Deep and Wide-field Study of Galaxy Evolution with Subaru GLAO

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元気・前向き
Powerful Positive Tohoku University
東北大学

東北大学

Subaru GLAO

- higher sensitivity in NIR
- better spatial resolution ~0.”2
- wider-field of view 15’Φ
- Imager / MOS / (multi) IFU
- complementary with HSC/PFS

★ Key Science Cases?

~ 2020’s

★ Specification for Conceptual Study?

This Talk

- Subaru-GLAO and Future Missions

  WISH / TMT / JWST / WFIRST / Euclid

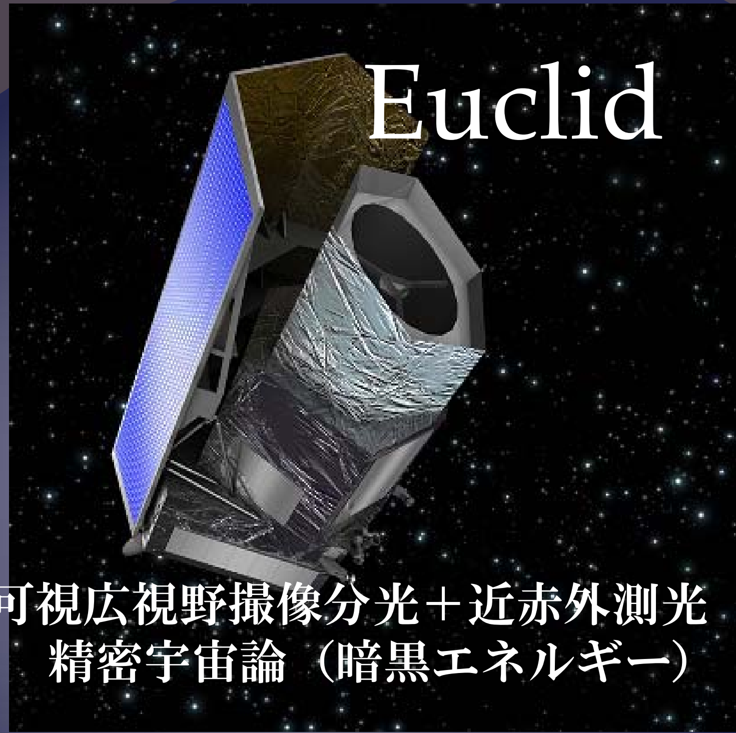
- MOIRCS Deep Surveys

- Subaru-GLAO Key Science Cases

Wide-field Imaging Mode
- comparison with future space missions

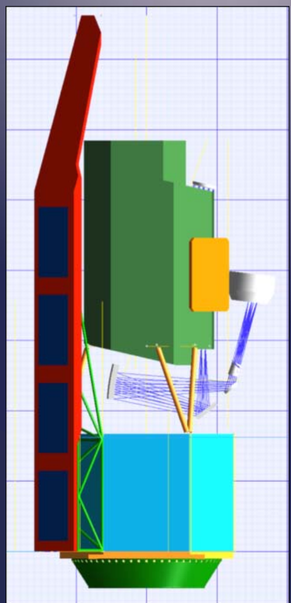
		GLAO	WISH	WFIRST AFTA	Euclid IR	JWST NIRcam
FoV	$arcmin^2$	~200	850	1000	1800	9.3/9.7 (19)
λ	μm	0.9-2.5	0.9-5.0	0.6-2.0	0.9-2.0	0.6-2.3/2.4-5.0
D	m	8.2	1.5	2.4	1.2	6.5
Pixel Scale	$arcsec^2$	0.1	0.156	0.11	0.3	0.0317/0.0648
N_{pix}	pix	~72M	128M (2RG)	288M (4RG)	64M (2RG)	32M / 8M
target depth	ABmag	26	28	27	24/26	31
target area	deg^2	~10	100	2500	15000/40	< 1

See also Iwata, I. (GLAO WS vs 6-10m) Tanaka, M. (GLAO workshop 2012)

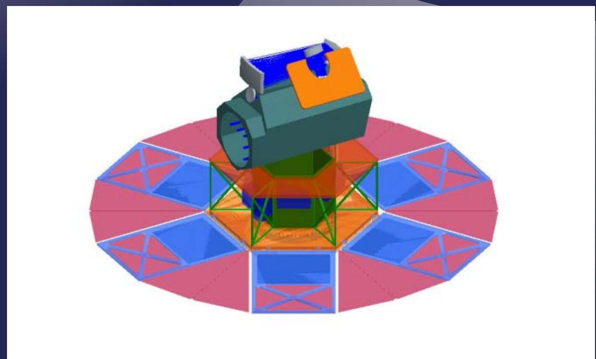


WFIRST

DRM1
1.3m



DRM2 1.1m Cost-down



“AFTA”
NRO
2.4m

超広視野初期宇宙探査衛星
WISH 1.5m 1-5μm 0.155”pix 850arcmin²
Ultra Deep Survey 28AB 100 deg²
- Galaxies Beyond Cosmic Reionization
- SNe (Ia cosmology, luminous CC at high-z)
Middle class
Total mass ~1.4t << 6.3t (WFIRST-AFTA)

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Advantages of Subaru GLAO in deep & wide-area imaging

- Cost Effectiveness / Easier Access
- K-band imaging > Euclid/WFIRST < WISH
- Narrow-band / Intermediate-band imaging

  > Euclid/WISH (also Akiyama san's talk)
- Flexibility in Wide –Field Strategy

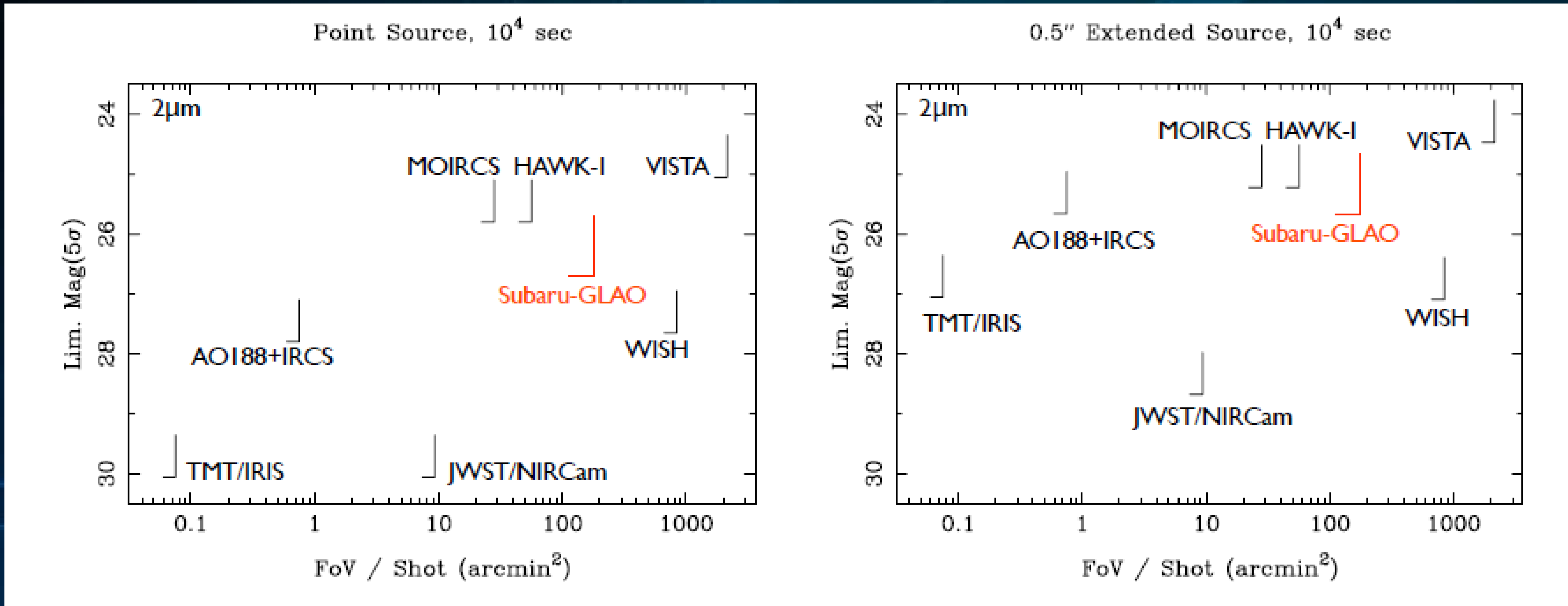
CANDELS and ground-based K-band

*All limiting magnitudes here are 5sigma in AB system

field	D/W	F160W Depth*	WFC3/IR Area	K-band Coverage
GOODS-N	Deep	27.2	6'x10'	K~25-26 AB , MOIRCS Deep Survey
GOODS-S	Deep	27.2	6'x10'	K~25-26 AB, ISAAC / HAWK-I (on-going)
EGS	Wide	26.5	6'x30'	K~24 AB, MOIRCS
COSMOS	Wide	26.5	8'x22'	K~25.5 AB, UltraVista (on-going)
UDS	Wide	26.5	8'x22'	K~25 AB, UKIDSS-UDS (on-going)

Spitzer S-CANDELS (3.6, 4.5um) AB~26.7
(but highly confused)

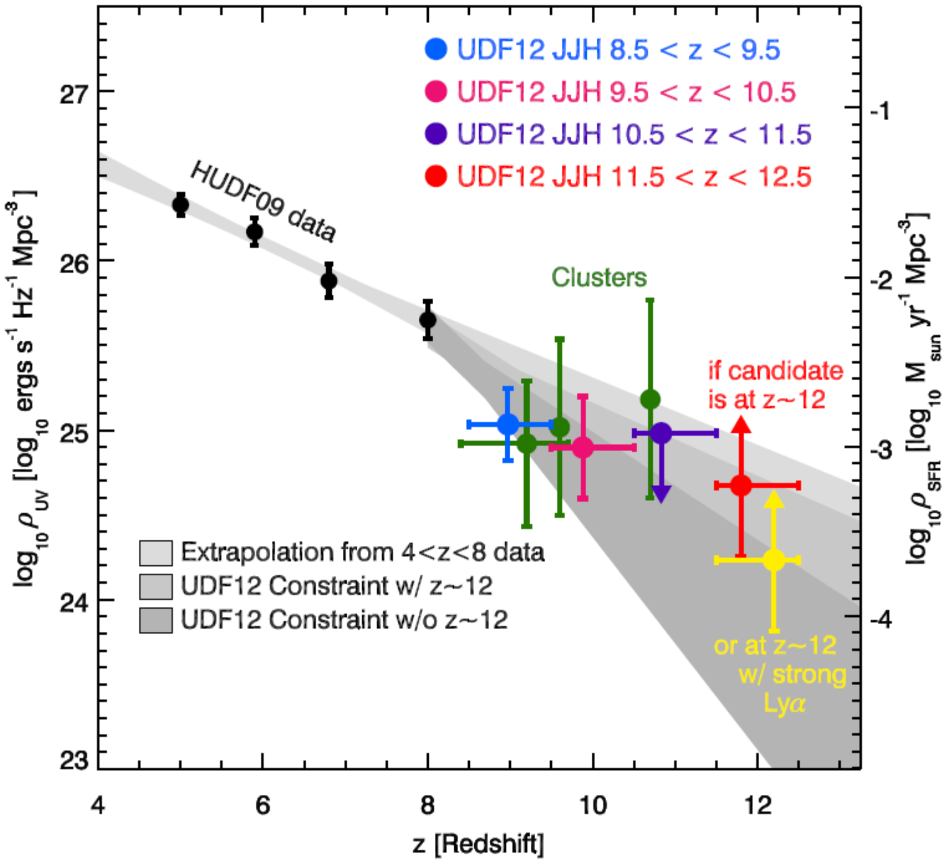
Broad-Band Space Mission Wins



From Subaru-GLAO proposal (Iwata)

~3 hours, 5σ

UV luminosity density evolution at High Redshift



From Ellis et al. (2012)

Empirical Luminosity Evolution (Oesch et al.)

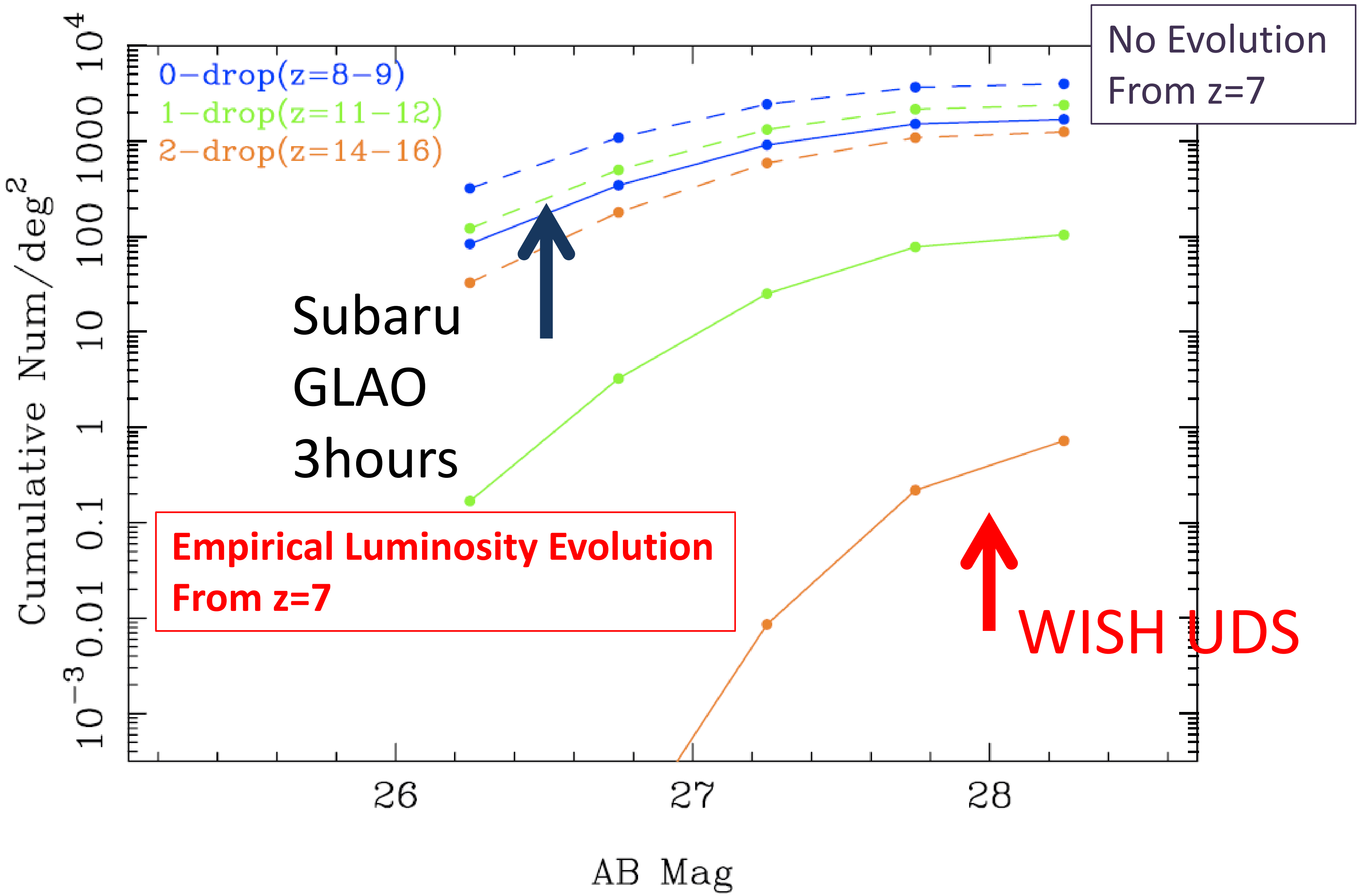
$M^* = -21.117 + 0.408(z-3.8)$, $\Phi^* = 1.1\times10^{-3}$ Mpc^{-3} $\alpha = -1.74$

z=8 M*=-19.4 … obs 27.9 mag (AB)

z=9 M*=-19.0 … obs 28.4 mag (AB)

