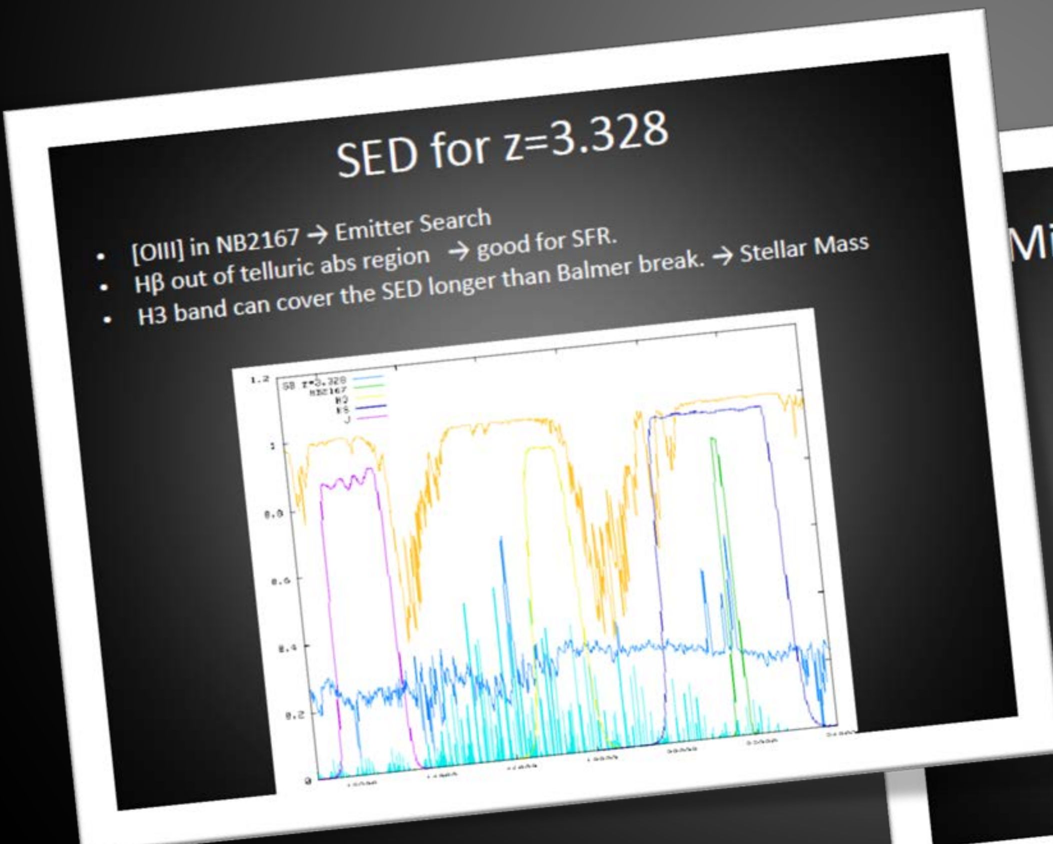
TAO/SWIMS Science Workshop
2015-09-17 ver.1

Quick Suvery of Protoclusers around AGNs

Ichi Tanaka
(Subaru Telescope)

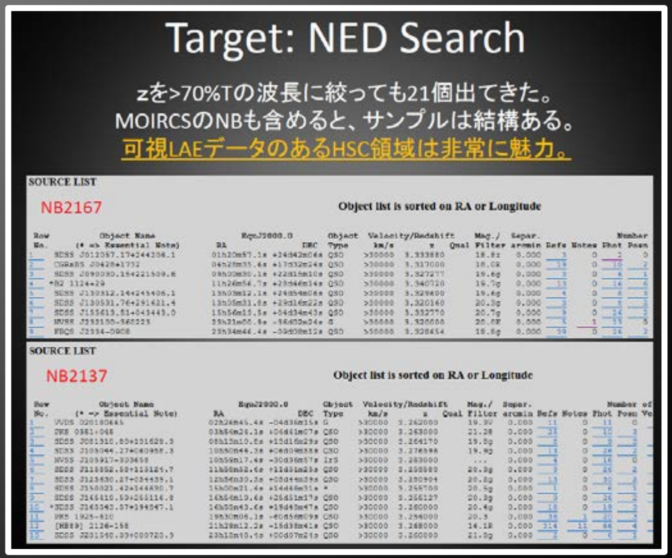
In 2013…

- I proposed the strong [OIII] emitter survey for PRG fields using SWIMS NB filters…



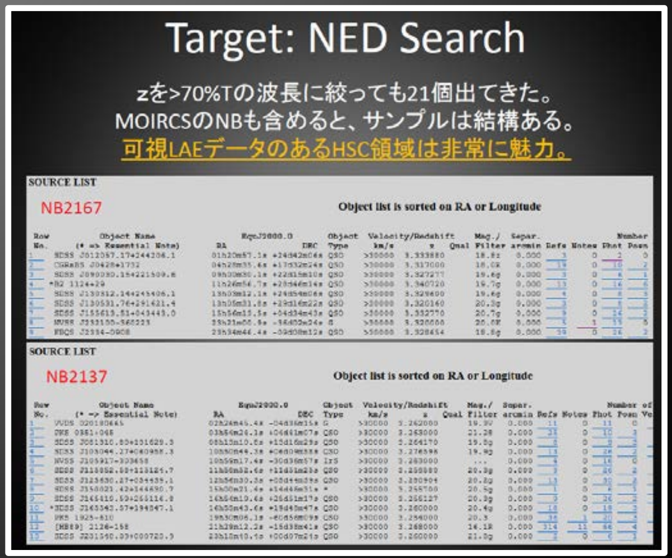
The Essence of 2013 Talk...

- [OIII] Emission would be useful to probe massive SF gals at z>2.6 (i.e. Hα not available).
- Quick PRG Environment Survey.
- Efficient J & K simultaneous imaging capability of SWIMS is the great advantage for quick survey.
- The LAE data by HSC NB527 → SWIMS O3Es Follow-up!
- Z~2 HAE & O3Es dual survey is still to do item.



The Essence of 2013 Talk…

- [OIII] Emission would be useful to probe massive SF gals at z>2.6 (i.e. Hα not available).
- Quick PRG Environment Survey.
- Efficient J & K simultaneous imaging capability of SWIMS is the great advantage for quick survey.
- The LAE data by HSC NB527 → SWIMS O3Es Follow-up!
- Z~2 HAE & O3Es dual survey is still to do item.



Case Study:
The [OIII] Emitters in the HS1700+64 Protocluster at z=2.3

(I.Tanaka et al, ASJ 2015 Fall meeting)

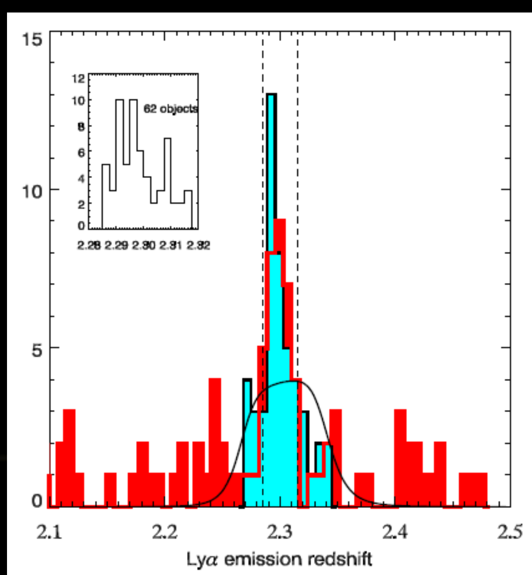
©N.Kashiikawa

Basic Interests…

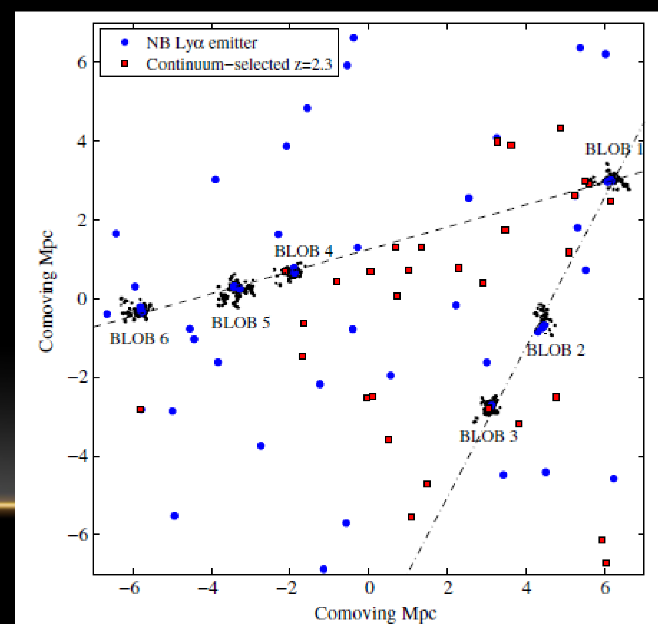
- Their counterparts in LAEs/HAEs/UV objects?
- How they can probe the structure?
- How the physical parameters are derived from the sample?
- Counterparts for the Interesting Objects (LABs, AGNs, SMGs)?

HS1700+64 PROTOCLUSTER

- Steidel et al. (2005). “Redshift Spike” at z=2.300 +- 0.015.
- The structure traced by 6 LABs (Erb+ 2011)!
- KBSS field … rich spec-z data (~100 sp-z cluster member).
- Rich auxiliary photometric set (UnGRJK) with multi-wavelength observations (Chandra, PdBI, Spittzer, Herschel etc…).

