July 6-10. 2009
“The Lyman Alpha Universe”, IAP

Stellar Populations of Lyman Alpha Emitters at z=3-4 investigated by the Deep Large Area Surveys in the Subaru-SXDS/UKIDSS-UDS Field

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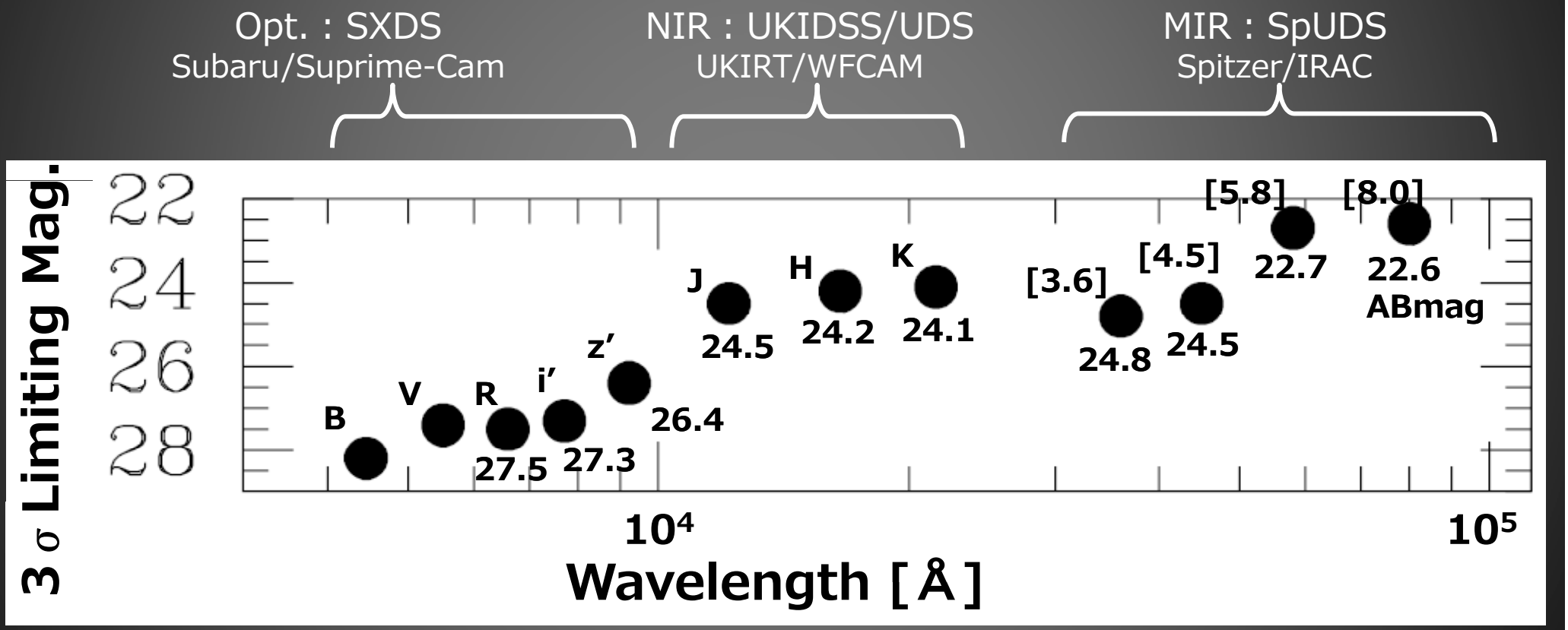
Subaru XMM-Newton Deep Field

- **Wide Survey Area : 0.65 deg^2**
- **Deep multi-wavelength images**



enable us to constrain the stellar pop. of
- faint LAEs by stacking method
- massive and/or red LAEs individually if they exist

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LAE samples

- **original samples** (NB-selected; **Ouchi+08**)

	w/ spec-z	w/o spec-z	Total
z=3.1	34	190	224
z=3.7	20	58	78

AGN hosts were removed based on multiband cat. and spectra.

divided at K(3σ) (~**24**ABmag)
(rest-frame opt.)

- **K-detected (>3σ)**

	w/ spec-z	w/o spec-z	Total
z=3.1	**5**	**0**	**5**
z=3.7	**3**	**3**	**6**

detected in rest-frame UV and opt. bands.
We analyzed them individually.

- **K-undetected**

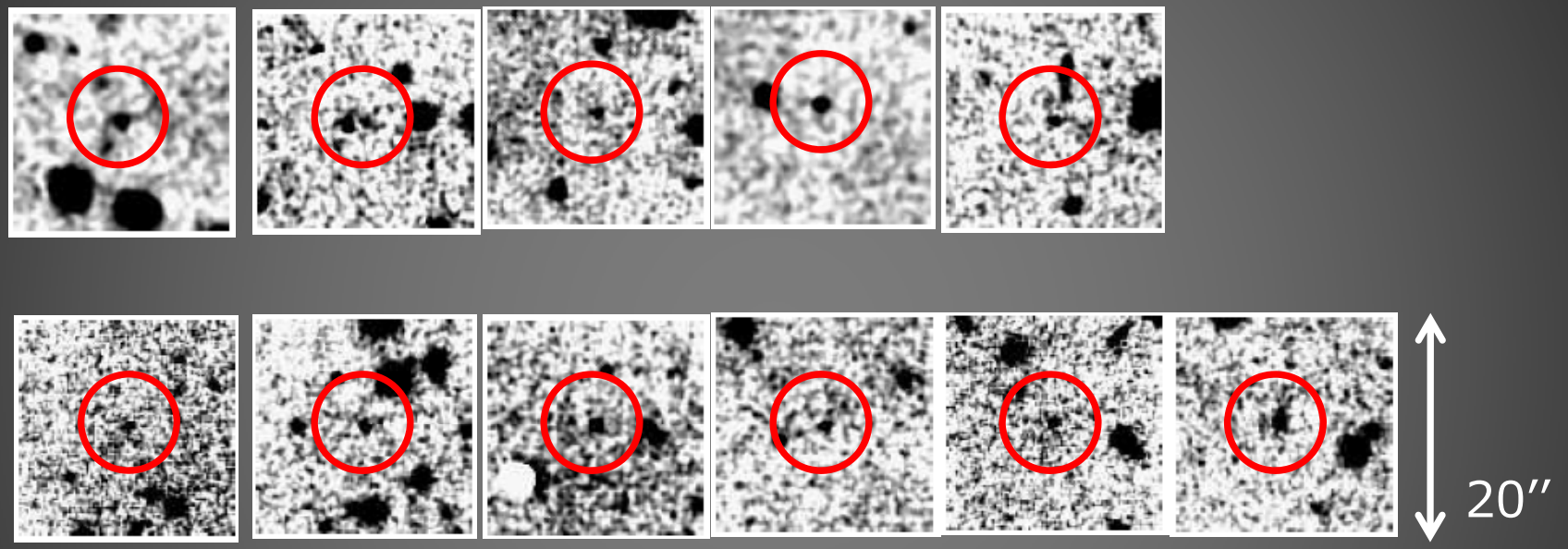
	w/ spec-z	w/o spec-z	Total	Total
z=3.1	**27**	**173**	200	**1**
z=3.7	**14**	**47**	61	**1**

