# Novel Picture for Lyman Alpha Emitters

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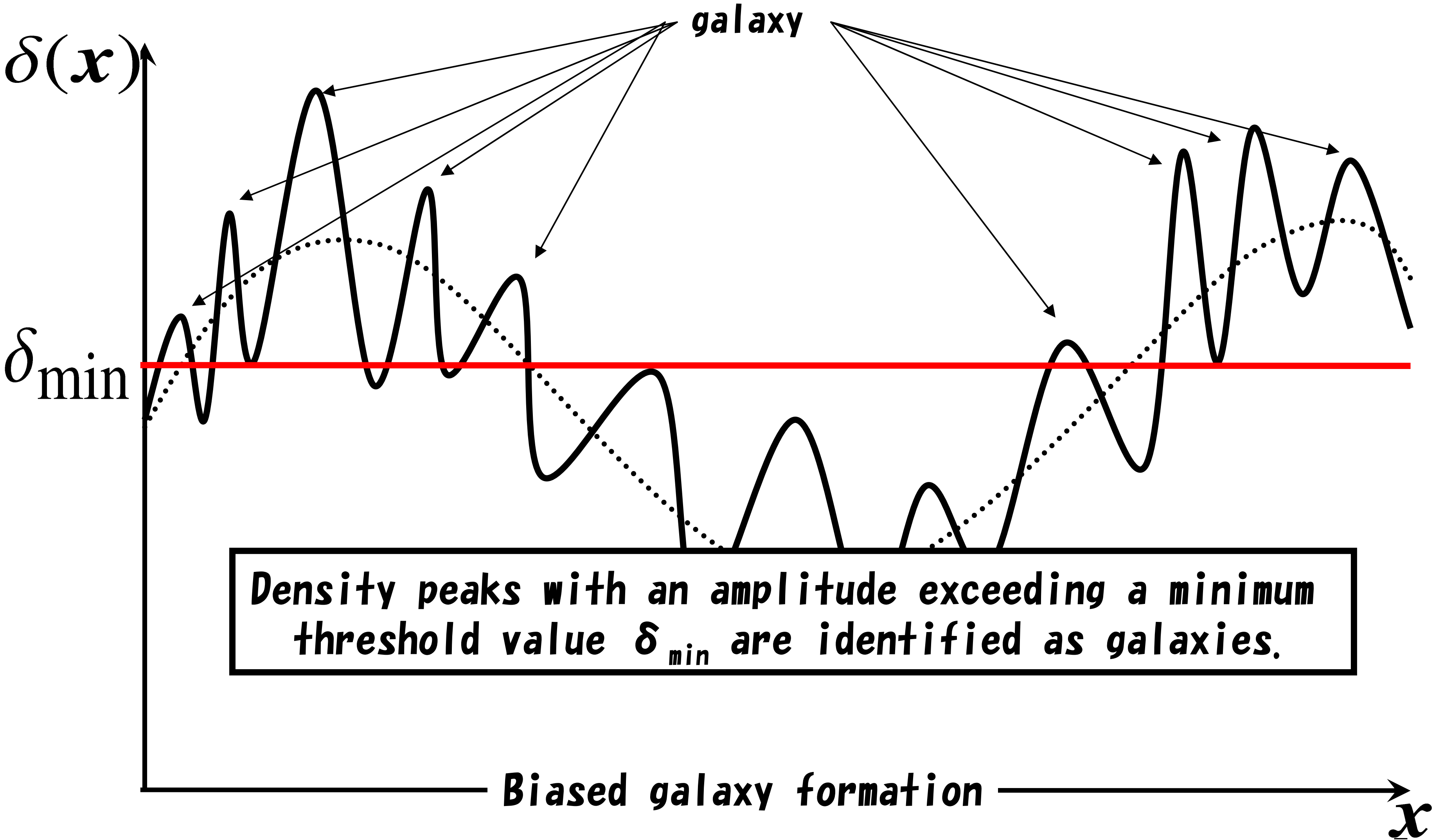
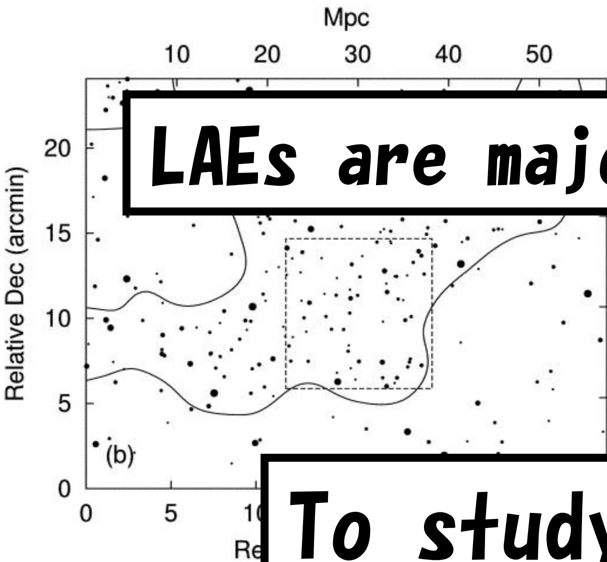
# Standard biased galaxy formation

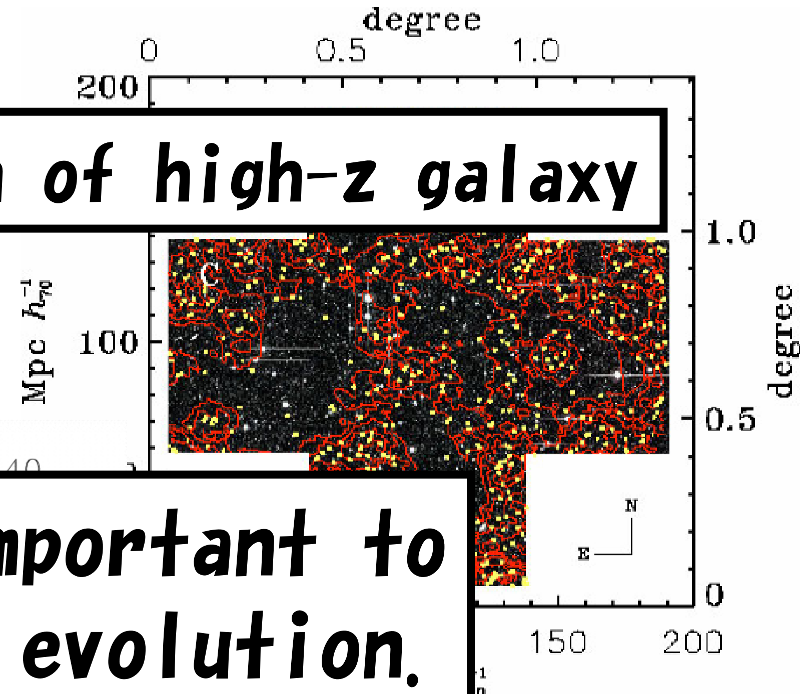


# Large-scale structure of Lyα emitters (LAEs)

LAEs (z=3.1)

