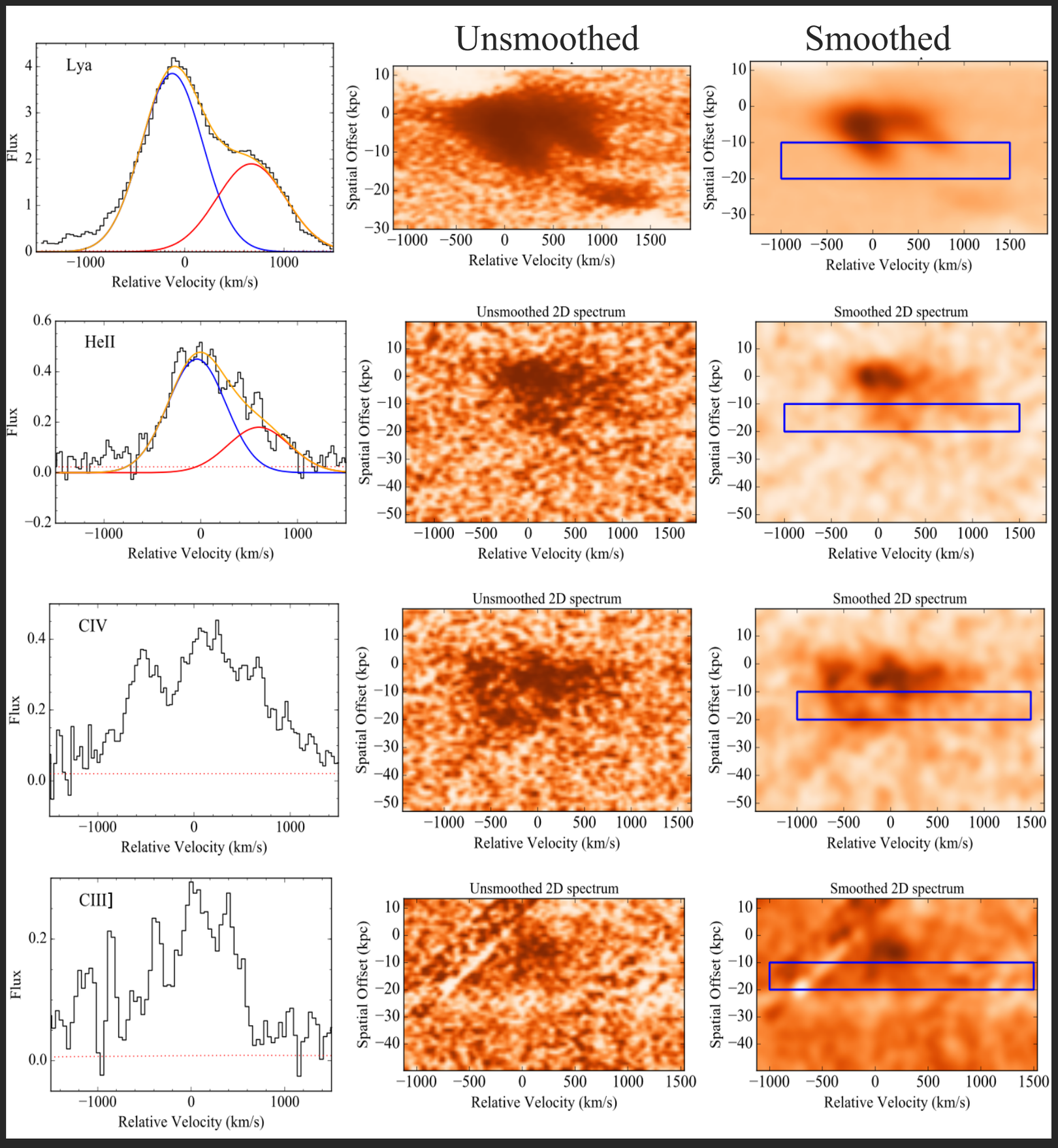




The first large scale structure with an overdnesity on (15 Mpc)^3 volume 10.8 at z>2.