stacking

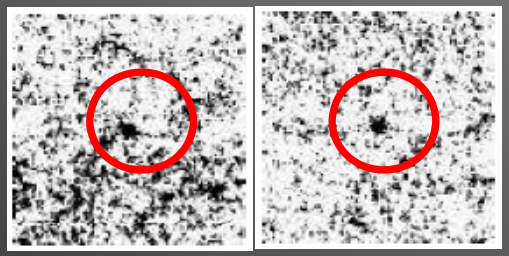
not detected in rest-frame opt. bands individually.
We perform stacking analysis.

K-band Images of LAEs

- **K-detected (>3σ)** **analyzed individually**



- **K-undetected** **analyzed by stacking method**



z=3.1 (200 LAEs) z=3.7 (61 LAEs)

fit model SEDs for these 13 LAEs.

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SED Fitting

- Stellar Population Synthesis Model
  Bruzual & Charlot (2003)

- Parameters
  - **Stellar Mass**
  - **Age** (< age of the universe at that redshift)
  - **Dust Extinction** : Calzetti law (Calzetti et al. 2000)
  - Metallicity : $Z/Z_{\odot}$ = **0.2**
  - SFH : **constant SF**, exponentially decaying SF
  - IMF : Salpeter IMF (Salpeter 1955)

- **10 Bands** for fitting.
  (R, i′, z′, J, H, K, 3.6μm, 4.5μm, 5.8μm, 8.0μm)
- Redshifts are fixed at z = 3.14 or 3.69

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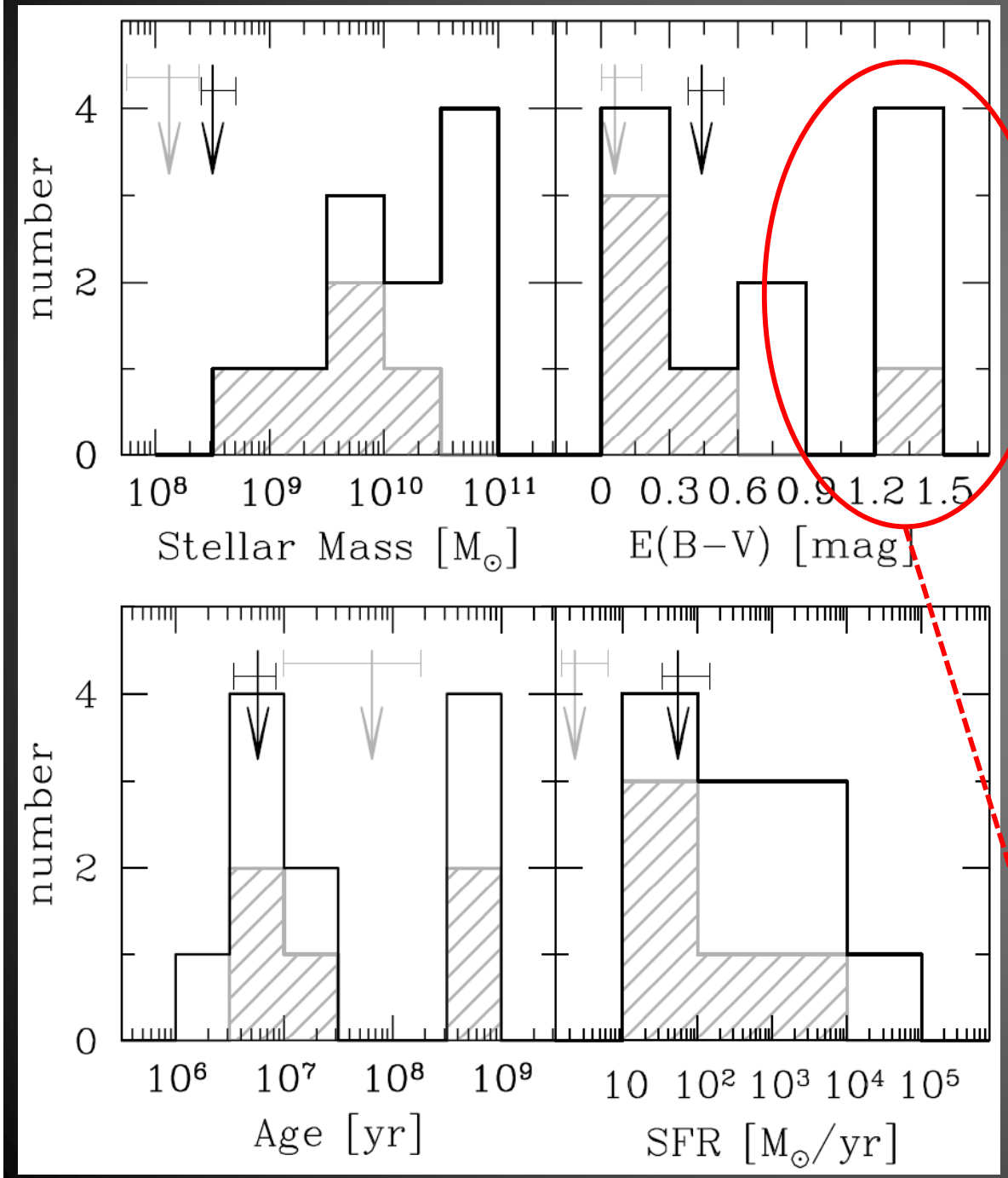
Distributions of the best-fit parameters



