Dark Matter Halo and Stellar Properties of Extremely Low-Mass Galaxies at z~2

(Kusakabe+16 in prep)

29/11/2016

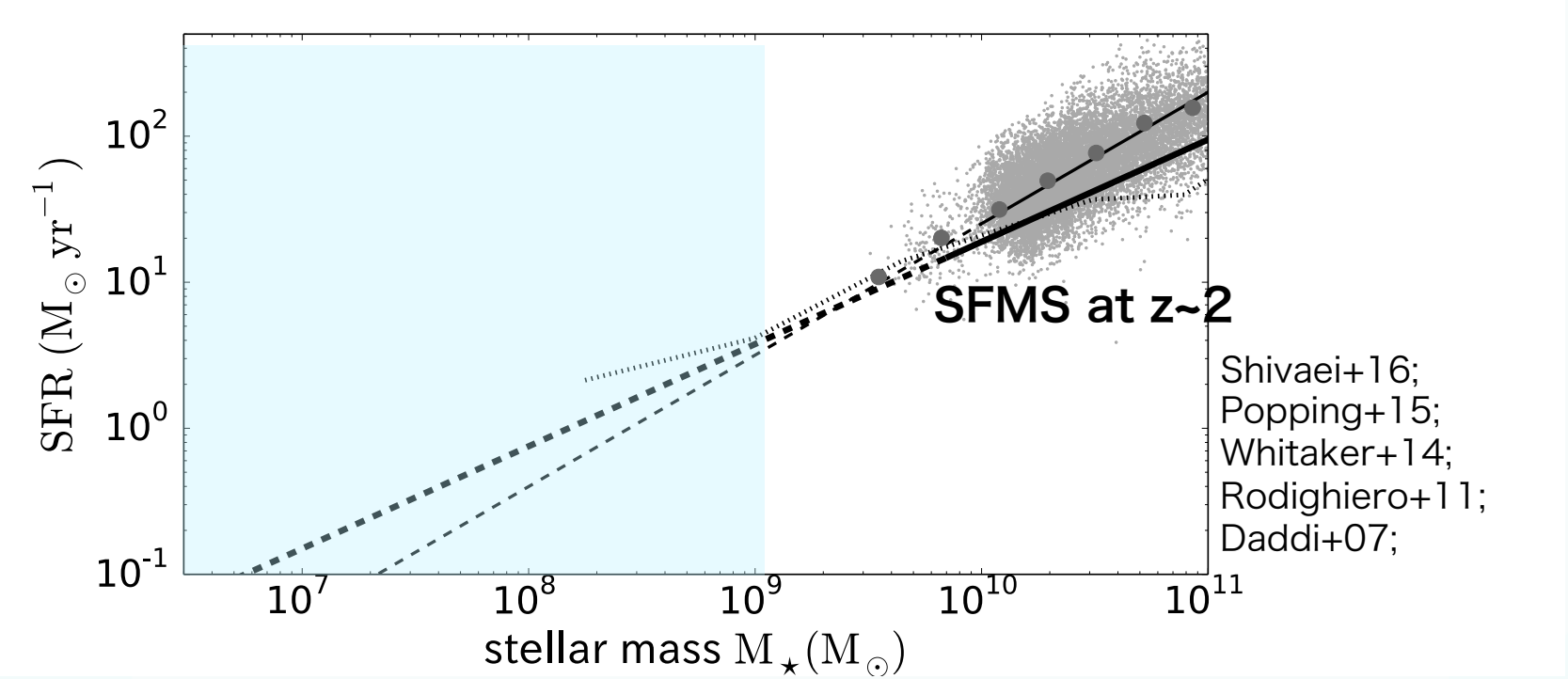
The 6th SUBARU International conference @Hiroshima

Haruka Kusakabe (The University of Tokyo)

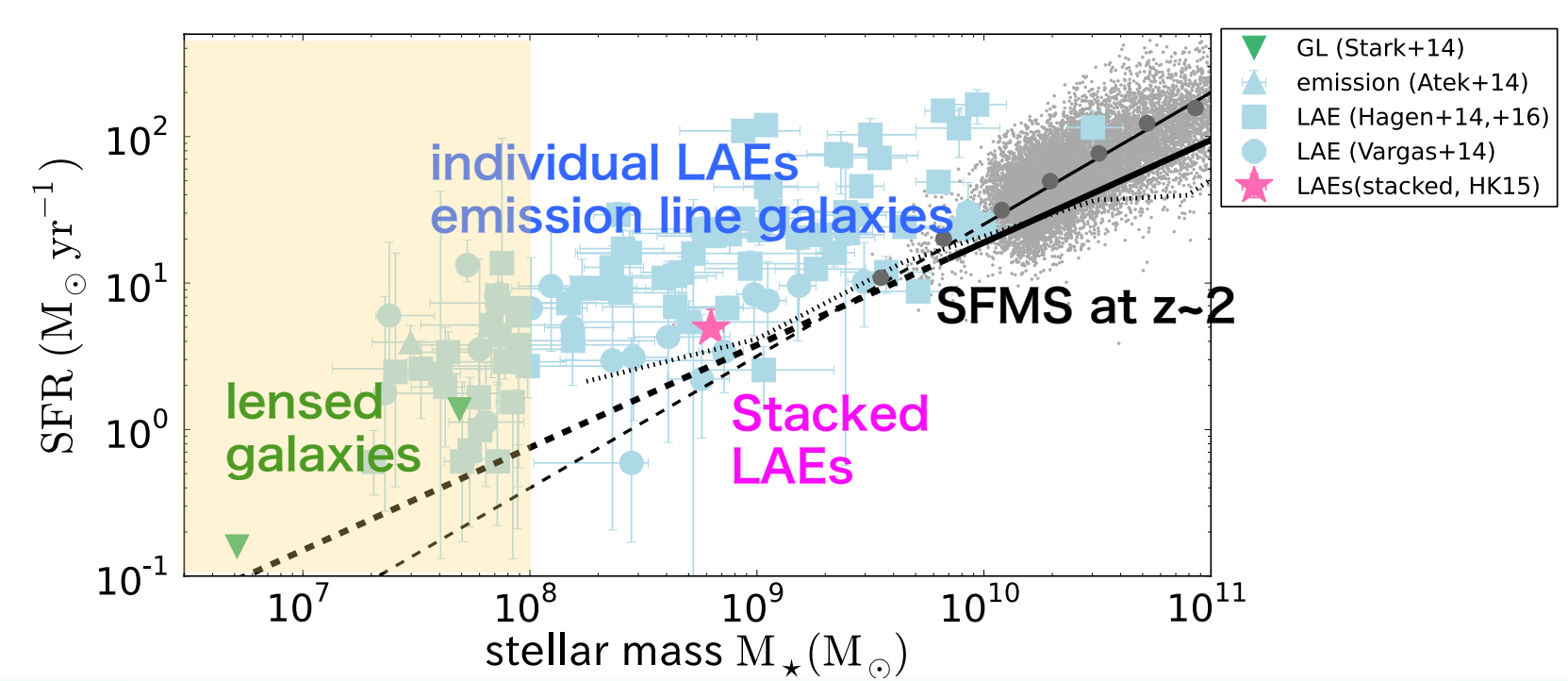
K. Shimasaku, K. Nakajima, R. Goto, M. Ouchi,