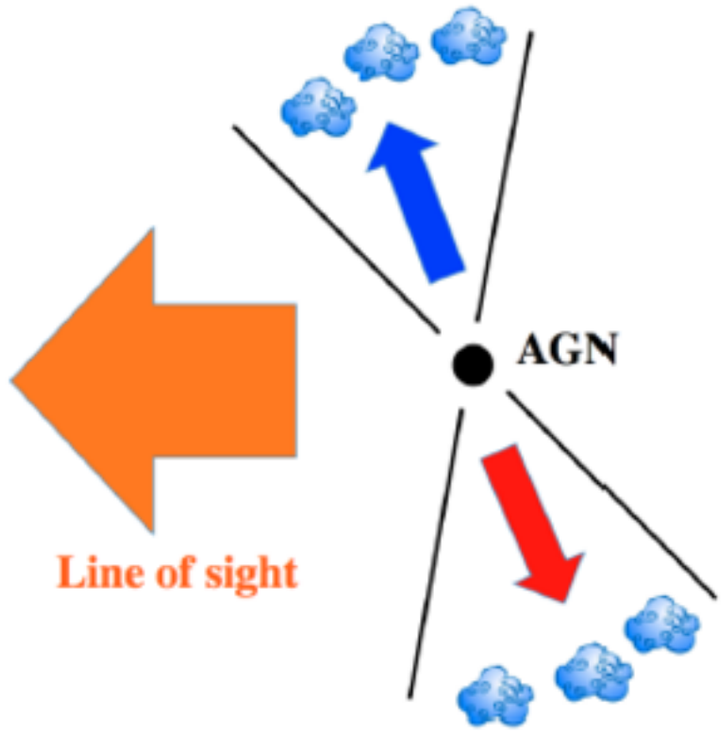
Cai et al. (2017b) ApJ 839, 131

LBT/MODS Observations: Huge kinematics never seen before in other nebulae



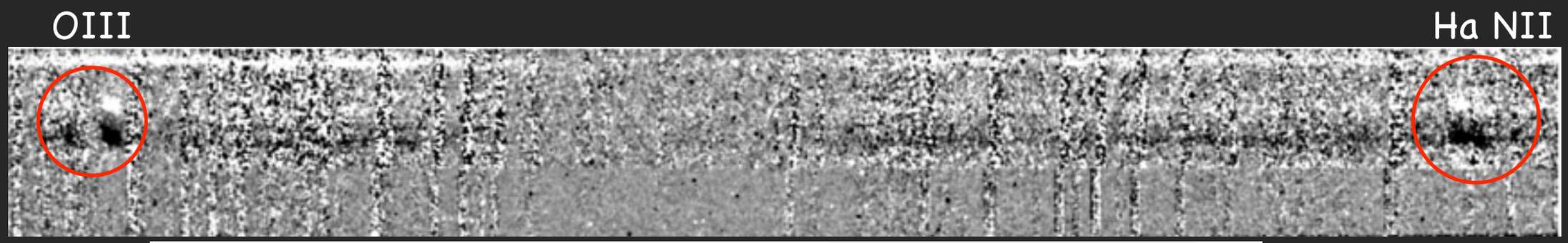
Cai et al. (2017) ApJ, 831, 71

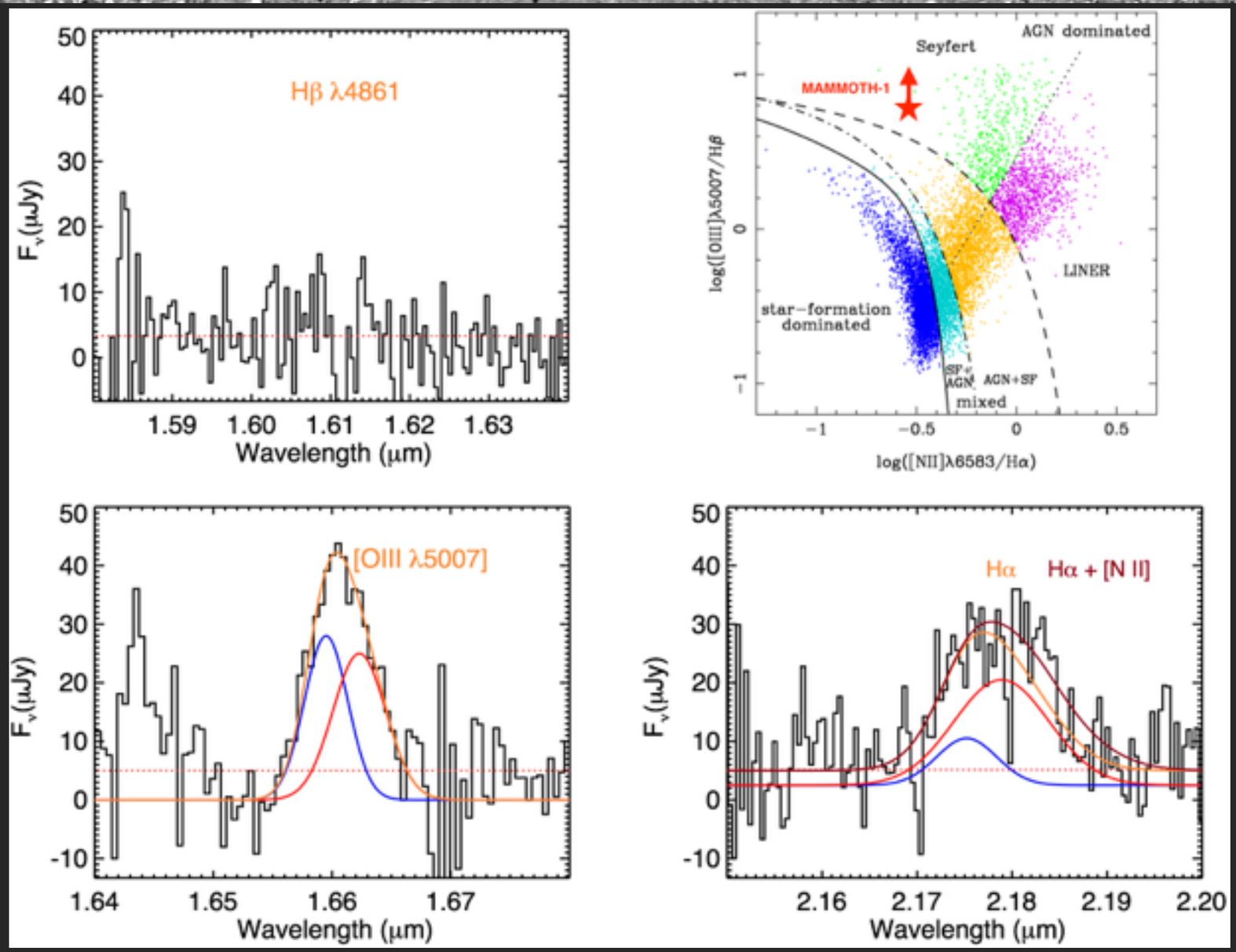
gas outflow model
(AGN feedback)



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

LBT/LUCI spectrum, 2.5-hour integration:



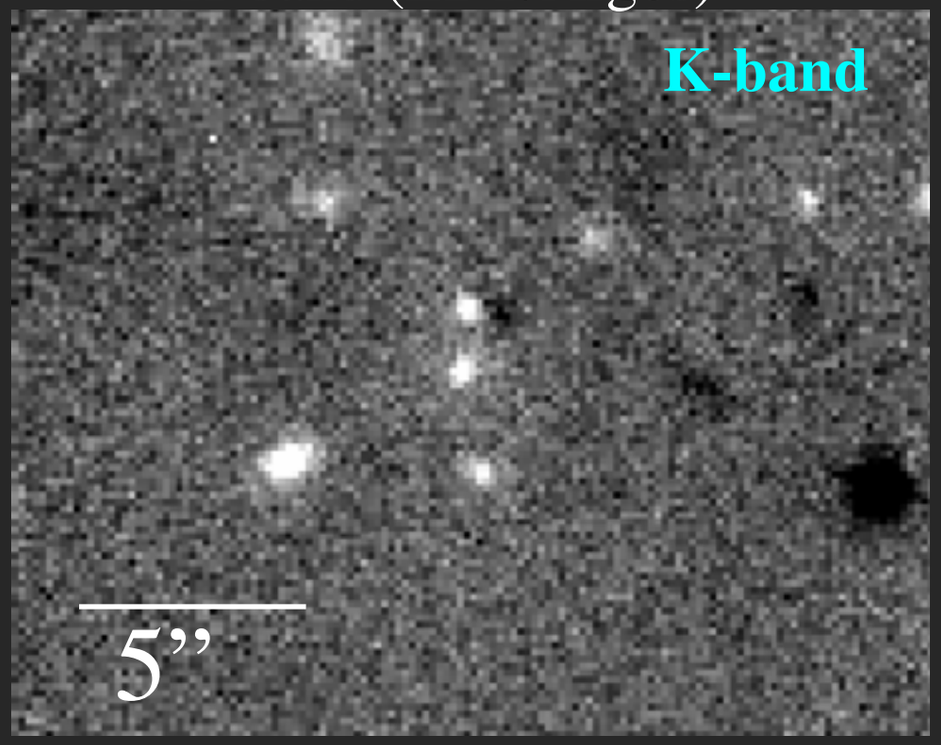


LBT Argos ground-layer AO commissioning observations

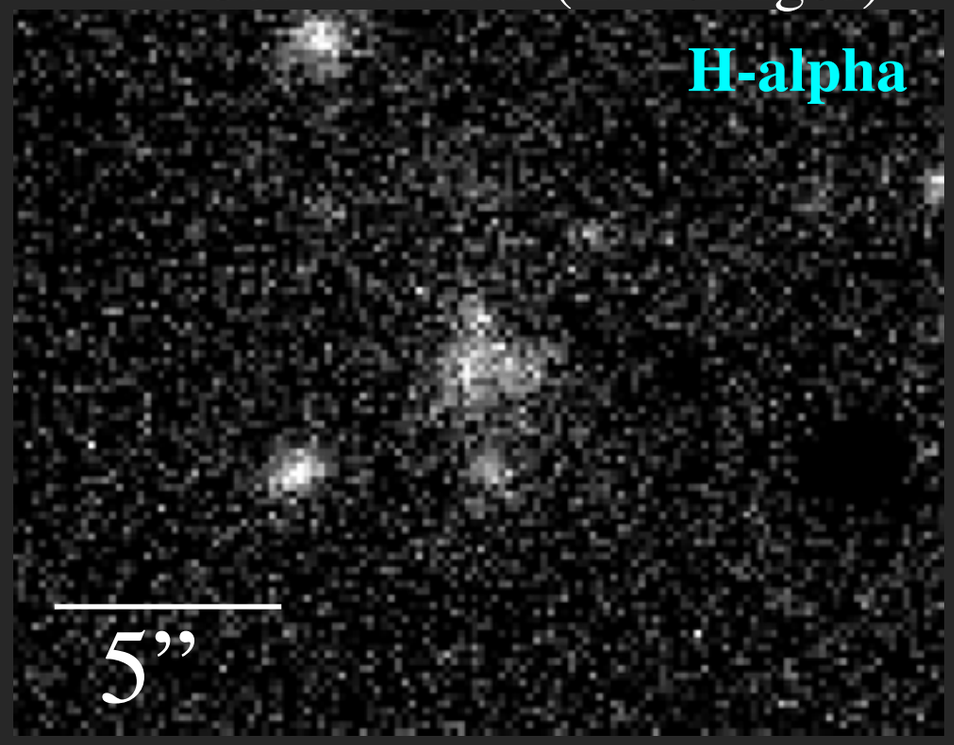
Cai + in prep.

MAMMOTH-1 H-alpha emission, FWHM = 0.25-0.3” in K-band

K-band (LBT/Argos)



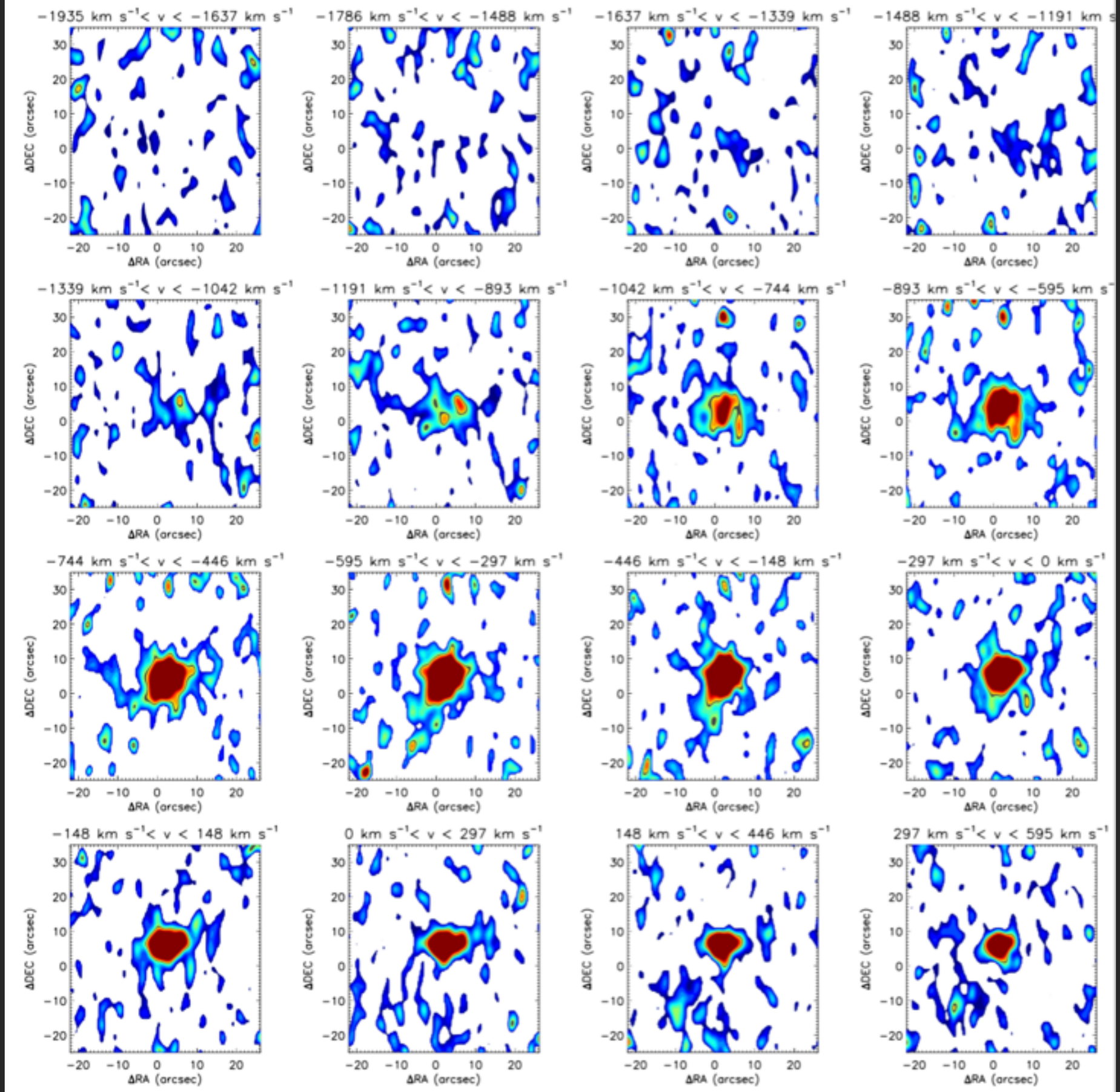
Br-Gamma filter (LBT/Argos)