↓, ↓ : K-undetected LAEs

M_{star}	~ 10^8 – $10^{8.5}$ [$M_\odot$]
Age	~ 5 – 50 [Myr]
E(B−V)	~ 0.1 – 0.4 [mag]
SFR	~ 1 – 10^2 [$M_\odot$/yr]

▨, □ : K-detected LAEs

M_{star}	~ 10^9 – $10^{10.5}$ [$M_\odot$]
Age	~ 1 – 10^3 [Myr]
E(B−V)	~ 0 – 1.5 [mag]
SFR	~ 10 – 10^4 [$M_\odot$/yr]

We find 4 **extremely red** LAEs.
- dusty starbursts?

At first, we focus on these objects.

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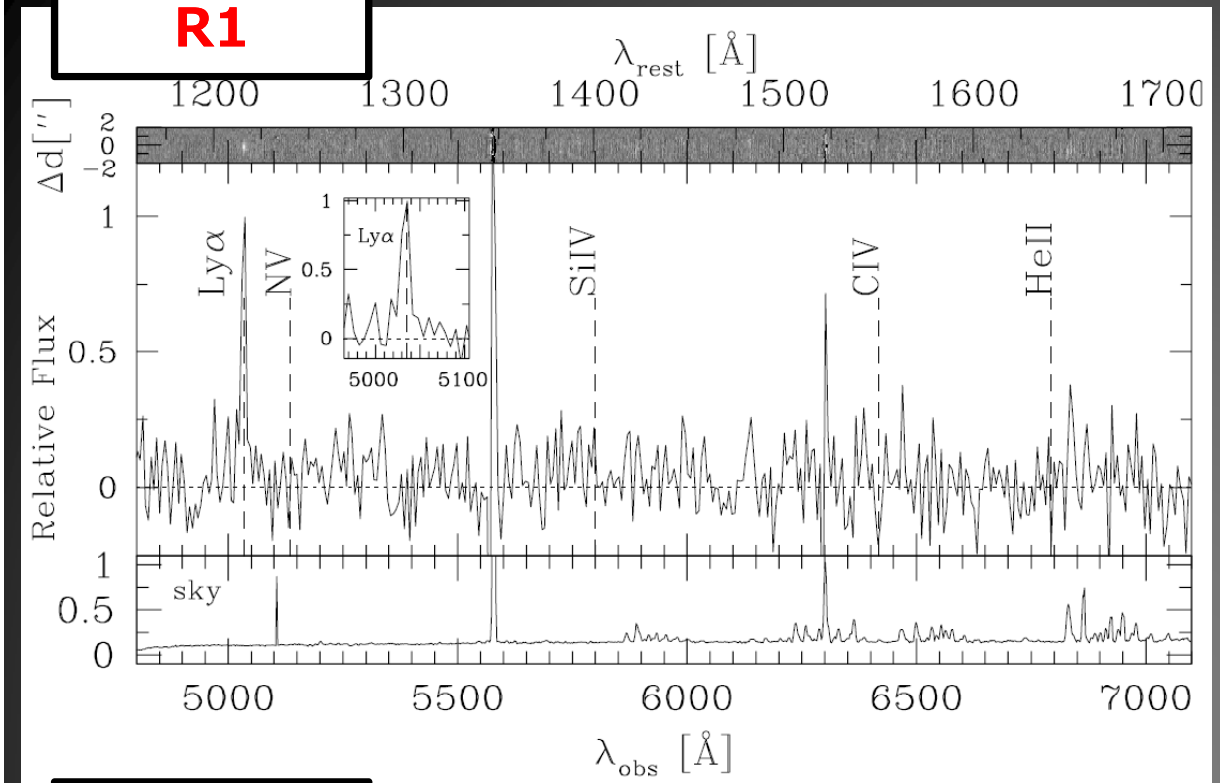
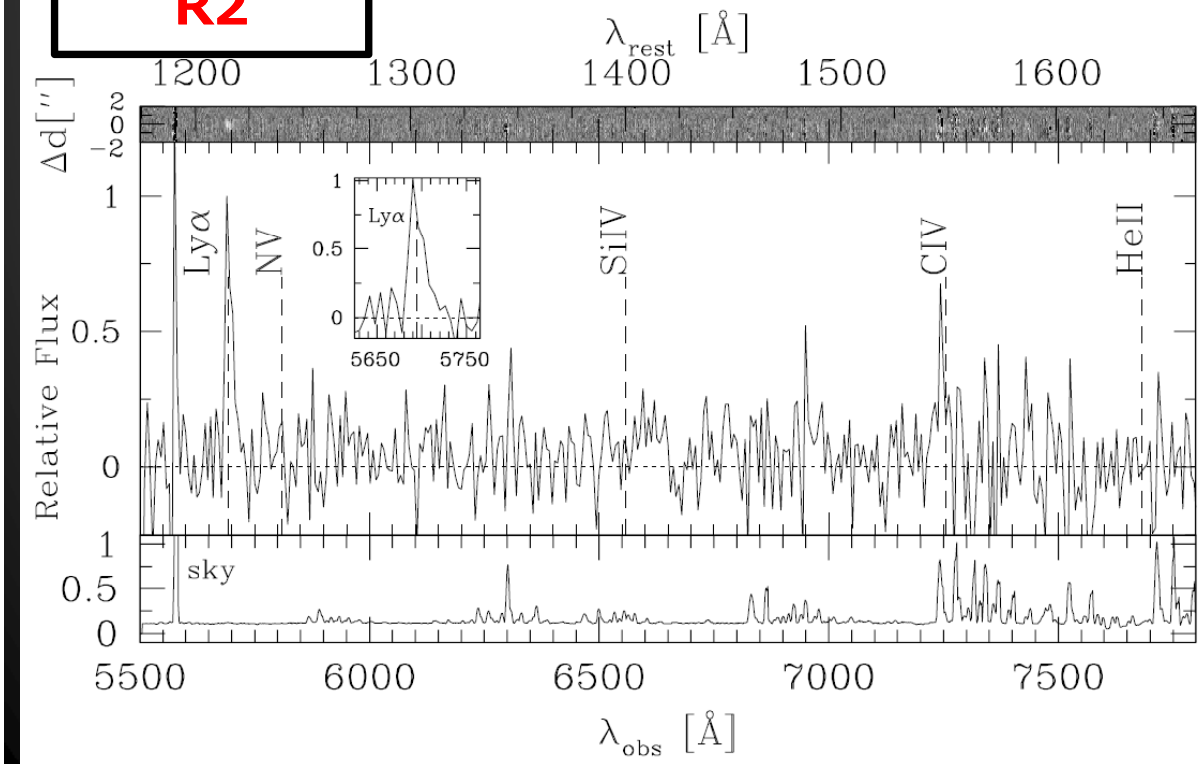
R1