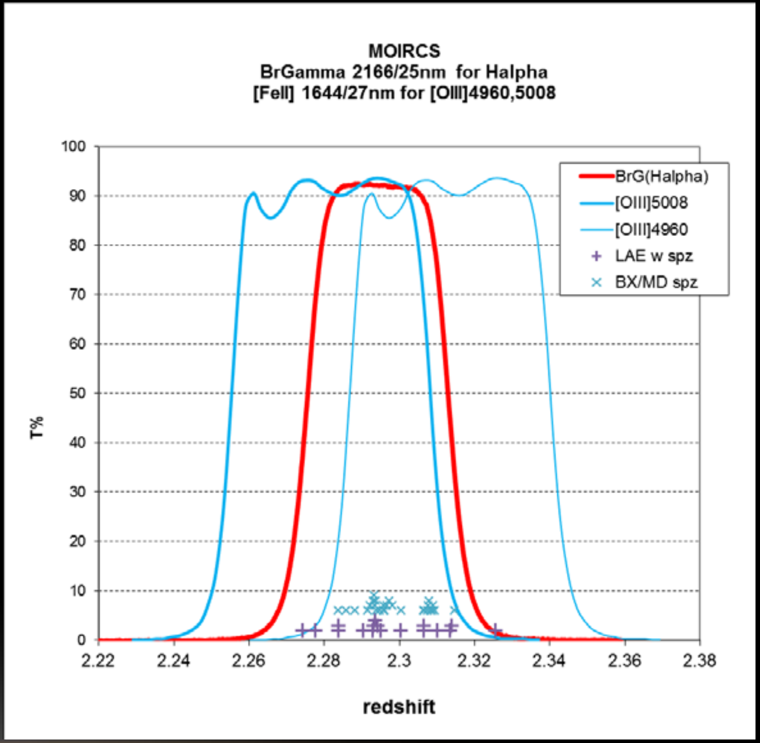


Bogosavljevic (2010)



Z=2.300 IS VERY SPECIAL BECAUSE…

- Hα enters into the BrG (2.166um) NB filter!
- [OIII] enters into the [FeII] (1.644um) NB filter!



Dual NB emitter selection will work!

Erb, Steidel have….

HAE: ~20hrs NB Imaging Data by Palomar. Depth ~23.6 (NB: Erb+ in prep)!

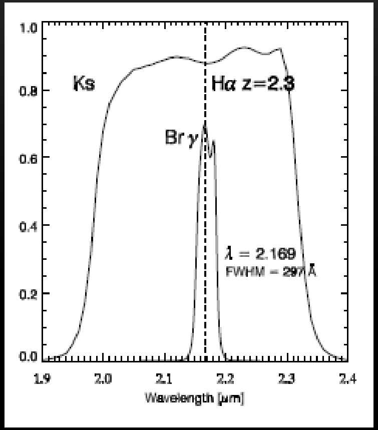
Also, deep LyA Emitter (LAE) data too.

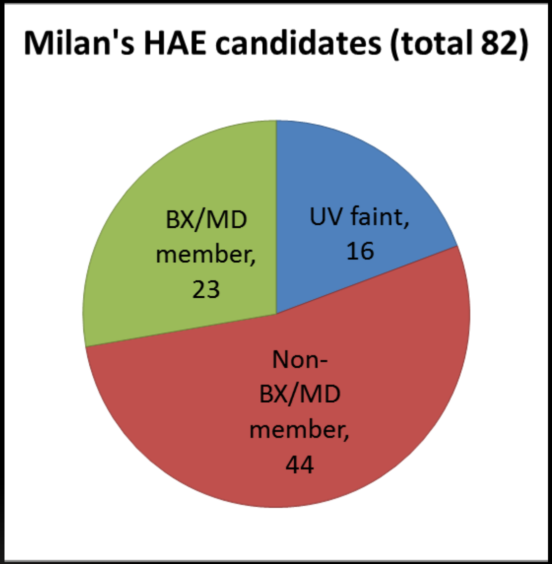
Erb's HAE sample should all be detected.

HS1700+64 PROTOCLUSTER: HAES

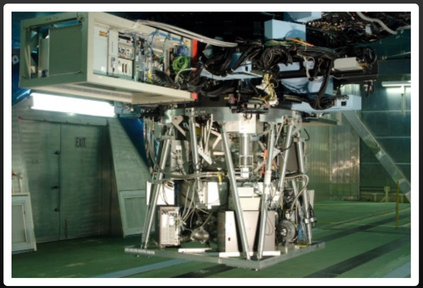
- HAEs … 82 candidates
  - UGR color selection does not work for >70% of sample.
  - Spec-z for only 21.

Many are too faint to confirm its redshifts spectroscopically.



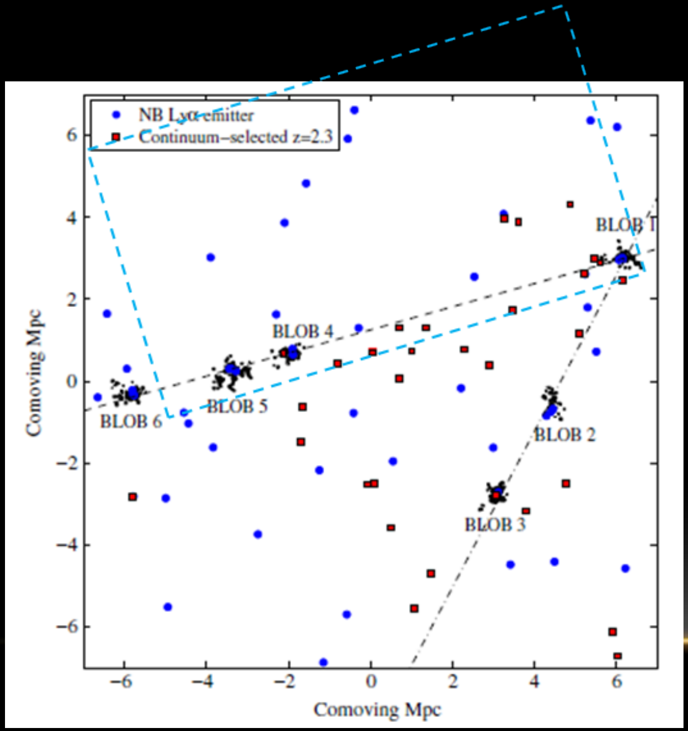


MOIRCS: OBSERVED FOV



The whole protocluster scale is huge! Only a part can be probed by a MOIRCS FOV.

Fov is set on the northern LSS with three blobs.



Obs:
2014-06-23 (UT) Sv Obs (after power down event).
Exposure: 1680 sec (H), 3420 sec (NB164)

Final FWHM = 3.3pix = 0.39”

Depth:
H: 3-sigma = 23.136mag (ap, vega)
NB: 5-sigma = 21.69 mag [=23.04 mag AB]

NB EXCESS OBJECTS

Emitter Selection:

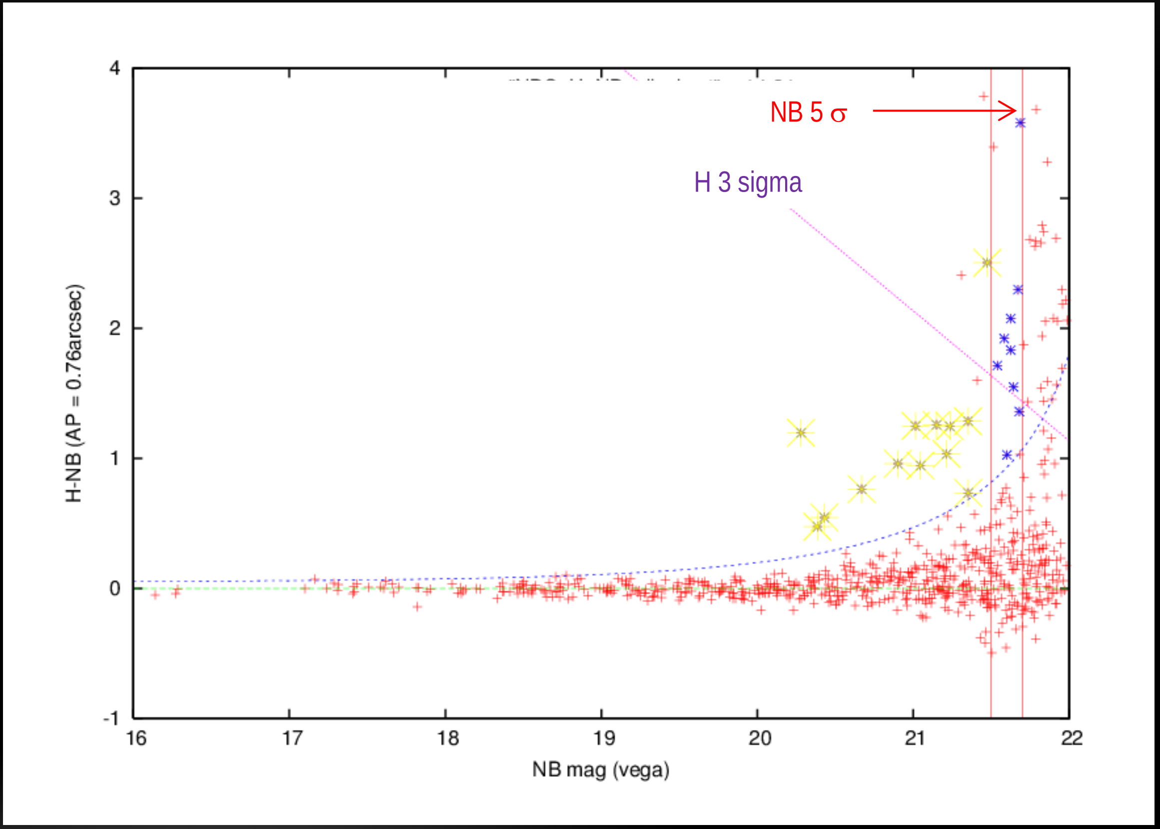
"3-sigma" NB excess selection are applied. Line detection limit of ~6E-17 cgs.

Catalog till NB=5 sigma limit … 22 obj.