K-band (Subaru, 0.5” seeing)

Comparing Ha with Lya, the Lya escape fraction is 100% — no dust

IFU (cosmic web imager) observations of MAMMOTH-1 nebula



Each sub-figure has a velocity bin of 300 km/s

from -2000 — +2000 km/s

present all pixels with flux > 2-sigma level

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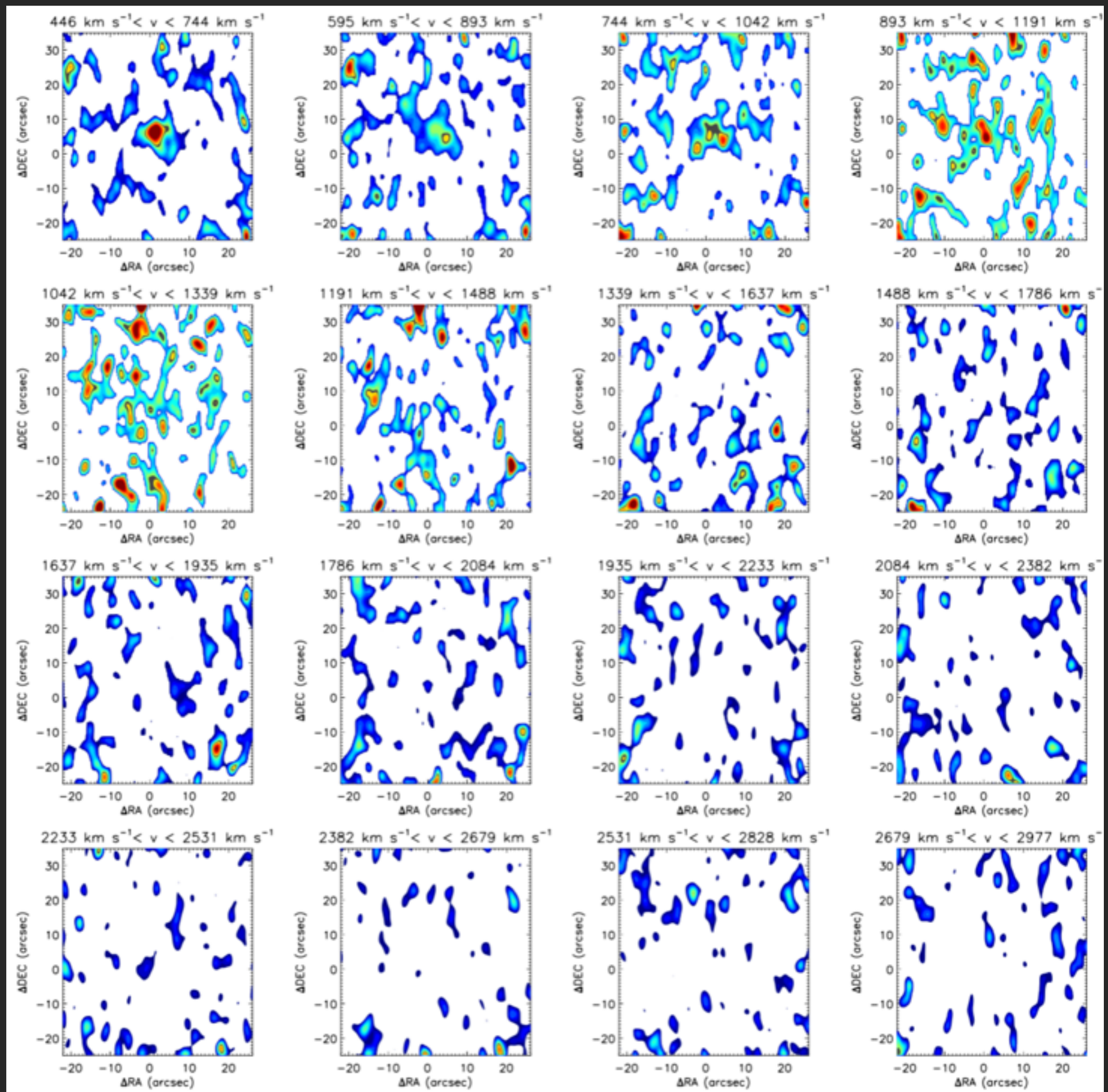