T. Hashimoto, A. Konno Y. Ono, Y. Harikane and J. Silverman

Stellar masses & SFRs at z~2



Stellar masses & SFRs at z~2

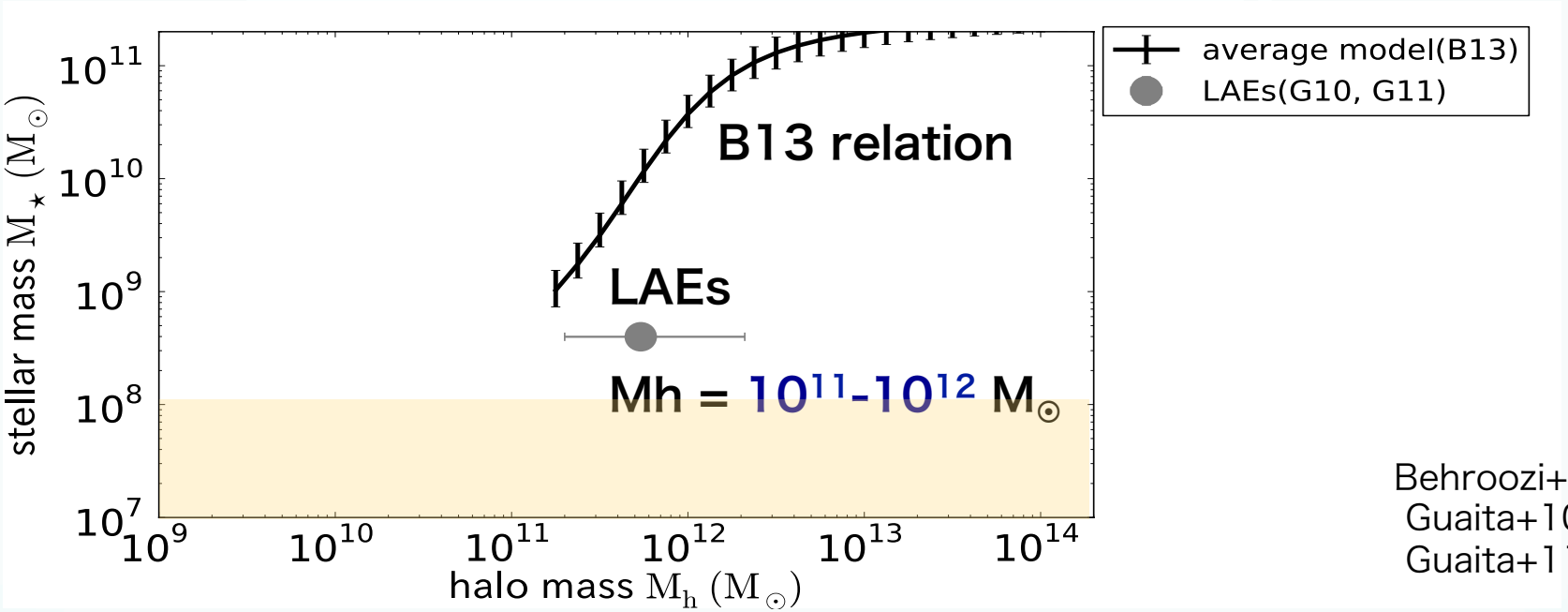


emission lines (e.g., Lyα) & Gravitational lensing survey

- problems
  individual: only bright gals, poor IRAC S/N
  stacked: only average properties
- Ms<$10^8 M_\odot$: less than 30 galaxies have stellar population estimates with large uncertainties

Shivaei+16;Popping+15;Whitaker+14; Rodighiero+11; Daddi+07; Kusakabe+15; Vargas+14; Hagen+14; Stark+14; Atek+14

Dark matter halos at z~2



Behroozi+13,
Guaita+10,
Guaita+11

- problems (Guaita+10):
  small sample size (250)→ large statistics error
  small survey area (0.3 deg²)→ suffer from cosmic variance
- No study for galaxies with Ms <~$10^8 M_\odot$

This study

Dark matter halo & stellar population properties of
- low mass ($Ms \sim 10^8 M_\odot$)
- extremely low-mass ($Ms < 10^8 M_\odot$)

galaxies at z~2

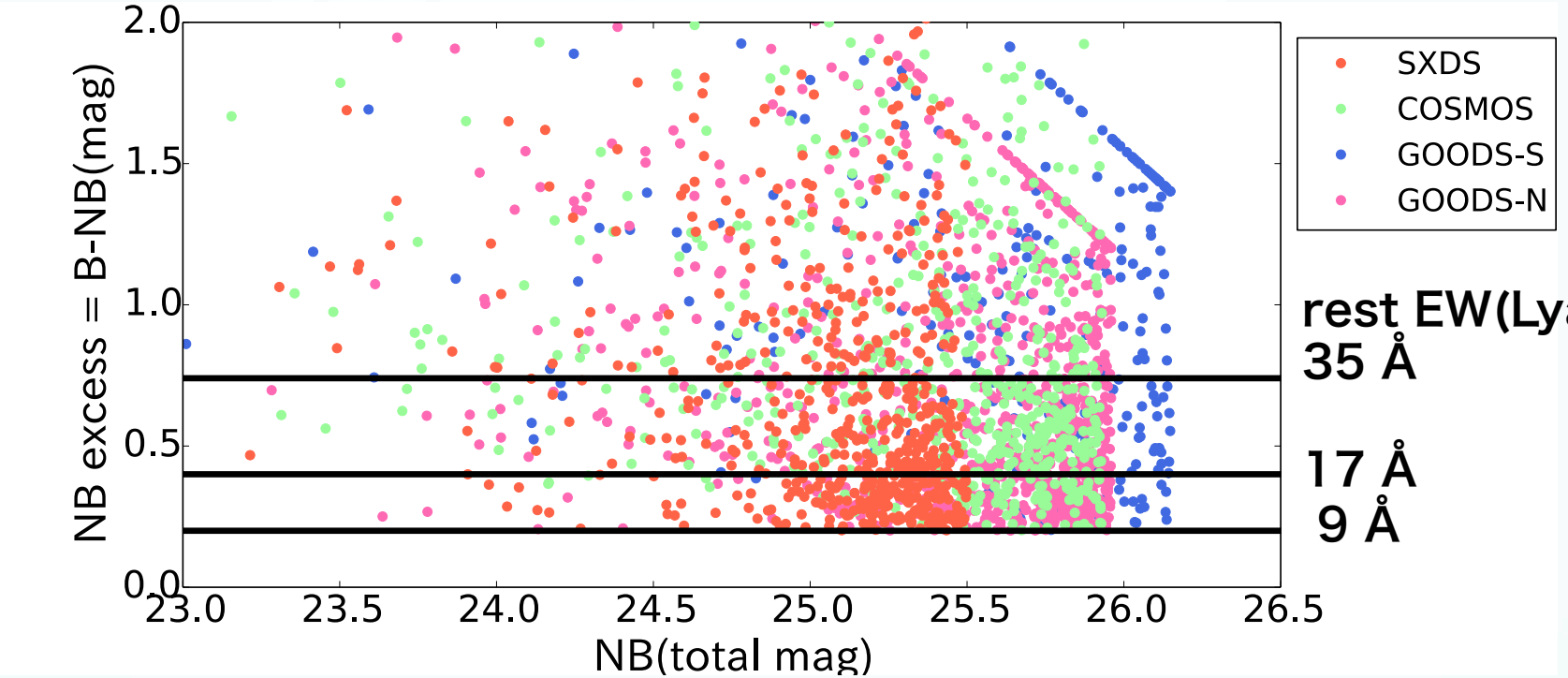
- ~2400 NB LAEs in ~1 deg^2
  NB <26.4mag(5σ)
- sub samples based on NB excess & magnitude
- dark matter halo masses: clustering analyses
- stellar properties: SED fitting