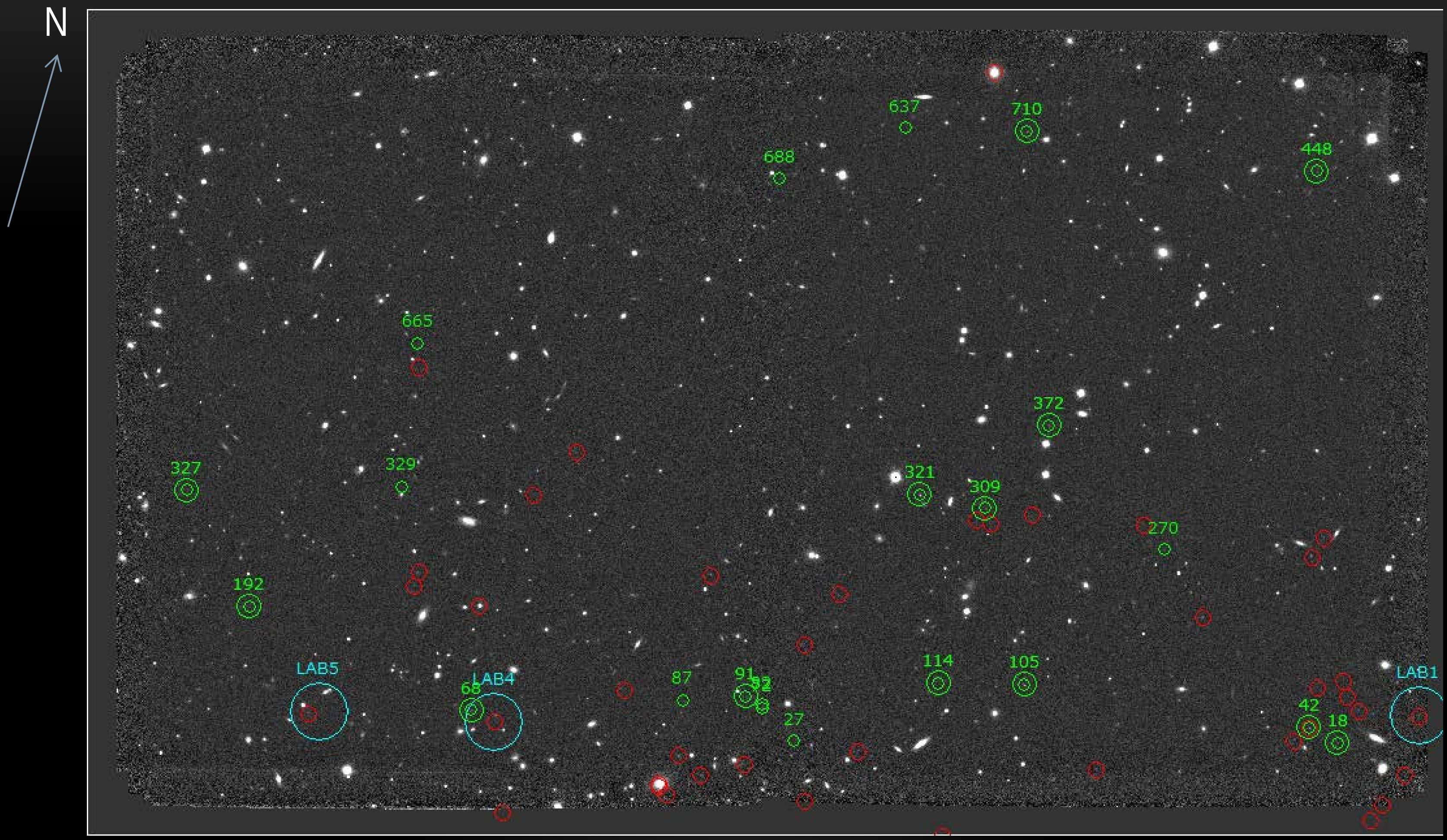
Catalog till NB<21.5 … 13 obj.

Cf: Koyama+2014 they counted 6 field emitters up to NB165~21.3, while we have 10 emitters.

→ ~3 sigma excess (lower limit for cluster)



CELESTIAL DISTRIBUTION OF EMITTERS

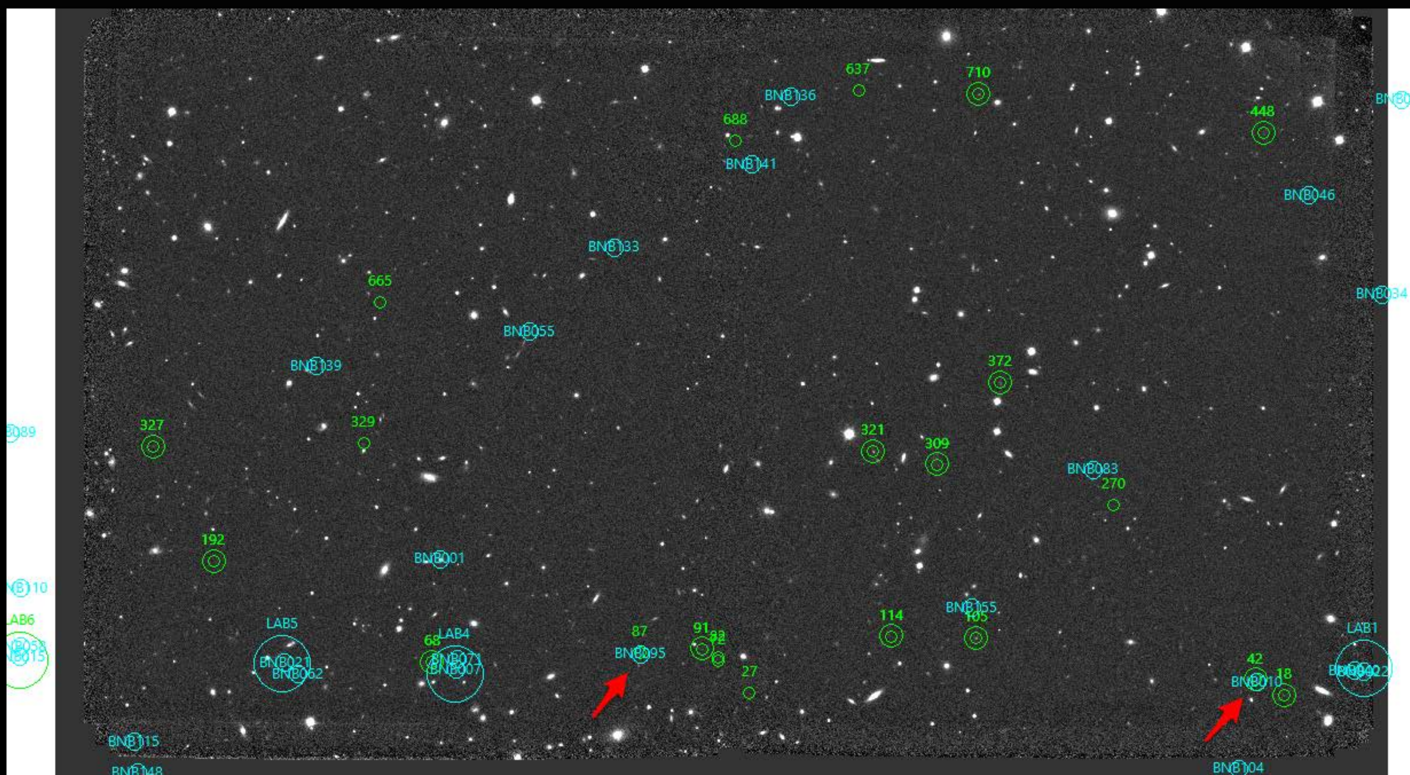


Double Green Circle: Emitters (NB<21.5)
Single Green Circle: Faintest Emitters (21.5<NB<21.7)
Red circle: Spec-z cluster members (2.24<z<2.36: z_cl=2.300)

Emitters are more at the lower half of the FOV!

LAE DISTRIBUTION AND OUR [OIII] EMITTERS

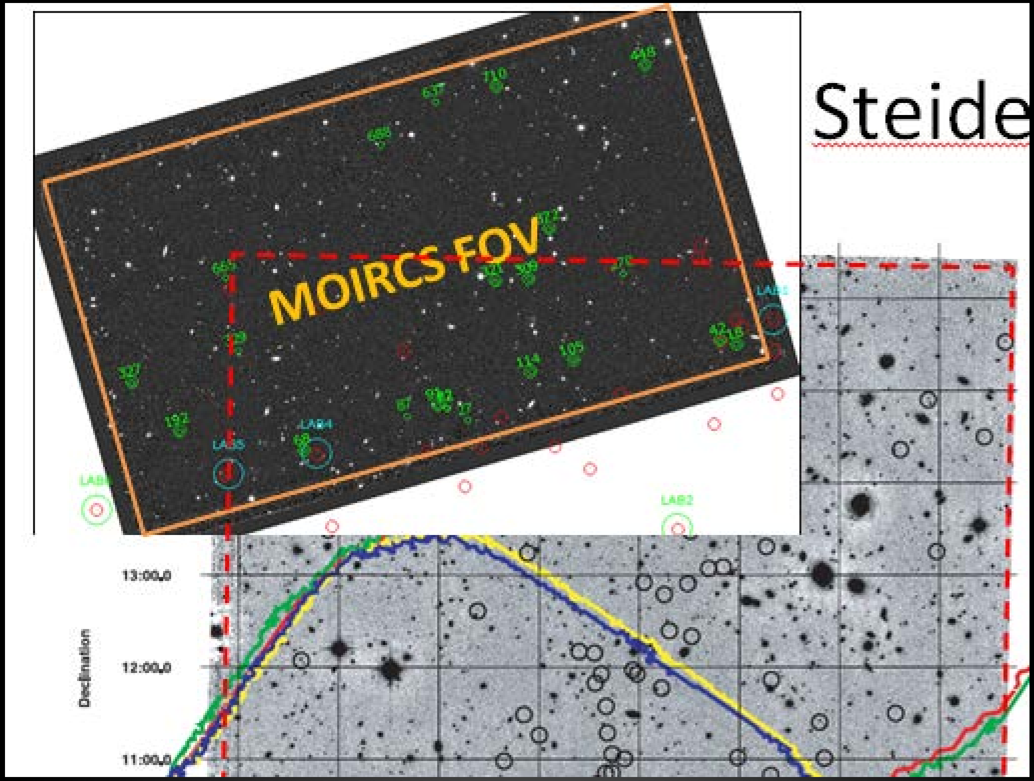
- Only 2 matches to our [OIII] emitters. One of them is AGN.



This may be natural, because the majority of LAEs are the low-mass, NIR-faint objects.
The overall distribution of LAEs and O3Es … similar? (not necessarily be the same!)