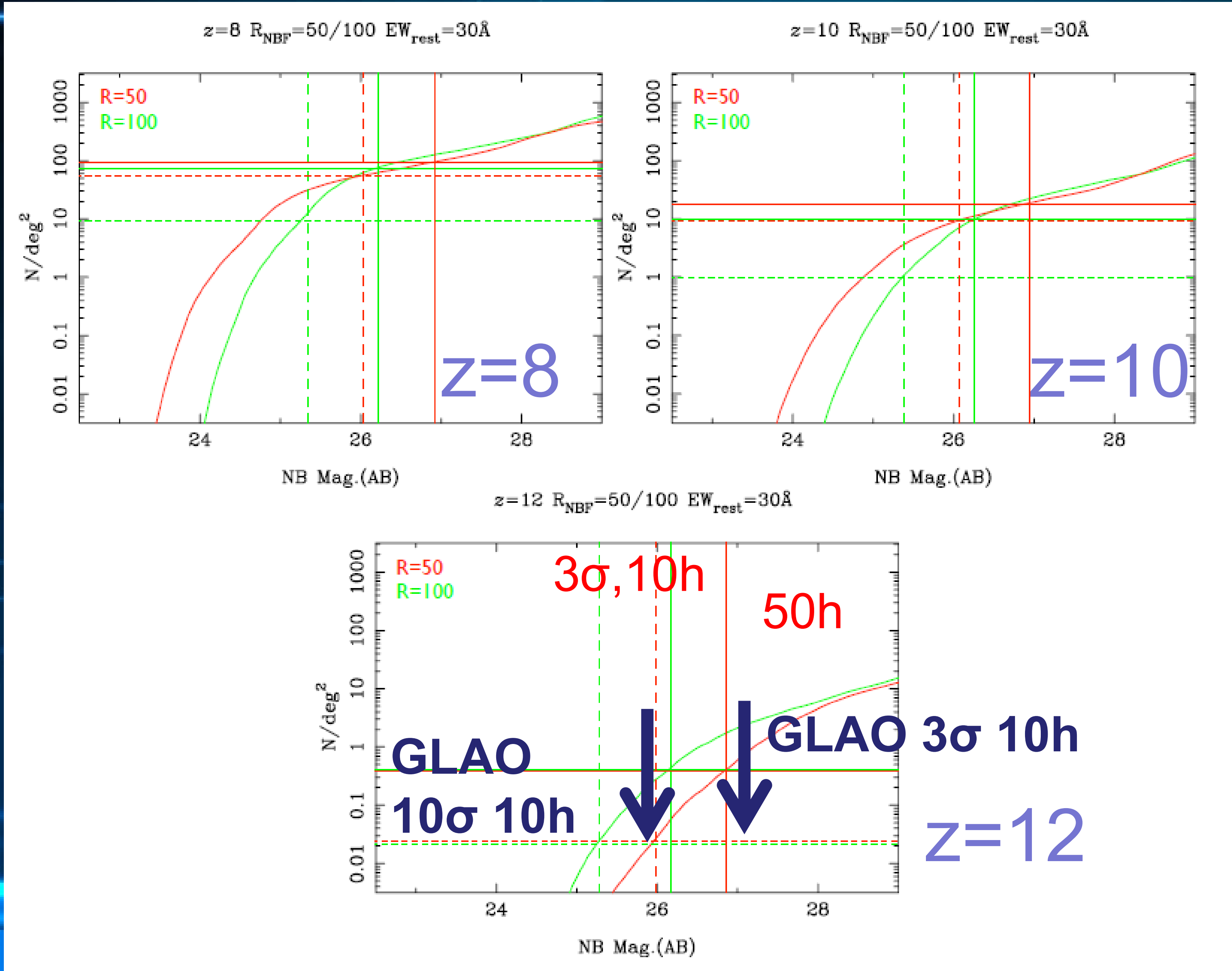
z=10 M*= -18.6 … obs 28.8 mag (AB)

Expected Number of High-z Galaxies



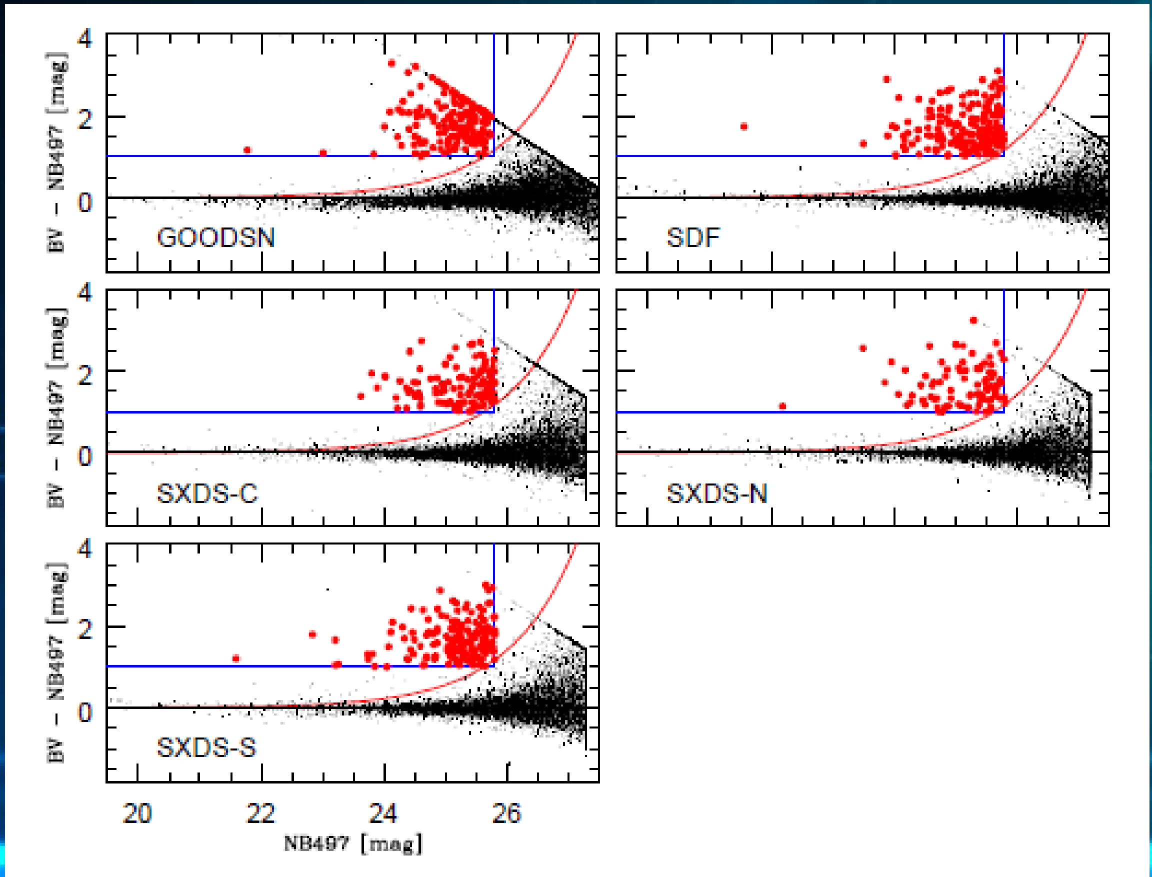
WISH Mission Proposal Draft (Iwata, Yabe et al.)

High-z LAE for WISH



Note:

To achieve the deep Narrow-band imaging, Broad-Band (or any continuum) data should be >1mag deeper (just to select the candidate).