Samples

Fleld	Area (min^2)	NB mag lim (5σ, mag)	Number of samples	Clustering analyses	SED fitting
SXDS	~1260	25.7, 2" ap	603	✔	✔
COSMOS	~850	26.1, 2"ap	619	✔	✔
GOODS-S	~830	26.4, 2" ap	269	✔	
GOODS-N	~910	26.1, 3" ap	950	✔	
TOTAL	**~1deg^2**		**~2440**		

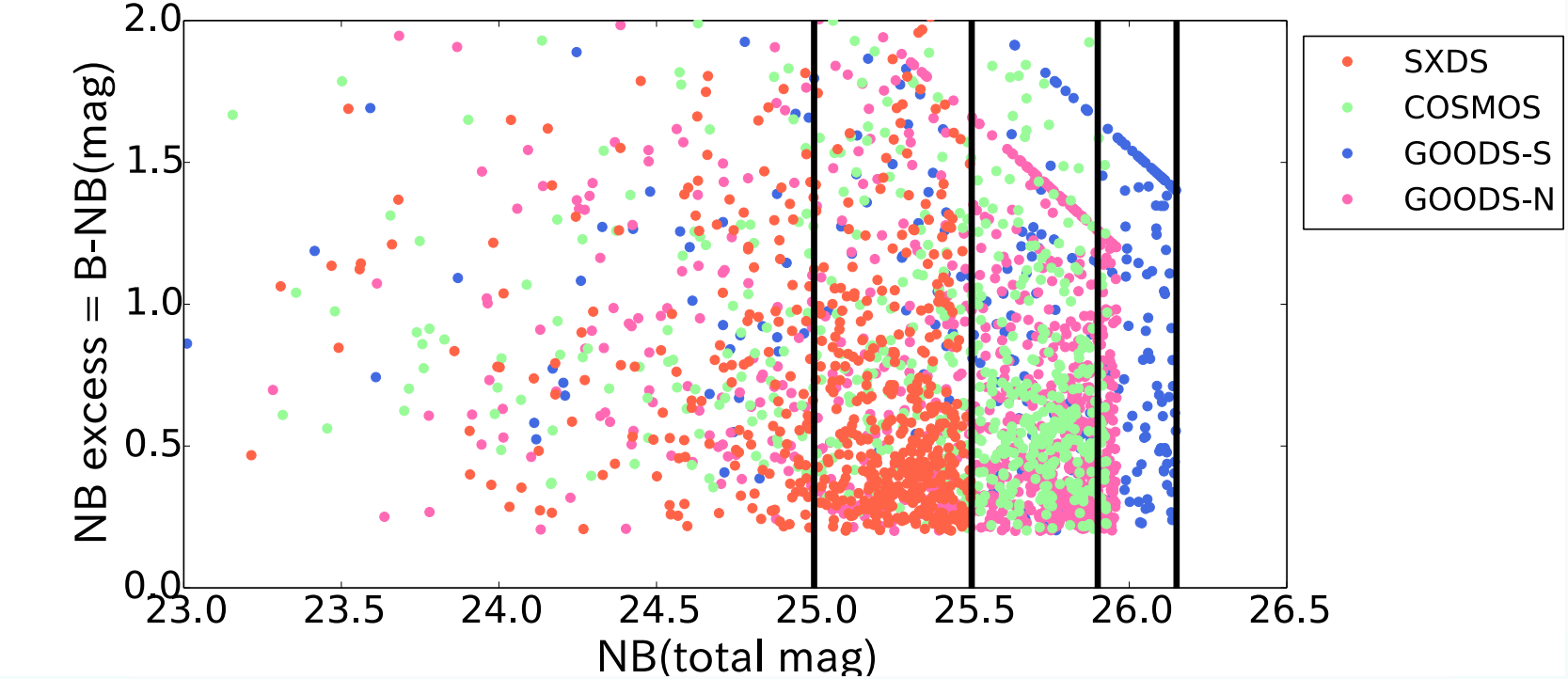
(Nakajima+12, 13, Kusakabe+15, Konno+16)

Sub-sample criteria



- Divided into three sub-samples based on NB excess implying EW(Lyα) = 9-17Å,17-35Å, >35Å