HAE DISTRIBUTION AND OUR [OIII] EMITTERS

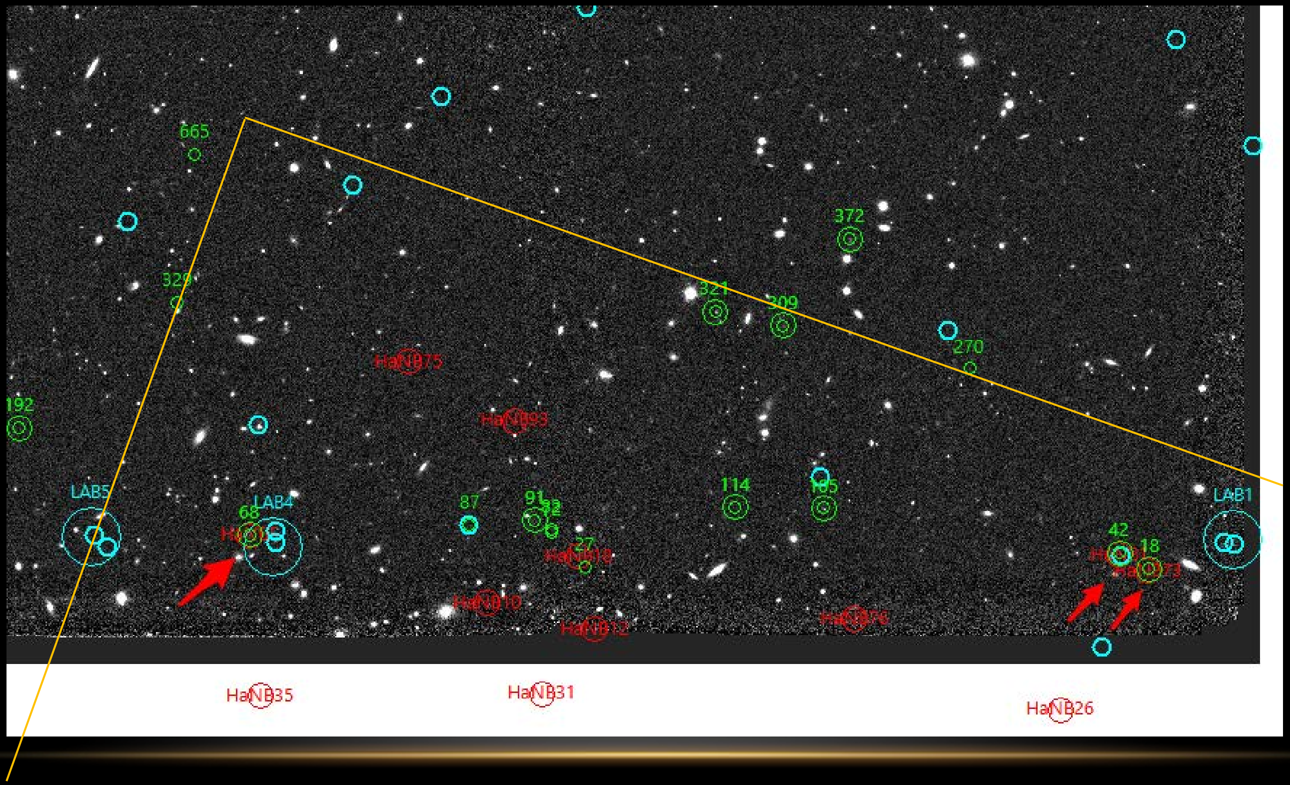
- Only a part of the Palomar NIR data overlaps with our FOV.



In our FOVs, there are 18 HAE candidates, with 3 spec-z member, 9 with BX/MD.

HAE DISTRIBUTION AND OUR [OIII] EMITTERS

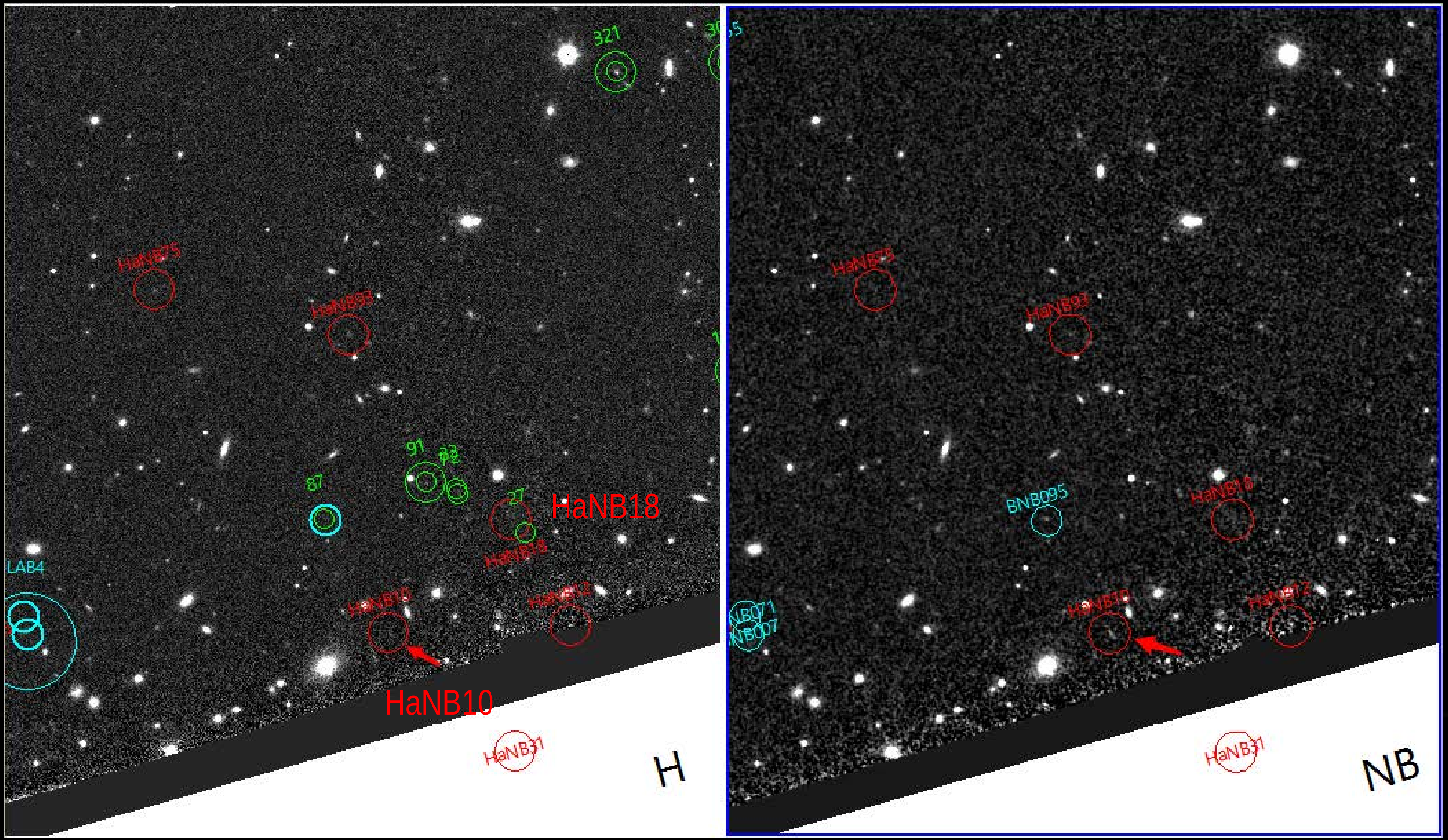
- Among 6 HAE candidates, 3 matches to our [OIII] emitters!
- Again, one of them is AGN.



4 HAEs are no counterparts, and our data is as deep as theirs. What about them?

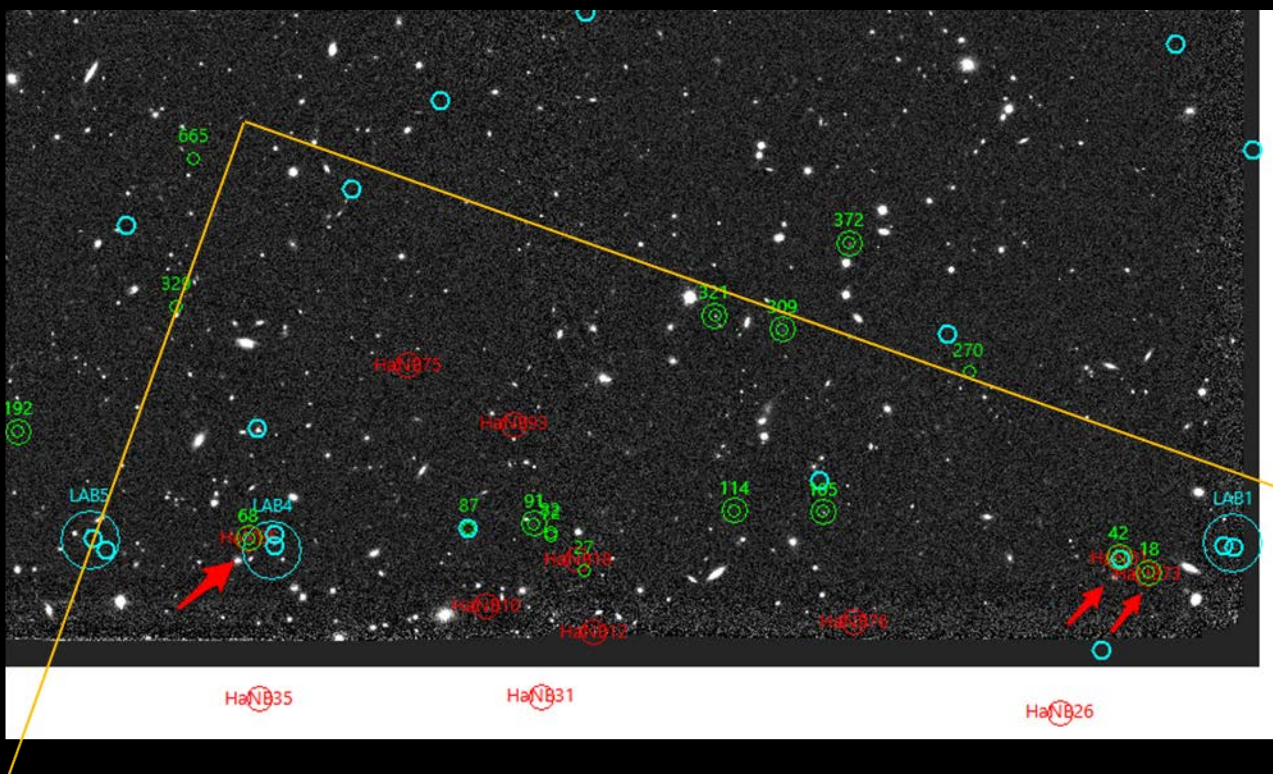
HAES WITHOUT [OIII] EMISSION

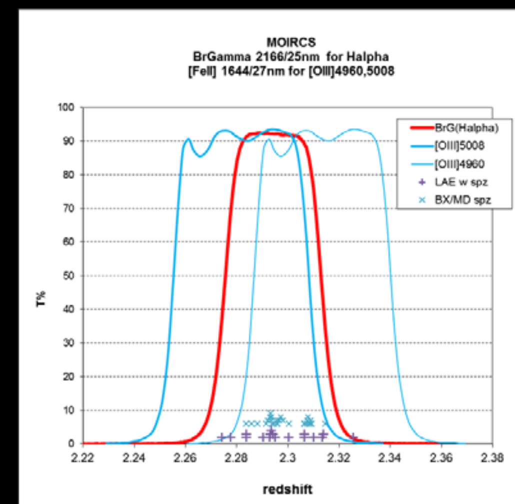
- HaNB10 is just outside our O3E detection region. But it shows a clear excess in NB image!
- Other three … Ha flux ~4-6 10^{-17}cgs level (our OIII limit is 6 10^{-17}cgs). OIII/Ha << 1 or Interlopers?
- HaNB18 is with spec-z….a [OIII]/Ha << 1 object (i.e., exciattion level as low as the local galaxyes)?