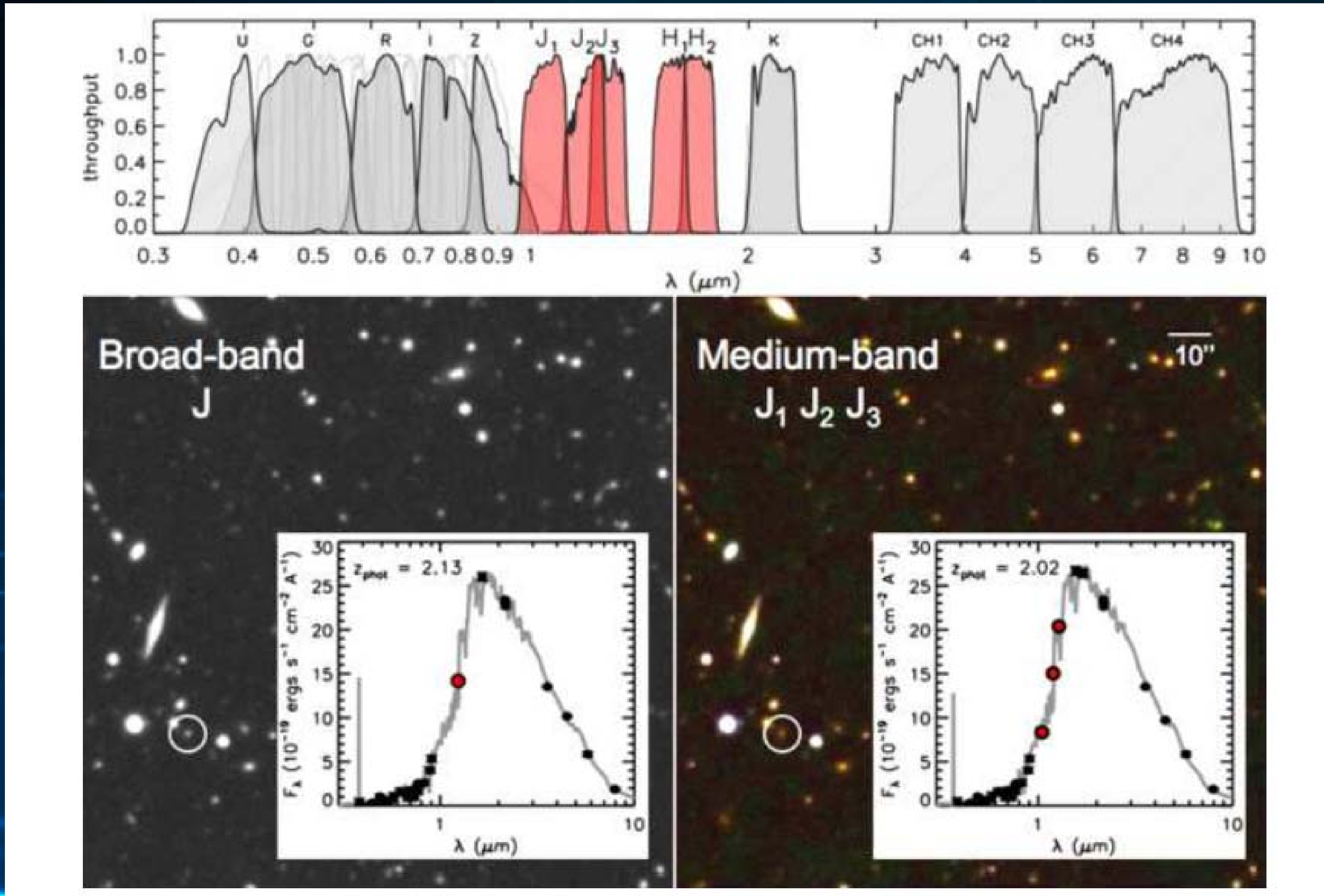


Best way is to combine Subaru GLAO NB with Space BB

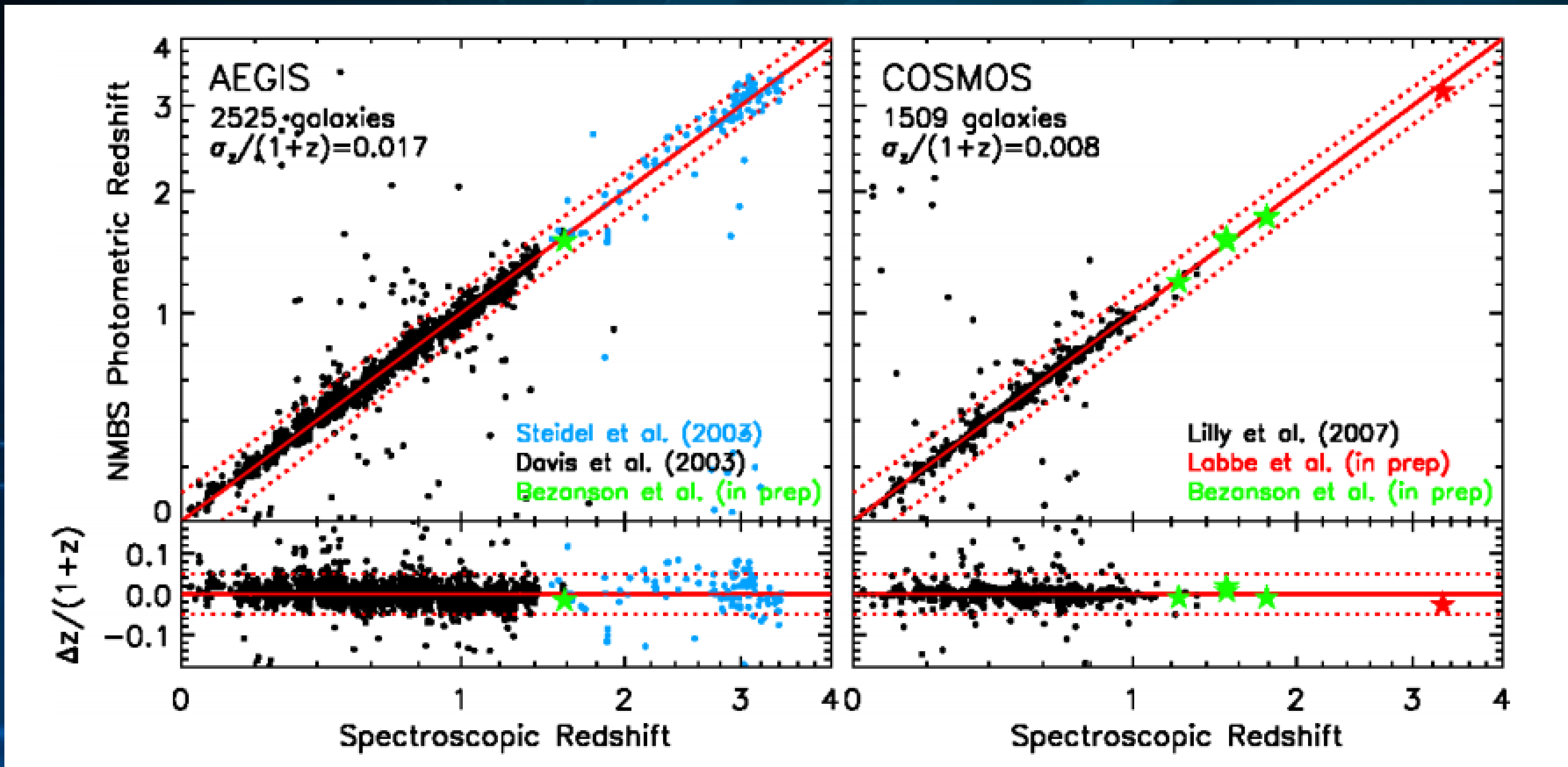
WISH
WFIRST-AFTA

Euclid Deep (26AB) is too shallow

NEW FIRM Whitaker et al. (2011)   Mayall 4m ~25 in J1J2 ~24 in H1H2

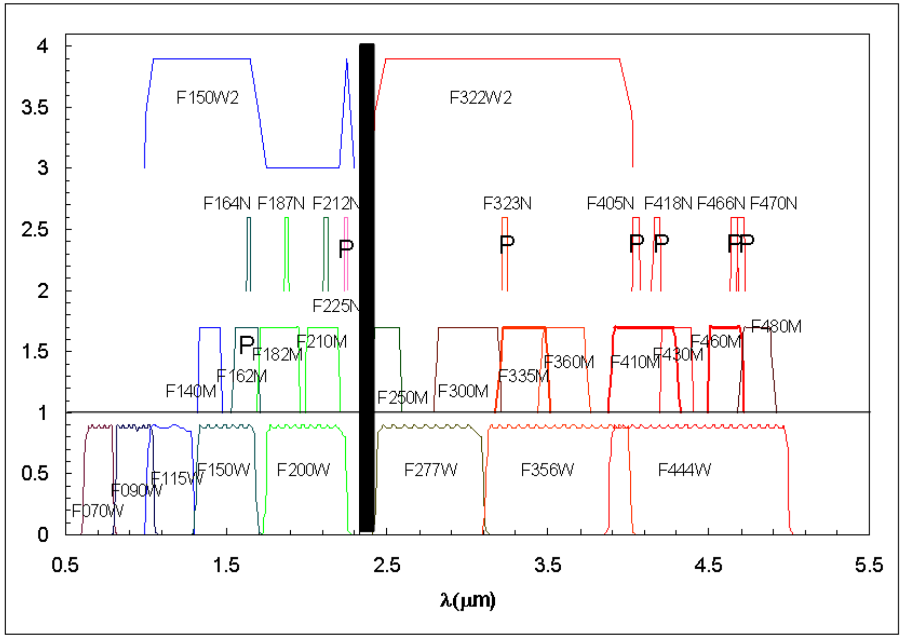


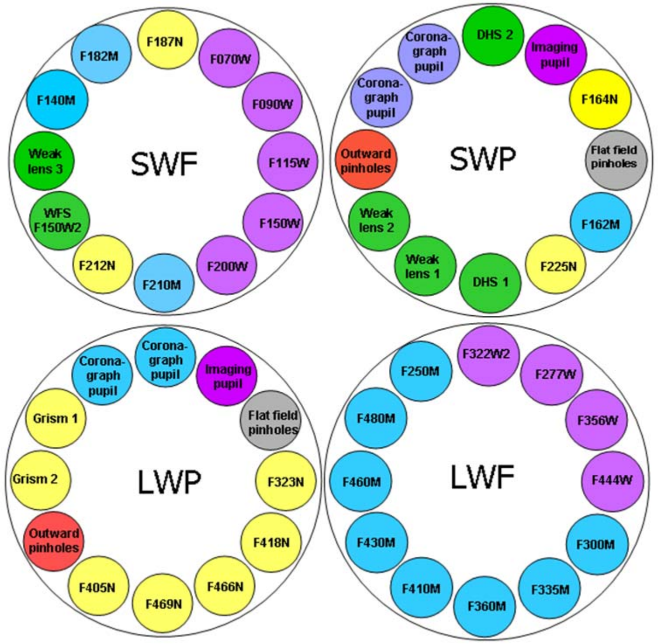
Photometric redshift in NEWFIRM survey



JWST NIRCam filters

Name	Center	lambda 1	lambda 2	Bandpass	Location	Transmission	Use
F070W	0.7000	0.6125	0.7875	0.1750	SW-Filt	0.85	General purpose
F090W	0.9000	0.7875	1.0125	0.2250	SW-Filt	0.85	General purpose
F115W	1.1500	1.0063	1.2938	0.2875	SW-Filt	0.85	General purpose
F150W	1.5000	1.3125	1.6875	0.3750	SW-Filt	0.85	General purpose
F150W2	1.5000	1.0000	2.0000	1.0000	SW-Filt	No NIRCam Req	DHS Blocking
F200W	2.0000	1.7500	2.2500	0.5000	SW-Filt	0.85	General purpose
F277W	2.7700	2.4238	3.1163	0.6925	LW-Filt	0.85	General purpose
F322W2	3.2200	2.4150	4.0250	1.6100	LW-Filt	0.85	Background Min.
F356W	3.5600	3.1150	4.0050	0.8900	LW-Filt	0.85	General purpose
F444W	4.4400	3.8850	4.9950	1.1100	LW-Filt	0.85	General purpose
F140M	1.4000	1.3300	1.4700	0.1400	SW-Filt	0.7	cool stars, steam
F162M	1.6200	1.5500	1.7010	0.1510	SW-Pup	0.7	cool stars, off-band for steam
F182M	1.8200	1.7290	1.9500	0.2210	SW-Filt	0.7	cool stars, steam
F210M	2.1000	1.9950	2.2050	0.2100	SW-Filt	0.7	methane
F250M	2.5000	2.4167	2.5833	0.1667	LW-Filt	0.7	methane
F300M	3.0000	2.8500	3.1500	0.3000	LW-Filt	0.7	water ice
F335M	3.3500	3.1825	3.5175	0.3350	LW-Filt	0.7	PAH
F360M	3.6000	3.4200	3.7800	0.3600	LW-Filt	0.7	Brown dwarfs,planets
F410M	4.1000	3.8950	4.3050	0.4100	LW-Filt	0.7	Brown dwarfs,planets
F430M	4.3000	4.2000	4.4000	0.2000	LW-Filt	0.7	carbon dioxide
F460M	4.6000	4.5000	4.7000	0.2000	LW-Filt	0.7	CO
F480M	4.8000	4.6000	5.0000	0.4000	LW-Filt	0.7	Brown dwarfs,planets
F164N	1.6440	1.6358	1.6522	0.0164	SW-Pup	0.6	[FeII]
F187N	1.8756	1.8662	1.8850	0.0188	SW-Filt	0.6	P-alpha
F212N	2.1218	2.1112	2.1324	0.0212	SW-Filt	0.6	Molecular hydrogen
F225N	2.2477	2.2365	2.2589	0.0225	SW-Pup	0.6	Molecular hydrogen
F323N	3.2350	3.2188	3.2512	0.0324	LW-Pup	0.6	Molecular hydrogen
F405N	4.0523	4.0320	4.0725	0.0405	LW-Pup	0.6	Br-alpha
F418N	4.1813	4.1604	4.2022	0.0418	LW-Pup	0.6	Molecular hydrogen
F466N	4.6560	4.6327	4.6793	0.0466	LW-Pup	0.6	CO
F470N	4.7050	4.6815	4.7285	0.0471	LW-Pup	0.6	Molecular hydrogen





Wide-field (or Wide patrol field) Spectroscopy
- Comparison with future TMT / JWST / etc..

		GLAO	TMT IRMS	TMT IRIS	WFIRST Grism/IFU	JWST NIRspec
FoV		~200□’	4□’	0.2-10□”	~1000□’ / 9□”	9□’ / 9□”
λ	μm	0.9-2.5	0.9-2.5	0.9-2.5	0.6-2.0	1-5
D	m	8.2	30	30	2.4	6.5
target Δλ/λ		~2000 →4000?	4000	4000-10000	100-300	100-1000/3000
MOS	Nobs	~100	~40	single	slitless	~100
note				IFU	AFTA, also see Euclid	MOS/IFU

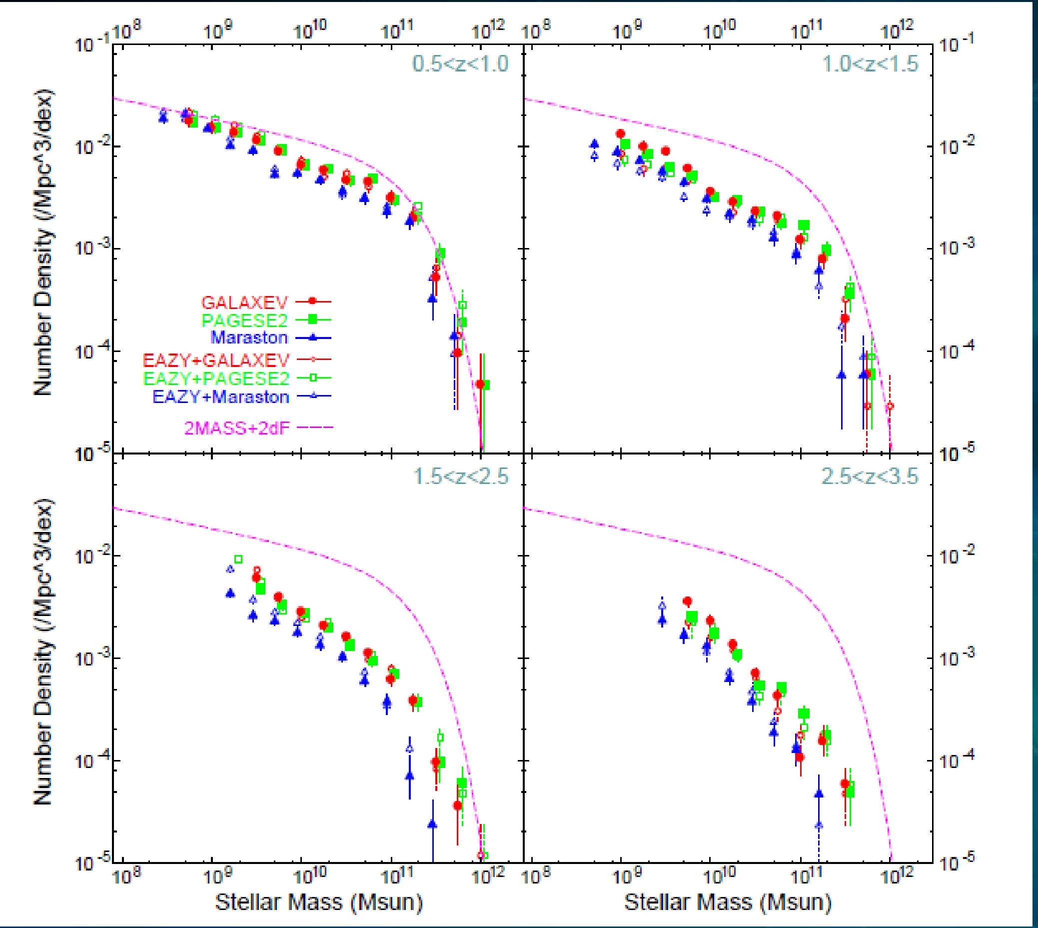
Advantages of Subaru GLAO in deep & wide-area spectroscopy

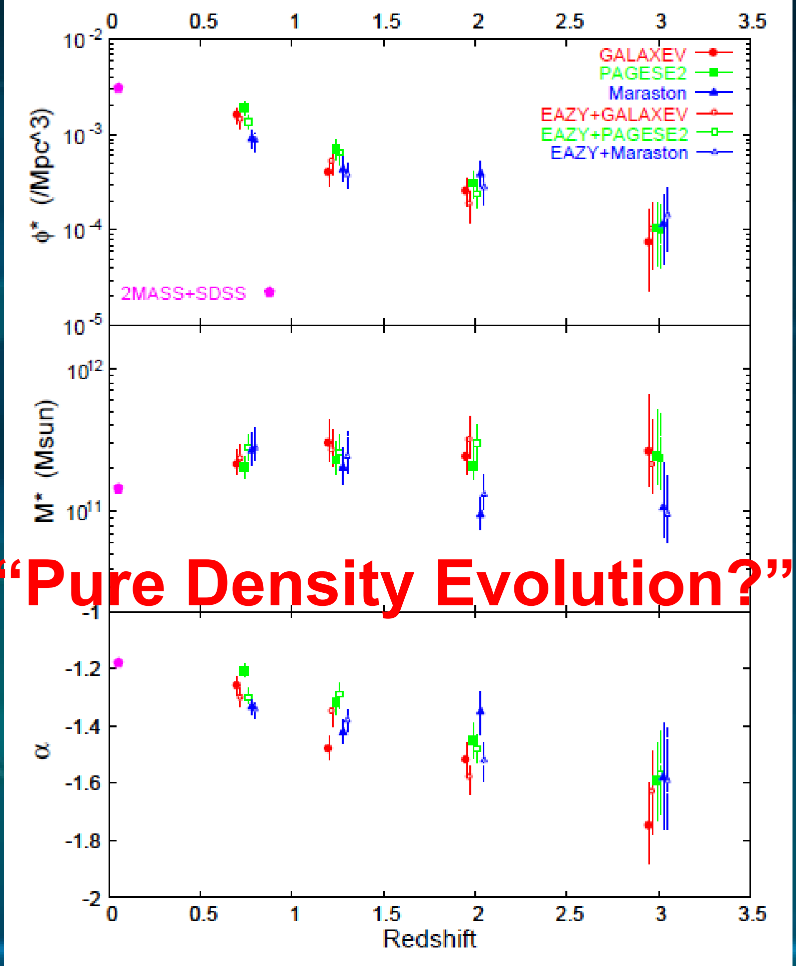
- Cost Effectiveness / Easier Access
- Wide-area >> TMT / JWST