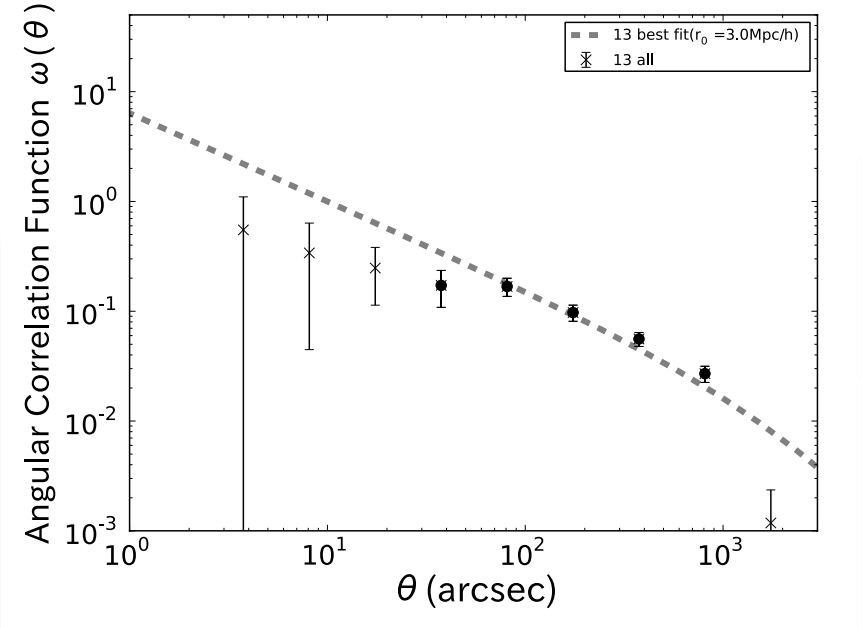
Sub-sample criteria



- Divided into four sub-samples based on NB magnitude: 26.15-25.9 mag, 25.9-25.5 mag, 25.5-25.0 mag, <25.0mag

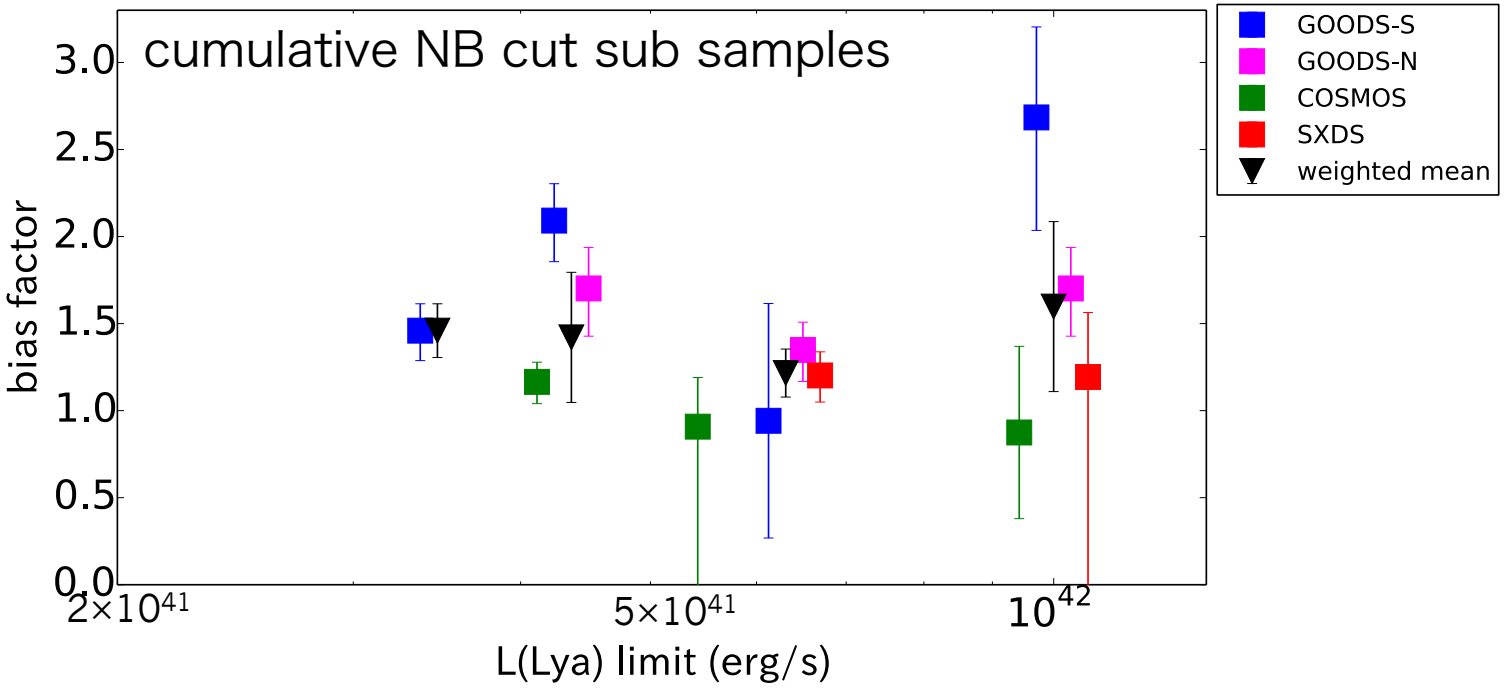
Clustering Analysis

Dark matter halo mass of cumulative sub samples



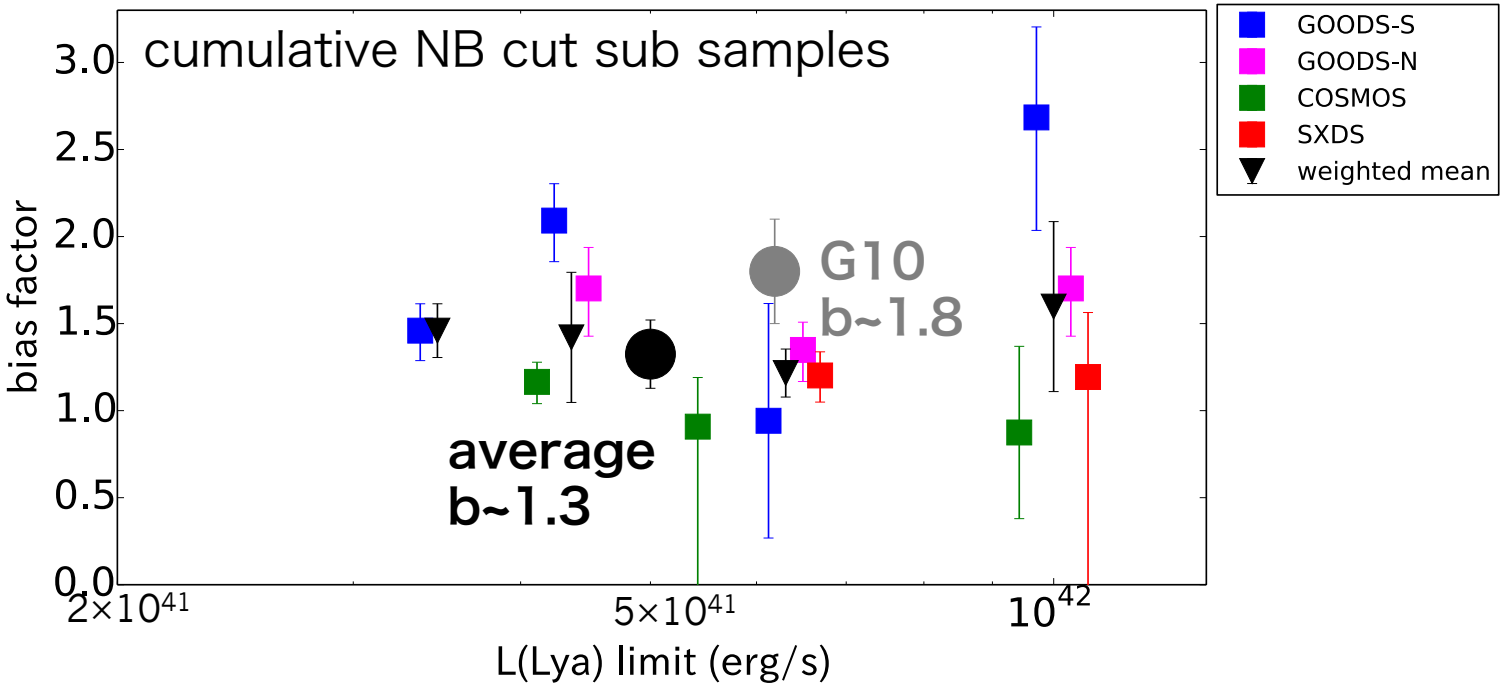
- ACF observation: Landy & Szalay+93 (error: poisson)
- ACF model: β=0.8, fitting range=40”-1000”
- bias factor-halo mass: Tinker+10