R2



Spectra of Two Red LAEs

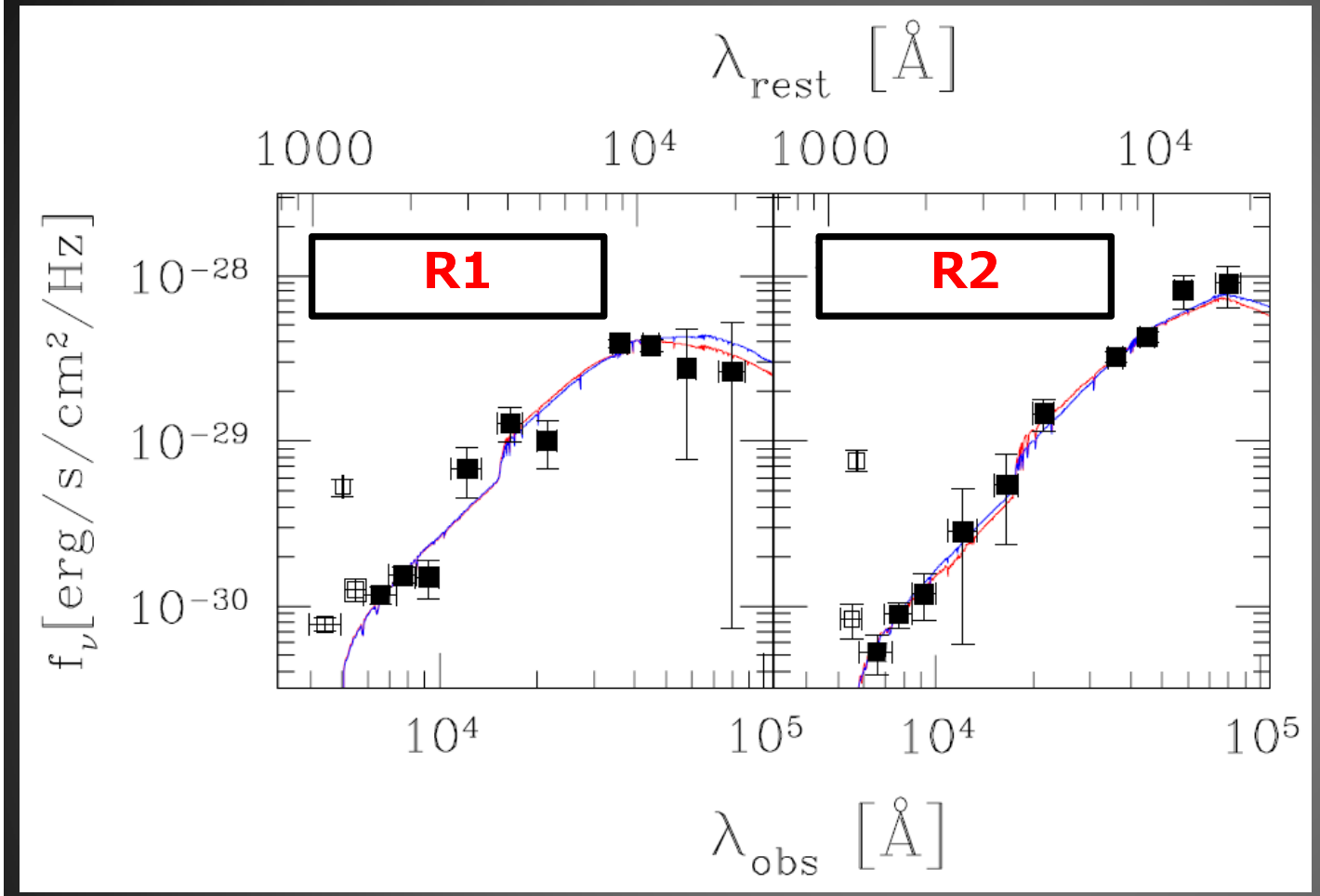
We confirm that they are

- **NOT** low-z emitters ([OII] or [OIII] emitters).

- **NOT** AGN-dominant galaxies.