  Combination of Wide-area & High Dispersion (R > a few 1000)
- K-band > Euclid/WFIRST
- Flexibility in Wide –Field Strategy

MOIRCS → Subaru GLAO

MOIRCS Deep Surveys





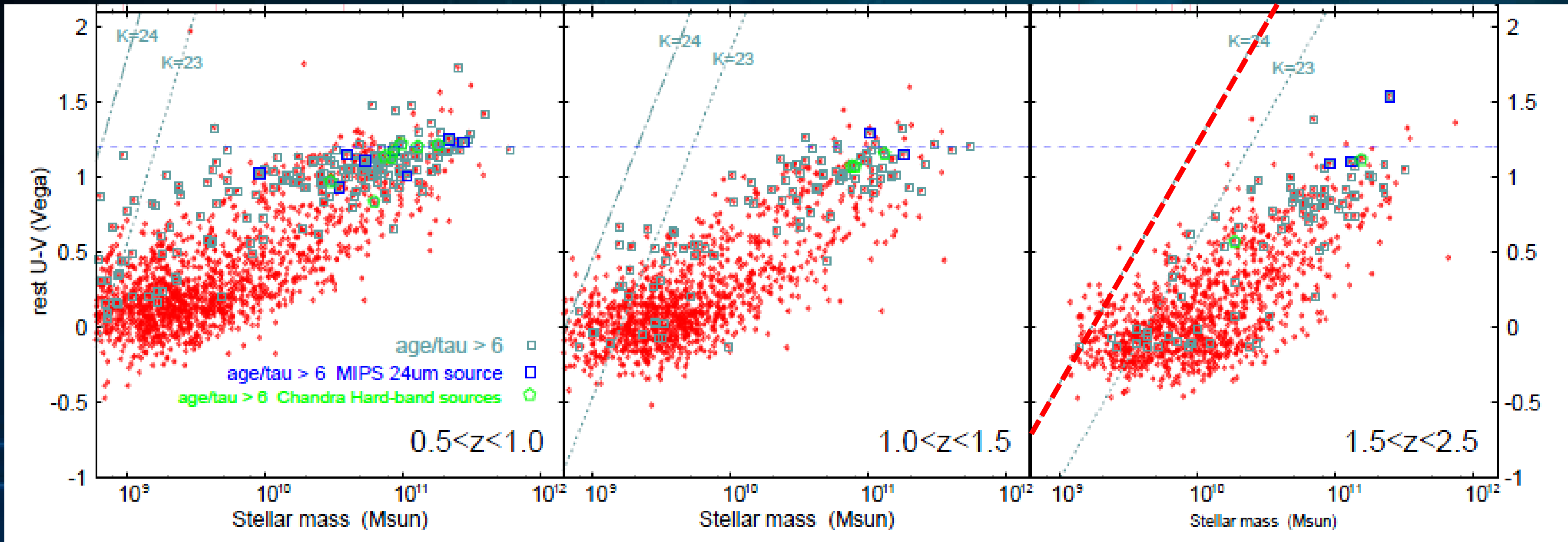
"Pure Density Evolution?"

Kajisawa et al. (2010)

MOIRCS Deep Survey

Stellar mass, Colors of galaxies

K~26AB



Kajisawa et al. 2011

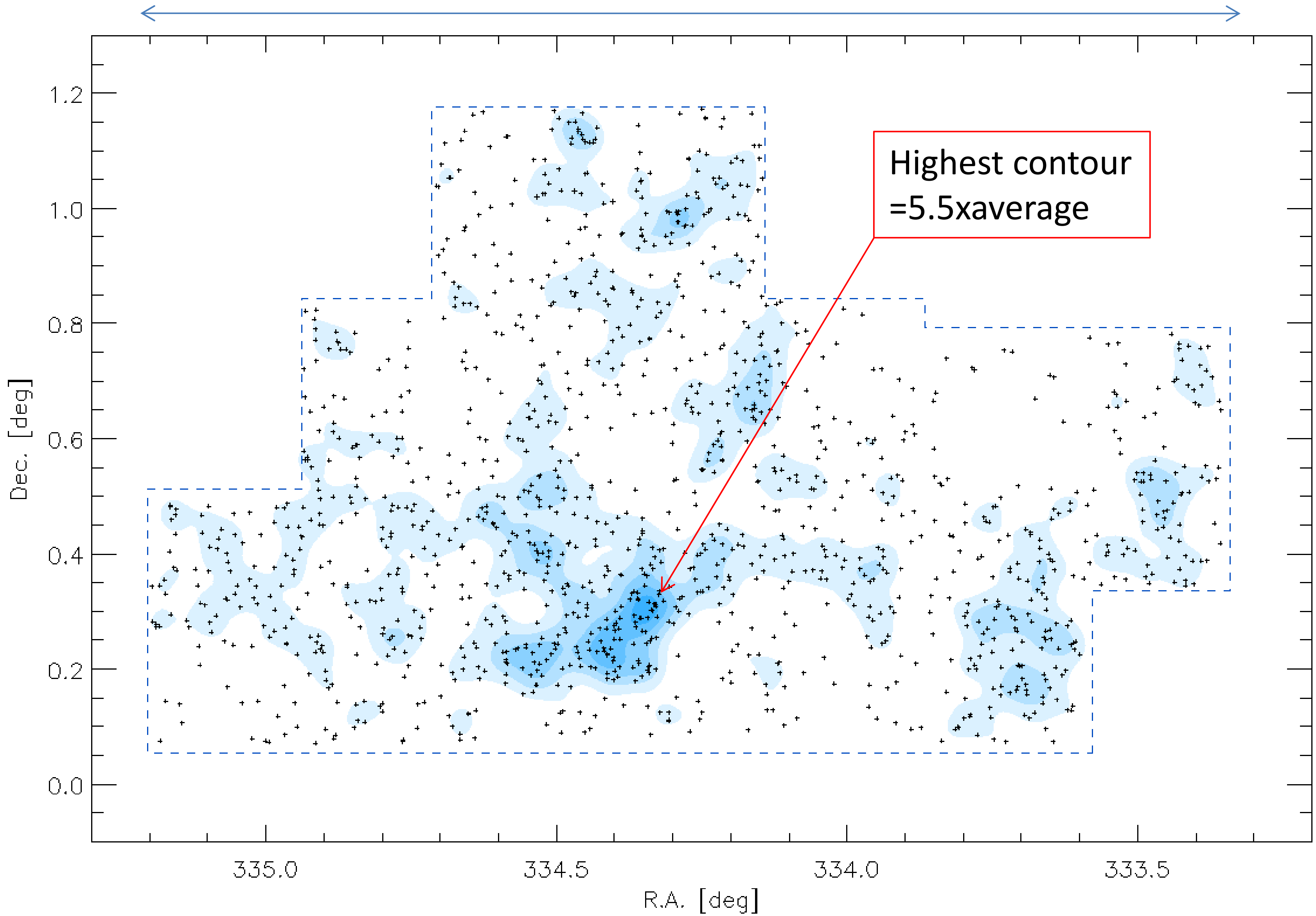
MOIRCS Deep Surveys

MODS GOODS-N → S-GLAO?

- Stellar Mass Function → faint end (<< JWST)
- Clustering → good case (< WISH)
- Size Evolution → environment
- LIRG Disks → good case with SPICA
- Mass-Metallicity Relation → MOS (<< TMT)
- AGN coevolution → good case (<< JWST)
- Quiescent galaxies → good case
- very high-z LAE → excellent case
- internal structure → if IFU (<<JWST / TMT) large statistical sample

Large-scale distribution of ~1500 Lyα Emitters

200Mpc (comoving)



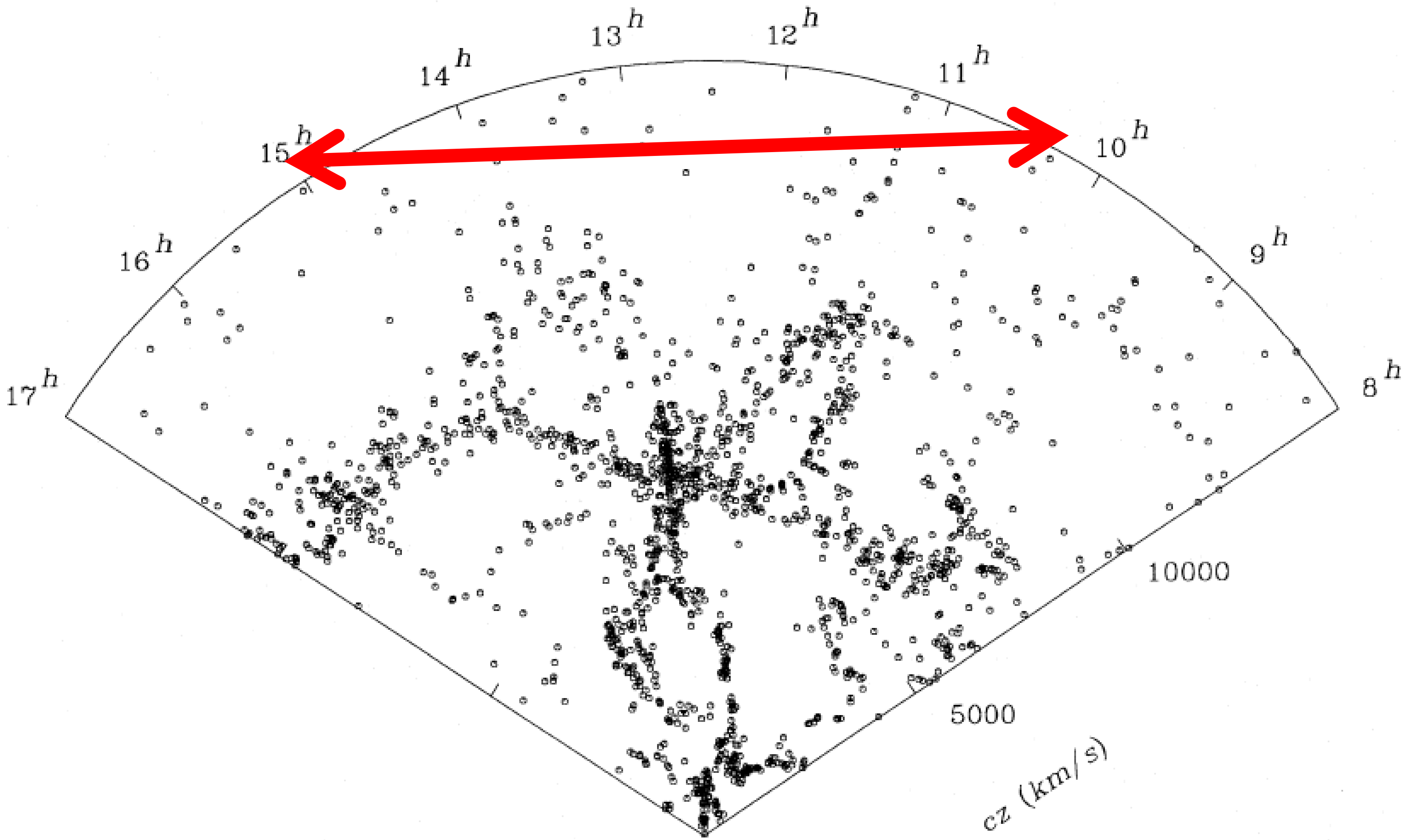
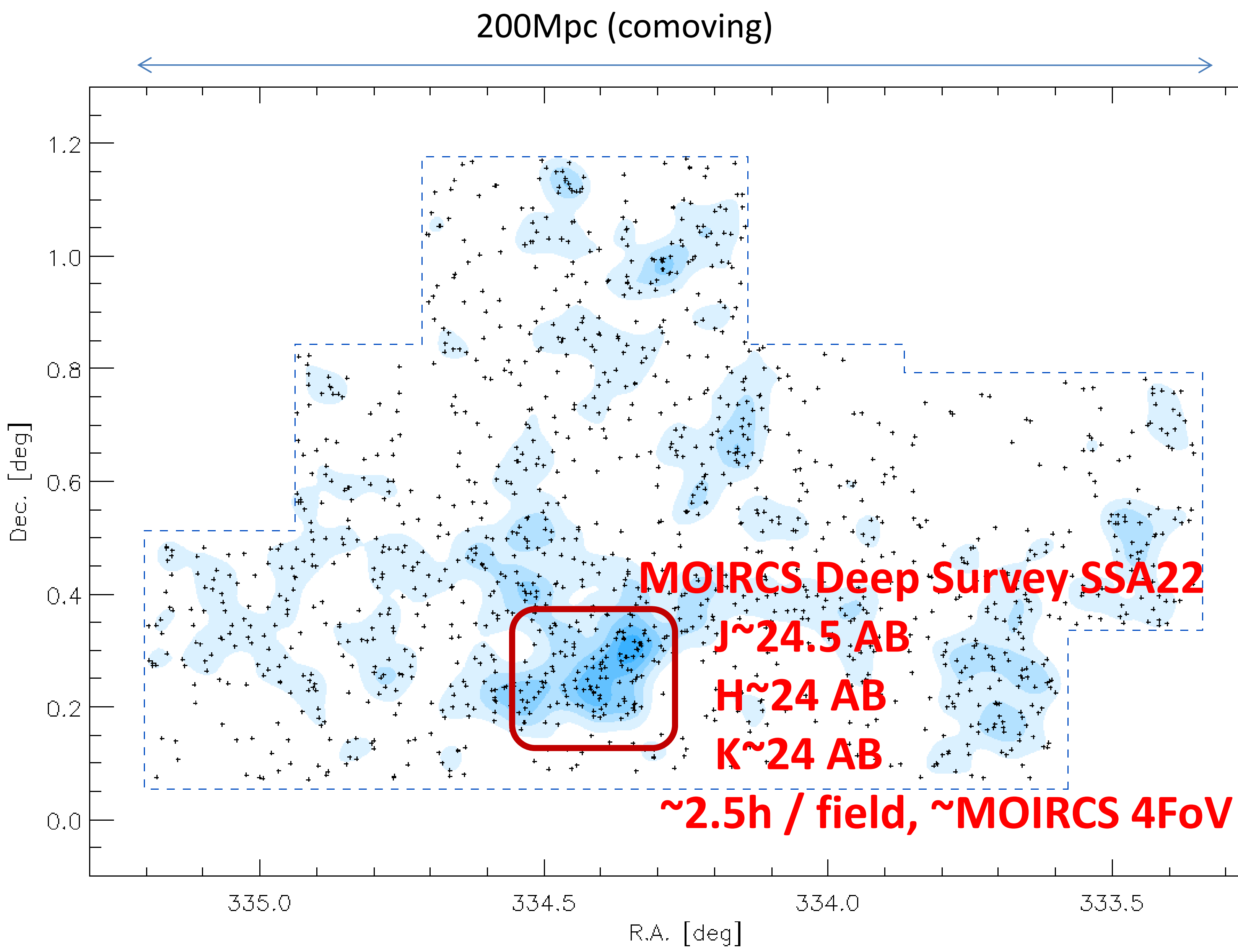