Dark Matter Halo masses



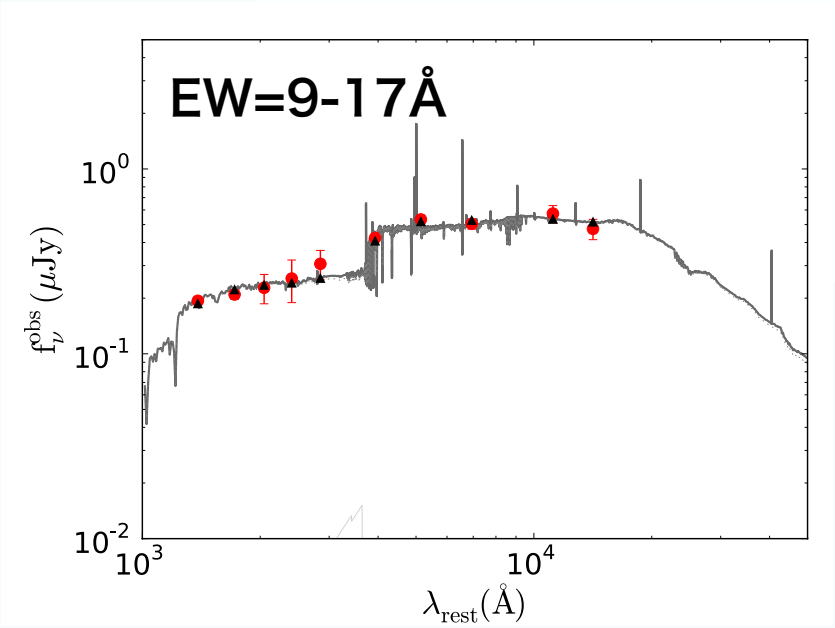
- large cosmic variance beyond statistics errors
- No significant dependence on L(Lya) limit
- No significant dependence on EW (NB excess)

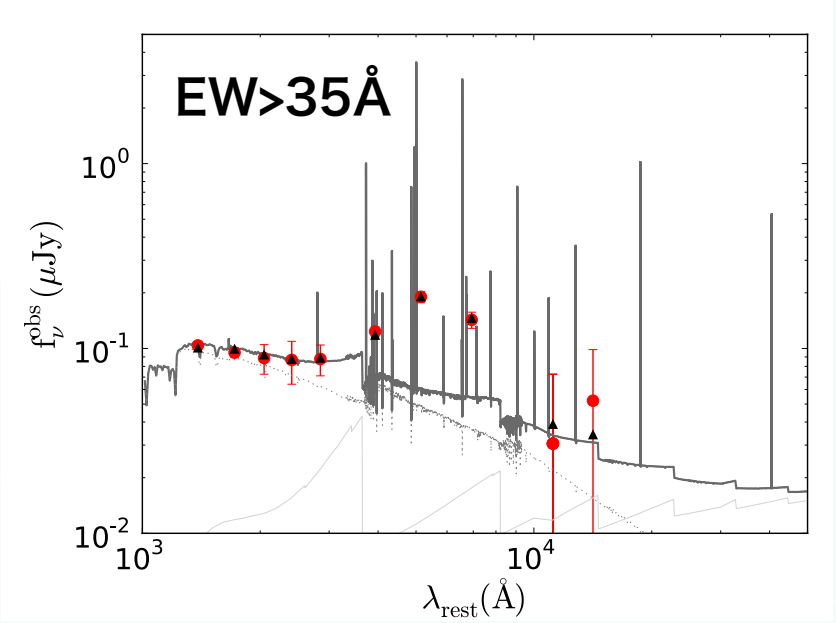
Dark Matter Halo masses



- average bias = 1.32±0.19 (2440 LAEs in 1 deg²)
  < bias=1.8±0.3 (G10; 250 LAEs in 0.3 deg²)