* The remaining two Red LAEs are not spectroscopically confirmed.

Two Red LAEs w/ spec-z



R1

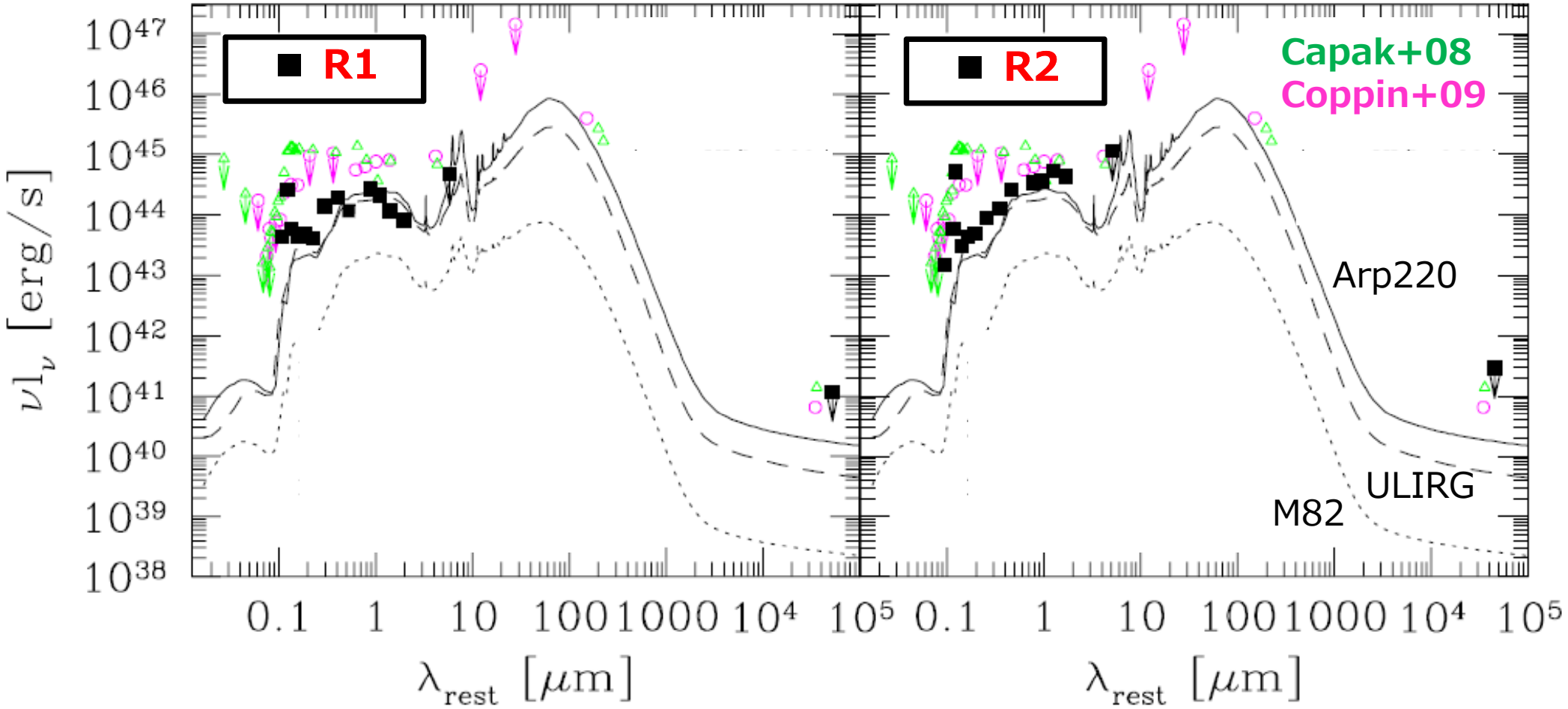
M_{star} = 2.1×10^{10} [$M_\odot$]
Age = 8.7 [Myr]
E(B−V) = 1.5 [mag]
SFR = 2.5×10^{3} [$M_\odot$/yr]

R2

M_{star} = 4.1×10^{10} [$M_\odot$]
Age = 29 [Myr]
E(B−V) = 1.5 [mag]
SFR = 1.5×10^{3} [$M_\odot$/yr]

- very red UV-to-NIR SEDs.
- E(B-V) = 1.5, SFR>10^3 $M_\odot$/yr → dusty starburst galaxies.
- n ~ 10^{-6} Mpc^{-3} ~ (1/10) * SMGs' number density (Chapman+05).

Comparison with local SBs and SMGs w/ Lya



Focusing on the UV-to-opt. SEDs, we find that the Red LAEs are

- similar to those of local starburst galaxies and ULIRGs.
- redder than the Lya-emitting SMGs of Capak+08 & Coppin+09.