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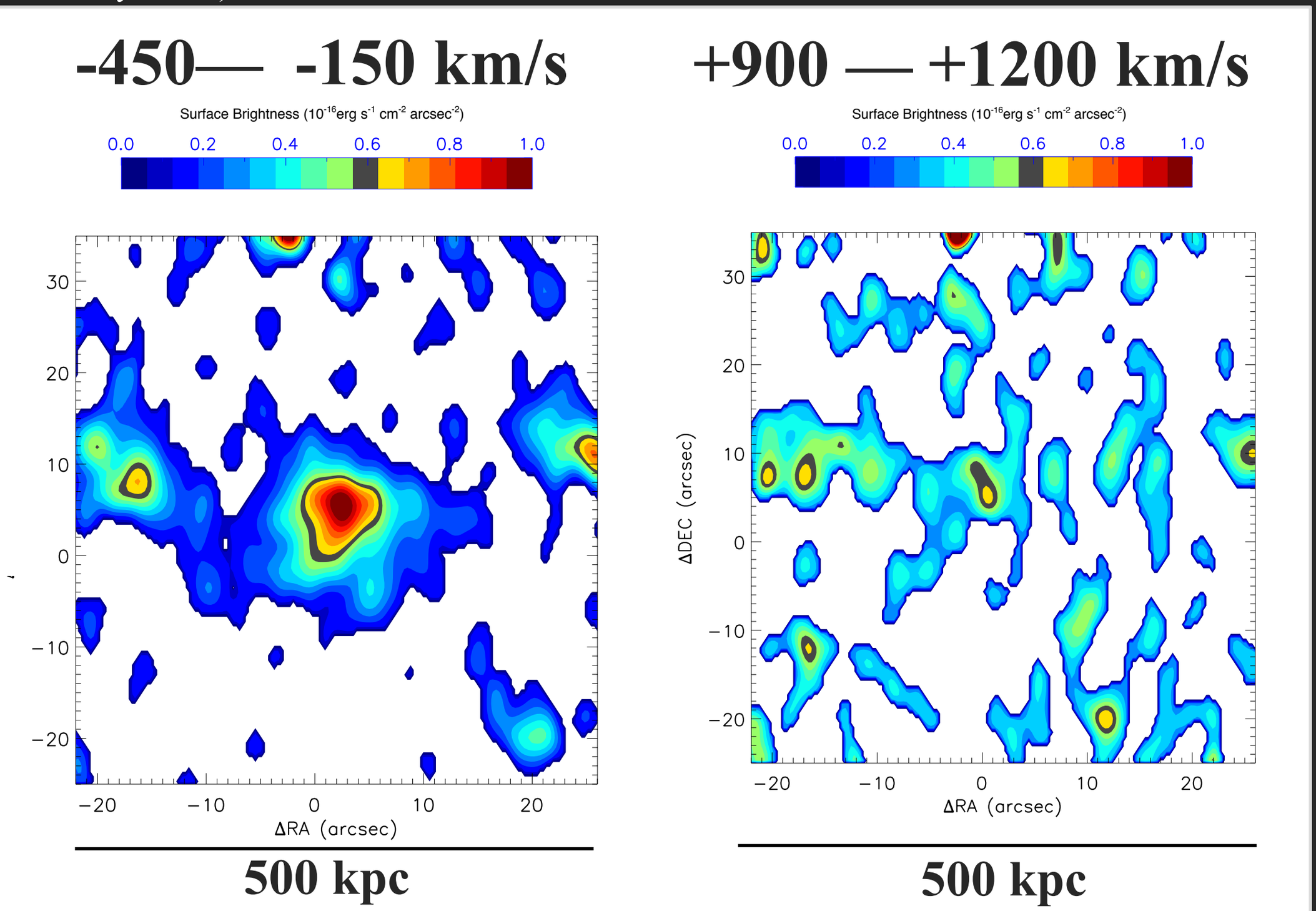
(preliminary result)