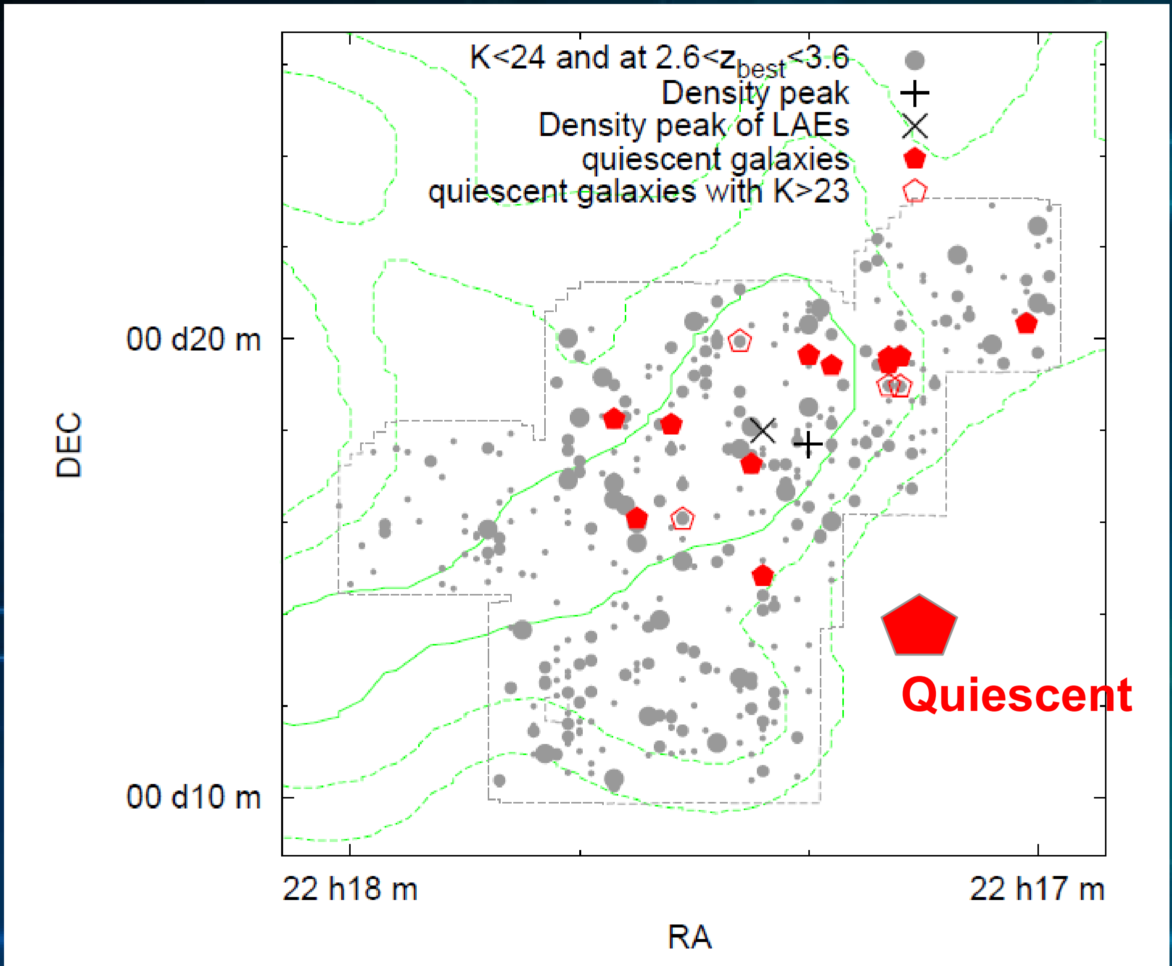
FIG. 1.—Map of the galaxy distribution in right ascension and velocity in the 12° strip limited by $m_{B(0)} \leq 15.5$. The declination range is $26.5° \leq \delta \gtrsim 38.5°$. This map contains 1761 galaxies.