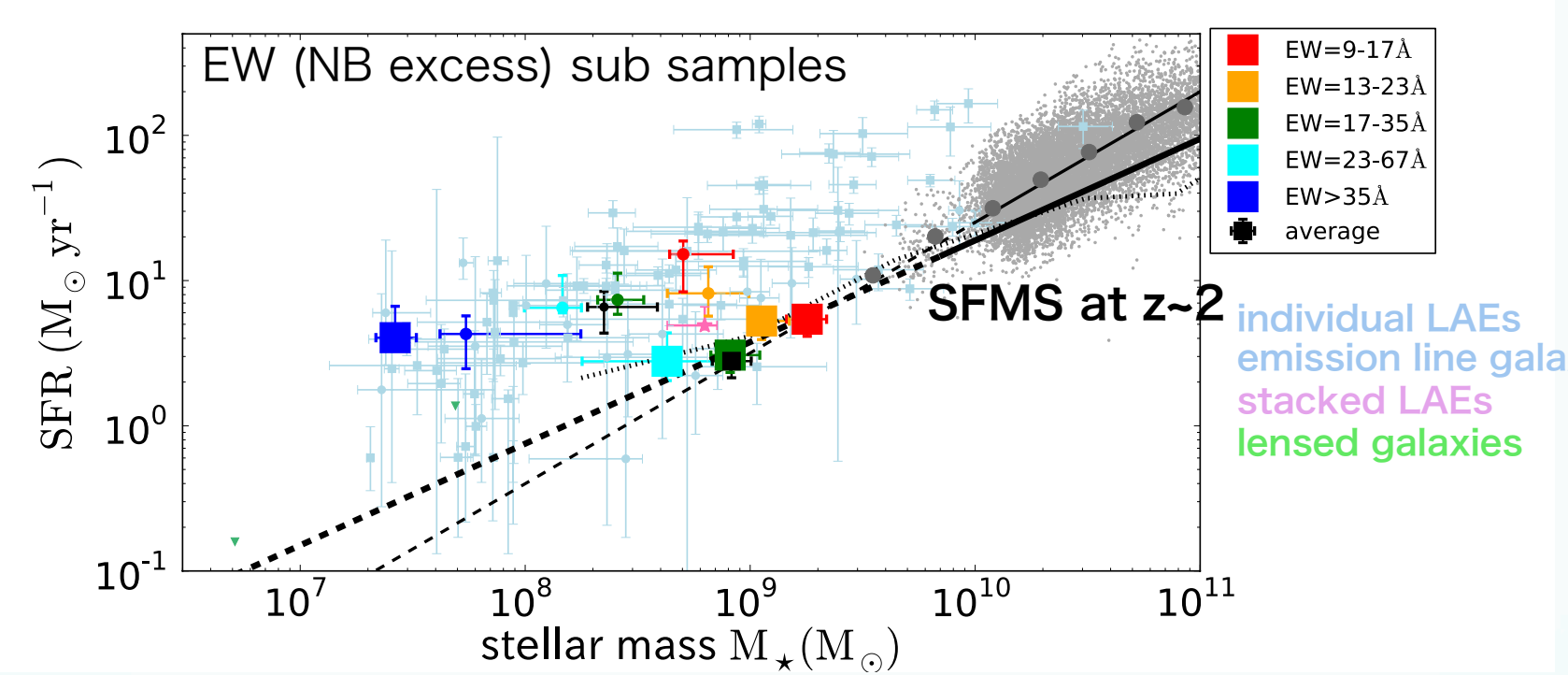
Stacked SED fit





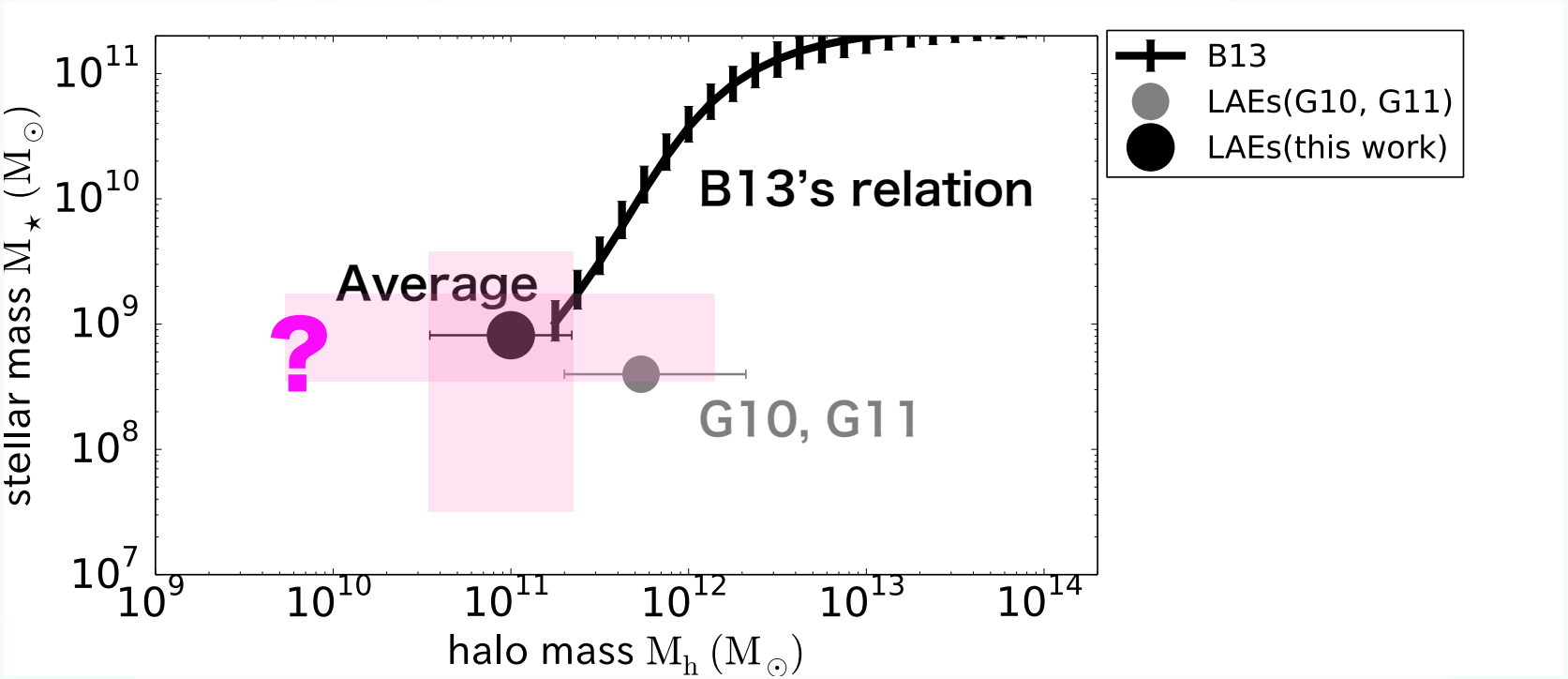
- observational data: B, V, R, I, z, J, H, K, IRAC ch1, ch2
- derived params: SFR, Ms, age, E(B-V), fesc(ion)
- model:
  BC03 with nebular emission (lines & continuum, Ono+10)
  constant SFH
  Z=0.2Zsun
  SMC-like attenuation curve (Kusakabe+15)