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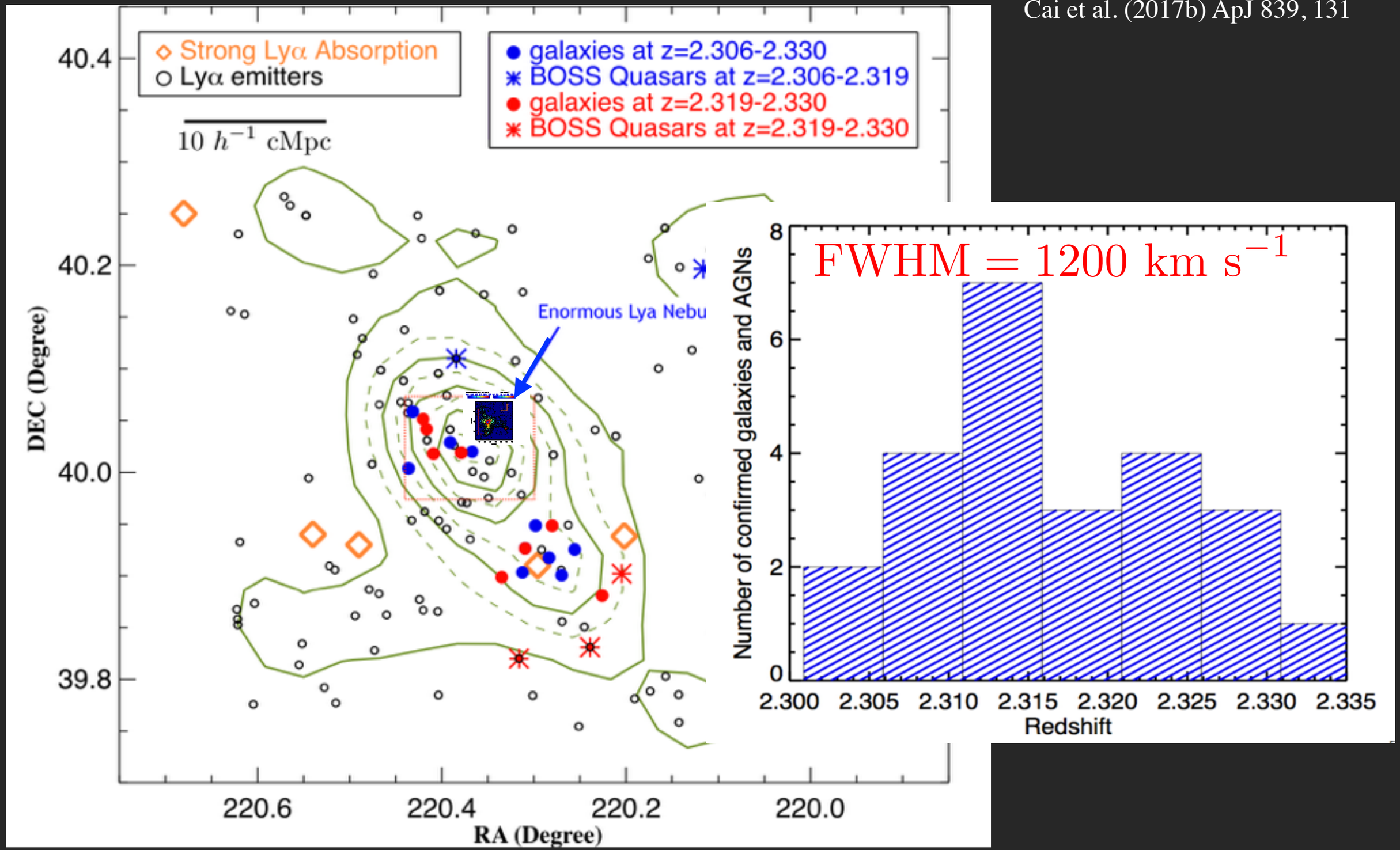
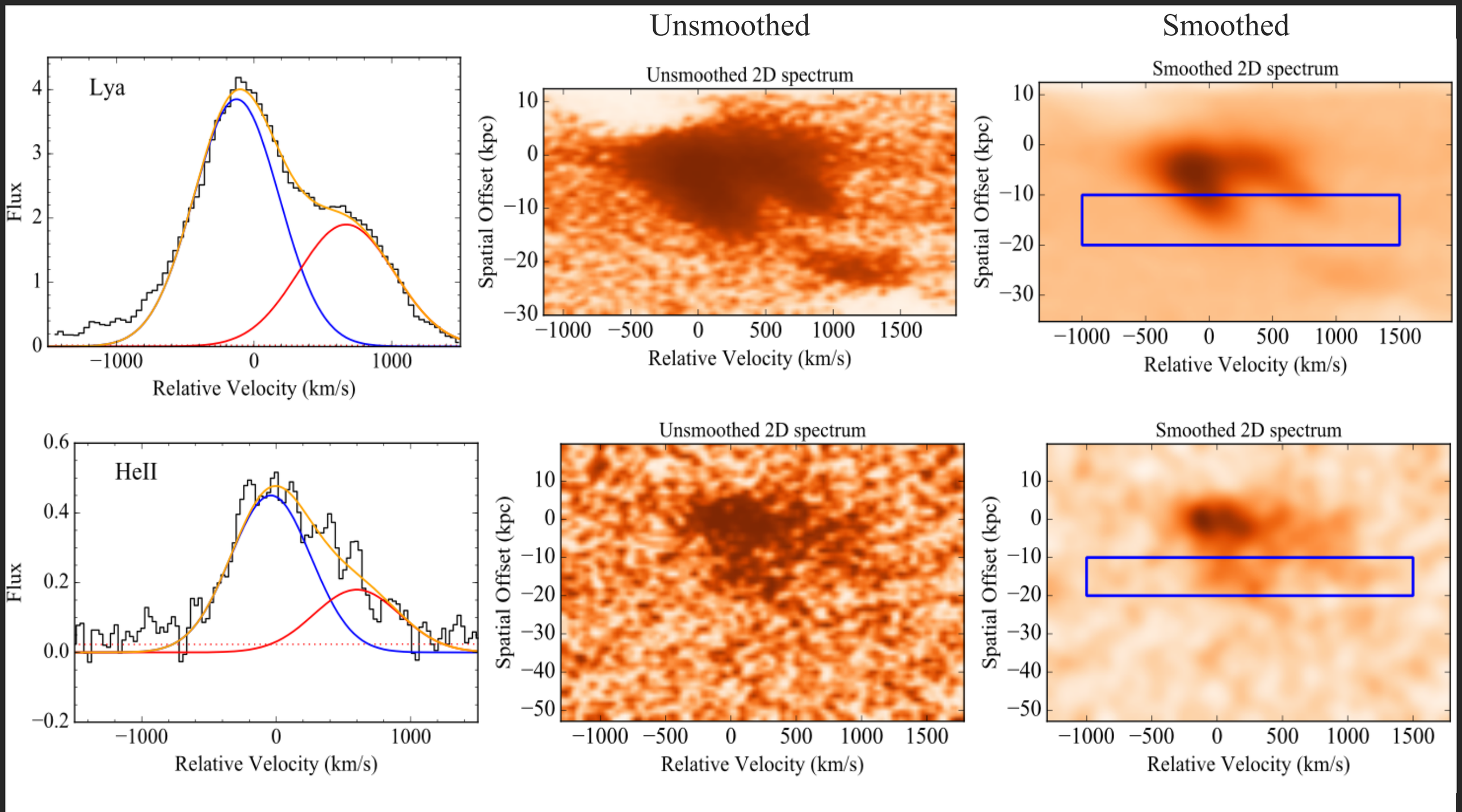
Cai et al. (2017b) ApJ 839, 131