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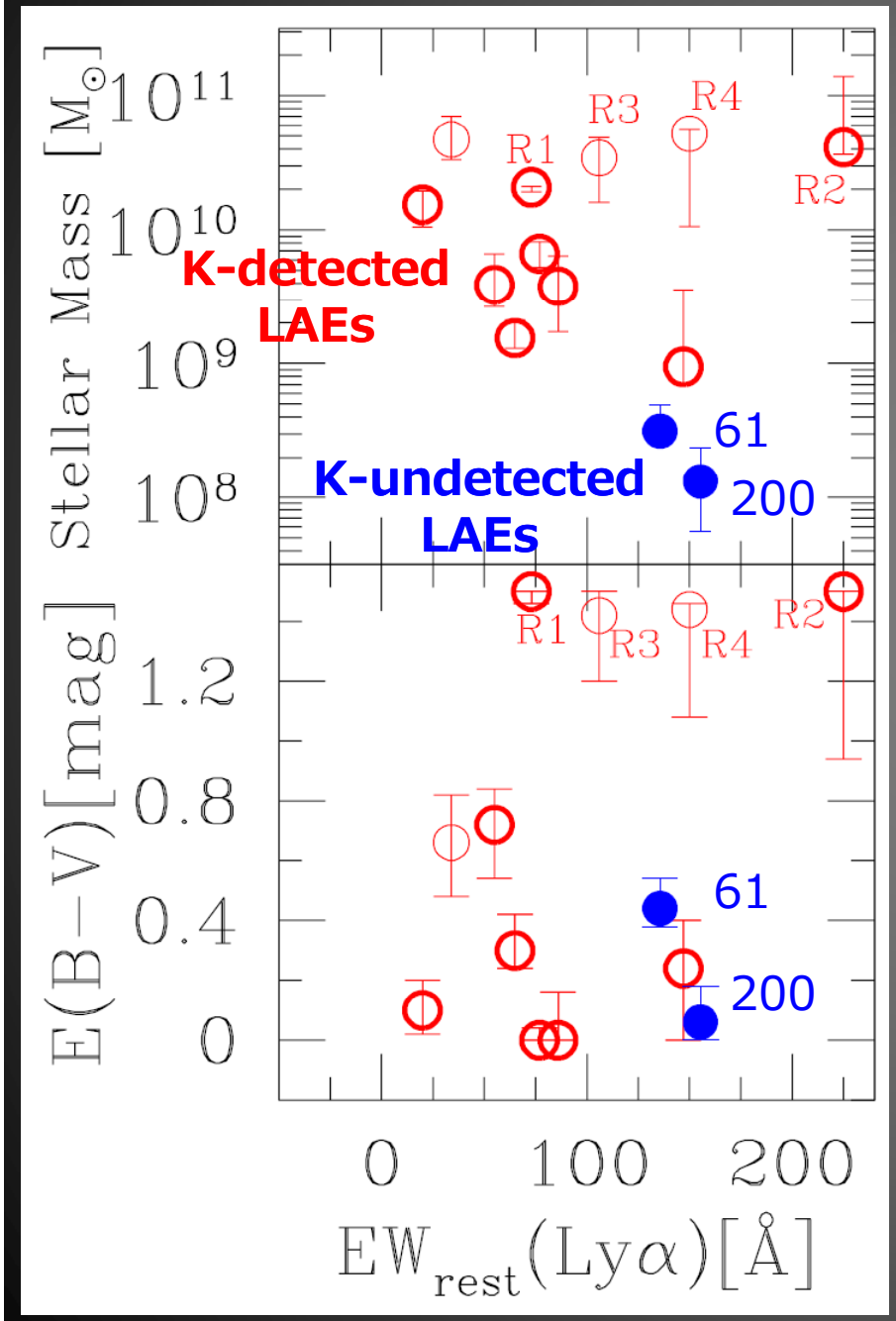
M_{star} or E(B−V) vs. EW(Lya)



M_{star} vs. EW(Lya)

There is **a weak anti-correlation**
(if the four red LAEs are excluded).

→ Does it mean that the correlation is mainly due to the fact that massive LAEs tend to be chemically enriched?

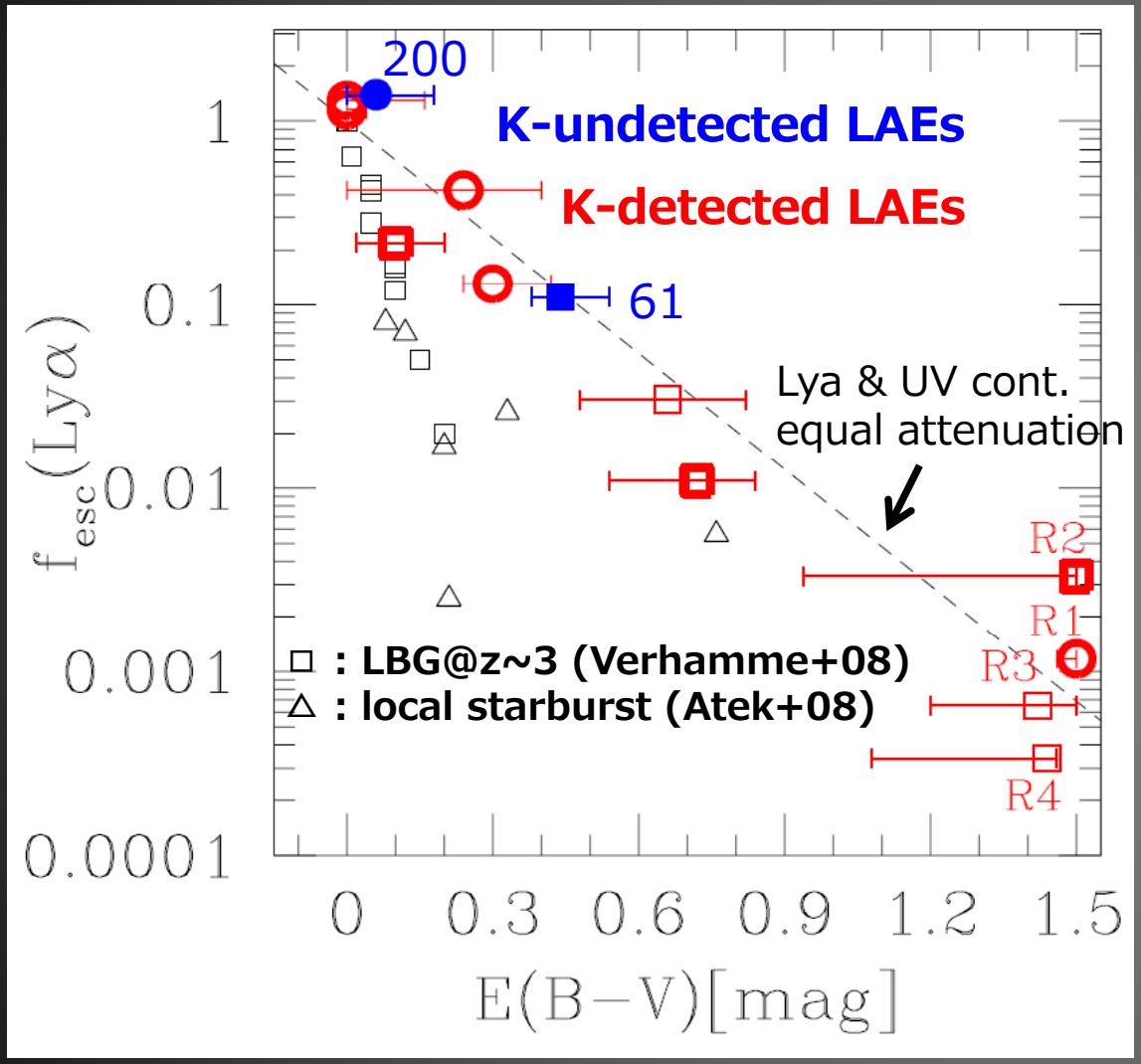
E(B-V) vs. EW(Lya)