Ms vs SFR



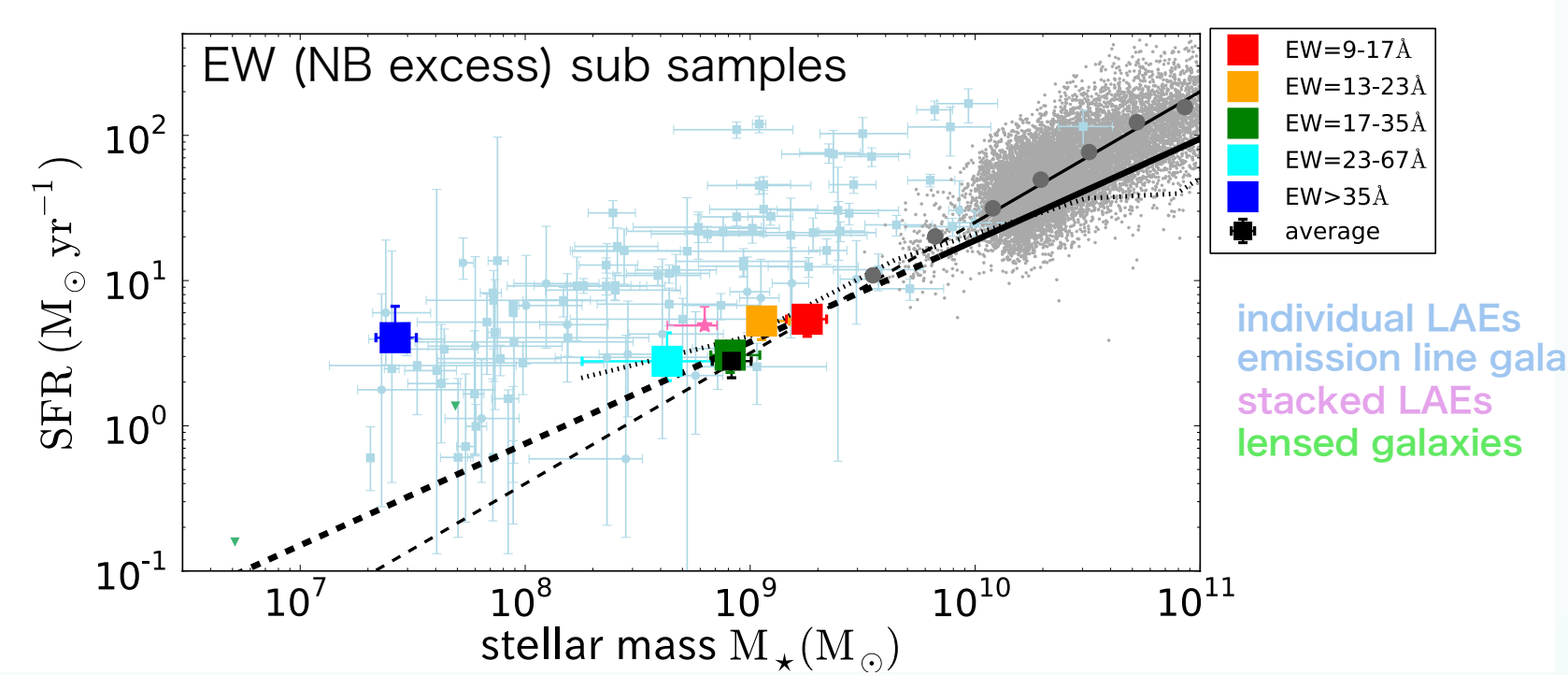
- Ms are distributed widely: ~10^7-$10^9 M_\odot$
- average LAEs: ~$10^9 M_\odot$

Mh vs Ms



- Average LAEs lie on B13 extrapolation
- Ms: 2 dex range
  Mh: maybe wide distribution
  HSC survey is useful for further study

Ms vs SFR



- LAEs with larger EW have smaller stellar masses
- 2/3 LAEs: lie on the extrapolation of the SFMS
- 1/3 LAEs: SB galaxies with stellar mass of ~$10^7 M_\odot$
  ~200 candidates of extremely low-Ms galaxies
  >> less than 30 galaxies in the previous work

Extremely Low-Mass LAEs: physical properties

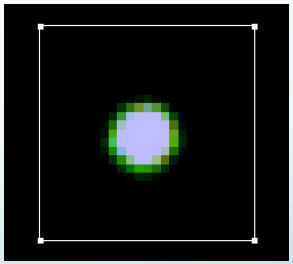
- EW(Lya)~80Å
  L(Lya)=1.7×10^{42} erg/s,
  β~-2
  M_{UV}~-18.5mag

(stacked properties)

- Ms ~2.6×10^{7} Msun
  sSFR ~160 /Gyr
  Age ~7 Myr
  fesc of LyC <~30%
  L(Ha) ~6×10^{41} erg/s

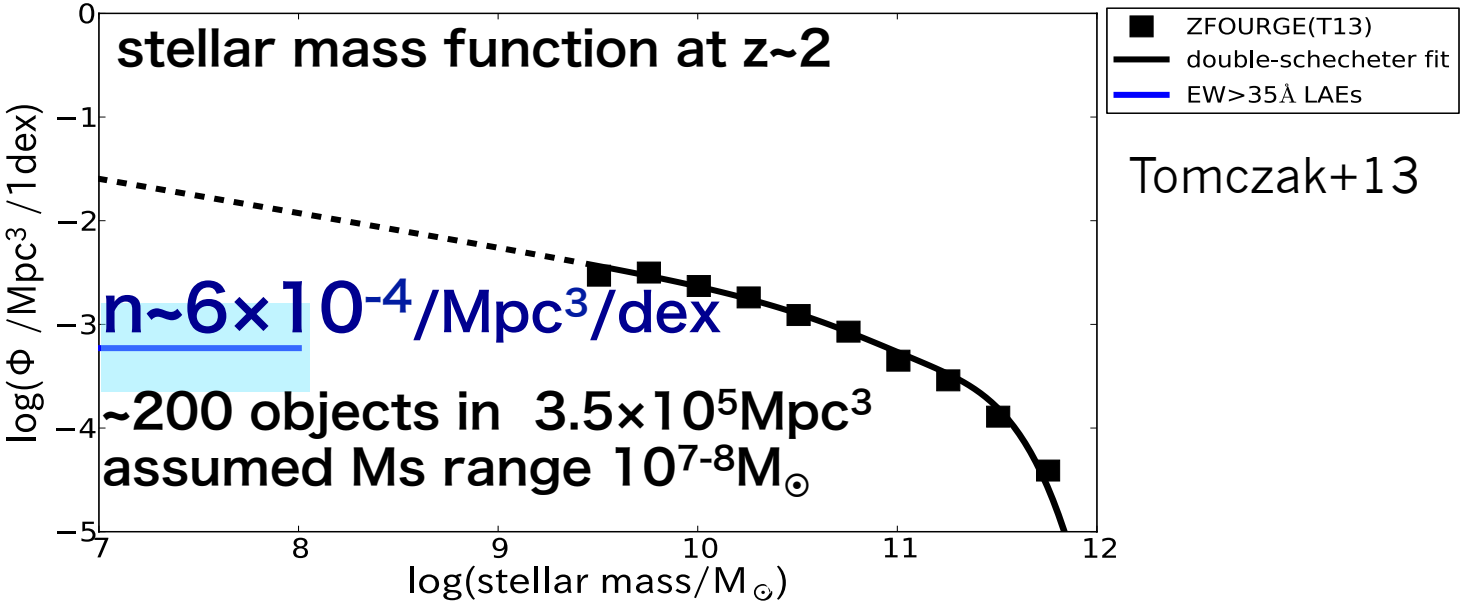
(stacked SED fitting)