LBT/MODS long-slit Observations: Huge kinematics

Cai et al. (2017) ApJ, 831, 71



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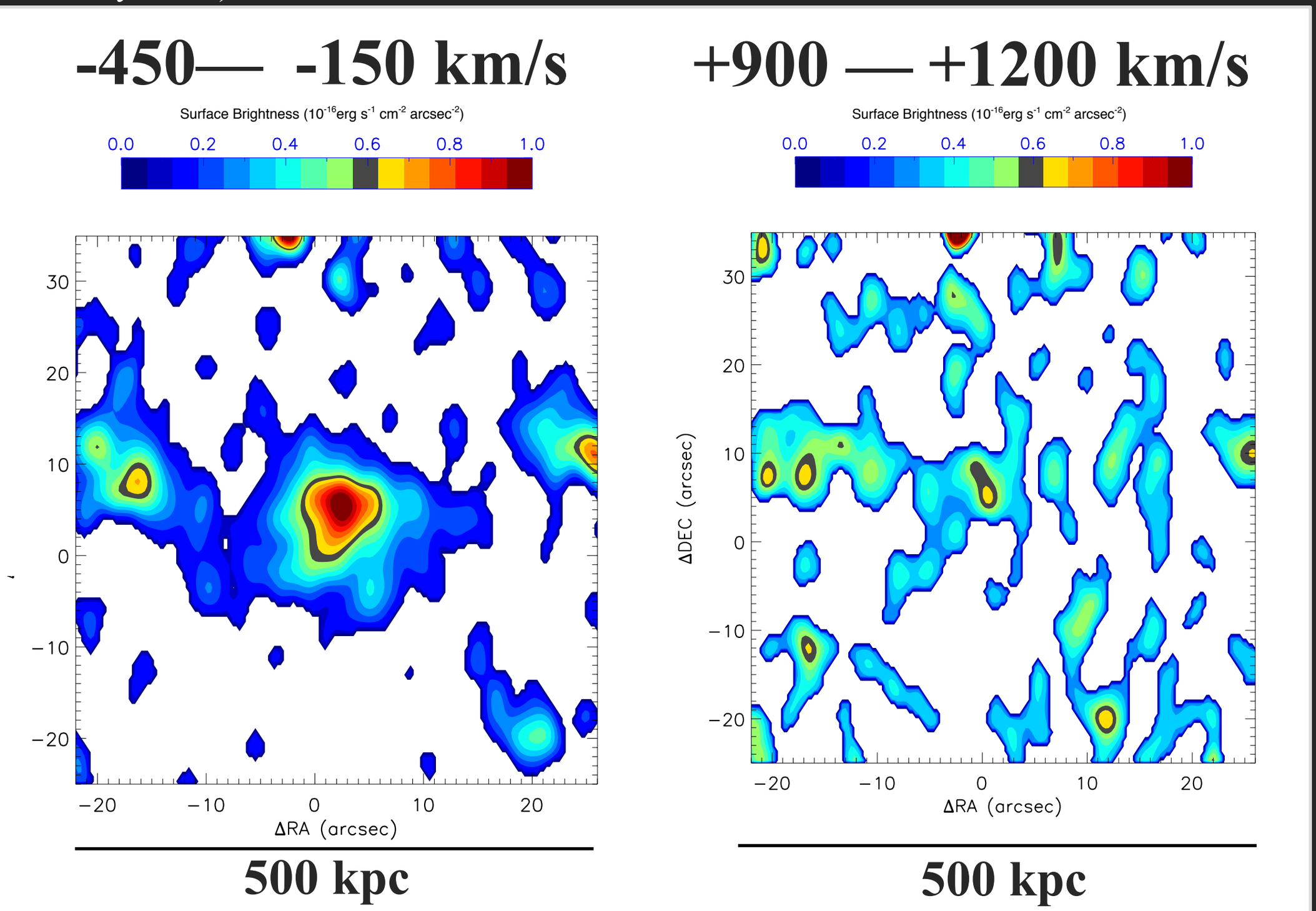


Summary

- Strongest Lyman alpha absorption (group) can be a very effective way to trace extreme overdensities/proto-clusters from huge survey volume —> not rely on existing sources, more unbiased way.

- The next few years is a golden age, with HSC, DESI, PFS, HETDEX, the confirmed protoclusters will increase from a few to a statistical sample. (MAMMOTH got 3.5-night Subaru/HSC time in 2017B).

- We systematically selected a few MAMMOTH fields at z=2.2 — 2.4 from Gpc^3 survey volume. spectroscopic confirmed three most massive overdensities using Keck, LBT spectroscopy; will soon be covered by deep ***HST*** and ***Chandra*** imaging.

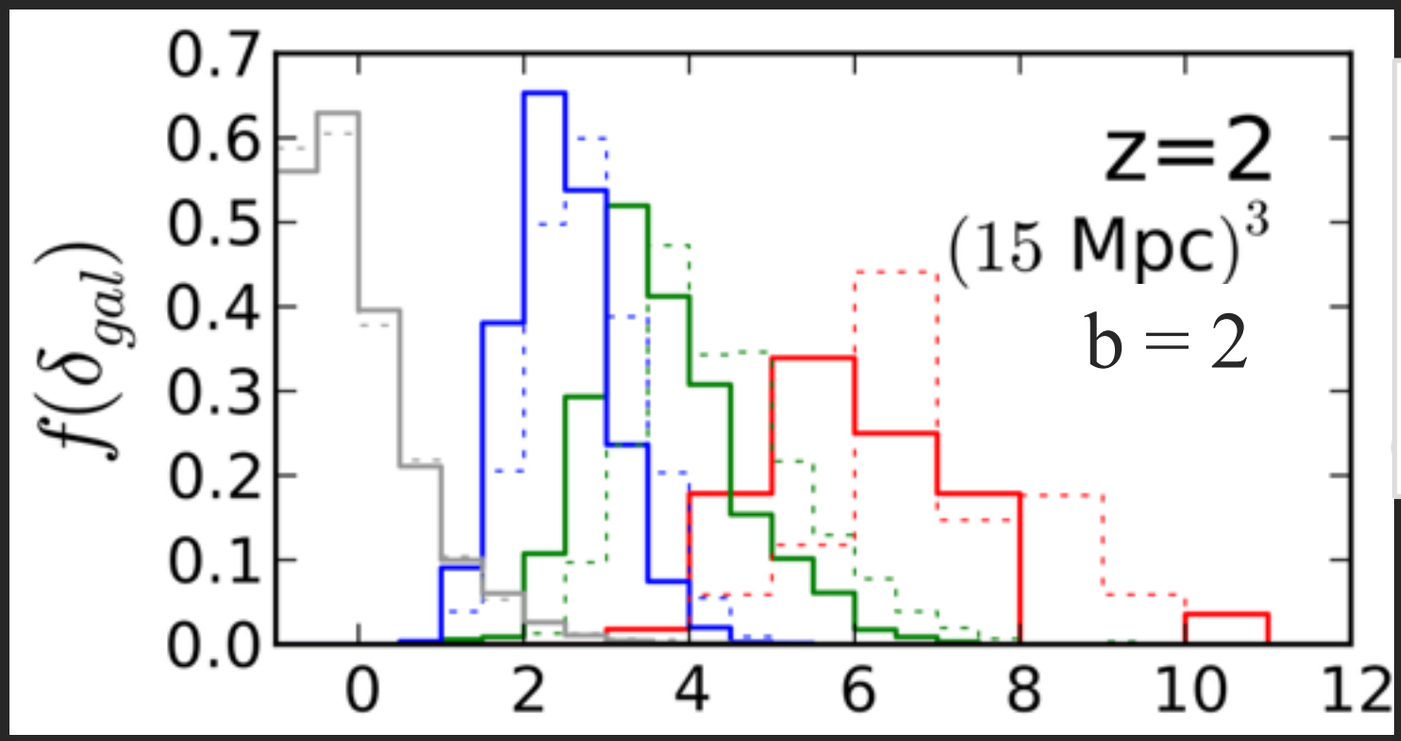
- We identified a sample of ultraluminous Lyman alpha nebulae. With IFU (CWI, KCWI), this unique sample will reveal IGM - galaxy interactions, ICM evolution.