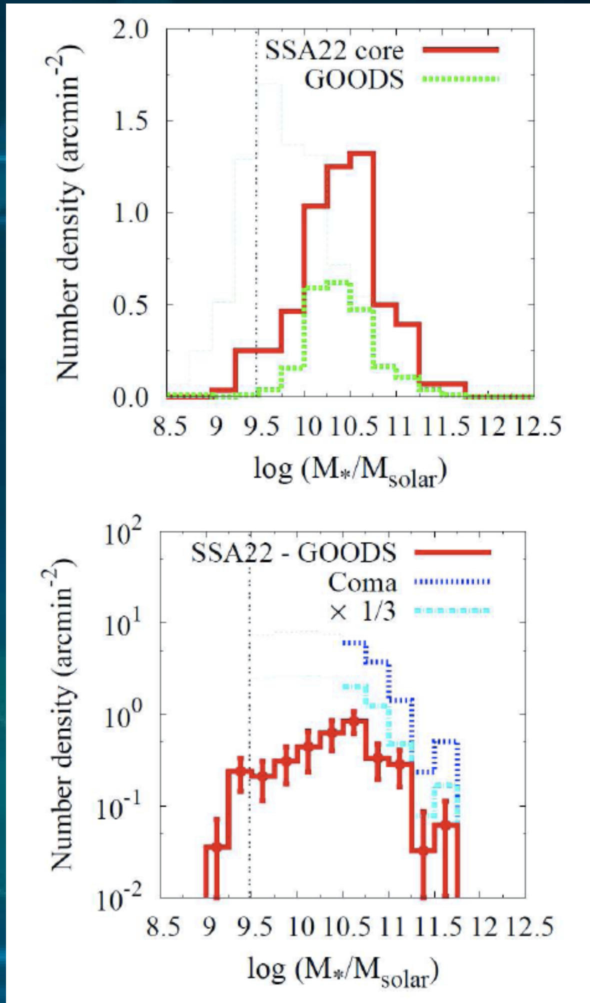
De Lapparent et al. 1988

Large-scale distribution of ~1500 Lyα Emitters

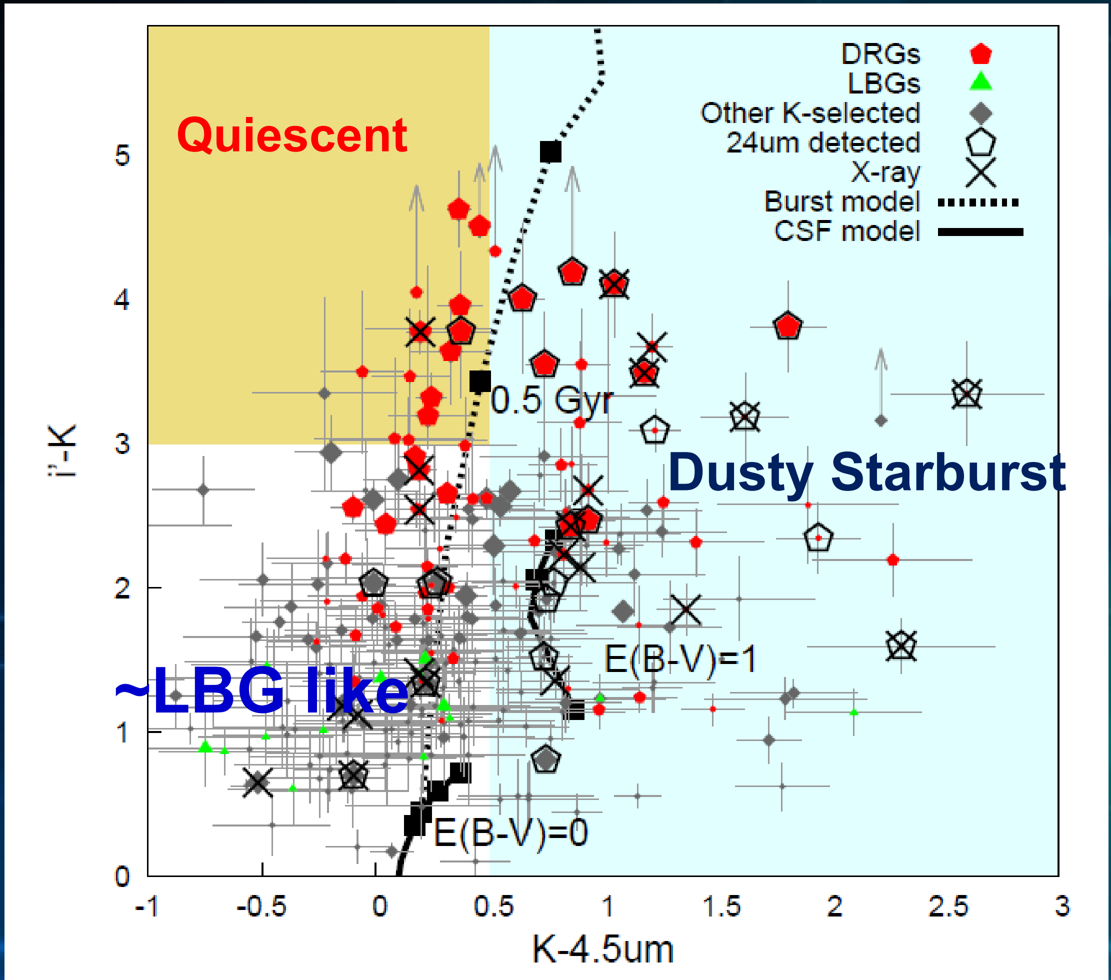


Distribution of photo-z selected z~3.1 Protocluster galaxies: K < 24AB

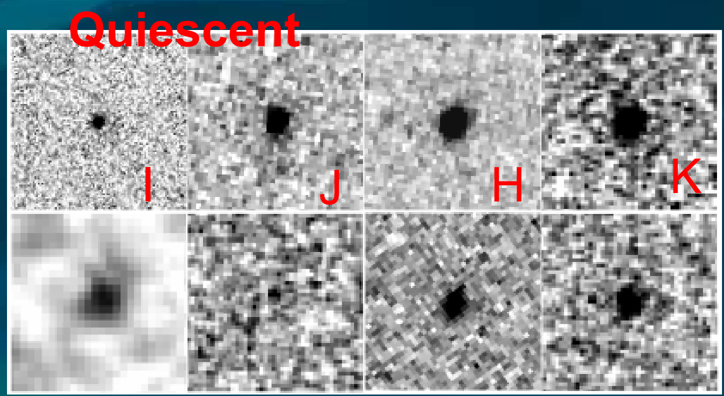


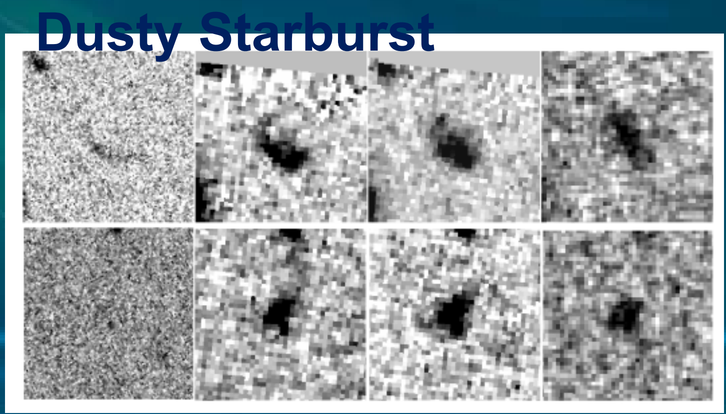


Properties of the protocluster galaxies at z=3.1

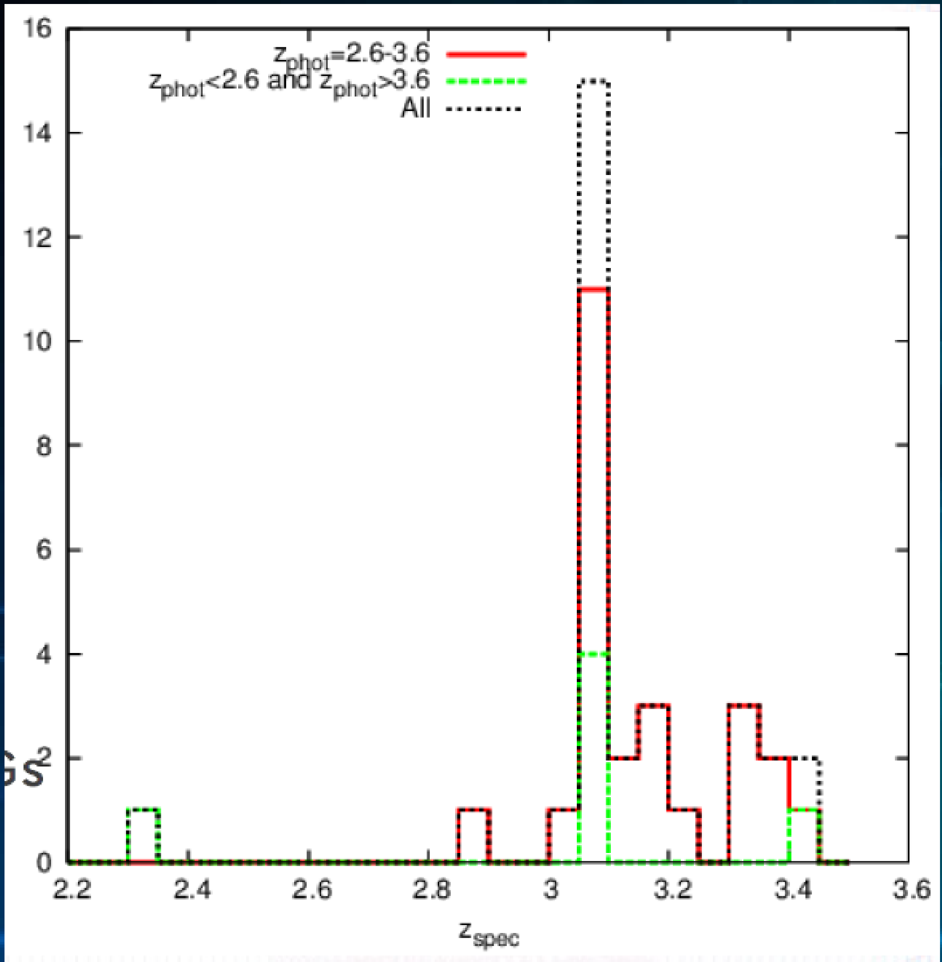


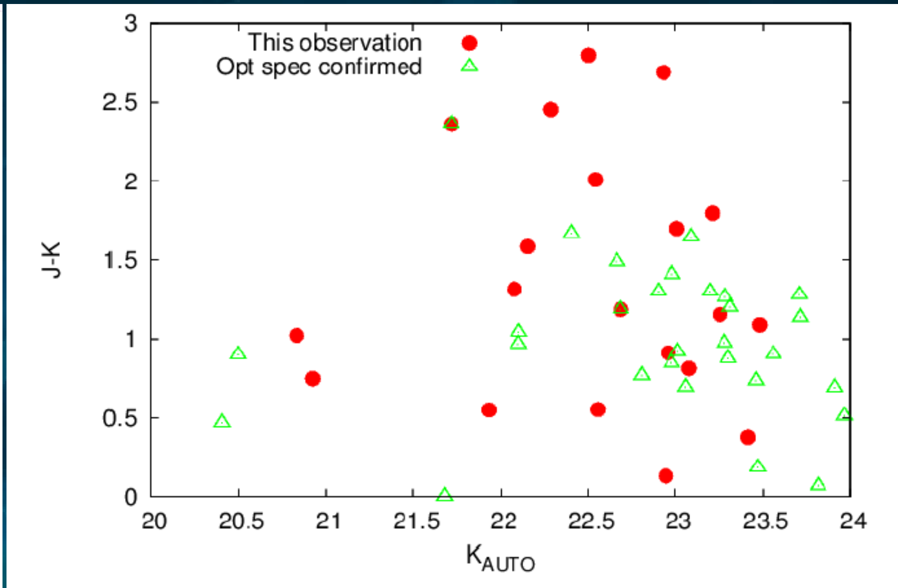
Kubo et al. (2013a)





MOIRCS VPH-K (R~2000) Spectroscopy for K-selected Objects





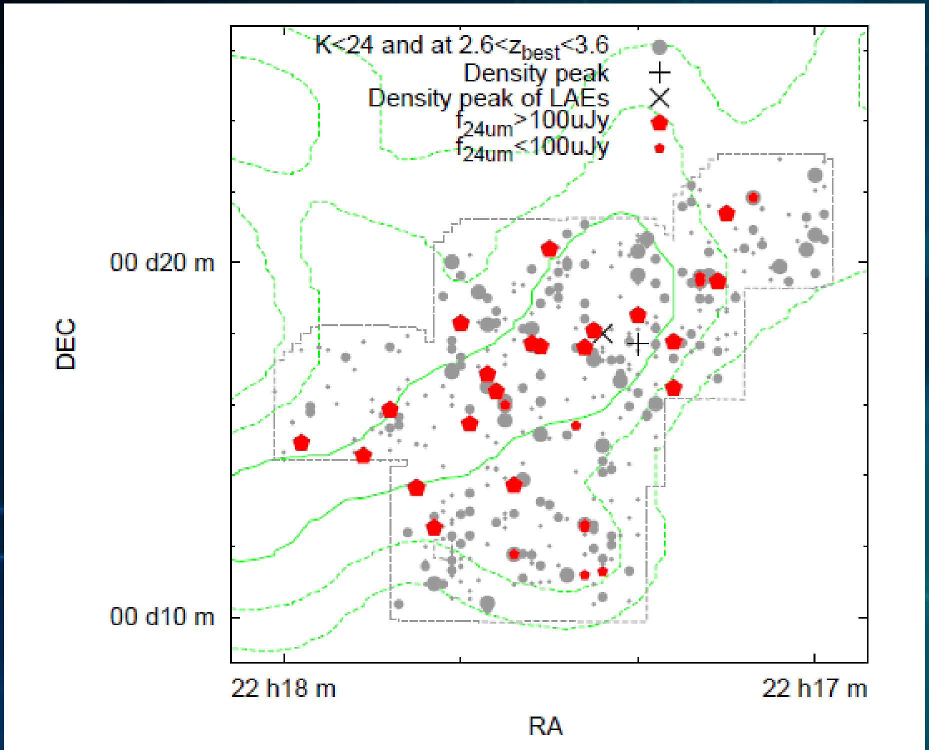
Complementary
with LBG/LAE (UV-selected)
K-band spectroscopy desired

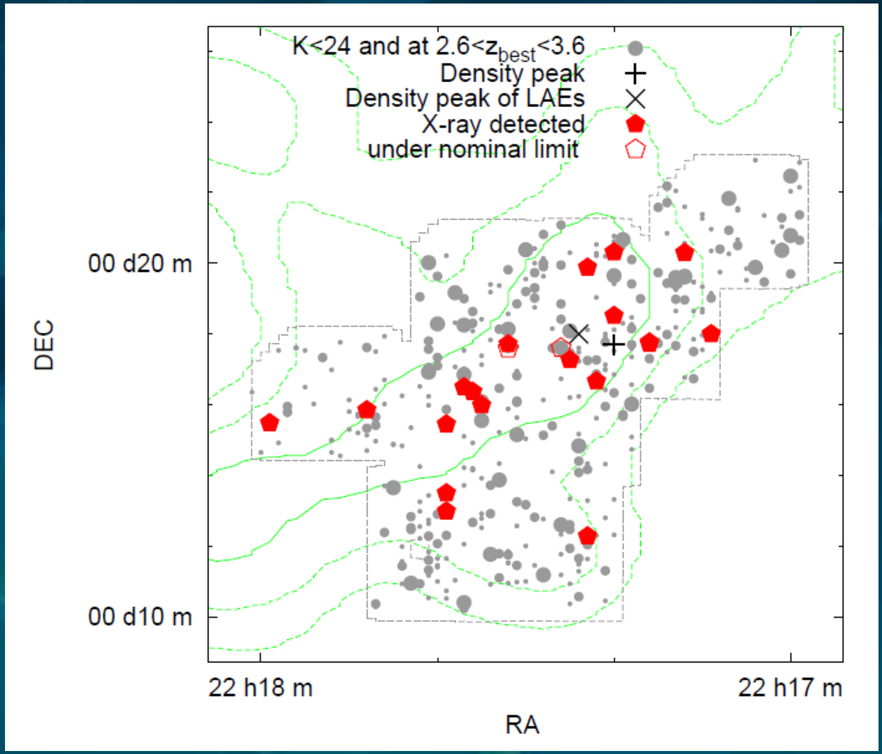
Kubo et al. 2013, ASJ meeting

K-selected Sample is useful in multi-wavelength Surveys

MIPS 24um-sources

Chandra X-ray sources





Hierarchical Galaxy Formation

- Cold accretion plays important role
  for active star-formation
  dissipative collapse / clumpy evolution

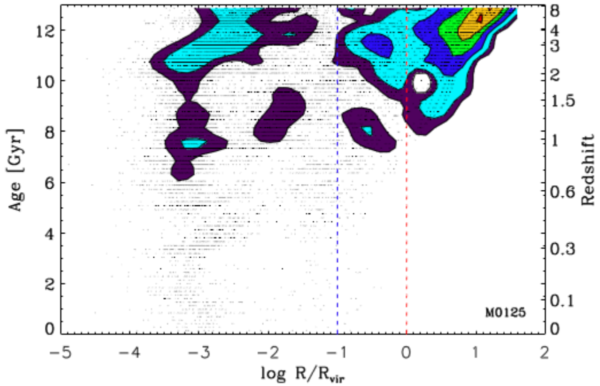
- ALWAYS BIASED galaxy formation
  down to the “scale of smearing”

- Consequently, massive galaxy formation
  may be in two phases
  dissipative collapse + dry assembly
  e.g., Oser et al. 2010; Naab et al. 2007

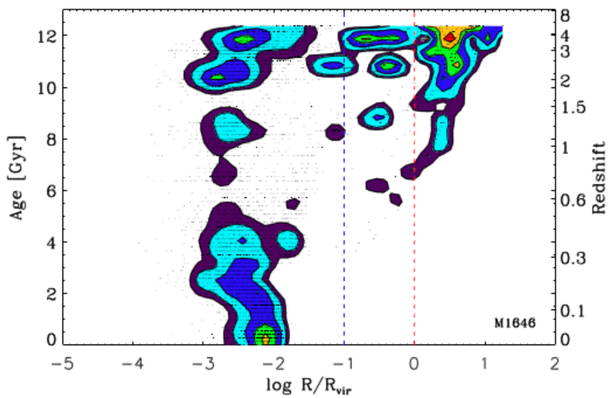
Origins of the
Stars in massive galaxies

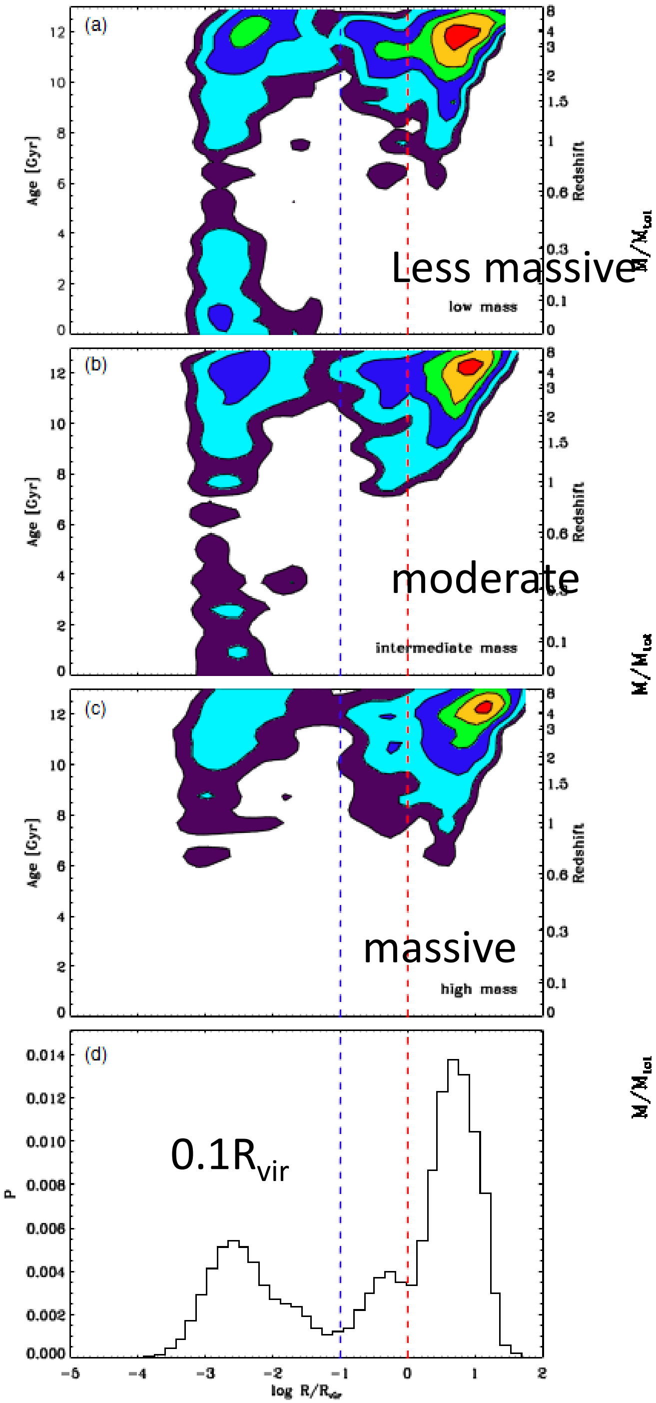
When and Where Stars Formed

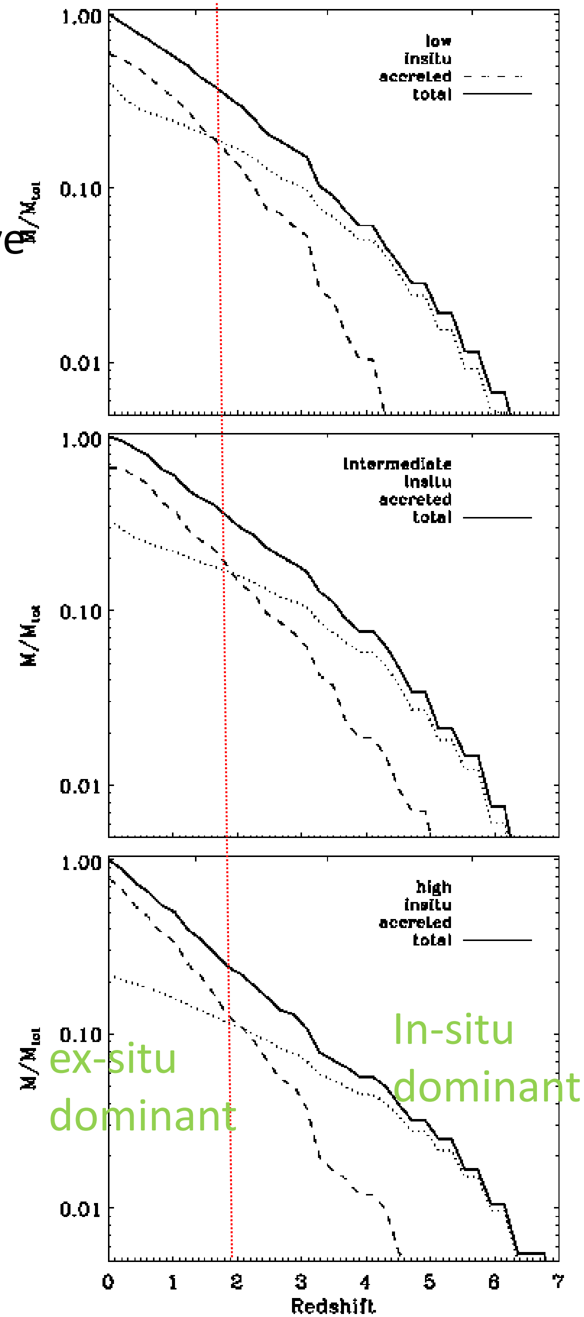
Massive gal(3×10^{11})



Less-massive (5×10^{10})





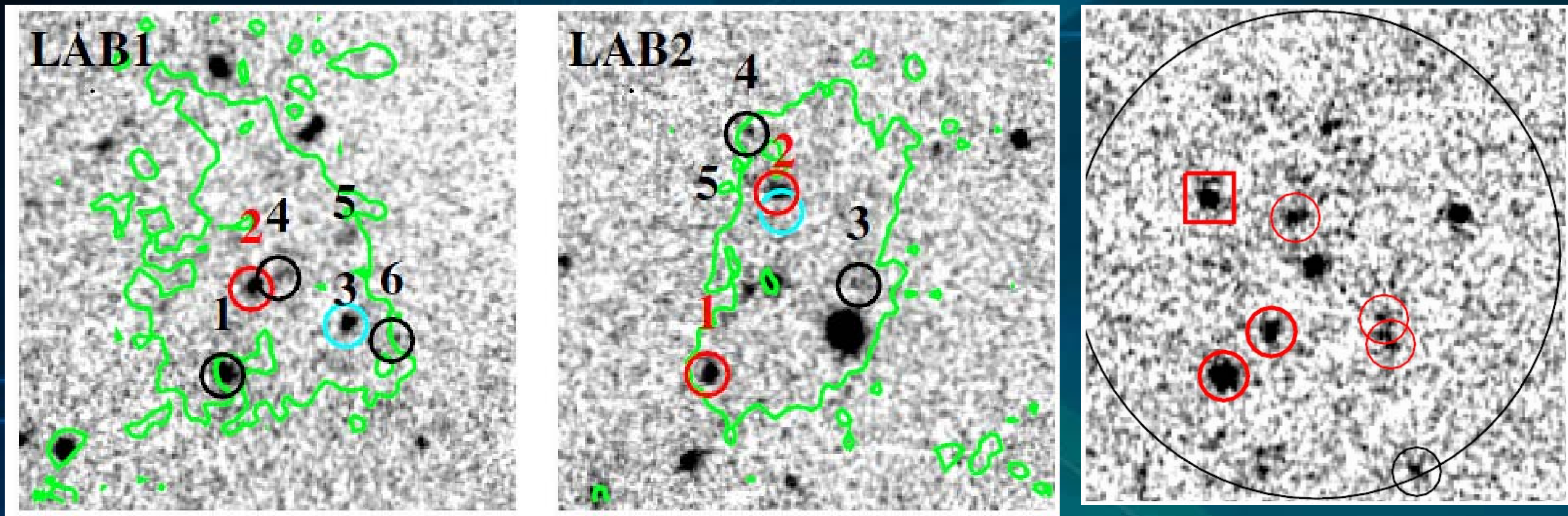


Oser et al. 2010

Examples of Hierarchically Forming Massive Galaxies

25" = 190kpc

SMG AzTEC SSA22-14



DRGs z=3.1

Other z=3.1

Uchimoto et al.

Key Science Cases for Subaru GLAO

Subaru GLAO Key Science Cases For Galaxy Evolution

- **NIR Narrow-Band Deep and Wide Survey**
  - **this is one of the cases, but need deep continuum**

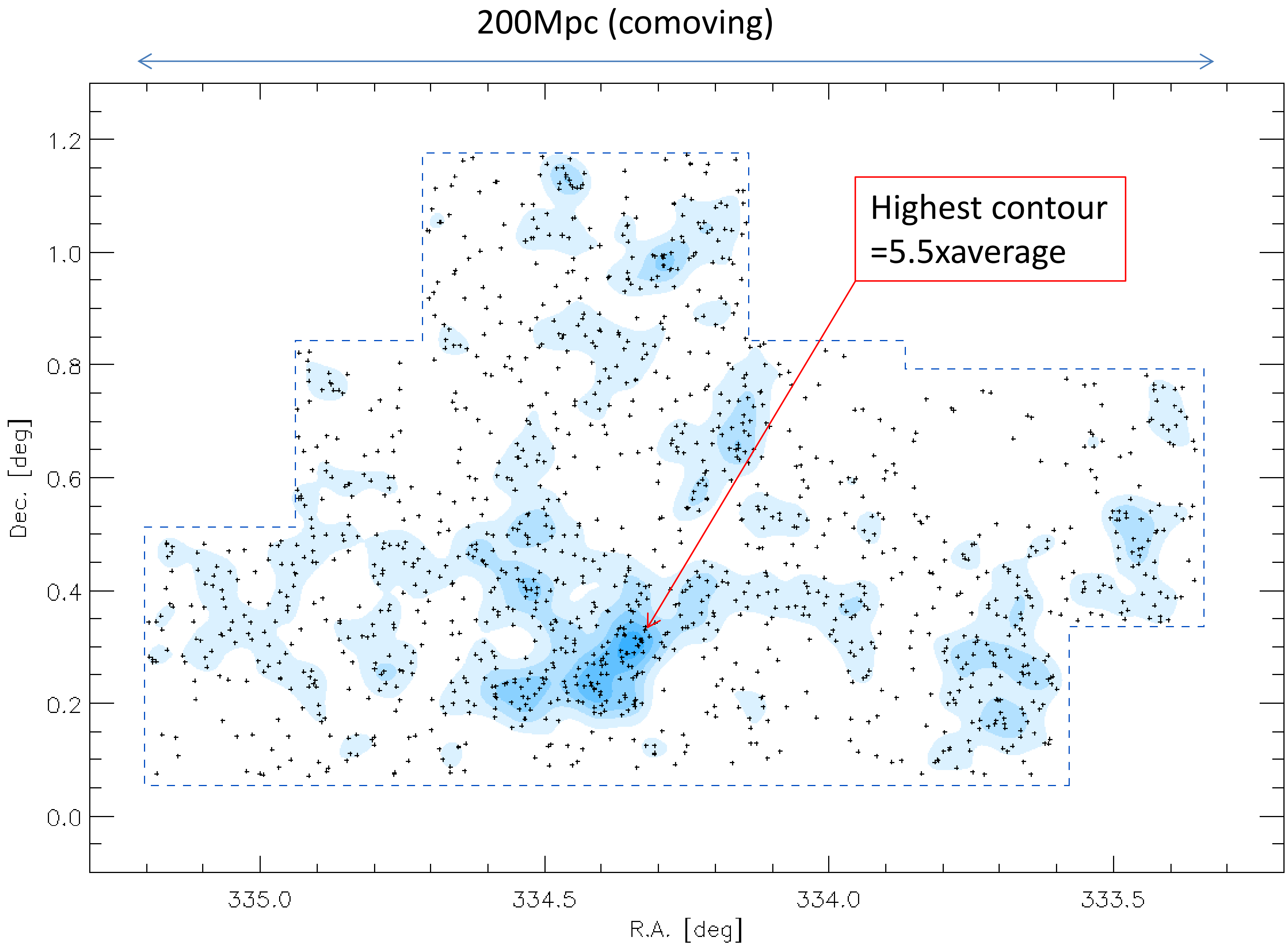
- **Statistical Approach for Mass Mapping**
  - **deep and wide K-band imaging** M_*
  - **wide spectroscopy/imaging for statistical sample of Δv, Reff** M_{dyn}

- **HSC/PFS definitely needs flexible deep and wide NIR**

- Wide-area mass mapping combined with simultaneous study of galaxy structure, especially at close environment

- type-Ia SNe rest-frame IR search and monitoring ~24-25AB, z~1, rest 1um

Large-scale distribution of ~1500 Lyα Emitters



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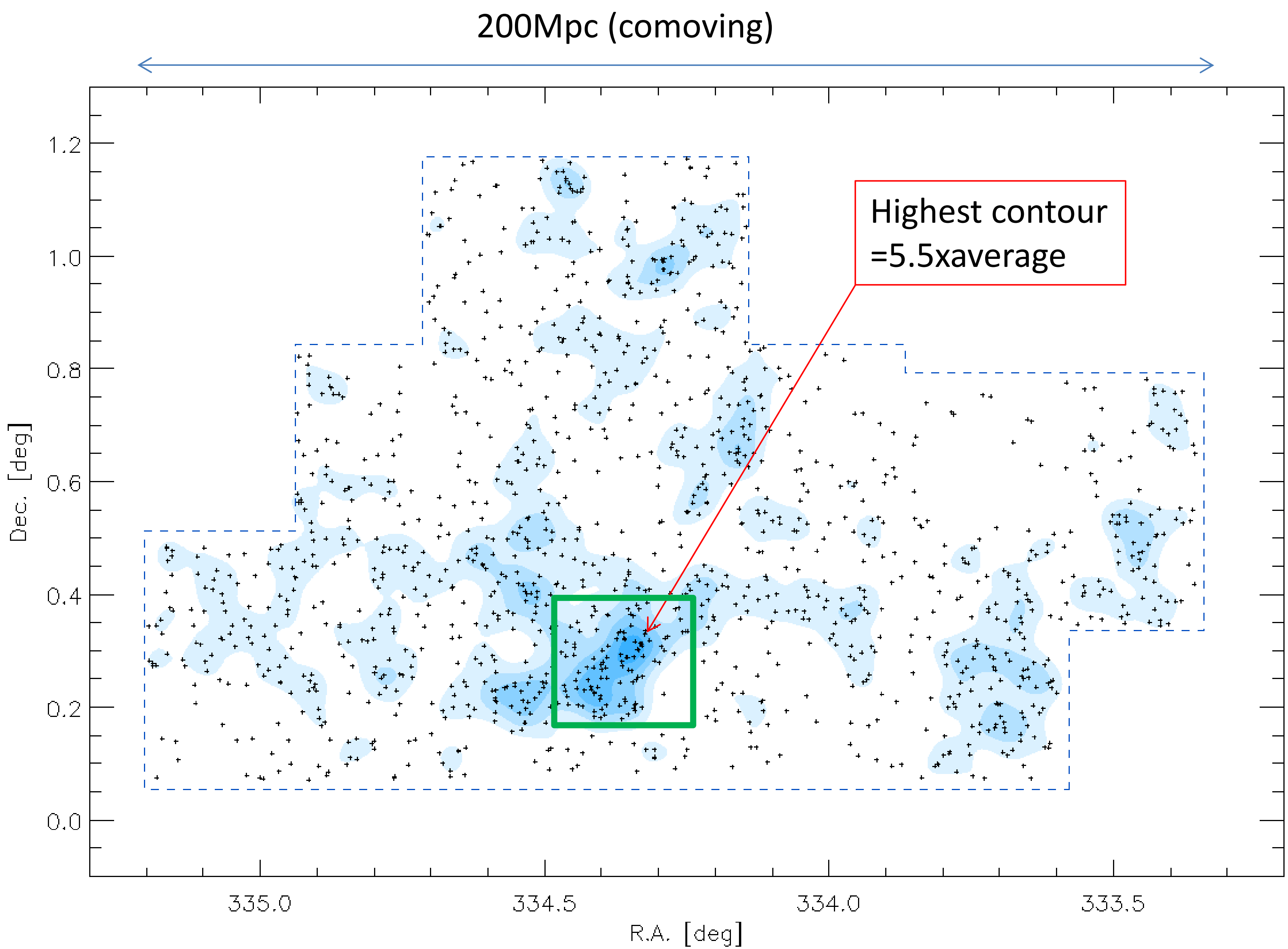
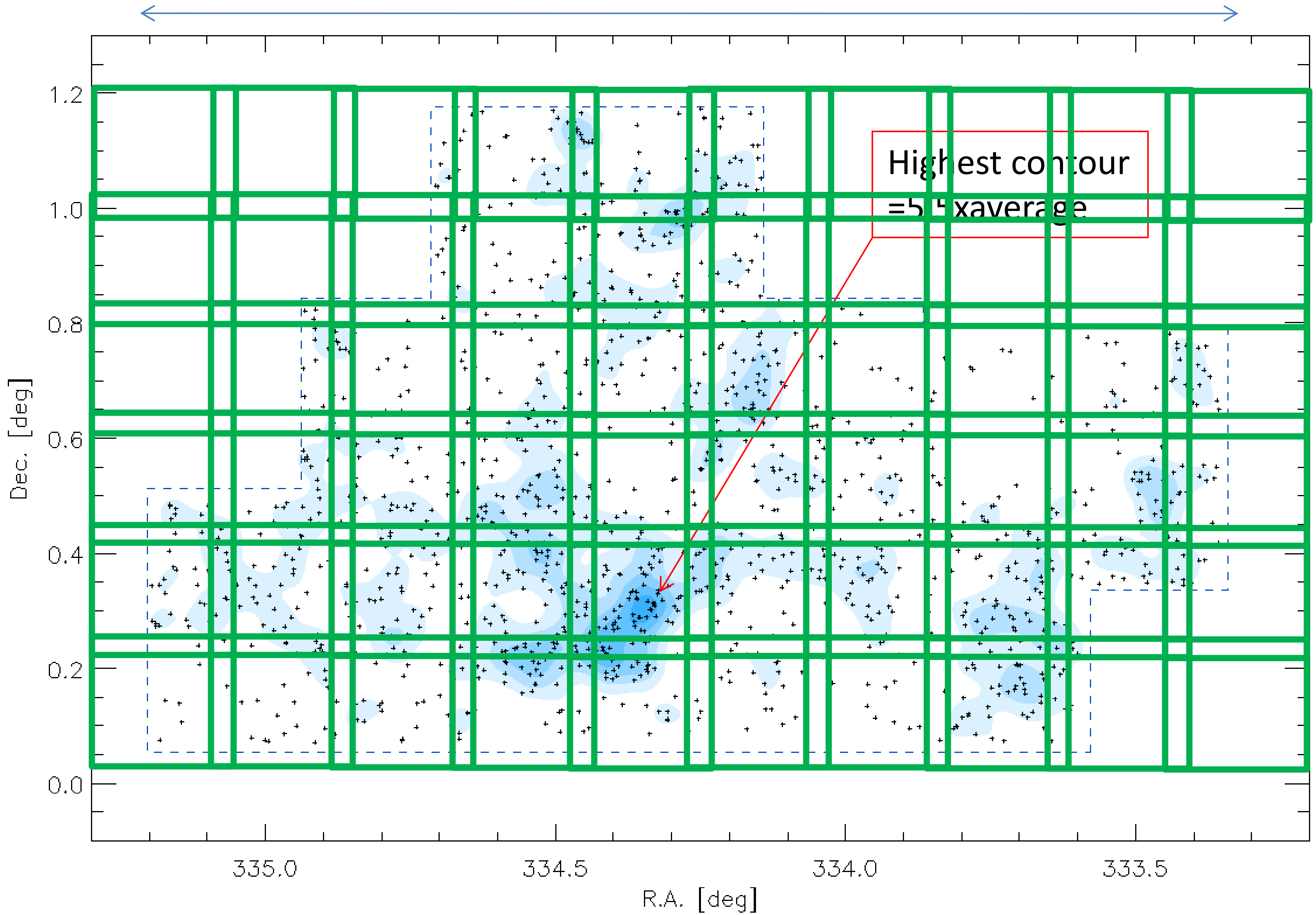