[OIII]EMITTERS WITHOUT HAE SIGNAL

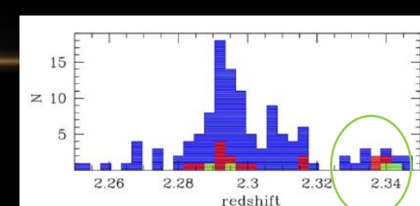
- There are several [OIII] emitter candidates without HAE signal.
- Likely the interlopers (natural) → need multicolor (phot-z) diagnostics.
- Sampling z range is wider than HAE filter … could be a (known) background structure.





OIIIE

HAE



3 BLOBS IN H... NO DETECTION

THE ASTROPHYSICAL JOURNAL LETTERS, 740:L31 (5pp), 2011 O

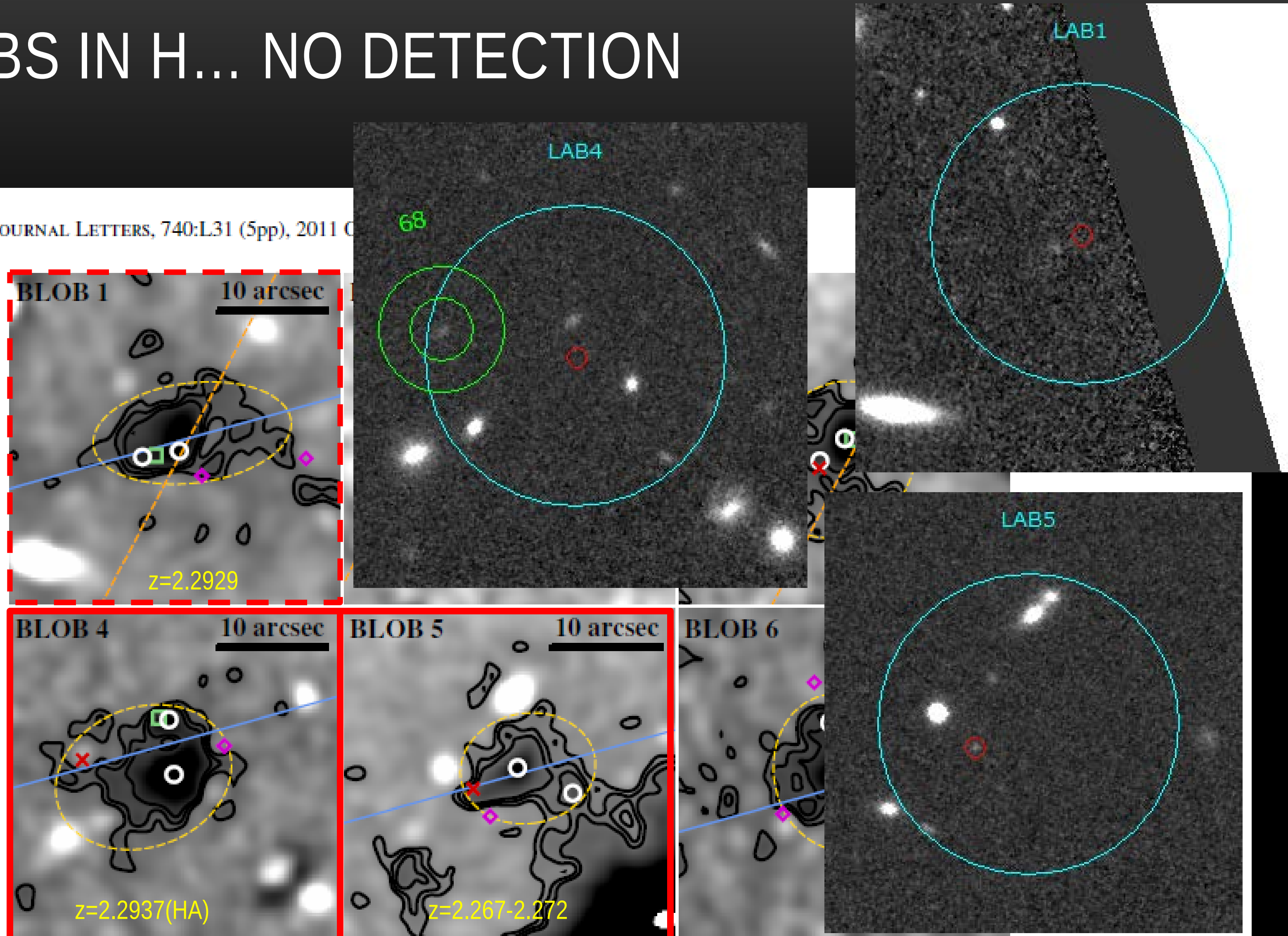
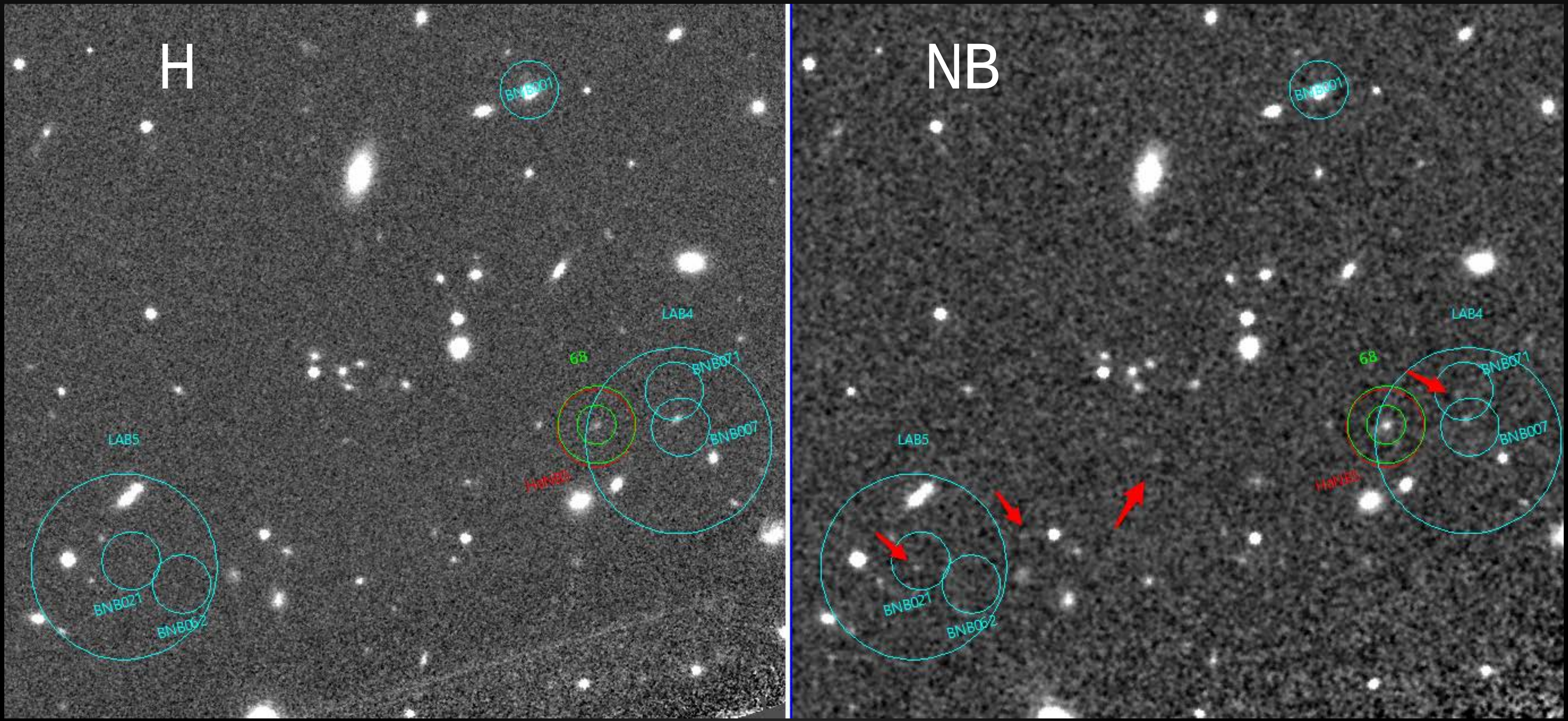


Figure 1. Six Lyα blobs are marked with contours on the smoothed, continuum-subtracted narrowband image. The contours are created after smoothing the image with a Gaussian of FWHM = 7 pixels ($\simeq$ 1″.7) and are marked at surface brightness levels of 1.5, 3, and 4.5×10^{-18} erg s^{-1} cm^{-2} arcsec^{-2}. Dashed yellow lines show ellipses fit to the largest 1.5×10^{-18} erg s^{-1} cm^{-2} arcsec^{-2} contour. White circles show portions of the blobs classified as narrowband Lyα emitters, red crosses show UV continuum-selected galaxies spectroscopically confirmed to belong to the $z = 2.3$ protocluster, magenta diamonds show UV-selected $z \sim 2$ candidates with unknown redshifts, and green squares show DRGs whose redshifts are unknown (except the DRG associated with Blob 3, which has an absorption redshift associating it with the blob). The solid blue line is a least-squares fit to the positions of Blobs 1, 4, 5, and 6 (also shown as the dashed line in Figure 2), and the dashed orange line is fit to the positions of Blobs 1, 2, and 3 (also shown as the dot-dashed line in Figure 2). The images are oriented with north up and east to the left, and the scale bar in each window corresponds to 10 arcsec, or 82 proper kpc at $z = 2.3$. The bright object in the lower right corner of the image of Blob 5 is a foreground star.