There is **NO clear correlation**
(even if the four red LAEs are excluded).

→ It is not necessarily true that more massive LAEs have larger E(B-V).

→ What is the cause of the above correlation?

f_{esc}(Lya) vs. E(B−V)



f_{esc}(Lya) vs. E(B-V)

- There is **a tight correlation.**
  - consistent with the case Lya and UV continuum are equally attenuated.

→ This might suggest that LAEs does not have uniform dust distribution.

- LAEs have lower f_{esc}(Lya) at given E(B-V) than
  - LBGs at z~3,
  - local starbursts.

→ LAEs are galaxies in which Lya photons can easily escape.

$$f_{esc}(\mathrm{Ly}\alpha) = \frac{L_{obs}(\mathrm{Ly}\alpha)\,[\mathrm{erg/s}]}{L_{int}(\mathrm{Ly}\alpha)\,[\mathrm{erg/s}]}$$

←

$$1.1 \times 10^{42} \mathrm{SFR}\,[M_\odot/\mathrm{yr}]$$

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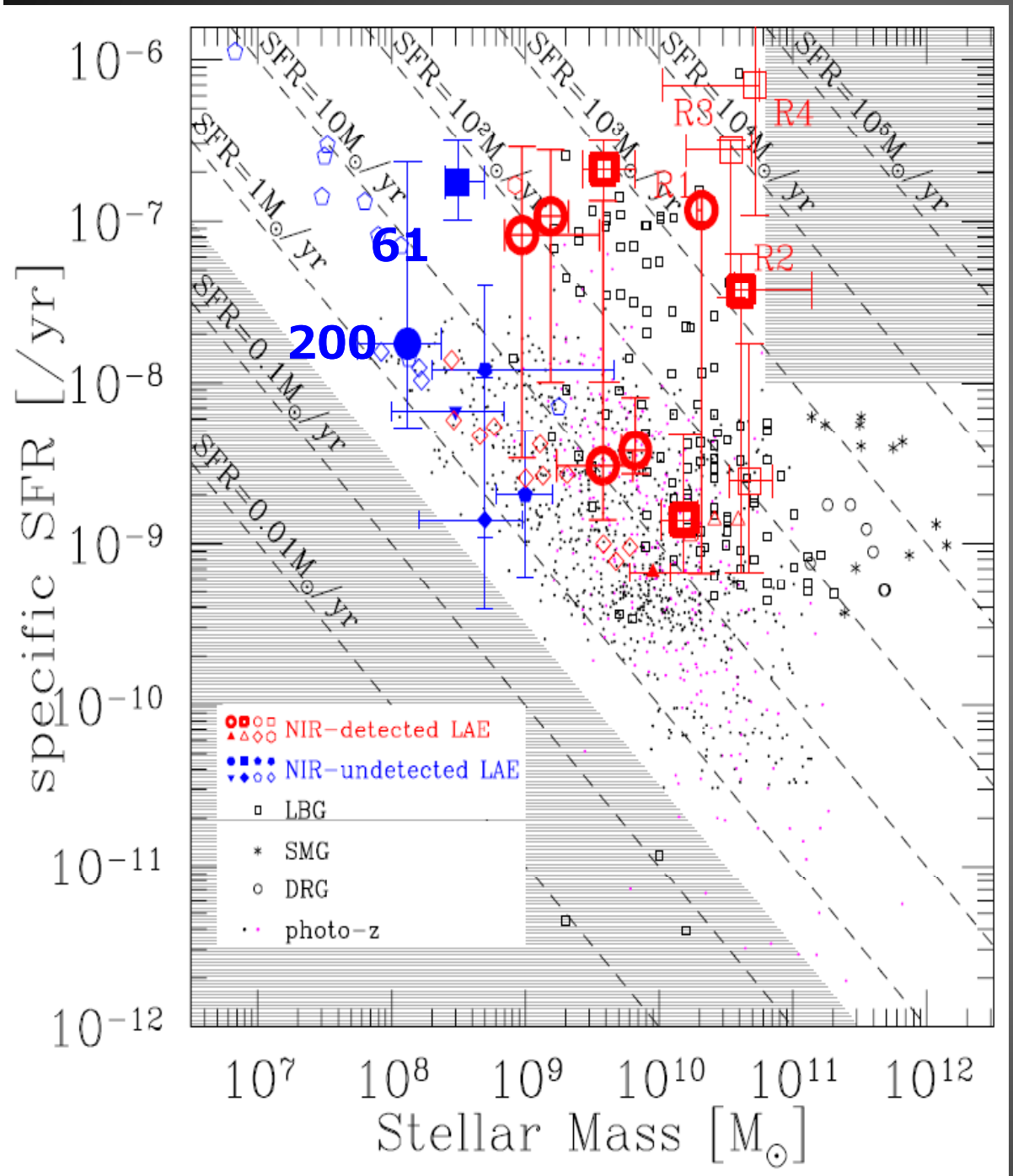
Specific SFR vs. M_{star}