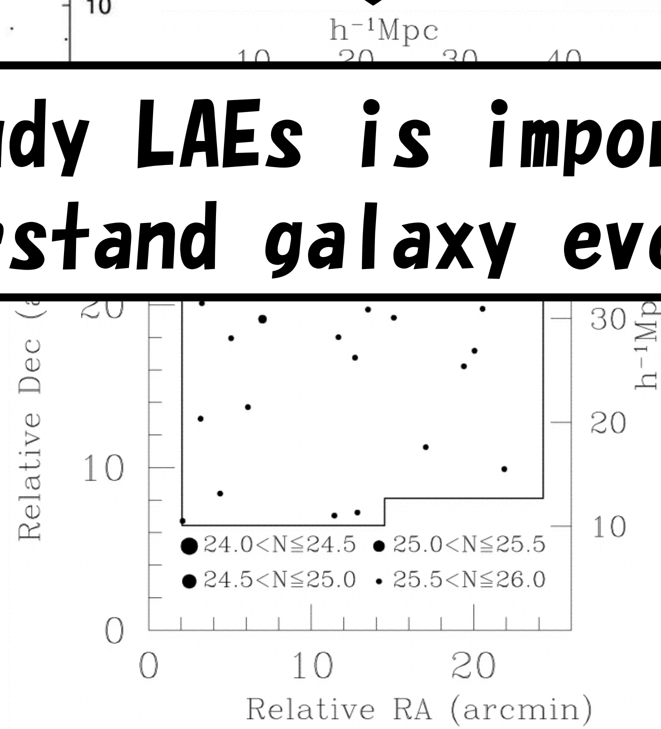



LAEs (z=5.7)



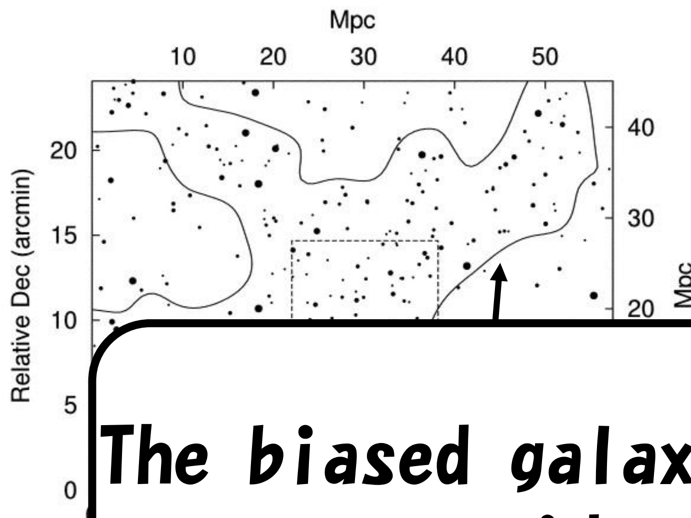

**LAEs are major population of high-z galaxy**

LAEs (z=4.8)



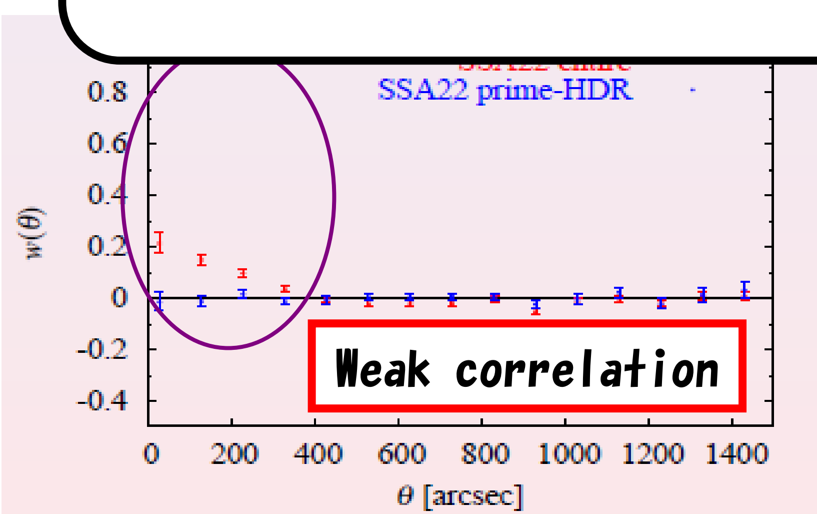

**To study LAEs is important to understand galaxy evolution.**

# LAEs in SSA22 region at z=3.1

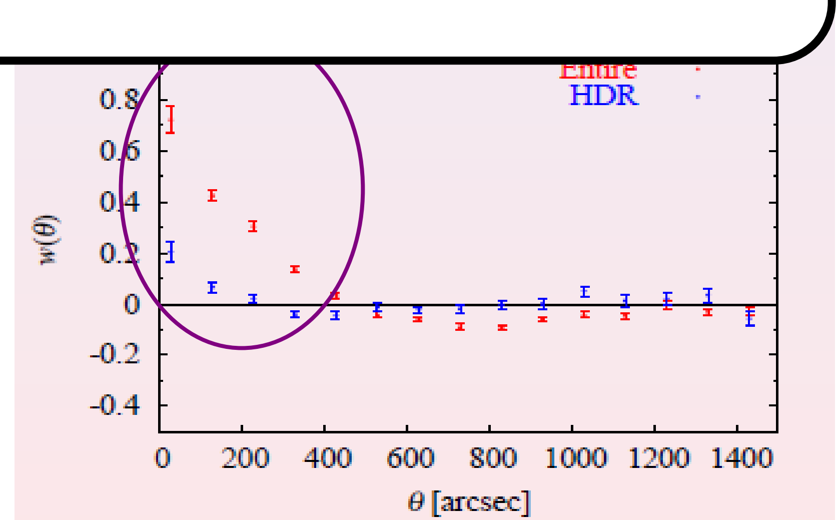



●The correlation of observation is weaker than theoretical expectation
→ Spatial distribution of LAEs is difficult
rmation

**The biased galaxy formation model does not consider properties of LAEs.**

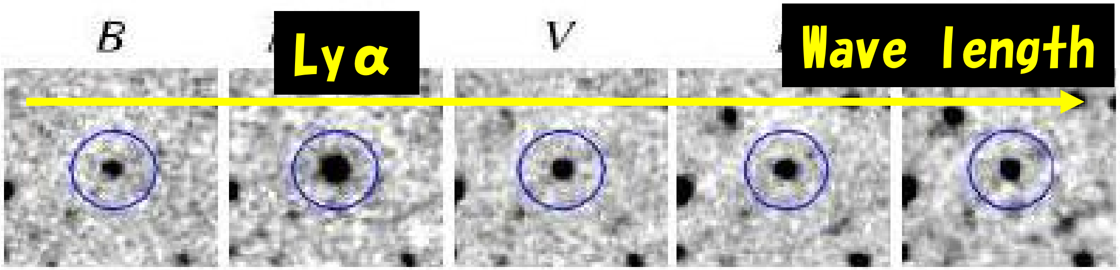


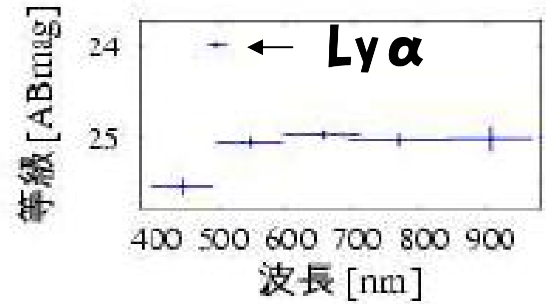

Hayashino et al., (2004)




Kauffmann et al., (1999)

# Observational Properties of LAEs




●s

●s

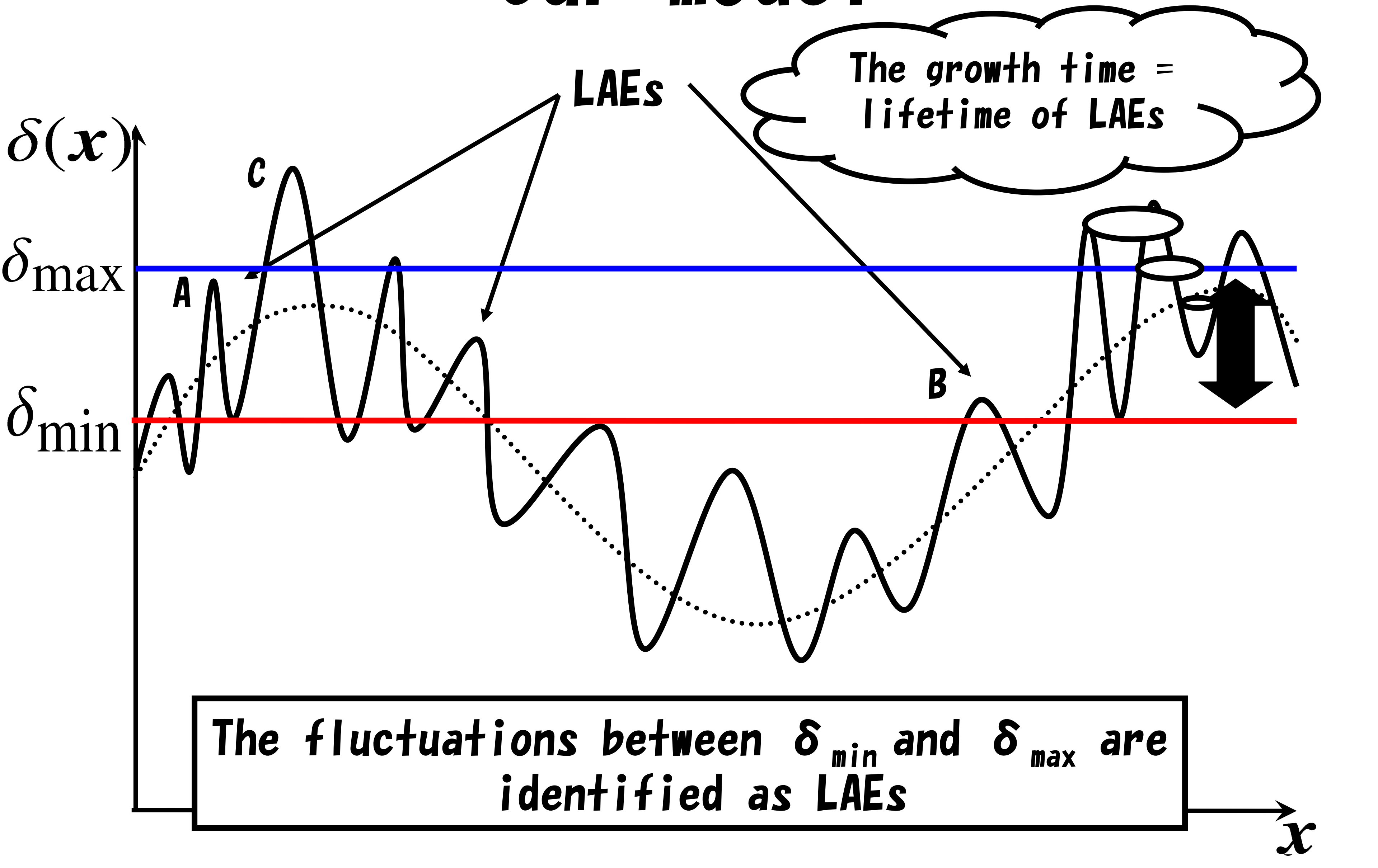
●m

**In this study,
we develop a new galaxy formation model
for LAEs based on their observational properties.**

●fainter continuum than LBG

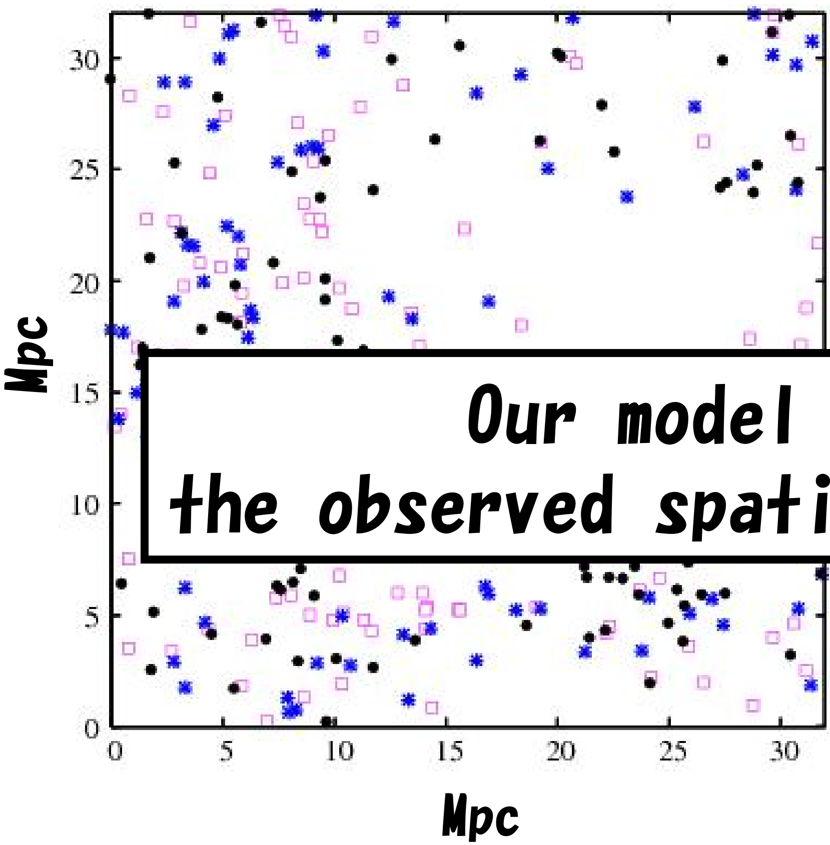
➡ These suggests that
LAEs are very young objects and have shorter lifetimes.

# Our model


The growth time = lifetime of LAEs
LAEs
δ(x)
δmax
δmin
A
B
C
x
The fluctuations between δmin and δmax are identified as LAEs

# result

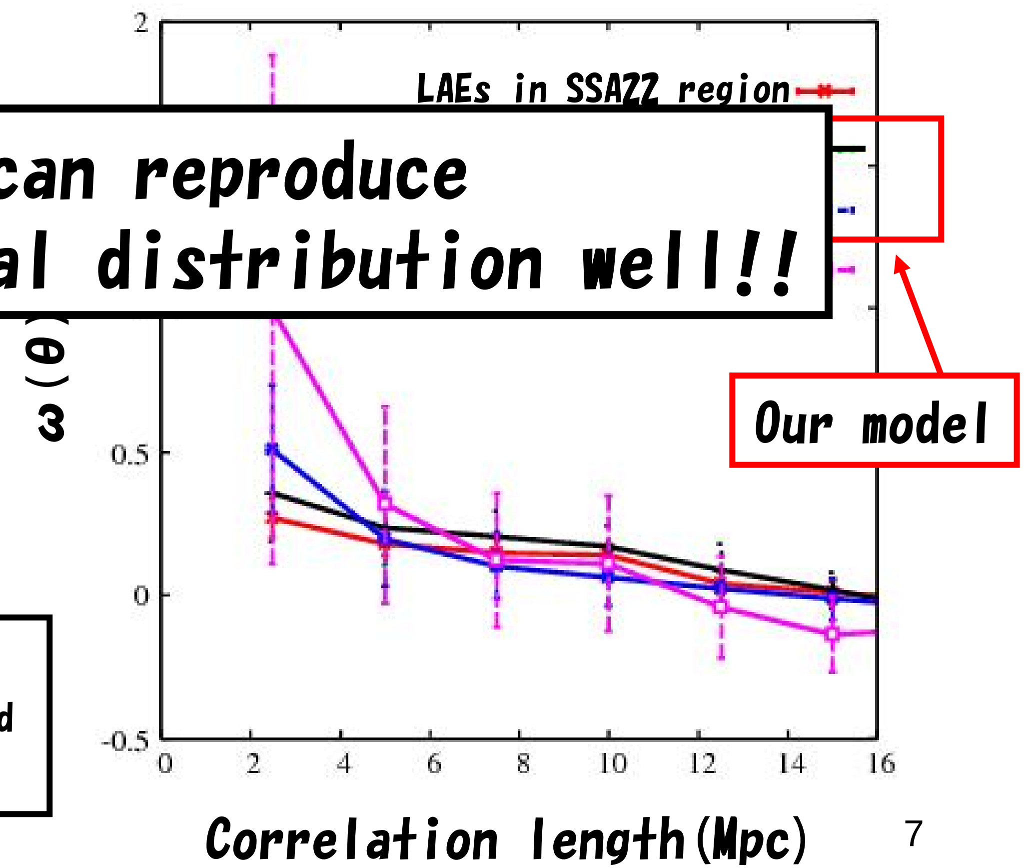
Spatial distribution of halos




- □ : biased galaxy formation model
- ＊ : halos from $5\times10^8$yr old to $6\times10^8$yr old
- ● : halos to $6\times10^7$yr old

- Simulation box : $(32h_{70}\mathrm{Mpc})^3$
- particle number : $(256)^3$
  - ⇒1 particle mass : $7.1\times10^7 M_{sun}$
- Initial z : z=51
- periodic boundary condition

Correlation function




**Our model can reproduce the observed spatial distribution well!!**

# summary

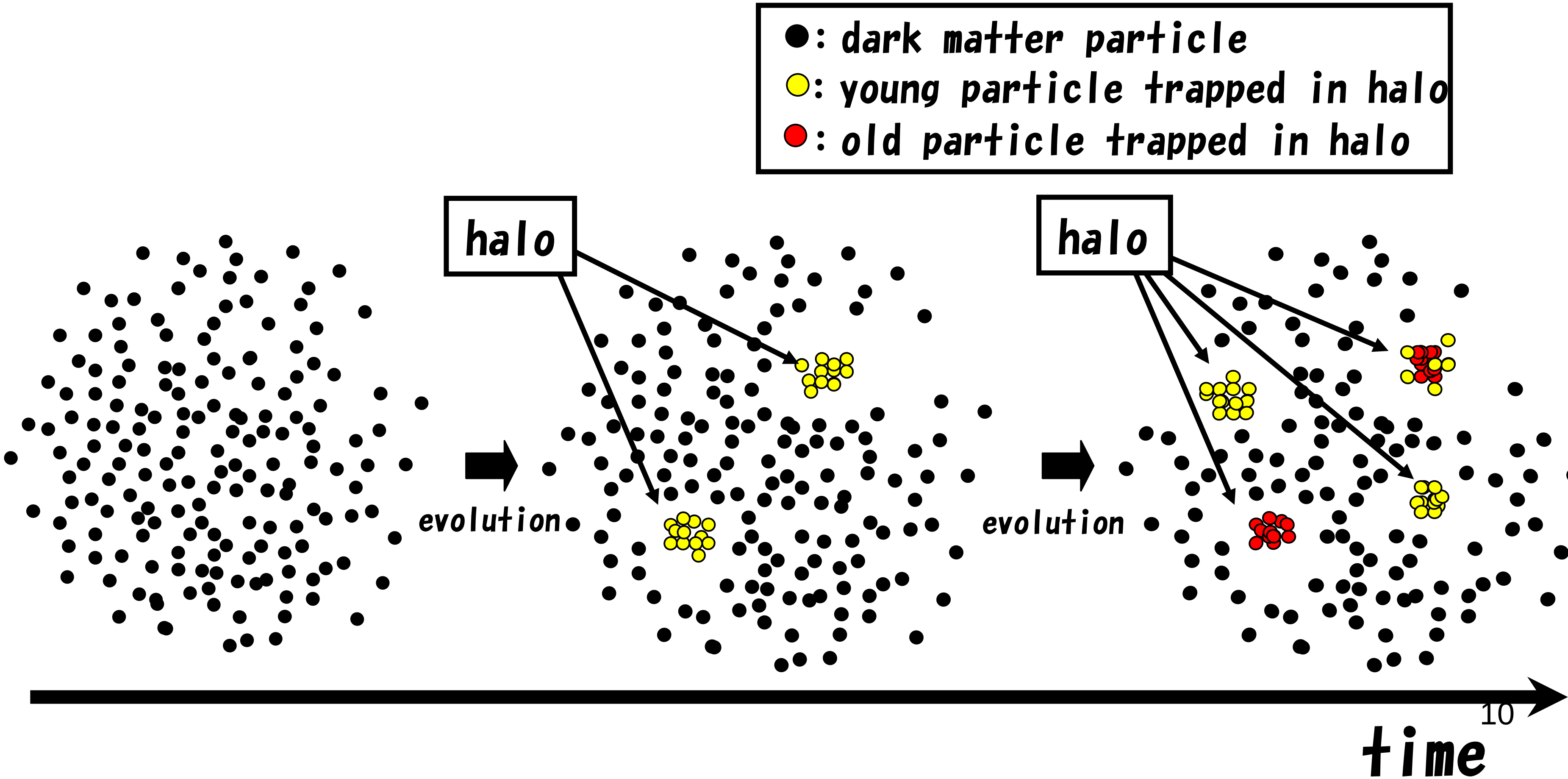
We calculate cosmological N-body simulation
to explain observed LAEs spatial distribution.
We consider the lifetime of the LAEs,
which has not been hitherto considered in the standard biased galaxy formation scenario.

●Our model can reproduce
observed spatial distribution of LAEs in SSA22 region.
●LAEs should be in the first phase of galaxy evolution.
●lifetime of LAEs is $6\times10^{7}$yr.

# Appendix

# Model and assumption

- the dynamical evolution of baryonic matter follows that of dark matter
- the dark matter particles begins the star formation,
when they trapped in halo.



# Calculation method and condition

## ●Calculation method

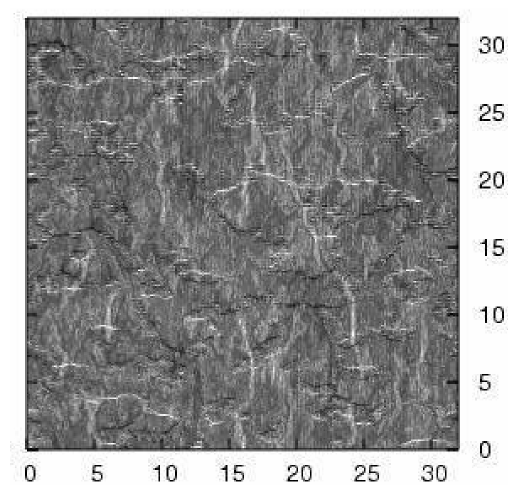
- N-body simulation(Particle-Particle-Particle-Mesh method+grape)
- we independently consider star formation history and chemical evolution of each substructure(particle) in galaxies with evolutionary spectral synthesis code 'PEGASE'.

  → we can treat more realistic dynamical and chemical evolution of galaxies.

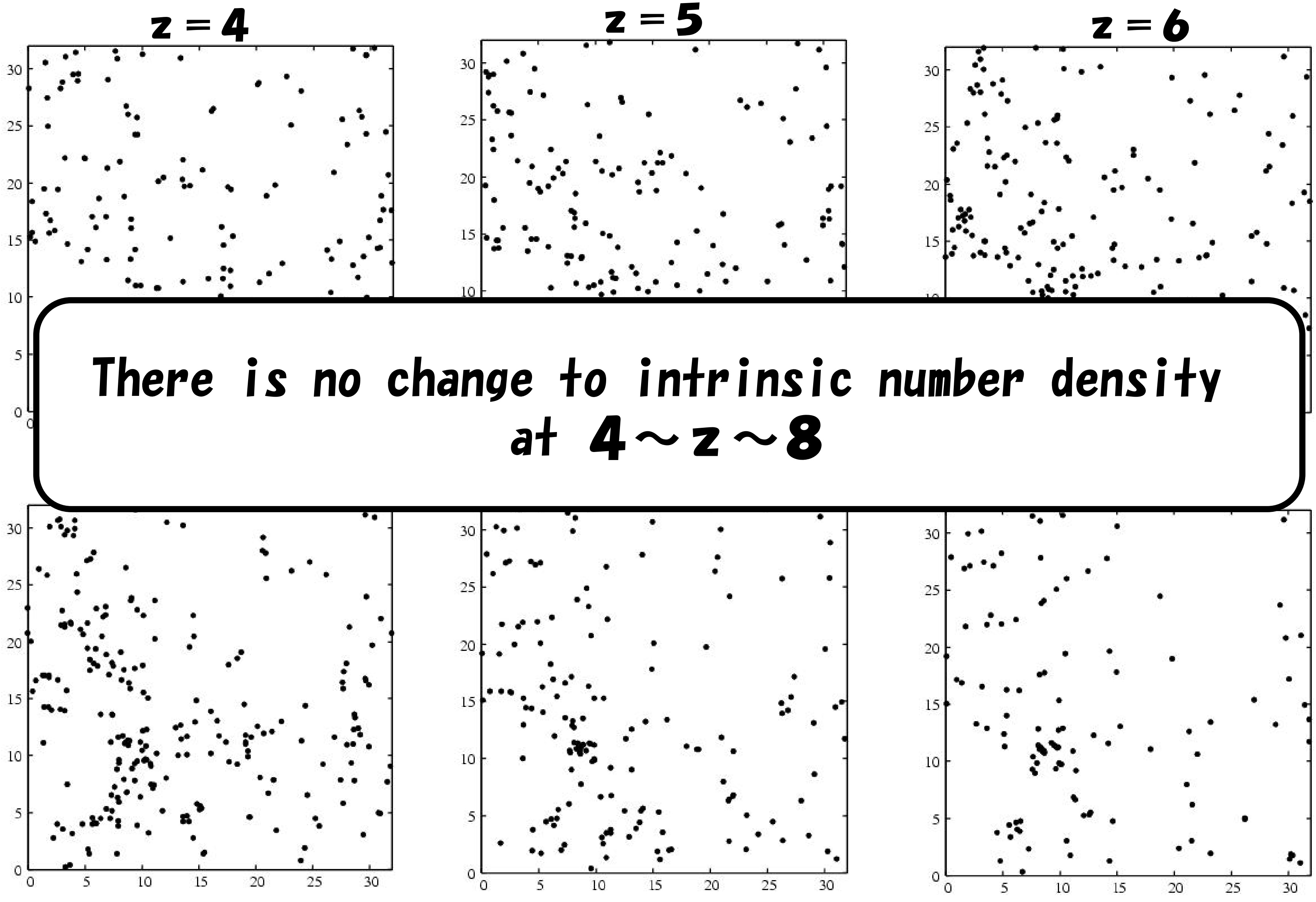
## ●calculation condition

- ΛCDM($\Omega_0$=0.27, $\Omega_\Lambda$=0.74, $\Omega_b$=0.02$h^{-2}$, h=0.7, $\sigma_8$=0.85)
- Simulation box : $(32h_{70}Mpc)^3$
- particle number : $(256)^3$

  ⇒1 particle mass : 7.1×$10^7$Msun
- Initial z : z=51
- periodic boundary condition

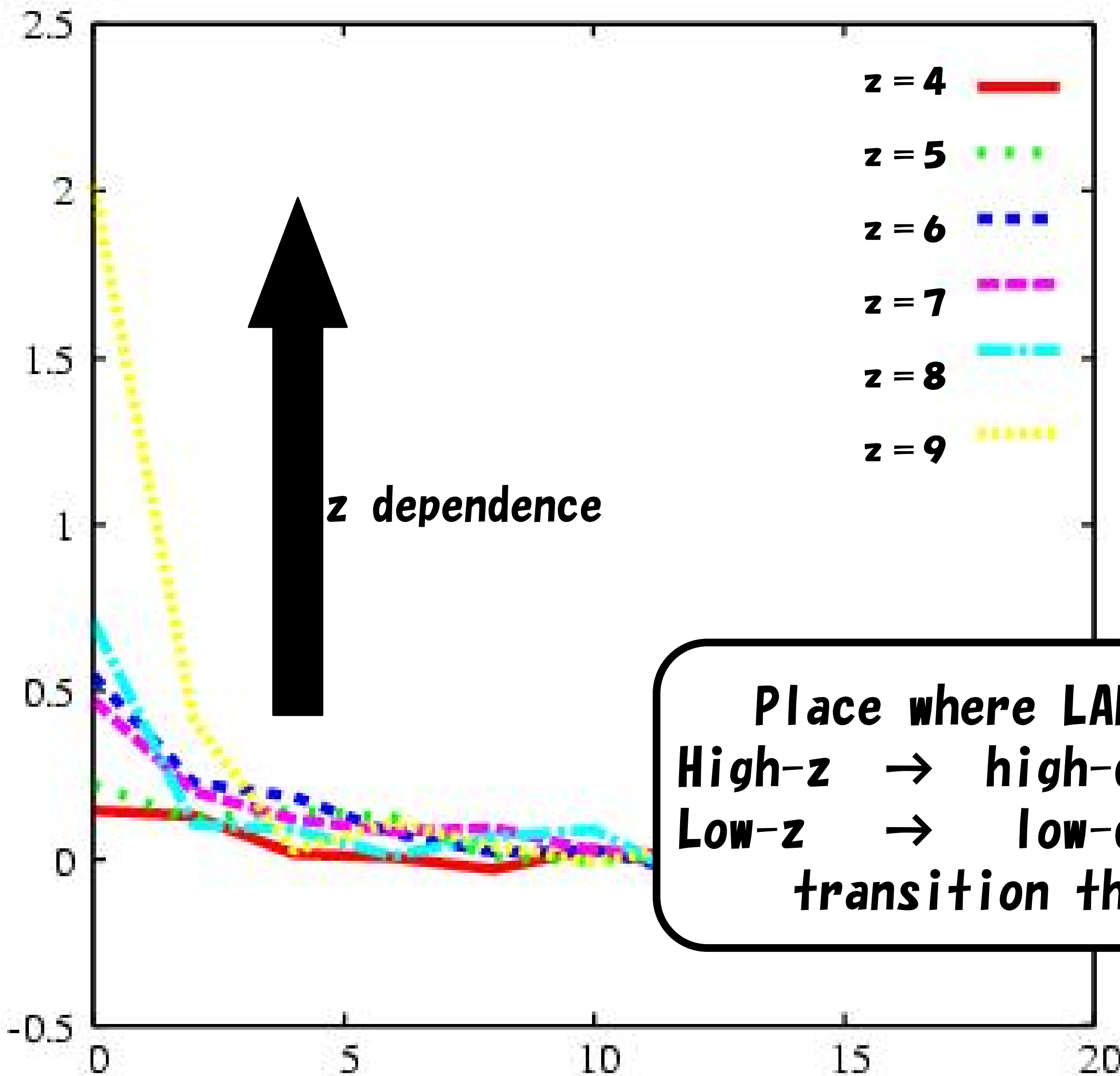


# Distribution of LAEs at high-z(z>3.1)




There is no change to intrinsic number density at 4～z～8

# Correlation function of LAEs at high-z(z>3.1)

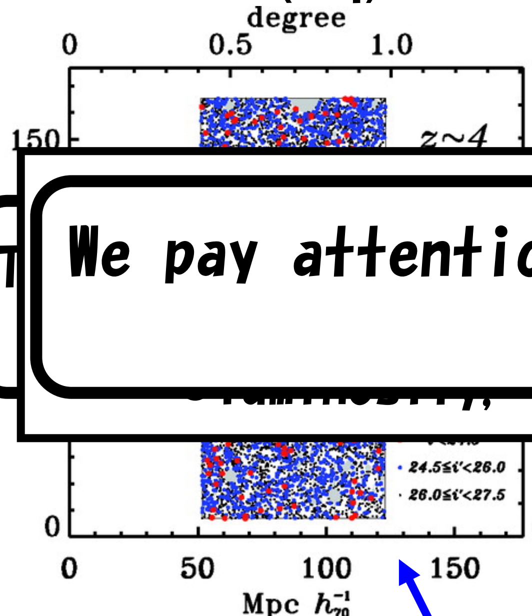



Place where LAEs reside
High-z → high-density peak
Low-z → low-density peak
transition this like

# Large scale structure of galaxies at high redshift (high-z)

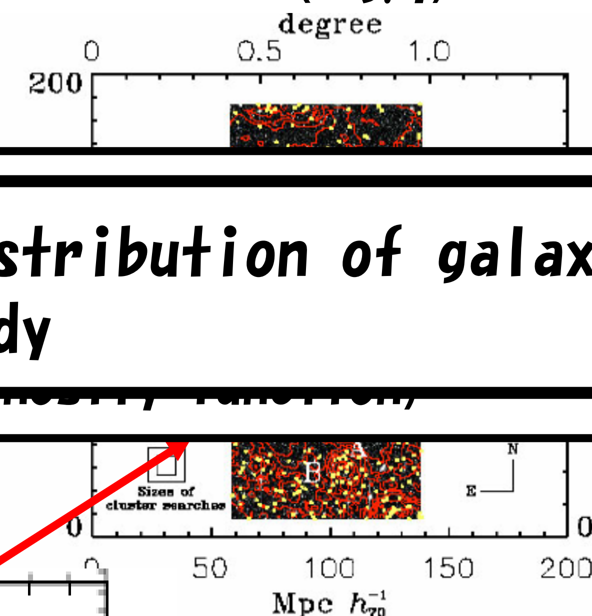
Discovery of large scale structure such as Lyman break galaxies (LBGs) and Lyα galaxies (LAEs) high-z

LBGs (z=4)



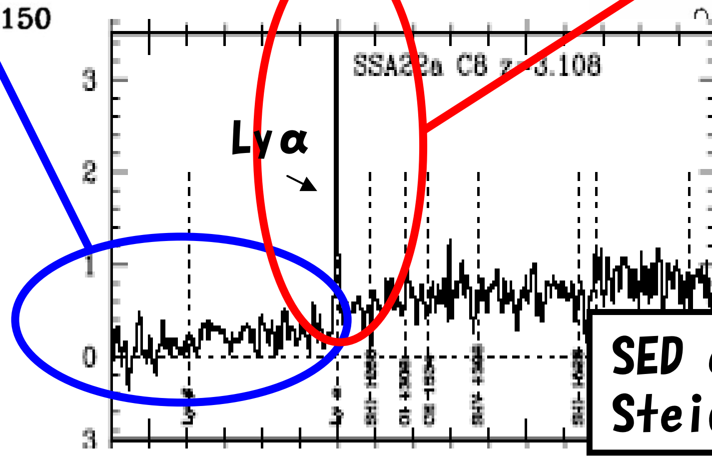

Ouchi et al., (2005)

LAEs (z=5.7)



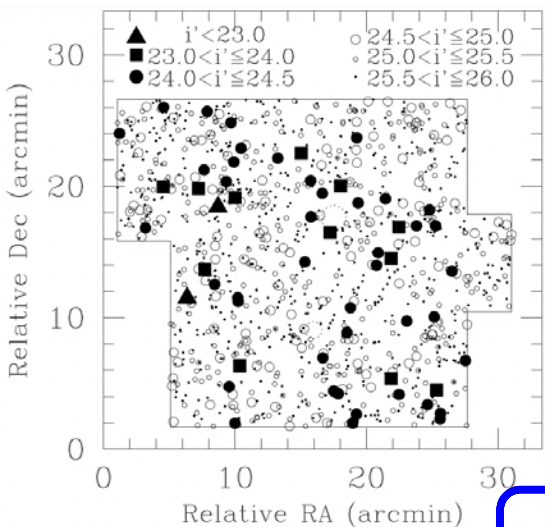

Ouchi et al., (2005)

**We pay attention to spatial distribution of galaxy in this study**




SED of high redshift galaxy
Steidel et al., (1998)

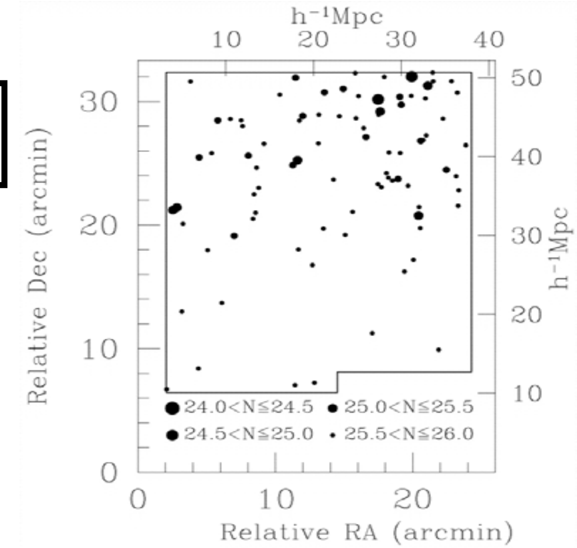
# spatial distribution of LBGs and LAEs




Ouchi et al., (2001)

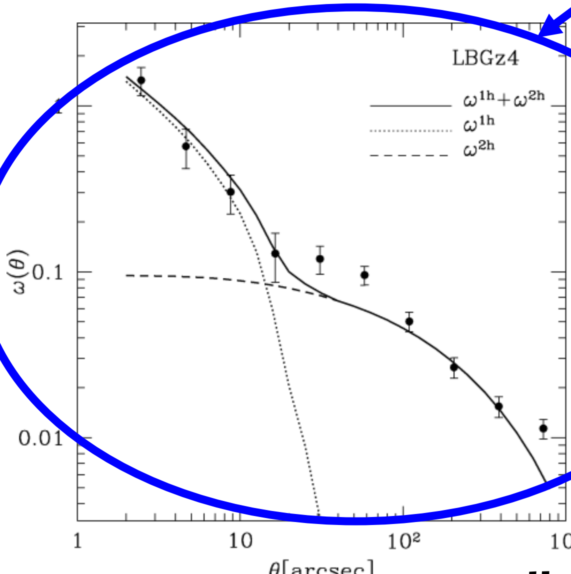
LBGs (z=4)

LAEs (z=5)

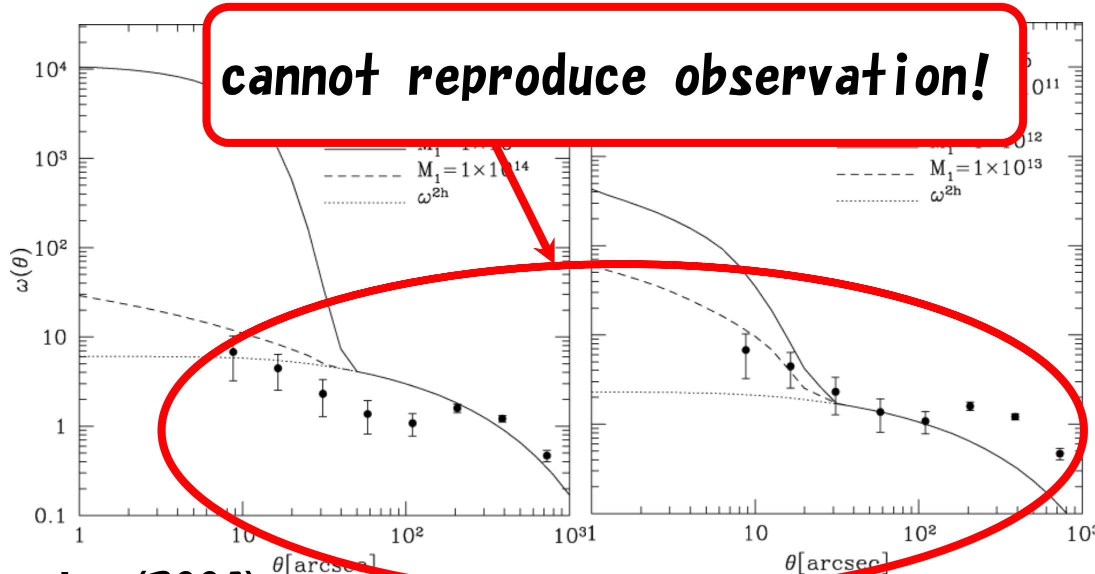



Ouchi et al., (2003)

matches observation!

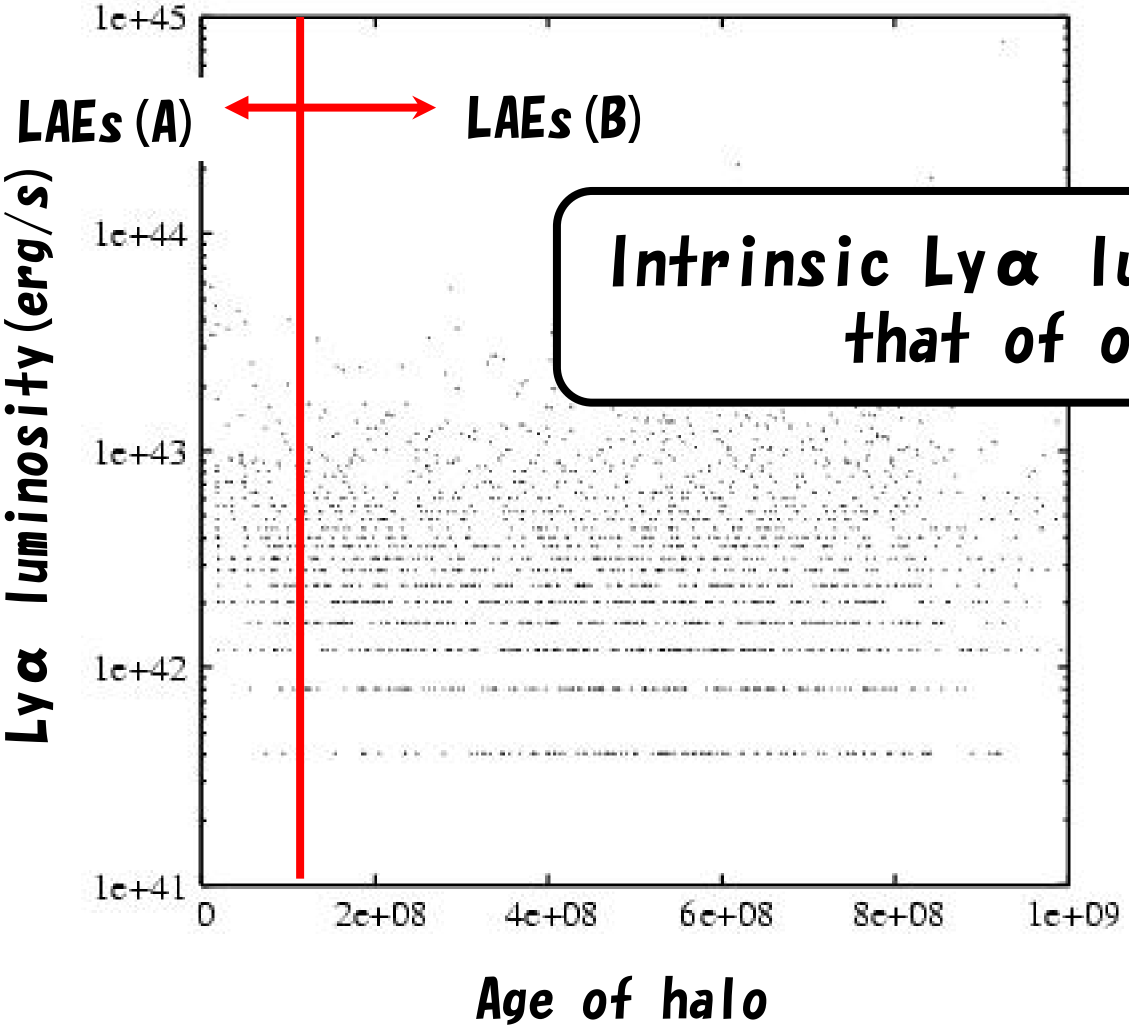



cannot reproduce observation!




Hamana et al., (2004)

# result(Lyα luminosity)




Intrinsic Lyα luminosity correspond that of observed LAEs.

ただしLyα光子のEscape fractionに不定性あり

# correlation function and density fluctuation

- density fluctuation at x δ (x)

$$\delta(\boldsymbol{x}) = \sum_{\boldsymbol{k}} \delta_{\boldsymbol{k}} e^{-i\boldsymbol{k}\cdot\boldsymbol{x}} = \left(\frac{L}{2\pi}\right)^3 \int \delta_{\boldsymbol{k}} e^{-i\boldsymbol{k}\cdot\boldsymbol{x}} d^3\boldsymbol{k}$$

- Relations with correlation function and density fluctuation

$$\xi(r) \equiv \langle \delta(\boldsymbol{x})\delta(\boldsymbol{x}+\boldsymbol{r}) \rangle$$

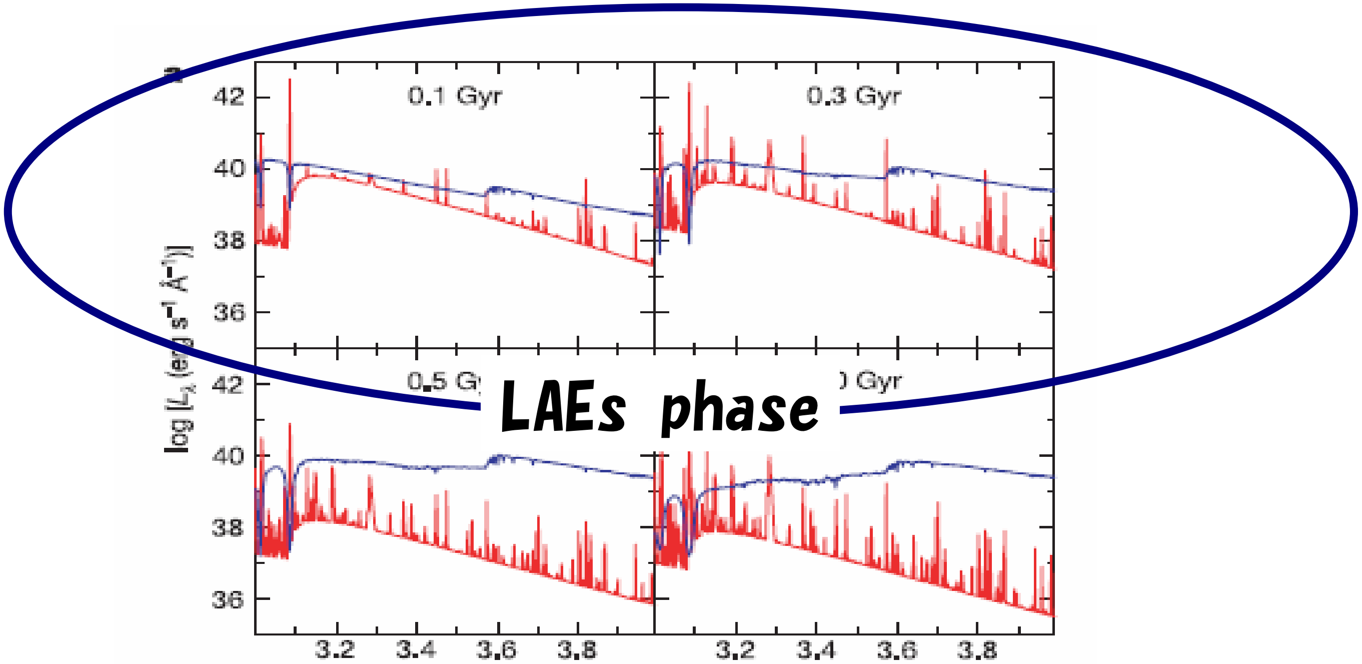
$$\Rightarrow \quad \xi(r) = \left(\frac{L}{2\pi}\right)^3 \int \langle |\delta_k|^2 \rangle e^{-i\boldsymbol{k}\cdot\boldsymbol{r}} d^3\boldsymbol{k}$$

**We draw out density fluctuation from correlation function!!!**

# Theoretical approach to LAEs

Mori & Umemura., (2006a,b)

← ultra high resolution simulation on the dynamical and chemical evolution of galaxy




●multiple supernova explosions at an early phase of $< 3 \times 10^8$ yr result in forming high density cooling shells, which emit so strong Lyα as to account for the luminosity of LAE.