- MAMMOTH can provide new constraints to structure formation, ICM evolution, through absorption and emission. Further, inspired by many great talks in the conference, we still need some crucial multi-wavelength observations: e.g., sub-mm follow-up for better understanding galaxy evolution.

Zheng Cai, Aug 5, 2017

MAMMOTH overdensiteis represents COMA-progenitors

	bias (b)	δ_g (15 cMpc)	δ_m (15 cMpc)
BOSS1441 (spec confirmed)	2	10.8	3.4
BOSS0034	2	8.3	3.1
BOSS1244 (spec confirmed)	2	6.6	2.7
BOSS1542 (spec confirmed)	2	6.4	2.7
BOSS0112	2	5.8	2.4
BOSS2335	2	4.8	2.0
BOSS1513	2	2.9	1.5



Red: Coma ($10^{15} M_\odot$) progenitors

Green: Virgo (4x $10^{14} M_\odot$) progenitors

Blue: Fornax ($10^{14} M_\odot$) progenitors

Chiang+13

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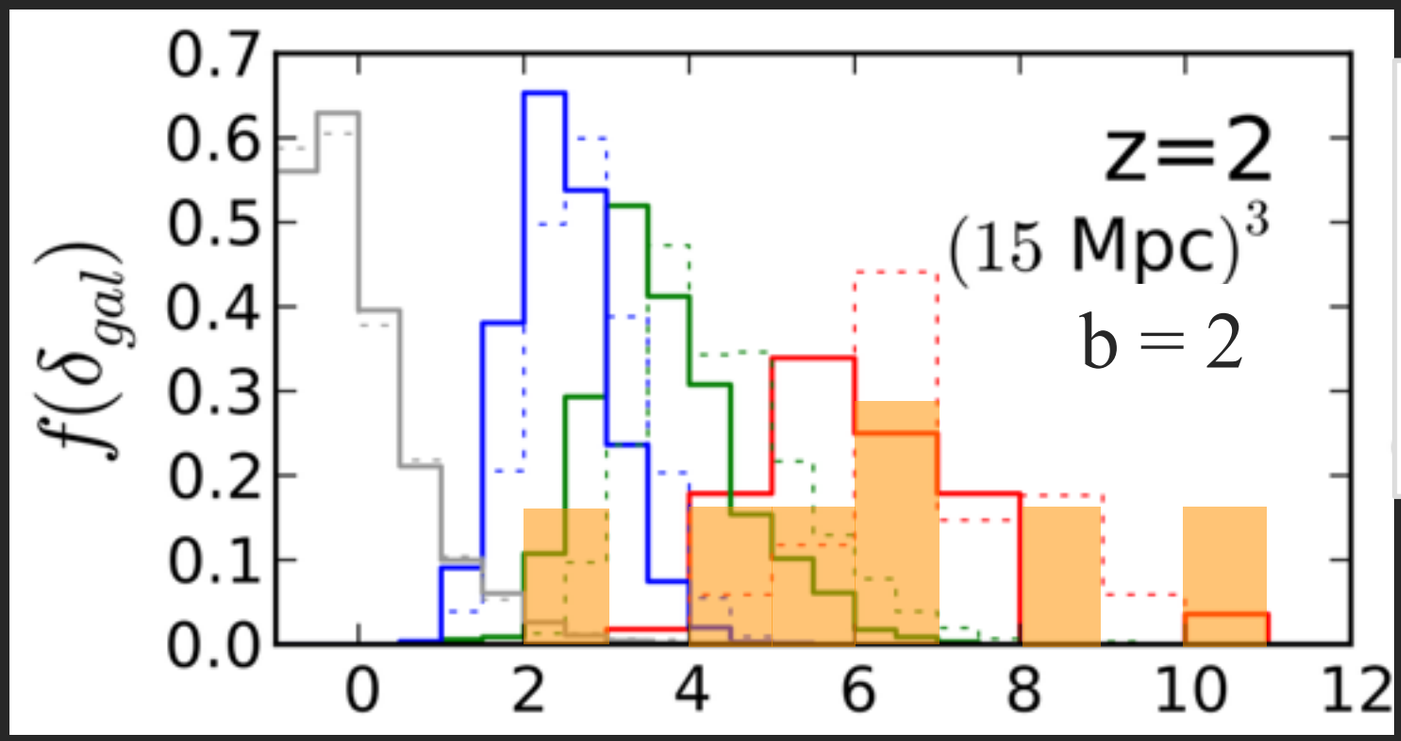

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Chiang+13

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

LBT/LUCI spectrum, 3-hour integration: