SSA22 天域の高赤方偏移 4 次元探査

Tomoki HAYASHINO (Tohoku University)
for Subaru 2005 Intensive Group

初代星・銀河形成研究会
2008 年 9 月 10 日 甲南大学

Subaru 2005 Intensive Group ;

山田 亨 (PI), **林野 友紀**, (**山内 良亮**), **中村 有希**, **香西 克紀**, **森本 奈々**,
中村 江里, **堀江 光典** (**東北大**), **松田 有一** (**国立天文台**), **梅村 雅之** (**筑波大**)

- 2002〜2004〜2005〜
- SSA22 z=3.1 Deep NB Survey for LAE/LAB/LAAs (SCam 7Fovs)
- $V_{com} \approx 200 \times 100 \times 60 Mpc^3$(SSA22) ; $\delta_{200} \approx 1$
  (control field=SXDF 3FoV+SDF)

  Huge Over-density Region !
- Standard CDM S.F.(ex. Millennium Simulation) 〜 5σ event

  ==> Cosmology (initial fluctuation?, BAO?, at large/small? scale, CMB)
  ==> Very Early Galaxy Formation (GRB/HN/SN at z>>10?)
- Also, SSA22 Huge ODR 〜 beyond 200Mpc scale.

=====> SCALE UP !

- SCam ; by factor(Intensive×2〜3)
- HSC ; by order(> ×10)

研究の発端

Protocluster region at high redshift

Steidel et al. (1998; 2000)

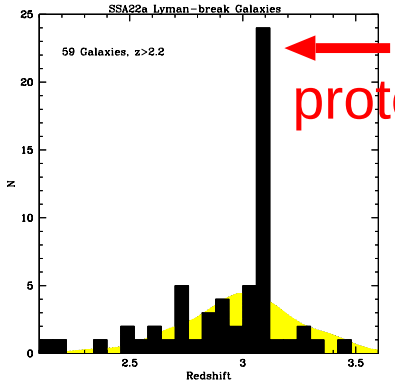
○ 14 **天域で** z=2.7∼3.4 LBG **を狙った** pencil-beam survey (9′ × 9′ FoV)

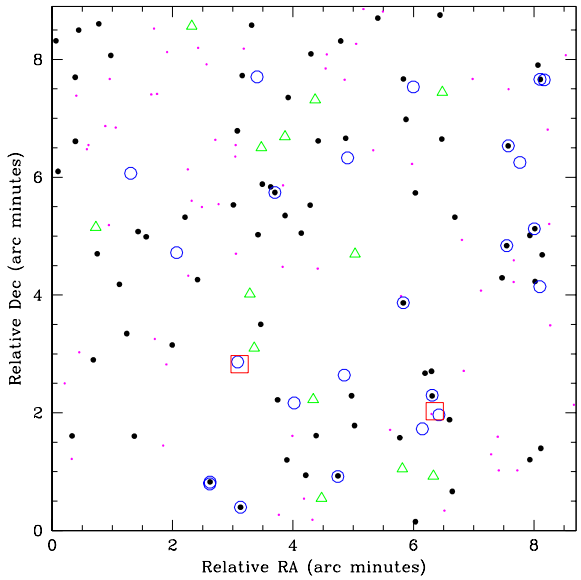
- SSA22 **天域** (RA=22^{h}17^m, Dec=+00°15′) **の** z=3.1 **に** LBG **高密度領域を発見**

$\Longrightarrow$ **期待値の約** 6 **倍の数密度**

○ z=3.09±0.03 LAE **を狙った** Narrowband (NB) survey

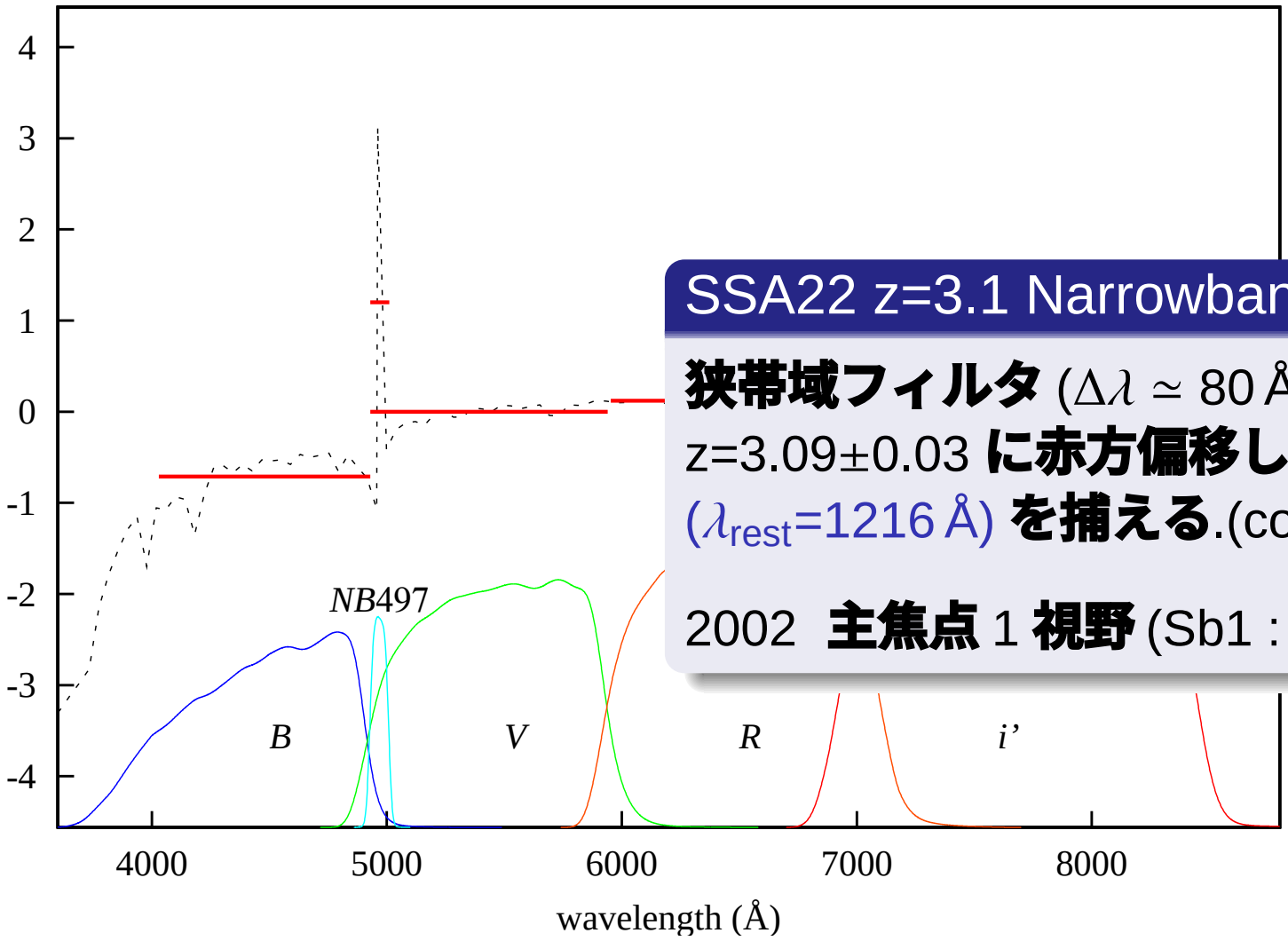
- 72 LAEs ($NB < 25.5_{AB}$, $EW_0 > 20$ Å) $\Longrightarrow$ 9′ × 9′ FoV **内に一様に分布**
- LAE **密度も期待値の約** 6 **倍**





Steidel's survey area ; 9'×9' (15Mpc×15Mpc com. at z=3)

SSA22 z=3.09 LAE **二次元探査**



SSA22 z=3.1 Narrowband Survey

狭帯域フィルタ ($\Delta\lambda \simeq 80$ Å) **を用いて**, z=3.09±0.03 **に赤方偏移した** Lyα **輝線** ($\lambda_{\rm rest}$=1216 Å) **を捕える**.(com. 60Mpc slice)

2002 **主焦点** 1 **視野** (Sb1 : 60Mpc×50Mpc)

SUBARU Extensive Narrowband Deep Imaging Survey

2005 Intensive Program

PI: **山田 亨** (**東北大学**)
17 nights $\Longrightarrow$ **内** 10 **夜を撮像**

SSA22 z=3.09 Extensive Deep Imaging

Sb1+Sb2 ($\approx$0.43 deg^2, Hayashino et al. 2004; Yamauchi et al. 2006) **のさらなる拡張隣接探査**

$\Longrightarrow$ SuprimeCam 5 **視野分の隣接領域を撮像** (2005/8~10)

各視野同じ深さで観測：

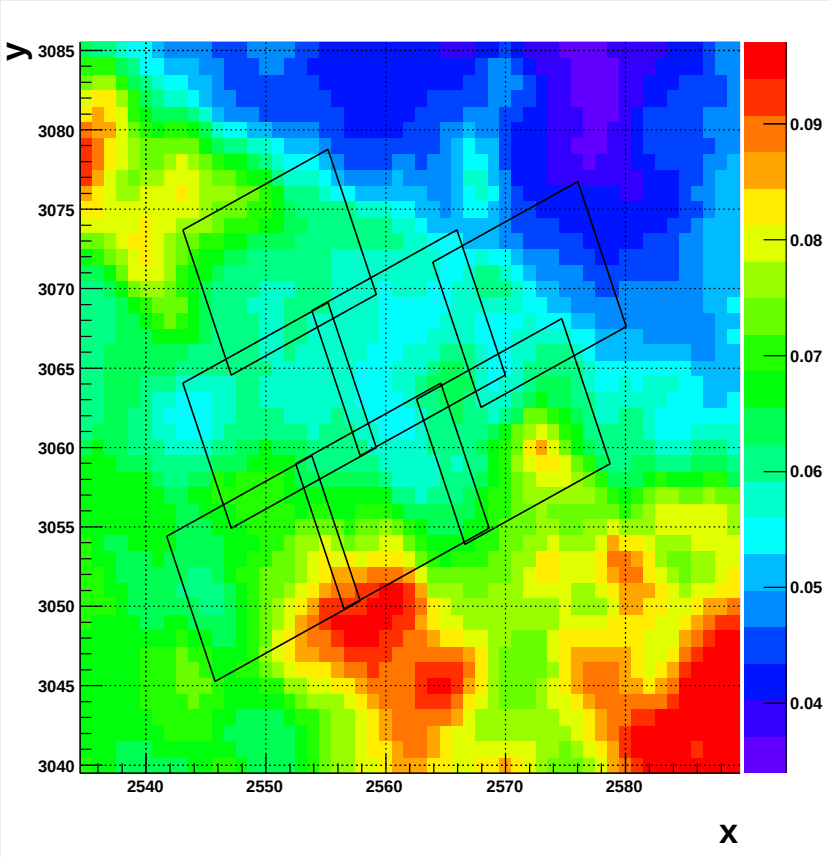
- *NB*497 (5.5 hours), *B* (1.0 hours), *V* (1.0 hours)
- Seeing FWHM $\approx$ 1.0 arcsec

更に一般領域として SXDF(C,N,S), SDF, GOODS-N **の** 3 **天域** (**計** 5 **視野**) **に対し、同程度の深い** *NB*497 **撮像**. (to see SSA22 overdensity δ)

銀河系吸収補正

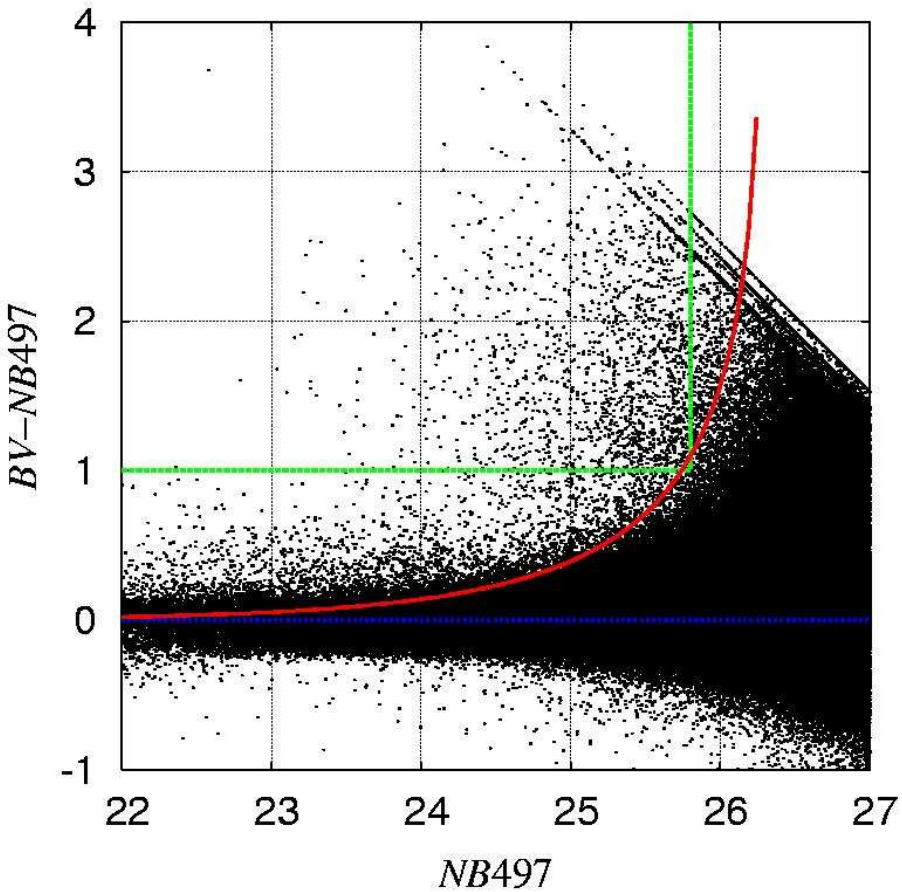
$E(B-V)$ map around SSA22

Schlegel et al. (1998)
COBE 100μm-MAP



- SSA22 **の銀緯：**-40°**；低い**
- Schlegel et al. (1998)**：銀河系の有意な吸収量**
- Cardelli et al. (1989) **による銀河系吸収曲線**
- NB497 **で** 0.2〜0.4 **等の吸収量：ローカルな補正が必要**

Detection criteria for SSA22 z=3.09±0.03 LAE



continuum: $BV = (2B + V)/3$

LAE 候補の検出

(1) $NB497 < 25.8_{\mathrm{AB}}$
(⇔ Lyα **光度：**
1.3×10^{-17} erg/s/cm^2 **以上**)

(2) $BV - NB497 > 1.0$
(⇔ $EW_0 > 28$ Å)

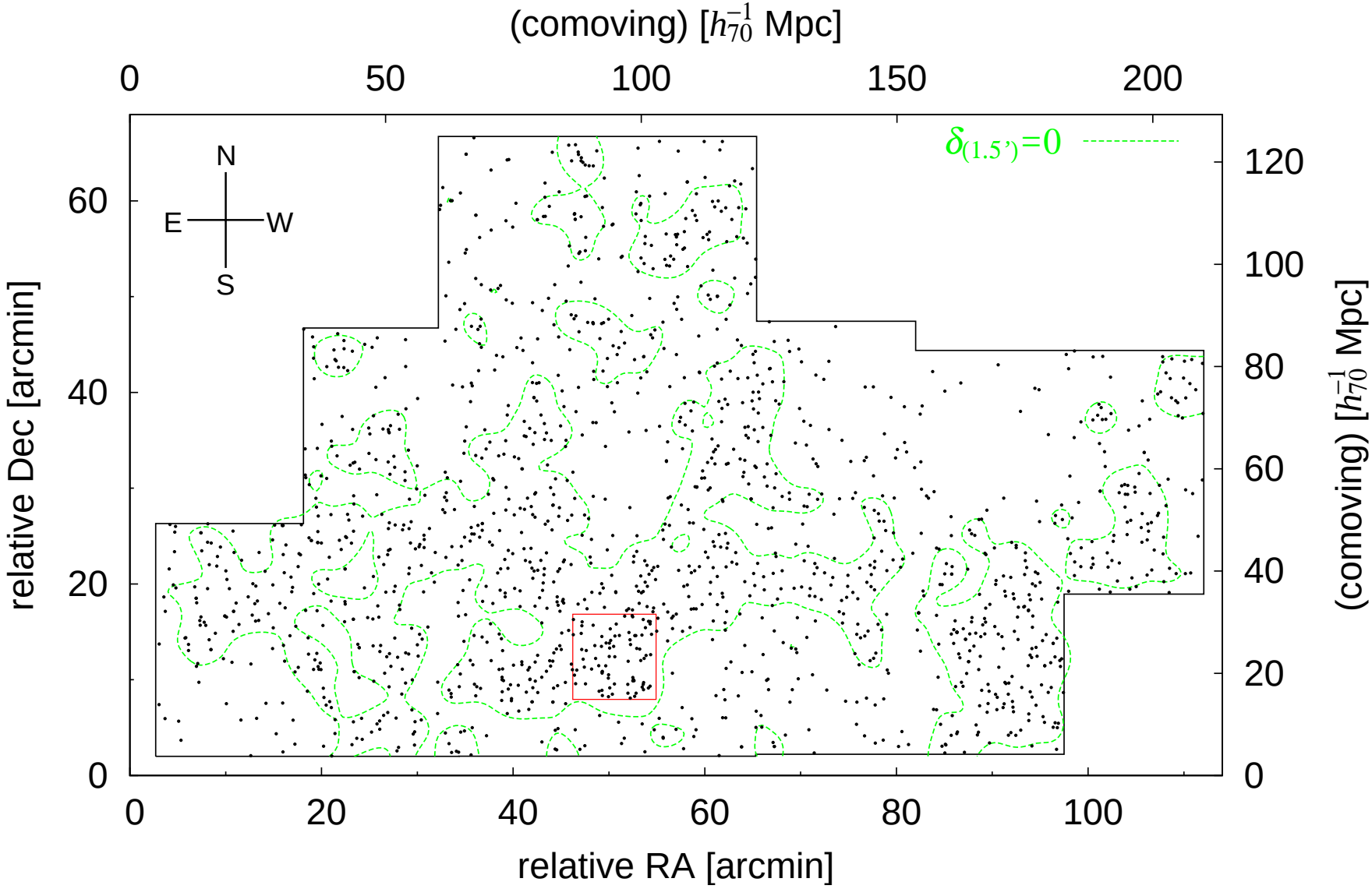
(3) $\sigma_{(BV-NB)} > 4.0$ (for Sb2 field)

(4) $V_c > 4\sigma$: $B - V_c > 0.2$

(5) $V_c < 4\sigma$: $BV - NB497 > 1.3$

$\Longrightarrow$ 1.3 deg^2 **（**≈4700 **平方分）の探査領域において、**
1598 **個の** LAE **候補を検出**

2D Sky Map of LAEs in SSA22 z=3.09±0.03



Total Survey Volume ≈ 200×100×60 Mpc^3

Overdensity of LAEs

Control fields: SXDF (C,N,S)+SDF

Overdensity:

$$\delta = \frac{\rho - \langle\rho\rangle}{\langle\rho\rangle}$$

SXDF (C,N,S):	$0.179\,\square'^{-2}$	424 **個**/$2363\,\square'^{2}$
SDF:	$0.245\,\square'^{-2}$	154 **個**/$628\,\square'^{2}$

$$\Longrightarrow \boxed{\langle\rho\rangle = 0.193\,\square'^{-2}}$$

Region	Area [arcmin^2]	N_{LAE}	δ_{LAE}	σ_m	σ_{gal}
SSA22 (Steidel)	100	100	4.18 ± 0.29	0.19	0.57
SSA22 (sb1)	768	364	1.46 ± 0.14	0.10	0.30
SSA22 (entire)	4726	1598	0.75 ± 0.09	0.055	0.17
Control fields	2991	578	0	0.064	0.19

$\sigma_{gal} = b \times \sigma_m$, here, b=3, 60Mpc thick each

SSA22(entire) **の出現確率は** $4\sim5\sigma(10^{-5\sim-6})$: Huge over-density region

Overdensity δ of High EW_0 LAEs

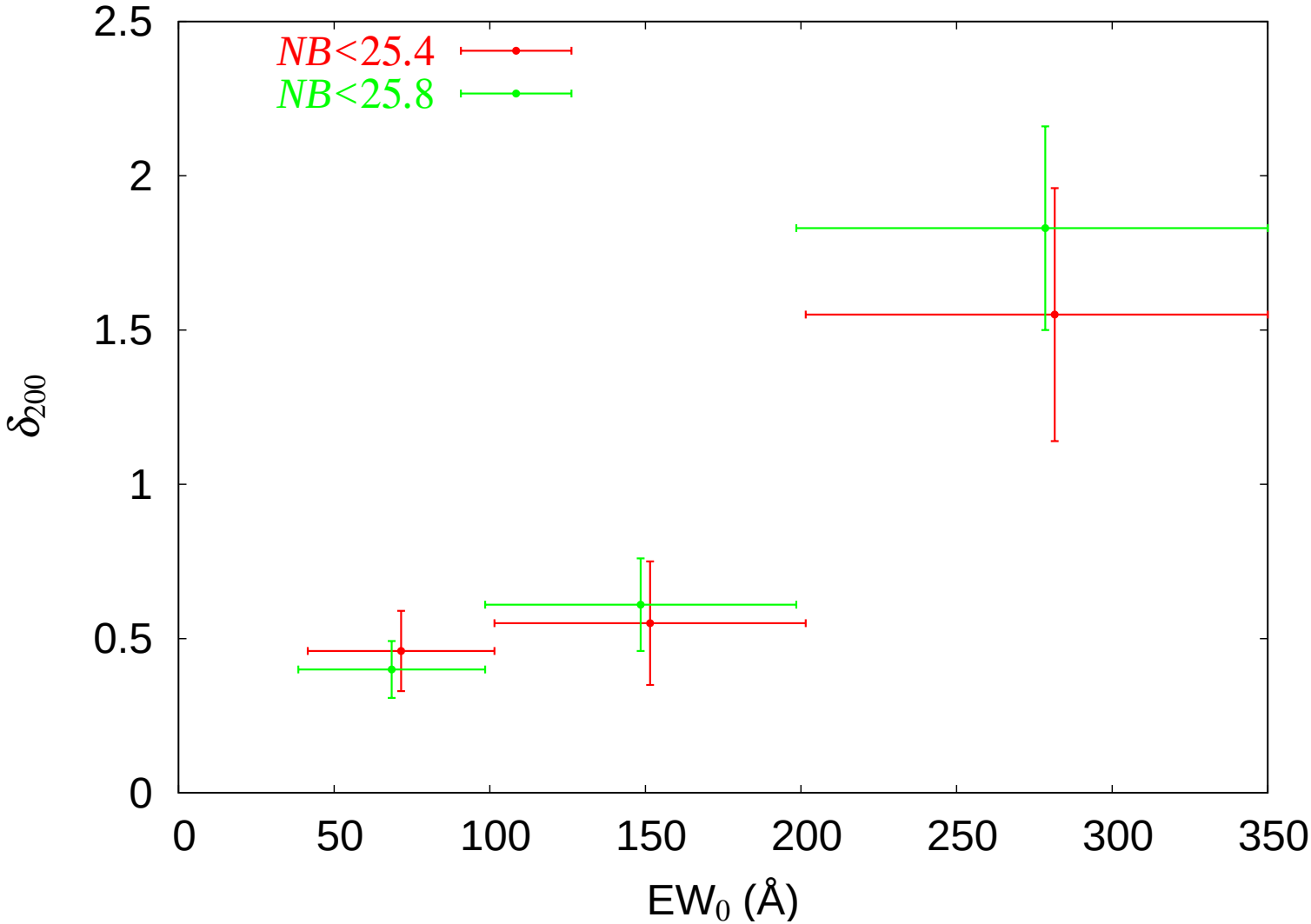
NB497<25.8, (<25.4)

BV-NB= 1.0~1.7, 1.7~2.2, >2.2

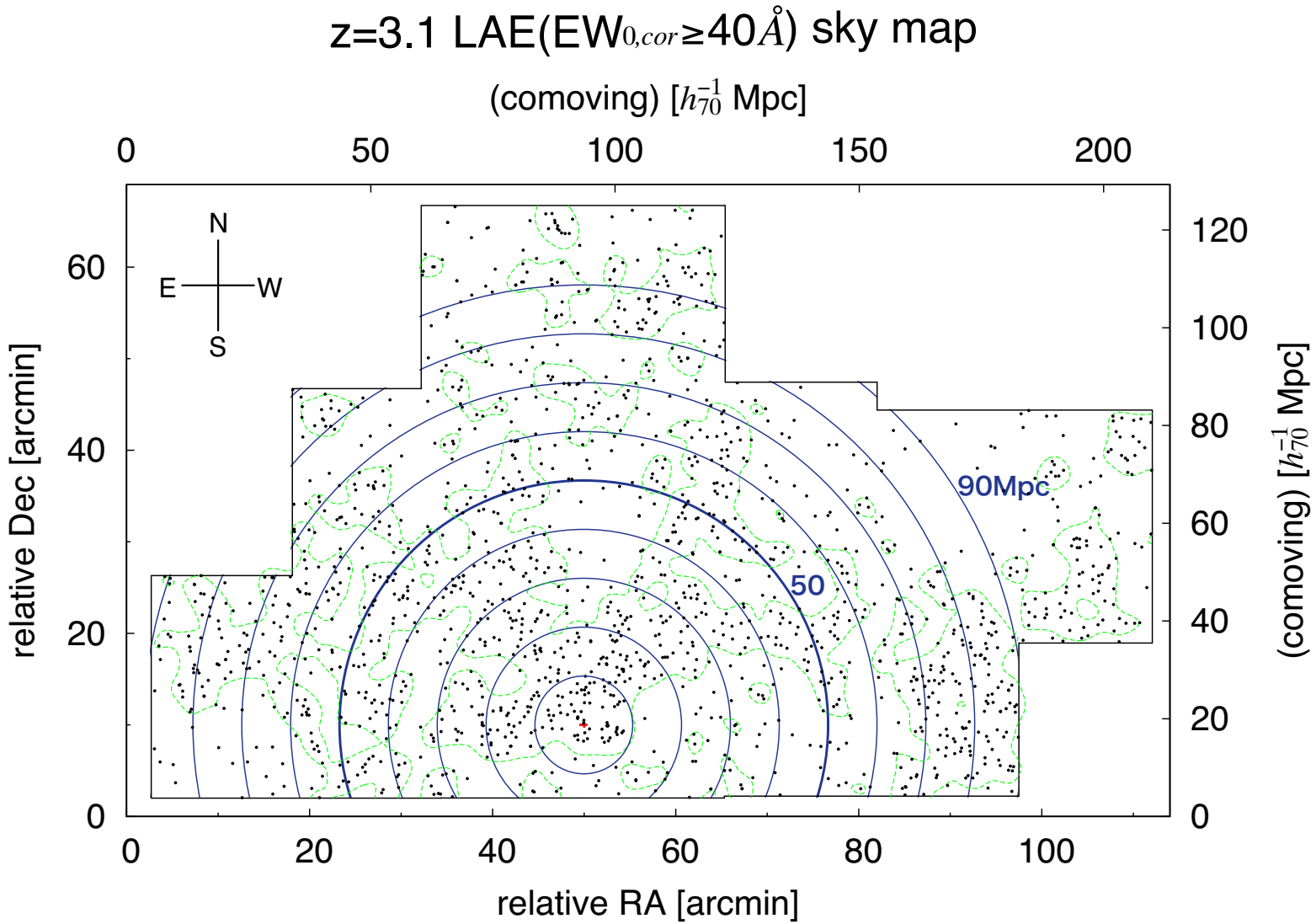
BV-NB	corrected EW_0
1.0	≈ 40Å
1.7	≈ 100Å
2.2	≈ 200Å

- $\delta_{200}(200 \times 100 \times 60 Mpc^3)$ vs EW_0
- $\delta_{ring}(R)$; radial profile of over-densities around Steidel's density peak
- (Anti-) correlation between Very Young(High EW_0) LAE & LBG-like LAE(BV-NB=1.0-1.2, V<26)
- Lyα Size(NB497 FWHM) as a function of EW_0

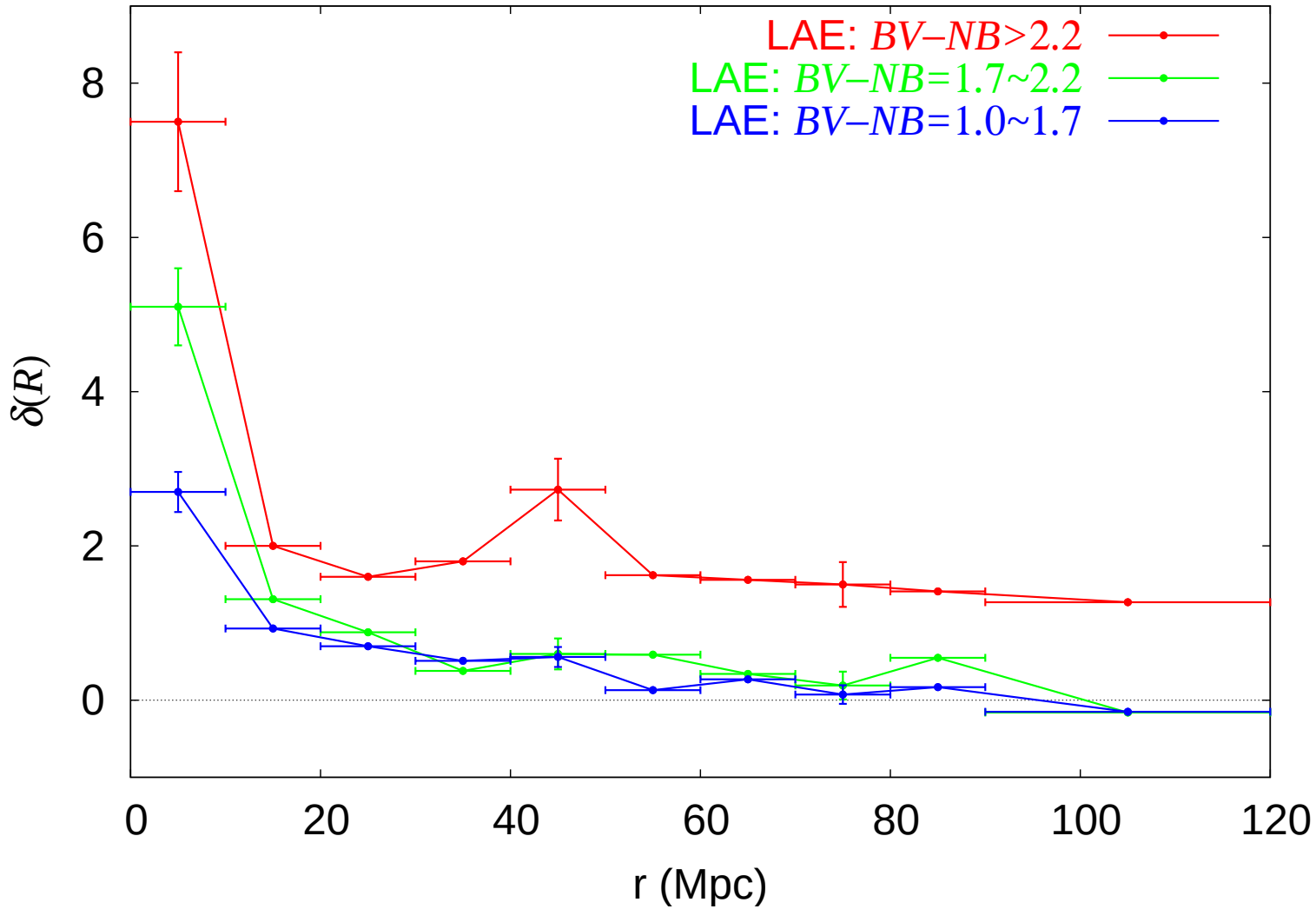
δ_{200} vs EW_0



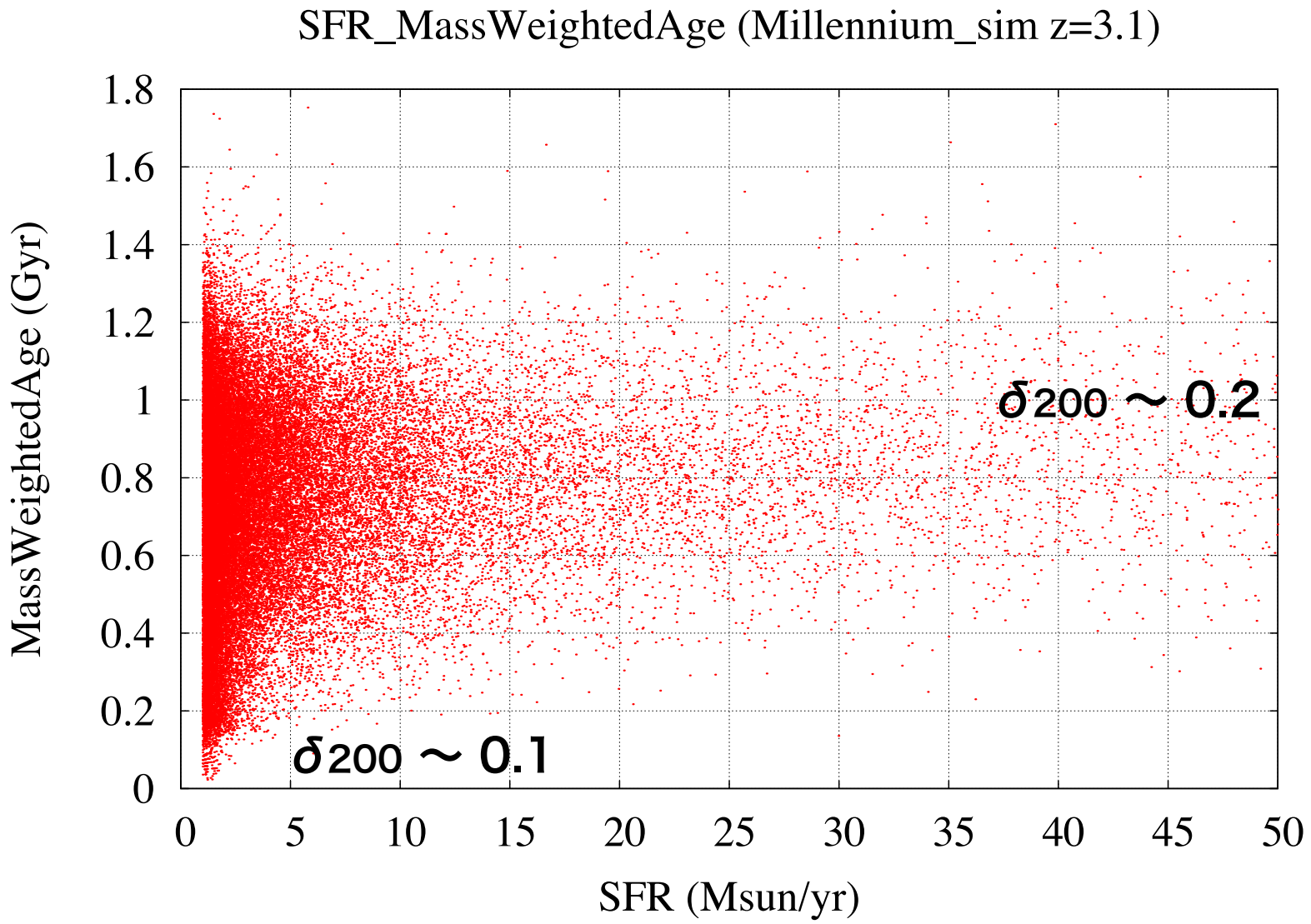
Radial Profi le of Over-density $\delta_{ring}(R)$ around Steidel's density peak



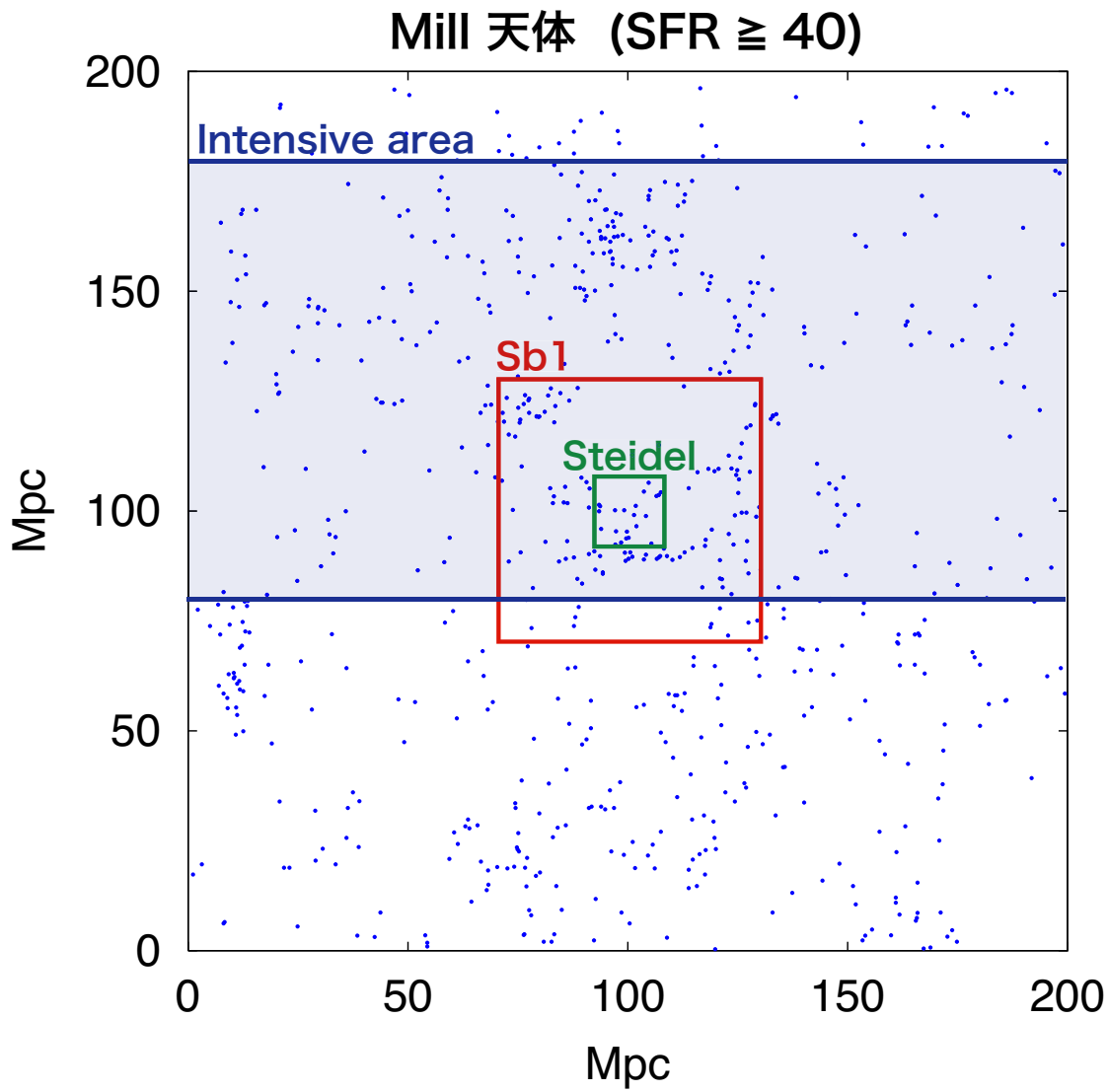
$\delta_{ring}(R)$ (1)



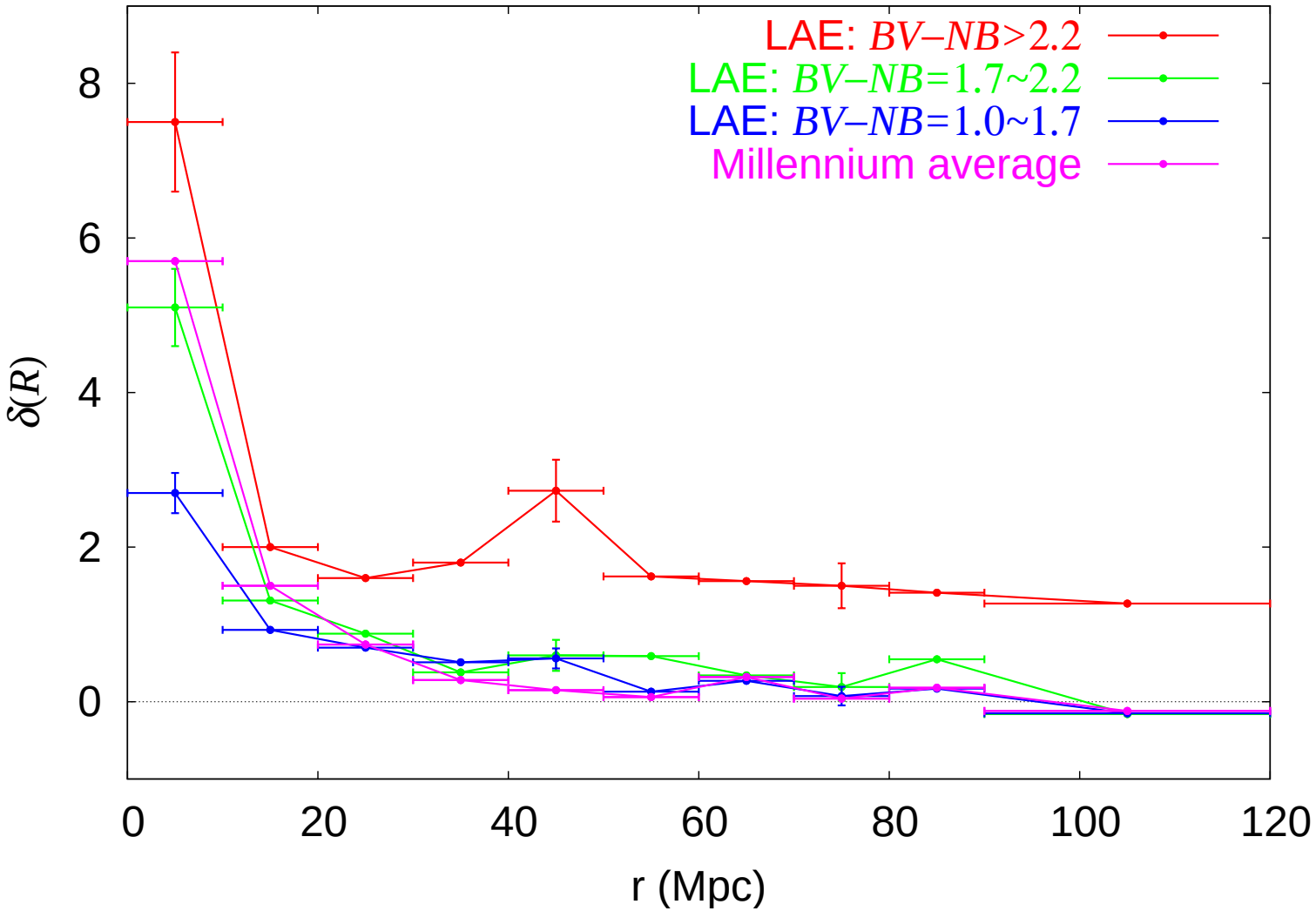
Millennium Simulation Galaxies ; SFR vs Age



SSA22 like(?) Sky Map of Mill. Galaxies(SFR> $40 M_s/y$)

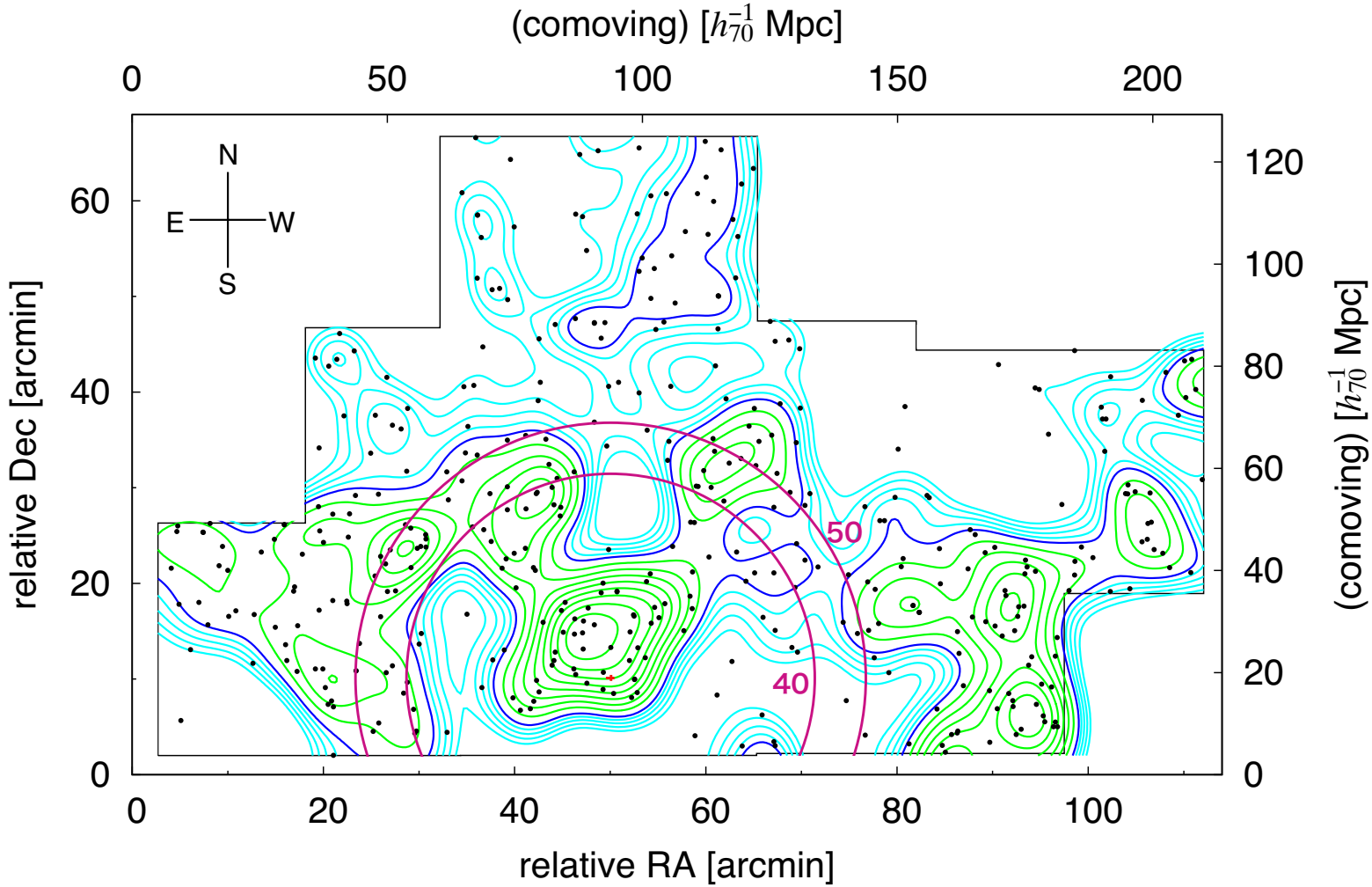


$\delta_{ring}(R)$ (2)

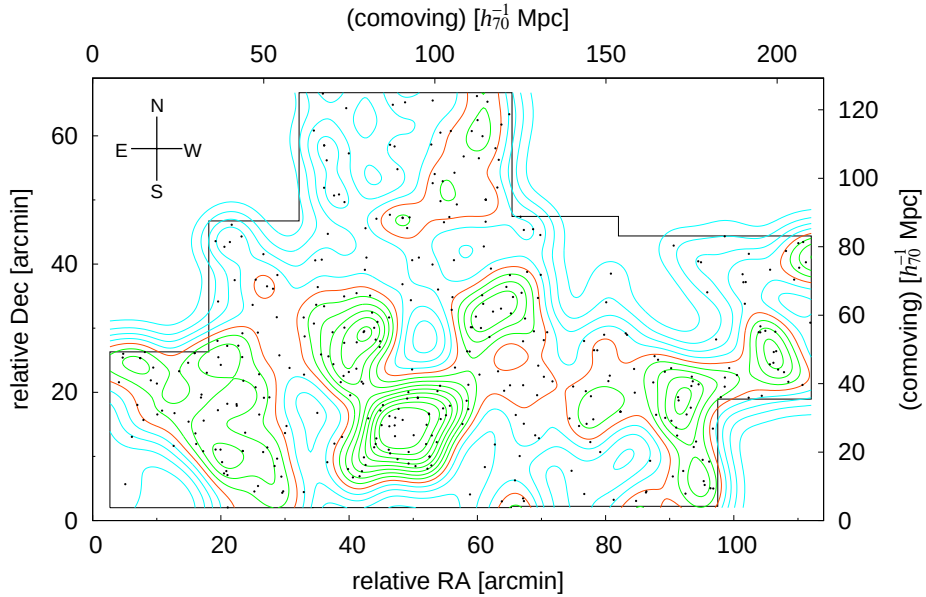


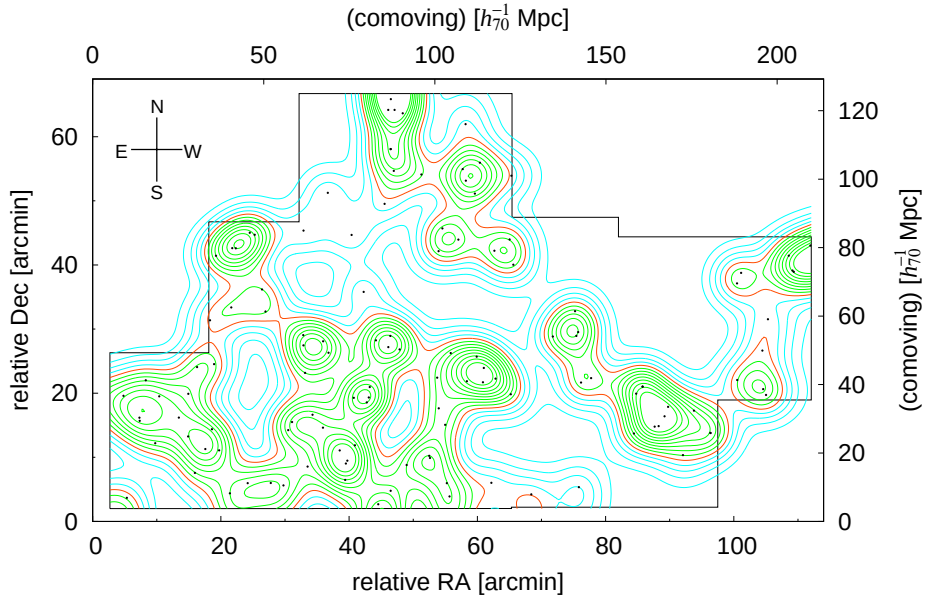
Ring like LSS? of High EW_0 LAEs

green ; high density region
sky blue ; low density region

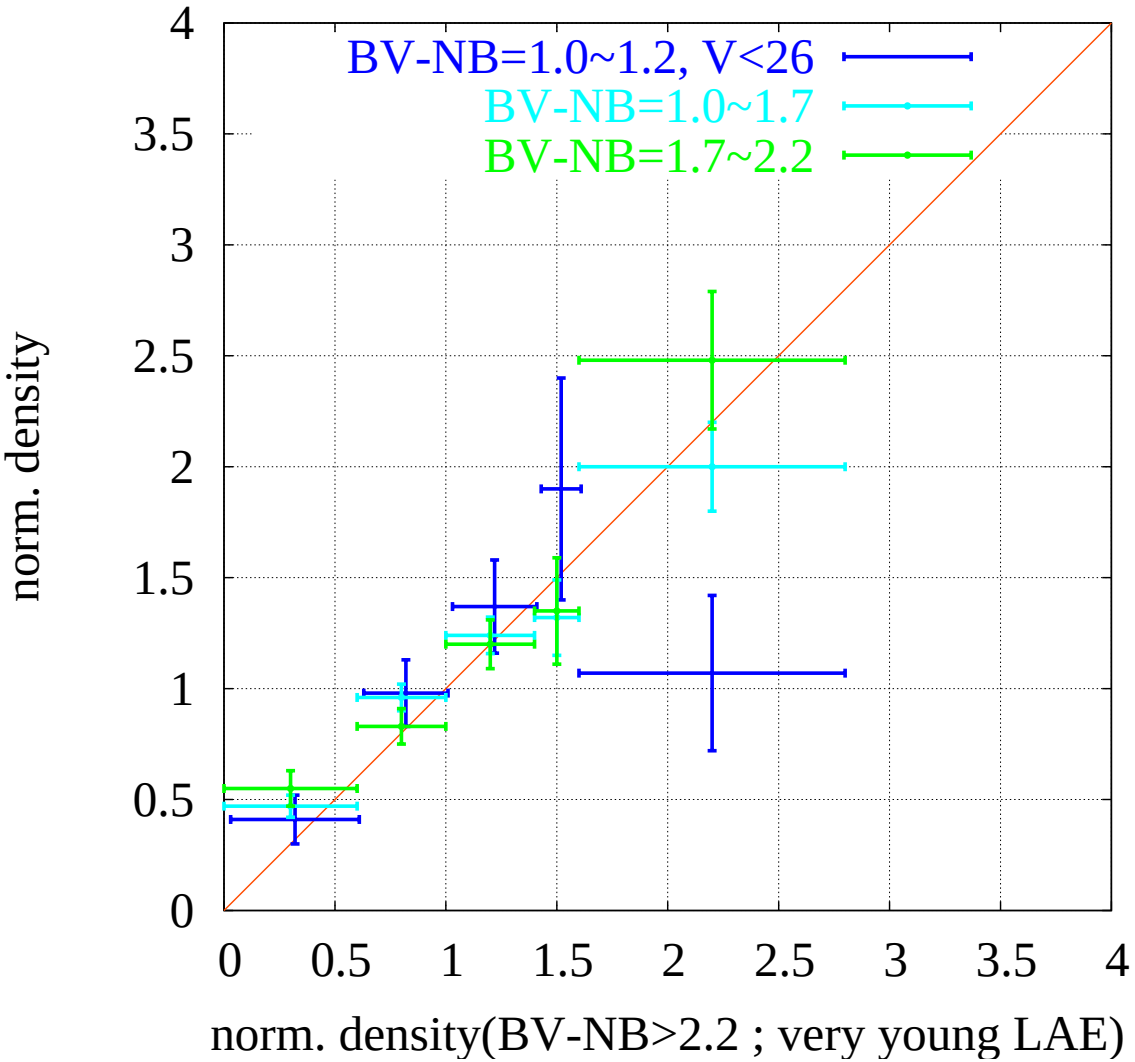


SKY MAPs for Very Young LAEs and LBG-like LAEs

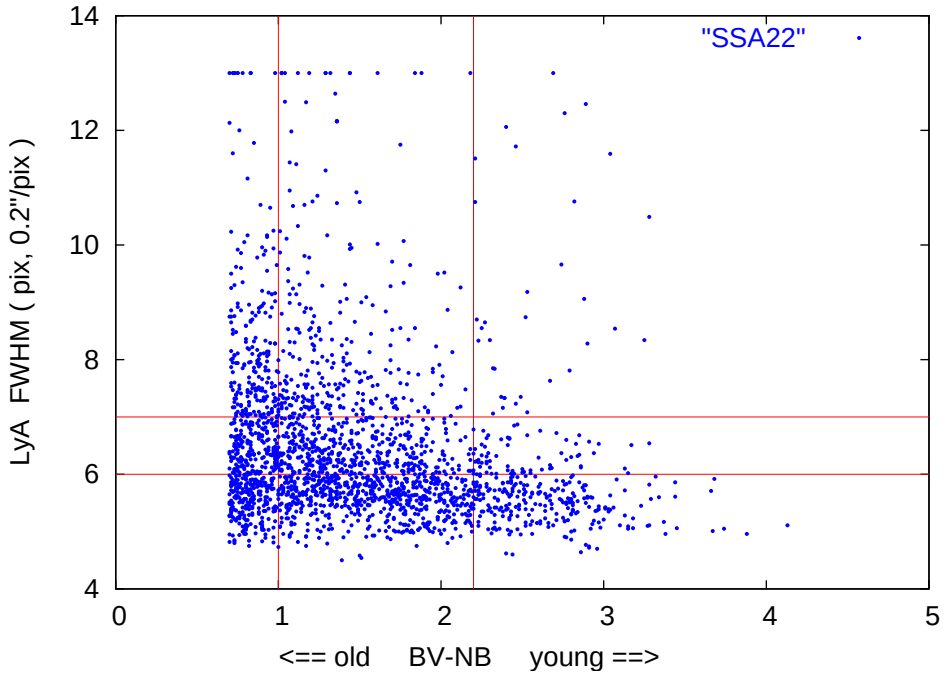


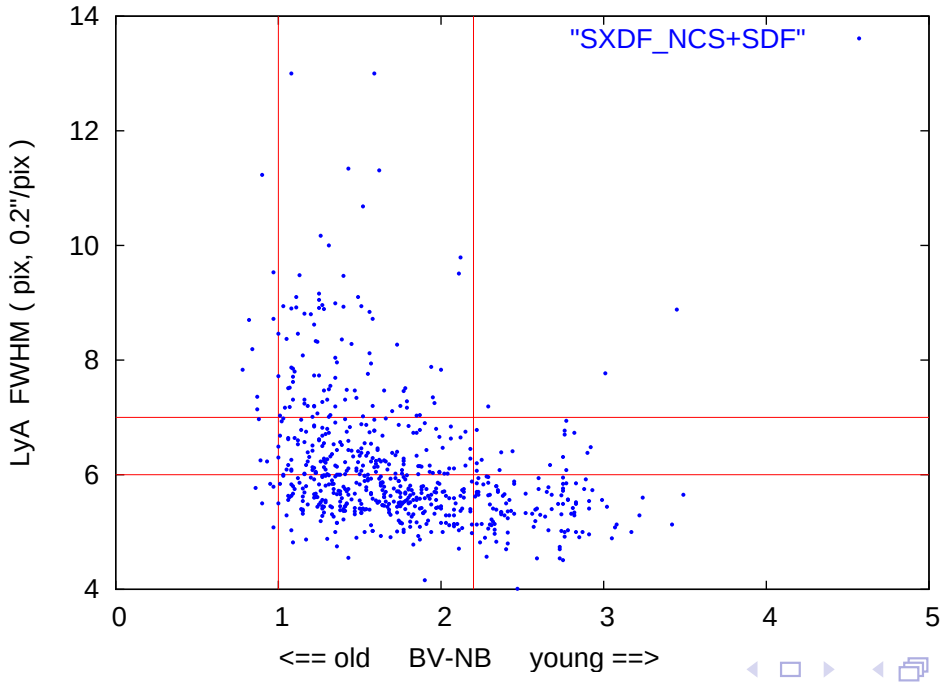


Anti-correlation between Very Young LAE & LBG-like LAE(BV-NB=1.0-1.2, V<26)



Lyα Size(fwhm) vs EW_0(BV-NB)





$$\delta_{200}(EW_{0,cor} > 200\text{Å} \;\; \& \;\; fwhm > 1.2\text{”}) \approx 3 \; !$$

$$\delta_{200}(EW_{0,cor} > 200\text{Å} \;\; \& \;\; fwhm > 1.4\text{”}) \approx 6 \; !!$$

SSA22 z〜3 Narrowband Imaging Survey

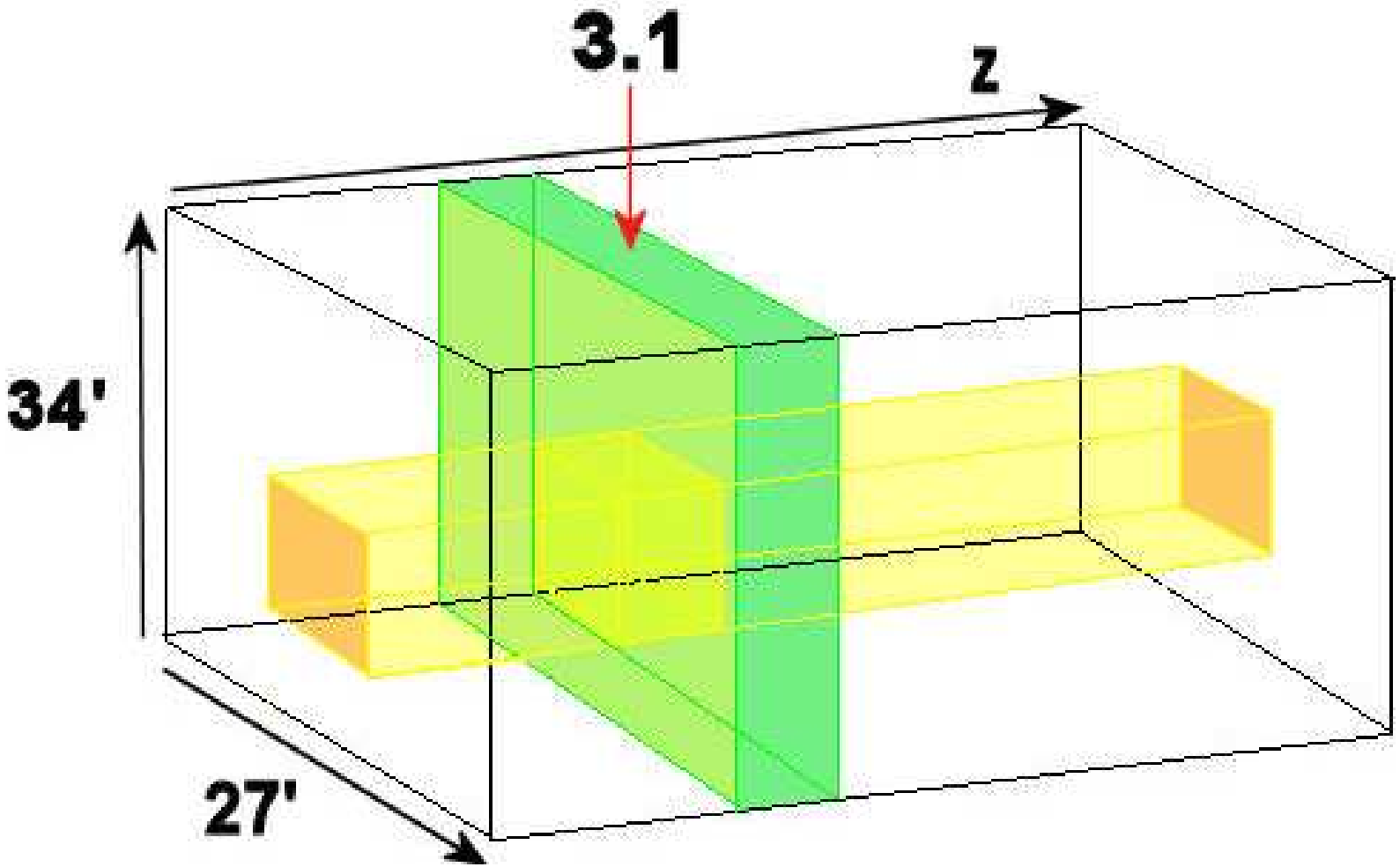
=====> need SCALE UP !

SCam ; by factor(Intensive×2〜3), soon!

===> HSC ; by order(Intensive×10) and
Survey for Other LSSs/Huge-ODRs

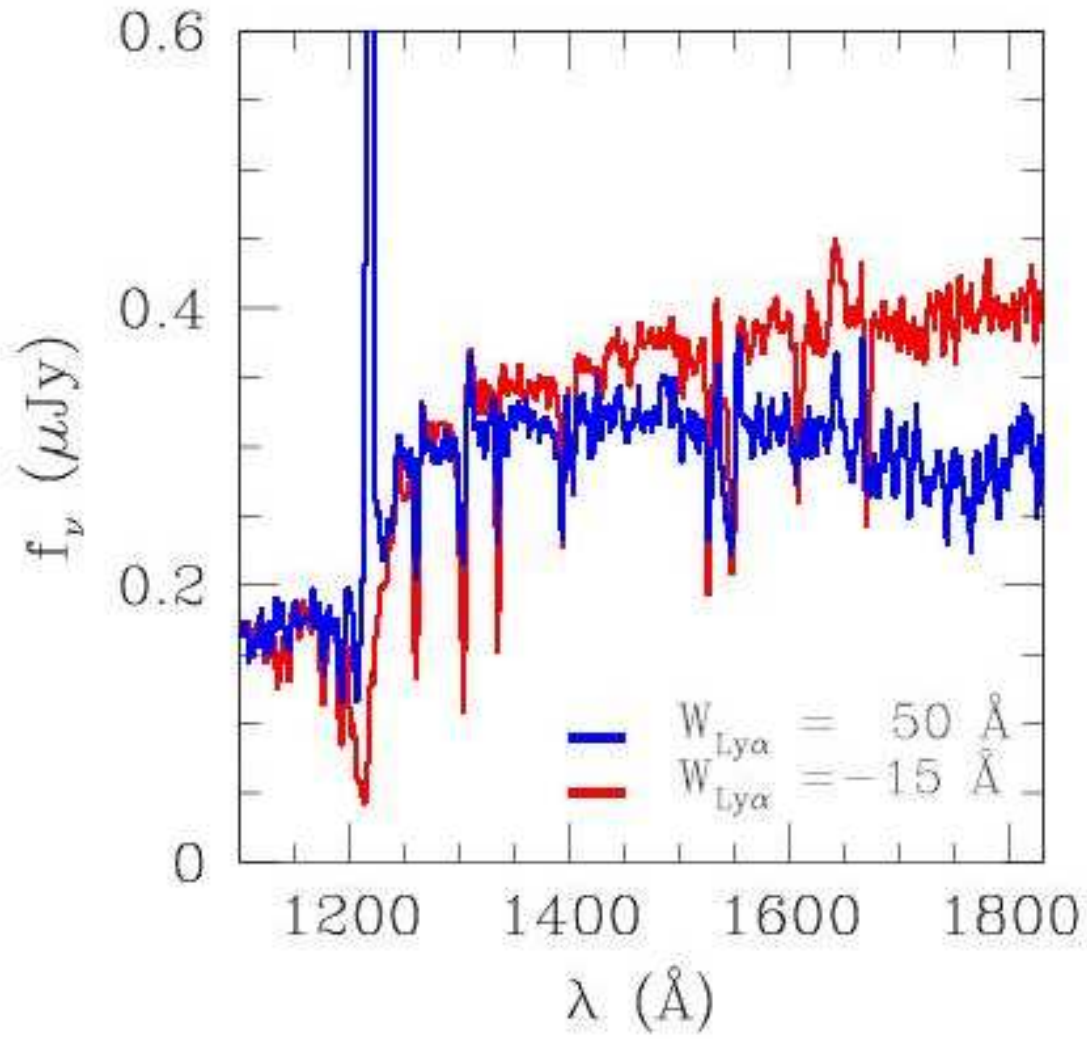
SSA22-Sb1 z~3 LBG **三次元探査**

VLT VIMOS obs. 2006 by Yamauchi et al.



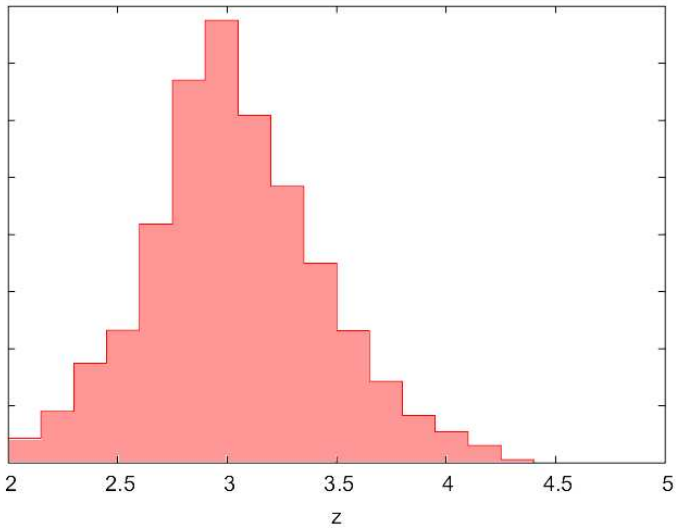
LBG Composite Spectra by Steidel et al.

blue ; emLBG
red ; absLBG



LBG Window Functions

Ours



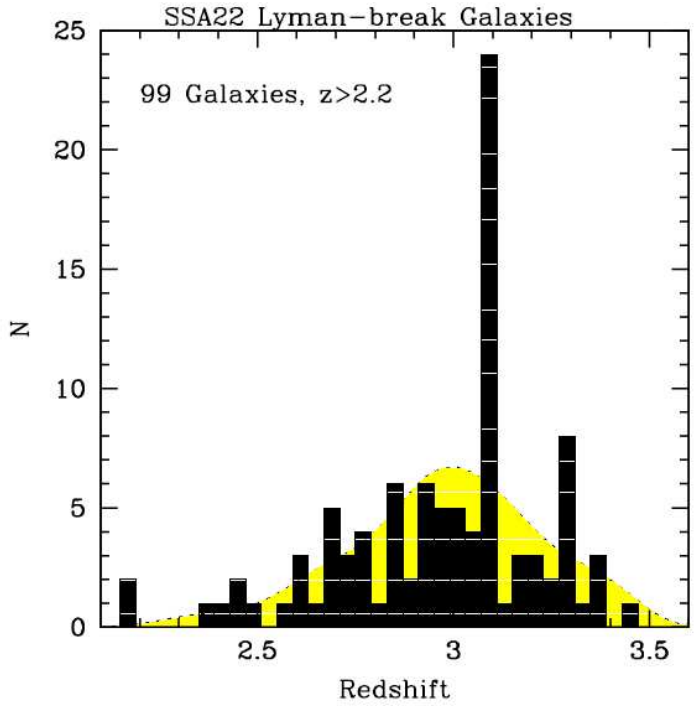
WF(3.3) / WF(3.1)=0.65

$V < 25.5$

$(U-V) - 1.8(V-R) > 0.85$

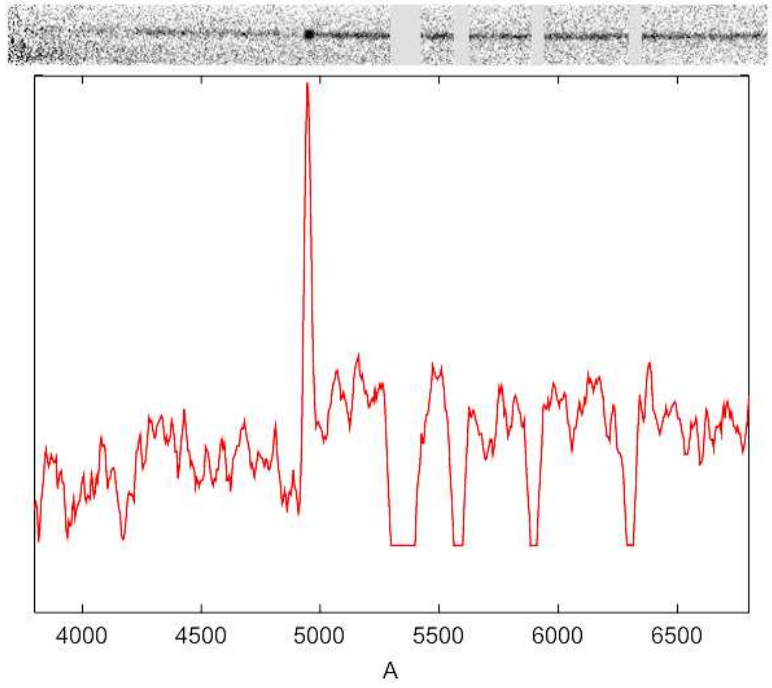
$R-i < 0.35$

Steidel's SSA22

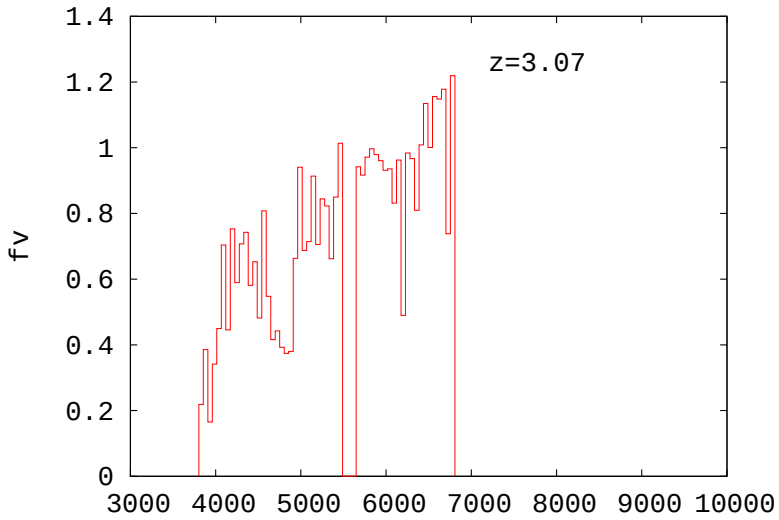


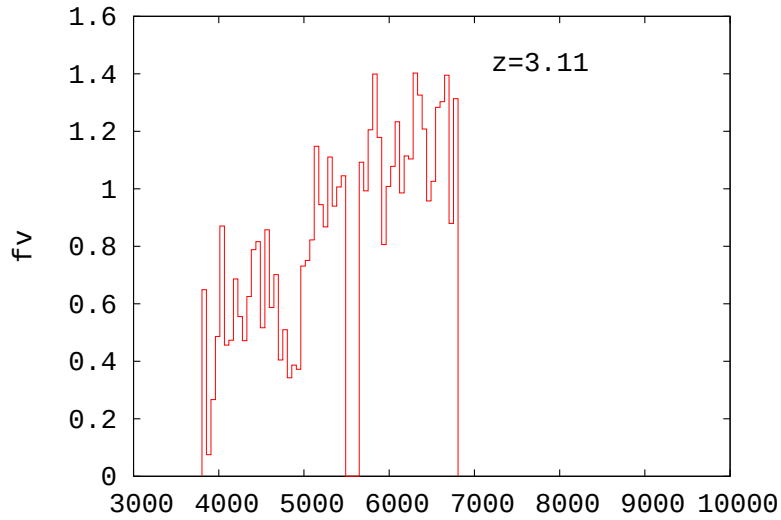
WF(3.3) / WF(3.1)=0.4

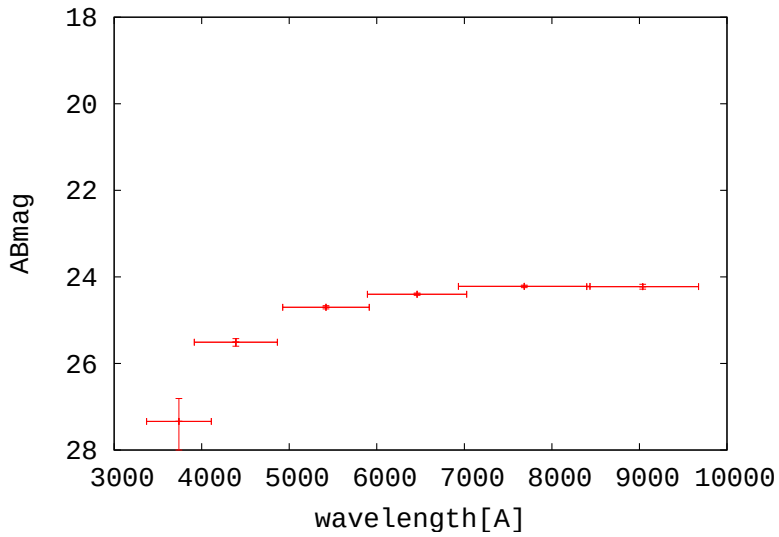
VIMOS emLBG (example)

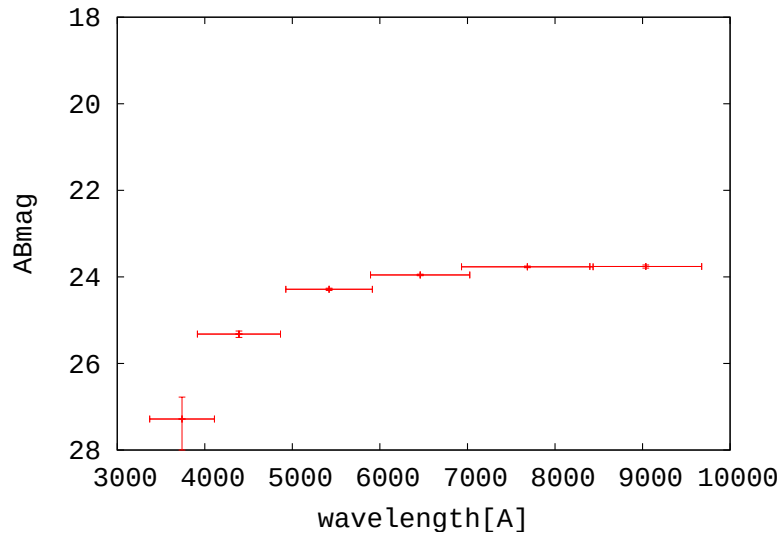


VIMOS absLBGs (example)

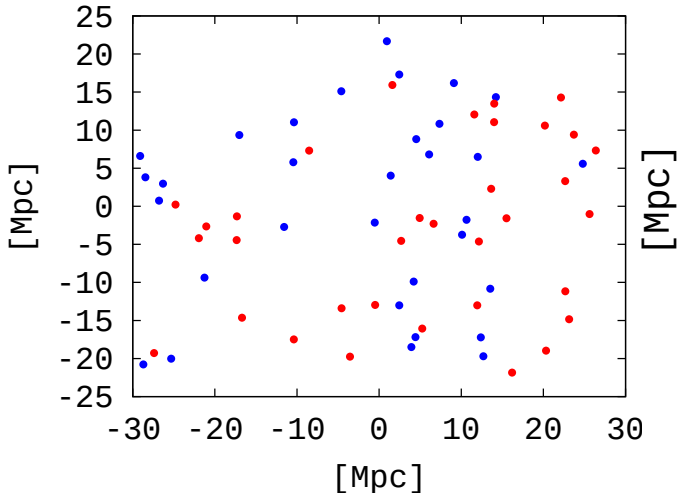


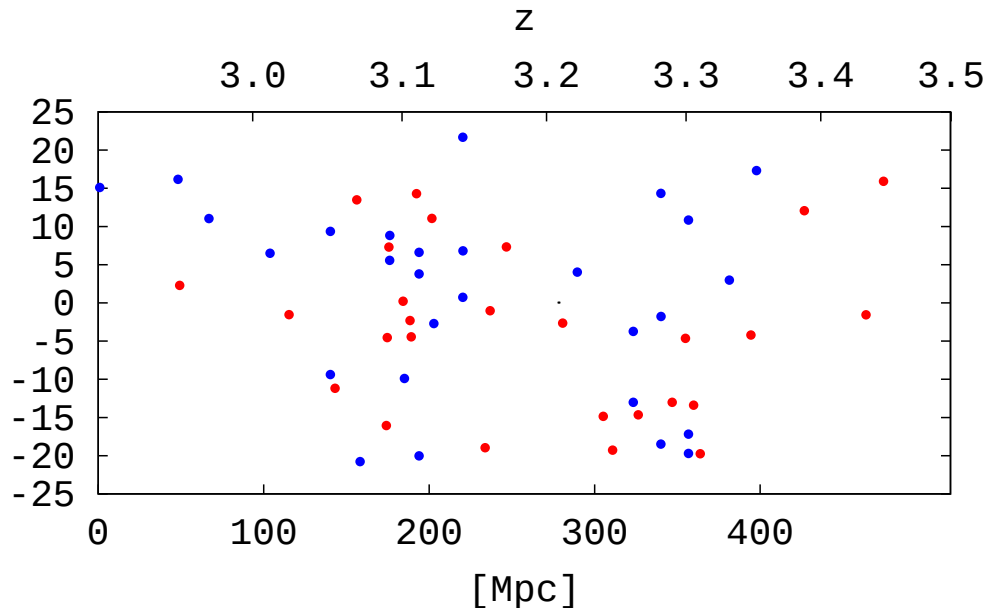


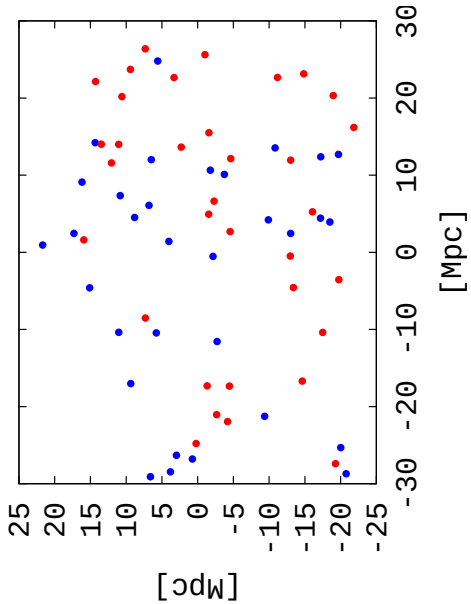


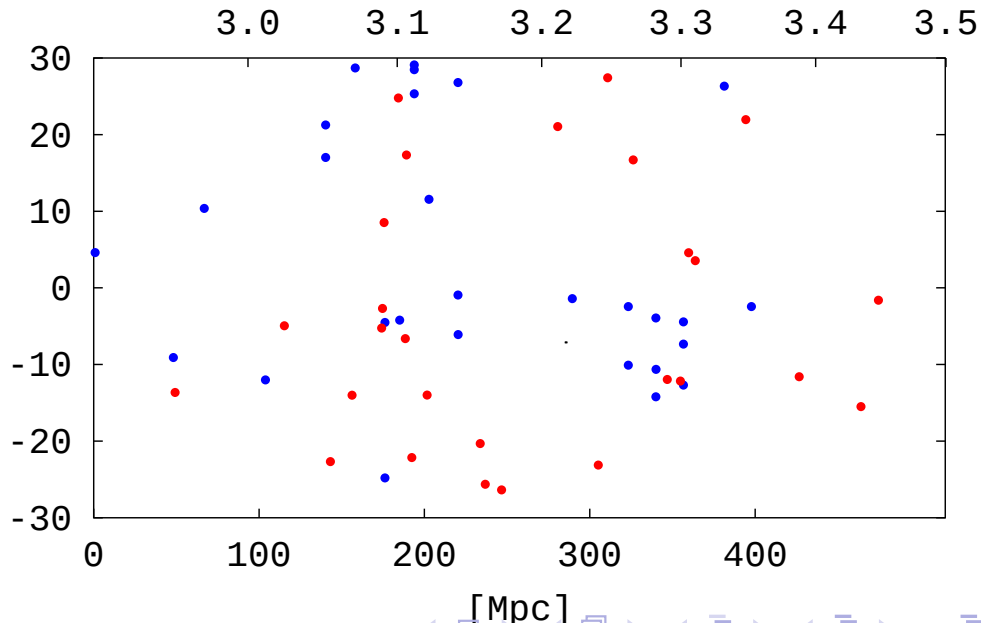


SSA22-Sb1 LBG **三面図** (red=emLBG, blue=absLBG)

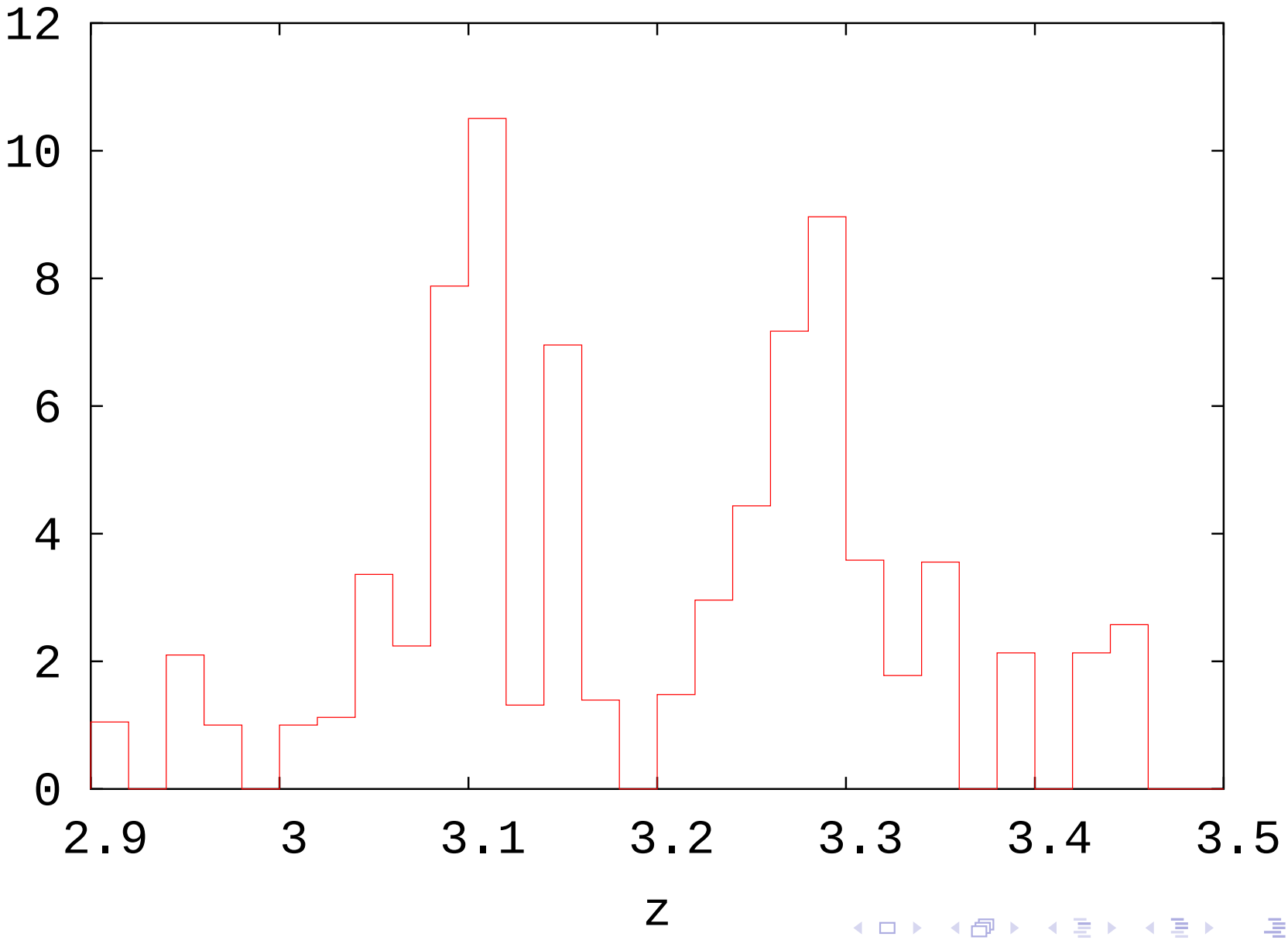








LBG(emLBG+absLBG) Redshift Distribution



A. Inoue VIMOS 2008 Obs.

==> More(~3 times) Statistics!!

SSA22-Sb1 z~3 **四次元(目)探査 = 変光探査**

SSA22 Sb1

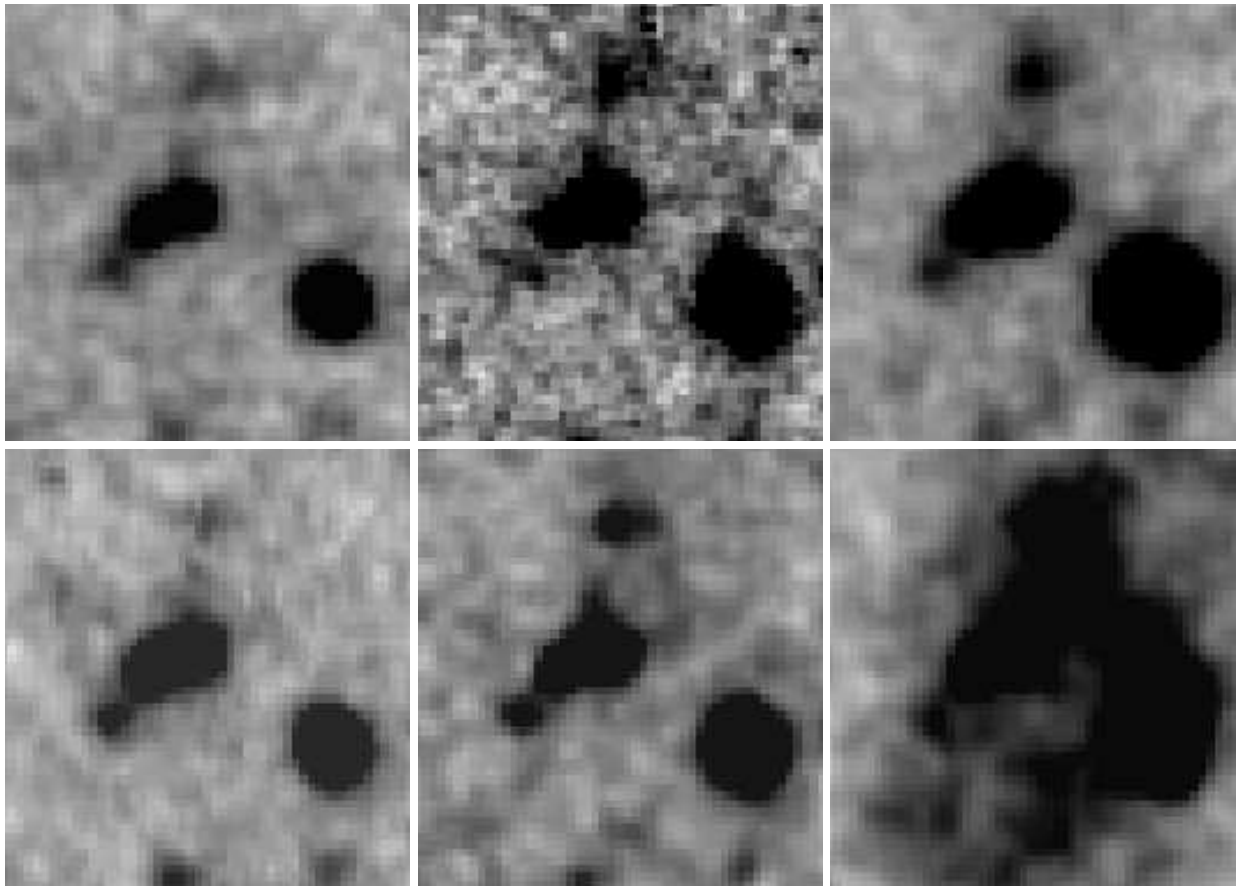
2002 B(1.8h), V(1.2h) (ours)

2003 B(0.8h), V(0.8h) (Capak archived)

Candidate Time Variability in LAB2

B02 V02 R02

27.1mag(422adu)



B03 V03 NB497(Lyα)

26.5mag(685adu)

V : Δflux(03-02)=263adu (1σ=120adu)