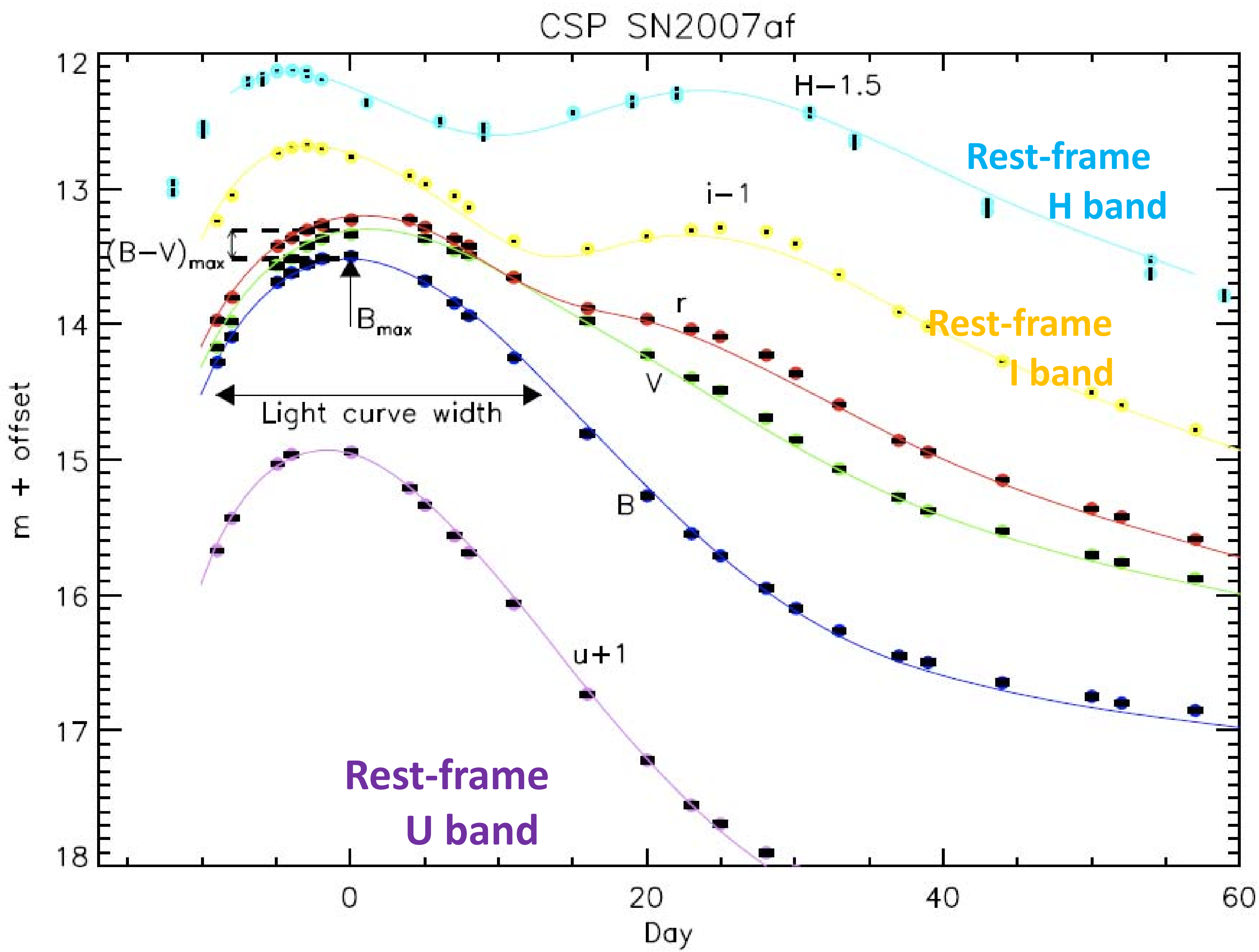
Large-scale distribution of ~1500 Lyα Emitters

200Mpc (comoving)

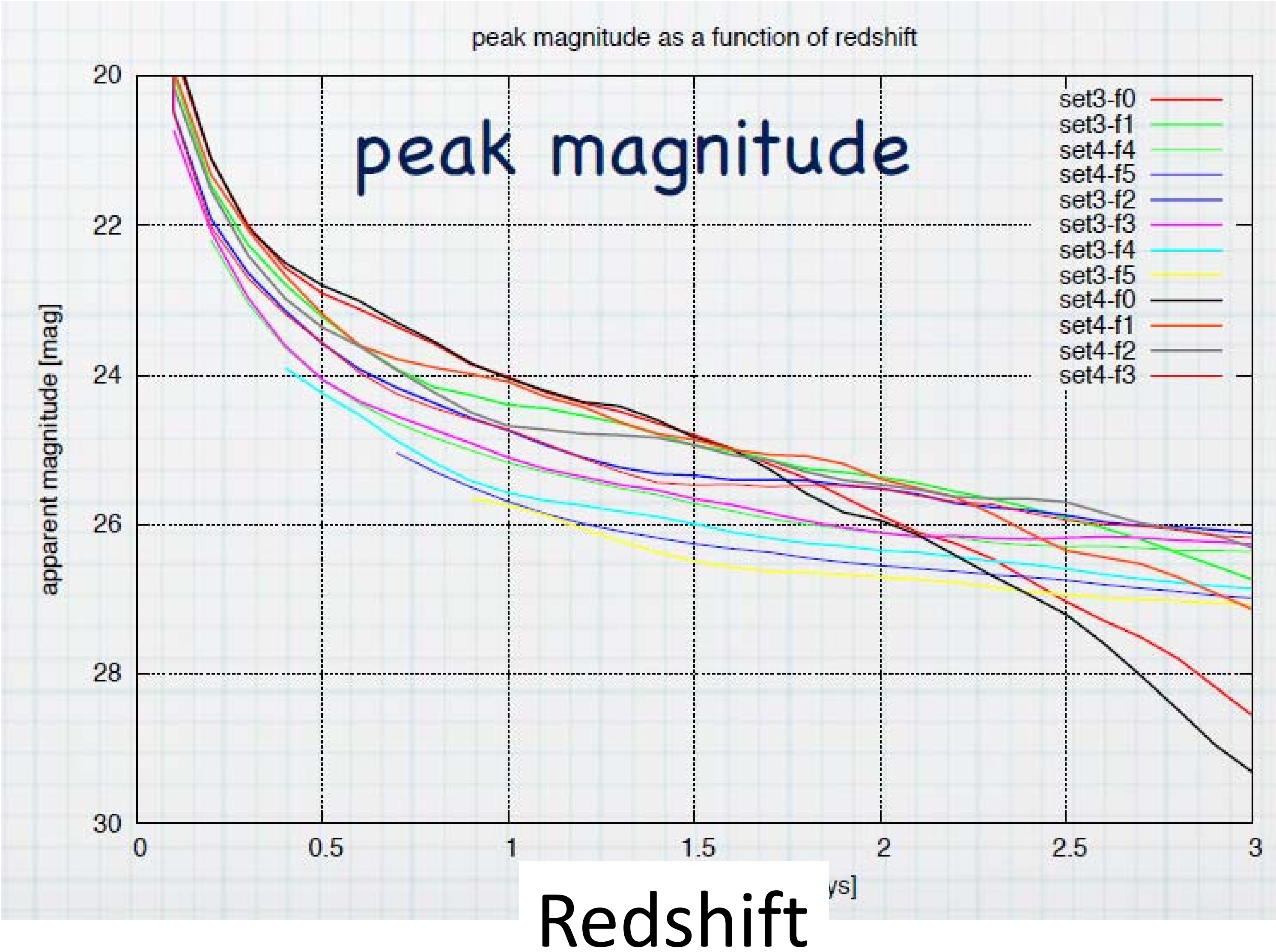


60 tiles of 15'x15'

Light Curves of Type Ia SNe



From Goobar and Leibundgut 2011



Morokuma、2010

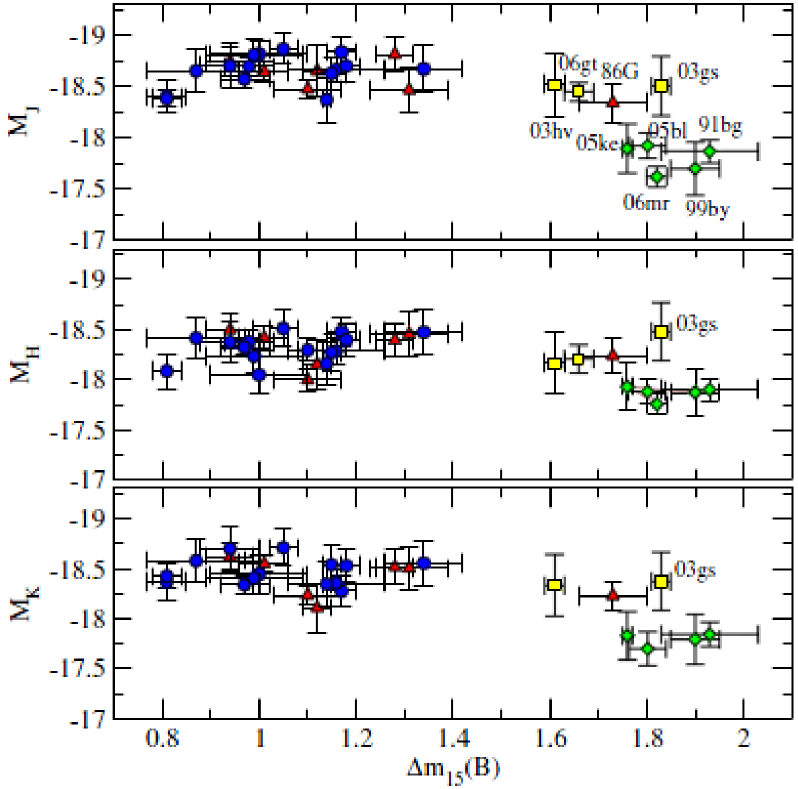
Krisciunas et al. 2009

Advantage: rest-frame IR

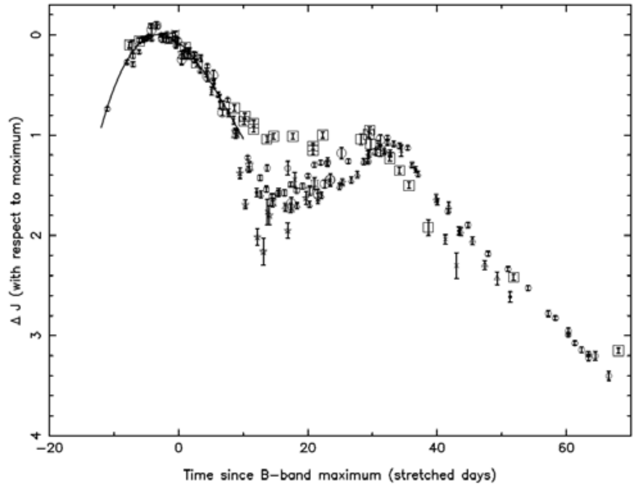
- Small scatter in peak magnitude
  n.b. more dispersion for $T_{peak}(IR)>T_{peak}(B)$

- Double peaks in Light Curve.
  First peak can be fitted by a single template

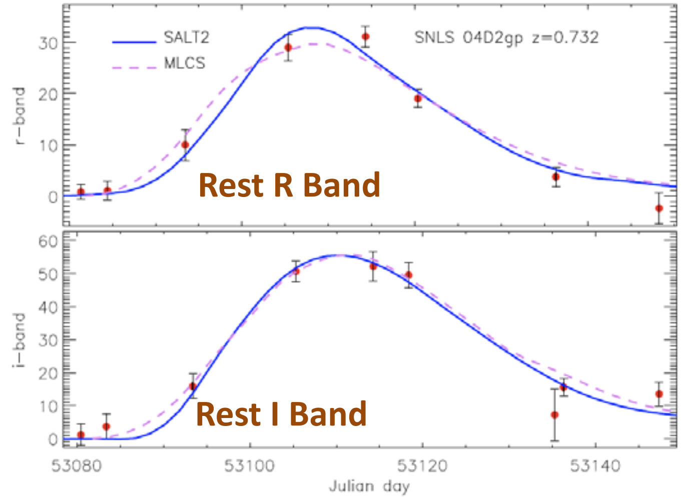
- Less sensitive to the Fitting Models of LC



J-band brightness



Time from B-band peak



From Goobar and Leibundgut 2011

Summary

(1) Advantages of Subaru-GLAO in ~2020
Cost-effectiveness, Easy Access, Flexibility

(1-1) Imaging
- Narrow-band (large telescope aperture)
  combined with future space wide-field missions
- K-band

➔ Key Cases: LAE at z~8-9,
Stellar-Mass Mapping at ~100Mpc scale at high-z
Probing hierarchical galaxy formation at virial scale
w/ large statistical sample

(1-2) Spectroscopy
- Combination of wide-field and high dispersion
  + moderate spatial resolution

➔ Key Cases: statistical approach to dynamical mass mapping