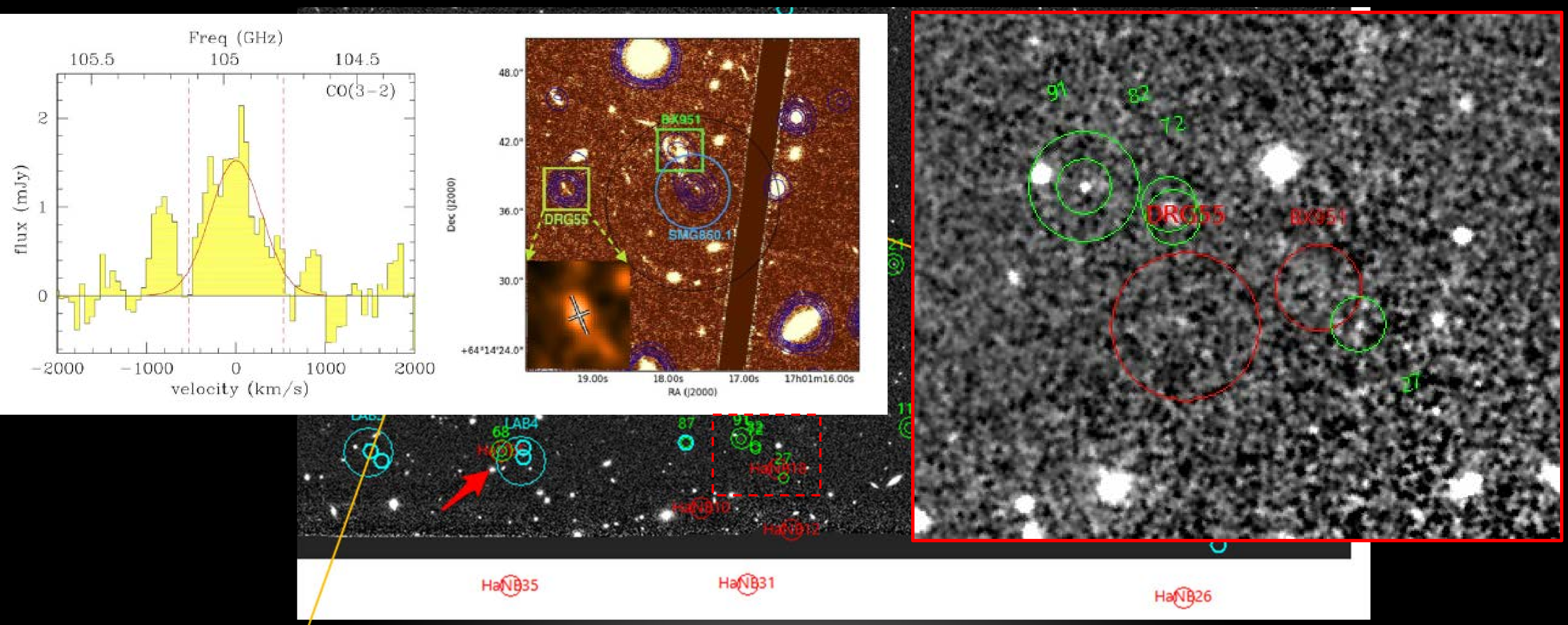
3 BLOBS IN H… NO DETECTION, HOWEVER…

- A detailed look for LAB4&5 shows some interesting faint NB-excess signals… might be a first detection of the Blobs counterparts.



SMG COUNTERPARTS

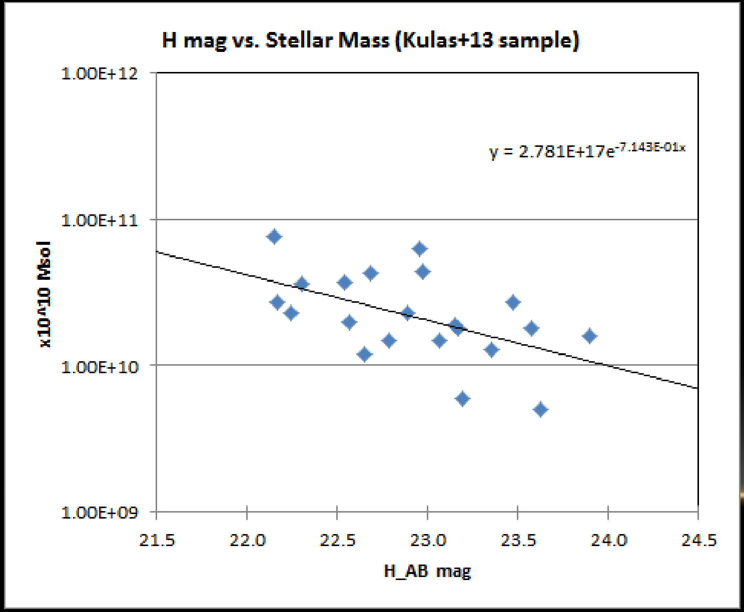
- Chapman+2015 reported four CO detection from the protocluster. Of these, two are in our FOV. Especially a region around SMG850.1 is interesting.

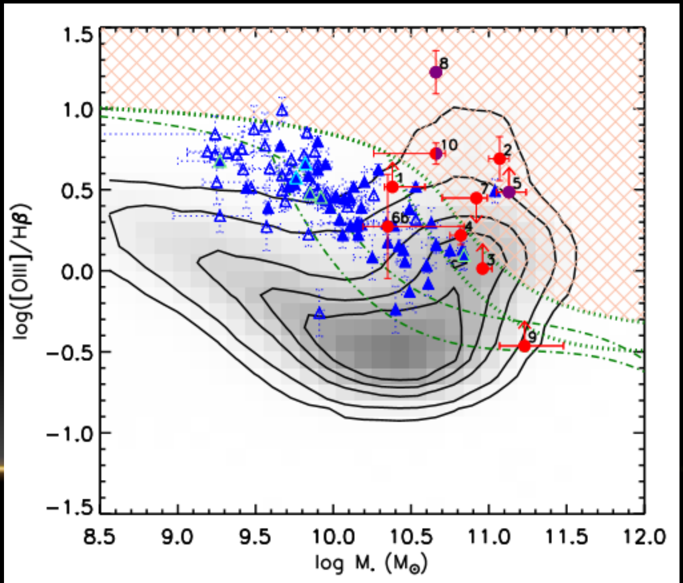


- DRG55 is CO redshift of 2.295. There is no excess signal in both Hα and [OIII] imaging. Heavy dust extinction?
- There is a hint of the OIII emission just at the position of SMG850.1.

[OIII] EMITTERS … PHISICAL PARAMETERS

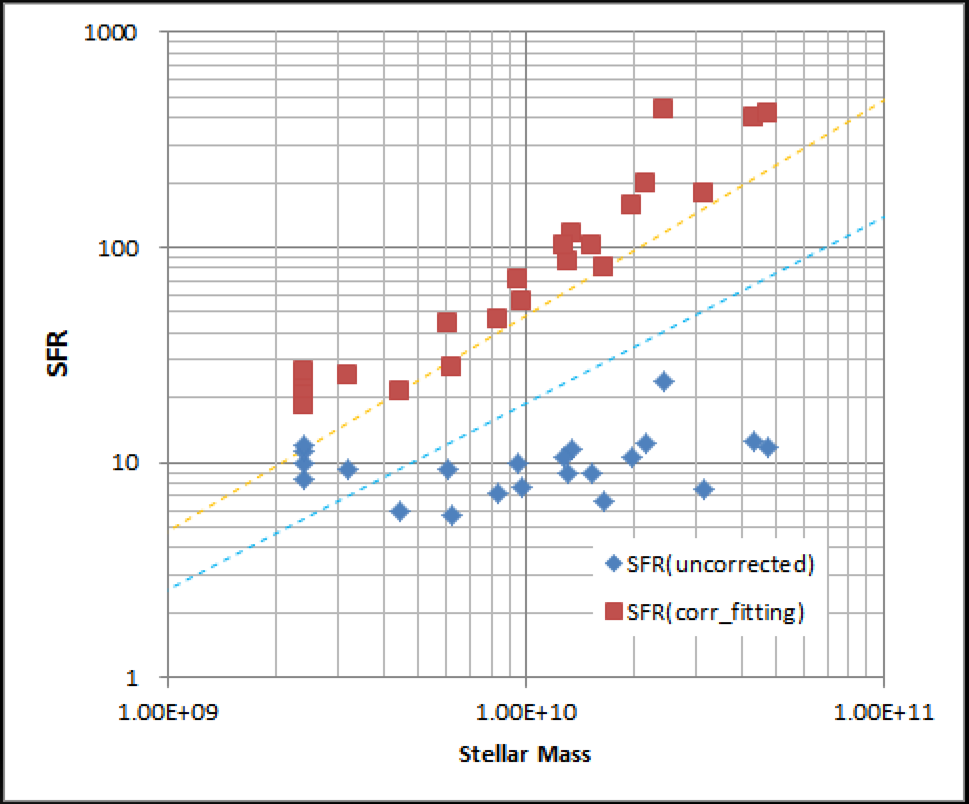
- Assuming that they are ALL at z=2.3, Stellar Mass and SFR is derived.
- H magnitude → Stellar Mass is assiming the constant M/L, which is based on the SED fittring-based mass estimate by Kulas et al. (2013).
- Dust Extinction is based on the Mass-A(Ha) relation by Garn & Best (2010).
- Conversion from [OIII]5008 to Ha is based on the KBSS result for z~2.3 (Coil+2015).