5”×5” cut out image of Subaru (NB, B, V)



- Mh ~10^{10}-$10^{11}M_{\odot}$
  Baryon Conversion Efficiency
  =SFR/baryon accretion rate ~0.1-1
  $\gtrsim$ typical value 0.1 from B13’s relation

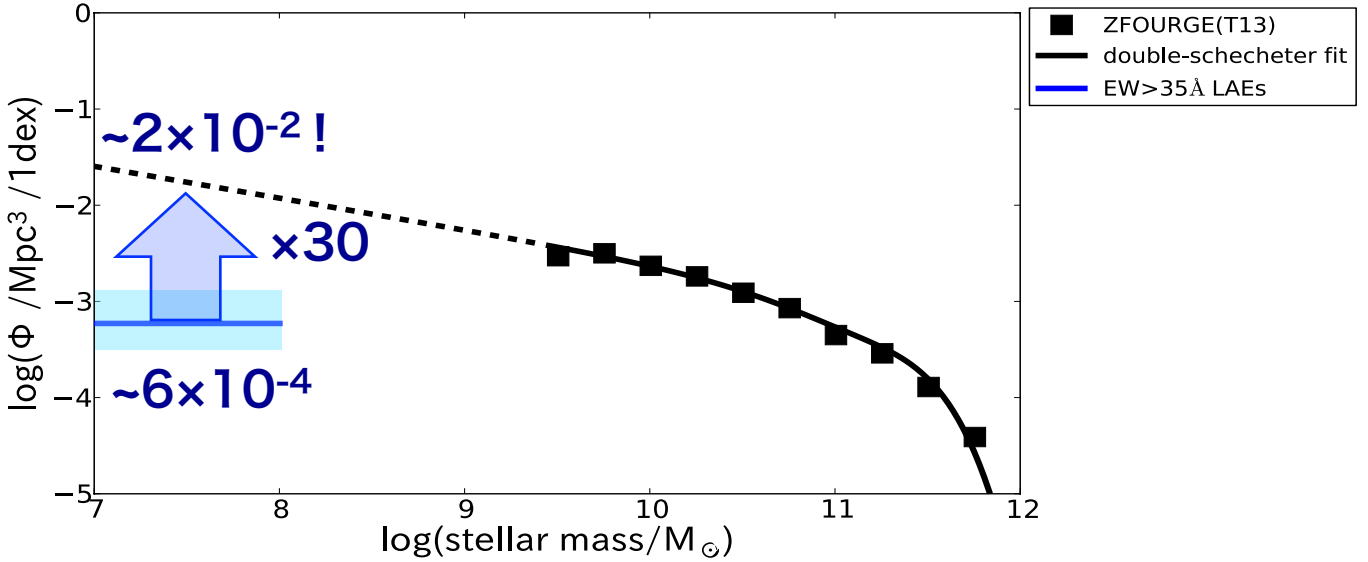
Extremely Low-Mass Galaxies: number density



- ~10-100 times smaller than extrapolation of SMF
  →large number of Extremely Low-Mass Galaxies with undetectably low SFRs

Extremely Low-Mass Galaxies: universality of the strong starburst

- galaxies form stars along SFMS at Ms=10^7 - $10^8 M_\odot$
  →staying time between Ms=10^7 and $10^8 M_\odot$ ~ 300 Myr
- age/staying time ~ 10/300~1/30
  n(Ms=10^7-$10^8 M_\odot$)=$6\times10^{-4}\times30\sim 2\times10^{-2}$ /Mpc^3/dex
  → comparable to extrapolation of observed SMF at z~2



Extremely Low-Mass Galaxies: universality of the strong starburst

- galaxies form stars along SFMS at $Ms=10^7$ - $10^8 M_\odot$
  →staying time between $Ms=10^7$ and $10^8 M_\odot$ ~ 300 Myr

- age/staying time ~ 10/300~1/30
  $n(Ms=10^7\text{-}10^8 M_\odot)=6\times10^{-4}\times30\sim 2\times10^{-2}$ /Mpc^3/dex
  → comparable to extrapolation of observed SMF at z~2

- majority of $Ms\sim10^7\text{-}10^8 M_\odot$ galaxies
  may experience the strong SB and
  may acquire significant fraction of mass from a strong SB

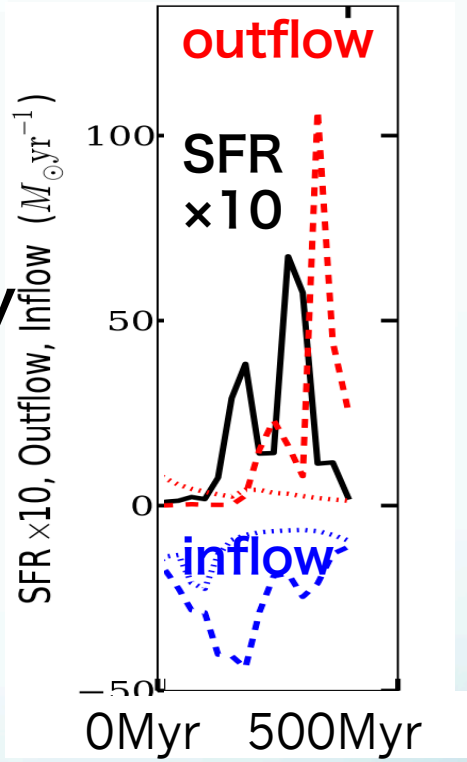
- more robust discussion will be obtained by HSC survey!

Extremely Low-Mass Galaxies: mechanism of short time burst

- Short time scale of the strong SB:
  - young age < 10 Myr
  - small number density

a) SN FB terminates the strong SB shortly
→SB phase before onset of SN FB?

b) no sufficient gas supply?
not inconsistent with
a relatively high BCE
(=SFR/baryon accretion rate)



FIRE simulation
(Muratov+15)

Summary

~2440 LAEs at z~2 from 1deg^2 field

- average bias parameter = 1.32 ± 0.19 Mh ~10^{10}-$10^{11}M_\odot$
  - large cosmic variance
  - smaller than Guaita+10 based on 0.3 deg^2 area
- stellar masses are distributed over ~10^7-$10^9M_\odot$
  large EW(Lya) objects have smaller stellar masses
- ~2/3 form star moderately lying on SFMS
  ~1/3 have extremely low stellar mass (Ms~10^7-$10^8M_\odot$)
  with strong star burst
- Extremely low-mass LAEs:
  - ~200 objects! >> 30 (previous work)
  - high sSFR, young age, high BCE →short burst time scale
- HSC enables us to study Mh variation of LAEs
  and physical properties of extremely low-mass galaxies