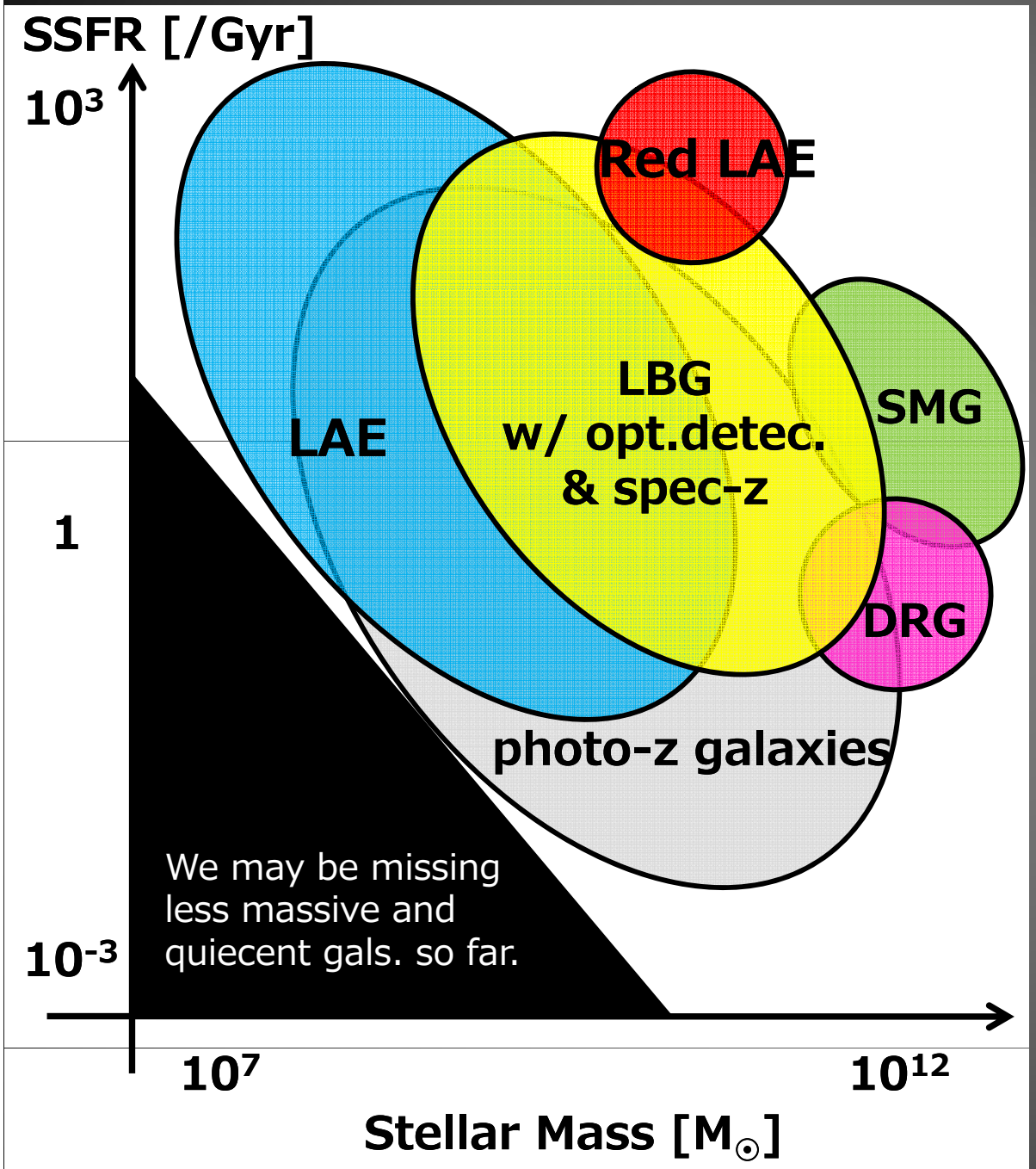


○ : LAE (K-detected, L+08, L+07)
● : LAE (K-undetected, G+06, N+07, L+08, P+07, F+09)
□ : LBG@z~3 (K-detected & w/spec-z) (Shapley+01, Papovich+01, Iwata+05)
○ : DRG@z~2 (vanDokkum+04, Wuyts+07)
∗ : SMG@z~2 (Chapman+05, Borys+05)
・・:I,K-selected galaxies@z~3(Feulner+05)

- compile the M_{star} and sSFR of high-z galaxies at z~2-3.

- For simplifying this figure, we draw a conceptual diagram:

Specific SFR vs. M_{star}



○ : LAE (K-detected, L+08, L+07)
● : LAE (K-undetected, G+06, N+07, L+08, P+07, F+09)
□ : LBG@z~3 (K-detected & w/spec-z) (Shapley+01, Papovich+01, Iwata+05)
○ : DRG@z~2 (vanDokkum+04, Wuyts+07)
＊ : SMG@z~2 (Chapman+05, Borys+05)
・・:I,K-selected galaxies@z~3(Feulner+05)

- **LAE**
  - tend to have higher sSFR and lower stellar mass than other high-z galaxy pops.
- **Red LAE**
  - have high sSFR.
  - as massive as LBGs. (distribute in an unique region.)

Summary

- Properties of Red LAEs
  - SFR > $10^3 M_\odot$ /yr, E(B-V)>1, n~10^{-6} [Mpc^{-3}].
  - red SEDs similar to the local starbursts and ULIRGs.

- Correlations
  - M_{star} vs. EW(Lya) : weak correlation.
  - E(B-V) vs. EW(Lya) : no clear correlation.
  - f_{esc}(Lya) vs. E(B-V) : tight correlation.

- sSFR vs. M_{star}
  - LAE : higher sSFR and lower M_{star}.
  - Red LAE: higher sSFR and as massive as LBGs.