[OIII] EMITTERS … M-SFR MAIN SEQUENCE

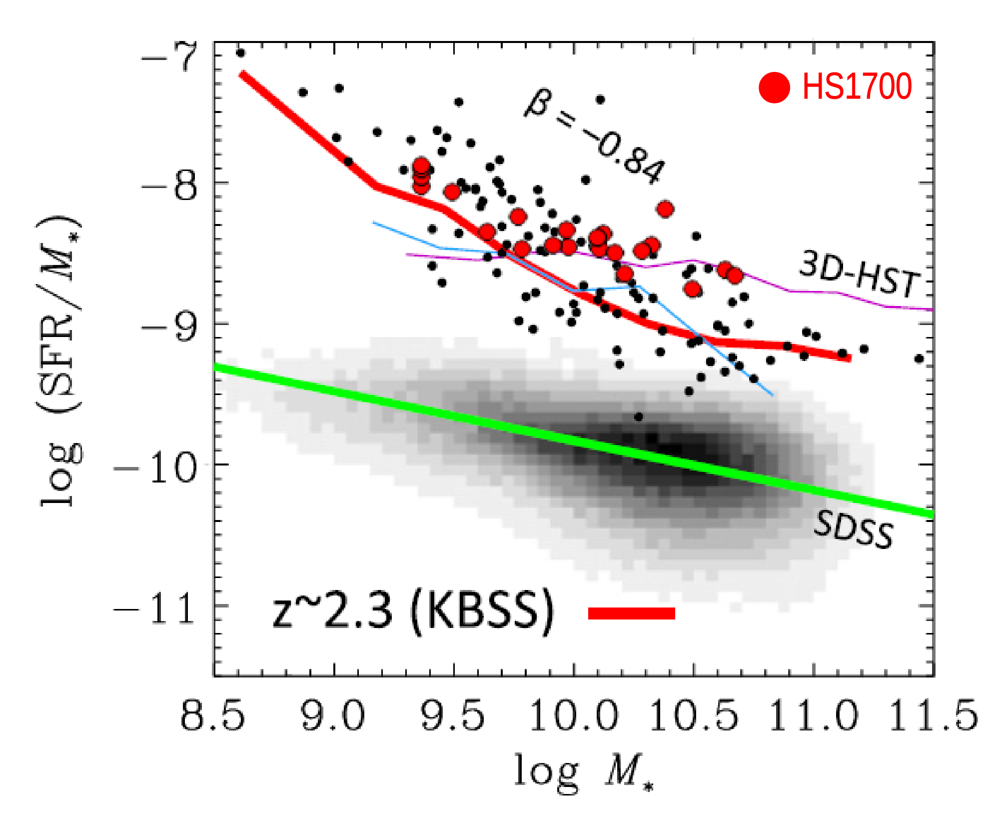
- The match to z~2 relation is good.
- The probed mass range is much heavier than that probed by LAEs … great for protocluster search at z>2.6



- Is the match TOO GOOD? Some interplay (: how low-z interlpers could behave)?
- Need refinement is necessary.

MASS-SSFR RELATION

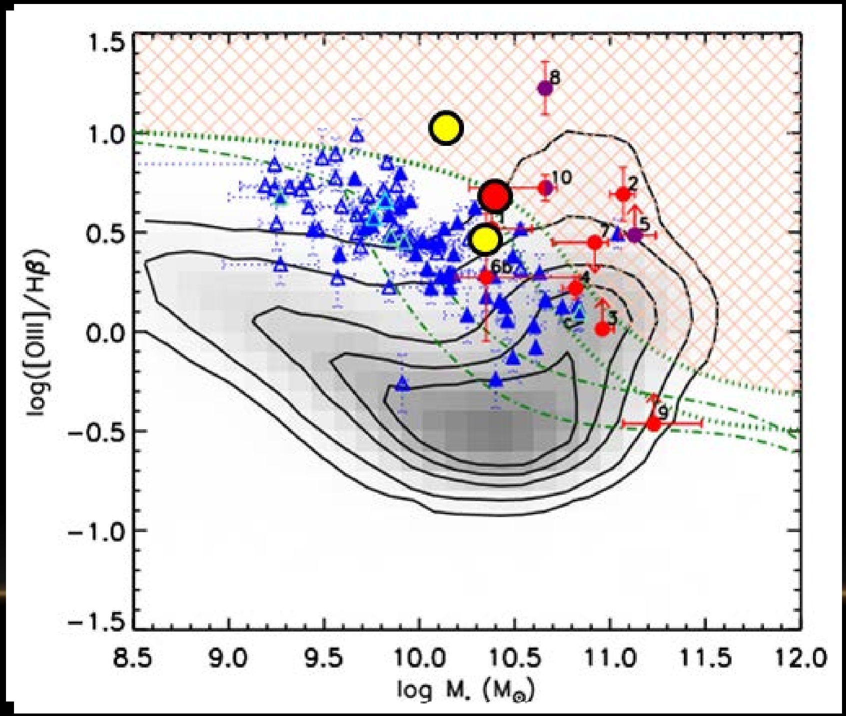
- Salim+2015 … Stellar Mass vs sSFR relation for z~2.3 (KBSS).
- Our data just distributes on the average KBSS relation, though lies on the upper edge of the distribution.
- Note that the error for both axes are large!



Reproduced from Salim+2015

MASS-EXCIATATION DIAGRAM

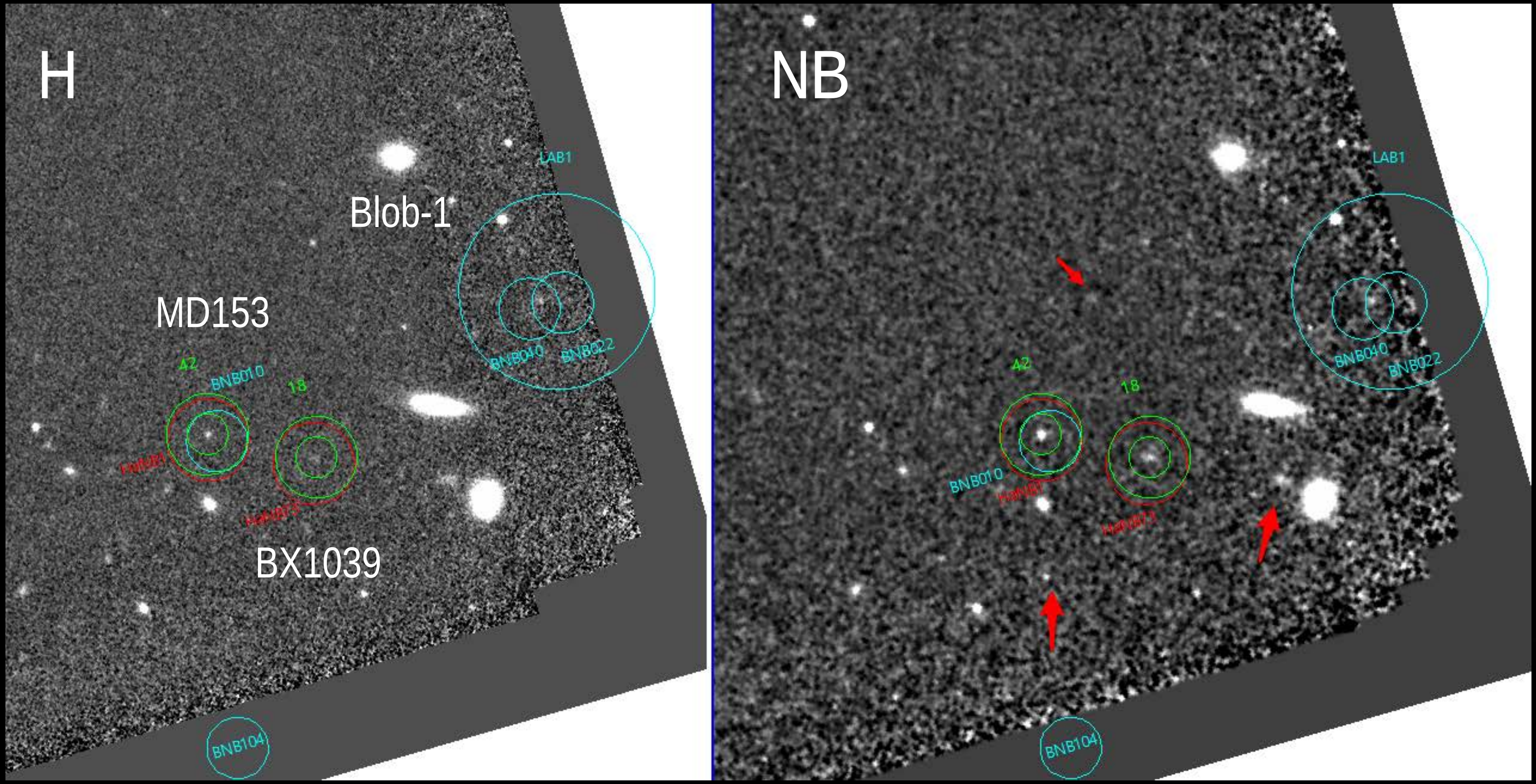
- Juneau et al. (2011) introduced the Stellar-mass versus [OIII]/Hβ ratio to find AGN in the sample.
- Coil et al. (2015) proposed the refinement for z~2, based on KBSS and MOSDEF.
- Our data has 3 HAEs (, one of them is the known AGN) … how MEx diagram works?



Reproduced from
Coil et al. (2015)

MASS-EXCIATATION DIAGRAM

- Other than MD153, an object (BX1039) may be the additional AGN.
- BX1039 is just next to MD153! Dual AGN? What' more, they are next to Blob1!



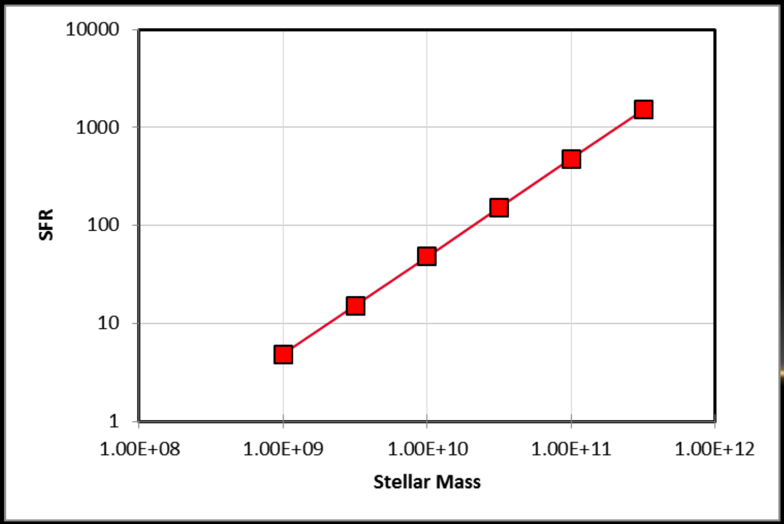
THE "EW-LIMIT" BIAS

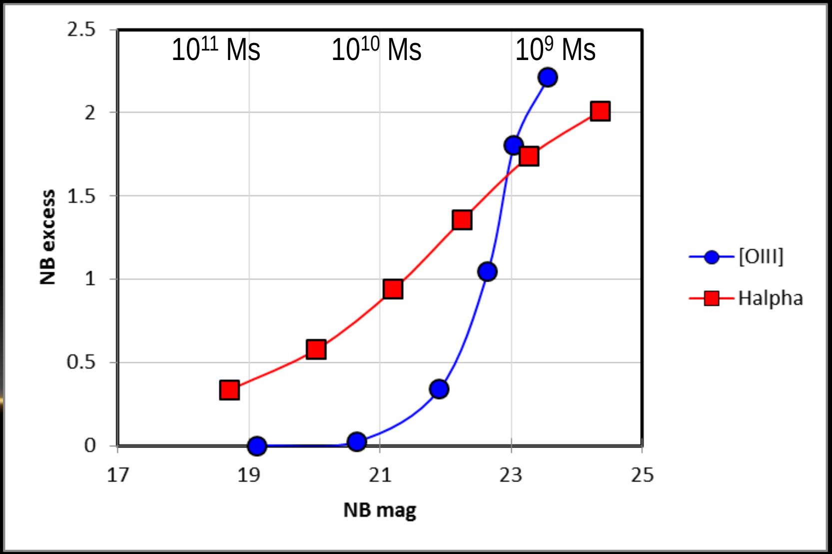
- Garn & Best (2010): more massive galaxies are more dusty.
- MEx diagram for z~2.3: [OIII]/Ha ratio is lower for massive galaxies.

→ Massive galaxies could be less bright in [OIII] emission.

Indeed, at $>10^{11}$ M_{solar}, the EW can be very low.

A fixed EW cut might give a bias to miss very high mass objects.





LESSONS LEARNED…

- The O3Es can be a good tracer of galaxies as massive as those probed by Hα emitters (up to ~10^{11} M_{solar}).
- LAE distribution is likely a poor tracer of the underlying mass structure in small scale.
- Due to the doublet nature of [OIII] emission, the O3Es could probe a wider redshift range than HAEs.
- A care (especially spec-z) must be taken when we discuss about the celestial distribution, star-formation rate, and the [OIII]/Hα ratio.
- Our O3Es candidates lie around the “main sequence” of M-SFR relation at z~2.
- O3Es can show a mo
- The “EW-limit” bias could be serious for very massive O3Es!

SLIDES BELOW ARE FROM THE WS2013…

1. Protoclusters at z=3.3 window

なぜz=3.3か

- Kバンドがrest Vの観測、HバンドがBalmer Break。H3-Kが rest B-V→信頼性の高いM/L推定。
- Jは2900A付近。J-H3カラーでブレイク→photo-zで有利。
- [OIII]5007がNB windows (NB2137,NB2167)に入る。
- z=3.328 → Hβがtelluric 吸収の外にある。→星形成率(Sp)
- [OII], [OIII], Hβが全てAvailable → R23でメタル、輝線診断(Sp)。

- Jバンドで同時撮像が可能→Red Old Galsも見えてくるだろう。
- 本当に面白い領域をJ1+H2&H3撮像に持ち込み、SEDフィット。

同時撮像によるJ-Kカラー

- z＞3：HとKとの間にBalmer Break。

  H-K jump objectの探査(Bremer & van Dokkum 2007)が可能。

ただし、H-Kで赤い天体は、J-Kでも赤い→同時撮像でJを撮れる事は本質的。

- HAE＠z~2.3に対しては、J-H撮像でダイレクトにブレイク検出（"J-H" Jump天体）。

Protoclusters at z~2.3もまだまだ？

- 同じフィルタでHα輝線を拾うと、z~2.3。
- “[OIII]+Hα”ペアフィルタ: NB163とNB165がある。

LAE vs. OIIIE vs. HAEの研究: 銀河質量、AGN、ダストと年齢という視点で、多面的に銀河団銀河を見れる面白さ。

✓TAOができる頃のz~2.5の原始銀河団の研究の状況は？

GP/GB Protocluster Survey

- まずは電波銀河周りのクイックサーチ。
  - NB 2.5hr, bb 1hrで氷山の一角が見えるはず。
  - 3.5時間/1天体。 冬なら3天体/nightとし、5晩15天体。
  - その約75%(Venemans+ 2007)に何らかの構造が期待？
- HSC NB527 Survey FieldでのLAE超過領域のフォローアップは極めて重要。
- 何らかの超過が見られたものを、SWIMS Medium-band Deep＋Deep+Opticalでフォローアップ。Opt+NIR MOS分光で確認。
- 10個以上の銀河団銀河形成現場を独自にカタログ化するのが目標ー銀河団銀河形成期の(非)多様性を調べるサンプルとしたい。

Target: NED Search

zを>70%Tの波長に絞っても21個出てきた。
MOIRCSのNBも含めると、サンプルは結構ある。
<u>可視LAEデータのあるHSC領域は非常に魅力。</u>

SOURCE LIST

NB2167

Object list is sorted on RA or Longitude

Row No.	Object Name (* => Essential Note)	EquJ2000.0 RA	DEC	Object Type	Velocity/Redshift km/s	z	Qual	Mag./ Filter	Separ. arcmin	Refs	Notes	Number Phot	Posn
1	SDSS J012057.17+244206.1	01h20m57.1s	+24d42m06s	QSO	>30000	3.333880		18.8z	0.000	3	0	2	0
2	CGRaBS J0428+1732	04h28m35.6s	+17d32m24s	QSO	>30000	3.317000		18.0R	0.000	19	0	10	2
3	SDSS J090030.15+221509.6	09h00m30.1s	+22d15m10s	QSO	>30000	3.327277		19.6g	0.000	3	0	6	1
4	*B2 1124+29	11h26m56.7s	+28d46m14s	QSO	>30000	3.340720		19.7g	0.000	13	0	16	6
5	SDSS J130312.14+245406.1	13h03m12.1s	+24d54m06s	QSO	>30000	3.329600		19.6g	0.000	4	0	8	3
6	SDSS J130531.76+291621.4	13h05m31.8s	+29d16m22s	QSO	>30000	3.320160		20.3g	0.000	3	0	8	2
7	SDSS J155613.51+043443.0	15h56m13.5s	+04d34m43s	QSO	>30000	3.332770		20.7g	0.000	9	0	26	2
8	NVSS J232100-360223	23h21m00.9s	-36d02m24s	G	>30000	3.320000		20.0K	0.000	5	1	13	0
9	FBQS J2334-0908	23h34m46.4s	-09d08m12s	QSO	>30000	3.328654		18.8g	0.000	39	0	26	2

SOURCE LIST

NB2137

Object list is sorted on RA or Longitude

Row No.	Object Name (* => Essential Note)	EquJ2000.0 RA	DEC	Object Type	Velocity/Redshift km/s	z	Qual	Mag./ Filter	Separ. arcmin	Refs	Notes	Number of Phot	Posn	Ve
1	VVDS 020180665	02h26m45.4s	-04d36m15s	G	>30000	3.262000		19.3V	0.000	11	0	11	0	
2	PKS 0351+045	03h54m24.1s	+04d41m07s	QSO	>30000	3.263000		21.28	0.000	25	0	10	3	
3	SDSS J081310.80+131629.3	08h13m10.8s	+13d16m29s	QSO	>30000	3.264170		19.8g	0.000	8	0	9	3	
4	SDSS J105044.27+060958.3	10h50m44.3s	+06d09m58s	QSO	>30000	3.276596		19.9g	0.000	13	0	26	2	
5	NVSS J105917-303658	10h59m17.4s	-30d36m57s	IrS	>30000	3.263000		...	0.000	4	0	16	0	
6	SDSS J115852.58+115124.7	11h58m52.6s	+11d51m25s	QSO	>30000	3.259580		20.3g	0.000	9	0	26	2	
7	SDSS J125630.27+054439.1	12h56m30.3s	+05d44m39s	QSO	>30000	3.280904		20.2g	0.000	13	0	30	2	
8	SDSS J150021.42+144630.7	15h00m21.4s	+14d46m31s	*	>30000	3.255700		20.5g	0.000	1	0	6	1	
9	SDSS J165419.59+255116.8	16h54m19.6s	+25d51m17s	QSO	>30000	3.255127		20.3g	0.000	9	0	26	2	
10	*SDSS J165543.57+194847.1	16h55m43.6s	+19d48m47s	QSO	>30000	3.260000		20.4g	0.000	18	0	19	3	
11	PKS 1925-610	19h30m06.1s	-60d56m09s	QSO	>30000	3.254000		20.3	0.000	36	1	20	3	
12	[HB89] 2126-158	21h29m12.2s	-15d38m41s	QSO	>30000	3.268000		16.1R	0.000	314	11	66	4	
13	SDSS J231548.39+000723.9	23h15m48.4s	+00d07m24s	QSO	>30000	3.260000		21.8g	0.000	2	0	6	1	

Conclusion

- 銀河団銀河の形成期では、非常に強くかつメタルプアな星形成が起きている可能性があり、z~3.3の[OIII]エミッタで、そういう銀河が集団で発生している現場を捉えたい。
- NB2169は、HSCでLAEもできる。H帯のMedium BandでBreakが拾え、K帯のMediumバンドと合わせる事でStellar Mass、good ph-zへと進める事が可能。
- J帯の同時撮像はforeground contamination除去のためのデータを効率よく得るのに不可欠。

- すばるではTargetedサーベイは(経験上)全く好まれない。
- しかし、TMT時代、独自なサンプルを持つ重要性ますます高まる？
- 銀河団の色んな事が分かるz~2-3で面白い事をしましょう。